U. S. DEPARTMENT OF AGRICULTURE.
FORESTRY DIVISION.
BULLETIN No. 4.

# REPORT

ON THE

# Substitution of Metal for Wood in Railroad Ties.

BY

E. E. RUSSELL TRATMAN, C. E.

TOGETHER WITH A DISCUSSION ON

## PRACTICABLE ECONOMIES IN THE USE OF WOOD FOR RAILWAY PURPOSES.

BY

B. E. FERNOW,
CHIEF OF FORESTRY DIVISION.

PUBLISHED BY AUTHORITY OF THE SECRETARY OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
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# LETTER OF SUBMITTAL.

FORESTRY DIVISION, DEPARTMENT OF AGRICULTURE,
*Washington, D. C., March* 10, 1890.

SIR: I have the honor herewith to submit a report on the use of metal as a substitute for wood in railroad ties, together with a brief discussion of other practicable economies in the use of wood material, this report being a sequel to Bulletins 1 and 3 of the Forestry Division, and forming a part of a continued investigation into the relation of railroads to forest supplies.

Respectfully,

B. E. FERNOW,
*Chief of Forestry Division.*

Hon. J. M. RUSK,
*Secretary.*

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# INTRODUCTORY.

It may seem superfluous to justify the publication by this Department of any new and useful information that has, directly or indirectly, a bearing upon the cultural conditions of the country; yet, since it might be questioned whether the investigations which form the principal subject matter of this report were germane to the work of the Forestry Division, a few words to establish this relation will not be considered out of place.

The value of the report on metal ties, as a compilation of hitherto unpublished and inaccessible or scattered information, will be self-evident and needs no argument to the engineer, for whose direct use and benefit it has been collated; but the indirect value to the country at large, and to the forestry interests especially, can only be realized by contemplating what effect the application of the information here presented may have upon our forest supplies.

Previous investigations by this division, notably those published in Bulletin I, 1887, have shown that the railroads of our country not only use a very large amount of forest supplies in their construction—probably not less than 20 per cent. of the total consumption of timber—but the material represented in this consumption is largely drawn from the thrifty young growth, the promise of the future, and thus the timber crop is utilized before it has reached the most profitable age and largest production per acre. More than that, the most durable and valuable timbers only are desired for this use, and, consequently, the forest areas which are culled of these valuable kinds must necessarily deteriorate in quality as regards their composition, the inferior kinds being left to dominate and exclude the more valuable kinds, which are placed at disadvantage by the unintelligent action of man in this culling process.

How much this is the case becomes apparent when we learn from reliable investigations that in the forests of Kentucky, where white oak represents 40 per cent of the natural growth, after it has been culled—mostly for railroad purposes—the new growth contains not more than 5 per cent. of this most valuable railroad timber.

The bulk of tie material is now largely cut from second growth, especially in the Eastern States, and young timber, from trees that will make only one tie, or at least only one tie from a cut, is called for by most specifications for ties.

This rapid and careless consumption of the best parts of the second growth can, of course, only be hurtful to the forestry interests of the future; we draw in this way upon the fund which we should hold in trust and allow to accumulate for the use of the next generation; worse, we do all we can to deteriorate the value of the investment by injuring its quality.

It has been shown repeatedly, all assertions to the contrary notwithstanding, that our annual consumption of wood products at present exceeds double the amount of wood material that can possibly reproduce itself annually on the area covered with wood growth. It is, therefore, of national interest and within the line of work of this Division to call attention to the necessity of husbanding timber supplies, and to furnish all and any information that may lead to a more economical use of these supplies or a substitution of other material where this is practicable. While such economy is desirable in all directions, it is especially so in regard to tie-timber, since, as has been stated, for this purpose the young promising crop of the future is utilized prematurely—and that of the best quality and of the most valuable timbers. Furthermore, it should be known that for those who furnish these supplies for the railroad companies there is but small, if any, profit in the trade. The ties are in most cases brought to the railroads by holders of small wood lots, and the price paid is hardly more than fair compensation for labor in making and hauling the ties, no value being placed upon the material itself. The substitution of metal for wood—even if this were effected readily and without delay—would therefore not result, as may be anticipated by some, in a loss to the owner of woodlands. He will only be prevented from killing the calf, as it were, before it is full-grown, while it has little or no value, and he is paid only for the slaughtering; in the end his crop, by being utilized later, will yield him proportionately more in quantity and value.

It has been suggested that railroads could be induced to substitute metal for wood only when it could be shown that an increase in the price of wooden ties is imminent. As will appear from an investigation recorded in this report, enabling us to compare conditions of the present tie market with those existing seven years ago, the price paid for ties in many localities is now even lower than it was formerly, notably in the northeastern States. Yet it would be a mistake to argue from this, as a general proposition, that more timber is in the country than before, that forest supplies are in excess of demand, and that prices are going to decrease continuously.

The law of supply and demand as affecting the price of this commodity is vitiated considerably by other conditions which influence the price. It is the excessive offer compared with the requirements, rather than excess of actual visible supplies available for the long run, that places the purchaser of this commodity in position to dictate the price, the offer coming from many holders of small parcels, who have no knowledge of general market conditions, and hence can not take advantage of a comparison between actual supplies in view and demand for the present and future in adjusting the price. The present temporary oversupply with low prices may be followed by a long-continued short supply and higher prices without any preconceived action on the part of those who market the supplies.

A timber crop, unlike an agricultural crop, is capable of being harvested at various stages of development. Timber fit for ties may be cut at any time, from the twenty-year-old sprout of the coppice to the old growth of the virgin forest, and the offer of the crop in this shape may be excessive at any time without necessarily indicating an overabundance of forest supplies in general and for the long run. The accidental simultaneous arrival at an age when the timber is fit for ties of a new growth over a large area may also in a given region make supplies appear plentiful if offered in that shape, and therefore for a time reduce the price; but this present oversupply and reduction of price must necessarily be at the expense of a future short supply and increase of price. Another reason for an apparent oversupply of tie timber may be found in the opening up of new sources of supply on such roads as are capable of extension, while the old roads, with no new fields, to enter, will necessarily experience a constant advance in prices with decreased offers, and will be the first to have recourse to metal on account of cheapness. These conditions are apparent from the replies received from various railroad managements, as recorded in the notes found in this report.

It should also be known that, within limits, a railroad management has it in its power—and this power is being used—to keep the price low by raising freight rates, so as to make the exportation of tie timber from its territory unprofitable. The condition of the tie market, then, can not be the only, or even the main, criterion as to when the time for substituting metal has arrived, even from a financial point of view.

But it is not a consideration of *initial* cost that makes the substitution of metal ties desirable and profitable. It is superiority of track, permanence of road-bed, safety, reduced cost of maintenance, and hence *ultimate* saving and economy, that recommend the metal tie, as will be seen from a study of the experiences in foreign countries here presented. It will be a matter of astonishment to our railroad engineers to find that almost 30,000 miles of railroad track lies on metal ties, which means over 15 per cent. of the railroad mileage of the world outside of the United states and Canada. The claim, then, that metal ties are an experiment and their general adoption premature for lack of experience, will have to be abandoned, as based simply on ignorance in regard to the real state of affairs.

The report, being primarily intended for the information of railway managers and engineers for the purpose of interesting them more directly in the introduction of a substitute for wood, is necessarily of a technical character; it is full of such details as alone can influence the judgment of the engineer. The laborious task which Mr. Tratman, without any adequate compensation, has performed in compiling the experience of the world in regard to this subject will, no doubt, be appreciated and the details welcomed by those most nearly concerned in it.

The general public will be interested only in the ultimate result, which bids fair to advance the use of more permanent types of railroad construction in the United States, insuring greater safety and speed of railroad travel.

The forestry interests of the country will be subserved by this report in a practical manner by spreading this information, which must lead to a reduction of the premature and illegitimate drain upon the forest resources of the future.

Perhaps an apology is due to the reader for the bulkiness of this report, which might possibly have been compressed into more compact form. The desire to make public as soon as possible the results of the investigation, and the fact that Mr. Tratman, leaving for Europe, could not devote more time to the literary form, must stand as an excuse for the deficiencies in that direction, which a carefully prepared index will also tend to alleviate.

That besides the adoption of metal ties there are other ways open to railroad managers for effecting desirable economies in the use of wood supplies has been pointed out at length in former publications of this division, and is again discussed more briefly in the present publication in connection with a canvass recently made in regard to consumption of timber supplies by railroads.

A curious lack of proper financial calculation has been noticeable in the writings of engineers when discussing the profitableness and making comparisons of the relative value on the balance sheet of various systems of construction. A railroad company that is bound by necessity to consider only the initial cost can, to be sure, always settle at once all financial questions by the limit of cash in hand; but few corporations are in such straitened circumstances, and the question constantly arises whether the temporary saving in initial cost is preferable to a greater initial expenditure which insures—either or both—decreased expenditure for maintenance and deferred expenditure for renewal.

This question is capable of solution by simple mathematical calculation, as will be shown further on in this report.

From such calculation it will appear, for instance, that a road using ties for which it pays 50 cents and which last eight years—like white oak, in many sections—can afford to pay $1.20 for a metal tie lasting thirty years (the presumed life of such ties) and be sure of saving at least the amount required for the renewals of the oak ties during thirty years; or, by doubling the life of the oak tie to sixteen years by means of preservative processes, we may pay 35 cents for such process and would still find an advantage on the balance sheet.

In conclusion, I may express the hope that the information here presented will not only be found of value and be welcome to railroad managers and engineers, but that its presentation from this office will bring them to a realization of their duty, as an intelligent and influential class of a great community with a future before it, to give thoughtful attention to the subject of forestry in general as one of the necessary economies in a modern civilized state.

Railroads, while the carriers of civilization, the promoters of development, have committed many sins for the benefit of the present at the expense of the future by needless forest devastation. Being institutions of a permanent character, it would seem that their managers ought to be interested in anything that pertains to judicious use of natural resources and to favorable cultural conditions, at least within the territory which their roads traverse. While with their large consumption of wood material they are directly concerned in the continuity of forest supplies, they must also be indirectly concerned in the prosperous development of their territory, and that proper use and recuperation of forest resources, proper disposition of forest and field areas are essential to continual development of prosperity should be recognized by them, and their influence to secure both should be brought to bear even were it only for their own selfish interest.

B. E. FERNOW.

NOTE EXPLANATORY TO REPRINT.—The opportunity has been taken by Mr. Tratman in this reprint to make slight alterations on pages 284 and 289, referring to the Brandwood tie, and to enlarge somewhat the list of errata to be found on page 58.

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# CONSUMPTION OF FOREST SUPPLIES BY RAILROADS AND PRACTICABLE ECONOMY IN THEIR USE.

By B. E. Fernow,
*Chief of Forestry Division.*

The requirements of our railroad system in regard to forest supplies have been discussed several times in publications from this Division. A comprehensive canvass in regard to the kinds and quantities of timber used for railroad ties and their life was published in Volume IV of Forestry Reports, in 1884, and a more extensive discussion and computation of the consumption of forest supplies by railroads were given in Bulletin 1 from this Division. A canvass, made this year and tabulated below, was undertaken to verify some of the conclusions reached and to ascertain what, if any, the change in supplies has been during the last six years, as far as change in prices and personal views of managers might indicate. The tabulation by geographical sections will recommend itself to students of the subject as an improvement on the alphabetical one adopted by Dr. Hough in the first report mentioned, since forest and market conditions differ so widely in the various sections of the country that the relation of railroads to tie supplies can be profitably discussed only from local points of view.

The larger roads, mainly, have been canvassed as indicating the general and most prevailing practice. In the summary, the percentage of mileage to which the report refers compared with that in operation within the section is calculated, and upon that basis the amount of forest supplies consumed by the railroad system of the section is computed. Since the report refers to nearly 60 per cent.—ranging from 32 to 87 per cent. in the various sections—of the total mileage, such basis for computation will furnish a sufficiently close approximation to the truth for general discussion.

The consumption of ties goes for new construction and for renewals. Both these uses are, to be sure, exceedingly variable, the latter naturally being influenced by the increase of new mileage as well as by many other causes; only a general approximation, therefore, is possible. The present canvass places the number of ties needed for repairs at 60,000,000 per annum, the figure which Mr. Dudley estimated in the Bulletin I referred to, and somewhat lower than that figured in Mr. Kern's paper in the same publication.* To this, as has been there shown, 13,000,000 ties may be added for new construction, or in round numbers our present railroad system consumes 73,000,000 railroad ties, requiring at least 365,000,000 cubic feet of raw material. A rough computation of the proportion in which the various timbers participate in this consumption allows the following distribution of material:

| | |
|---|---|
| Oak ties | 45,000,000 |
| Chestnut ties | 3,500,000 |
| Pine ties | 12,500,000 |
| Cedar ties (red, white, and California) | 5,000,000 |
| Hemlock and tamarack ties | 2,500,000 |
| Cypress ties | 1,500,000 |
| Redwood ties | 2,500,000 |
| Various | 500,000 |

The oak, therefore, our most valuable timber, furnishes over 60 per cent. of the material, and not only from choice trees mostly, but from the young growth, which may make "one tie to the tree" or "one tie to the cut."

For bridge and trestle timber, etc., another 60,000,000 cubic feet of sawed material are to be added; so that a consumption of 500,000,000 cubic feet of wood. in the shape of forest-grown (round) timber for railroad purposes, which was claimed in a former publication, stands as a reasonable figure. This requires the annual culling of the best timber from probably more than 1,000,000 acres of our natural forest lands; and to furnish this amount continually not less than 10,000,000 to 15,000,000 acres of well-managed forest would be required, or in the absence of management—as at present—the area to be reserved for this purpose would have to exceed probably 50,000,000 acres, or more than 10 per cent. of our present forest area.

Since the railways are responsible for a very large amount of the consumption of timber, it must be one of the problems of a rational forest policy, in a country where forest management is not yet practiced, to encourage such economies in the use of timber as are within reasonable reach of railroad managers.

The use of wood and the method of using it are largely matters of custom everywhere. In the United States the enormous supplies which the native forest yielded have induced not only a very extensive but also a very wasteful use of wood, until now we have reached a point when the prospect of reduced supplies makes the study of economies a matter of national concern, and within a not too distant time private interest will also awaken to the need of it.

As a nation, with our present conception of private property rights, we have but little opportunity to check the wasteful use of our forest resources, except so far as this can be done by disseminating informa-

*As will be shown further on, this figure is probably over 30 per cent. below actual requirements, and a consumption of 80,000,000 ties for renewals nearer the truth.

tion which will lead to private economy. As far as the Government holdings of timber lands—still some 70,000,000 acres—are concerned, certainly a rational management is the need of the hour. The conditions in which this common property is left at present, even if considered merely from a business point of view, are deplorable. They are a disgrace to our nation.

In recognizing the necessity of Government action with regard to forest resources, the United States is the most backward of all civilized nations. Not only have all the European nations firmly established forest administrations, for at least that part of the woodlands held in the hands of the Government, but even Japan and China are inaugurating such, and the English colonies in India, Australia, and in Africa are fully imbued with this claim on Government supervision. Even in Canada the future action of the Government is at least not precluded, the Government retaining title to the land which is stripped of its timber, from which Canada, in fact, derives its principal revenue.

The consumption of timber for railway purposes includes ties, fences, telegraph poles, bridges, trestles and culverts, station-houses and other buildings, rolling stock, fuel. In all of these uses most companies would find it to their advantage to study economy.

Economy in the consumption of timber may be effected in two ways: (1) By the use of other materials as substitutes; (2) by employing means to increase the durability and life of the timber used.

The possibility of substituting metal for ties is fully discussed in Mr. Tratman's report and needs no discussion here.

While it can not be expected that the use of this substitute will be brought about by any consideration of the waning forest supplies, it is fortunate that the advantages, direct and indirect, which accrue from the use of metal ties are such as to recommend their employment; even before the time when the initial cost of the metal tie compares more favorably with that of the wooden tie and its financial advantage becomes palpable.

Those roads which have a sufficiently permanent and sound financial status, to allow them to carry on their operations with a view to ultimate saving rather than to economy in first cost, and to consider reduction of maintenance expenses the financial aim of a well-managed railroad, may even now profitably adopt the higher priced metal tie.

The use of metal for the construction of rolling stock—not only car-frames and truck-frames, but of entire cars—has proved quite feasible and satisfactory. The economy to the railway company will consist in reduced cost of maintenance and repairs, and in longer life.

A mail car built entirely of steel, on a plan patented by Mr. Green, was put in actual service on the Louisville, New Albany and Chicago Railway (Monon route) some time in 1888, and Mr. Watkeys, the master mechanic of the road, informed me in September last that the car is still in use and has given satisfactory results. He stated that up to September 26 it had made about 88,000 miles, and had not cost anything for repairs. The cars on the experimental line of the Meigs Elevated Railway at Cambridge, Mass., are of metal throughout; the truck and floor frames are of iron and steel, and the body has transverse ribs or frames of metal tubes with sheet-metal panels. Freight cars with metal frames are already used quite largely.

The use of stone for buildings, and of stone and metal for bridges, trestles, and culverts, suggests itself, and the substitution of these materials for lumber is, in fact, gradually progressing on all lines that have acquired permanency. Yet this tendency does not seem to have made a very great impression when we find that even in New England and the middle group of roads—leaving out the Pennsylvania Railroad—from 3,500 to 4,450 feet B. M. of timber per mile is used, while Southern and Northwestern roads, which are expected to use more wood in construction, average hardly any more, and the more western roads, with fewer stations, and probably fewer water-crossings, use about 3,000 feet.

While bridges are being more or less replaced by stone and iron structures, wooden trestles even in permanent and well established roads continue the rule, and it is very questionable whether the accidents resulting every year from burning of wooden bridges and trestles or from their collapse and washing out are not more expensive to the railroad companies than better structures. Filling in to solid bank should be done as fast as possible, or at least preserved timber and paint should be employed in the construction of trestles. The substitution of iron and cement pipe for wooden culverts, or masonry and arches and abutments with iron roof or concrete, would also prove a final economy.

In regard to station-houses, freight-sheds, shops, round-houses, car-sheds, it is again the economy of maintenance which would dictate the use of stone or brick and iron sheeting. The use of paint at least should be insisted upon as long as wood is used. The objection that with increased needs it is cheaper to replace a small wooden structure by a larger one, is not valid when the design for the smaller structure is in the first place made with a view to enlargement and addition.

The use of wood for fuel can hardly be said to be objectionable and uneconomical, as far as forestry interests are concerned, if managed with proper discrimination. In fact, a very great waste in the American forest results from the fact that much of the inferior material can not be utilized for firewood, and remains in the woods to feed and make more destructive the recurring forest fires. Some two and a half to three million cords of wood are probably consumed for locomotive use. Wood-burning locomotives are still found in all sections where fuel supply from the forest is plentiful and coal expensive. The only objection that can be made to this use is that timber fit for better purposes is largely placed in the wood pile. Another objection, perhaps more easily avoided, is that wood-burning engines are more likely to set fire to the forests through which they pass; on such, therefore, more efficient spark-arresters than are used in many instances should be employed.

In passing, I may point out the superiority of live hedges along the tracks, where such protection is needed, in preference even to wire fences.

But, as we have seen, by all means the largest consumption and of the most valuable timber is that for railway ties.

There are various directions, besides the substitution of metal or other material, in which a more economical use of wood in this part of railroad construction can be and ought to be effected. Such economies consist:

(1) In using only the most durable timbers.

(2) In giving proper attention to the cutting and piling of ties before they are used.

(3) In paying attention to the drainage and ballast material of the road-bed.

(4) In replacing ties in the road-bed which have rotted from the attack of a specific fungus by ties of a kind not liable to attack by the same fungus, so as to avoid its spread.

(5) In boring spike holes and filling the old ones when re-spiking, and in the use of more permanent rail fastenings.

(6) In the use of tie-plates in order to reduce flange-cutting; and lastly,

(7) In the use of preserving processes to lengthen the life of the timber.

These economies, it must not be overlooked, have also a tendency to improve other conditions of railway management. They tend to effect greater permanency of road-bed and hence greater safety to life and rolling stock; for every improvement made in the track by lengthening the life of ties reduces the necessity for frequent disturbance of the road-bed, which is a well recognized advantage.

*Duration or life of timber.*—Comparative tests of the durability of various timbers have never been made, and the experiences of the practice give only conditional results, since a comparative account of conditions under which the timber is grown, handled, and placed, is rarely made. Not only do different species show varying durability, that is, resistance to decay, but the same species seems to exhibit a variation according to the locality where it is grown, and the part of the tree from which the wood is taken, and even its age seems to influence durability.

An attempt has been made to make the color of the heart-wood a criterion of the durability of the various timbers, and the following exhibit might tempt one to accept, at least partially, the propriety of such a standard.* That the sap wood is less durable than the heart is of course well known.

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* See Dr. H. Mayr, "Die Waldungen von Nord Amerika, etc."

If we denote by *v. d.* = very durable, *d.* = durable, and *n.* = not durable timbers, we find:

| Pronounced black, brown, or red heart. | Gray, light brown, light red, yellow heart. | White or slightly colored heart. |
|---|---|---|
| Lignum vitæ *v. d.* | Cucumber tree *n. d.* | Beech *n.* |
| Mesquit *v. d.* | Tulip tree *n. d.* | Birch *n.* |
| Catalpa *v. d.* | Black locust *v. d.* | Gum *n.* |
| Osage Orange *v. d.* | Coffee tree *d.* | Maple *n.* |
| Mulberry *v. d.* | Honey locust *d.* | Linden *n.* |
| Black walnut *v. d.* | Sassafras *d.* | Hemlock *n.* |
| California Cedar *v. d.* | Elm *d.* | Spruce *n.* |
| Red Cedar *v. d.* | Oak *d.* | Fir *n.* |
| Bald Cypress *v. d.* | Willow *n.* | Torreya *v. d.* |
| Redwood *v. d.* | Pine *d.* | Lawson's Cypress *v. d.* |
| Tamarack *v. d.* | White cedar *v. d.* | Port Orford Cedar *v. d.* |
| Douglas fir *d.* | Cypress (Cala.) *v. d.* | |

The color of the heart-wood is due probably to the presence of tannin, which acts as an antiseptic, by making the albuminates in the sap insoluble; and since the most durable timbers seem to be those of southern localities, where therefore intense light and heat favor the formation of this antiseptic principle, it would also be reasonable to expect that trees grown in open stand would be more durable, and that the observed greater durability of second growth is due to the fact that it has grown up under full influence of sunlight.

The three timbers which without coloration of the heart show great durability are characterized by a strong smell, which leads to the presumption that ætheric oils take the place of the tannin and afford protection against attacks by fungus growth.

Some timbers, like the catalpa, begin soon to form heart-wood, while others, like the hickory, begin so late that but a small part of the trunk yields durable timber. This certainly is noteworthy in growing tie timber.

But the idea that the young wood is more durable because it is young, which seems to prevail among railway managers, must be considered erroneous. On the contrary, young wood, which contains a large amount of albuminates, the food of fungi, is more apt to decay, other things being equal, than the wood of older timber. Sound, mature, well-grown trees yield more durable timber than either young or very old trees. It is the rapid growth, exhibited in broad annual rings and due to favorable soil and light conditions, which yields the most durable timber in hard woods, and only as far as the growth in the virgin forest has been slow ought there to be a difference in favor of second-growth timber. In conifers, however, slow growth with narrow rings, which contain more of the dense summer wood in a given space, yields the better timber. The turpentine (pitch) accumulated in the summer wood of the conifers acts as a preservative by preventing the penetration of water and hindering the development and spread of fungus growth. Hence tapped trees on the tapped side where the pitch has concentrated itself—"light-wood"—is almost indestructible, while the rest of the tree, deprived of its turpentine, has lost its durability. In all cases within the same species, the heavier and denser wood is the most durable.

Coniferous woods, then, from comparatively poor soils, high altitudes and dense forest, and hard woods or deciduous, from rich, deep, warm soils and isolated positions, produce the most durable material.

Without means of determining the exact relative value of the different species, it is only possible to give the following enumeration, which, in general, proceeds from the most durable to the less durable ones:

EASTERN RANGE:

Conifers: Bald cypress (*Taxodium distichum*, Rich.); Red cedar (*Juniperus Virginiana*, L.); White cedar (*Chamæcyparis sphæroidea*, Spach.); Arbor-vitæ, White cedar (*Thuya occidentalis*, L.); Tamarack (*Larix Americana*, Michx.); Long-leaved pine (*Pinus palustris*, Miller); White pine (*Pinus Strobus*, L.); Red pine (*Pinus resinosa*, Ait.); Cuban pine (*Pinus Cubensis*, Griseb.); Short-leaved pine (*Pinus echinata*, Miller); Hemlock (*Tsuga Canadensis*, Carr.); Spruces (*Picea alba*, Link., *P. nigra*, Link.)

Broad-leaved trees: White oak (*Quercus alba*, L.); Post oak (*Quercus obtusiloba*, Michx.); Basket oak (*Quercus Michauxii*, Nutt.); Burr oak (*Quercus macrocarpa*, Michx.); Chestnut oak (*Quercus prinus*, L.); Live oak (*Quercus virens*, Ait.); Osage orange (*Maclura aurantiaca*, Nutt.); Hardy catalpa (*Catalpa speciosa*, Warder.); Black locust (*Robinia pseudacacia*, L.); Honey locust (*Gleditschia triacanthos*, L.); Red mulberry (*Morus rubra*, L.); Chestnut (*Castanea vulgaris*, var. *Americana*, A. DC.); Kentucky coffee tree (*Gymnocladus Canadensis*, Lam.); White elm (*Ulmus Americana*, L.); Slippery elm (*Ulmus fulva*, Michx.); White ash (*Fraxinus Americana*, L.); Black ash (*Fraxinus sambucifolia*, Lam.); Green ash (*Fraxinus viridis*, Michx.)

ROCKY MOUNTAIN REGION:

Mesquit (*Prosopis juliflora*, DC.), Red cedar (*Juniperus Virginiana*, L. and *J. pachyphlœa*, Torr.); Pinyon pine (*Pinus edulis*, Engelm.); Fox-tail pine (*Pinus aristata*, Murray); Douglas spruce (*Pseudotsuga Douglasii*, Carr.); Western larch (*Larix occidentalis*, Nutt.); Burr oak (*Quercus macrocarpa*, Michx.); Bull pine (*Pinus ponderosa*, Dougl.); Engelmann's spruce (*Picea Engelmanni*, Engelm.).

PACIFIC SLOPE:

Yew (*Taxus brevifolia*, Nutt.); Redwood (*Sequoia sempervirens*, Endlicher); Lawson's cypress (*Chamæcyparis Lawsoniana*, Parl.); Sitka cypress (*Chamæcyparis Nutkaensis*, Spach.); Canoe cedar (*Thuya gigantea*, Nutt.); White cedar (*Libocedrus decurrens*, Torr.); Douglas spruce (*Pseudotsuga Douglasii*, Carr.); Western larch (*Larix occidentalis*, Nutt.); Live oak (*Quercus chrysolepis*, Liebm.); Post oak (*Quercus Garryana*, Dougl.); Sugar pine (*Pinus Lambertiana*, Dougl.); Engelmann's spruce (*Picea Engelmanni*, Engelm.); Western hemlock (*Tsuga Mertensiana*, Carr.)

The *time of felling* has always been thought to influence the durability of timber. But while practical considerations will limit the choice of time, theoretically, with proper after-treatment no such influence can be admitted.

Early winter felling should have the preference, because, possibly, less fermentable sap is then in the trees; mainly, however, because the timber will season with less care, more slowly and more evenly, and before the temperature is warm enough for fermentation to set in.

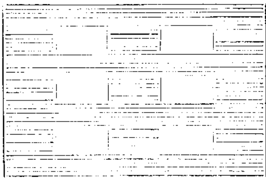
If the wood is cut "in the sap" it is more liable to fermentation and to the attacks of insects and more care is necessary in seasoning; for the rapid seasoning, due to the warm dry atmosphere, produces an outer seasoned coat which envelopes an unseasoned interior liable to decay. When cut in the leaf, as is done when the chestnut oak is cut for tanbark, it is advantageous to let the trees lie full length until the leaves are thoroughly withered (two or three weeks), before cutting to size. With conifers this is a good practice at any season, and if it can be done, all winter-felled trees should be left lying to leaf out in spring, by which most of the sap is worked out and evaporated, for it is the stored up albuminates, the fungus food, which are utilized in the budding and leafing.

After felling, further attention is needed to secure *thorough seasoning.* The idea expressed in some of the reports on the life of ties, that seasoning is of no consequence, contradicts all known facts. Under certain conditions of the roadbed this seasoning of the ties may satisfactorily progress while in place, but by so much as it is imperfect, by so much is danger from rot invited.

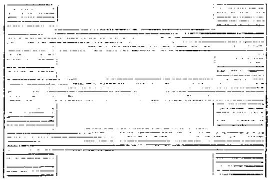
The experience of the Delaware and Hudson Canal Company, "that ties seasoned one year, being properly piled and the bark taken off, would last longer than ties used the same year they are cut and the bark left on," is sound and incontrovertible. Unfortunately no experiments are at hand to show the absolute money value of seasoning, because the length of time to which the life of ties is prolonged by seasoning is unknown.

That the careless piling of ties which is so often practiced costs the railroad companies thousands of dollars through the earlier deterioration of their roadbed, is quite certain. As proper piling does not mean extra cost, for it can be almost as easily done as not, it should be strictly insisted upon.

Most roads prescribe in their specifications for ties a method of piling, but this is done rather for convenience of inspection and loading than for securing proper seasoning. Piling, upon sound principles, is shown as the result of the specifications for the New York and New England, Pennsylvania, Lake Shore and Michigan, the Cleveland, Dayton and Columbus, Kansas City, Fort Scott and Gulf (which shows a diagram on its specification card), and a few other roads. The practice of these roads can be without difficulty and should be imitated by all others. The requirement is, to pile never more than fifty ties in a neat square pile, in such a manner that one tier contains six to nine ties, separated from each other by a space equal to about the width of the tie, the next tier consisting of one tie placed crosswise at each end of the first tier. The bottom tier should consist of two ties, or better, poles, to raise the pile from the ground. The piles to be 5 feet apart. The end view of the pile thus:



The side view thus:



In this manner a better result at least will be obtained than by the indiscriminate close tumbling together of the ties, so often practiced.

If possible, the piling ground should be somewhere in the woods, or at least away from the sun, wind, or rain, so as to secure a slow and uniform seasoning.

If dried too rapidly, the wood warps and splits, the cracks collect water, and the timber is then easily attacked and destroyed by rot.

The best method of obtaining proper seasoning, in a shorter time, without costly apparatus, is to immerse the prepared timber in water, from one to three weeks, in order to dissolve and leach out the fermentable matter nearest the surface. This is best done in running water—if such is not at hand, a tank may be substituted, the water of which needs, however, frequent change. Timber so treated, like raft timber, will season more quickly and is known to be more durable.

If practicable, the application of boiling water or steam is advantageous in leaching out the sap.

The Atchison, Topeka and Santa Fé road has made the experiment of leaching pine ties for two months, with the result of increasing their durability to a considerable extent (time not stated). It also reports that pine ties cut in summer and placed in track while green last three years; if cut in winter and seasoned before use, they last about five years; if cut in winter and water seasoned, they will last five and one-half years.

In the canvass made in 1883 the question was asked, whether ties were preferred from old or young growth, and whether hewn or sawed. While in the majority of cases the answer runs "hewn, and one tie to the cut, from small trees" or even "one tie to the tree," there are others who see no difference in the durability of sawn or hewn, some even preferring the former, especially with coniferous woods and when all heart can be secured.

Some give as reasons for their preference for young timber, that old timber is more liable to check, or more difficult to work "being tougher," or, and this is the most likely reason for observed inferiority, because poorer timber is furnished in sawed ties, namely, such as is not good enough for other purposes. Some use sawed ties because they can be had more cheaply—probably where other roads insist on hewn ties; others use hewn ties because they can be had more cheaply—probably where saw timber is scarce and coppice growth plenty.

It has been stated before that there is not necessarily any superiority to be found in young growth; on the contrary, well-grown mature trees furnish more durable timber. In fact, the young timber of conifers is invariably poor, especially if quickly grown, and the young timber from the dense hard-wood forest, where it grows slowly, is also poor. It is, therefore, an inexcusable waste and folly to insist indiscriminately upon ties cut from trees that will make but one tie or that the cut should make but one tie. The excuse for it can be found only in the fact that hewn ties do seem to last longer under otherwise unfavorable conditions and can be furnished only from such timber. It is claimed by some roads that hewn ties will last 30 per cent., or from one to three years, longer that sawn. The reason is obvious. The sawn face is more or less rough and collects water, and thus gives opportunity for fungus growth, while the smoother face of the hewn tie sheds the water. With hard woods of good growth, careful manufacture, proper seasoning, and with well-drained road-bed, the advantage of the hewn tie would probably not be equal to the enormous waste of wood necessary in its manufacture.

Some of the reports of those roads which make no difference between sawn and hewn ties, or which prefer the former, are worthy of note.

The Grand Trunk Railway desires that a tree should average four ties, and says "it matters not whether they be hewn or sawn, so long as the upper and lower faces are flat and the sides uncut. Oak ties are taken when sawn on four faces, but no other kind." The ties used by the road—oak, tamarack, hemlock, and cedar—average six to seven years in duration.

The Detroit, Lansing and Northern Railroad, using oak with a life of eight and hemlock with a life of five years, finds no difference between hewn and sawed ties, "if made of similar timber."

The Kansas City, Fort Scott and Gulf Railroad, using oak with a life of eight years, says: "If made from large timber, no preference is had between ties that are sawn and those that are hewn. Large timber is deemed best."

The preference is given to sawn ties, and from large trees, by the Oregon and California Railroad, using red fir of eight years life; by the Bangor and Piscataquis Railroad, with cedar of fourteen and tamarack of seven years' duration (put in track when half seasoned, although full seasoning is recognized as preferable); by the Mobile and Northwestern Railroad in Mississippi, "if all heart can be obtained and large timber, as it has less sap-wood. The small trees along the line of road do not make as good ties as the large timber."

The Arkansas Midland Railroad prefers sawed ties, although they are more costly. "Cypress ties should only be sawed from large trees, post oak and white oak ties from small trees are equally as good as from large ones."

The Alabama Great Southern makes a point that the ties should "not be cut through the heart of the tree," the philosophy of which is, probably, that the long-leaf pine ties are liable to have the heart break out and sliver. The significant statement is also made that the oak from the south end of the road is not as durable as that from the mountains on the north end. The difference is probably due to track conditions rather than to locality of growth.

*Durability or life of ties.*—The life of timber in use as ties is reduced by two causes, namely, a mechanical one, the breaking of the wood fiber by the flange of the rail and by the spikes, and a chemical or physiological one, the rot or decay which is due to fungus growth. These causes work either in combination or, more rarely, independently. A soft wood may be easily cut into and made useless before rot takes place—as, for instance, in the case of such otherwise durable woods as redwood, chestnut, etc., but the breaking of the fibre in most cases is only the antecedent and forms part of the favorable conditions for the fungus growth—other timbers may be attacked by rot first, which, of course, is followed soon by a breaking of the fiber.

The exterior conditions favorable to decay have been discussed at length in Bulletin 1; the controllable ones consist mainly in the drainage conditions of the road-bed. Rock ballast is best drained, and hence the best record comes from such road-beds; gravel is next best and clay or loam is about the worst; on the other hand, where soft-wood ties, like chestnut, are used, the hard rock ballast, while unfavorable to decay, reduces their life by pounding and cutting. Sand ballast seems to vary considerably; a sharp, coarse silicious (not calcareous) sand with good under-drainage should be next best to gravel, while some reports give a heavy black soil and loam as better than sand. The reason why sand, although offering good drainage, is favorable to decay, may be sought in its great capacity for heat, which induces fermentation.

In Louisiana "ties on black loamy soil rot out in one-third the time of those laid in a clay soil. Ties exposed to the sun all day rot out in less time than those which are shaded a part of the day. Shade and a free circulation of air are requisite to the best lasting of any timber in our climate."

From fifteen years' experience on the Cumberland and Pennsylvania Railroad it is stated that ties supported in stone ballast have 20 per cent. longer life, as far as rot is concerned. The Eastern Kentucky Railroad claims that with slag ballast oak ties will last two years longer than in sand, while on the Cleveland, Columbus, Cinncinnati, and Indianapolis Railway such ties were found to last two years less in slag ballast than in gravel. The nature of the slag, it should not be forgotten, is very varying, and hence its value for ballast. The East Tennessee, Virginia and Georgia Railroad allows in rock ballast eighteen months longer life than in a soil bed, and notes in sandy soil the most rapid decay.

Experience on the Hannibal and St. Joseph Railroad ranges the various kinds of ballast as follows: stone ballast best; next, coarse gravel; next, soil, and worst, cinder and sand ballast.

The New York, New Haven and Hartford Railroad, six years ago, ballasted its road with broken stone to a depth of 14 inches; stone of not more than 2 inches in size was used, and at the rate of 4,000 cubic yards to the mile. It was expected that ties in such a road bed would last two years longer than in gravel ballast. Yet now it is found that, with the heavy traffic, the high rate of speed, and weight of engines and trains and the use of chestnut ties, these do not last more than five years, the cutting of the rail on the upper and of the stone on the lower side wearing the ties rapidly.

Even the oak tie will succumb to the pounding it receives from such ballast, as the report of the Erie Railroad shows, which, while admitting that ties are less liable to decay in broken stone ballast, finds this ballast "on the heavily used portions of the line hard on the ties, by cutting, so that the oak ties are worn out before they rot."

Thus the life of ties of the same timber varies considerably, not only according to climate, and character of the timber, and the treatment the ties receive before being laid, but also according to the character of the road-bed and the traffic. From the reports of the 283 companies in 1883—which, by the-by, are now so consolidated that the 85 companies reporting to this year's inquiry represent almost 50 per cent. more mileage than the former 283—the following tabulation has been made, showing the range and average duration of ties of various timbers under present usage. The aim of well-managed roads, of course, should be so to combine conditions of road-bed, inspection, and handling of ties, that the highest average duration at least should be obtained.

The long life given to honey locust in the table on page 25 is probably due to a misnomer, black locust being meant, as honey locust is probably not a very lasting timber. The duration of mesquite, if sound, is claimed to be interminable.

| Kind. | Range. | Average. |
|---|---|---|
| Conifers: | | |
| Redwood | 8-15 | 11-12 |
| Bald cypress | 4-12 | 8-10 |
| Red cedar | ...... | 10 |
| Tamarack | 4-12 | 7-8 |
| White cedar | 4-10 | 7 |
| Pine, long-leaf | 5-10 | 6-7 |
| Pine, red and white | 4-8 | 6 |
| Pine, bull (California) | 6-9 | 6-7 |
| Pine, bull (Colorado) | 3-6 | 5 |
| Hemlock | 2-8 | 4-6 |
| Spruce | 3-7 | 5 |
| Broad-leaved trees: | | |
| White oaks | 3-12 | 7-8 |
| Chestnut | 4-12 | 7-8 |
| Honey locust | ........ | 10 |
| Coffee tree | 7-10 | ........ |
| Cherry, black walnut, locust, sassafras | 6-10 | 7 |
| Mulberry | 5-6 | 6 |
| Mesquite | ........ | ........ |
| Elm | 4-9 | 6-7 |
| Black oaks | 2-7 | 4-5 |
| Ash, beech, maple | 2-7 | 4 |

The suggestion of Mr P. H. Dudley (see Bulletin I), that ties which are attacked by a specific fungus in a given locality be replaced by ties of a different species not so attacked, in order to get rid of the infection, is worthy of consideration.

The necessity of employing an expert to determine the fungus causing the rot and to designate what kind of timber to substitute in order to avoid the specific fungus, would probably form the practical objection to this expedient.

## METAL TIE-PLATES AND METHODS OF FASTENING.

The experience that the more durable timbers can not be utilized to the full length of their life, because of the flange cutting which destroys them mechanically, suggests at once the use of metal tie- or bed-plates or other means for reducing this mechanical destruction. Such bed-plates correspond to the rail chairs in use on English roads, but are less expensive. Some time ago the use of a hard-wood plate, let into a soft-wood tie under the rail-foot, was proposed, but the advantage thus gained was probably not proportioned to the labor of inserting the plate, for it seems not to have found wide application.

The use of a sheet of felt, one-quarter of an inch thick, placed between tie and rail, has been found quite satisfactory in France with preserved ties in preventing flange cutting, the felt lasting five to ten years. The experiment of the Baltimore and Ohio Railroad of using lead, sunk into the wood, is well known. Though effective to some extent the expense was too great. The method of fastening the rail to the tie has also much to do with the wear of the tie.

That the wear from spiking and frequent respiking must needs reduce the life of the tie is obvious; not only is the fiber destroyed mechanically, but water collects in the old spike holes and induces rot, while the loosening of the spike and consequently of the rail produces a vertical pounding which accelerates the wear of the rail-foot into the tie.

That by boring spike holes before the spike is driven the adhesion of the spike is increased, the track kept longer in safe condition, the wear under the rail-foot reduced, and the tie made to last longer has been shown in Bulletin 1, where experiments in this direction are recited at length. The filling of the old spike holes with wooden plugs to reduce the liability to rot was reported as satisfactory practice by the careful manager of the Cleveland, Mount Vernon and Delaware Railroad, who used plugs $\frac{1}{2}$ by $\frac{1}{2}$ by 5 inches in size. The New York, Pennsylvania and Ohio road also uses such plugs.

The common spike, now almost exclusively in use, must be considered the poorest and most unsatisfactory part of our railroad construction. Not only is a large part of the reduction in the life of railroad ties to be charged to these imperfect fastenings, but they are probably responsible for more damage to rails and rolling-stock, and for more accidents than is generally recognized. An improvement, therefore, in rail-fastenings is decidedly needed.

Various changes in the shape of the spikes have been made, which do not, however, appear to increase the efficiency of an ordinary well-made spike; tests at the St. Louis bridge having shown that ragging and curving even reduce the efficiency below that of the ordinary spikes.

The most promising improvement in spike-fastenings is, perhaps, the Davies locking spike, recently come into use, which seemingly obviates some of the objections to which all spike fastenings are exposed.

Its sharp cutting edges reduce the dangers from mechanical destruction of the wood-fibre; and as it runs diagonally across the fibre ($\overline{\setminus}$) it will undoubtedly hold more firmly than the straight spike, and thus, by keeping rail and tie closely connected and diminishing the necessity of frequent respiking, will necessarily save the tie from premature destruction.

The use of wood screws with washers or screw-bolts would of course be superior in every respect to the present spike fastenings, and this change alone in the fastening material would make ties last considerably longer, besides insuring greater safety. Such screw fastenings, of various designs, with holes bored to receive them, are now largely used in Europe. In this country the Bush interlocking bolts have been employed with good results by the New York Central and Pennsylvania railways. Another screw fastening of simple construction is designed and used by Mr. M. W. Thomson, engineer of maintenance of way, Pennsylvania Railroad. The only objection to the use of such fastenings is their greater cost, increased labor, and need of skilled labor in their use. But after all, the use of bed-plates in connection with proper fastenings alone can satisfy present requirements of track where heavy traffic on wooden ties with flange rails is to be safe.

The experience with bed-plates in Germany shows that after the plate has adjusted itself to the tie, which requires some time and some cutting into the wood, "the line which was employed for seven years for the purpose of determining this wear, gave hardly any wear to the ties protected by plates; in every case showing less than 1 millimeter loss per year," while that of oak ties, unprotected, was nearly four times as large (one-fifth inch).

Other roads, where bed-plates are used, report considerable increase of life not only of spruce ties on the tangent, but also of oak ties which were used on the curves, giving in such position the oak ties 16.6 and the spruce ties (treated) 16.7 years' life, a very remarkable service.

Bed-plates are to serve the following objects:

(1) A more even distribution of rail pressure over a greater area of the tie, and thereby
(2) Retardation of the mechanical destruction of the tie by cutting, and
(3) Less danger of tilting of rails;
(4) To prevent the lateral bending of spikes or screws and thereby loosening of rail;
(5) To increase resistance of screws and spikes against lateral motion or spreading of rails.

To attain these objects the following conditions in the form of the plate are necessary:

(1) It should be sufficiently large to increase sensibly the bearing surface upon the tie. A length of 5½ inches and a width of 4½ inches in addition to the width of the rail-foot, or altogether 8½ to 9 inches are considered minimum dimensions.
(2) It should be sufficiently thick to take up all pressures without effect on the shape of the plate; the minimum thickness is given as one-half inch.
(3) It should be so placed that the larger bearing surface be on the inside of the rail where the pressure is greatest and resistance therefore most needed, so that 2½ inches lie inside and 2 inches outside the rails.
(4) It should increase the resistance of spikes or bolts against lateral pressure, by projecting shoulders against which the fastenings bear.
(5) It should relieve the fastenings from lateral pressures by having the rail-foot rest directly against projecting shoulders.
(6) It should be secured against lateral motion upon the ties by having the lower surface provided with short sharp ridges (not deeper than three-sixteenths to one-fourth inch, three being used, the inner tooth-rim deeper than the outer), or other contrivances which increase the friction between plate and wood.

After considerable experience with other forms, a bed-plate answering all these requirements has been designed and used by Mr. Post, the well known railroad engineer of the Netherlands Railway. The gradual development of the ideal bed-plate is described by him in Glaser's "Annalen für Gewerbe und Bauwesen," 1887, and the first and ultimate forms are shown in accompanying cuts.

He remarks in regard to results:

(1) After 100 to 500 trains the ridges have sunk into the oak ties; knots must be avoided under the bed-plate.

(2) After twenty months the impressions of the ridges were found sharply cut and the edges unbattered.

(3) The gauge was kept almost as well as with metal ties, *i. e.*, better than with oak ties without plates.

(4) The fastenings showed neither wear nor loss of shape nor loosening.

On the Prussian railways, instead of the parallel sharp ridges a network of diagonally crossing ribs is cast on the under surface of the plate, which reduces expense and has been found entirely satisfactory and fully answering the purpose of close adjustment between tie and plate.

In the United States and Canada several roads, among which the Intercolonial, Atlantic and Pacific, and Maine Central, have begun the use more or less extensively of a bed-plate weighing 2 pounds, which consists of a simple steel channel 8 inches long, 3⅝ inches wide, 3-16 inch thick, and with flanges turned down on the long sides ⅝ inch deep, which are driven into the tie parallel with the fiber, two spike holes having previously been punched into the plate. While these plates are certainly exceedingly simple and easy of application, they can not, of course, satisfy all the requirements demanded above; their bearing surface is rather small and the metal thin; there is also the objection that the flanges open new grooves for water to penetrate and collect in, thus presenting favorable conditions for the rot, which is not the case in the above described forms.

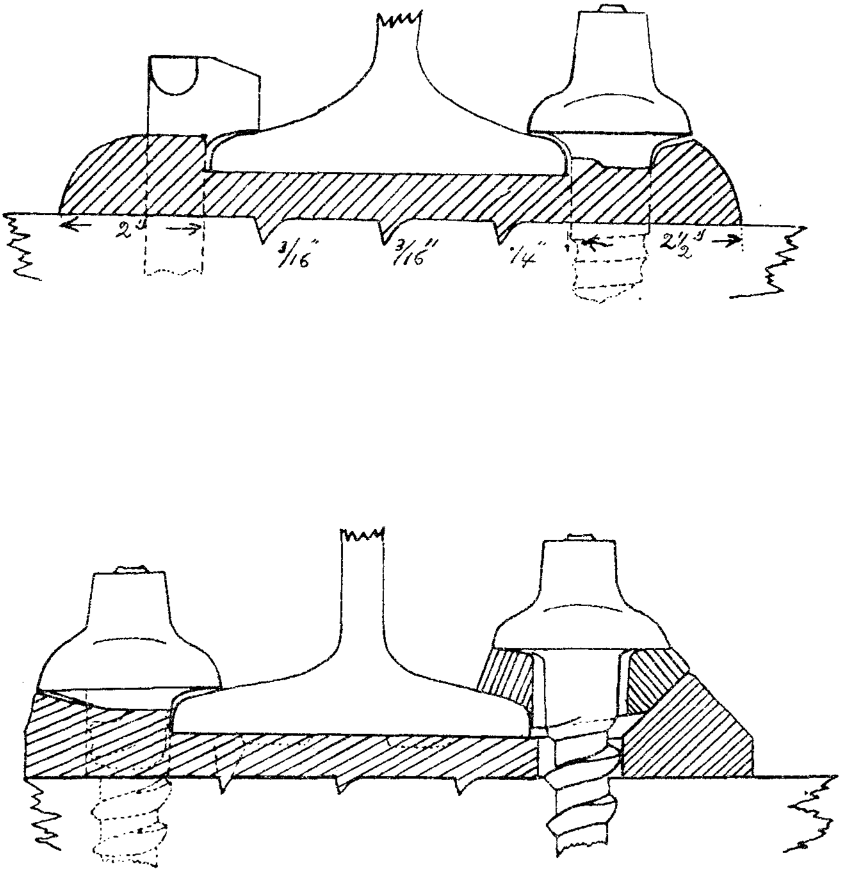
In regard to the brief experience had with this plate, the chief engineer of the Intercolonial Railroad says:

> The Servis tie-plate does very good service on cedar ties and at joints, but does not appear of sufficient strength, as now manufactured, to resist the heavy traffic passing over them, as we have found they very soon become hollow backed.

Mr. L. B. Robinson, manager of the Atlantic and Pacific Railroad Company, western division, makes the following statement:

> We bought about 70,000 of these bed-plates last year for an extension of our line, which will, however, not be opened until next month (May), so that we had but little experience with these plates.
>
> About a year ago I put a few of these plates under rails on our main line. The rails were light weight, 50 pounds to the yard; the ties were California redwood, which is a soft timber. We are using on this division engines weighing sixty tons. The few plates that we put there have made a very fair showing. Without the plates the rails in the same locality have sunk into the tie from one-half to one and one-half inches, while rails resting on the bed-plates are simply even with the top of the tie; in a very few instances they have sunk into the tie, say one-eighth of an inch. The plates are of too small an area, in my judgment, for such soft timber as California redwood. If they had been made an inch and a half longer and an inch wider I think much better results would have been obtained.
>
> As soon as our extension, noted above, is opened, these plates will be subjected to heavy traffic, and in the course of the next six months I may be able to give you more definite information.

The manager of the Maine Central Railroad, using principally cedar




POST'S TIE BED PLATE

ties, expresses his entire satisfaction with the use of the Servis plate, and says:

Their use has so thoroughly demonstrated their great benefit, not only as a bed plate but also as a rail brace, keeping the track from spreading, that they now receive the hearty commendation of all our trackmen.

From these remarks we may infer that the bed-plate, like all other parts of railroad construction, must be adjusted to the special conditions of track and traffic. What is satisfactory and sufficient in one case may not be so under changed conditions.

The Perkins tie-plate, resting on a thin wooden block placed on the tie avoids the cutting into the tie by the rail flanges, but, besides other disadvantages, is apt to reduce the efficiency of the fastenings, thereby failing in one important office of the ideal plate.

Other bed-plates which strive to meet more of the requirements made by Mr. Post, as stated above, are the Thomson (Pennsylvania Railway), the Cox (McConway and Torley), the Wrenshall, the Sandberg, and the Stuart elastic plates.*

Lately a "shoulder tie-plate" has been placed on trial on the Pennsylvania lines. This plate, weighing 4 pounds, is stamped out of one quarter-inch steel plate, 12 inches in length and 5 inches in width, thus giving about three times as much bearing surface as the rail, while along the rail-foot on both sides a shoulder of about one-eighth-inch depth is raised in the process of stamping, which helps to keep the spikes from wearing at the neck and to preserve the gauge.

It is asserted that the use of bed-plates will increase the wear of rails. This is conceivable under two conditions, namely, if the fastenings are imperfect and loose, allowing the pounding of the rail upon the plate, or if the bearing surface is enlarged beyond proper limits, counteracting the elastic features of the tie, especially upon an unelastic ballast (stone). Here, as everywhere in railroad construction, the relation of each part to the other and to the service required must be kept in view.

Even the use of a properly constructed splice-bar, like the "Samson," must be counted among the means of economizing in the life of ties.

*Preserving processes.*—With the adoption of means which secure the tie against mechanical destruction the question of preserving it against rot assumes at once a new aspect.

While in France not a tie is laid without subjecting it to a preserving process, and while the same practice prevails largely in England and in Europe generally, but little has been done in this direction in the United States.

The reasons for this neglect are various, mainly the cheapness of tie timber and the expense of preservative processes, and further the ob-

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* See, in this connection, Mr. Russell Tratman's paper on "The Improvement of Railway and Street Railway Track," in Transactions of the American Society of Civil Engineers, March, 1890. The Holgate tie-plate, with lugs instead of shoulders, in successful use on the Grand Trunk Railway, came too late to our notice to be noticed in the text.

servation that flange cutting proceeds often more rapidly than rotting. Uncertainty in regard to the efficacy of various processes, unsatisfactory experience with processes improperly applied, and unwillingness to spend on initial cost for the sake of a future saving may also have had something to do in retarding the introduction of preserving processes.

In railroad building there is such an intimate and mutual relation of the different parts of construction that no one can be determined upon without keeping in view all the others. As we have seen, the use of rock ballast, which promised by its effectual draining a longer life to the chestnut tie, by its hard pounding destroyed it sooner than it would have been destroyed by rot in a gravel or dirt ballast. So, too, preserving processes which soften the wood fiber, as some are apt to do, while preventing rot would reduce the life of the tie through mechanical action, while a process that hardens the wood, as claimed for the burnettizing, might make even a soft tie last as long as an untreated hard-wood tie. But the combination of bed-plates with preserving processes promises to make almost as satisfactory and perhaps as economical and safe a track as one on metal ties.

The various processes, their value and their cost, have been at length and admirably set forth in a pamphlet by the Society of Civil Engineers and in more condensed form in a report by Col. Henry Flad, civil engineer, contributed to Bulletin 1 of this division. Some new processes have come into use since the preparation of that report; but as the value of such processes can only be determined by years of experimental use, the discussion of these is left to some future time.

I should, however, mention one new process quite at variance with the conceptions upon which all processes have hitherto been based. While those processes attempt to eliminate the sap of the wood and substitute in part, at least, an antiseptic, which is to keep out moisture and make the germination of fungi impossible, "vulcanizing" is carried on upon the claim that by pressure and heat such changes in the chemical constitution of the sap can be produced as to make it incapable henceforth of sustaining a fungus growth. While the argument upon which the effect is claimed in the pamphlet of the New York Vulcanizing Company is open to criticism and stands upon a rather uncertain physiological basis, it is not impossible nor improbable that the claimed change in the chemical constitution of the sap is produced, but whether, under the influence of atmospheric agencies, bacteria, and fungus spores this change will remain permanent and the fungus growth be prevented remains still to be seen. It is claimed that the teredo has not attacked vulcanized wood; but this fact does not argue immunity from attacks by fungi.

According to a statement of Mr. F. K. Hain, manager of the elevated railroad lines in New York, "yellow pine timbers treated by this process have been in use on the road for the past six years, without showing any rot and hardly any wear by cutting, where untreated timber rapidly decayed. Most of the timber now in use by this company has been treated by this process, and all renewals are made with vulcanized timber." From an analysis of vulcanized oak, made by Dr. C. F. Chandler, it appears that the formation of antiseptics during the process has really taken place in the wood, the analysis showing altogether 11.90 per cent. of such materials, namely, 0.36 per cent. neutral oils, turpines, etc.; 0.77 per cent. phenols, and 10.78 per cent. resinous acids.

The process consists simply in subjecting unseasoned wood to dry air, heated to from 400 to 600 degrees F., under pressure of 100 to 175 pounds per square inch, heat and pressure being regulated according to the nature of the timber and the result to be obtained.

The fiber of the wood seems to be hardened, and the color can be kept natural or changed at will.

Altogether, this process is among the most promising of the many designed to lengthen the life of timber. Its advantages, besides simplicity and cheapness—the present charge is $8 per thousand feet B. M., which would bring the cost per tie to 3 cents—are, that unseasoned timber is preferably used, that the fiber is not weakened, that the timber may be worked after treatment without exposing any untreated part, for it seems treated through and through, that it seems unaffected by atmospheric changes, being thoroughly seasoned by the process.

A few notes on the status and experience of tie preserving in this country which have come to the writer's notice may find insertion here.

Heavy oil of tar, commonly called creosote (either from wood-tar or coal-tar), and chloride of zinc are the most commonly employed materials in this country.

The Chicago Tie Preserving Company, at its own works (which supply ties for the Chicago, Rock Island and Pacific Railway under contract) and at the works erected by it at Laramie, Wyo., for the Union Pacific Railway, and at Las Vegas, N. Mex., for the Atchison, Topeka and Santa Fé Railway, uses the zinc tannin process; the Southern Pacific Railway has both creosote and zinc plants at its Houston works; the Creosote Lumber Construction Company, of Fernandina, Fla., and the Carolina Oil and Creosote Company, of Wilmington, N. C., use the wood creosote oil; the Lehigh Valley Creosoting Company, of Perth Amboy, N. J., Eppinger & Russell, of New York, and the Old Dominion Creosoting Works, of Norfolk, Va., use dead oil of coal-tar; the Louisville and Nashville Railway has a creosoting plant of its own, used for piles and timber; the Boston and Maine Railway has a kyanizing (corrosive sublimate) plant at Portsmouth, N. H., which has been used for treating hemlock ties.

The Louisville and Nashville Railway's creosoting works, situated at West Pascagoula, have for ten years creosoted piles to protect them against the teredo, also bridge and trestle timber, but have never creosoted ties, because it is believed that with ties at 23 to 30 cents apiece the additional expense would not be justifiable. The chief engineer writes that the cost of creosoting them would be about $24 per 1,000 feet board measure, or $1 per tie, including creosoting, freight, and handling, assuming that they take 1½ gallons of oil per cubic foot.

This reasoning is not quite fair, since ties would not, or need not, take up more than one-third of the material stated, and are probably more cheaply handled than bridge and trestle timber. The cost without transportation is stated at 25 cents per tie by Colonel Flad. Creosoting is, no doubt, the most expensive process, and as it is said to soften the timber may not even be found as desirable for tie preserving as a process using metal salts.

Mr. F. C. Prindle, of the Carolina Oil and Creosote Company, Wilmington, N. C., writes as follows:

> We are now using only our heavy wood creosote oil for creosoting purposes. I suspect that the chief difficulty in introducing creosoted ties in this country lies in the fact of their considerable first cost, and the prevailing policy with new roads seems to be to build as cheaply as possible at the outset and then each succeeding administration is much inclined to keep the yearly repairs of roadway down to the minimum, and the long-run policy of building permanently at first and with very much smaller repair bills afterward seems to be ignored. The approximate increase in cost of a creosoted over a plain tie is about $14 per 1,000 feet board measure when creosoted with 10 pounds of oil per cubic foot and $16 when creosoted with 12 pounds of oil per cubic foot, or about 60 cents per tie.

The Newport News and Mississippi Valley Railway had thirty pine ties creosoted with dead oil of coal-tar at the Old Dominion Creosoting Works, Norfolk, Va., some years ago; one was taken up in July, 1887, after five years' service, and was reported to be in good condition and likely to last for fifteen years more. The ties were in track under heavy traffic, but the spikes maintained a firm hold. Mr. S. D. Puller, manager of the works, states that prices range from 75 to 85 cents per tie at the works. Mr. George S. Valentris, manager of the Eppinger & Russell Creosoting Works, New York, states that ties treated with dead oil of coal-tar have given satisfactory results, but that the first cost keeps them from being generally used; the cost is from 90 cents to $1 for a tie 8 inches by 6 inches and 8 feet length.

The Atlantic Coast Line put down some creosoted pine ties three years ago, the process costing $10 per M feet, B. M., or 12 cents per cubic foot, which would bring the cost per tie to a little over 40 cents.

The Savannah, Florida and Western Railroad Company creosotes yellow pine piling and bridge timber at $12 per M feet, B. M.

The Boston and Maine Railroad Company for eight years used hemlock ties kyanized, with bichloride of mercury, at 10 cents per tie, with satisfactory results, but when hemlock ties increased in price, and cedar ties, lasting eight years, became cheap (33 cents), no advantage seemed to accrue from the use of the process and it was abandoned.

Even if we allow the cost of the hemlock tie at 35 cents, if by the process it can be made to last twelve years, which seems not unreasonable to expect, it would be cheaper than the cedar ties, since the annual charges together with cost of renewal compare as 5.98 to 5.67 cents in favor of the preserved hemlock tie.

The average cost of treatment by the zinc process (burnettizing) is placed at 20 cents by the Chicago Tie Preserving Company.

The Chicago, Rock Island and Pacific Railroad has had such ties in use for the last four years, expecting them to last sixteen years. The manager of the road writes as follows:

The life of an ordinary hemlock tie is three years; the life of a hemlock tie burnettized is sixteen years, twice as great as the life of an oak tie. We would use hemlock ties entirely, treated in this manner, if the facilities for burnettizing were sufficient to meet the requirements; and it is probable that in contracts to be made in the future we shall demand increased facilities and to an extent to meet all necessities, in which event we would, of course, use no oak ties at all. The hemlock tie costs 25 cents and the cost of burnettizing is 20 cents, making the total cost 45 cents, which is also the cost of an oak tie.

The Atchison, Topeka and Santa Fé Railroad Company kindly furnishes the following statement in regard to the cost of burnettizing with the Wellhouse process at Las Vegas:

| | Cents. |
|---|---|
| For chemicals | 11.7 |
| For labor | 4.3 |
| For fuel | .6 |
| | 16.6 |

This is almost 50 per cent. higher than the figures of Colonel Flad.

Mr. A. A. Robinson, general manager, under date November 21, 1889, adds:

The indications thus far are favorable and satisfactory. In 1885 we placed 305 of these treated pine ties in the main track just north of the bridge over the Kansas River in North Topeka. A few weeks since I examined these ties and found no evidence of decay, each tie being apparently as sound as a dollar.

Since oak ties last year on that road cost 48 cents free on board at Kansas City (a low price), and the pine ties 34 cents in New Mexico, the oak lasting seven and a half years, the treated pine, even if we increase its price to 60 cents, would need to last only ten years and yet be cheaper. Experience with burnettized ties would allow an assumption of twice that life as not extravagant.

In all calculations of the advantage in the use of ties of longer life an important one is often overlooked, namely, the reduced necessity of disturbing the track, with all the advantages which that implies.

The value of this indirect advantage, to be sure, it is almost impossible to establish by mathematical calculation, but the direct financial superiority of one tie system over another is perfectly capable of being figured upon a mathematical basis, and the factors to be used for such calculation are not doubtful.

There has been much difficulty experienced, even by the writers in the publication referred to of the Society of Civil Engineers, in getting at a proper basis upon which to compare the financial value of two tie systems of varying cost and duration, or the eventual saving of one over the other.

For a perpetual concern like a railroad the first cost is not always the most important factor of calculation. In fact, the saving of labor for renewals and maintenance is now the vital question in the cost of railroad management. When this is brought to a minimum by perfection of the road, safety and comfort in traveling as well as a safe dividend will be secured.

We may dismiss at once as improper in a community with well established financial systems any calculation which does not apply compound interest. There can be a dispute only as to the rate of interest, which in discounting long-standing investments is usually taken at less than the current rate of interest. But, while the choice of the rate is of importance when the actual amount of saving is to be calculated, if the existence only of a saving—no matter of what amount—is to be established, this choice of rate of interest becomes irrelevant as long as we use the same rate in all cases which we compare. And, especially in the case of two tie systems, the saving which the one of longer duration brings, by virtue of greater safety and permanence of road-bed, is incalculable, so that to establish its superiority financially we need to prove only that it is not more expensive.

The expenditure for a tie system, which must be renewed at given intervals, may be conceived as a series of intermittent rents. In order to make them comparable with another series of rents, which are paid out at different intervals we must transform both series into annual rents.

The sum total of the amounts represented in the intermittent rents, with compound interest discounted to the present date, are to be equal to annual rents discounted in the same way. If R = intermittent rent or charge, $p$ = rate of interest, $n$ = period of payment, $r$ = annual rent or charge, we have

$$R + \frac{R}{1.0p^n} + \frac{R}{1.0p^{2n}} + \cdot \cdot \cdot = \frac{r}{1.0p} + \frac{r}{1.0p^2} + \cdot \cdot$$

Summing up both sides, which represent two endless falling geometric series, we get

$$\frac{R\,1.0p^n}{1.0p^n - 1} = \frac{r}{0.0p};$$

or

$$r = R\,\frac{1.0p^n}{1.0p^n - 1}\,0.0p$$

This is the only proper way of determining the so-called annual charge, and with this formula a table of annual charges has been constructed and appended to this report, which allows ready comparison of systems of varying cost and duration as to their profitableness. This table is calculated for a 5 per cent. rate of interest.

If a lower rate of interest is used in calculating the annual charges, these, to be sure, fall out lower, but the amounts of saving increase. So that it may be assumed that the table calculated upon a 5 per cent. basis gives the most conservative, practically applicable results.

If the actual amount saved is to be determined, we need only find and compare the capitals which produce annually if placed on simple interest the amounts of the annual charge; or to arrive at the amount of that capital directly, we need only omit in the above formula the multiplication with $0.0p$. Calling $C + R = S$, the sum from which we may take the amount R for first construction and have the amount C left to produce R at stated intervals of $n$ years, we have

$$S = R \frac{1.0p^n}{1.0p^n - 1}$$

Using the table of annual charges, we see that a tie costing 30 cents and lasting 5 years involves an annual charge of 6.93 cents, which corresponds to a capital of $1.39. Were we to pay 20 cents more for a tie lasting ten years, the annual charge would be 6.47 cents, corresponding to a capital of $1.29; or use of the latter ties would mean a capital saving of 10 cents per tie or $260 per mile of track laid with 2,600 ties.

This does not include the saving which comes by virtue of the less frequent necessity of renewal, and which can be determined in a similar manner; a table of annual renewal charges is also appended.

If objections should be made to employing indefinite time, as has been here done, in the capitalization, and it is desired to relate the capital to any given term for which the business is supposed to run, the following formulas should be employed, representing the accumulation of recurring expenditures, with compound interest at the end of the business term:

R = amount paid out once in $n$ years,
$m$ = the number of terms of $n$ years,
V = the total value of the investment at the end of $m\,n$ years,
$p$ = the rate of interest; then

$$V = R \frac{(1.0p^{mn} - 1)\ 1.0p^n}{1.0p^n - 1} \tag{1}$$

If we consider two systems in which the corresponding values are $V_{,}$, $R_{,}$, $m_{,}$, $n_{,}$ and $V_{,,}$, $R_{,,}$, $m_{,,}$, $n_{,,}$ we have from (1)

$$V_{,} = \frac{R_{,}\ 1.0p^{n_{,}}\ (1.0p^{m_{,}n_{,}} - 1)}{1.0p^{n_{,}} - 1}$$

(2)

$$V_{,,} = \frac{R_{,,}\ 1.0p^{n_{,,}}\ (1.0p^{m_{,,}n_{,,}} - 1)}{1.0p^{n_{,,}} - 1}$$

Since for comparison we must have $m_{,}n_{,}=m_{,,}n_{,,}$ the values (2) give

$$\frac{V_{,}}{V_{,,}}=\frac{R_{,}}{R_{,,}}\,\frac{1.0p^{n_{,,}}-1}{1.0p^{n_{,}}-1}\,1.0p^{n_{,}-n_{,,}} \tag{3}$$

From this we see that the first or second system will be the more advantageous, according as $\frac{V_{,}}{V_{,,}}$ is less or greater than 1.

If, for instance, we introduce into these equations the following elements, in one case a tie costing 60 cents in the roadbed, lasting eight years, in the other case a tie costing the same but lasting sixteen years, 2,600 ties to the mile, we find for a term of thirty-two years, in the first case an expenditure of investment and accumulated interest of $18,131.18, and in the other case of $10,836.42, or, since

$$\frac{V_{,,}}{V_{,}}=\frac{2600\times 60\times 1.05^{8}-1\times 1.05^{8}}{2600\times 60\times 1.05^{16}-1}=0.60,$$

the saving of the longer-lived tie amounts to 40 per cent. By discounting the difference in accumulated expenditures after thirty-two years, namely, $7,294.76 to the present year, according to formula $E=\frac{A}{1.0p^{n}}$, we get the present capital saving, namely, $1,531.90. This represents the financial advantage of the tie of longer duration for a thirty-two year run. For a longer run this amount increases naturally.

The simplest and most satisfactory way, however, of comparing two systems is by taking recourse to a calculation of annual charges.

## ANNUAL CHARGES.

As we have seen the expenditure R occurring now and recurring every $n$ years, like that for the renewal of railroad ties, is changed into an annual charge $r$ by the formula as developed above

$$r=R\frac{1.0\,p^{n}\;0.0\,p}{1.0\,p^{n}-1}$$

in which $p$ is the rate of interest and $1.0p=\frac{100+p}{100}$

In the following table the fraction $\frac{1.0\,p^{n}\;0.0\,p}{1.0\,p^{n}-1}$ has been computed for rate of interest at 5 per centum, and for various terms of $n$.

By multiplying the fraction, given for 1 cent expenditure, under the term in which the expenditure is to recur, with the actual amount of the expenditure in cents the annual charge is found.

This multiplication is carried out in the table for varying expenditures from 20 cents to 125 cents.

If the expenditure is not now incurred, but becomes first necessary after $n$ years and then recurs at intervals of $n$ years, like the cost of replacing railroad ties (assuming that first laying is done at a different figure), the formula for the annual charge is changed into

$$r = \frac{R \quad 0.0p}{1.0p^n - 1}$$

For this the needful computations are found in Table II.

*Examples.*

(1) A hemlock tie, costing 40 cents in the road-bed, lasts five years; how long must it last to allow an additional expenditure of 25 cents for a process of impregnation without increasing its ultimate cost?

Find under column 5 (years) the annual charge for 40 cents $=9.23$; find for $40+25=65$ cents the annual charge nearest in amount to 9.23, this, being 9.14, belongs to column 9 (years); so that to justify the expenditure a duration of between eight and nine years must be attained.

(2) A railroad company is offered hemlock ties at 25 cents which will last five years, and oak ties which will last eight years costing 45 cents. Which is cheaper, when the cost of replacing is 15 cents?

| | Cents. |
|---|---|
| Find from Table I for 25 cents under column 5 (years) the annual charge..... | 5.78 |
| Add from Table II for cost of replacing every 5 years annual charge for 15 cents ........ | 2.72 |
| Annual charge for hemlock tie = ........ | 8.50 |
| Find for 45 cents under colum 8 (years) the annual charge ........ | 6.96 |
| Add for cost of replacing every 8 years at 15 cents........ | 1.58 |
| Annual charge for oak tie = ........ | 8.54 |

The oak tie under such conditions can only indirectly be cheaper by being more easily kept in condition.

(3) It is proposed to increase the life of the hemlock tie, by means of burnettizing, to sixteen years; how much can be paid for the process in order not to exceed the cost of an oak tie, and what is the amount of saving in capital over an oak tie, if the process can be kept at 20 cents per tie, when there are 2,600 ties per mile and 15 cents per tie must be paid for first laying and again for replacing?

The annual charge for the oak tie having been found, as above, to be 8.54 cents, look under column 16 (years) for an annual charge of the same or nearly the same amount; this is 8.30 cents, corresponding to an expenditure of 90 cents; add to this annual charge, that for 1 cent as many times as it is necessary to bring it up to 8.54 or $2\frac{1}{2}$ by 0.09, which brings the annual charge for the hemlock tie to 8.53, corresponding to an expenditure of $92\frac{1}{2}$ cents; or since the hemlock tie originally cost 25 cents we may spend $67\frac{1}{2}$ cents for the preserving process and yet keep the financial value of the hemlock tie at least equal to that of the untreated oak tie.

If we can keep the cost of process at 20 cents, making the hemlock tie in the bed $25+20+15=60$ cents, and the oak tie $45+15=60$ cents, the annual charge for the oak tie is 9.28, or per mile of 2,600 ties \$241.28; the annual charge for the hemlock tie is 5.53, or per mile of 2,600 ties \$143.78; the capital corresponding to these charges, bearing interest at 5 per cent., would be

| | |
|---|---|
| For oak ........ | \$4,825.60 |
| For hemlock ........ | 2,875.60 |
| Difference........ | 1,950.00 |

That is to say, although the original expenditure is the same in both cases, namely, 60 × 2,600 = $1,560, in the long run the tie of twice the duration effects a saving of more than its original cost.

(4) A metal tie costing $1.25, lasting thirty years, and then being worth for old iron 50 cents, requires an expenditure of 30 cents to lay down first and then of 40 cents for replacing; what is the proper annual charge?

| | Cents. |
|---|---|
| The annual charge for $1.25 through 30 year terms, according to Table I, is.... | 8.12 |
| This is diminished by the annual charge on 50 cents recurring after the first term of thirty years, according to Table II, namely, .............................. | 0.75 |
| | 7.37 |
| To this must be added from Table II, the annual charge on 40 cents, recurring every thirty years after the first term = .................................... | 0.60 |
| | 7.97 |
| and also the annual charge for the initial expenditure of 30 cents occurring only once according to formula $r=R\frac{1.0p^n\ .0.0p}{1.0p^{n+1}-1}$ which for $n=\infty$ becomes $=\frac{R\ 0.0p}{1.0p}$ | |
| or for 30 cents and 5 per cent. rate of interest...................... $\frac{30\times 0.05}{1.05}=$ | 1.43 |
| making total proper annual charge .......................................... | 9.40 |

Such a tie, then, would be financially superior to an oak tie costing 55 cents laid and lasting seven years, or to a preserved tie costing 85 cents in the road-bed and lasting twelve years, as can be readily seen by finding the corresponding annual charges in Table I.

## TABLE I.—*For computing annual charge of initial expenditures.*

| Expenditure. | Term of years. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 13. | 14. | 16. | 18. | 20. | 22. | 24. | 26. | 28. | 30. |
| | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* |
| 1 cent........ | 0.282 | 0.231 | 0.197 | 0.173 | 0.155 | 0.140 | 0.129 | 0.120 | 0.112 | 0.106 | 0.101 | 0.092 | 0.085 | 0.080 | 0.076 | 0.072 | 0.069 | 0.067 | 0.065 |
| 20 cents....... | 5.64 | 4.62 | 3.94 | 3.45 | 3.10 | 2.81 | 2.59 | 2.40 | 2.24 | 2.13 | 2.02 | 1.84 | 1.71 | 1.60 | 1.52 | 1.45 | 1.39 | 1.34 | 1.30 |
| 25 cents....... | 7.05 | 5.77 | 4.93 | 4.32 | 3.87 | 3.52 | 3.23 | 3.00 | 2.80 | 2.66 | 2.53 | 2.31 | 2.14 | 2.00 | 1.89 | 1.81 | 1.73 | 1.67 | 1.62 |
| 30 cents....... | 8.46 | 6.93 | 5.91 | 5.18 | 4.64 | 4.22 | 3.89 | 3.61 | 3.38 | 3.19 | 3.03 | 2.76 | 2.56 | 2.40 | 2.27 | 2.17 | 2.08 | 2.01 | 1.95 |
| 35 cents ...... | 9.87 | 8.08 | 6.89 | 6.04 | 5.41 | 4.92 | 4.53 | 4.21 | 3.93 | 3.72 | 3.53 | 3.22 | 2.99 | 2.80 | 2.65 | 2.53 | 2.43 | 2.34 | 2.27 |
| 40 cents....... | 11.28 | 9.23 | 7.88 | 6.90 | 6.19 | 5.62 | 5.18 | 4.81 | 4.49 | 4.25 | 4.04 | 3.69 | 3.42 | 3.20 | 3.03 | 2.89 | 2.78 | 2.68 | 2.60 |
| 45 cents....... | 12.69 | 10.39 | 8.86 | 7.76 | 6.96 | 6.32 | 5.82 | 5.41 | 5.04 | 4.78 | 4.54 | 4.15 | 3.84 | 3.61 | 3.41 | 3.26 | 3.12 | 3.01 | 2.92 |
| 50 cents ...... | 14.10 | 11.54 | 9.85 | 8.63 | 7.74 | 7.03 | 6.47 | 6.01 | 5.60 | 5.32 | 5.05 | 4.61 | 4.27 | 4.01 | 3.79 | 3.62 | 3.47 | 3.34 | 3.25 |
| 55 cents. ..... | 15.51 | 12.70 | 10.84 | 9.49 | 8.51 | 7.73 | 7.12 | 6.61 | 6.15 | 5.85 | 5.55 | 5.07 | 4.70 | 4.41 | 4.17 | 3.98 | 3.82 | 3.68 | 3.57 |
| 60 cents....... | 16.91 | 13.85 | 11.82 | 10.35 | 9.28 | 8.43 | 7.72 | 7.21 | 6.71 | 6.38 | 6.06 | 5.53 | 5.12 | 4.81 | 4.55 | 4.34 | 4.16 | 4.01 | 3.90 |
| 65 cents....... | 18.32 | 15.00 | 12.81 | 11.22 | 10.06 | 9.14 | 8.41 | 7.81 | 7.26 | 6.91 | 6.56 | 5.99 | 5.55 | 5.21 | 5.93 | 4.70 | 4.51 | 4.35 | 4.22 |
| 70 cents....... | 19.73 | 16.16 | 13.79 | 12.08 | 10.83 | 9.84 | 9.06 | 8.41 | 7.82 | 7.44 | 7.07 | 6.45 | 5.98 | 5.61 | 5.31 | 5.07 | 4.86 | 4.68 | 4.55 |
| 75 cents....... | 21.14 | 17.31 | 14.78 | 12.94 | 11.61 | 10.54 | 9.71 | 9.01 | 8.37 | 7.98 | 7.57 | 6.91 | 6.41 | 6.01 | 5.69 | 5.43 | 5.21 | 5.02 | 4.87 |
| 80 cents ...... | 22.55 | 18.47 | 15.76 | 13.81 | 12.38 | 11.25 | 10.36 | 9.62 | 8.93 | 8.51 | 8.08 | 7.37 | 6.83 | 6.41 | 6.06 | 5.79 | 5.55 | 5.35 | 5.20 |
| 85 cents....... | 23.96 | 19.62 | 16.75 | 14.67 | 13.15 | 11.95 | 11.00 | 10.22 | 9.48 | 9.04 | 8.58 | 7.83 | 7.26 | 6.81 | 6.44 | 6.15 | 5.90 | 5.69 | 5.12 |
| 90 cents....... | 25.37 | 20.97 | 17.73 | 15.53 | 13.93 | 12.65 | 11.65 | 10.82 | 10 04 | 9.57 | 9.09 | 8.30 | 7.69 | 7.21 | 6.82 | 6.51 | 6.25 | 6.02 | 5.85 |
| 95 cents....... | 26.78 | 21.93 | 18.72 | 16.39 | 14.70 | 13.35 | 12.30 | 11.42 | 10.59 | 10.10 | 9.59 | 8.76 | 8.12 | 7.62 | 7.20 | 6.89 | 6.59 | 6.36 | 6.17 |
| 100 cents...... | 31.19 | 23.08 | 19.70 | 17.26 | 15.48 | 14.06 | 12.95 | 12.02 | 11.15 | 10.64 | 10.10 | 9.22 | 8.54 | 8.02 | 7.58 | 7.25 | 6.94 | 6.69 | 6.50 |
| 105 cents...... | 32.60 | 24.24 | 20.69 | 18.12 | 16.25 | 14.76 | 13.59 | 12.62 | 11.70 | 11.17 | 10.60 | 9.68 | 8.97 | 8.42 | 7.96 | 7.61 | 7.29 | 7.03 | 6.82 |
| 110 cents...... | 34.00 | 25.39 | 21.67 | 18.98 | 17.02 | 15.46 | 14.24 | 13.22 | 12.26 | 11.70 | 11.11 | 10.14 | 9.40 | 8.82 | 8.34 | 7.97 | 7.63 | 7.36 | 7.15 |
| 115 cents...... | 35.41 | 26.54 | 22.66 | 19.85 | 17.80 | 16.17 | 14.89 | 13.82 | 12.81 | 12.23 | 11.61 | 10.60 | 9.82 | 9.22 | 8.72 | 8.38 | 7.98 | 7.70 | 7.47 |
| 120 cents...... | 36.82 | 27.70 | 23.64 | 20.71 | 18.57 | 16.87 | 15.53 | 14.42 | 13.37 | 12.76 | 12.12 | 11.06 | 10.25 | 9.62 | 9.10 | 8.70 | 8.33 | 8.03 | 7.80 |
| 125 cents...... | 38.23 | 28.85 | 24.63 | 21.57 | 19.35 | 17.57 | 16.18 | 15.02 | 13.92 | 13.30 | 12.62 | 11.52 | 10.68 | 10.02 | 9.48 | 9.06 | 8.68 | 8.37 | 8.12 |
| Add for each additional 5 cents ........ | 1.410 | 1.154 | 0.985 | 0.863 | 0.774 | 0.703 | 0.647 | 0.601 | 0.560 | 0.532 | 0.505 | 0.461 | 0.427 | 0.401 | 0.379 | 0.362 | 0.347 | 0.334 | 0.325 |

## TABLE II.—*For computing annual charge of renewal.*

| Expenditure. | Term of years. | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 3. | 4. | 5. | 6. | 7. | 8. | 9. | 10. | 11. | 12. | 14. | 16. | 18. | 20. | 22. | 24. | 26. | 28. | 30. |
| | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* | *Cents.* |
| 1 cent........ | 0.317 | 0.232 | 0.181 | 0.147 | 0.123 | 0.105 | 0.09 | 0.079 | 0.07 | 0.063 | 0.051 | 0.042 | 0.039 | 0.03 | 0.026 | 0.023 | 0.019 | 0.017 | 0.015 |
| 10 cents....... | 3.17 | 2.32 | 1.81 | 1.47 | 1.23 | 1.05 | 0.90 | 0.79 | 0.70 | 0.63 | 0.51 | 0.42 | 0.39 | 0.30 | 0.26 | 0.23 | 0.19 | 0.17 | 0.15 |
| 12 cents....... | 3.80 | 2.78 | 2.17 | 1.76 | 1.48 | 1.26 | 1.08 | 0.95 | 0.84 | 0.76 | 0.61 | 0.50 | 0.47 | 0.36 | 0.312 | 0.28 | 0.23 | 0.20 | 0.18 |
| 15 cents....... | 4.76 | 3.48 | 2.72 | 2.21 | 1.85 | 1.58 | 1.35 | 1.19 | 1.05 | 0.95 | 0.77 | 0.63 | 0.59 | 0.45 | 0.39 | 0.35 | 0.29 | 0.26 | 0.24 |
| 20 cents....... | 6.34 | 4.64 | 3.62 | 2.94 | 2.26 | 2.10 | 1.80 | 1.58 | 1.40 | 1.26 | 1.02 | 0.84 | 0.78 | 0.60 | 0.52 | 0.46 | 0.38 | 0.34 | 0.30 |

# REPORT ON THE CONSUMPTION OF TIES AND OTHER LUMBER BY RAILROADS IN THE UNITED STATES.

The following tabulation is made up from reports of the railroad companies named, kindly furnished in answer to a circular of inquiry.

The various roads have been grouped in sections, in order more readily to compare their requirements for wood material with conditions of supply. The foot-notes are made up from the general statements accompanying reports or from published annual reports of the roads. The roads are numbered consecutively, and foot-notes refer to the roads whose numbers they bear.

To admit a comparison of prices, those reported to this Department in a similar canvass six years ago have been added in italics.

The summary which heads the tabulation of separate reports is calculated upon the basis of these reports; the mileage of total track, where not stated in the reports, has been based upon that given in Poor's Manual for 1888, with due consideration of double track and sidings. The mileage of roads reporting refers to either 1888 or 1889, and the reports themselves cover varying periods of twelve months during this period.

Altogether, approximations only can be expected from inquiries of this kind, but they are quite sufficient for the purposes in view.

In regard to the summary, the following remarks are in place.

The number of ties per mile in track has been ascertained by multiplying the reported mileage of each road by the number of ties used for each mile of road, adding up the sums thus obtained and dividing by the total mileage reported in the section. From this the total number of ties in track appears to be 515,892,918.

The number of ties used for renewal is evidently an understatement of average conditions, since this would make the average life of ties eight and three-fourths years, which it is impossible to believe. It is likely that in many cases the year for which the report was made has been one in which, for various reasons, less replacement has been effected than usual on the reporting roads. The increased new mileage, especially of Western roads, also tends to make the proportionate requirement for renewals appear less than it is in reality. By taking the proportionate number of ties of various timbers used as calculated upon the percentages of each reported, multiplying this by the average life for each kind and dividing by the total number of ties laid in the year of the report, the average life per tie would come to 6.6 years. This would bring the annual average requirement for renewal to round 80,000,000 ties, which is probably nearer the truth and brings the average number of ties per mile needed for renewals to 417, or 15.5 per cent. of ties in track.

One of the roads reporting has adopted a simple method of ascertaining the durability of ties, by making a notch on the face of the tie, near one end, on placing it in the track, and adding a notch each year afterwards while it remains in the roadbed.

The cross-section of ties, as commonly used by the various roads (the + sign in the tabulation denoting that larger cross-sections are also employed), allows a ready calculation of the size of the tie.

There is a wide range in the area of cross-sections, extending from 36 to 90 inches, making a variation in the solid contents of the tie from 3.15 to 8.55 cubic feet. While in some cases the larger dimensions indicate inferior timber, in many cases the best and most valuable timber is used for ties of the largest size.

In thickness, 6 inches are specified commonly by the roads of the New England, Central Northern, Northwestern, and Southwestern groups, while the Middle Atlantic, South Atlantic, and, to some extent, the Central Northern and Gulf groups prefer ties 7 inches thick. As to width, the New England roads demand usually an average of 6 inches, and in two cases only 5. A width of 7 inches is called for in all the groups, but chiefly by the Middle Atlantic and Central Northern. Half the call for ties 8 inches in width is from the Central Northern group, the balance mainly from southern regions, and the demand for a width of 9 inches is mostly from the South. While, no doubt, the weight of the tie, approximately indicated by its cross-section, is an important factor in its efficient service, it is questionable whether these large cross-sections are chosen and adjusted with this demand in view. Probably local conditions, which allow or make more convenient the use of large dimensions (as from the virgin forests in the South), dictate these specifications.

There is great diversity in the dimensions of ties used. Of the roads reporting, 51, or 62.5 per cent. of all, use ties 8 feet in length, and 10, or a little more than 12.5 per cent., demand ties 9 feet long. Ties of 8 feet length are used in all the groups except the Gulf and Middle Atlantic. Ties 8½ feet in length are used chiefly in the Middle Atlantic and Central Northern groups, while those 9 feet in length are used almost exusively in the South Atlantic and Gulf groups.

*Reports on the consumption of forest supplies by railroads.*

SUMMARY FOR THE WHOLE COUNTRY.

| No. | Districts. | Miles of track. | Miles reported. | Per cent. of total track reported. | Ties per mile in track. | Ties used annually for renewal by reporting roads. | Proportionate number used by all roads. | Ties per mile for renewal. | Kinds of timber used for ties. | Percentage of each. | Average prices. | Bridge and other lumber used annually by roads reporting. | Average amount of lumber per mile used annually by roads reporting. | Proportionate amount of lumber used by all roads. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | *Feet, B.M.* | *Feet, B.M.* | *Feet, B.M.* |
| 1 | New England group.. | 10,813 | 6,506 | 60.2 | 2,752 | 2,373,000 | 3,941,860 | 365 | Chestnut . | 52 | 36–55 | 24,499,202 | 3,766 | 40,721,758 |
| | | | | | | | | | Oak ...... | 6 | 36–55 | | | |
| | | | | | | | | | Cedar .... | 26 | 33 | | | |
| | | | | | | | | | Various .. | 16 | 35–47 | | | |
| 2 | Middle Atlantic group | 31,281 | 23,135 | 73.9 | 2,728 | 7,067,850 | 9,543,318 | 305 | Oak ...... | 73 | 40–70 | *64,613,262 | 4,449 | 100,898,871 + |
| | | | | | | | | | Chestnut . | 8 | 25–60 | | | |
| | | | | | | | | | Pine ...... | 11 | 46–64 | | | |
| | | | | | | | | | Cedar .... | 5 | 35–53 | | | |
| | | | | | | | | | Various .. | 3 | | | | |
| 3 | South Atlantic group. | 16,224 | 6,256 | 38.6 | 2,726 | 2,471,188 | 6,402,041 | 395 | Oak ...... | 43 | 25–33 | 27,593,036 | 4,411 | 71,564,064 |
| | | | | | | | | | Pine ..... | 50 | 20–25 | | | |
| | | | | | | | | | Cypress .. | 7 | 27–28 | | | |
| 4 | Northern Central group. | 56,032 | 33,519 | 60.1 | 2,916 | 9,149,667 | 15,224,071 | 272 | Oak ...... | 78 | 25–55 | 150,391,938 | 4,092 | 229,282,944 |
| | | | | | | | | | Cedar .... | 11 | 15–40 | | | |
| | | | | | | | | | Tamarack | 3 | 15–18 | | | |
| | | | | | | | | | Hemlock . | 5 | 15–18 | | | |
| | | | | | | | | | Various .. | 3 | | | | |
| 5 | Gulf and Mississippi group. | 12,522 | 5,558 | 44.4 | 2,770 | 2,026,400 | 4,563,964 | 365 | Oak ...... | 68 | 25–29 | 9,300,500 | 3,167 | 39,657,174 |
| | | | | | | | | | Pine ...... | 32 | 20–25 | | | |
| 6 | Northwestern group.. | 20,744 | 16,961 | 81.8 | 2,759 | 5,411,974 | 6,681,449 | 319 | Oak ...... | 40 | 31–60 | 46,242,425 | 2,863 | 59,390,072 |
| | | | | | | | | | Elm ...... | 4 | | | | |
| | | | | | | | | | Pine ...... | 26 | 18–39 | | | |
| | | | | | | | | | Various .. | 30 | 16–33 | | | |
| 7 | Southwestern and Pacific group. | 43,881 | 20,520 | 46.8 | 2,310 | 6,377,785 | 3,752,584 | 311 | Redwood . | 15 | 36–53 | 53,618,185 | 3,188 | 139,892,628 |
| | | | | | | | | | Cedar .... | 7 | 22–38 | | | |
| | | | | | | | | | Fir ...... | 5 | 22–38 | | | |
| | | | | | | | | | Pine ..... | 15 | 25–34 | | | |
| | | | | | | | | | Oak ...... | 54 | 26–75 | | | |
| | | | | | | | | | Cypress .. | 4 | | | | |
| | Totals.. | 191,497 | 112,455 | 58.8 | 2,694 | 34,877,864 | 60,034,647 | 310 | ............ | .......... | .......... | 356,258,548 | 3,748 | 681,407,511 |

* Returns from the Pennsylvania Railroad and from the eastern division of the Baltimore and Ohio included no report as to the amount of lumber used, and the above estimate is made without reference to those roads, which include 8,602 miles of track, or more than one-third of the whole mileage of the group. These roads use iron, brick, and stone for bridges and buildings more largely than other roads, but it would probably be fair to add 25 per cent. to the above estimate on their account.

*Reports on the consumption of forest supplies by railroads*—Continued.

NEW ENGLAND GROUP.

[NOTE.—Words and figures in italics represent the reports from an inquiry on the subject of the consumption of forest supplies by railroads made eight years ago and are reproduced in the present case for the purpose of comparison.]

| No. | Roads. | Length of track. | Average no. in track per mile. | Ties. Used for renewal for year reported. | Per mile for renewal. | Kinds of timber. | Price. | Cross-section. | Where obtained. | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *Feet—B. M.* |
| 1 | Connecticut River | 158 | 2,640 | 64,000 | 405 | Chestnut | 22½–45 | 35+ | On line of road | 350,000 |
| | | | | | | *Chestnut* | **40** | | | |
| 2 | Boston and Maine | 1,210 | 2,640 | 600,000 | 496 | Cedar | 33 | 36+ | On line of road | 8,000,000 |
| | | | | | | *Cedar* | **33** | | | |
| 3 | Bennington and Rutland | 70 | 2,500 | 44,000 | 628 | Red oak<br>Chestnut<br>Hemlock | 36 | 48 | On line of road | 65,500 |
| 4 | Fitchburg | 730 | 2,800 | 250,000 | 343 | Chestnut | 42 | 42 | On line of road | 2,500,000 |
| | | | | | | *Chestnut* | **50** | | | |
| 5 | Boston and Albany | 858 | 2,640 | 285,000 | 332 | Chestnut | 50 | 49 | On line of road | 800,000 |
| | | | | | | *Chestnut* | **51** | | | |
| 6 | New York and New England | 730 | 2,600 | 250,000 | 340 | Chestnut, 90 per cent | 35–50 | 49+ | On line of road | 2,270,000 |
| | | | | | | Oak, 10 per cent | 40 | | | |
| | | | | | | *Oak and chestnut* | **38–45** | | | |
| 7 | New York, New Haven and Hartford | 1,066 | 2,800 | 300,000 | 281 | Chestnut, 75 per cent | 44 | 36+ | On line of road | 7,438,702 |
| | | | | | | Oak, 25 per cent | | | | |
| | | | | | | *Oak and chestnut* | **48** | | | |
| 8 | Central Vermont | 736 | 3,000 | 250,000 | 340 | Hemlock<br>Tamarack | 35–40 | ...... | Canada | 1,500,000 |
| | | | | | | *Hemlock* | **15–25** | | | |
| | | | | | | *Tamarack* | **31** | | | |
| 9 | Housatonic | 230 | 2,700 | 800,000 | 348 | Chestnut, 66 per cent | 38 | 36+ | On line of road | 150,000 |
| | | | | | | Oak, 31 per cent | | | | |
| 10 | New York, Providence and Boston | 216 | 2,992 | 100,000 | 463 | Chestnut, 75 per cent | 45–55 | 49+ | On line of road | 625,000 |
| | | | | | | Oak, 25 per cent | | | | |
| | | | | | | *Chestnut and oak* | **50** | | | |
| 11 | Long Island | 502 | 2,889 | 150,000 | 300 | Yellow pine, 55 per cent | 47 | ...... | ...... | 800,000 |
| | | | | | | Spruce, 30 per cent | 37 | | | |
| | | | | | | Chestnut, 10 per cent | 40 | | | |
| | | | | | | Various, 5 per cent | 90 | | | |
| | Totals | 6,506 | 2,752 | 2,373,000 | 365 | ...... | ...... | ...... | ...... | 24,499,202 |
| | | | | | | | | | Per mile | 3,766 |

1. Two hundred acres of woodland owned. Price of ties lower than twenty years ago. Outlook good for what we require. 2. Formerly used kyanized hemlock eight years, at cost of 10 cents per tie. Cedar now so cheap and hemlock so dear, the process has been abandoned. 4. Supply of ties and posts increasing. 5. Pine and chest-

nut plenty for several years to come. More ties offered than are wanted. 6. White oak growing scarce. Chestnut more plenty. Using some creosoted timber. 7. Supply probably decreasing, but more ties offered than are needed. 8. Own 2,000 acres of growing timber. No material change in price of ties for several years. 10. Supply of ties good for fifteen or twenty years. 11. Timber supply decreasing. Have put in creosoted ties this year as an experiment, at double the cost of untreated ties. Fernolined timbers put in interlocking signal foundations three years ago show no signs of decay.

## MIDDLE ATLANTIC GROUP.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | New York Central and Hudson River | 3,723 | 2,800 | 660,000 | 177 | Pine, 48 per cent | 60 | | 54+ | Pine from Georgia, oak and cedar from Michigan, chestnut from Pennsylvania. | 16,455,323 |
| | | | | | | Oak, 23 per cent | 60 | | | | |
| | | | | | | Cedar, 8 per cent | 40 | | | | |
| | | | | | | Chestnut, 21 per cent | 60 | | | | |
| | | | | | | *Pine* | | **77** | | | |
| | | | | | | *Oak* | | **80** | | | |
| | | | | | | *Cedar* | | **53** | | | |
| | | | | | | *Chestnut* | | **62** | | | |
| 13 | Delaware, Lackawanna and Western | 1,746 | 2,900 | 895,756 | 513 | Pine, 22 per cent | ........... | | 42+ | ........................ | 19,185,000 |
| | | | | | | Oak, 59 per cent | | | | | |
| | | | | | | Cedar, 8 per cent | | | | | |
| | | | | | | Chestnut, 11 per cent | | | | | |
| | | | | | | *Pine* | | **25** | | | |
| | | | | | | *Oak* | | **75** | | | |
| | | | | | | *Cedar* | | **33** | | | |
| | | | | | | *Chestnut* | | **45** | | | |
| 14 | New York, Ontario and Western | 480 | 3,000 | 174,000 | 362 | Chestnut, 50 per cent | 35 | | 42+ | 2/3 on line of Maryland, 1/3 from the south, and from Canada. | 1,320,890 |
| | | | | | | Oak, 10 per cent | 45 | | | | |
| | | | | | | Pine, 20 per cent | 46–50 | | | | |
| | | | | | | Cedar, 20 per cent | | | | | |
| 15 | New York, Lake Erie and Western | 2,869 | 2,800 | 700,000 | 244 | Oak, 82 per cent; chestnut, 18 per cent | 55 | | 49+ | On line of road, Virginia and West Virginia. | 5,320,050 |
| | | | | | | *Oak* | | **65** | | | |
| | | | | | | *Chestnut* | | **50** | | | |
| 16 | New York, Susquehanna and Western | 198 | 2,816 | 66,377 | 335 | Oak, 75 per cent; chestnut, 25 per cent | 45–50 | | 49 | On line of road | 309,520 |
| | | | | | | *Chestnut* | | **45** | | | |
| 17 | Rome, Watertown and Ogdensburg | 773 | 2,800 | 300,000 | 388 | Cedar, 53 per cent; oak, 14 per cent; chestnut, 2 per cent; tamarack, 23 per cent; hemlock, 8 per cent. | ........... | | 48 | Canada | 2,494,243 |
| 18 | Central Railroad of New Jersey | 1,167 | 2,600 | 290,159 | 248 | Oak, 43 per cent | 67 | | 49+ | 7/10 on line, 3/10 from south | 2,062,500 |
| | | | | | | Chestnut, 21 per cent | 41 | | | | |
| | | | | | | Pine, 18 per cent | 64 | | | | |
| | | | | | | Cypress, 14 per cent | 55 | | | | |
| 19 | Pennsylvania Railroad, east of Pittsburg. | 6,596 | 2,640 | 2,500,000 | 379 | Oak | 40–70 | | 49+ | Partly on line, partly Maryland, Virginia, and Carolinas. | |
| | | | | | | *Oak* | | **80** | | | |
| 20 | Allegheny Valley | 401 | 2,600 | 95,338 | 238 | Oak | 40 | | 63 | On line | 300,000+ |
| 21 | Erie and Pittsburg | 124 | 2,800 | 40,000 | 323 | Oak, Cherry, Locust | 43–53 | | 56+ | ........................ | 1,030,751 |

*Reports on the consumption of forest supplies by railroads*—Continued.

MIDDLE ATLANTIC GROUP—Continued.

| No. | Roads. | Length of track. | Ties. Average no. in track per mile. | Ties. Used for renewal for year reported. | Ties. Per mile for renewal. | Ties. Kinds of timber. | Ties. Price. | Ties. Cross-section. | Ties. Where obtained. | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *Feet—B. M.* |
| 22 | New Castle and Beaver Valley | 24 | 2,800 | 7,631 | 317 | Oak<br>Cherry<br>Locust | 43–53 | 56+ | | 63,314 |
| 23 | Baltimore and Ohio, East division | 2,006 | 2,600 | 605,000 | 302 | Oak | 40 | 49+ | On line | |
| | | | | | | *Oak* | **30–50** | | | |
| | West division | 878 | 3,000 | 243,588 | 277 | Oak | 40 | 56+ | On line | 4,520,671 |
| | | | | | | *Oak* | **40** | | | |
| 24 | Philadelphia and Reading | 2,150 | 2,650 | 500,000 | 233 | Oak, 30 per cent<br>Chestnut, 10 per cent<br>Pine (yellow), 60 per cent | 60<br>40<br>50 | 56+ | Line of road and Southern States. | 11,551,000 |
| | Totals | 23,135 | 2,728 | 7,067,850 | 305 | | | | | *64,613,262 |
| | | | | | | | | | Per mile | 4,449 |

12. Since the war have been using Georgia pine in part for ties on account of difficulty of procuring oak and chestnut. Eight hundred thousand ties are reported as the average number used for repairs. 13. Use iron for bridges. 14. Increase in price of southern ties about 5 cents. No increase for three or four years in price of those procured on line of the road. Use fernoline in timber trestles on all joints and surfaces in contact. 16. Price of ties advancing. Looks as though the time is coming when we shall have to look to other countries for timber. 18. Supply on line of road decreasing. Put in a few creosoted ties eighteen years ago. 19. Price not increased, but quality deteriorating. 23. Ties becoming scarce on line of road. During the year ending September 30, 1888, the account for material and labor included 259,315 ties on the division west of the Ohio River, \$107,993.92, or $41\frac{2}{3}$ cents per tie; 609,462 ties on the division east of the Ohio River, \$213,586.83, or 35 cents per tie.

* It will be noticed that no report of lumber used by the Pennsylvania Railroad Company or by the eastern division of the Baltimore and Ohio is made. More than one-third of the mileage of this group is therefore left out of the report of lumber consumed, and this needs to be taken into account.

SOUTH ATLANTIC GROUP.

| No. | Roads. | Length of track. | Ties. Average no. in track per mile. | Ties. Used for renewal for year reported. | Ties. Per mile for renewal. | Ties. Kinds of timber. | Ties. Price. | Ties. Cross-section. | Ties. Where obtained. | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| 25 | Florida Southern | 323 | 2,640 | 173,070 | 536 | Pine | 20 | 70+ | On line | 300,000 |
| 26 | Florida Central and Peninsular | 594 | 2,640 | 250,000 | 421 | Pine, 80 per cent<br>Cypress, 20 per cent | $22\frac{1}{2}$<br>27 | 59+ | On line | 534,000 |
| 27 | Savannah, Florida and Western | 660 | 2,640 | 330,000 | 500 | Pine | 25 | 70 | On line | 4,000,000 |
| | | | | | | *Pine*<br>*Cypress* | **25**<br>**30** | | | |
| 28 | Weldon and Wilmington | 858 | 2,580 | 316,232 | 368 | Pine, 86 per cent<br>Oak, 14 per cent | 20<br>33.3 | 49+ | On line | 3,316,514 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29 | South Carolina Railway Company | 287 | 2,640 | 117,137 | 408 | Cypress, 98 per cent | 28 | | 70 | On line | 963,450 |
| | | | | | | Pine, 2 per cent | 22 | | | | |
| | | | | | | *Cypress* | | **28** | | | |
| | | | | | | *Pine* | | **22** | | | |
| 30 | Richmond and Danville | 427 | 2,992 | 166,750 | 390 | Oak | 29½ | | 49+ | On line | 3,903,160 |
| 31 | Virginia Midland and Washington and Ohio. | 405 | 2,816 | 239,445 | 591 | Oak | 30 | | 48–56 | On line | 3,167,500 |
| | | | | | | *Oak* | | **35** | | | |
| 32 | Western North Carolina | 382 | 2,640 | 108,000 | 283 | Oak | 30 | | 63 | On line | 2,119,561 |
| 33 | North Carolina Division | 290 | 3,000 | 84,554 | 291 | Oak | 31¼ | | 56 | On line | 750,000 |
| 34 | Atlanta and Charlotte | 409 | 2,640 | 140,000 | 342 | Oak | 15–31 | | 56+ | On line | 2,675,000 |
| 35 | South Carolina Division | 393 | 2,900 | 156,000 | 399 | Oak, 54 per cent | 14–27 | | 56+ | On line | 1,087,390 |
| | | | | | | Pine, 46 per cent | 23.3 | | | | |
| 36 | Columbia and Greenville Division | 298 | 2,816 | 160,000 | 537 | Oak, 25 per cent | 30 | | 56+ | On line | 1,746,461 |
| | | | | | | Pine, 75 per cent | 25 | | | | |
| 37 | Georgia Pacific, First Division | 210 | 2,816 | 100,000 | 476 | Pine, 67 per cent | 25 | | 63+ | On line | 1,050,000 |
| | | | | | | Oak, 33 per cent | 25 | | | | |
| 38 | Georgia Pacific, Second Division | 226 | 2,816 | 80,000 | 354 | Oak | 25 | | 63+ | On line | 1,230,000 |
| 39 | Newport News and Mississippi Valley | 494 | ........ | 50,000 | 101 | Oak | 25 | | 56 | On line | 750,000 |
| | Totals | 6,256 | 2,726 | 2,471,188 | 395 | | | | | | 27,593,036 |
| | | | | | | | | | | Per mile | 4,411 |

25. Own 1,500,000 acres of pine and cypress Ample supply for ten years. 26. Timber supply good at present. 27. Have begun to use creosoting process on piling and bridge timber. 28. Have used some creosoted ties for three years. 29. The company has 20,000 acres of woodland, but reserves its own timber and gets supplies mainly from other parties. 30. Supply, except for ties, insufficient. Pine obtainable only in limited quantities. 33. Bridge timber rather scarce. 34. Price of ties advanced 20 per cent. 37. Very soon timber will be hard to obtain. 38. Pine timber scarce. Oak on part of the line, but will soon be less easy to get.

## NORTHERN CENTRAL GROUP.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | Cleveland and Pittsburgh | 303 | 2,816 | 75,000 | 248 | Oak | 35–50 | | 56+ | West Virginia | 2,195,000 |
| | | | | | | *Oak* | | **56** | | | |
| | | | | | | *Cedar* | | **50** | | | |
| 41 | Cleveland, Akron and Columbus | 194 | 2,640 | 50,000 | 258 | Oak | 42 | | 56 | On line, Michigan and elsewhere. | 175,000+ |
| | | | | | | *Oak* | | **45** | | | |
| 42 | Pittsburgh, Youngstown and Ashtabula | 164 | 2,800 | 53,430 | ........ | Oak | 43–53 | | 56+ | ........ | 1,319,396 |
| | | | | | | *Oak* | | **55** | | | |
| 43 | Illinois Central | (3,478) | 2,640 to 2,816 | 395,348 | 114 (258) | Oak | 37 | **30–50** | 48+ | Line of road | 6,969,508 |
| 44 | Chicago and Eastern Illinois | 420 | 3,000 | 140,000 | 333 | Oak | 33 | **36** | 48 | Line of road | 1,600,000 |
| 45 | Chicago, Rock Island and Pacific | 3,143 | 3,000 | 200,000 | 190 | Hemlock, 33 per cent | ........ | | 48 | Mostly on line | 11,500,000 |
| | | | | 400,000 | (280) | Oak, 67 per cent | | | | | |
| 46 | Chicago, Burlington and Quincy | 2,135 | 3,000 | 902,100 | 422 | Oak, 80 per cent | 40–54 | **40–60** | 48 | Oak, Missouri and Illinois | 15,367,000 |
| | | | | | | Cedar, 20 per cent | 31–47 | | ........ | Cedar, Michigan and Wisconsin. | |
| 47 | Chicago and Alton | 1,112 | 3,000 | 350,000 | 314 | Cedar, 10 per cent | 38 | | ........ | On line and Missouri | 2,000,000 |
| | | | | | | Oak, 90 per cent | | | | | |

*Burnettized.

*Reports on the consumption of forest supplies by railroads*—**Continued.**

NORTHERN CENTRAL GROUP—Continued.

| No. | Roads. | Length of track. | Ties. Average no. in track per mile | Ties. Used for renewal for year reported. | Ties. Per mile for renewal. | Ties. Kinds of timber. | Ties. Price. | Ties. Cross-section. | Ties. Where obtained. | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *Feet—B. M.* |
| 48 | Green Bay, Winona and St. Paul | 237 | 2,640 | 70,000 | 295 | Hemlock, 57 per cent | 15 | 42+ | On line | 605,000 |
| | | | | | | Tamarack, 29 per cent | 15 | | | |
| | | | | | | Cedar, 7 per cent | 15 | | | |
| | | | | | | Pine, 7 per cent | 11 | | | |
| 49 | Flint and Père Marquette | 900 | 3,000 | 300,000 | 333 | Hemlock, 75 per cent | 15 | 36+ | On line | 500,000 |
| | | | | | | Oak, 15 per cent | 30 | | | |
| | | | | | | Tamarack and ash, 10 per cent. | 15 | | | |
| | | | | | | *Hemlock* | **15** | | | |
| | | | | | | *Oak* | **35** | | | |
| 50 | Chicago and Northwestern | 4,645 | 3,000 | 1,125,000 | 242 | Oak, 60 per cent | 45–55 | 49+ | On line | 18,241,468 |
| | | | | | | Cedar, 30 per cent | 20 | | | |
| 51 | Chicago, Milwaukee and St. Paul | 6,788 | 2,990 | 1,800,000 | 265 | Oak, 67 per cent | 45 | 48+ | On line, and Missouri, Indiana, and Tennessee. | 36,102,197 |
| | | | | | | Cedar, 22 per cent | | | | |
| | | | | | | Tamarack, 11 per cent | 26 | | | |
| | | | | | | *Oak* | **40** | | | |
| 52 | Detroit, Grand Haven and Milwaukee | 252 | 2,640 | 111,600 | 444 | Oak | 18–40 | ...... | On line | 7,992,264 |
| | | | | | | *Oak* | **30** | | | |
| | | | | | | *Hemlock* | **18** | | | |
| 53 | Lake Shore and Michigan Southern | 2,259 | 2,640 | 711,678 | 315 | Oak, 70 per cent | 54 | 56+ | Michigan, West Virginia, and Kentucky. | 11,475,254 |
| | | | | | | Cedar, 27 per cent | 31 | | | |
| | | | | | | *Oak* | **47.7** | | | |
| | | | | | | *Cedar* | **30.9** | | | |
| 54 | Michigan Central | 2,304 | 2,800 | 650,000 | 282 | Oak, 75 per cent | 45 | 48+ | On line | 2,000,000 |
| | | | | | | Cedar, hemlock and tamarack, 25 per cent. | 18 | | | |
| 55 | Evansville and Terre Haute | 563 | 2,700 | 245,000 | 435 | Oak | 33 | 48 | On line | 1,650,000 |
| | | | | | | *Oak* | **37½** | | | |
| 56 | Louisville, New Albany and Chicago | 599 | 2,760 | 165,000 | 275 | Oak | 30 | 48 | Partly on line and partly other places in State. | 550,000 |
| | | | | | | *Oak* | **30** | | | |
| 57 | St. Louis, Alton and Terre Haute | 271 | 2,600 | 58,120 | 214 | Oak | 12½–25 | 50+ | Partly on line | 1,278,200 |
| 58 | Northwestern Ohio | 94 | 2,700 | 25,000 | 266 | Oak | 55 | 56+ | West Virginia mostly | 50,000 |
| 59 | Toledo, Peoria and Western | 280 | 3,000 | 75,000 | 268 | Oak, 84 per cent | 40 | 50+ | 20 per cent. on line; 80 per cent. southern Illinois. | 540,000 |
| | | | | | | Cedar, 16 per cent | 40 | | | |
| 60 | Wabash | 1,827 | 3,000 | 730,000 | 399 | Oak | .......... | 56+ | Chiefly on line | |
| | | | | | | Locust | | | | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 61 | Columbus, Hocking Valley and Toledo | 450 | 3,000 | 135,000 | 300 | Cherry<br>Oak<br>*Oak* | <br>40<br>35 | 63+ | $\frac{2}{3}$ on line; $\frac{1}{3}$ West Virginia | 1,378,000 |
| 62 | Louisville, Evansville and St. Louis | 352 | 2,900 | 82,391 | 234 | Oak<br>*Oak* | 25<br>32 | 48+ | On line | 1,392,051 |
| 63 | Ohio and Mississippi | 749 | 3,000 | 300,000 | 400 | Oak<br>*Oak* | <br>28 | 59+ | On line | 5,511,600 |
| | Totals | 33,692 | 2,916 | 9,149,667 | 272 | | | | | 130,391,938 |
| | | | | | | | | | Per mile | 4,092 |

40. Advance of $4\frac{1}{2}$ per cent. in price of ties since last year; supplies decreasing. 41. Price of ties fixed by the company; supplies sufficient for renewal, but not for construction. 43. Had land but disposed of it; timber supply declining. Number of ties stated for average of 19 years, with an average mileage of 1,530 miles. The following table of the comparative statement of maintenance of way for ten years is of interest in this connection. From this statement the remarkably low average figure of 240 ties per mile for renewal results in making the life of the oak tie and cedar, which were used formerly, over eleven years, at an average price of less than 35 cents.

Maintenance of way, Illinois Central Railroad.

| Year. | Miles of road at end of year. | Labor on track. | New rails. | | Cross-ties. | | Repairs of bridges. | Other items. | Total. | Mileage of engines. | Expense per mile run by engines. | Repairs of fences. | Repairs of station buildings and water works. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1879 | 1,286.72 | $297,363.40 | 9,276.00 tons | $125,062.70 | 264,520 | $93,107.51 | $73,119.56 | $125,041.92 | $640,575.53 | 5,460,371 | 11.73 cts | $33,416.86 | $45,755.09 |
| 1880 | 1,320.35 | 343,982.23 | 9,767.49 " | 215,365.32 | 260,116 | 93,330.32 | 105,551.62 | 49,399.09 | 807,628.58 | 6,513,611 | 12.39 cts | 36,981.94 | 80,887.34 |
| 1881 | 1,320.35 | 411,018.91 | 10,098.47 " | 169,718.80 | 345,260 | 127,279.76 | 114,193.18 | 30,399.46 | 852,610.11 | 7,006,532 | 12.16 cts | 36,690.33 | 70,699.58 |
| 1882 | 1,908.65 | 690,112.59 | 8,438.00 " | 128,521.48 | 604,096 | 201,648.26 | 174,826.24 | 17,277.34 | 1,212,385.91 | 10,218,008 | 11.87 cts | 31,032.57 | 87,588.26 |
| 1883 | 1,927.99 | 742,476.20 | 8,191.79 " | 183,239.65 | 425,627 | 153,739.00 | 121,101.03 | 72,294.71 | 1,272,850.59 | 10,702,152 | 11.89 cts | 30,084.49 | 87,291.93 |
| 1884 | 2,066.35 | 706,751.86 | 6,342.73 " | 93,446.25 | 462,665 | 154,083.19 | 173,831.23 | 107,236.13 | 1,235,348.66 | 10,121,434 | 12.20 cts | 21,394.71 | 94,122.03 |
| 1885 | 2,066.35 | 749,254.19 | 8,747.31 " | 87,331.95 | 508,756 | 176,835.69 | 164,586.39 | 88,126.28 | 1,266,134.50 | 11,227,043 | 11.27 cts | 21,932.48 | 94,518.19 |
| 1886 | 2,149.07 | 705,553.82 | 6,376.40 " | 63,238.84 | 492,524 | 174,515.72 | 172,144.65 | 63,976.69 | 1,179,429.72 | 11,619,353 | 10.15 cts | 26,668.91 | 123,519.83 |
| 1887 | 2,355.12 | 760,093.33 | 6,092.66 " | 79,917.84 | 573,898 | 197,989.47 | 250,337.47 | 61,441.88 | 1,349,779.99 | 13,557,308 | 9.95 cts | 31,905.46 | 129,526.76 |
| 1888 | 2,552.55 | 847,806.67 | 8,172.36 " | 106,372.94 | 654,141 | 214,130.73 | 310,908.42 | 115,898.04 | 1,595,116.80 | 14,857,053 | 10.74 cts | 40,423.29 | 170,023.85 |

45. The length of track reported includes more than a thousand miles of new road requiring no ties for renewal. The proper figures per mile for renewal would therefore be larger than those given above. Used Burnettized hemlock ties four years; cost of process 20 cents per tie. During the year ending March 31, 1888, with a line of 1,528 miles, 704,642 ties were used in repairs, at a cost of $308,110.41; in 1887, 527,409 ties were used, at a cost of $218,020.31. 48. Timber and tie supply near road good for twenty years. 49. Company owns land and has reserved some for growth of timber and ties. 50. Just trying Burnettized ties at Milwaukee. 51. Company have 60,000 acres of woodland in Wisconsin, mostly hard wood. The report for 1888, covering 5,678 miles, showed the expenses for renewals of ties to have been $768,960 as against $865,682 in 1887, or $135 and $152 per mile, respectively. At the end of 1888 there were 550,945 ties on hand, valued at $217,204.50. 52. The report for the year ending May 31, 1888, covering 4,210.75 miles of main track and 1,026.59 miles of side track, showed that 830,903 ties were used in repairs and renewals, at a cost of $325,358 and $147,565 for laying ties, making cost of laying $17\frac{3}{4}$ cents. There were on hand 1,094,953 ties, valued at $366,425. 53. No difficulty in securing ties. 54. Ties abundant. Prices lower than formerly. In 1887 the expenditure for renewals was $319,137. During 1888 the renewals required 723,065 ties, at a cost of $270,137.44, or $37\frac{1}{3}$ cents per tie. 56. Good timber getting scarce on line of road; mills decreasing. 57. Outlook for timber supplies not favorable. 58. Price of ties increased 20 per cent. in ten years. 60. Price of ties increasing. Supply near road decreasing. 61. Timber supplies getting short. Bridge timber advancing in price. 63. Timber land abundant.

*Reports on the consumption of forest supplies by railroads*—Continued.

### GULF AND MISSISSIPPI VALLEY GROUP.

| No. | Roads. | Length of track. | Average no. in track per mile. | Ties. Used for renewal for year reported. | Per mile for renewal. | Kinds of timber. | Price. | Cross-section. | Where obtained. | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *Feet—B. M.* |
| 64 | Alabama Great Southern | 354 | 2,800 | 170,000 | 480 | Oak | 12–29 | 56+ | On line | 1,600,000 |
| | | | | | | *Oak* | 25 | | | |
| 65 | Louisville and Nashville | 2,622 | 2,800 | 1,150,000 | 438 | Oak, 70 per cent | | 63 | On line | |
| | | | | | | Pine, 30 per cent | | | | |
| | | | | | | *Oak* | 27–50 | | | |
| 66 | Mobile and Ohio | 597 | 3,000 | 120,000 | 201 | Pine, 30 per cent | 20½ | 56 | On line | 2,250,000 |
| | | | | | | Oak, 70 per cent | 27½ | | | |
| 67 | New Orleans and Northeastern | 196 | 2,800 | 100,000 | 510 | Oak, 2 per cent | 30 | 60 | On line | 1,500,000 |
| | | | | | | Pine, 98 per cent | 25 | | | |
| 68 | East Tennessee, Virginia and Georgia | 1,789 | 2,640 | 486,400 | 272 | Oak, 63 per cent | 35 | 63 | On line | 3,950,500 |
| | | | | | | Pine, 37 per cent | 25 | | | |
| | Totals | 5,558 | 2,770 | 2,026,400 | 365 | | | | | 9,300,500 |
| | | | | | | | | | Per mile | 3,167 |

64. Price of ties increased. Suitable timber near the road nearly exhausted. 65. No report of lumber consumed by this road was obtained. The amount is probably not less than 8,000,000 feet, which may properly be added to amount given in the table. 67. Supply of pine and cypress abundant, oak and poplar limited. Creosoted trestle-work. 68. Supply plentiful.

### NORTHWESTERN GROUP.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 69 | Chicago, St. Paul, Minneapolis and Omaha. | 1,627 | 3,000 | 650,000 | 399 | Oak, 49 per cent | 45 | 48+ | Chiefly on line | 9,500,000 |
| | | | | | | Elm, 29 per cent | 27 | | | |
| | | | | | | Pine, 13 per cent | 22 | | | |
| | | | | | | Various, 9 per cent | 22 | | | |
| | | | | | | *Oak* | 35 | | | |
| | | | | | | *Elm* | 25 | | | |
| | | | | | | *Pine* | 25 | | | |
| 70 | Chicago, St. Paul and Kansas City | 812 | 3,000 | 100,000 | 123 | Pine, 80 per cent | 25 | 54+ | | |
| | | | | | | Hard wood, 20 per cent | 48 | | | |
| 71 | Burlington, Cedar Rapids and Northern. | 1,158 | 2,640 | 243,708 | 210 | Oak | 43 | 48+ | Southwest Missouri | 2,030,695 |
| | | | | | | *Oak* | 50 | | | |
| 72 | Union Pacific | 5,158 | 2,992 | 1,550,000 | 300 | Oak, 39 per cent | 52–60 | 48+ | Missouri and Colorado | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Soft wood, 61 per cent | 39 | | | Wyoming and Oregon | 6,650,000 |
| 73 | Duluth, South Shore and Atlantic | 561 | 2,800 | 75,966 | 135 | Cedar, 50 per cent | 16–21 | | 49+ | On line | 683,000 |
| | | | | | | Hemlock, 33 per cent | 16 | | | | |
| 74 | Minneapolis and St. Louis | 551 | 2,800 | 210,000 | 381 | Oak, 22 per cent | 50 | | 42+ | One-third on line, two-thirds Wisconsin. | 2,148,730 |
| | | | | | | Cedar, 35 per cent | 33 | | | | |
| | | | | | | Mixed, 43 per cent | 40 | | | | |
| 75 | St. Paul, Minneapolis and Manitoba | 3,030 | 2,640 | 400,000 | 132 | Oak, 67 per cent | 36 | | 42+ | On line | 6,050,000 |
| | | | | | | Tamarack, 33 per cent | 25 | | | | |
| 76 | St. Paul and Duluth | 258 | 3,000 | 150,000 | 581 | Oak, 20 per cent | 31 | | 42+ | | 1,530,000 |
| | | | | | | Tamarack, 25 per cent | 20 | | | | |
| | | | | | | Pine, 55 per cent | 18 | | | | |
| | | | | | | *Oak* | | 33 | | | |
| | | | | | | *Tamarack* | | 25 | | | |
| | | | | | | *Pine* | | 22 | | | |
| 77 | Northern Pacific | 3,506 | 2,600 | 2,032,300 | 579 | Oak, 31 per cent | 39 | | 56 | | 17,650,000 |
| | | | | | | Pine and spruce, 52 per cent | 28 | | | | |
| | | | | | | Tamarack, 17 per cent | 30 | | | | |
| | | | | | | *Oak* | | 35 | | | |
| | | | | | | *Pine and Tamarack* | | 25 | | | |
| | Totals | 16,961 | 2,759 | 5,411,974 | 319 | | | | | | 46,242,425 |
| | | | | | | | | | | Per mile | 2,863 |

69. The road makes its price for ties. No fluctuation. 71. But little valuable timber on line of the road. 72. Three years ago had Burnettizing works in operation at Laramie, Wyo., but have no preserving process now in use. During 1887 there were used in renewals, 1,284,629 ties, as follows: 420,201 oak, 173,071 cedar, 504,975 pine, 186,382 of other kinds. The cost for renewals of ties was $732,911.05 in 1887, or 57 cents per tie, and $559,068.05 in 1886. The material on hand was as follows: 1887, ties 480,516, value $224,950.35; switch ties, 482,603 feet B. M., value $12,304.53. 1886, ties 220,359, value, $99,312.31; switch ties, 775,991 feet B. M., value $17,502.90. 75. Road owns 500,000 acres of wood land. Doing all we can to preserve timber from fire and waste. 77. Timber supply ample at present.

## SOUTHWESTERN AND PACIFIC GROUP.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 78 | Hannibal and St. Joseph | 367 | 3,300 | 100,000 | 273 | Oak | 20–40 | | 42+ | On line | 1,284,000 |
| | | | | | | *Oak* | | 41 | | | |
| 79 | Atchison, Topeka and Santa Fé | 3,700 | | 883,621 | 236 | Oak, 27 per cent | 48 | | 48 | Missouri and Arkansas | |
| | | | | | | Cedar, 38 per cent | 38 | | | Wisconsin and Michigan | |
| | | | | | | Pine, 35 per cent | 34 | | | New Mexico | |
| | | | | | | *Oak* | | 65 | | | |
| | | | | | | *Cedar* | | 45 | | | |
| 80 | Denver and Rio Grande | 1,545 | 3,000 | 600,000 | 388 | Oak | 75 | | 49 | Two-thirds on line, one-third Colorado and Arkansas. | 5,000,000 |
| | | | | | | Pine, Spruce, Cedar | 25–30 | | | | |
| | | | | | | *Pine and spruce* | | 60 | | | |
| 81 | St. Louis and San Francisco | 1,441 | 2,850 | 478,081 | 332 | Oak | 26 | | 48+ | Missouri and Arkansas | 6,241,000 |
| 82 | Kansas City, Fort Scott and Memphis | 1,192 | 3,000 | 341,272 | 286 | Oak | 33.3 | | 48+ | Missouri and Arkansas | 4,272,595 |
| | | | | | | *Oak* | | 56 | | | |
| 83 | Missouri Pacific | 3,549 | 2,640 | 700,000 | 197 | Oak | 12–30 | | 48+ | Missouri and Arkansas | 4,648,553 |
| | | | | | | *Oak* | | 36½ | | | |
| 84 | St. Louis, Arkansas and Texas | 1,227 | 3,000 | 736,200 | 600 | Oak | 24 | | 56 | On line | 5,500,000 |

*Reports on the consumption of forest supplies by railroads*—**Continued.**

SOUTHWESTERN AND PACIFIC GROUP—Continued.

| No. | Roads. | Length of track. | Ties. | | | | | | | Bridge and other lumber used. |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Average no. in track per mile | Used for renewal for year reported. | Per mile for renewal. | Kinds of timber. | Price. | Cross-section. | Where obtained. | |
| | | | | | | | | | | *Feet—B. M.* |
| 85 | Texas and Pacific | 1,651 | 2,600 | 440,000 | 266 | Oak, 57 per cent | 30½ | 48+ | On line | 5,500.000 |
| | | | | | | Pine, 34 per cent | 29 | | | |
| | | | | | | Cypress, 9 per cent | 37 | | | |
| 86 | St. Louis, Iron Mountain and Southern | 1,548 | 2,828 | 485,000 | 313 | Oak | 12–25 | 50+ | On line | 17,385,000 |
| 87 | Southern Pacific | 4,300 | 2,850 | 1,613,611 | 375 | Redwood, 62 per cent | 30–53 | 48+ | Pacific coast and on line | 3,787,037 |
| | | | | | | Cedar, Fir, Pine } 38 per cent | 22–36 | | | |
| | | | | | | *Redwood* | 37½ | | | |
| | Totals | 20,520 | 2,310 | 6,377,785 | 311 | | | | | 53,618,185 |
| | | | | | | | | | Per mile | 3,188 |

78. Outlook for supply along the line poor. 79. Use Wellhouse process for timber and ties. Have a timber plantation at Hutchinson. 81. Supply of timber ample. 82. During 1888, 307,985 ties were used for renewal at a cost of $112,123 or 36.4 cents per tie. 83. During 1888, on a mileage of 3,119 miles, 1,465.121 ties were put in the track at a cost, including labor, of $365,582 or equal to 38.33 cents per tie; also 704 sets of switch ties put in the track at a total cost, including labor, of $39.29 per set. 85. Timber abundant for years to come. From December 15, 1885, to May 31, 1888, there were 2,176,768 new ties used, costing 36½ cents each, or a total of $728,365.09. The cost of ties in the maintenance of way account was $215,603.57 in 1887; and $129,531.99 in 1888. 86. Supply ample; mills increasing. 87. Report gives valuable information in regard to diminution of timber supplies by fires and by theft; company has a large grant of Government land, which is being sold to liquidate debt of the company for construction; has just established a timber preserving plant at a cost of $43,700.

# REPORT

ON THE

# SUBSTITUTION OF METAL FOR WOOD IN RAILROAD TIES,

BY

E. E. RUSSELL TRATMAN, C. E.

# LETTER OF TRANSMITTAL.

103 TRIBUNE BUILDING,
NEW YORK CITY,
*January* 31, 1890.

SIR: Herewith I submit my final report upon the use of metal track on railways as a substitute for wooden ties.

This report presents at considerable length, and in considerable detail, the development of the use of such track in many foreign countries, the experience thus obtained and the present state of the metal track question. The bulk of the information has been obtained from official sources. Foreign railway managements as a rule have manifested great courtesy and a willingness to furnish full information both in regard to the various systems of track, the conditions of service, and the results obtained. In order to show the thoroughness of my investigation, I may state that my memoranda show personal letters of application for information written to over three hundred individuals, of whom about two hundred have replied. A large number of the replies have been very full and complete, and have been accompanied by drawings, reports, etc. Many of these returns necessitated further correspondence, asking for missing links of information, more complete data, etc., or sending information requested by the persons making the returns. The total of the direct correspondence has amounted to about six hundred letters, with about three hundred communications received. These figures are exclusive of requests for information included in private or general business correspondence. Circulars containing a request for information, with a list of questions showing the character of the information desired, have been sent out with most of the letters of inquiry, and have also been sent to many of the foreign technical and engineering papers. A copy of the circular is appended. In all, about five hundred of these circulars have been sent out. Most of the information obtained, and that of the most complete and valuable character, has been received in answer to the personal letters of application for information. The American and foreign technical and engineering journals have been studied for published information relating to the matters under investigation.

The report presents the results of more than two years of direct work and investigation for this special purpose, but the subject is one which has occupied my attention for a longer time.

It will of course be understood that the rail support itself can not be considered independently, and therefore detailed information is presented in regard to conditions of track, traffic, and rolling stock, all of which conditions have an important bearing upon the general question of the substitution of metal for wooden supports for the rail.

The report covers, as will be seen by the tabular summary accompanying it, nearly 25,000 miles of railway laid with metal track, out of a total mileage of the world (exclusive of the United States and Canada) of 187,721 miles, or a relation of 13.21 per cent. to this total mileage. Allowing for omissions (which will necessarily occur in a work of this extent), incomplete returns, figures not brought up to recent date, etc., there is probably a total length of about 30,000 miles of railway having metal track, or a relation of nearly 16 per cent. to the total mileage of the world (exclusive of the United States and Canada). These few figures show at a glance the great importance of the subject considered in this report, and show also that in other countries the subject has long ago passed the experimental stage in which it still rests in this country. The first part of the report is devoted to details, descriptions, and statistics relating to the several railways, and this matter is compiled mainly from official returns and statements. The second part of the report consists of a general review of the subject, and a summary of the information on several points.

I am particularly pleased to be able to show in this report that in the United States the subject is now receiving much attention by railway men, and that practical tests on a scale sufficiently large to enable definite conclusions to be made and opinions to be formed are now in progress in this country. Valuable results may be expected from these trials, and they will certainly tend to increase to a considerable extent the general interest which is felt by railway men in this subject. It is to be hoped that the results will be such as to lead to an extensive introduction of tested and approved forms of ties. It may be taken for granted that the tie adopted will be an American production and not an importation.

It is the object of this report to bring the matter clearly and fully before the practical railway men and railway financiers. It will, I think, show that the use of metal ties is not only in the interest of forestry and the preservation of the timber resources of the country, but is also in the interest of the railways by reason of the reduction in maintenance expenses and the increased safety in operation. The introduction of metal ties will therefore be for the benefit of the forests, the railway companies, and the public.

I am, sir, respectfully yours,

E. E. Russell Tratman,
*Jun. Am. Soc. C. E.*

B. E. Fernow, Esq.,
*Chief of Forestry Division, Department of Agriculture,*
*Washington, D. C.*

# CIRCULAR.

The following circular was addressed to numerous railway companies, managers, and engineers in foreign countries, and also to manufacturers and others possessing information upon, or likely to be interested in, the subject of metal track for railways.

## METAL TRACK FOR RAILWAYS.

The information outlined below is desired for the purpose of a report to the U. S. Department of Agriculture on the use of metal ties (sleepers) for railway tracks, and it is requested as a favor that all information furnished should be as complete as possible and sent at the earliest possible convenience.

Respectfully,

E. E. RUSSELL TRATMAN, C. E.,
103 *Tribune Building, New York City, U. S. America.*

### INFORMATION.

Railway:

1. Name.
2. Route.
3. Length of lines laid with metal ties (sleepers).
4. Character of same. (Particulars of grades, curves, etc.)
5. Dates when laid.
6. Engineer in charge.
7. Character of traffic.
8. Weight of locomotives and weight on driving wheels.

Tie (sleeper):

9. Longitudinal, transverse, or bowl.
10. General form.
11. Dimensions, including thickness. (Figured drawings.)
12. Weight.
13. Material.
14. Spacing, center to center.
15. How treated. (Paint, anti-rust process, etc.)
16. Manufacturer.
17. First cost, at factory or delivered.
18. Expense of maintenance.
19. Attachment of rails. (Details and drawings.)
20. Arrangements for curves.
21. Tie-rods; if used, how attached and adjusted for gauge.

Tie (sleeper)—Continued.

22. Durability.

Track:

23. Material of ballast.
24. Behavior of ballast under sleeper.
25. Construction of road-bed. (Drawing.)
26. Section and weight of rail.
27. Rail joints; how made.
28. Rail joints; on sleeper or suspended.
29. Reasons for adopting metal sleepers.
30. General results; satisfactory or otherwise.
31. Is there trouble with maintenance of track?
32. Is there trouble with rail attachments?
33. Is there trouble from breakages; how and where do they usually occur?
34. Efficiency, etc., as compared with wooden sleepers.
35. Cost, material, and durability of wooden sleepers.
36. Climate, and effect of same on metal or wooden sleepers.
37. General remarks.
38. Opinions.

NOTE.—The writer of this report will be pleased to be notified of any omissions or corrections, and to receive additional information, with drawings, reports, statistics, or other matter relating in any way to the general subject of this report. He will also be pleased to have correspondence with persons interested in the subject. All communications should be addressed to—E. E. RUSSELL TRATMAN, C. E., Room 103, Tribune Building, New York City, U. S. America.

## ERRATA.

NOTE.—Owing to the departure of Mr. Tratman for England before the report on Metal Track could be put into print, the proof-reading and the making of the index devolved upon the undersigned, both of which tasks have been very difficult on account of the exceedingly technical character of the report. There may be found, therefore, in addition to the errata below, others that have been overlooked, and the index may not prove so valuable as the author himself could have made it; any deficiencies in these respects the reader is asked to excuse and emend.

B. E. FERNOW.

Page 29, line 16 from top, read "Torley" for "Tooley."

Page 59, line 6 from top, read "designed" for "describes."

Page 59, line 12 from bottom, read "Greaves" for "Graves."

Page 65, after line 8 from bottom, add "some of the earlier Webb ties were made with closed ends."

Page 69, line 24 from bottom, the paragraph beginning "The track of this road" should have been set in the larger type, as it is not a part of the letter quoted in the two paragraphs preceding.

Page 70, after line 16 from top, add "Steel ties are said to be laid on the Harrow extension."

Page 70, line 24, beginning at "As regards maintenance" the remainder of the paragraph should have been set in the larger type, as it is not a part of the letter quoted immediately above.

Page 70, after line 3 from bottom, add "These ties are still in use."

Page 78, line 15 from bottom, read "had" for "have."

Page 86, line 7 from bottom, read "Fraisant" for "Fraisans."

Page 89, line 2 from top, read "designed by the engineers of the company" instead of "invented."

Page 91, line 13 from top, read "Contamin" for "Contannin."

Page 92, line 2 from bottom, read "cotter" for "cotler."

Page 95, line 5 from top; page 136, line 14 from top; page 145, line 13 from top and line 16 from bottom, read "Hoesch" for "Hosch."

Page 98, line 14 from top, and page 101, line 17 from bottom, ∩ should be used instead of Λ.

Page 117, line 1 from top, "| beam" should read "I-beam."

Page 166, line 9 from bottom, "28 inch thick" should read ".28 inch thick" and "36 inch thick" should read ".36 inch thick."

Page 181, line 7 from bottom, "34 miles" should read "30 miles."

Page 181, line 2 from bottom, "vertical 1 inch" should read "vertical for 1 inch."

Page 188, drop all Notes from "Being relaid, etc." to Note: "Ties in good condition," each one line. "Buckled steel" refers to Steel Ties only; "5 miles, etc.," refers to Vautherin ties only.

Page 205, line 19 from top, "for" should read "from."

Page 205, line 19, "The ties were made for plates" should read "The ties were made from plates."

Page 248, line 6, "4085 miles" should read "4.085 miles."

Page 256, line 14, "rig" should read "rib."

Page 262, line 1, "put up down" should read "put down."

Page 263, line 23 from top, "Cardova" should read "Cordova."

Page 286, line 19 from bottom, the brace used should have been as follows:

Page 318, "standard" should read "Standard."

Page 325, line 9 from top, for "railways will" read "railway ties will."

Plate VIII, first tie marked O should bear name "Cosijns type."

# PART I.

## USE OF METAL TIES ON RAILWAYS IN FOREIGN COUNTRIES AND IN THE UNITED STATES.

## SECTION 1.—EUROPE.

### ENGLAND.

GENERAL REMARKS.—The idea of using metal supports for railway rails was considered in the early days of railways. Mr. R. M. Stephenson, in his "Rudimentary Treatise on Railways," published in London in 1850, describes the five systems mentioned in the following paragraph:

Mr. Barlow describes a cast-iron combined longitudinal and chair which was tried on the Southeastern Railway. Each longitudinal stringer was in two pieces, with one side of the rail chair upon each piece; when put together, with the rail in place, a bolt (or two bolts at the joint chairs), was passed through the lower part of each chair, under the rail, holding the two pieces together. No transverse connections are mentioned or illustrated, but presumably tie-rods or bars were used. Mr. W. Brunton's track was very similar, but had a deeper web along the under side of the longitudinal, and the top instead of being longitudinal sloped upwards from the middle, forming a wide shallow V trough, with the rail along the middle. Mr. Greaves' system consisted of two hollow cast-iron bowls in the shape of the frustum of a cone and connected by two tie-rods, one at the top and the other at the bottom of the bowls. A rail chair was cast on the top of each bowl, and the rails were keyed in the chairs in the usual way. Mr. W. H. Barlow patented a track with cross-ties bent up at the rail seats to fit the wide flanges of the Barlow bridge rail; another plan was to have a bridge rail bolted to a plate bent to the required form, and all bolted to the tie. Mr. Macdonald Stephenson's system consisted of kite-shaped plates of boiler iron one-half or five-eighths of an inch thick, with both ends turned up and notched to receive the rail. The rail joints were secured by a taper wedge or key driven between the rail and the side of the notch in the plate. The plates formed a continuous bed under each rail, and were connected at the rail joints by transverse tie-rods.

About 1853 iron longitudinals on the Macdonnell system were laid under the Brunel rails of bridge section on the Bristol and Exeter Railway (now a part of the Great Western Railway system), and in 1886 were reported by Mr. Walter Browne to be still in good condition. They were all out of the main track, however, in 1888. (See Great Western Railway.) Cast-iron bowls had been tried, experimentally, previous to 1877 on the Great Northern Railway and other lines running out from London. Within the present decade steel cross-ties have been tried on a number of roads, generally in connection with the standard English system of double-headed or bull-headed rails in chairs. No railway has really adopted steel ties, but Mr. Webb, of the London and Northwestern Railway, has laid down about 56 miles of his system at different parts of the line, and a few trial lots of the same system have been tried on other main lines, but only for experiment. A steel cross-tie with heavy steel rails of flange section is being tried on the Northeastern Railway, and this experiment is of special interest, as the type of track is similar to that which would probably be used in this country should steel ties be introduced, and as it is under severe conditions of traffic its behavior will be some guide for American railway engineers. An English engineer writing to me in December, 1888, on this subject, made the following remarks:

> The chief difficulty is in the adaptation of the steel sleepers [ties] to the double-headed rail, as it does not make a good job, although perhaps Mr. Webb would say to the contrary. The steel sleeper is essentially a sleeper for flat-bottomed [flange] rails, and until our railway companies alter their rails I do not think steel sleepers will come into general use. The Northeastern Railway Company is now trying 3 or 4 miles with a flat-bottomed rail on a steel sleeper, and there appears some promise in this, but it will take years to convert English engineers to the steel sleeper; there are some conditions of traffic opposed to it, as well as the satisfactory experience with our present system.

With the English system of track, the rails are supported in cast-iron chairs, weighing from 20 to 56 pounds each, placed one at each end of every tie, and this practice tends to reduce very greatly any cutting of the tie, as the weight coming upon the rail is distributed over an area of about 7 by 12 inches, or 7 by 15 inches, so that the ties can be counted upon to last out their natural life; while in this country the flange of the rail, 4 to 5 inches wide, cuts into the ties, so that they have often to be taken out before decay has commenced. It may be mentioned, however, that metal tie-plates are now being introduced here to reduce this cutting of ties. English track, therefore, with preserved ties and a broad surface to carry the loading, is very economical in maintenance, and Mr. Owen, the engineer of the Great Western Railway, stated in September, 1889, that as long as creosoted timber ties can be obtained at anything like the present prices, there is no probability of metal ties being generally adopted on English railways. The life of wooden ties used in England is estimated at from eight to thirty years. Descriptions and illustrations of the track on different roads may be found in my paper on "English Railway Track" (Transactions of the American Society of Civil Engineers, New York. June, 1888).

The manufacture of metal ties is a very large industry and is carried on by a number of the most important steel works and foundries. Up to 1888 about 525,000 tons of steel ties had been manufactured, and about 70,000 or 80,000 tons have been turned out since; most of these are for India, with a few hundred tons for railways at home and in other countries. Very large quantities of cast-iron ties have also been manufactured for export, principally plates and bowls for India and bowls for South America. Up to June, 1888, about 2,000,000 pairs of plates for double-headed rails and 600,000 pairs of plates for flange rails, had been supplied for railways in India.

NORTHEASTERN RAILWAY.—Some years ago several steel ties of the type designed by Mr. Charles Wood, of Middlesborough, were tried for about two and a half years, under the supervision of Mr. Cudworth, the engineer. It is stated that the results were not very satisfactory, as the ties cracked where pierced for the fastenings, and the fastenings themselves were very liable to wear. (See Wood's Ties.) I was informed in July, 1889, that they had all been taken out some time since. The ties were of inverted-trough section; the fastenings consisted of a crescent-shaped piece of steel, with the ends projecting up through holes in the tie; one end was shaped to hold the rail-flange and the other end extended nearly to the height of the rail-head, a wooden key being driven between it and the web of the rail. Some steel ties of the type designed by Mr. Webb, of the London and Northwestern Railway, have been in service on the Stockton and Darlington section, and on a piece of track north of Ferryhill. In July, 1889, they had been in service about four and a half years, and had given satisfactory results, but having riveted jaws or chairs they were of course expensive.

In 1887 an experiment was begun with some steel ties designed by Mr. Cabry, the chief engineer, and Mr. Kinch, one of the resident engineers. (See Plate No. 1.) About 10,000 of these ties are now in service on the Central Division, and on the main line on the Northern and Southern Divisions, where the traffic is heaviest and where the trains run at the highest speeds. Under these conditions they have given such excellent results that in July, 1889, the directors of the company, so I am informed, ordered a further supply. One of the most noticeable features of this track is, that steel flange rails, weighing 91 pounds per yard, are used instead of the double-headed or bull-headed rails generally used on English railways. The tie is stamped out of a steel plate and is of inverted trough section with a very narrow flange or rib on the lower edges, being a modification of the Vautherin type of tie. The ends are open. It is 8 feet long, 8 inches wide on top, $3\frac{1}{2}$ inches deep, and 12 inches wide at the bottom. It is of uniform section throughout, with a uniform thickness of three-eighths of an inch. Its weight is 150 pounds. In the operation of stamping, the part under each rail is pressed up at an angle to give the rail the usual inward inclination of 1 in 20. At the same operation four pieces are pressed up out of the metal at each rail seat; three of these are on the outside of the rail, one forming a clip or jaw to hold the rail-flange, the other two being studs against which the rail flange abuts and which keep the gauge exact; the fourth projection forms a jaw to hold the inner flange of the rail. The jaw on the outer side is $2\frac{1}{2}$ inches wide and bears five-eighths of an inch in upon the rail-flange; the jaw on the inner side is $3\frac{1}{2}$ inches wide and projects about three-eighths of an inch over the rail-flange but does not touch it, leaving space for the steel wedge or key to be driven tightly between the jaw and the rail-flange. The keys are tapering, 8 inches long, are split at the smaller end, and weigh $1\frac{1}{2}$ pounds each. In the track the ties are spaced eleven to a rail length of 30 feet, averaging 2 feet $8\frac{3}{4}$ inches from center to center. It is said that they compare favorably in cost with the present system of wooden ties and cast-iron chairs, and it is expected that by their use the cost of maintenance of the track will be materially reduced. In July, 1889, they had been in service for eighteen months, and had given very satisfactory results. Their maintenance had given no trouble, and the cost of maintenance was as nearly as possible the same as that of track on wooden ties. The ties are manufactured by Messrs. Bolckow & Vaughan, of Middlesborough, and some of them have been sent to Italy to be tried as an experiment. They were patented in the United States, November 13, 1888 (No. 392,849).

The rails are of flange section, weighing 91 pounds per yard; they are $5\frac{1}{8}$ inches high with a flange $5\frac{1}{2}$ inches wide and a head $2\frac{9}{16}$ inches wide. To put a rail in position it is tilted slightly and the inner side of the flange slipped under the inner jaw, sufficient space being then allowed for the outer side of the flange to clear the outer jaw; when on its seat the rail is slid under the outer jaw and the key driven on the inner side of the rail. As the rail-flange is overlapped by both jaws, it cannot be forced out of them by the side pressure of the wheels of trains even if the keys are displaced, though it might be tilted over a little. The heaviest engines in use are tank engines, with a wheel-base of 22 feet 6 inches; they weigh $55\frac{3}{5}$ gross tons and have $16\frac{3}{4}$ tons on the driving-wheels.

The following tables, prepared by Mr. Cabry, the chief engineer, and Mr. Worsdell, the locomotive superintendent, in December, 1888, show the cost of the track with flange rails on steel ties and the cost of the ordinary track laid with bull-headed rails in cast-iron chairs on wooden ties. Both are exclusive of ballast. I have reduced the figures to American money.

*Statement of cost of 1 mile of single track on steel ties.*

| Materials. | Numbers. | Weight. Tons. | Weight. Lbs. | Rate. | Amount. | Total. |
|---|---|---|---|---|---|---|
| Steel flange rails, 90 pounds per yard | | 141 | 960 | \$19.37½ | \$2,740.18 | |
| Fish-plates, 13 pounds each | 704 | 4 | 192 | 28.75 | 117.46 | |
| Fish-bolts and nuts, 1½ pounds each | 1,408 | | 2,112 | 41.92 | 39.61 | |
| | | | | | | \$2,897.25 |
| Steel ties, 150 pounds each | 1,936 | 129 | 1,440 | 23.75 | 3,079.00 | |
| Steel keys, 1½ pounds each | 3,872 | 2 | 1,328 | 55.00 | 142.60 | |
| | | | | | | 3,221.60 |
| Carriage of materials | | 274 | 1,860 | 1.25 | 343.53 | |
| Storage and incidental expenses | | 274 | 1,860 | .25 | 68.71 | |
| Use of locomotive in distributing materials on the line, at, say \$75 per mile | | | | | 75.00 | |
| Labor of laying, cubic yards | 1,760 | | | .25 | 440.00 | |
| | | | | | | 927.24 |
| Cost per mile | | | | | | 7,046.09 |

*Statement of cost of 1 mile of single track on wooden ties.*

| Materials. | Numbers. | Weight. Tons. | Weight. Lbs. | Rate. | Amount. | Total. |
|---|---|---|---|---|---|---|
| Steel bull-headed rails, 90 pounds per yard | | 141 | 960 | \$19.37½ | \$2,740.18 | |
| Fish-plates, 13 pounds each | 704 | 4 | 192 | 28.75 | 117.46 | |
| Fish-bolts and nuts, 1½ pounds each | 1,408 | | 2,112 | 41.92 | 39.61 | |
| | | | | | | \$2,897.25 |
| Chairs, 40 pounds each | 3,872 | 69 | 320 | 13.12½ | 907.50 | |
| Keys | 3,872 | | | 9.37½ | 36.30 | |
| Spikes, 22 ounces each | 11,616 | 7 | 292 | 33.61 | 239.65 | |
| Creosoted wood ties | 1,936 | | | .62½ | 1,210.00 | |
| | | | | | | 2,393.45 |
| Carriage of materials | | 352 | 836 | 1.25 | 440.46 | |
| Storage and incidental expenses | | 352 | 836 | .25 | 88.11 | |
| Use of locomotive in distributing materials on the line, at, say \$75 per mile | | | | | 75.00 | |
| Labor of laying, cubic yards | 1,760 | | | .25 | 440.00 | |
| | | | | | | 1,043.57 |
| Cost per mile | | | | | | 6,334.27 |

SUMMARY OF STATEMENTS OF COST.

| | Track on— Steel ties. | Track on— Wooden ties. | Difference. |
|---|---|---|---|
| Cost per rail length, 30 feet | \$40.03 | \$35.98 | \$4.05 |
| Cost per yard | 4.00 | 3.59 | .41 |

LONDON AND NORTHWESTERN RAILWAY.—Experiments with steel ties have been made on this road during over nine years and on a fairly large scale. Particulars of the experiments have been published from time to time, and the trials are given considerable prominence in discussions on matters relating to metal track. The ties are of a form designed by Mr. F. W. Webb, the mechanical superintendent of the line; they are of the familiar inverted-trough section, with small flanges on the bottom edges, and are of uniform section and thickness; they are a modification of the well-known Vautherin type. (See Plate No. 2.) They were first laid in August, 1880; in 1885 there were 32,174 in service; in June, 1886, there were 55,000 in use on this road in addition to trial lengths on other English lines; in 1888 there were 83,204 of these ties in service, and the road had between 20 and 30 miles of track laid with them; in November, 1889, Mr. Webb stated that there were then 56 miles of track and about 100,085 ties in use. They are of rolled steel, five-sixteenths of an inch thick; length, 9 feet; width on top, 6 inches; width at bottom, 11 inches; depth, $2\frac{1}{2}$ inches; weight, 136 pounds each. The rails are of bull-headed section weighing 84 and 90 pounds per yard, the latter being now the standard rail. The chairs, instead of being of cast-iron, are made of three pieces of steel, rolled and stamped to shape from plates one-half an inch thick made from the crop ends of rails; one piece forms a tie-plate 15 by 6 inches, five sixteenths of an inch thick, with the middle part bent to fit the bottom of the rail and give the inclination of 1 in 20; the other pieces are one-half an inch thick and form angle brackets, the inner one fitting the web and lower head of the rail, and the outer one being placed so as to allow of a wooden or steel key being driven between it and the web of the rail. The steel key has a projection which fits into a vertical groove in the chair, so that it cannot work loose. A liner of brown paper or canvas soaked in tar is sometimes interposed between the angle-pieces and the tie-plate and between the tie-plate and tie. The chairs are fastened to the tie by six three-quarter inch rivets, three on each side of the rail, passing through the angle-pieces, tie-plate, and tie; the rivet-holes are punched in a hydraulic press. The ties and chairs are made and fitted complete at the railway company's works at Crewe, and the cost is said to compare favorably with that of the ordinary system of cast-iron chairs weighing 45 pounds each, spiked and screwed to wooden ties 10 by 5 inches. This may be so in this case, where everything is done in the company's shops, and where the ordinary track is of an expensive character, but if made under contract for orders, the amount of shop-work required would probably make the finished tie very expensive.

With these steel ties the distance from the bottom of the tie to the top of the rail is $8\frac{3}{16}$ inches, while with the wooden tie it is $12\frac{1}{8}$ inches. The ties are covered with ballast, which is brought nearly up to the level of the top of the rail head on the outside of the track and between the rails it is about 2 inches below the top of the rail head. It has been said that the ballast would be less affected by frost at a depth of 5 inches, where the wooden ties rest, than at $2\frac{1}{2}$ inches where the steel ties rest; but this is probably of little practical account. The reduced depth of the tie of course effects a saving in the quantity of ballast. The ties are spaced 3 feet apart center to center.

The following is a comparison of the two systems, column A being for track on steel ties and column B for track on wooden ties:

| London and Northwestern Railway. | A. | B. |
|---|---|---|
| **Ties:** | | |
| Length ........ feet.. | 9 | 9 |
| Breadth ........ inches.. | 11 | 10 |
| Depth ........ do.... | $2\frac{1}{2}$ | 5 |
| Thickness ........ do.... | $\frac{5}{16}$ | ..... |
| **Chairs:** | | |
| Length of bearing on tie ........ inches.. | 15 | $14\frac{3}{8}$ |
| Width of bearing on tie ........ do.... | 6 | $7\frac{3}{4}$ |
| Area of bearing on tie ........ square inches.. | 90 | 111 |
| **Weight of one tie complete:** | | |
| Two chairs ........ pounds.. | 48 | 90 |
| Fastenings, liners, etc ........ do.... | | 12 |
| One tie ........ do.... | 136 | 140 |
| Total ........ do.... | 184 | 242 |

The ends of the ties are open, but it is claimed that no trouble has been experienced from lateral motion or shifting of the track when properly ballasted, although some have been in use in the South Wales district on curves of 660 feet radius on a grade of 1 in 38.

It is not stated, however, whether the entire curve was laid with these ties or whether only a few were laid for trial. In the latter case there might have been sufficient wooden ties to hold the track in place. Considering that wooden ties are found to shift in the track in some places, it seems only reasonable to provide at least as much end bearing or area for metal ties as for wooden ties, especially on lines where there are many curves. Mr. Bricka, engineer-in chief of the French state railways, in his report on metal track, made to the minister of public works in 1886, attributes this freedom from lateral motion to the rigidity of the heavy rails, to the slight lateral play of the cars, and to the use of locomotives with inside cylinders and running gear. He saw the ties in use on tangents and flat curves, but thought they would shift on sharp curves. In view of extensive experience on other lines, he considered that the ends of metal ties should be closed. This is the generally accepted conclusion.

The traffic is very heavy as regards the number and speed of trains. The heaviest main-line engine weighs 95,200 pounds, on six wheels, and the heaviest load on any one pair of driving-wheels is 33,600 pounds. Mr. Bricka, in the report above mentioned, refers to this heavy traffic, and states that on one section there were twenty-four express trains per day, often running at nearly 60 miles an hour, besides numerous freight-trains. He says the ties were first made of wrought-iron, but later of Bessemer steel non-dephosphorized. Some ties of harder Bessemer steel, made by the acid process, cracked through the rivet holes and some of the steel-plate chairs also cracked through the holes. Some cast-iron chairs had also been tried. There were in service at the time of his visit 30,000 ties, of which 18,000 were in the main track. He gives the cost of a steel tie as $2.50 and of a creosoted pine tie $2.10, including chairs and spikes complete. The steel ties are dipped hot in tar and then in sand, to increase the adhesion in the ballast. Nevertheless considerable trouble was experienced from rusting, which Mr. Bricka attributes to the use of slag and cinders for ballast. The sulphur, being kept damp by the climate, produces a chemical action similar to that observed in tunnels. In Holland and Belgium, however, no trouble has been experienced from rusting, even in cinder ballast.

These ties, with the English rails and chairs complete, have been tried experimentally in this country on the Pennsylvania Railroad.

MIDLAND RAILWAY.—In 1885, 250 tons of steel ties were rolled by the Cockerill Works, in Belgium, for this line. (See plate No. 3.) These ties were designed by Mr. A. Langley, chief engineer of the road, who has stated that they answer very well, but that the cost as compared with that of wooden ties is against them. In July, 1889, Mr. Langley stated that about 10,000 steel ties were then in the track, but that their use was not being extended. They have proved efficient in service and the maintenance is practically the same as with the creosoted wood ties. The steel ties are of inverted trough section, with a narrow flange on the bottom edges, and have the ends flared out and bent down. The closed ends prevent lateral motion and also prevent any tendency of the sides to spread. The ties are 8 feet long over all, 8 inches wide on top, 3 inches deep, 13 inches wide over all at the bottom. They are of uniform thickness and section throughout, the thickness being five-sixteenths of an inch. The weight is about 132 pounds each and the cost $1.76 each. The joint ties are spaced 2 feet 2 inches apart, center to center, and the intermediate ties 3 feet apart. The ties are rolled from steel which is specified to be of such quality and temper that it will not crack or split when stamped or rolled to shape. The holes may be punched or drilled according to the engineer's approval. The ties are not tarred nor painted, but are given one coat of linseed oil, laid on hot, at the works.

On each tie there are two cast-iron chairs weighing 40 pounds each (pattern of 1885), each chair being secured to the tie by a pair of patent steel twin bolts of ⊔ shape, seven-eighths-inch diameter, with four lock-nuts. The bolt-holes in the ties are fifteen-sixteenths inch diameter, $3\frac{1}{4}$ inches from center to center crosswise, and 11 inches from center to center lengthwise of the tie, the inner holes being four feet five-eighths of an inch apart center to center. The base of the chairs is $7\frac{3}{4}$ by 14 inches, and a felt pad one-eighth of an inch thick is placed between the chair and the tie. The rails are of bull headed section, weighing 85 pounds per yard, and are fastened in the chairs by wooden keys. The wooden ties weigh about 134 pounds each. The weight per yard of the ordinary track is estimated as follows: Steel, 170 pounds; wrought-iron, 14.9 pounds; cast-iron, 110 pounds; wood, 151.9 pounds; total, 446.8. The weight of the heaviest engine is about 78 tons in working order, and the number of ordinary trains in twenty-four hours is two hundred and thirty, exclusive of special trains, light engines, etc.

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski stated in regard to this road that there were 10,000 ties of the form designed by Mr. Langley, being a modification of the Vautherin type, but that the experience with them only dated from January, 1886, and, therefore, no definite opinions could be given as to the results.

A few of the Tozer steel ties have been laid as an experiment. (See Tozer ties.)

GREAT NORTHERN RAILWAY.—Mr. T. H. Horn, assistant engineer, stated in December, 1888, that the experience with metal ties on that line was so limited that no results could be given which would be of service. Short lengths of several types had been laid down experimentally, but altogether there was not then a mile of track on which metal ties had been introduced. The first cost, as compared with that of ordinary fir ties with chairs and fastenings, tells against them. The ties of the Howard type for main lines were of inverted trough section, with a deep depression at each end, forming a seat for the bull-headed rails, which were secured by keys in the usual way. (See plate No. 4.) These ties were 8 feet long and weighed 140 pounds each; they were made from plates of Siemens steel three-eighths of an inch thick. (See Howard ties.) The track of this road is laid with steel rails of bull-headed section, weighing 82 pounds per yard.

At the International Railway Congress held at Milan, Italy, in 1887, the following particulars in regard to this road were presented by Mr. Kowalski:

About 1,000 ties were in service, and four types were being tried, Webb, Moss-Bay Company, Howard, and Tozer. All were of steel. The Webb ties weighed 176 pounds each, complete; the Moss-Bay and Howard ties 139.5 pounds, and the Tozer ties 137.5 pounds, exclusive of the fastenings. They were all laid on embankments, and were on tangents. The traffic consisted of passenger and freight trains running at reduced speed. The weight of the engines was about 60 to 70 tons. The ballast was mainly of gravel. The first cost of the track appeared to be three times as great as that of track with wooden ties, but the experience was too short for any judgment to be formed as to the cost of maintenance and the durability. The elasticity of the track and the easy riding of the trains were the same as with ordinary ties. The inconveniences were in the difficulty of attaching the several pieces to the body of the tie, and in case of derailment the ties would probably be damaged. The company had at that time no intention of extending the use of metal ties on its road.

The following report on the Howard tie was made in February, 1887, by Mr. Bastin, and was published in The Indian Engineer, of Calcutta, March 31, 1888:

On the 7th instant I arrived at Holloway Station, on the Great Northern line, to inspect the Howard steel sleepers (ties), which I superintended the laying of in May of last year. After the ballast had been cleared away I made a thorough examination of them, and am pleased to report that they are in as good condition as when they were laid down. The gauger over this portion of the line informed me that the sleepers had not required any attention whatever since they were laid down: the ballast had not been touched nor had the keys had a hammer upon them. They were purposely laid upon a part of the line over which the most and the heaviest of the traffic passes, so that with such an amount of traffic and the long and severe frost they had been well tested. I also examined some other steel sleepers, laid side by side of the Howard sleepers. These other sleepers are trough-shaped, with cast-iron chairs bolted to them, the ends of the sleepers being turned down. These sleepers are like the Belgian type on the Midland line near Bedford, and, like them, they had shifted endways; and after the frost went they had to be reballasted. I have been to see the sleepers on the Midland line again to-day, Belgian type, and although they were reballasted after the frost they have again shifted so that the line is not perfectly true, the want of straightness being quite obvious.

GREAT WESTERN RAILWAY.—About 1853 the Macdonnell system of track, with metal longitudinals, was introduced on the Bristol and Exeter Railway (now the Bristol and Exeter division of the Great Western Railway), and in August, 1889, the resident engineer reported that the last of it had been taken up only about twelve months previous. This gives some idea of its life, and it must be borne in mind that it was in use under very heavy traffic. The ordinary track of this line was built on the plan designed by Mr. Brunel for the Great Western Railway, and consisted of rails of bridge section secured to wooden longitudinals, which were connected at intervals by wooden transoms. The gauge was 7 feet. The Macdonnell track consisted of iron longitudinals; the plates were a little over 1 foot wide, about one-half an inch thick under the rail, and five-sixteenths of an inch thick at the edges. In the middle, on the upper side, was a rib about 2 inches high, fitting into the hollow of the rail. On each side of the rib was a wooden packing half an inch thick and about 2½ inches wide, upon which the rail flanges rested. A shallow rib on each side, about 2½ inches from the middle rib, held the wooden packing in position. The rails were fastened by bolts passing through the plate, packing, and rail flange, the nuts being screwed down on the flange. In some cases the plates were flat for their entire width; in other cases they were slightly curved down, outside the outer ribs, to a depth of about three fourths of an inch. The plates were connected at intervals by transverse T irons. The rails were about 3 inches high, 2⅝ inches wide, and 6 inches wide over the flanges; the middle space or groove was about 2 inches deep, ⅞ to 1 inch wide. This form of rail is still in use. The resident engineer stated that while he could not recommend the Macdonnell system for main track, it may be very serviceable for light railways or for side tracks; he has used it and is still using it for the latter purpose. The main objection to it is said to be the difficulty in keeping the rails tight upon it, and the number of bolt-holes weakens the plates so much that they were continually breaking, especially near the rail-joints. Another objection is, that "in very hot weather the expansion is so great as to displace it several feet from its proper position." In 1886 this track was reported by Mr. Walter Browne to be in good condition.

The Tozer ties have been tried, but Mr. Lancaster Owen, chief engineer, stated in September, 1889, that only a few ties of this type have been put down, and only as an experiment.

LONDON AND SOUTHWESTERN RAILWAY.—Mr. Andrews, the chief engineer of the road, writing in August, 1889, stated—

The experience with metal ties on this line is very limited. About four years ago a few were laid down and are still in service. They were pressed out of mild steel plates about five-eighths of an inch thick, and were of inverted channel form, with cast-iron chairs secured to them by wrought-iron bolts. When they were laid considerable time and trouble was expended in thoroughly filling them and packing them with gravel ballast; but now that the track has become consolidated, they do not require much more attention than timber ties. The chairs, however, break more frequently than on wooden ties, and the bolts require frequent attention.

The wooden ties used are of redwood fir, obtained from the Baltic, and in view of the number available, the facilities for obtaining them, and the price paid, it is not considered that the company can do better than continue to use them. The company creosotes its ties, and the value of a creosoted tie is about 78 cents, delivered. Jarrah and other hard-wood ties from Australia have been offered at different times, but their high cost, delivered in England, prohibits their adoption, even though, as is urged, they would last much longer than the Baltic fir ties.

The track of this road consists of double-headed steel rails, 30 feet long, weighing 82 pounds per yard; they are $5\frac{1}{4}$ inches high, with heads $2\frac{1}{2}$ inches wide. They are secured by wooden keys in cast-iron chairs, weighing 40 pounds each, which are fastened to the wooden ties by three round spikes driven into hollow tree-nails; the chairs have a base of $6\frac{3}{4}$ by 14 inches. The rail joints are even and suspended, and are spliced by deep fish-plates, with four bolts. The wooden ties are 9 feet long, 5 by 10 inches section; they are spaced 2 feet 2 inches apart, center to center, at the joints, 2 feet 5 inches next to the joints, and 2 feet $10\frac{1}{2}$ inches intermediate. In 1890, rails weighing 87 pounds per yard and chairs weighing 45 pounds each are to be used.

LONDON, CHATHAM AND DOVER RAILWAY.—Mr. William Mills, chief engineer, stated in August, 1889:

No metal ties are used, for the reason that the creosoted ties are found to last, in a general way, as long as the rails, and it is to the company's interest to renew both rails and ties at the same time. The line passes through a brick-making locality, and has the advantage of being able to sell the bulk of its old ties at about half their original cost.

Probably very few railways are able to dispose of their old wooden ties to such advantage, and in many cases in this country it is not easy to get rid of them except by burning. As regards renewals, it would seem to be still more to the company's interest to have ties which would not have to be renewed as often as the rails, especially as the present system of track is already an expensive system to build, so that the increased cost for metal track would be comparatively small.

LONDON, BRIGHTON AND SOUTH COAST RAILWAY.—Mr. F. D. Banister, chief engineer, stated in August, 1889:

The only experience with metal ties on this line has been a small trial, which was unsatisfactory; and the result was not sufficient to warrant any departure from the general system of using Baltic fir ties, creosoted by Brystie's process.

METROPOLITAN RAILWAY.—This is one of the city (underground) and suburban railways of London, the traffic on some sections of which is very heavy and is carried on under exceptional conditions. Mr. J. J. Hanbury, resident engineer, states:

A trial has been made with twelve steel ties of the Tozer type; they were in service about two years, at the end of which time it was found that the chairs began to work a little, owing to the wear of the stud which fits into a hole in the tie. (See plate No. 4.) These ties were considered to be unsuitable for this road. Some steel trough ties, similar to those of the Midland Railway, but weighing 145 pounds each, have been tried; they were made by the Tredegar Iron and Coal Company. The rails used are of double-headed section, carried in cast-iron chairs bolted to the ties.

METROPOLITAN DISTRICT RAILWAY.—This is another of the city (underground) and suburban railways of London. Mr. George Estall, engineer and locomotive superintendent, stated in October, 1889:

Steel ties of the Tozer type have been tried on this road for a length of about 30 feet; they are laid in a locomotive yard, on the level, and are spaced 2 feet 8 inches to 3 feet apart, center to center. They were not painted or otherwise treated. The ballast is of gravel. They were laid for trial only, and the results have not been sufficiently satisfactory to lead to their adoption; as regards maintenance, rail attachments, and general efficiency, they are said to be inferior to timber; they are also too rigid, and are bad for packing. Mr. Estall is not in favor of their use. No breakages have occurred. The wooden ties used are of Memel fir, creosoted; they cost $1.50 each, and last fifteen years. The rails are of bull-headed section, weighing 87 pounds per yard, laid with suspended joints, and supported in cast-iron chairs in the usual way.

MERSEY RAILWAY.—This is a tunnel line, connecting Liverpool and Birkenhead. Mr. C. A. Rowlandson, resident engineer, stated in July, 1889, that about a dozen steel ties of the Tozer type had been tried, but only on a side-track. They have, however, stood very well as regards freedom from corrosion by the ash ballast and in keeping their level or surface.

GREAT EASTERN RAILWAY.—Some steel ties have been in use on this road for several years. They are of the inverted trough section, with closed ends, and the rails are carried in cast-iron chairs of the usual form fastened to the tie by a pair of twin bolts. They are 8 feet long, and were manufactured by the Darlington Steel and Iron Company. At the International Railway Congress held at Milan in 1887, Mr. Kowalski stated that a trial was being made with 500 ties, and that 4,000 were to be laid. The experience with them was then too short to enable any opinions to be given.

FURNESS RAILWAY.—In August, 1889, Mr. F. Stileman, chief engineer, stated:

A few years ago a trial was made with some steel ties of the Howard type (see plate No. 4); they were of inverted trough form, and of arched section; a deep depression at each end formed a seat for the rails, which were secured by keys in the usual way. It was found, however, that with keying the rail up the ends of the tie were sprung, and in the course of four or five months, with the traffic passing over, the ties split so that they had to be taken out. They were of steel and were shaped cold, the recesses for the rails being stamped by hydraulic machinery. (See Howard ties.)

The company now uses none but wooden ties, 9 feet long, 10 by 5 inches section, sawn out of timbers 9 feet by 10 inches by 10 inches. After being dried they were creosoted, which cost about 16 cents per tie. Their life will average from twelve to fourteen years. The chairs have a base of about 15 by 7½ inches and weigh nearly 50 pounds each. The rails are of bull-headed section, weighing 84 pounds per yard; they are fastened in the chair by oak keys, scalloped out in the middle, with a saw-cut at one end, which enables the end to close when being driven and to open out when in place.

NORTH STAFFORDSHIRE RAILWAY.—A steel tie has been tried at Stoke-upon-Trent, on this road, and in January, 1890, after two years' experience, a large order was given to the Chair and Sleeper Company for these ties, which are described further on. The ties were of V-section, with ordinary cast-iron chairs secured to the flanges.

## TIES.

*The Livesey Ties.*—A number of different forms of metal tracks have been designed by Mr. James Livesey, of London, and have been extensively used, especially in South America, by Mr. Livesey and other engineers. (See India and South America; and Plates Nos. 20 and 26.) The types most used are those consisting of bowls and tie-bars. Among the principal forms are the following:

(1) Cast-iron bowls, arranged in pairs and connected by transverse flat wrought-iron tie bars. The bowls are oval in plan, and the upper part forming the chair can be adapted for double-headed or flange rails. Two fixed clips hold the outer side of the rail, and on the inner side is a flexible jaw let into a socket and having a key driven between it and the rail.

(2) Wrought-iron bowls, also arranged in pairs and connected by tie-bars. They are practically rectangular on the bottom and oval on top, shaped like a dish-cover. They are adapted for flange rails. The fastening consists of a steel strip, of ⌴ shape; the longitudinal leg is within the bowl and is secured by a bolt, the washer of which holds the outer flange of the rail; a metal key is driven between the rail and the upright leg, which is inclined inward.

(3) Wrought-iron cross-ties. These are of inverted trough section, being a modification of the Vautherin type; some of these have horizontal flanges on the lower edges. The ends are closed and rounded off, and project deeper into the ballast than the body of the tie. The fastenings consist of two riveted clips, one bearing on the outer flange of the rail and the other projecting over the inner flange, with a key driven between the clip and the flange. A fastening similar to that of No. 2 may also be used.

(4) Steel cross-ties. For meter gauge lines these ties are 5 feet 6 inches long over all, 10 inches wide at the bottom; 5¼ inches wide on top, with rounded corners and curved sides. The ends are curved down. Thickness, seven-thirty-seconds of an inch throughout. Each rail rests on a tie-plate 9½ by 5 inches in size, seven-sixteenths of an inch thick, which is fastened to the tie by two rivets three-fourths of an inch in diameter. There are two jaws about 3 inches long, pressed up out of this plate; the outer one holds the outer rail-flange, and a corrugated key 6½ inches long is driven

between the inner jaw and rail flange. The tie is bent at the rail seats to give the rails an inward inclination. These ties are similar to the steel ties on the Indian State railways.

*The Tozer ties.*—Messrs. J. and H. Tozer of London, manufacture steel ties which are fitted with chairs for double-headed or flange rails. They are of inverted trough form, rounded in section, and deeper than is usual. (See plate No. 4.) For standard gauge lines the ties are 8 feet long, 9 inches wide on the bottom, and $4\frac{1}{8}$ inches deep. The sides are about one-fourth of an inch thick and the top three-eighths of an inch thick. The ends are bent down and flared out at the corners; the tie is bent from the middle to give the rails the inward cant of 1 in 30. For flange rails a flat chair is used $9\frac{3}{4}$ by 4 inches, having two jaws, one of which grips the rail flange, while a key is driven between the other jaw and the flange; the thickness is three-fourths of an inch under the rail. On the bottom of the chair is a pin or stud, which engages with a hole in the tie and prevents spreading of the track; in setting the chair, it is placed on the tie at right angles to its normal position, with the stud in the hole; it is then turned round into position, the ends of the chair passing under jaws or lugs pressed up out of the metal of the tie; the chair has stops at diagonally opposite corners, to prevent it from being turned beyond its proper position. The rails are then laid and the keys driven, after which the chair cannot shift in either direction. The chairs and ties are made to give an exact gauge of 4 feet $8\frac{1}{2}$ inches, but in order to allow for widening the gauge at curves the chairs are so arranged that by reversing one and inserting it in the opposite direction under the lugs the gauge will be widened half an inch, while by reversing both of them the gauge will be widened 1 inch. To give this adjustment the keys must be always on the outside of the rails. If keying on the inside is practicable, the gauge may be also increased by reversing one or both of the chairs and keying one or both of the rails on the inside. The several increments of widening of the gauge are thus as follows: $\frac{1}{2}$, $\frac{5}{8}$, and 1 inch; $1\frac{1}{8}$, $1\frac{1}{4}$, $1\frac{5}{8}$, $1\frac{3}{4}$, and $2\frac{1}{4}$ inches. The weights are as follows: steel tie, 93 pounds; two cast-iron chairs, 18 pounds; two steel keys, $1\frac{1}{2}$ pounds; total weights $112\frac{1}{2}$ pounds. A steel chair is also used, riveted to a steel tie five-sixteenths of an inch thick. The ties are of Bessemer steel and are dipped in a preservative solution. Their cost, as quoted in March, 1888, was about $26.25 per ton, free on board. For double-headed rails the only difference is in the form of the chairs, which are of the usual shape, with high sides to hold the rail and the wooden or metal key; but with the addition of the round stud on the bottom and the stops to keep the chair in place. Small trial lots have been used on several English railways, a few have been sent to China, and 365,000 (20,000 tons) to the Argentine Republic. The advantages claimed are the broad surface of the chairs to distribute the load over the tie, the reduction in the number of loose parts, and the adaptation to present tracks with double-headed or bull-headed rails. The lugs which hold the chairs in place have a good holding-down power, but are claimed to be elastic; so that while giving a firm grip in the chair they render it less liable to fracture than by being held too rigidly.

*The Kerr and Stuart ties.*—Messrs. Kerr and Stuart, of London, manufacture a variety of steel ties of different forms for permanent and light railways, portable railways, and street railways. Their special patent type is a steel cross-tie of inverted section, bent up at the ends to give the rails an inward inclination of 1 in 20. The ends are closed. These ties are for flange rails. The outer flange is held by a riveted jaw or brace, which projects upward and bears against the under side of the rail head. The inner flange is held by a bolted clip, the lower part of which fits into a T-shaped slot in the tie; a steel cotter locks the bolt and clip in position. (See plate No. 4.) The ties are all of mild steel, made by the Bessemer or basic process, rolled in lengths, sheared off, and stamped while hot. The clips are of steel, stamped by hydraulic pressure. This system of tie and fastening is also applied to girder rails for street railways. Following are the particulars of some of these ties: For 2 feet gauge, 4 feet long, costing 96 cents each; for meter gauge, 5 feet 4 inches long, costing $1.20;

for standard gauge, 6 feet 8 inches long, costing $1.56; for the Indian gauge of 5 feet 6 inches, 7 feet 6 inches long, costing $1.86. This tie is considered by the manufacturers to be especially adapted to very narrow gauges, such as 24 inches, on account of the firm support of the rail by the outer brace; it is used for a line of this gauge in Venezuela. Other forms of trough ties are made with different systems of fastenings. One fastening consists of a clip holding the outer flange of the rail, and a gib and cotter on the inner side. Another fastening (Walker & Bear's patent) consists of two loose clips; a small clip or gib holds the inner flange of the rail, and a larger clip on the outer side has a wooden key driven between it and the rail. Steel cross-ties of the pattern of the Indian State Railways are also manufactured, and have been supplied to the Morvi Railway in India. These are of rounded trough section, with the rail seats inclined 1 in 20 and the ends closed and curved down. At each rail seat are jaws to hold the rail, which is fastened by a steel key.

The ties are rolled with the metal of the top thicker than the sides and they are afterwards pressed to shape by hydraulic pressure, and the clips punched out and bent. The following are the particulars of some ties of this type:

| Gauge. | | Weight. | Length. | | Price, complete with keys. | Suitable for rails weighing per yard— |
|---|---|---|---|---|---|---|
| *Ft.* | *In.* | *Pounds.* | *Ft.* | *In.* | *Dollars.* | *Pounds.* |
| 2 | 6 | 35 | 4 | 6 | 0.69 | 25 to 30 |
| 3 | 3⅜ | 65 | 5 | 4 | 1.02 | 40 to 60 |
| 4 | 8½ | 80 | 6 | 9 | 1.32 | 60 to 80 |
| 5 | 6 | 95 | 7 | 6 | 1.56 | 60 to 80 |

*The Howard ties.*—The steel ties manufactured by J. and F. Howard, of Bedford, for main lines, are of approximately semi-circular cross-section, of different dimensions and section at different parts of their length. (See Plate No. 4.) Each tie is made from a steel plate pressed to shape by hydraulic power. The rail seat for double-headed rails is a depression in the tie deep enough to admit the web and lower head of the rail, which is secured by a wooden key driven between the web and the side of the depression in the tie. No bolts or rivets are used. These ties were patented in the United States December 22, 1885 (No. 333,015). In July, 1889, the firm reported that the manufacture of ties for main lines had not been commenced on a large scale, but that trial lots had been supplied to a few lines (see Great Northern Railway and Furness Railway). In March, 1888, special plant for making ties was patented in England. The plate of each tie is rolled so that the portions where the rail recesses are to be formed are left thicker, the trough formed on the under side by the corrugation being filled up or partially so, or the raised portion may be left solid throughout the length of the tie. The rail recesses are partially formed by the rolls which produce the plates, and for this purpose depressions are formed upon the periphery of one roll and corresponding indentations upon the periphery of the other roll; so that the plates in being rolled are indented at the parts where the recesses are to be formed. The plates are then passed through rolls with similar projections and indentations, which give the plates their finished form. The plates are passed between these rolls as they leave the plate rolls and while still hot, and are subsequently shaped by suitable presses. The rail recesses are finished to the proper shape by cutting appliances, consisting in the use of an endless or revolving table composed of a number of links or small platforms carried upon wheels. The plates are placed upon these platforms, and as the table moves forward they are caused to pass under a number of cutters, arranged one before the other, by the action of which the surplus metal is removed. Several ties may be operated upon at the same time on one table, and after passing under the cutters they are delivered from the table with rail recesses or seats in a finished state.

The firm makes a specialty of metal ties for light and portable railways, and has supplied them for light railways for agricultural, mining, and construction work in many countries with succesful results. These ties are of steel plates, with one or two vertical corrugations lengthwise of the tie, and having the sides bent down; the ends are open. The corrugations are cut away at the rail seats to let the flange of the rails rest on the flat part of the plate, and a serrated metal key is driven between the rail and the side of the recess thus formed. There are no bolts, clips, or rivets. Ties with two ribs or corrugations are used at rail joints. For portable railways, with rails weighing up to 14 pounds per yard, the ordinary ties are 5 inches wide and the joint ties 6⅝ inches wide; for semi-portable railways, with rails weighing up to 30 pounds per yard, the ties are 5⅛, 5¾, and 6⅞ inches wide; for light railways, using locomotives, with rails weighing up to 40 pounds per yard, the ties are 9½ inches wide at the bottom and about 3 inches deep. Ties of this latter form have been used on the Donna Christina Railway in Brazil. Ties for main lines laid with flange rails are of somewhat similar form, but with closed ends; to make a seat for the rail, the metal of the corrugation is pressed down level with the surface of the tie, thus thickening the metal at the seat; a steel key is driven between the rail and the side of the corrugation, and in pressing down the metal it is made to project over the seat so as to form a clip to hold the rail flange. This type of tie was patented in the United States February 2, 1886 (No. 335,523). Another form of tie consists of two pressed steel bowls connected by a wrought-iron tie-bar; each bowl is made of a steel plate flanged down to the form of an oblong box; it is flat on top with outward flaring sides, and rounded ends corrugated vertically. The tie-bar passes through the bowl, and is held by a flat curved cotter lying in a depression in the top of the bowl. There are two transverse corrugations, which are pressed down at the middle to leave room for the rail flange, and the rail is secured by two serrated steel keys. The weight is said to be only about half that of the ordinary cast-iron bowls.

*The Wood steel ties.*—The steel tie designed by Mr. Charles Wood, of Middlesborough, is said to have been the first steel tie used with flange rails on English railways, and to be still in use in England and the British colonies. It is of modified Vautherin type, of inverted trough section, and having horizontal flanges on the lower edges. (See Plate No. 4.) Each rail fastening consists of a half hoop or crescent of steel, the lower part being inside the tie, and the ends projecting upwards through holes in the top, having stops or lugs to prevent them from rising too high and to bring them into proper position. The outer end of the crescent is bent over to bear on the outer flange of the rail, while the inner edge projects higher and has a wooden key driven between it and the rail, the key bearing against the web and flange of the rail. Some of these ties were tried on the Northeastern Railway in England; and they have also been used in South America. For light and portable railways steel ties with different forms of clips and bolt fastenings are used.

*The White tie.*—This is a patent pressed-steel tie, designed by Mr. Henry White, of Newport, and manufactured by Ibbotson Bros., of Sheffield. At a meeting of the British Association in 1887, Mr. White read a paper on "An improved steel railway tie with chairs pressed out of the solid," the following notice of which is taken from Engineering, London, England, September 23, 1887:

"This was a trough section tie, to suit any ordinary type of rail, and the chairs being stamped on it there were no bolts or rivets required. Hydraulic presses with suitable dies are used. The steel trough is first cut to the required length, heated, and inserted between the open dies of a press, or, if both chairs are made at once, of a pair of presses. These roughly form two corrugations at each end, corresponding with the jaws of the chairs. The metal for this is gathered up endwise, thus shortening the original length of the piece of steel operated on. Another heat being taken, the partly-made tie is placed between the dies of the finishing press and the jaws are given their final form. The lower dies in this case have two hinged pieces which project upwards, and when the upper dies descend they close inwards, causing one of each pair of jaws to assume the undercut form necessary to fit the rail and hold it firmly in its place. A loose piece, resembling the lower part of the rail, is inserted between the jointed pieces, to form a resistance block for them to close against. It was claimed that ties so formed give a larger base to the rail, hold it more firmly, and are stiffer than any others hitherto used."

*The Sampan tie.*—The Sampan combined railway tie and chair is a comparatively recent invention, and, I believe, has not yet been tried. It is intended to be made of cast-steel, the recent improvements in steel manufacture enabling a reliable quality of material and work to be obtained at reasonable cost. The tie is of shallow inverted trough section, with outward flaring sides and closed ends; a middle rib runs along the whole length of the under side of the tie, and this rib is deeper than the sides; there are also four transverse ribs, one under each rib and two intermediate. (See plate No. 4.) The thickness is increased at the rail seat. The chairs for bull-headed or double-headed rails are cast with the tie and form a part of it, the rails being secured by wooden or metal keys in the usual way. The joint ties are of extra width at the ends, and the rails are secured in the joint chairs by two cast steel keys, which are drawn and held together by a bolt passing through them parallel with the rail. This is claimed to make an efficient joint, dispensing with splice-bars and bolts. If desired, the ends with the chairs can be cast separately and connected by a tie-bar; this arrangement is said to be adapted for railways in South America and other countries where the traffic is not too severe. These ties have been patented by the Railway Sleeper and Tie Company, of Manchester.

*The Bankart tie.*—This is a cross tie, the invention of Mr. Hubert Bankart, consisting of an **I** beam laid on its side (H) with a part of the upper flanges cut away to allow the rail to rest on the horizontal web; the inner flange of the rail is overlapped by the flanges of the tie, which are undercut, and on the outer side of the rail is an angle wedge or key, bearing on the rail flange and web, and having a rib at the back which fits into a groove in the flanges of the tie and prevents vertical motion. (See plate No. 4.) No bolts or nuts are required, this fastening being used at the rail joints. The key may be placed on the inside or outside of the track, but the flanges must be cut according to which arrangement is adopted. These ties are said to have been tried in Brazil, but I have not been able to obtain any definite information respecting them.

*The Bagnall ties.*—The firm of W. G. Bagnall, of Stafford, manufactures different forms of metal ties, principally for light and portable railways, and the ties have been used to some extent. The type used is a pressed steel cross-tie, narrower and deeper at the middle than at the ends, and having grooves and ribs running lengthwise on the surface. For permanent roads a tie is used having a groove running from each end nearly to the middle; corrugated steel clips are riveted on and a steel key is driven between the rail flange and one of these clips. (See plate No. 4.) Another form of tie with riveted clips has the groove running in from each end and two raised ribs along the middle portion of the tie. Joint ties of this form are of extra width, with two grooves at each end and three ribs at the middle. With other forms of ties lugs are stamped up out of the metal to hold the rail flanges, the rails being secured by keys. A tie for collieries, mines, and light tracks has the lugs bent over to embrace both flanges of the rail, the rail being slipped under the lugs, and no keys or other loose pieces being used. For portable railways, the rails and ties are riveted together to form sections of track, one end of the rails of each section having the splice-plates riveted on.

*The Tredegar ties.*—Besides the steel ties made for the Metropolitan Railway, the Tredegar Iron and Steel Company makes other forms, including corrugated steel ties for use with flange rails. These are made of various sizes, and weigh from 12 pounds ($2\frac{1}{4}$ pounds extra for fastenings) for a gauge of 24 inches to 62 pounds (4 pounds extra for fastenings) for standard gauge.

*The Nut and Bolt Company's ties.*—The Patent Nut and Bolt Company, of Newport, manufactures a tie of double channel or **H** section. The lower part is of trough section, $2\frac{9}{32}$ inches deep, $10\frac{1}{4}$ inches wide at the bottom, about $5\frac{1}{2}$ inches wide on top, and having on the upper part two vertical ribs forming a channel $1\frac{1}{2}$ inches deep and $4\frac{3}{4}$ inches wide. The horizontal part is eleven-thirty-seconds of an inch thick, and the sides of the channel are three-eighths of an inch thich. For double-headed rails the fastenings consist of two loose jaws. The outer one fits the web of the rail and the under side of the head. It rests on the horizontal part of the tie, and has a hooked lug on the bottom which passes through a hole in the tie and takes a bearing on the inside. On the inner side of the rail is a similar jaw, but with the top flat and having a slot near the base. A flat taper steel key is driven horizontally through slots in the sides of the channel and the base of the jaw in a similar way to the fastening used with the Denham-Olpherts plate-ties in India. The chair and fastening make a heavy and cumbrous arrangement, and the jaws are liable to wear and thus cause rattling. It has been suggested that the outer jaw might be riveted. The holes for the keys and chairs are punched cold. The ties weigh 154 pounds each. They are said to have been in service under heavy traffic at the Alexandria Dock, Newport, and on the lines at the works of the manufacturers.

*The Quetch ties.*—This system of track has been described in an Indian paper as an English system, and it is said to have been awarded a bronze medal at the Railway Exhibition at Paris, in 1887. The rails are of bridge section with very wide flanges, about 14 inches wide over all. The joint and intermediate chairs consist of channel plates with lugs on the side to hold the rail flanges, and a rib in the middle to fit into the hollow of the rail, keys being driven through the webs of the rail and this rib. The gauge is maintained by transverse tie-rods fastened by vertical cotters. The track seems to resemble the Macdonnell track on the Great Western Railway.

The following is given as the weight per mile of single track:

| | No. | Weight. |
|---|---|---|
| | | *Tons.* |
| Rails, 24 feet long, 106 pounds per yard | 440 | 165.00 |
| Chairs: | | |
| Joint, 90 pounds each | 440 | 43.75 |
| Intermediate, 45 pounds each | 1,320 | |
| Tie rods, $1\frac{1}{4}$ inch diameter, 30 pounds each | 888 | 12.25 |
| Keys: | | |
| Joint, 3 pounds each | 1,760 | 4.00 |
| Intermediate, 3 pounds each | 1,320 | |
| Springs, for keys | 3,080 | .25 |
| Cotters, for tie-rods, 3 pounds each | 1,760 | 2.50 |
| Total | 11,008 | 227.75 |

*The MacLellan ties.*—The MacLellan & Smith patents are for ties of embossed steel, either in the shape of bowls or cross-ties. A description of the former will be found in this report, under "India" (Calcutta Port Railway), and of the latter under "Australia" (South Australian Government Railways). (See plates Nos. 18 and 25.) They are manufactured by P. & W. MacLellan, of the Clutha Iron Works, Glasgow. MacLellan's wrought-iron ties have also been used in India, on the State Railways.

*The Chair and Sleeper Company's tie.*—The tie manufactured by this company, of Widnes, Lancashire, and in use on the North Staffordshire Railway, is a steel tie of **V**-section. For double-headed rails, the ordinary cast-iron chairs are secured to the flanges. For flange rails an angle plate at each end, as long as the width of the top of the tie, is secured by two rivets, and supports the outer side of the rail, while two loose riveted clamps are forced round upon the rail flange on the inner side. At joints the vertical part of the riveted angle-bar is as long as a splice-bar, and has four projections or studs, which engage with the holes in the webs of the rails. Bolts are thus dispensed with. The tie is intended for light railways, collieries, etc., as well as for main lines.

SUMMARY OF METAL TRACK FOR ENGLAND.

| | Miles. |
|---|---|
| Northeastern Railway | 5 |
| London and Northwestern Railway | 56 |
| Midland Railway | 5 |
| Great Northern Railway | $\frac{3}{4}$ |
| London and Southwestern, London, Brighton and South Coast, Metropolitan, Metropolitan District and Mersey Railways (estimated) | $\frac{3}{4}$ |
| Great Eastern Railway | $2\frac{1}{2}$ |
| Total | 70 |

## SCOTLAND.

GENERAL REMARKS.—The length of railways in Scotland is about 2,900 miles, laid exclusively with wooden ties.

GREAT NORTH OF SCOTLAND RAILWAY.—Mr. P. M. Barnett, chief engineer, writing in August, 1889, stated:

Metal ties have not been tried on this line. The ties used are of Scotch fir, 9 feet long, $4\frac{1}{2}$ inches thick, $5\frac{1}{2}$ inches face, and 10 inches wide at bottom. All the ties are creosoted, and the cost, including creosoting, was, at the time of the report, 56 cents per tie. The forests from which the ties for this line are supplied are in the counties of Aberdeen, Banff, Elgin, and Inverness.

HIGHLAND RAILWAY.—Mr. M. Patterson, chief engineer, stated in August, 1889:

Metal ties have never been tried on this line. Scotch fir and larch and some Baltic fir are used. The Scotch and Baltic fir is all creosoted, and the company has now begun to creosote the larch ties. The ties are 9 feet long; the foreign ones are of rectangular section, 10 by 5 inches, and the native ones are slabbed on the back for a breadth of 5 inches to give a seat for the chairs. The larch ties cost 84 cents to 86 cents and the fir ties 60 cents, when creosoted. The line is in the best part of Scotland for native ties, and considerable quantities are sent to lines in the south of Scotland and some to England.

## IRELAND.

MIDLAND GREAT WESTERN RAILWAY.—Some years ago Mr. James Price, while chief engineer of the road, introduced a system of cast-iron ties, experimentally, and obtained excellent results. The following description refers to ties of the type used, but as subsequently improved upon by Mr. Price, who has furnished me the particulars. Each tie consists of two boxes and a tie-bar. The boxes are 6 by 6 inches square, $4\frac{3}{4}$ inches deep, open at the top; they are cast with a hollow base 12 by 12 inches square, 2 inches deep, and one side of the box (transverse to the rail) is extended to the width of the base, having a bolt hole in each wing. The box is partly filled with a special mixture of "sawdust asphalt," consisting of sawdust mixed with well-boiled tar, as little of the latter as possible being used. This material is said to be everlasting, permanently elastic, and very cheap. Upon this is placed a plate fitting into the box like a piston, and the rails (of flange section) rest on this plate and not on the sides of the box; so that they have a firm but elastic bearing. The tie-bar is 3 inches deep by half an inch thick, with a clip or jaw on the upper edge at each end, to hold the outer flange of each rail. The inner flange is held by a short flat plate of the same shape as the end of the tie-bar. Bolts of 1-inch diameter pass through the plate, tie-bar, and the wings of the box, and by the use of bolts with tapered necks a very strong grip can be given on the rail flange. The ballast is brought up level with the top of the boxes.

## FRANCE.

General Remarks.—In this country no railway has definitely adopted metal ties for general use, but experiments with different forms of ties have been made and are still being conducted on five of the seven principal railway systems; in some cases to a sufficient extent to enable conclusions to be drawn as to comparisons between track on metal ties and on wooden ties. There has been a tendency toward the designing of ties of complicated construction, made up of a number of parts or difficult to manufacture; such ties, however, are necessarily more expensive and troublesome than ties which are simple in design and easy to manufacture, and for these reasons their wider introduction is not probable, after practical trials shall have proved their deficiencies. The majority of metal ties now in use are of forms derived from the type designed by Mr. Vautherin, a French engineer; this type consisted of a cross-tie of inverted trough section, with sides flaring outward from the top, and having a narrow horizontal flange on each lower edge. The Vautherin tie is the basis of the form of a very large number of the ties designed and introduced within recent years. These ties were first used in 1864, on the Paris, Lyons and Mediterranean Railway, and were used later on the same company's lines in Algeria. Mr. Clerc, of the Western Railway, in a paper published in the Revue Générale des Chemins de Fer, Paris, March, 1889, stated that of the numerous systems of metal ties which have been tried, the majority had not proved satisfactory, and only a few would bear close investigation. Of these numerous systems few had been designed by persons experienced with railway work; for while the manufacturers have considerable interest in the adoption of metal ties, most railway engineers prefer wooden ties, and difficulty in obtaining wood appears to them to be the only reason justifying the use of metal ties. The time when this difficulty will really necessitate the use of metal ties can not yet, he says, be foreseen. The price of wooden ties was then less than it had been during thirty years, and this reduction was apparently due to the development of certain districts and the facilities of transportation resulting from the extension of the railway systems. The use of creosoted ties has increased the durability of the track, and no limit of service can yet be assigned to ties of creosoted beech; such ties have been in service for twenty-five years, and were in good condition at the end of that time, except a few not thoroughly treated and some which had been split, cut by the chairs, or otherwise damaged, but which had not decayed. Nevertheless, Mr. Clerc believes that the question of the use of metal ties should not be overlooked, and trials have in fact been made upon the line with which he is connected.

In 1885 Mr. Bricka, engineer in chief of the state railways, was directed by the minister of public works to investigate the principal systems of metal track in use in Europe, and he presented a very complete and valuable report, embodying the results of his investigations. He came to the conclusion that the use of track with metal ties is advantageous, and is not in general more expensive than that with wooden ties, when the proportion of the prices does not exceed 8 to 5. He recommended cross-ties of the Berg-and-Mark or Post sections, both of which are modifications of the Vautherin tie. He further recommended that a series of practical trials should be carefully conducted. If properly carried out the cost would not be great, and the results thus obtained and recorded would be extremely valuable. He did not think, however, that the use of metal ties would become general in France to replace wooden ties, as there are yet extensive timber resources and the use of wood will be always economical in forest districts. A point not referred to, however, is the superiority of track on metal ties over that on wooden ties, especially under heavy and rapid traffic. Metal longitudinals have only been tried to a very limited extent.

*Use of old rails.*—Several forms of ties in which old rails are to be used have been designed by Mr. Ozanne. They consist of different forms of cast iron plates and rail chairs combined, placed in pairs and connected by an old rail, forming a tie-bar, bolted or keyed to them.

STATE RAILWAYS.—The following information is taken from a special detailed report, sent to me in March, 1888, by Mr. Bricka, the engineer in chief, and from other reports sent by division engineers, dealing with the several queries contained in the circulars accompanying my letters of inquiry.

The reason for using metal ties was that engineers had learned from the experiments and trials made in Germany, Austria, and Switzerland that the use of metal ties offered considerable advantages; the engineers, therefore, decided to employ such ties to a sufficient extent to enable them to judge for themselves as to the results to be obtained from their use. Up to the date of Mr. Bricka's communication (March, 1888) the track had remained in good condition; it was as firm as and more solid than track on wooden ties; there was no trouble with the rail attachments, and no breakages had occurred; no difficulty was experienced with the maintenance, which, after a time, tended to become less than the maintenance of track on wooden ties. The rails are of double-headed section on some parts of the line, and of flange section on other parts. The ordinary cast-iron chairs have been used on some of the metal ties on account of the large stock on hand of double-headed rails; but with metal ties there is less need of such chairs for the purpose of distributing the pressure. The joints are suspended and are spliced by fish-plates and four bolts. The ballast is of sand, gravel, or broken stone; on the outside of the track it is brought up level with the under side of the rail head; on the inner side it is level with the bottom of the rail and is crowned toward the middle of the track. The wooden ties are of pine from the Landes, impregnated with chloride of zinc, which cost 52 cents each in the southwest district of the system. Oak ties cost 95 cents, and, since 1886 or 1887, these ties also have been impregnated with chloride of zinc, which increases the price 11 cents per tie. The temperate climate of the region in which this system of railways lies is favorable to the life of wooden ties. Atmospheric agencies do not appear to affect the metal ties, which only corrode in tunnels and when laid in ballast containing sulphurous material. No preservative process or coating is applied to these ties. The engines with three axles weigh 56 tons, and those with four axles 75 tons, including the tender. The load on the axles of the engines is from 10 to 13 tons. The speed of express trains ranges from 38 to 50 miles per hour. The lines are of standard gauge, 4 feet 8½ inches.

(*A*) *Paulet and Lavalette ties* (See plate No. 5).—These ties were laid in August, 1885, for a length of 11,119.20 feet, on the line from Paris to Bordeaux (section from Montreuil-Bellay to Niort). Mr. Tyndall, of Tours, was the engineer in charge. There are nine trains per day, with a speed of 37 to 50 miles per hour. The line is double track, and the profile and alignment of the track laid with these ties are as follows:

| | Feet. |
|---|---|
| Profile: | |
| Level | 2,246.80 |
| On grades of 1 per cent | 5,412 |
| On grades of .5 per cent | 721.60 |
| On grades of .1 per cent | 2,738.80 |
| Alignment: | |
| On tangents | 3,690.69 |
| On curves of 1,640 feet radius | 7,428.51 |

The ties are made of iron and are of two forms, single and double. The single ties are made of two angle-irons 3.6 inches wide, 2.8 inches high, .36 inch thick, and 7.55 feet long; these are placed back to back and have the ends bent slightly outward. A rib on the bottom of each of the two rail chairs rests between the angle-irons, and each chair is secured by four rivets passing through the angle-irons and rib. The weight is about 165 pounds per tie. The double ties are placed 24 or 32 inches apart, and are connected at the ends by irons of the same section bent to the form of a U, the legs being parallel with the main angle-irons and riveted to them; the ribs of the chairs lie between the main and end pieces and are secured by the rivets. The double ties used at curves have the angle-irons about 32 inches apart, and weigh 308 pounds each; those used at the rail joints have the angle-irons about 24 inches apart, and weigh 290.4 pounds each. The single ties on straight lines are spaced 33 inches apart, centre to centre, and 32 inches from the joint ties. On curves two of the double ties are substituted for four single intermediate ties, leaving one single tie at the middle. The double ties are spaced 32 inches apart, or 34 inches from the single ties. The ties were manufactured by the Société Anonyme des Hauts Fourneaux, of Maubenge. The first cost was about $45 per ton, and the expense of maintenance is said to be lower than that of track with wooden ties. These ties must be manufactured with great care, as otherwise the rivets may not fit exactly and may throw the track out of gauge. They are more expensive in first cost and are less advantageous than ties of the Vautherin type. The rails used are of double-headed section, 5.3 inches high, with heads 2.4 inches wide, and weighing 76.5 pounds per yard. The upper parts of the chairs are of the usual form, and the rails are secured in them by keys. The ballast is of broken granite, and is about 22 inches deep between the rails and 12 inches deep under the ties. The width of ballast is 23.4 feet on top, extending 3.4 beyond the ties. The road-bed at subgrade is flat.

Mr. Bricka stated in his letter that the Paulet and Lavalette ties were only used on a short length of track. They have given satisfactory results, but on account of the high price and the chances for damage which they present, the ties derived from the Vautherin type are much preferred, more especially as their advantages have already been demonstrated in other countries. Mr. Tyndall, division engineer, writing in May, 1888, in regard to these Paulet and Lavalette ties, stated that those laid up to that date, for a length of 2.5 miles, had given satisfaction, no chairs having been broken and no rivets loosened. He thought that they would be better if made 8.2 feet long instead of 7.55 feet, and that for sand ballast ⊥ irons should be used, with the inner flanges just wide enough to meet, so as not to allow the sand to pass up into the tie while being tamped. The track was good, and the cost of keeping it in repair was about the same as for the track alongside of it, which was laid on wooden ties.

(*B*) *Vautherin ties of uniform section for double-headed rails* (See plate No. 5).—At the time of the report there were on the line from Paris to Bordeaux 4.25 miles laid with these ties on the section between Chartres and Bron, 3.1 miles were being laid on the section between Niort and La Rochelle, and ties were being manufactured for 18.6 miles more. Those on the first section were laid in January, 1887, under the supervision of Mr. E. Colin (See paragraph D). On this section the ties are on the level for about 1 mile, and for the remainder of the distance on grades of from 1.2 per cent. to .2 per cent.; about 2.67 miles are on tangents, and the remainder on curves of from 1,804 feet to 9,840 feet radius. The line is single track, and the traffic consists of twenty-two trains per day, the speed of the express trains being from 37 to 50 miles per hour. Mr. Delaunay was the engineer in charge of the second section, the traffic of which consisted of twelve trains per day. The rails are of similar section and weight to those already described. The ballast is of sand and clean gravel, about 13.2 inches deep under the ties. The width of the ballast bed is about 11.7 feet on top and 17 feet at the bottom. The road-bed at subgrade is crowned. The ties are of modified Vautherin type, of uniform section throughout, having the top table of uniform thickness, and having ribs instead of horizontal flanges on the lower edges. They are 8.2 feet long, 4.8 inches wide on top, 3.2 inches deep, and 10.12 inches wide at the bottom; the thickness of the top table is .4 inch, while that of the sides varies from .28 inch near the bottom to .32 inch near the top. The weight is 126.72 pounds. In the track they are spaced 21 inches apart, center to center, at joints, and intermediate ties, 39.2 inches apart. No special arrangement of the ties is used at curves. The ties are of mild steel and are manufactured by the Société de Denain et d'Anzin, and cost about $30 per ton delivered at the track. The expense for maintenance during the first year is about the same as with wooden ties, but it diminishes afterwards. This type of tie has given general satisfaction, and judging from experience in other countries, they should have a life of at least thirty years. The chairs used are of cast-iron, of the ordinary form, but having a lug on the under side which fits into a slot in the tie; they are fastened by two bolts with ⊥ heads inside the tie.

(*C*) *Vautherin ties of varying section, for flange rails* (See plate No. 6).—On the line from Paris to Bordeaux (section between Chartres and Bron) 4.2 miles were laid in January, 1887, under the supervision of Mr. Colin (See paragraph E). About 1 mile of this distance is on the level, the remainder being on grades of .7 to .1 per cent.;

about 3.25 miles are on tangents, the remainder on curves of 5,000 to 8,200 feet radius. The traffic consists of twenty-two trains per day. The ballast is of broken granite and the section of road-bed is as described in Paragraph B. The rails are of flange section, 5.2 inches high, 5.2 inches wide over the flange, with a head 2.4 inches wide, and weigh 78 pounds per yard. On the line from Tours to Sables (section between Bressuire and Sables), 4.6 miles were laid in March, 1887, under the supervision of Mr. Madelaine. About 1.25 miles are on the level, the remainder being on grades of 1.4 to .7 per cent.; about 2.1 miles are on tangents, and the remainder on curves of 2,427 feet to 6,000 feet radius. The traffic consists of twelve trains per day. The ballast is of the same material and the road-bed is of the same general section as described above, except that the bed at subgrade is flat and not crowned. The rails are of flange section, 5.2 inches high, 4 inches wide over the flange, with a head 2.4 inches wide, and weigh 76.4 pounds per yard. The ties are of the modified Vautherin type, of varying section and thickness of top table, being somewhat similar to the "Post" type of tie (Netherlands State Railways). They are very similar to those described in Paragraph B, but the thickness of the top table varies from .40 inch or .44 inch at the rail seat to .28 inch or .32 inch at the middle; they are 8.52 feet long, with a top table 6 inches wide. They are bent to give the rails an inward cant of 1 in 20, and the ends are closed. They are of mild steel and weigh 124.3 pounds each. They were manufactured by the Société de Denain et d'Anzin, and cost $34 per ton. The expense for maintenance during the first year is about the same as with wooden ties, but it then begins to diminish. The ties have given good results and are expected to last thirty years in service. The fastenings used are of two types; the first consists of a bolt on each side of the rail flange, the bolt having a ⊥ head inside the tie, and a clamp or washer held down on the rail flange by the nut; the clamp has a projection which fits into a slot in the tie; the second type of fastening consists of an arrangement of gibs and cotters, each side of the rail flange being held by a gib, and a vertical cotter being driven on one side. This latter type is said to be satisfactory, and to appear to be superior to the fastening by bolts and clamps, a result which is at variance with early experience with gib and cotter fastenings, it having been found, as a rule, that the cotter worked loose, or else rusted in so that it could not be moved and must be broken off, the whole fastening, as a rule, soon becoming loose enough to make a noisy rattling track. Some of the German railways, and the Western Railway of Switzerland, also report good results from the use of an improved gib and cotter fastening. For rail lengths of 20 feet the end ties are spaced 24 inches, center to center, and the intermediate ties 36 inches; for lengths of 36 feet, the middle and end ties are spaced 24 inches, center to center, and the intermediate ties 39.2 inches.

Mr. Edmond Colin, engineer of the First Division (Premier Arrondissement), sent me in July, 1888, a detailed report of experiments made under his charge on this division, with three types of metal ties. The trials were made on the line from Paris to Bordeaux (section between Chartres and Bron), on a single track. These ties had, however, been in service too short a time to enable their durability to be determined, but no breakages had been observed since the ties were laid. They were all of mild steel, and were manufactured by the Société de Denain et d'Anzin. They were spaced 24 inches apart, center to center at the joints, and 39.2 inches intermediate. The ballast used is very fine sand or gravel, mixed with 40 per cent. of broken flint; it is brought up level with the top of the ties, and is about 14 inches deep under the rail seats, where it is packed into the tie. The ballasting has to be done with great care, and requires at first more continuous care with metal ties; but it holds in them better, and after the first year the maintenance requires considerably less time. The track on metal ties keeps in better line and surface and is more solid than track on wooden ties. The oak ties used cost 92.2 cents each, and 5.6 cents more if treated with chloride of zinc; their average life is twelve years. The climate of the region is temperate, but the wooden ties are affected by the various conditions of the ballast, according to the seasons; while moist in the spring and autumn, it dries completely in the summer; the fastenings then work loose and the tie has a tendency to split. With the metal ties the atmospheric influences give no cause for apprehension, and it has been observed that these ties do not rust more than the rails. The traffic consists of fourteen passenger trains (the speed of express trains being 37 to 50 miles an hour) and eight freight-trains (carrying merchandise, grain, wine, and cattle) in twenty-four hours. The locomotives are of three classes: (1) with two axles coupled, weighing 36 tons; (2) with three axles coupled, weighing 33 to 37 tons; (3) with four axles coupled, weighing 53.3 tons; the load per axle is from 11 to 14 tons. Following are the details of Mr. Colin's report:

(*D*) *Modified form of Vautherin type of tie, with uniform section and thickness throughout* (See paragraph B).—These ties were laid between November, 1886, and February, 1887, for a length of 4.4 miles; 1.25 miles was on the level and the remainder on grades of .13 to 1.15 per cent.; about 3 miles were on tangents, and the remainder on curves of 1,640 to 9,840 feet radius. The section is uniform for the whole length, and is that of a Vautherin tie of which the upper table is widened, and the sides have a rib along the bottom edge instead of a horizontal flange. The tie is horizontal, quite flat, 8.2 feet long, 4.8 inches wide on top, 9.2 inches wide inside at the bottom, and 3.2 inches deep; the sides flare outward from the top and then turn down vertically; the thickness varies from .28 inch and .32 inch at the sides to .40 inch on top. The weight is 129 pounds. The ends are bent down vertically to close the ends of the trough. A few of the ties were coated with coal tar at the works; the others were not given any preparation. The cost was $30 per ton at the market rates of 1886 and $28 per ton at those of 1888. The maintenance expense during the first year was nearly equal to that of track with wooden ties, but it tended to diminish sensibly after the first year. No special arrangements are made on curves. The rails are of double-headed section, 36.08 feet long, weighing 76.5 pounds per yard. They are carried in cast-iron chairs, which are similar to those used on wooden ties, but have a lug on the under side which fits into a slot in the top table of the tie. Each chair is fastened by two T-headed bolts, and the rails are secured in the chairs by wooden keys. The rails are laid to break joint, the joints are suspended, and are spliced by fish-plates and four bolts. The results obtained have been satisfactory, the track keeping in good line and surface. The passage of trains is as smooth as on a track laid with wooden ties; at first it was a little harder, but there is now no difference. The maintenance presents no difficulty, and there is only one special precaution to be taken for lining of the track. To shift the track in lining up it is necessary, owing to the closing of the ends of the tie, to open up the ballast to the outside of the end of the tie on the side towards which it is to be brought back, and to open up the ballast in the interior of the tie from the opposite end; unless this is done the track will shift back to its original position on the passage of the first train. The rail fastenings give no trouble. During the first few months there were some chairs broken, which was attributed to insufficient packing of the ties. Only one tie had been found broken; it was broken transversely under the chair, and the break appeared to be due to a defect in the manufacture. The replacing of this tie was done without any difficulty by removing the ballast, sliding the new tie in under the rails, and then attaching the chairs. The ties behave well, and the only improvement suggested was the strengthening of the rail chairs. The opinion given was that this type of tie is quite satisfactory and gives perfect safety.

(*E*) *Modified form of Vautherin type of tie, with varying section* (See paragraph C).—These ties were laid in February and March, 1887, for a length of 4.46 miles; 1.24 miles were on the level, and the remainder on grades of .12 to .7 per cent.; 3.53 miles were on tangents, and the remainder on curves of 4,920 feet to 8,200 feet radius. The general form is similar to that described above (paragraph D), but the section varies at different parts of the length, and the top table has an extra thickness of metal at the rail seats. The tie is bent to give the rails an inward inclination of 1 in 20, and the ends are closed. The length is 8.52 feet; width of top table, 6 inches; weight, 124.3 pounds. Some are tarred at the works, the others are used without treatment. The price was $34 per ton at the market rates of 1886. The experience as to cost of maintenance has been the same as noted for the preceding type (paragraph D). No special arrangements are made on curves. The rails are of flange section, 36.08 feet long, weighing 76.5 pounds per yard. They are placed directly on the ties. Some are fastened to the ties by gib and cotter fastening, a vertical cotter being used; the others are fastened by bolted clamps. There are two clamps to each rail; they are of ┏ shape; the horizontal part bears on the flange of the rail and the vertical part rests on the tie and has a projection which fits into a hole in the top table of the tie; a tee-headed bolt passes up through the tie and clamp and is secured by a nut on top. The track was first laid with even joints, but was then being changed to break-joint, that system being preferred; the joints are suspended and are spliced by fish-plates and four bolts. The remarks as to results and maintenance are the same as for the preceding type described (paragraph D), except that the passage of trains was still a little less smooth than on track with wooden ties. The rail attachments gave no trouble and there had been no breakage. Experience up to that date had shown that the gib and cotter fastenings were better than those with clamps. The opinion given was that this type made a very solid track and one very easy for maintenance.

(*F*) *Boyenval and Ponsard tie* (See plate No. 6).—Ties of this type were laid in April, 1888, for a length of 298.48 feet on a tangent of a grade of 0.25 per cent. They are of uniform section throughout, and the cross-section is that of three troughs, the middle one open at the top and the two outer ones open at the bottom. The ties are horizontal, 8.2 feet long, 8 inches wide on top, 10.2 inches wide at the bottom, and 2.8 inches deep; the width of the top is made up of two bearing surfaces 2.4 inches wide and a channel 3.2 inches wide; the bottom width is made up of two channels 3 inches wide, a middle bearing 2.8 inches wide, and two flanges .7 inch wide. The thickness of top and bottom is .32 inch, and of the sides .20 inch. The weight is 129.8 pounds. They were all tarred at the works, and the price was $2.48 each. The ends of the two outer channels are closed by riveted angle-pieces. The rails are of double-headed section, 36.08 feet long, weighing 76.5 pounds per yard; they are carried in cast-iron chairs a little stronger than those used with wooden ties, and having a lug on the bottom which fits into a hole in the tie. Each chair is fastened to the tie by four bolts. No special arrangement would be used for curves. The rails are laid to break-joint; the joints are suspended and are spliced by fish-plates and four bolts. The results obtained had so far been satisfactory, and the passage of trains was as smooth as on a track with wooden ties. There had been no breakages, no trouble with the fastenings, and no difficulty with maintenance, while the lining up was easily effected; the maintenance would not differ much from that with other metal ties. The experience with this type of tie had been too short to allow of any definite opinion being given. It may be noted, however, that the shape is difficult to roll, and the tie can not be considered as easy to manufacture.

The double-headed rails used with metal ties are of "hour-glass" section; 5.4 inches high, with heads 2.64 inches wide and web .72 inch thick at the middle; the radius of the top table is 3.6 inches for a width of 1.6 inches; the radius of the top corners is .38 inch, followed by an inward curve of .88 inch radius. The flange rails are 5.2 inches high, 5.2 inches wide over the flange, and 2.4 inches wide in the head; the head has a top radius of 8 inches, top corners of .32 inch radius, vertical sides, and .24 inch bottom radius. The clamps for flange rails are 2.56 by 2.24 inches over all for the outer flange, and 2.56 by 1.86 inches for the inner flange; the thickness is .52 inch, and the total depth 1.24 inches. The bolt holes are .84 inch square; the nut washers are 1.28 inches diameter, with a hole .84 inch in diameter, and a thickness of .10 inch. The gib and cotter fastening consists of one gib on the outer side, and on the inner side two gibs with a vertical cotter between them; the cotter is 6 inches long, .8 inch thick, 1.08 inches wide at the top, and .76 inch wide at the bottom. The outer holes in the tie are 1.56 inch long, and the inner ones 2.5 inches long; they are 4.56 inches apart in the clear, and .88 inch wide. The chairs on the Vautherin ties have a base of 13 by 4.48 inches, the longer dimensions being length-wise of the ties; the jaws are 4.84 inches wide; the bolts are .76 inch diameter. The chairs for the Boyenval and Ponsard ties have a base of 8 by 11 inches.

Mr. A. Delaunay, engineer of the Saintes division (Arrondissement de Saintes), stated in June, 1888, in regard to the metal ties used on the section from Niort to La Rochelle (See paragraph B), that the trials were made on a length of 3.1 miles; the line was on a tangent and one curve of 3,280 feet radius, and had grades not exceeding .5 per cent. (5 millimeters per meter). The track consisted of steel rails of double-headed symmetrical section, 18.04 feet long, carried on six cross-ties and resting in chairs weighing 21 pounds each. The ballast, which was then being renewed, is of calcareous gravel, very clean and of coarse size, and exceptionally of broken stone screened. For the trials, Vautherin ties of uniform section were employed, weighing 130.24 pounds each, and laid six to a rail length. Special chairs are used, weighing 22.33 pounds, and having a lug on the bottom which fits into a hole in the tie. The bolts attaching the chairs to the ties do not work loose after the first tightening has been made. In laying the ties the rails and joints were not disturbed. For the six months they had been in service the ties had given good results in gravel and broken stone ballast, and made a very stable track, the riding on which was as easy as over a track laid with wooden ties. The packing had to be renewed rather frequently at first. This maintenance work caused an extra expense for labor of about two men per month, who have been added to the gang of five men, whose section of 4.96 miles includes five renewals of metal ties. The first ballasting holds better in sand or gravel than in broken stone. While the trial was too recent to enable him to pronounce on the results obtained, he considered it probable that six months later they would be able without difficulty to reduce the section gang to four men. The traffic consisted of five passenger trains in each direction per day, composed of 50 to 70 cars, and hauled by engines with four coupled axles, weighing 53 tons.

Writing again in December, 1888, Mr. Delaunay stated that his opinion, in common with that of most engineers in France, was that the double-headed or bull-headed rail was the only form suitable with wooden ties for lines with heavy and fast traffic; but he believed, nevertheless, that the flange rail on steel ties would possess all the superiority and advantages claimed by its advocates over those of the double-headed rails. The latter have, however, been used on metal ties on the State Railways only because there was a large stock of these rails which it was necessary to use. Trials with flange rails on metal ties have been made on other divisions with excellent results. He considered that the cause of the metal tie had definitely gained its success, and that its advantages could only be contested by companies whose financial conditions do not permit them to pay at once the existing difference of cost between wooden and metal ties.

The following information was presented by Mr. Kowalski at the International Railway Congress held at Milan, Italy, in 1887:

Metal cross-ties were used in regular service for about 16.43 miles; there were 2.48 miles laid with ties of the Paulet type, 4.65 miles with a modification of the Vautherin type of tie, using cast-iron chairs, and 9.30 miles with the "Post" tie. The first weighed about 220 pounds each, and the others about 125.4 pounds. They were all of mild steel, but it was intended to try 5,000 cross-ties of hard steel. As the laying of these ties had only been commenced in December, 1886, no precise information as to the results could then be given.

In August, 1889, the engineer-in-chief stated that since March, 1888, metal ties had been laid for a length of about 13.18 miles, 11.68 miles on the line from Tours to Sables d'Olonne, between St. Mesury and Bressuire, and 1.50 miles near the station at Chartres. There had also been 70,000 ties ordered. The total length of the lines of this system was then 1,609.5 miles, and the length actually laid with metal ties about 31.62 miles.

PARIS, LYONS AND MEDITERRANEAN RAILWAY.—Iron ties were laid on this line during 1862 and following years, but by 1872 they had all been taken out. The engineer stated in February, 1888, that these ties were more expensive than wooden ties, and were taken out because, on account of the constant traffic, they made a less firm track and lasted a shorter time. The ties were 7.34 feet long, 5.6 inches wide on top, 8.4 inches wide on the bottom, and 2.4 inches deep; the thickness was .20 inch to .28 inch on the sides, and .32 inch on top, with a middle portion .52 inch thick for a width of 1.44 inches, this being given by extra metal on the under side of the top table. A gib and cotter fastening was used, and not being well adapted for this purpose was very likely the cause of the track being less firm than on wooden ties. On the Algerian lines owned by this company, however, 100,000 ties were laid in 1870 and gave good results; in February, 1888, 60,000 more iron ties were being laid. The conditions on these lines, however, are not the same as those obtaining in France; the burning climate causes the very rapid destruction of wooden ties, while the metal ties, much less injured by the passage of a very few trains, act sufficiently well in service, and enable a certain economy to be realized over the wooden ties on account of their longer life. (See "Algeria").

Vautherin ties were first used in 1864, on the line from Besançon to Lons-le-Saulnier, then in course of construction; 600 ties were used, which were manufactured by the Fraisant Works of the Iron Works Society of Franche Comté.

The present ordinary track is laid with rails 32.8 feet long, placed on twelve wooden ties in main track, or eleven ties at stations, and on branches where the speed is only about 31 miles per hour. In main track they are spaced 24 inches, center to center, at the joints, 28 and 34 inches next to the joints, and 36 inches intermediate; for branches they are spaced 24 inches at joints, 30 inches next to the joints, and 3 feet 3⅜ inches intermediate; for sections with very heavy traffic 13 ties are used, spaced 32 inches center to center. Iron tie-plates, fastened by screws which hold the rails, are used on the ties next to the joint, and the outer angle-bar of each joint has a flange sufficiently wide to allow of the screw passing through it. To prevent creeping, some of the iron tie-plates have one side bent up to fit the rail-flange and web; these plates are screwed to the tie and bolted to the web of the rail.

EASTERN RAILWAY.—In February, 1888, the director of construction reported that up to that time they had made only very limited trials with ties of several forms, and had not been able to draw favorable conclusions for the adoption of any one of these forms in preference to ties of hard wood (oak or beech), simply injected with dead oil of coal-tar (creosote). These wooden ties thus prepared gave results which did not admit of doubt as to their superiority in first cost, in maintenance expenses, and in renewals. The trials with metal ties were, however, being continued, more with a view to the requirements of a probably distant future than to any present interest. The company estimates that the life of its creosoted oak ties is about twenty-five years, and that, therefore, the present introduction of metal ties is not necessary. The road is of standard gauge.

One of the most interesting forms of metal ties tried on this road is a tie designed by Mr. Guillaume, the engineer of permanent way, which has been laid for a length of about 13 miles (See plate No. 7). It is of trough or channel section placed in normal position, that is, with the open part upwards. It is 8.46 feet long, 10 inches wide and 3.2 inches deep; the thickness at the bottom is 0.36 inch. The ends are bent down 3.28 inches below the level of the bottom, in order to offer resistance to lateral motion of the tie in the ballast. The weight of the tie is 171.6 pounds, or about 190 pounds including the fastenings. Each rail rests on two blocks of elm, creosoted and compressed; these blocks are 8.8 inches long, 3.12 inches square under the rail, and have the top inclined to give the rail an inward inclination of 1 in 20; they are thick enough to carry the rail clear of the sides of the tie. The elm blocks are made in England, and give much better results than blocks of oak, not compressed, which have also been tried; they have not allowed any slack or play, and have not been seriously depressed or cut under the flange of the rail. The absence of metal contact between the rail and the the sides of the tie is claimed as an advantage; this might be true with such a form of tie, which would give only two narrow bearing surfaces, but it has been conclusively shown with other forms of ties that the metal contact, where there is a wide bearing surface, need not be objectionable if proper fastenings are used. The rail is fastened by two flat steel plates, cast and annealed, placed between the wooden blocks and sides of the channel; each plate has a hooked lug on the upper part of one end to hold the rail flange, and has also a stud on the side fitting into a hole in the side of the channel; the plates weigh about 4.07 pounds each, or 16.28 pounds for the set. They can be placed or removed separately, after driving out the wooden blocks, without disturbing the rails, thus rendering renewals easy; it would seem, however, as though the fixing of the plates and the driving of the wooden blocks back in place in case of renewals or repairs, would disturb the track and make a good deal of work necessary to adjust it to proper line and surface and give it proper stability in the ballast. The depth from the head of the rail to the bottom of the tie is 8.76 inches. Mr. Bricka reported adversely to this form of tie, on account of the cutting away of the flanges or sides of the channel at the rail-seats, and he was of opinion that experience had shown that wooden bearing blocks were neither necessary nor desirable with metal ties. There are sixteen ties to a rail length of 39.36 feet, spaced 24 inches center to center at joints and 30 inches intermediate, with the fourth and fifth ties from the end of each rail spaced 31.2 inches center to center. The ballast between the rails is level with the middle of the web of the rail, and on the outer side of the track it is level with the middle of the head of the rail. The engineer stated in April, 1888, that the provisional trials were satisfactory, but that they were restricted to making them on a very limited scale, the superiority of properly creosoted wooden ties over all forms of metal ties being established in the minds of engineers. The rails are of flange section, weighing 74.4 pounds per yard; they are 39.36 feet long, laid to break joint. The joints are suspended and are spliced by a pair of fish-plates with four bolts; the inner plates are of deep section, having a vertical web projecting below the flange.

In 1886 one hundred ties of the Post type had been laid.

The following particulars were presented by Mr. Kowalski at the International Railway Congress, held at Milan, Italy, in 1887:

There were placed, about 1865, 2,200 iron cross-ties, 100 being of the Vautherin type and the rest of a type designed by the company's engineers as a modification. About 1886 there were laid 100 ties of the Post type and 100 ties of a type designed by the engineer. The Vautherin ties weighed 88 pounds, the company's old and new types 109 pounds and 141.15 pounds, respectively, and the Post ties 169.61 pounds. The two latter types were each laid with 50 ties on a tangent and 50 ties on a curve of 3,608 feet radius, with a grade of 0.3 per cent. in the direction of the traffic. The traffic in 1886 consisted of 21,682 trains, of which 12,031 were passenger trains, and 9,651 were freight trains; the average speed of passenger trains is 40.3 miles per hour. The heaviest locomotives, with four axles, weighed 56 tons. The tonnage hauled in 1886 amounted to 4,616,000 tons. The rails were of steel, weighing 60.36 pounds per yard. The ballast was of a sandy nature, fairly good. The Vautherin ties were taken out in about six years; most of them were cracked. The company's old type of ties lasted better, but the work of ballasting was 45 per cent. greater than with wooden ties, and they were all taken out on account of the wear of the fastenings. The other types appeared to give better results, but the experience was then too short to enable any opinions to be expressed. The passage of trains over these ties was very smooth, and similar to that over wooden ties.

WESTERN RAILWAY.—The metal ties, of which I received particulars in March, 1888, were invented and manufactured by Mr. Chappee, at Mans, and were laid, in May, 1887, for a length of about 656 feet on the line from Paris to Havre, under the supervision of Mr. Banchal. They are on curves of 4,920 feet radius and a grade of 0.5 per cent. The tie consists of a wrought-iron inverted channel iron, upon which the rail-chairs are cast in place. (See plate No. 7.) The channel iron is 8.2 feet long, 8 inches wide, and 2.8 inches deep; the thickness of the top table is 0.36 inch. The upper part of the cast-iron chairs is of the u-ual form for a double-headed rail, but there is a wing of ˥-shape on each side, which fits over the side of the tie. These wings are 4 inches wide, 4 inches thick at the side of the tie, and 3.6 inches deep below the top of the tie. They thus embrace the flanges of the channel and project 2 inches inside and outside of them; while at the middle, under the rail, they completely fill the space inside the channel. The width of the lower part of the chairs, over the wings, is 12 inches, and the rails have a bearing for that distance, which is double the bearing given by an ordinary chair. In each side of the tie are two holes 0.8 inch diameter, one to each chair, through which the metal can flow and so securely fasten the chair in its place. Both chairs are cast at the same time. The weight, including chairs, is about 297 pounds. The cost is about $3 per tie, the channel-iron itself costing $2. The time of the trial—one year—was then too short to permit of the maintenance expenses or the probable life being determined. The ties are not painted or otherwise protected against rust, and no special arrangements are made for curves. The rails are of steel, of double-headed section, and weigh 78 pounds per yard. They are secured in the chairs by wooden keys. The joints are suspended and are spliced by a pair of fish-plates and four 1-inch bolts. One of each pair of plates has a vertical web projecting below the rail. The ballast is of quarry chips, about 12 inches deep under the ties. The road-bed at subgrade is horizontal. The ties are spaced as follows: For a rail 19.668 feet long, 24 inches, center to center, at joints, 28 inches next to the joints, and 32 inches intermediate; for a rail 26.24 feet long, 24 inches at joints, 29.08 inches next to the joints, and 34 inches intermediate, except the middle ties, 34.04 inches. The climate is temperate, its hygrometric condition average, and it exercises no particularly destructive influence on the ties. In March, 1888, the director of works stated that there are found in France, in quantity more than sufficient to meet the demand, excellent species of wood for ties, which are delivered in the form of ties at advantageous prices and which would always be given the preference over metal ties. Under these conditions, and without being indifferent to the investigations which have been made in various places in regard to the substitution of metal for wood for service as ties, this company had only made very limited trials of metal ties. In sending particulars of the tie above described, it was stated that the experiments were too recent to enable any reliable conclusions to be drawn as to the advantages or disadvantages, or any opinions to be formed based on the experience acquired. These trials are not of any immediate interest to the company, as the railway is largely, and under advantageous conditions, supplied with ties of oak or beech of good quality, which when creosoted cost about $1 each and last about twenty-five years.

In a short article in the Revue Générale des Chemins de Fer, March, 1889, Mr. Clerc, the director of works, stated that after having made trials, lasting during two years, of the metal ties already described, on parts of the line under the heaviest traffic, the company had ordered 5,000 more of the same type, with some modifications suggested by experience, in order to carry on the experiments on a large scale. This additional step is interesting, when the statements made by Mr. Clerc in March, 1888, are considered, as the metal ties seem to have been looked upon with favor in spite of the plentiful supply of wood. (Mr. Chappee also proposes to make the tie with the channel-iron placed with its open side upward.)

The company exhibited specimens of its track at the Paris Exposition of 1889, and the following tables of weights are taken from Engineering, August 9, 1889.

*Table of metal track. (Weight per yard=527 pounds).*

| Material for 39 feet 4 inches of track. | Unit weights. | Separate weights. | | |
|---|---|---|---|---|
| | | Steel. | Cast-iron. | Wrought iron. |
| | *Pounds.* | *Pounds.* | *Pounds.* | *Pounds.* |
| 2 rails, 39 feet 4 inches long, 88.7 pounds per yard | 1,164 | 2,328 | ...... | ......... |
| 2 pair of fish-plates | $37\frac{1}{2}$ | 75 | ...... | ......... |
| 8 fish-bolts, 1 inch diameter | $1\frac{1}{2}$ | .... | ...... | 12 |
| 18 metal ties (132 pounds of steel, 110 pounds of cast-iron) | 242 | 2,380 | 1,984 | ......... |
| 36 keys, David system | $2\frac{1}{4}$ | 80 | ...... | ......... |
| Total | | 4,863 | 1,984 | 12 |

*Table of ordinary track. (Weight per yard=388 pounds).*

| Material for 26 feet of track. | Unit weights. | Separate weights. | | | |
|---|---|---|---|---|---|
| | | Steel. | Cast-iron. | Wrought iron. | Wood. |
| | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* | *Lbs.* |
| 2 rails, 60 pounds per yard | 529 | 1,058 | ....... | ........ | ....... |
| 4 fish-plates | $34\frac{1}{2}$ | 69 | ....... | ........ | ....... |
| 16 tie-plates | 33 | ....... | 528 | ........ | ....... |
| 8 fish-bolts, seven-eighths inch diameter | 1 | ....... | ....... | 8 | ....... |
| 12 screws, seven-eighths inch diameter and $4\frac{1}{2}$ inches long | $\frac{3}{4}$ | ....... | ....... | 9 | ....... |
| 48 screws, seven-eighths inch diameter and $5\frac{1}{2}$ inches long | 0.8 | ....... | ....... | 38 | ....... |
| 10 ties | 165 | ....... | ....... | ........ | 1,650 |
| 16 keys | $2\frac{1}{5}$ | 35 | ....... | ........ | ....... |
| Total | ........ | 1,162 | 528 | 55 | 1,650 |

In 1875 the company adopted a steel flange rail, weighing only 60 pounds per yard, to reduce the expense; since then the track on grades and sharp curves has been strengthened by the use of angle-bars on the inner side of the joints, ten ties per rail-length instead of nine, and iron tie-plates on each tie except those at the joints. The angle-bars are fastened to the ties by coach screws, to prevent creeping of the track. The wooden ties are creosoted with dead oil of coal-tar, at the company's works. At first the Bethell process was used, requiring 35 to 40 pounds of creosote for beech ties. Since 1876 the ties are first steamed under a pressure of five atmospheres, reducing the amount of creosote to 26 or 28 pounds and giving it a better distribution among the fibers. The oak ties are said to require 8 to 11 pounds of creosote.

NORTHERN RAILWAY.—In February, 1888, Mr. Contannin, engineer of permanent way, stated that this road had laid on its Belgian lines 1,700 ties of the Séverac type during eighteen months, and was then about to place 10,000 of these ties on its French lines. In order to establish a comparison, allowing for the great difference between the first cost of wooden ties and that of metal ties, it was hoped that a sensible economy would be realized in the maintenance expenses, but the experience was then too short to enable an opinion to be pronounced. (See Belgium.)

At the International Railway Congress held at Milan, Italy, in 1887, Mr. Kowalski stated that 1,500 ties of the Séverac type had been in use on this company's Belgian lines for about two years, and had given good results. (See "Belgium.")

SOUTHERN RAILWAY.—In September, 1889, this company reported that no metal ties have been used, even for experiment.

PARIS AND ORLEANS RAILWAY.—This company reported in March, 1888, that no trials had been made with metal ties, as the forests in the neighborhood of the railway enable the company to count upon sufficient resources for a long time to come. The woods used are oak and pine. The average price of the oak ties is 90 cents each, and their average life is fifteen to sixteen years. The pine ties, which are being abandoned, cost 66.4 cents each creosoted, and 61.4 cents treated with sulphate (presumably of copper, but not stated); the average life of the latter is ten years; the creosoted ties are of too recent date for conclusions to be drawn as to their life.

## TIES.

*Paulet and Lavalette ties.*—These ties have been described under the heading of the State railways, on which lines they are used with double-headed rails. They are also made for flange rails, the only difference being in the form of the chair, which has a flat-top with two lugs, a key being driven between one lug and the rail-flange. The chairs are secured by three rivets. The ends of the angle-irons may be straight instead of flared out. The weight of ties for standard gauge tracks is 165 pounds, with chairs for double-headed rails, and 154 pounds with chairs for flange-rails. The ties are also made for meter gauge lines, and may be made of tee-irons instead of angle-irons if necessary (See plate No. 5).

*The Brunon ties.*—These ties are of pressed steel, and were invented by Mr. Barthol-emy Brunon, but have, I believe, not been put in service. They are of ∩ section, narrow and deep at the middle and broad and shallow at the ends, the sides sloping up to the top table. The thickness is .32-inch throughout, and the weight about 77 pounds per tie. The rail seats are pressed up and holes are made in the sides of the elevated seat for the ends of a bent bolt which lies within the tie. For flange-rails clips are used which hold the flanges and are fastened by the bolt. For double-headed rails the same plan is adopted but the clips are larger, one bearing against the web and lower head of the rail, and the other embracing the side of the lower head. At the joints angle-bars are used having an extension of the flange bent to fit the curve of the rail-seat, the bolts passing through these flanges in the same way as through the ordinary clips. The ordinary joint bolts are used.

*The Decauville ties.*—These ties are used for the well-known system of Decauville's portable railways, which are for narrow-gauge plantation lines, contractor's lines, light railways, etc. They are of inverted channel irons, with the flanges bent round to close the ends. The rails are usually riveted to the ties. A line of 24 inches gauge was built on this system through the grounds of the Paris Exposition of 1889; the ties were about 3 feet 7⅝ inches long, 5.6 inches wide, 1.16 inches deep, and .20-inch thick; they were spaced 10.4 inches apart, center to center, at the joints, and 25.56 inches intermediate. The rails were of flanged section, 2.4 inches high and 2.5 inches wide; each rail was fastened to the tie by three rivets, two through the inner flange and one through the outer flange. The sections of track were 16.40 feet long, with fish-plates at the rail joints. This track could carry a service load of 3 tons per axle, and a 48-ton gun was hauled over it by using four trucks with four axles each, the trucks being coupled in pairs. The line was used for passenger and freight traffic, and was operated by compound, four-cylinder, double-truck engines, weighing 11.3 tons in working order. The tramway at Laon is laid with a similar track and operated by similar engines. This line has grades of 6 per cent., with curves of 88.56 feet radius. For particulars of these two lines see Engineering News, New York, September 1, 1888, and June 1, 1889. The system is also referred to in the part of this report referring to "Light and Portable Railways."

*The Goupillon ties.*—These are a modification of the Vautherin type of tie, and resemble the "Post" tie; but there is claimed to be less work done on the metal than with the "Post" tie, which is bent to give the inclination to the rail. The fastenings are entirely different in character. The ties are horizontal, but at the rails the metal is thickened, and so shaped as to form a rail seat giving the desired inclination, and having a depression to receive the flange of the rail. They are 8.85 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, 4 inches deep over all; the sides are vertical for 2.6 inches from the bottom. The thickness of the sides increases from .24 inch at the bottom to .28 inch at the top; the top table is .36 inch thick, but extra metal is added on the under side, making it .52 inch thick for a width of about 2 inches. The thickness under the rail is .76 inch. The rails are fastened by screws of different forms, the heads being wide and holding the rail-flange. They may be (1)—only long enough to screw through the thickness of the metal of the tie; or (2)—long enough to screw also through a thick iron washer inside the tie, which takes both the screws; or (3)—the ordinary long screw spikes used in European railway practice may be used, screwing into wooden blocks placed inside the tie, one under each rail. The ends of the ties are closed. For rails of 56 to 60 pounds per yard, the ties would weigh between 132 and 154 pounds each. These ties have not, I believe, been put in service.

*The La Gressiere ties.*—These are cross-ties of deep inverted channel section with vertical sides and a rib on each bottom edge. Along the whole length of the top table is a deep groove. A tie-plate the full width of the tie is riveted at each rail seat. The rail is fastened by broad clamps or flat spikes, which pass through slots in the tie-plate, and project down into the groove in the tie. A long taper key or cotter is driven horizontally through a slot in the lower part of each rail clamp, holding them tightly in place. The ties weigh 66 pounds for meter gauge lines, and 121 to 132 pounds for standard gauge. They are said to have been tried on the Eastern Railway, but no information respecting them has been furnished by that road.

SUMMARY OF METAL TRACK FOR FRANCE.

| Railways. | Cross-ties. |
|---|---|
| | *Miles.* |
| State | 31.62 |
| Eastern | 13.00 |
| Western | 2.50 |
| Northern | 5.00 |
| Total | 52.12 |

## HOLLAND.

GENERAL REMARKS.—Mr. Post, in his paper presented before the Society of Civil Engineers, France, in 1885, stated that Holland was a country not possessing any metal tie producing industry, but able to obtain plenty of cheap native and foreign timber, the latter being imported, at a low rate, by sea, river, canal, and rail. Nevertheless, nearly all the railways have been using metal ties for some years, not on account of pressure from the government, but because they are persuaded that it is to their own interest.

In Mr. Bricka's report to the Minister of Public Works of France, in 1885, is given the following table of mileages:

*Table of mileage of railway track. Holland*, 1878–1884.

| Year. | Main lines. | Local lines. | Total track. | Wooden ties. | Metal longitudinals. | Metal cross ties. | Stone, etc. |
|---|---|---|---|---|---|---|---|
| 1878 | 1027.34 | ...... | 1764.52 | 1653.54 | .62 | 49.60 | ...... |
| 1879 | 1034.78 | ...... | 1624.40 | 1538.84 | 10.54 | 75.02 | ...... |
| 1880 | 1068.26 | .... | 1718.64 | 1589.68 | 10.54 | 118.42 | ...... |
| 1881 | 1096.66 | 3.10 | 1778.78 | 1627.50 | 10.54 | 140.74 | ...... |
| 1882 | 1126.54 | 4.34 | 1922.62 | 1750.88 | 10.54 | 161.20 | ...... |
| 1883 | 1235.66 | 4.34 | 2066.46 | 1876.12 | 10.54 | 179.80 | ...... |
| 1884 | 1279.06 | 39.68 | 2204.16 | 1988.34 | 7.44 | 203.98 | 4.34 |

NETHERLANDS STATE RAILWAYS.—The Netherlands State Railway Company, which operates the system of railways owned by the State, has had a thoroughly intelligent, careful, and practical investigation made as to the merits and advantages of different forms of ties. The company was singularly far-seeing, and when the engineer began the work he began with a careful system of records as to the track and the results obtained. Mr. Post, the engineer of permanent way, during the earlier experiments designed and adapted a special form of tie which, after some modifications shown by experience to be desirable, has been adopted as the standard form of metal tie on this railway system, and is also extensively used in other countries. This is the cross-tie of mild steel, of varying thickness and cross-section, which is now so well known as the "Post" tie.

In 1865 the company put down on the Deventer and Zwolle line 10,000 ties of the Cosijns type. (See plate No. 8.) Each tie consisted of an ordinary I beam, laid with the web horizontal (⊢⊣); under each rail was an oak block with a groove cut in it for the rail flange; the rail was fastened by two bolts. The ties were 8.85 feet long, 8 inches wide, and weighed 124.74 pounds each. The results on the whole were satisfactory. The cost of packing had not been much higher than with wooden ties, and the renewals of the wooden blocks had not cost more than those of wooden ties. Experience showed, however, that the fastenings were defective, the bolts being too long and permitting a transverse sliding of the blocks with the rails on the tie. For this reason it was found better to attach the rails directly to the metal ties. In 1880 the company again took up actively the question of metal track, and at that time Mr. Post was directed to investigate the results of trials made by other companies. Acting upon his report the company decided to select the type of tie which seemed the best adapted for the purpose, to place it in the track, and to observe it carefully; also, to lay a section of track on wooden ties, in continuation of the track on metal ties, and under the same condition of line and traffic. It was further resolved that the following year a second type of metal ties should be selected, profiting by the experience of other countries, and endeavoring to avoid any defects observed in the first type, in order to be able to form opinions as to the comparative merits of the different types. In 1886 the company had, besides the types of composite (iron and wood) ties of Cosijns and Renson, six types of metal ties and three types of fastenings. While continually improving the ties, it was decided in 1884 to adopt the latest types, as improved by Mr. Post. This track consisted of steel cross-ties of varying section, weighing 110 to 121 pounds, with bolts 0.88 inch diameter, having eccentric necks, steel clamps for the rails, and plain Verona nut locks.

The trials were all made on the Liege and Luxembourg line. The several types of ties were as follows: (See plate No. 8.)

(0) Oak ties of half-round section, 8.53 feet long, 4 inches wide on top, 11 2 inches on the bottom, 5 inches deep. There were 1,120 laid in 1881.

(I) Rolled iron ties of inverted trough section ("Vautherin" type), weighing 88 pounds each; 7.71 feet long, 9.4 inches wide at bottom; they were bent up at the end at an inclination of 1 in 20, and the extremities were closed. In 1881 there were 4,133 of these laid.

(II) Rolled iron ties of similar section, weighing 104 pounds each; 8.20 feet long, 8.8 inches wide at bottom over the flanges; the ends were inclined at the rail seats and then curved down; the extremities were closed by angle-irons and two pieces of angle-iron were riveted inside at the middle 20 inches apart. In 1882 4,001 of these were laid.

(III) Mild steel ties of inverted channel section, with wide horizontal flanges at the bottom (Haarmann type); they were of the form used on the Prussian State railways and weighed 110 pounds each; 8.20 feet long, 10 inches wide over the flanges, and of similar longitudinal section to No. 2. In 1883 2,089 of these were laid.

(IV) Mild steel ties similar to No. 3, also as used on the Prussian State railways, but weighing 114.4 pounds each. At the middle, and placed 16 inches apart, were two riveted pieces of Z-iron. In 1883 2,090 of these were laid.

(V) Mild steel ties of inverted trough section ("Vautherin" type), 8.53 feet long, 8.8 inches wide at the bottom, weighing 95.5 pounds. The tie was horizontal, but at the rail seats for a distance of 10 inches the metal was pressed up cold to the desired inclination and at the end of the rail seat the metal sloped back to the normal level of the tie (Hoesch-Lichthammer method). In 1884 11,680 of these were laid.

(VI) Mild steel ties of inverted trough section, but of polygonal instead of pyramidal section ("Post" type). They were rolled with varying section and thickness and an inclination of the rail seats. The bottom was horizontal, with the closed ends projecting below it. They were 8.36 feet to 8.7 feet long, 9 inches wide at the bottom, 3.3 inches deep; 110 pounds weight, or 121 pounds for curves, grades, etc. The price in May, 1886, was $21.2 per 2,200 pounds at the works. All the ties, whether for tangents or curves, had the four holes drilled in identically the same places. In 1884 and 1885 47,338 of these ties were laid, and 50,000 in 1886.

The fastenings were as follows: (See plate No. 8.)

(A) Iron bolts, .76 inch diameter, with eccentric necks, giving .08 inch to .56 inch adjustment of gauge. Iron clamps and Verona nut locks were used. These were used in 1881, 1883, and 1884 for types of ties I, III, IV, and V.

(B) Steel bolts of Ibbotson's type, having ⊥-heads. A square washer received the thrust of the rail flange and gave an adjustment of gauge of .08 inch to .64 inch; the rail clamp was of channel shape, one leg resting on the rail flange, and the other on the tie, outside of the gauge plate. This is the Roth and Schuler system and was used in 1882 for ties of type No. II.

(C) Steel bolts .88 inch diameter, with eccentric necks, giving an adjustment of gauge of .32 inch to .64 inch. The steel rail clamps had the upper surface roughened to give a grip to the Verona nut lock. A few bolts of special dimensions were used at the extremities of curves. These were laid in 1884, 1885, and 1886 with ties of type No. VI.

During 1886 and 1887 three more types of ties were designed by Mr. Post, as follows: (See plate No. 8.)

(VII) This type was in general similar to No. VI but was narrower and deeper at the middle than at the ends, the bottom swelling downward and the sides at the middle flaring inward so that the bottom edges nearly met. It is more easily laid in the ballast, but is more difficult to manufacture.

(VIII) This is similar to No. VII, but at the narrow part the sides flare outward in ∧-shape; bottom width 9.4 inches at ends and 5.4 inches at the middle. Types VIII and IX are easy to manufacture. The object of narrowing the tie at the middle is to throw the principal bearing at the rail seat to insure the stability of the track; it also increases the rigidity of the tie.

(IX) This is similar to No. VIII but has the bottom horizontal, the increased depth at the middle being obtained by curving up the top table.

At the end of 1886 there were 134,000 metal ties in service, the weight, date, class, etc., of which are given in a table, which will be found a few pages further on, in the company's report to the Railway Congress of 1887.

Of 124,000 ties laid since 1880, not one had to be removed. The ties of types Nos. VI to IX, being of varying section and thickness, corresponded to weights of 126.50 and 139.15 pounds of ties of uniform thickness, an economy of 15 per cent. In the Dutch contracts, official account is taken of this difference in weight to compare the behavior of ties of varying section with that of ties of uniform section; it is the price per tie, with an equal section under the flange of the rail, which guides in the selection. The price paid by the company previous to

1887 for steel ties of varying section, not narrowed at the middle and not tarred, was about $20 per 2,200 pounds at the works. The price per tie was about $1.10 to $1.20.

The following table gives the results of these trials, showing cost of maintenance; the prices do not include first cost. Twelve of the sections are in rough country, with a traffic of twenty-five or more trains per day; the other nine sections are in flat country, with fourteen trains per day. All are single track. The varying conditions of grades and curves appear to have no particular effect upon the cost of maintenance, but the cost is affected materially by the amount of traffic, being much higher on the divisions with twenty-five trains than on those with fourteen trains. Respiking on the trial divisions laid with wooden ties was carried on in 1886 and 1887, so that the cost would not be less for 1887, and it would tend to increase with the age of the wood. None of the oak ties had needed renewing, but it soon became necessary, and this work, apart from the cost of new material, increased the maintenance expenses considerably. On the other hand, these expenses with metal track were generally highest during the first year of service, gradually diminishing thereafter.

*Cost of maintenance on trial tracks with wooden and of metal ties, Netherlands State Railway Company.*

| Trial number. | Trains per day. | Section of line. | From— | To— | Grade in millimeters per meter. | Radius of curves in meters. | Length of trial in meters. | Number of ties. | Types. Ties. | Types. Fastenings. |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| | | | *Kilom.* | *Kilom.* | | | | | | |
| 1 | 25 | Liége-Tongres | 15.620 | 14.612 | 12.0 | 500 | 1.008 | 1,120 | Oak. | Spikes. |
| 2 | 25 | ... do | 16.666 | 15.620 | 12.0 | 750 / straight. | 1.046 | 1,133 | I. | A. |
| *3 | 25 | Bilsen-Hasselt | 41.093 | 40.170 | 1.2 | straight. | 0.923 | 1,000 | I. | A. |
| 6 | 25 | Liége-Tongres | 7.946 | 7.432 | 16.0 | 1,000 | 0.514 | 600 | II. | B. |
| 7 | 29 | Liers-Flémalle | 1.831 | 1.393 | level. | 1,000 | 0.438 | 500 | II. | B. |
| 8 | 25 | Tongres-Bilsen | 25.031 | 24.570 | 8.0 | straight. | 0.461 | 500 | II. | B. |
| *9 | 25 | Bilsen-Hasselt | 43.625 | 43.349 | 4 0 | straight. | 0.276 | 300 | II. | B. |
| 11 | 25 | Liége-Tongres | 3.790 | 3.640 | 16.0 | 350 | 0.150 | 201 | II. | B. |
| 12 | 25 | ....do | 12.787 | 12.528 | 13.0 | 500 | 0.259 | 300 | II. | B. |
| 14 | 25 | ....do | 4.002 / 3.640 | 3.790 / 2.836 | 16.0 | 350 | 1.016 | 1,328 | III. IV. | A. |
| 17 | 25 | ....do | 12.528 | 12.315 | 13.0 | 500 | 0.213 | 250 | IV. | A. |
| 21 | 25 | ....do | 4.412 / 4.755 | 4.302 / 4.748 | 16.0 | 530 | 0.117 | 200 | VI. | C. |
| 22 | 25 | ....do | 8.000 | 9.000 | 16.0 | 1,000 | 1.000 | 1,081 | VI. | C. |
| 4 | 14 | Hasselt-Wychmael | 22.238 | 21.130 | 2.9 | straight. | 1.108 | 1,200 | I. | A. |
| *5 | 14 | Wychmael-Achel | 32.673 | 31.940 | 3.4 | straight. | 0.733 | 800 | I. | A. |
| 10 | 14 | Hasselt-Wychmael | 8.408 | 7.301 | 3.9 | straight. | 1.107 | 1,200 | II. | B. |
| 13 | 14 | .. do | 1.562 | 1.218 | 6.5 | 500 | 0.344 | 400 | II. | B. |
| 15 | 14 | .. do | 1.218 | 0.765 | 6.5 | 500 | 0.453 | 500 | III. IV. | A. |
| 16 | 14 | Achel-Eindhoven | 47.334 | 47.795 | 0.8 | 2,000 | 0.461 | 500 | III. | A. |
| 18 | 14 | ....do | 47.795 | 48.256 | level. | straight. | 0.461 | 500 | IV. | A. |
| 19 | 14 | ....do | 46.868 | 47.334 | 0.8 | straight. | 0.466 | 505 | V. | A. |
| 20 | 14 | ....do | 52.709 | 52.032 | 1.0 | 2,000 / straight. | 0.677 | 735 | VI | C. |
| 23 | 14 | ....do | 57.342.50 | 56.425.9 | 1.0 | 2,000 | 0.083.40 | 93 | VIII. | C. |
| 24 | 14 | ....do | 57.425.95 | 57.509.10 | 1.0 | 2,000 | 0.083.15 | 93 | IX. | C. |

*Cost of maintenance on trial tracks with wooden and of metal ties, etc.*—Continued.

| Trial number. | When laid. | Date when observation commenced. | Days in service. From beginning observation to January 1, 1888. | Days in service. 1887. | Cost of maintenance in francs per kilometer per day. 1881. | 1882. | 1883. | 1884. | 1885. | 1886. | 1887. | Average from beginning observation to January, 1888. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
| 1 | 1881 | July 1, 1881 | 2,375 | 365 | 0.159 | 0.217 | 1.226 | 0.396 | 0.483 | 1.101 | 0.423 | 0.605 |
| 2 | 1881 | ....do | 2,375 | 365 | 1.128 | 0.422 | 0.576 | 0.195 | 0.086 | 0.538 | 0.842 | 0.650 |
| *3 | 1881 | Sept. 1, 1881 | 2,313 | 365 | 1,930 | 0.829 | 1.884 | 0.255 | 0.501 | 0.383 | 1.135 | 0.952 |
| 6 | 1882 | Jan. 1, 1882 | 1,826 | 365 | ...... | ...... | 1.214 | 0.489 | 0.658 | 1.112 | 0.552 | 0.801 |
| 7 | 1882 | ...do....... | 1,826 | 365 | ...... | ...... | 1.582 | 0.277 | 1.160 | 0.494 | 0.573 | 0.817 |
| 8 | 1882 | ....do....... | 1,826 | 365 | ...... | ...... | 1.676 | 0.533 | 1.253 | 0.118 | 0.046 | 0.725 |
| *9 | 1882 | ...do ....... | 1,826 | 365 | ...... | ...... | 1.687 | 0.861 | 0.953 | 0.278 | 0.625 | 0.881 |
| 11 | 1883 | Oct. 1, 1882 | 1,553 | 365 | ...... | ...... | 0 | 1.084 | 1.974 | 1.187 | 1.660 | 1.389 |
| 12 | 1883 | ....do ....... | 1,553 | 365 | ...... | ...... | 0 | 0.891 | 0.465 | 0.264 | 0.746 | 0.557 |
| 14 | 1883 | ....do ....... | 1,553 | 365 | ...... | ...... | 0 | 1.647 | 1.792 | 0.867 | 1.610 | 1.392 |
| 17 | 1883 | do ....... | 1,553 | 365 | ...... | ...... | 0 | 1.132 | 1.111 | 0.498 | 1.000 | 0.879 |
| 21 | 1885 | Apr. 1, 1885 | 1,005 | 365 | ...... | ...... | ...... | ...... | 0.036 | 0.078 | 0.983 | 0.495 |
| 22 | 1887 | June 1, 1887 | 214 | 214 | ...... | ...... | ...... | ...... | ...... | ...... | 0 | 0 |
| 4 | 1881 | June 15, 1881 | 2,390 | 365 | 06.635 | 0.595 | 0.614 | 0.198 | 0.156 | 0.418 | 0.297 | 0.407 |
| *5 | 1881 | Sept. 1, 1881 | 2,313 | 365 | 1,584 | 1.027 | 0.790 | 0.326 | 0.536 | 0.569 | 0.227 | 0.632 |
| 10 | 1882 | Jan. 1, 1882 | 1,826 | 365 | ...... | ...... | 1.077 | 0.475 | 0.329 | 0.503 | 0.595 | 0.596 |
| 13 | 1883 | Sept. 15, 1883 | 1,569 | 365 | ...... | ...... | 0 | 0.433 | 0.438 | 0.879 | 0.583 | 0.543 |
| 15 | 1883 | ....do ....... | 1,569 | 365 | ...... | ...... | 0 | 0.246 | 0.412 | 0.258 | 0.429 | 0.313 |
| 16 | 1883 | Mar. 1, 1884 | 1,401 | 365 | ...... | ...... | ...... | 0.311 | 0.143 | 0.329 | 0.802 | 0.421 |
| 18 | 1884 | ....do ....... | 1,401 | 365 | ...... | ...... | ...... | 0.299 | 0.372 | 0.533 | 0.651 | 0.471 |
| 19 | 1884 | ...do ....... | 1,401 | 365 | ...... | ...... | ...... | 0.551 | 0.897 | 0.277 | 0.492 | 0.554 |
| 20 | 1885-'86 | June 1, 1886 | 579 | 365 | ...... | ...... | ...... | ...... | ...... | 0.144 | 0.252 | 0.212 |
| 23 | 1887 | Sept. 1, 1887 | 122 | 122 | ...... | ...... | ...... | ...... | ...... | ...... | 0 | 0 |
| 24 | 1887 | ...do ....... | 122 | 122 | ...... | ...... | ...... | ...... | ...... | ...... | 0 | 0 |

*Marshy ground.

REMARKS.—These trial-lengths are on single-track road. First group, 25 to 29 trains per day; second group, 14 trains per day. Rails, 76.45 pounds per yard; steel angle splice bars. Ballast—gravel, sand, and cinder. Heaviest engine on these lines 50 tons, with 13½ tons on the heaviest axle; heaviest engine on other lines, 68 tons with 13.9 tons on the heaviest axle. Speed up to 50 miles per hour (on some parts 60 miles per hour). A day's maintenance per man costs 2.19 francs; the results of columns 15 to 22 may be transformed into days by dividing by 2.19. The figures in columns 15 to 22 give the expense for work of maintenance, not the expense for purchase of new spikes, bolts, washers, etc. Not one of the metal ties in this table, nor of the 124,000 steel ties in use on other lines of the Netherlands State Railway Company, has broken in the track.

Mr. Renson, engineer of the Liege and Luxembourg division, has stated that the actual cost of maintenance per kilometer for track on metal ties, after three and a half years' service, was equal to that for oak ties of the same age; the cost of the latter would, however, go on increasing until renewals became necessary, as they would ere long, while the cost for metal ties would diminish, owing to the settling together of the pieces. The ties of type No. 1 tended to shift, and after some months of service a number of bolts worked loose in a very short time. The shifting of the ties was prevented by filling in the ballast on the outside of the track to the level of the rail-heads. The use of steel nut-locks prevented the loosening of the bolts, so that only one inspection and tightening per year was needed. Experience with some nut-locks of poor quality led Mr. Rost to the opinion that such were worse than none at all; he prefers the nut-locks with one spiral turn to those with two turns, the latter giving less pressure and not retaining their spring. The labor of maintenance was about .35 day's work per day-kilometer; the labor on long sections of line with uniform types of ties was even less. The maintenance includes lining, raising, tamping, trimming, inspection of nuts, etc. The cost of renewals was *nil*, not one tie having been broken. A gang of four men, working two hundred and fifty days per year, can maintain 4.96 miles of metal track in good condition. Heavier ties are used on curves, owing to the greater wear caused by the thrust of the rail-flange. In order to test the comparative merits of the rail fastenings used with metal and with wooden ties, an experiment was made in 1885 by placing wooden packing pieces under rails on both forms of ties; after four months' service it was found that those on the metal ties were simply compressed, while those on the wooden ties were crushed and bruised, showing evidence of a hammer action of the rail, due to the inefficient holding of the spikes.

The standard tie of the Post type is 8.36 to 8.7 feet long; at the middle it is of $\Lambda$ section, 4.48 inches deep, top radius 1 inch, $4\frac{1}{4}$ inches wide inside at the bottom and 5.4 inches wide over all at the bottom; the sides slope about 1 to 3; average thickness .24 inch. At the rail-seat the section is polygonal, 4.4 inches wide on top, 10.20 inches wide over all at the bottom, 2.98 to 3.02 inches deep; thickness of sides from .24 and .28 inch at lower part to .32 to .36 inch at upper part; thickness of top table .36 to .40 inch, and .48 to .52 inch at the middle, the thickness being increased at the bolt holes. At the extremities of the rail seats, the section is of rounded trough form, 4.96 inches wide on top, 9.4 inches wide over all at bottom, 2.56 to 2.60 inches deep, 1.40 to 1.52 inches radius of top corners; thickness from .24 and .28-inch at sides to .32 and .35 at middle of top table. The top table is sloped up at the rail seats to give the rails an inward inclination; it slopes down again to the horizontal and is bent down to close the end, projecting below the body of the tie. On the bottom edges are ribs of triangular section about .60 or .72 inch deep, and projecting .52 inch beyond the face of the side of the tie; these ribs prevent damage to the edge in tamping, and by lowering the neutral axis give additional stiffness, while they also make the section easier to roll. The bolt holes are .92 by 1.24 inches, oblong, with rounded corners. The weight of the tie is about 117.7 pounds. The rail clamps are 2.4 by 2.6 inches, with a .96 inch bolt hole; one end of the clamp rests on the rail flange and the other end on the tie; the greatest thickness is .96 inch; the top is toothed. The plain Verona nut locks are of .24 by .24 inch square section, .47 to .51 inch wide over the spiral, and .94 to 1.01 inch inside diameter; the grooved Verona nut locks are of .26 by .26 grooved section, .51 to .58 inch wide. The bolts are .88 inch diameter, with Whitworth thread; they are 3.08 inches long under the head; the head is 1.52 by 1.84 inches in size and .56 inch thick; the eccentric neck under the head is .88 by 1.20 inches, oblong, with rounded corners. The nuts are of hexagon shape, 1.08 inches deep, with the lower face toothed. Two forms of bolts are used, type "A" being for three different adjustments of gauge, and type "B" for the points of change from one of these variations to another, as at the extremities of sharp curves. For the convenience of the trackmen, the type "A" bolts have a piece chipped off the edge of the end, while those of type "B" have a larger piece cut off and have also a groove cut across the end; these marks not only serve to distinguish the two classes of bolts, but by their position enable the trackmen and inspectors to see at once the gauge to which the rails are set. The "A" bolts have the eccentric neck projecting on one side only of the shank, the neck being .88 by 1.20 inches, giving a projection of .32 inch; the "B" bolts have the neck the same size but projecting .24-inch on one side of the shank and .8 inch on the other. The weight of the bolt nut is about 1.1 pounds.

The weights of the track are as follows:

*Material for 29.54 feet of track.*

| | Pounds. |
|---|---|
| 2 rails 29.52 feet long, 68 pounds per yard | 1,334.52 |
| 2 pair splice bars, 46.2 pounds per pair | 92.40 |
| 8 splice bolts, with nuts and washers, 1.65 pounds each | 13.20 |
| 40 rail clamps, .88 pound each | 35.20 |
| 40 fastening bolts, with nuts and washers, 1.1 pounds each | 44.00 |
| 10 steel ties, 117.7 pounds each | 1,177.00 |
| Total | 2,696.32 |
| Weight per yard | 273.87 |

*Material for 39.38 feet of track.*

| | |
|---|---|
| 2 rails, 39.36 feet long, 76.45 pounds per yard | 2,006.40 |
| 2 outer splice bars, 25.08 pounds per pair | 50.16 |
| 2 inner splice bars, 25.96 pounds per pair | 51.92 |
| 8 splice bolts, with nuts and washers, 1.32 pounds each | 10.56 |
| 52 rail clamps, .88 pound each | 45.76 |
| 52 fastening bolts, with nuts and washers, 1.1 pounds each | 57.20 |
| 13 steel ties, 117.7 pounds each | 1,530.10 |
| Total | 3,752.10 |
| Weight per yard | 285.75 |

Mr. Bricka, in his report to the minister of public works (France) in 1885, spoke very highly of the Post ties, and stated that the weeds growing in the ballast at certain points were evidently from the preceding year (his inspection was made in April, 1884) and proved that frequent ballasting was not necessary. He did not approve of the reduction of the thickness of parts of the tie in order not to exceed a weight of 110 pounds, and he preferred to the bolts with eccentric necks, used for fastenings, the Ruppel clamp fastening or the Heindl clamp, which is a modification of the former (see "Germany," Prussian State Railways; and "Austria," State Railways). Since the date of Mr. Bricka's report, the weight of the tie has been increased as noted; and it will be noticed later on that Mr. Post has now, in his latest type of tie, abandoned the eccentric neck bolts and adopted the Roth-Schuler system of fastening, type "B" (See plate No. 9); he still, however, allows the bolt to resist the lateral pressure, instead of transferring some of it to the tie by using a clamp with a lug fitting into a hole in the tie, which is the feature which Mr. Bricka considers to be advisable. The report gives the following statement of the track in 1884:

| | Miles. |
|---|---|
| Main line | 851.88 |
| Total track | 1,286.50 |
| Wooden ties | 1,267.28 |
| Metal ties | 14.88 |
| Stone, etc | 4.34 |

The report made to me in March, 1888, by Mr. Kalff, chief engineer, gave the following particulars:

The system comprised 910 miles of line, of which 91 miles were laid with metal ties. The traffic consisted of passenger and freight trains, the speeds ranging from 20 to 47 miles per hour; the engines weigh from 50 to 68 tons in working order, with a maximum of 7 tons on each driving wheel. The "Post" ties are of mild steel, (Thomas, Martin, or Bessemer); they are spaced 3 feet 2 inches apart at the widest spacing, and at the suspended joints they are 1 foot 5 inches apart, so that the ends of the fish-plates butt against the rail clamps and prevent creeping. The ties are not tarred or otherwise treated. They are manufactured by the Hoerde Steel Works, Hoerde, Germany, and the Angleur Steel Works, Angleur, Belgium. They cost $22 per ton at the works, not tarred, and the fastenings cost 22 cents per tie. The maximum adjustment of the gauge is a widening of five-eighths inch. Of the 10,000 ties ("Cosijns" type) laid in 1865, 9,550 were still in use and were expected to last twenty years more. The ballast is of gravel, sand, and ashes; it fills the hollow of the tie and makes a compact mass. The width of road-bed at subgrade is 32 feet 9¾ inches; it is crowned 7⅞ inches, so that the ballast is 17 $\frac{11}{16}$ inches thick in the middle and 27⅛ inches thick at the sides; the ballast is brought up level with the top of the rails, the rail being left clear on both sides, and has side slopes of 2½ to 1. The ties were adopted on account of durability, economy, and security; the results, have been satisfactory, and there has been no trouble with maintenance, rail attachments, or from breakages: of 162,634 ties laid, not one had been broken. The use of the "Post" tie was being extended on the line. The climate is damp, but the loss of weight by rust is only about 4 per cent. in twenty years. The oak ties cost $1 each. The minimum radius of curves where these trials were made is 1,148 feet; maximum grade 1.6 per cent.

The track of this railway consists of steel flanged rails, weighing 68, 76.45, and 80.5 pounds per yard; the latter are 5.55 inches high, with a flange 4.08 inches wide; the head is deep, with vertical sides, 2.4 inches wide, 8 inches radius of top table, .56 inch radius of top corners. The joints are spliced with angle bars having short flanges, and the outer bar, with the heaviest section of rail, projects up the side of the rail head. The bars are 30.4 inches long: the inner holes are spaced 4 inches and the outer holes 7.8 inches apart, center to center; the holes in the outer bar are 1.12 inches square, with rounded corners, those in the inner bar are 1.08 inches diameter. The joint bolts are of steel, 1 inch diameter, 4.24 inches long under the head. With wooden ties, spikes .56 by .64 inch section, and 6.48 or 5.8 inches long are used. At the joint ties the rail rests on a grooved iron tie-plate, 7.2 inches square, with 4 spike holes; the spikes engage with notches in the angle bars. The wooden ties are spaced 22 inches apart, center to center, at the joints, and 27.12 to 39.2 inches apart intermediate, there being 10, 11, or 12 ties to a rail length of 29.52 feet. A space of about .28 inch is left between the ends of the rails. The steel ties are spaced with 10, 11, or 12 to a rail length of 29.52 feet; they are about 18.08 inches apart, center to center, at the joints, and 28.68 to 39.2 inches apart intermediate. With rails 39.36 feet long, 13 ties are used; they are spaced 24.08 inches at the joints, 34.76 inches next to the joints, and 38.64 inches intermediate. Splice bars 30.4 inches long are used, with notches in the flanges to admit the rail clamps.

The latest type of "Post" tie, as modified in 1889 (See plate No. 9), presents some changes from the previous type which had been most extensively used. The bolt holes are circular instead of oblong, and the extra thickness of metal at the hole is given a channel form to fit the heads of the bolts and prevent them from turning. The method of fastening is also different, being a return to type "B," already described, being the Roth-and-Schuler system.

A square gauge-washer is used, with the bolt hole .92 inch diameter, so placed as to be .24, .32, .48, and .56-inch from the sides, thus permitting a very close adjustment of gauge according to the position of one, two, three, or four of the washers on each tie. The rail flange butts against this washer. The clamp is of channel form, one side resting on the rail flange and the other on the top of the tie, and prevents the clamp from turning. A grooved Verona nut-lock is used between the nut and clamp. The washer is 1.72 inches square and .56 inch thick. The clamp is 3.16 by 2.48 inches, .56 inch thick, and 1.24 inches deep over all; its hole is 1 by 1.32 inch oval. The bolt is .88 inch diameter in a .92-inch hole in the tie; it is 3.52 inches long under the head, with Whitworth thread; the head is 1.52 inches square, .56 inch thick. The tie is 8.36 to 8.7 feet long. At the outer part of the rail seat it is 3.78 inches wide on top, 9.4 inches wide on the bottom, 3.28 to 3.32 inches deep, .24 to .36 inch thick at sides, .36 to .40 inch on top, .48 to .52 inch at middle of top table. At the rail seat it is 4.08 inches wide on top, 2.98 to 3 inches deep, in other respects of similar dimensions as above. At the inner side of the rail seat it is 5.04 inches wide on top, 2.56 to 2.60 inches deep, in other respects as above. At the intermediate parts and at the ends it is the same width and depth, .24 and .28 inch thick at the sides and on top. The cross section is polygonal, each side having two planes, and the angles are rounded off by curves of 1.12 to 1.52 inches radius. At the middle the section is narrow and deep, either the top or bottom of the tie being horizontal; the section here is **Λ**-shaped with the top bent to a radius of 1 inch, and the sides sloping at an inclination of 1 to 3; the depth is 4.6 inches, width at bottom about 5 inches, and the thickness of the sides .24 inch. The sides of the channel in which the bolt heads fit are .24 inch deep. A heavy rib of triangular section is on the lower edges of the sides.

*Report of the International Railway Congress*, 1887.—The following is a translation of the report presented by this company at the International Railway Congress, held at Milan, Italy, in 1887:

The experience with the 10,000 "Cosijns" cross-ties, laid in 1865, has brought out four facts: (1) There is no fear of rust; after twenty-two years' service the weight has only diminished 4 per cent. The ballast is of gravel and sand; on other lines it has been observed that ordinary ashes do not corrode the iron to a greater extent. (2) While in general the interposition of plates between the rail and the tie may not be desirable, as by such interposition the bolt permits a transverse motion of the rail on the tie, the gauge is fairly well maintained. (3) The bolt gives good results as a fastening of the rail to the tie; while the iron of the bolts was only .68 inch thick, there were still a number of bolts in use after twenty-two years' service. (4) A good tie lasts for a long time. After twenty-two years' service on the line between Deventer and Zwolle, with an average traffic of twelve trains per day (actually sixteen trains per day), there are in service and in good condition 9,547 ties (95½ per cent.), and there is no reason to expect that they will not last twenty years more. The 4½ per cent. taken out would still have been in service if the splicing of the old rails had been sufficient. These results with an old type of tie promise well for the latter types of improved ties. The metal ties taken out have brought seven times the price of old wooden ties.

The result of this first trial encouraged the company to commence in 1880 a methodical and practical study of the question of metal ties, and it now presents some of the results of this work. Information was acquired as to the results obtained abroad and in Holland both as regards the track and the manufacture. In order to keep within the limits of practice and economy it was decided that the first cost of the ties to be tried should not exceed 25 or 50 per cent. above that of oak ties, this difference representing the general valuation of the former over the latter. Each year a certain number of ties were put in service, and it was the endeavor each year, in spite of the favorable impression from the beginning, to improve upon the tie and fastening of the preceding year, avoiding defects observed and profiting by the experience acquired, by the experience of other companies, and by the progress effected in manufacture. Of each of the types in service special observation was taken of the maintenance, noting minutely every hour of work and keeping record of each piece (spikes, bolts, etc.) broken or replaced. As a base of comparison a new track was established on a trial section of line with good oak ties (presenting 4 inches wide of heart wood under the flange of the rail), under ordinary conditions of operation; this track was carefully maintained and the maintenance expenses noted in the same way as with the experimental sections of track with metal ties. Proceeding in this way the company put ties in service as follows up to January 1, 1887:

| Year. | Number. | Character. | Weight (each). |
|---|---|---|---|
| | | | *Pounds.* |
| 1865 | *10,000 | Cosijns | 123.64 |
| 1881 | *4,133 | Type I | 88 |
| 1882 | *4,001 | Type II | 103.84 |
| 1883 | †2,089 | Type III | 110 |
| 1883 | †2,090 | Type IV | 110 |
| 1884 | †11,680 | Type V | 95.48 |
| 1884 to 1887 | †100,000 | Types VI to IX | ‡110 to 121 |
| Total | 134,000 | | |

* Iron.
† Steel.
‡ Corresponding to 126.5 to 139.15 pounds of uniform section.

None of the 124,000 ties laid since 1880 have been taken out of the track.

The results of the observations of twenty-one trials made up to January, 1887, are presented in the table. [This table has already been given, as extended by Mr. Post later to include the year 1887.—E. E. R. T.] Columns 1 to 14 show the conditions of the track and traffic, the types of ties and fastenings and the duration of the observation; columns 15 to 21 show the cost of maintenance in francs per day and per kilometer; these prices do not include the first cost, but the labor of renewals. The sections are grouped in two parts. The first group includes twelve sections in uneven country (columns 5 and 6) where the number of trains per day is twenty-five or more (column 1); the second group includes nine sections in flat country, with only fourteen trains per day. A record of thirty years of observations and for several kilometers would give, it is true, more conclusive figures, but while awaiting more complete data we can already make the following observations, taking into account the facts observed and the records kept of the trials given in the table.

(1) The sections Nos. 11 and 14 are on a curve of 1,148 feet radius and a grade of 16 millimeters per meter (1.6 per cent.). The oak ties formerly used here had to be re-spiked every year owing to the motion of the rail flange which cut into the spikes .12 to .16 inch per year. Some ties of Type III, with attachments "A," however, taken out of the curve for the inspector after 1188 days of service (1553 days in 1887), showed only .08 inch of widening of gauge, each of the bolts being cut into .04 inch by the flange of the rail. In other curves of larger radius than 1,148 feet there is no cutting of the bolts. The top table of the ties of Type III taken out of this curve only presented a very slight wear and the bolt holes did not show any ovalisation or enlargement. These ties are of steel; iron does not so well resist the wear at the rail seat and bolt holes. In view of the very unfavorable circumstances under which these ties were laid, we need have no fear as to these two kinds of wear, but at the same time it is reasonable to put thicker ties on curves and to space them closer together. The cost of maintenance in this part has never reached 2 francs per day per kilometer (64.5 cents per mile per day).

(2) As regards the work of maintenance, sections Nos. 3 and 9 are under equally unfavorable conditions, the country being marshy.

(3) The average cost of maintenance on four sections, Nos. 2, 3, 4, and 5, which have had about the same service as section No. 1, with wooden ties, does not differ sensibly from the cost on section No. 1. In order to judge of the importance of this result it is necessary to bear in mind the following particulars: (*a*) Type I of the metal cross-ties is used on these four sections and is the most primitive of the forms used, each of the other types, II to VI, being an improvement upon the preceding. It may, therefore, be supposed that any of the other types would have given still better results. (*b*) The adzing and re-spiking of the wooden ties, which commenced in 1886, must be continued in 1887, so that the maintenance expenses for this section will be as high as in 1886, and it may be presumed that it will increase with the age of the wood. (*c*) The maintenance expenses of sections Nos. 2 to 5, however, show a tendency to decrease with the consolidation of the track. (*d*) Since the oak ties were laid in 1881 not one has been renewed, which proves that they are of excellent quality; renewals must soon begin, however, and will add considerably each year (apart from first cost) to the expenses of work of maintenance.

(4) The average maintenance expenses per day per kilometer of sections Nos. 6, 7, 8, 12, and 17 does not exceed .89 franc, and that of sections Nos. 10, 13, 15, 16, 18, and 19 is about .60 franc, although these sections only date from 1883 and 1884.

(5) The observations of Type VI are too short to judge of its value by the maintenance expenses. The company has also put in service in 1886 and 1887 ties of Types VII, VIII, and IX. [Already described.—E. E. R. T.]

(6) The putting in service successively of sections Nos. 2 to 21 not having up to the present time occasioned a higher rate of maintenance expenses than would have obtained with wooden ties, it may be admitted that a company which puts in every year a certain number of metal ties of reasonably good design will not increase its maintenance accounts and need not increase its staff.

(7) A piece of track near Liege (with twenty-five trains per day), 984 feet long, on a curve of 1738.40 feet radius and a grade of 1.6 per cent., laid with ties of Type III, was left, after having been carefully packed, for forty months (three and one-third years) without packing or surfacing or any other work except inspection of the nuts. At the end of that period the track was still in good condition. This proves that a good metal track, once well laid and packed, does not require more inspection or maintenance than a track on wooden ties; on the contrary it would be dangerous to leave a track on wooden ties for three and one-third years unattended to, under these conditions.

(8) The diagrams of the gauge-registering apparatus are much more regular for tracks on metal ties of Types I to IX than for those on wooden ties, even when the latter are new.

(9) The inclination of 1 in 20 of the rail, which is often disturbed on wooden ties by the turning outward of the rail, is maintained invariable with metal ties of Types I to IX.

(10) The lateral displacement of the tie by the traffic is *nil*, or insignificant, even on sharp curves, provided that the tie is properly closed at its extremities. It has been observed that intermediate closings, as in Types II and IV, are absolutely superfluous, as Types I and III, without these intermediate pieces, do not shift.

(11) The re-adzing of the rail seats and re-spiking, in 1886, of some of the oak ties of section No. 1, necessitated the replacing of two tie-plates and four hundred and eighty spikes; the renewal of attachments of metal ties is insignificant, especially for Type "C."

(12) Rolled iron is not recommended as a material for ties; mild steel of good quality is the best material in every respect for manufacture, inspection, solidity, and durability.

(13) Track laid with rails breaking joint has given, with angle splice bars, good results, especially on curves.

(14) The joints should be suspended and spliced by angle bars.

(15) The Types VI, VII, VIII, and IX leave nothing to be desired. The hollow trough packs itself easily in any ballast; gravel, sand, ashes, or broken stone. Generally the ballast forms a compact core adhering to the interior of the tie, filling it entirely at the rail seat, and increasing its base. If the packing does not extend more than 16 inches on each side of the flange of the rail, the tie can never "dance," and the shape of the tie tends to drive the ballast towards the rail seat.

(16) The track men, who are generally opposed to metal ties at first, very soon become accustomed to them. It is easy to obtain an excellent track, even with inexperienced men, by giving them proper instructions.

(17) To test the bending which ties of Type VI would sustain without cracking in case of derailment, the company made a series of tests of bending the tie cold at each side of the rail seat; punched ties, not annealed, of varying section, would bend 75 degrees before cracking; it was concluded that with steel, the form of the tie and the punching (with round corners) in question, annealing is not necessary, the deformation of the tie in case of derailment never being 75 degrees at the bolt holes. Ties punched and annealed would bend (like ties not punched and not annealed) 180 degrees without cracking. In view of this remarkable result the company considered annealing to be desirable, but with the condition that it did not cost more than a few centimes per tie.

We end this description by the calculation of the normal maintenance in a case determined by the engineer of the system on which the twenty-one trials have been made: "A track of Type VI, C fastenings, in the conditions of line, ballast, and operation of the Liege-Hasselt section, can, after 3 years for consolidation, be properly maintained at the rate of 100 days' work per year per kilometer. A gang of four men, working 250 days per year, can then, giving 50 days to other work, maintain in good condition, 4.96 miles of track."

For further details of the work done on this system, see the paper by Mr. Post on "Maintenance expenses of track on wooden and metal ties," printed in my preliminary report (Bulletin No. III).

HOLLAND RAILWAY.—The Holland Railway Company (or Dutch Railway Company), first used "Vautherin" ties weighing 72.6 pounds each, curved to give the rails an inward inclination, and open at the ends; the rails were fastened by gibs and cotters, but the cotters worked loose, being too narrow and not having sufficient bearing surface. The company now has mild steel ties of Vautherin section, as this is found to be the best shape for sand ballast (See plate No. 11). The ties are of two forms, joint and intermediate; all are 8.53 feet long. The joint ties are 6.4 inches wide on top (of which 4 inches are slightly thicker and form the rail seat), 8.72 inches wide inside at the bottom, 11.2 inches wide over the flanges, and 2.64 inches deep over all; the thickness is .24 inch at the sides and top, .32 inch at the rail seat, and .72 inch at the middle of the rail seat, where there is a rib 1.2 inches wide on the under side of the top table. The weight is about 112.2 pounds. The intermediate ties are 3.2 inches wide on top, 6.8 inches wide inside at the bottom, 9.2 inches wide over the flanges, and 2.64 inches deep; the top table is .52 inch thick for a width of 1.36 inches. The ends of both forms are closed by riveted angle pieces. The tie is horizontal, but at each end is a tie plate, 11.6 by 2.8 inches, secured by two rivets. This plate has an inclined seat for the rail, and has a rib on each side parallel with the rail flange. This rail is held by a T-shaped clamp on each side; one side of the head of the clamp rests on the rail flange and the other side on the rib of the tie plate, with the lower part between them; a ⊥-headed bolt passes up through the tie plate and clamp. The shape of the tie allows for an adjustment of gauge. The ties are dipped cold in tar. For the light line from The Hague to Scheveningen a lighter tie of Vautherin section is used, with a bolt fastening similar to that of the Left-Bank-of-the-Rhine Railway. (See "Germany.") For lines of which it owns the concessions the company has abandoned wooden ties, but Mr. Bricka, in his report in 1885, stated that it had not received permission from the State to substitute metal for wood on the lines of which it is only the lessee. With the track on this road Mr. Bricka mentions a straight splice bar of three thicknesses, similar to the Samson bar used in this country. A later form of tie used is without the horizontal flanges, but has a rib on the inner side of each bottom edge. For main lines they are 5.84 inches wide on top, 7.2 inches wide inside at the bottom, and 8.8 inches wide over all, 3.2 inches deep, .24 inch thick on the sides and .32 inch on top. For local lines they are 4.4 inches wide at top, 5.4 inches wide inside at bottom, 6.64 inches wide over all, 2.4 inches deep, .20 inch thick on the sides, and .24 inch on top.

Mr. Bricka, in his report to the minister of public works (France) in 1885, gives the following statement of the track of this road at the end of 1884:

| | Miles. |
|---|---|
| Main lines | 175.40 |
| Local lines | 35.34 |
| Total track | 496.62 |
| Wooden ties | 417.26 |
| Metal longitudinals | .62 |
| Metal ties | 78.74 |

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski presented the following particulars:

There were 92.13 miles of metal track in service on December 31, 1886; this included 30.07 miles of the "Vautherin" ties, 1.24 miles of the Haarmann system (as a test), 27.03 miles with the company's type of ties, and 33.79 miles with the Vautherin and the company's ties mixed. The latter are straight, with riveted tie plates giving the inclination to the rails; the mixed plan was adopted to remedy the inconveniences of the old type of "Vautherin" ties with open ends, by replacing these ties at the joints with ties of the new system. Up to 1882 they were of iron, but since that time of mild steel. The joint ties are heavier than the intermediate ties; the first weigh 111.10 pounds, the latter 96.8 pounds; the fastening plates weigh 1.32 pounds per pair, the bolts .88 pound each, making a weight of 117.26 or 102.96 pounds per tie complete. The ties are placed on embankments and in cuttings, on curves and tangents, on grades and level line. The ballast is of fine sand and gravel, and the ground in some places is marshy. The traffic over the metal ties is very heavy; on some parts there are more than sixty trains per day, with speeds of 52.7 to 55.8 miles per hour. The train loads are about 700 or 800 tons, and the engines weigh 68 tons. The rails are of hard steel, weighing 77.65 pounds per yard. The experience dated from 1868, and the results were so satisfactory, especially as to the solidity of the track, even in case of accident, that the use of metal ties was being continued. At the prices of that time (1886) the cost per meter of track was as follows: On half-round oak ties treated with chloride of zinc, $1.79; on mild steel ties of the company's type, $2.28; the rails with splice bars and bolts are included at $1.09; a wooden tie, with four spikes, cost only 59.4 cents; a metal tie, with fastenings, costs about $1.04. The first "Vautherin" ties were too light and had been abandoned; the strengthened "Vautherin" ties dated from 1878–'79, and had necessitated 2 per cent. of renewals per year during the three years previous to 1887; of the company's ties laid in 1880, none had been renewed up to 1887. The track on metal ties is very elastic and very agreeable for passengers. The results were so satisfactory that from 1887 the company intended to lay 1,000 tons (about 22,000 ties) per year.

DUTCH-RHENISH RAILWAY.—Ties of the Vautherin type were used up to 1885. They were of wrought iron, 8.53 feet long, 4 inches wide on top, 9.2 inches wide at the bottom, and 2.4 inches deep; the bottom flanges were .8 inch wide; the thickness was .28 to .32 inch at the sides and .36 inch on top. The weight was 99 pounds. The tie was horizontal, closed at each end by an angle plate. A tie-plate was used to give the required inclination to the rail, and the fastenings consisted of bolted clamps on the Ruppel system (see "Germany: Prussian State Railways"). Being of wrought iron the bolt-holes were found to wear large. The following is Mr. Bricka's statement of the track for 1884:

| | Miles. |
|---|---|
| Main lines | 167.10 |
| Local lines | 3.10 |
| Total track | 339.14 |
| Wooden ties | 267.84 |
| Metal longitudinals | 6.82 |
| Metal ties | 64.48 |

DUTCH CENTRAL RAILWAY.—In Mr. Bricka's report to the minister of public works (France), in 1885, this road is mentioned as a line of minor importance. Since about 1878 experiments have been made with wrought-iron ties similar to those on the Main-Neckar Railway, in Germany, with fastenings similar to those used on the Left-Bank-of-the-Rhine Railway, in Germany. They gave good results and effected an economy in maintenance. The following is a statement of the track for 1884:

| | Miles. |
|---|---|
| Main lines | 62.62 |
| Local lines | 1.24 |
| Total track | 81.84 |
| Wooden ties | 35.96 |
| Metal ties | 45.88 |

TIES.

*The Post Ties.*—(See plates Nos. 8 and 9.)—These ties have been described in detail under the head of the Netherlands State Railways. Mr. Post's main improvement is in the variation of the thickness and in the methods of manufacture, and he has shown how this method might be applied to improve other forms of ties in use. While the wear of steel ties at the point of contact with the bolt may be very small, Mr. Post has considered it well to increase the thickness of the tie at this point; it adds little to the weight of the tie, but increases its life, and is especially adapted for light ties with a thin top-table. A middle rib on the underside of the table increases the thickness at the bolt-holes; this rib runs the whole length of the tie, being thickest at the rail seat and decreasing towards the middle and ends. With an extra thickness of .16 inch at the bolt-holes, the weight of the tie is only increased by 6.6 to 8.8 pounds, and it enables a reduction of 22 or 33 pounds to be made (without changing the thickness at the bolt-holes) in the exaggerated weight of some rolled steel ties of varying section, such as the two types of the Belgian State Railway, which weigh 165 pounds each, corresponding to 189¾ pounds of a tie of uniform section. The material used is soft or mild steel, necessarily of good quality in order to stand the process of manufacture and the tests. The specified tests require a piece of a tie to be flattened cold under a steam hammer, and the plate then bent to a curve of 3 inches radius without cracking. Another piece must have the sides pressed together till the tie is of ∩ section, with a top curve of .6 inch radius. The fastenings have proved efficient, so that direct contact between the rail and tie is not considered any objection; there is little if any more noise than with wooden ties; there is no rattling, and crystallization of the metal has not been found to occur. The effect of making the middle of the tie deeper and narrower is to give the tie a better hold on the ballast, to force the ballast to pack under the rail seat, and to increase the stiffness of the tie so that it will be strong enough should the ballasting give way. Ties of Type VI have been made for rack railways, the thickness being increased at the holes for the bolts which support the rack-rail chair at the middle of the tie in the same way as described for the ordinary bolt-holes.

The manufacturers have been required to guarantee to replace damaged ties during two years, but now this has been increased to five years. A tie of this type has been designed for the Indian gauge of 5 feet 6 inches. It is 8 feet 7⅞ inches long, horizontal at the middle, inclined 1 in 20 at the rail seats, and closed at the ends; at the rail seats it is 9¼ inches wide and 2⅜ to 3½ inches deep; at the middle it is 4.4 inches wide and 5 inches deep. The thickness of the sides varies from .24 inch at the bottom to .31 inch at the upper part; the thickness of the top varies from .28 inch to .43 inch, the latter being at the rail seat. Weight, 125¼ pounds. Instead of bolt fastenings lugs are to be stamped up out of the tie and a steel key driven between the rail flange and the lug on one side; the system is the same as that now used with steel ties on the Indian State Railways and other lines, and is claimed to be cheaper and better than the bolt system used in Europe. A similar tie, but weighing only 116 pounds, has also been designed and is said to be as strong as the steel ties now used in India. In a proposal made by Mr. Post's English agent for a supply of ties for the Indian State Railways, he bid for the "Post" tie and for the type of tie specified by the engineer;

the price was slightly in favor of the former, owing to its reduced weight with equal strength. The price quoted to me in February, 1888, by this gentleman was about \$25.62½ per ton at the port.

In September, 1887, there were in service in railways in Belgium, France, Holland, Germany, and Switzerland about 334,500 "Post" ties, or about 18,753½ tons. There were in course of manufacture 83,900 ties for standard gauge, weighing 4,363 tons; for a gauge of 3 feet 6 inches in Sumatra, 70,000 ties, weighing 3,040 tons; for rack railways, 20,000 ties, weighing 760 tons; an aggregate of 518,400 ties, or 26,916½ tons. In March, 1888, Mr. Post stated that there was a total of about 457,300 ties (about 23,800 tons) of types VI, VII, VIII, and IX then in the track in different parts of the world, and that about 272,700 more (about 12,700 tons), including the narrow gauge and rack railway at Sumatra (See "Asia") were ordered and being manufactured. This made a total of about 730,000 ties, or 36,500 tons. They were in use in Holland, Belgium, France, Germany, Switzerland, and Asia (colonies). About 50,000 ties have been introduced into the Argentine Republic. In January, 1890, Mr. Post stated that in addition to the ties in Holland, Belgium, France, Germany, and Switzerland, there were 200,000 in Sumatra, 50,000 in the Argentine Republic, and 71,000 were to be sent to the Transvaal (South Africa) in February. Within three months there would be, he stated, a million of these ties in service.

The following table, prepared by Mr. Bodmer, civil engineer, the London agent, shows the number of "Post" ties sold up to September 26, 1889. Bids had also been invited for 71,430 ties for the Dutch South African Railway. The contraction referred to is making the tie narrow and deep at the middle:

| Where used. | Contraction. | Number. |
|---|---|---|
| Netherlands State railway | With | 12,732 |
| Do | Without | 47,390 |
| German State railways: | | |
| Magdeburg | do | 44,200 |
| Cologne | do | 1,700 |
| Altona | do | 3,000 |
| Strasburg | do | 33,600 |
| Cockerill, Seraing, Belgium | do | 200 |
| Military railway, Schoneberg | With | 5,750 |
| Do | Without | 2,300 |
| German State railways: | | |
| Frankfort | do | 108,492 |
| Erfurt | do | 61,487 |
| Friedrich Krupp, Essen, Germany | do | 400 |
| Pfalz railway, Germany | With | 176,000 |
| Fortifications, Spandau | do | 1,050 |
| Dutch Colonies, Sumatra | do | 100,000 |
| Bavarian railway, Ritaikon-Ingolstadt | do | 360 |
| German State railways (Berlin) | do | 2,020 |
| Jura, Bern, Luzern railway (Switzerland) | do | 6,000 |
| Carlos Stegman, Carlsruhe, Germany (for the Argentine Republic) | do | 50,000 |
| Total | | 656,181 |
| Manufactured in France and Belgium | | 200,000 |
| Total | | 856,181 |

## SUMMARY OF METAL TRACK FOR HOLLAND.

| Railways. | Longitudinals. | Cross-ties. |
|---|---|---|
| Netherlands State (1888) | | 91.00 |
| Holland (estimated to 1889) | 1.24 | 120.00 |
| Dutch Rhenish (1885) | 6.82 | 64.48 |
| Dutch Central (1885) | | 45.88 |
| Total | 8.06 | 321.36 |

## BELGIUM.

GENERAL REMARKS.—In this country quite extensive experiments with metal track have been made on several lines, and the Government has conducted experiments on the State railways since 1846. In 1885 and 1886 the subject of the use of metal ties was warmly discussed in the Chamber of Representatives, the principal object being to forward the interests of the iron industry; the minister of railways then secured an appropriation of $180,000 for the purpose of carrying on further experiments on the State railways. In March, 1889, at a meeting of the chamber, the minister stated that the results had not been satisfactory. He had hoped that if the tests were successful the authorities would have been able to adopt metal track on a part of their system, and thus render a great aid to the national industry by advancing the condition of the iron trade. At this meeting there was a rather sharp discussion on this point, several of the members being in favor of more extensive tests and wishing tests made of the "Z-iron" tie [described later on]. The minister stated then that three types of metal ties had been tried; of these one had failed, but the inventor claimed that the failure was due to a defect in the quality of the material, and he was granted a further trial; the other two systems had not been long enough in service to enable a definite opinion to be given. He was opposed to increasing the number of types to be experimented with. The Government has been asked to have these "Z-iron" ties tried on the State railways, but the minister of railways declined on the ground that the Government preferred to await the results of the trials being made on the State and concessionary lines before proceeding with new trials or adopting new types. Mr. Bricka, in his report to the minister of public works (France) in 1885, stated that Belgium was the only country in which after a trial on a large scale metal track had been at one time almost entirely abandoned. He attributed this to the fact that the trials to which he referred, covering a length of 23.56 miles, were made by order of the Government on account of the agitation raised by the metal industries about 1877. It was proposed to lay about 93 miles at once. The ties were of the original "Vautherin" type; they were not of a good section and were of very poor material; proving unsatisfactory they were taken up and no attempts were made to improve upon the system. A similar agitation was raised in 1884, and a commission was sent to investigate the progress being made in Germany, with the result that the Belgian engineers began to have a better opinion of metal track. Since then the Government has ordered trials to be made with different types of track, and these trials are still being carried on.

*Wooden ties.*—The West Flanders Railway reported in August, 1888, that metal ties have not been employed, as oak ties 10.4 inches by 5.2 inches can be procured for 70 cents each.

Belgian State Railways.—Experiments with various forms of metal track have been made on the State railways since 1846 and are still in progress. Up to 1885 only unsatisfactory results had been obtained; but this was attributed to bad or defective designs or material, and did not cause the abandonment of the trials.

In March, 1886, Mr. Flamache, engineer of the State railways, presented a paper at a meeting of the Belgian Society of Engineers, on "The History of Metal Railway Tracks," to which was appended a note by Mr. Mussely, an engineer of the same roads, detailing the trials made since 1846. These trials were briefly as follows: In 1846 there were four systems in use on the line between Brussels and Antwerp: (1) the Poncelet system of semi-circular plates of cast-iron, with rolled-iron tie-bars; (2) the Poncelet system with square plates; (3) the Gobert system of two cast-iron plates with an old rail reversed, this rail having a notch which formed a chair; (4) the Marchal system of rolled plates, with ordinary chairs secured by bolts and nuts. In 1851 the administration put in 5,000 ties of the Greaves and Barlow system, similar to the Poncelet system. In 1868, 7,804 "Vautherin" ties were laid. About 1869, 500 tons of the Legrand-Salkin system were laid. Between 1872 and 1879 several systems were examined, but none were considered worthy of trial. In 1878–1879 there were laid 74.56 miles of single track with the Hilf longitudinals (See "Germany") and 94,035 miles of single track, similar to the Rhenish Railway type (See "Germany"). In March, 1879, 2,000 of the Desoignies cross-ties were laid. In 1879 the Serres and Battig system of longitudinals was tried. In 1881, 500 Helson ties were laid. The Hilf longitudinals were similar to those on the Alsace-Lorraine Railway, Germany; but there was much trouble from breakages, owing to the bad quality ot the metal, and at the end of four years all of the track was taken out. With the Serres and Battig system there were many breakages, owing, the inventors claimed, to the quality of the material; these were soon abandoned. The "Vautherin" ties, laid in 1878, were 7.87 feet long, 4 inches wide on top, 9.52 inches wide at the bottom, 2.4 inches deep; the top table .36-inch thick; the bottom flanges .96 inch wide and .32 inch thick. The ties were curved longitudinally, to give the rail its inward inclination, and near each end a piece of angle-iron was riveted with the vertical leg inside the tie. The fastenings were on the Ruppel plan (See "Germany—Left Bank of the Rhine Railway"), consisting of bolted clamps with lugs fitting into holes in the tie; at the joint ties the clamps extended over the whole width of the rail-flanges. The weight was 105.65 pounds. The 2,000 Desoignies ties were laid on the line from Brussels to Ghent; they were of approximately rectangular section, weighing 88 pounds; the fastenings consisted of a riveted clamp on one side, and a bolted clamp on the other side, of the rail. Owing to the poor quality of the iron, breakages occurred with both these types, and the holes were enlarged, while, owing to their being curved and laid in broken-stone ballast, the track was not stable. These were only in service for about two years.

In December, 1885, it was decided to try 35,000 ties of the "Post" type, but heavier than those on the Netherlands State Railways; 35,000 ties of the Braet plan, being a modification of the "Post" type; and 5,000 ties of the Bernard type.

The first were of the old form, 8.2 feet long, 10 inches wide, 2.84 to 3.6 inches deep, .48 inch thick in the middle, and .64 inch thick at the rail-seat; the fastenings consisted of bolted clamps with spring washer nut-locks. There were twelve ties to a rail length of 29.52 feet, and the rails were laid with suspended joints. The weight was 165 pounds per tie. Mr. Bricka considered this too heavy, and thought that a thickness of .32 inch to .48 inch would be sufficient. The "Braet" ties were designed or adapted by Mr. Braet, engineer of the Belgian State railways; they are 8.2 feet long, 10.8 inches wide at the bottom, 3.8 inches deep at the middle, and 4.4 inches at the rail-seats; the thickness is .36 inch at the middle and .52 inch at the rail-seats; the weight is 165 pounds. With both these types the Ruppel plan of bolted clamp-fastenings is used. The Bernard tie is composed of two channel-irons 7.54 feet long, 4.8 inches high, and 2.24 inches wide over the flanges; the thickness is .24 inch. These are placed back to back, 7.32 inches apart, and at each end is a flat base-plate 16 inches wide and 36 inches long, fastened to the bottom flange of each channel-iron by four rivets .80 inch diameter, and turned up to close the end of the tie. At each end of the top of the tie is a grooved tie-plate 7.96 inches wide and 13.2 inches long under the rail, resting on the top of the upper flanges of the channel-irons; the plate gives the usual inward inclination to the rail. Hook-headed bolts pass through the upper flanges of the channel-irons and through the tie-plates, the rails being fastened by large washers or clamps, with a recess in the top to receive a coiled-spring nut-lock. The tie is filled with and buried in the ballast, to increase its weight and the stability of the track. The weight, complete, is 231 pounds, and there are eight ties to a rail length of 22.96 feet. It was said during the discussion in the chamber that they had not given satisfactory results (see "The Bernard Tie"). The "Post" ties were made at the Louviere works, and cost $24.09 per ton; the "Braet" ties were made at the Cockerill works, and cost $23.80 per ton; the "Bernard" ties were made at the Couillet works, and cost $29.90 per ton.

The following particulars are taken from a special report sent to me in May 1888, in regard to the track laid with the "Bernard" ties. There were about 3½ miles (18,450 feet) of line laid with 5,000 of these ties; 4,000 were on grades of 0.16 per cent. and 1,000 on level track. The first were laid in 1884, the remainder in June, 1886. Mr. Mathieu was the engineer. The weight of the tie is given as 215.6 pounds. The cost is $2.90 per tie at the works, the durability and the cost of maintenance are not yet determined. The metal is not painted or treated in any way. Passenger and freight traffic is hauled over the line; the engines weigh from 35 to 75 tons, including tenders, and the cars weigh empty 4 to 9 tons. The rails are flange section, 76.5 pounds per yard; the joints are suspended and fastened by splice-bars. There are 8 ties per rail length of 29.52 feet. The ballast is of broken stone; it is 20 inches deep in the middle, level with the top of the ties between the rails, and level with the rail-heads between the tracks and outside. The line is of standard gauge and the width of road-bed is as follows: 6.56 feet center to center of inner rails of double track, 4.92 feet center to center of rails of each track, 3.28 feet from center of outer rails to edge of ballast, 30 inches width of ballast slope. The reason for adopting metal ties was to obtain a solidity, a bearing-surface, and a weight which would increase the durability and diminish the expense of maintenance. The results have been very satisfactory; the track is solid, the fastenings hold well and give no trouble. No breakages had occurred and there was no trouble with maintenance. The ties present the advantage that on account of the extra length of bearing-surface they can be considered as two ties spliced together and the number can be reduced 33 per cent. below the ordinary number of ties. Their bearing in the ballast and their weight are very great, giving them exceptional stability. The climate is moist and variable, but no special observation has been made of its effect upon the ties.

*The Cockerill tie.*—A tie of the "Post" type, of which the Cockerill works sent particulars in February, 1888, was 8.2 feet long, 9.6 inches wide inside at the bottom, 10.8 inches wide over the ribs. The top was horizontal except at the rail seats, and the bottom was horizontal throughout. The ends were closed and bent below the level of the bottom of the tie, being 6 inches deep. Weight, 164.56 pounds. At the middle it was 3.64 inches deep with a top table .36 inch thick. At the outer part of the rail seat it was 4.4 inches deep with a thickness of .52 inch, and at the inside part it was 3.8 inches deep with the same thickness of the top table. The thickness of the sides was from .30 inch at the bottom to .36 and .46 inch at the top. The fastening bolts were 3.44 inches long under the head, .84 inch diameter, with ⊥ heads and hexagon nuts. The clamps were 2.28 inches by 2.60 inches, with a bolt hole .88 inch diameter; a lug at the outer side made the depth over all 1.80 inches, and this lug fitted into the oblong bolt hole (1.6 by .92 inch) in the tie. Spring washers for nut-locks are used. The rail joints were spliced with angle bars having a rib on the under side of the edge of the flange. The bars were 27.20 inches long, with four bo't holes, the inner ones 6 inches apart center to center, and the outer ones 4 inches. For a rail length of 29.52 feet there were twelve ties, spaced 22 inches apart center to center at the joints, 25 inches apart next to the joints, and intermediate ties 32 inches apart. Other ties of this type were 8.2 feet long, 8.88 inches wide inside, 10 inches wide over the ribs. The depth over all was 2.84 inches at the middle, where .48 inch thick, and 3 inches where .64 inch thick. At the rail seat the thickness was .64 inch and the depth 3.6 inches. The width of the top table was 5.04 inches, except at the rail seat, where it is 4.4 inches, and just outside it narrows to 3.78 inches. These ties are not narrow-waisted at the middle, but are of uniform section and thickness between the rail seats. The adjustment of gauge is effected by the use of clamps with lugs of different width, instead of by eccentric necks on the bolts. The more recent form of track has rails weighing 76.5 pounds per yard, with joints spliced by bars 31.84 inches long and four bolts, The joint ties are spaced 24.24 inches center to center.

From 1885 to May, 1888, 2,625 tons of the "Post" type of tie had been manufactured for these lines by the Angleur works. They were of Thomas Gilchrist steel, not tarred or treated; they weighed 110 to 165 pounds each, and cost $22 to $25 per ton. Most of the ties of this type were considerably heavier than those used on the Netherlands State railways (Holland). Continued experience on these latter lines has shown the weight of 117.7 pounds to be sufficient in every way, and the inventor considers, as does Mr. Bricka, that the extra weight is quite unnecessary, involving extra cost, and only resulting in putting useless and dead metal into the track.

The Belgian State railways system comprises 1,990 miles, and on January, 1888, there were 219,485 metal ties in service.

GREAT CENTRAL RAILWAY—Different forms of metal track have been tried. Among them was the Serres and Battig system of longitudinals (See "Austria"), but there were many breakages and the trial was not successful. In 1873 the superintendent of permanent way reported that he was fully satisfied with the experience so far obtained with metal ties. He was unable to employ them further at the time in consequence of the extraordinary advance that had taken place in the price of iron. The company's report for 1887 stated that the favorable results during 1886 had been still more marked during 1887. In the latter year 6,000 additional metal ties were substituted for wooden ties. Satisfactory results are said to have been obtained with a "Z-iron" tie weighing 149.6 pounds and costing not more than $1.80 each; these were laid about 1887.

Since 1886 there have been in service 11,000 iron ties of two types, manufactured by Caramin & Co., of Thy-le-Chateau (see Plate No. 11), and they are giving very good results as to security and economy in maintenance, according to a statement sent to me by the engineer-in-chief in October, 1889. He stated that so far not a single one of these ties had been taken out of service, while on the state railways, where steel ties are used, quite a number had to be taken out owing to breakage. This unfavorable result he attributed to the alteration in the metal produced by the punching of the holes for the bolts. With steel special precautions must be observed in the manufacture, while with iron there is less need of such care. He does not, however, proscribe the use of steel for ties, but thinks much progress is still to be made in metallurgy before this material will be definitely successful for such purposes.

The ties now used weigh, complete, about 154 pounds; they are 8.52 feet long for standard-gauge track. This weight is sufficient for a moderate traffic with an average speed of 37.2 miles per hour for passenger trains, but he considers that the weight should be increased to 176 or even 198 pounds for tracks with very heavy traffic. Various kinds of ballast have been used with these ties; ashes mixed with earth (a very inferior quality of ballast), river gravel and broken stone; good results have been obtained with all these materials. The gravel should be slightly earthy, so as to form a solid core under the tie. This railway has a length of 365.18 miles.

These ties are of semi-cylindrical section, with horizontal flanges on the lower edges and having a flat top table; the horizontal flanges are cut away at the middle of the tie. They are 8.52 feet long, 3 inches deep, 6.4 inches wide inside at the bottom and 9 inches wide over the flanges; the upper face of the top is flat for a width of 3 inches. The flanges are .36 inch thick; the sides are .36 inch at the bottom and .40 inch at the top, and the top table is .52 inch thick. Inside the tie, under each rail, is an iron plate 10.8 inches long and about .75 inch thick, fastened by two rivets passing through the top of the tie. Each rail rests on a grooved tie-plate, giving the rail the usual inclination, and having a channel for the rail flange and a rib along each side. Short screws, about 3¾ inches long over all, pass through the tie-plate and tie and are tapped into the iron plate riveted inside; these screws have wide round heads, which bear on the flange of the rail and the rib of the tie-plate, and have a square projection on top for the track-wrench. The older ties of this form weighed 149.38 pounds complete; but the newer ones, adopted in 1887, weigh 152 pounds, made up as follows: Tie, 133.30 pounds; tie-plates, 5.10 pounds; riveted plates, 9.06 pounds; rivets, 1.63 pounds; screws, 2.91 pounds.

The other type of tie, adopted in 1886, was of similar section; but inside, under each rail, was an oak block 9.3 inches long; this was held in place by an iron plate 9.8 inches long, riveted to the tie by two rivets to each flange; the plate was about .27 inch thick, with a rib in the middle about 1.15 inches wide, making the thickness at that part about .56 inch. The rail rested on a tie-plate having a rib on each side, but no channel for the rail flange. The fastenings consisted of screws similar to those described above, but 6.12 inches long over all, passing through the wooden block and the thick part of the bottom plate. The weight of each tie, complete, was as follows: Tie, 130.64 pounds; tie-plates, 4.73 pounds; riveted plates, 17.20 pounds; screws, 3.96 pounds; oak blocks, 4.77 pounds; total, 161.30 pounds.

At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski presented the following particulars respecting these ties:

Five thousand were laid in 1886 and 5,000 were to be laid in 1887; they were placed under unfavorable conditions and in ground imperfectly drained; they were on embankments and in cuts on tangents and curves of 1,640 feet, 1,968 feet, and 2,624 feet radius, and on a maximum grade of 3.5 per cent. During the first year the traffic consisted of 1,498 passenger trains and 2,920 freight trains, a total weight of 1,068,258 tons. The speed of the former is 37.2 miles per hour and that of the latter 15.5 miles per hour. The passenger engines weigh 31 tons, and the freight engines 52 tons. The rails are of flange section, weighing 74.35 pounds per yard. The ballast is of ashes and quarry gravel. The track keeps in good condition and the fastenings keep tight. The price of the iron tie is double that of the wooden tie. The work of maintenance during the first year of service was less than that of wooden ties. The arrangement of fastening with screws and an iron plate was being adopted in place of the wooden block.

NORTHERN RAILWAY.—On the Belgian lines of the Northern Railway of France, the "Severac" tie has been used. In 1885 there were 1,500 of these ties in the track, 750 at Engis, near Liege, and 750 near Charleroy. Since they had been laid 6,000 trains had passed over them, and no creeping of the rails or displacement of the keys which fasten the rails had been observed. At a meeting of the Belgian Society of Engineers in March, 1886, it was stated that 1,500 of these ties had been in service for nine months under a traffic of sixty-four trains per day, and were in as good condition as when laid, while no difference could be noticed between the noise when passing over these ties or wooden ties. They were manufactured by the Augleur Works (See "the Severac ties"). The following particulars are from a statement received in May, 1888, in regard to the "Severac" ties: In June, 1885, they were laid on 1,968 feet of single track on the line from Namur to Liege; and in July, 1885, on 1,968 feet of single track on the line from Erquelinnes to Charleroy. On the former section there were curves of 4,920 feet radius, and grades of 3.8 per cent.; on the latter section there were curves of 1,640 feet radius, and grades of 1.46 per cent. Mr. Bernard was the engineer of the line to Namur. The locomotives weigh about 38 to 69 tons in working order, including the tender; the cars weigh 3.6 to 8 tons empty. The traffic is passenger and freight. The tie is an **I**-beam, 8.2 feet long, 4.8 inches high, 3.2 inches wide over the flanges, .32 inch thick; on the bottom is a plate 9.6 inches wide and .32 inch thick, secured by eighteen rivets; it runs the whole length of the tie and is turned up at the ends. A chair for the rail is riveted to the top at each end of the tie. The weight of the tie complete is 204.6 pounds. The ties are made of iron at the Angleur Works; they are not treated in any way, and cost the railway company $1.08 each, but the net cost at the works was higher than this, according to the statement of the inventor. The cost of maintenance had not been defined, but was very low. The joint ties were spaced 24 inches apart, center to center, and the intermediate ties 34 inches. The ballast is of ashes; it is 20 inches deep in the middle, level with the rails between and outside of the tracks, and level with the tops of the ties between the rails. The dimensions of the road-bed are as follows: 6.56 feet between tracks (center to center of rails), 4.92 feet center to center of the rails of each track, 3.28 feet from center of outer rails to top of ballast slope, 30 inches width of ballast slope. The rails are of flange section, weighing 60.36 pounds per yard; the joints are suspended, and are spliced in the usual way. The reason for using metal ties was to compare the cost of their maintenance with that of the track on wooden ties. The results were satisfactory; there was no trouble with maintenance, and the only trouble with the rail fastening (a taper key driven between the rail flange and a lug on the tie plate) was that before driving the keys to a tight bearing it was necessary to dress the track in line and surface, as after the keys have been finally driven this dressing is impossible on account of the extreme stiffness and rigidity of the track. The only breakages were in the chairs which appeared to be rather weak; no accidents were caused by these breakages. The ties appeared to behave much the same as wooden ties; they are well made, but as regards bearing they do not present more advantages than wooden ties, which would have a width of 9.6 inches. The climate is moist and variable, but no particular observations have been made of its effect on the ties. Oak ties cost $1.17 each, including the rail fastenings, and have an average life of fifteen years. Creosoted beech ties cost $1.09 each, including rail fastenings, and have an average life of twenty years.

Liege and Luxembourg Railway.—The Serres and Battig system of iron longitudinals (See "Austria") has been tried, but with unsatisfactory results owing to numerous breakages. The "Coblyn" type of cross-ties has also been used. The principal trials have been with the "Post" type of steel cross-tie, with very good results, as noted under "Holland," Netherlands State Railway.

Liege and Seraing Railway.—The Society of Economic Railways (Liege to Seraing and extensions) has, after making experiments, adopted the "Coblyn" type of steel ties to replace oak ties. In the company's report presented at a meeting in May, 1888, it was stated that renewals with these ties would be carried on as needed, and by small sections.

Local Railways.—A special statement received in May, 1888, shows that the Local Railways Company laid in December, 1887, 500 iron ties of the "Bernard" type, covering 2,437 feet on the line from Jedoigne. They were on tangents and curves of large radius, also on grades and curves, to 98.4 feet radius. Mr. Dartevelde was the engineer. The ties and fastenings were of steel, but the chairs were of iron. The weight per tie was 132 pounds, and there were 6 ties to a rail length of 29.52 feet. The cost was $2.10 each at the works. The rails were of flange section, 6.4 inches high, weighing 60.36 pounds per yard; the joints were suspended. The results, etc., are the same as given in the statement relating to the Belgian state railways. Trials have also been made with the "Coblyn" type of steel ties.

For the Charleroy suburban lines the company has adopted the "**Z**-iron" tie. These lines are 9.3 miles long, one meter gauge, with maximum grades of 6 per cent. and curves of 82 feet radius. There are three lines; on two of them the traffic consists of thirty trains per day, and on the third line fifty-four trains. The lines were opened in 1887, and the track has given good results from the beginning, especially in regard to its freedom from noise; there were 12,829 ties in service. The lines follow the country roads, and the track is in some places in the paved streets, and in other places on waste ground along the side of the highway. The ties weigh 114.4 pounds each, including fastenings, and cost $1.30 each. The passage of trains is as easy and quiet as on track with wooden ties; the crossings are laid with wooden ties and no difference is noticed when the trains pass from track with metal ties to track with wooden ties, or *vice versa.* This is claimed to be due to the rigid fastening of the rails by a taper key.

The following is an abstract of a report made to the company in October, 1888, by Mr. F. Grumieaux, engineer and superintendent of the Charleroy lines:

The lines are of very irregular profile: of the 9.3 miles total length, 6.2 miles present grades of 3 and even 6 per cent. The rails are 29.52 feet long; those laid in the streets weigh 60.3 pounds per yard and have eight ties to a rail length; those laid at the side of the road weigh 43.2 pounds per yard and have ten ties to a rail length. The passage of trains is as smooth and easy as on track with wooden ties, as can be noted at crossings where wooden ties are used. The taper keys first used were too small; on the Lodelinsart line, where there is a grade nearly 1.24 miles long, varying from 3.5 to 6 per cent., down which the engines run with the brakes partly applied, there was considerable creeping of the rails, the ends of the rail touching one another and the ties being shifted laterally so that the tangent became a series of bends. This part of the track was relaid in June, 1888, and stronger keys were used, after which there was neither creeping nor displacement of the track. The ties taken out had a thin coat of rust, but the experience was then too short to allow of any opinion to be formed as to the ultimate effect on the ties. Some Belgian engineers have affirmed that metal ties can only be used with gravel or broken stone ballast, as ashes will destroy them by corrosion, owing to the sulphurous matter contained in this material. These lines, however, are ballasted entirely with ashes, and the future will show whether the opinions of these engineers are well founded. No figures could be given as to the cost of maintenance and repairs, and in fact German and Dutch engineers are of opinion that it is not until the third year of service that the good results of the use of metal ties become apparent.

*The Severac Ties* (See plate No. 10).—The "Severac" tie consists of an I-beam with a broad plate riveted to the bottom; this plate extends the whole length of the tie, and is turned up at the ends. The size of the plate on plan is exactly that of an ordinary wooden tie and the height and width of the closed end are the same as those of a wooden tie, so that the volume of the ballast resting on the bottom plate is practically equal to the volume of a wooden tie. By this means the tie itself may be comparatively light for handling, say about 198 pounds, and very heavy when in place in the track, being more firm or stable than wooden ties. To the top table of the I-beam are riveted two rail chairs, giving the rails an inward inclination. There are two projecting lugs on each chair: the outer one holds the outer flange of the rail, while the inner one has a taper steel key driven between it and the rail flange.

There are various modified forms of these ties. They may have a plate riveted on the top as well as on the bottom; or they may be rolled with a narrow top flange and a wide bottom flange, so as to dispense with the riveted plate, the bottom flanges being cut through at the corners and bent up to form a closed end. They may also be of tee-section (T or ⊥), with the horizontal flanges bent down or up, as the case may be, to close the ends. This form may be used for narrow-gauge lines, the horizontal flanges being bent down or up and then horizontally, so as to form a top table at the ends and a bottom table at the middle, or *vice versa;* this is advantageous for lines where it is desirable to economize in the width of the ballast, as the resistance to lateral motion is then at some distance from the ends of the tie. (This is one of the special features claimed for the Standard steel tie, now being tried in the United States.) Another form is of ⊥-section, with a piece of angle-iron riveted to each side of the top of the web, under each rail, forming a rail seat. Another form is of similar section, but has a saddle piece of Λ-shape at each rail; the flat top rests on top of the web of the tie and forms a rail seat, while the horizontal flanges are riveted to the bottom flanges of the tie. The fastening intended to be used was a bed-plate of mild steel riveted to the tie; there were two lugs, the outer one holding the outer flange of the rail and the inner one being bent down to hold the inner side of the flange, or bent back when a rail or tie was to be removed. This would require a very soft metal to stand this bending and rebending without cracking, and steel made by the Gilchrist process was considered the best for this purpose. The fastenings by means of lugs and a key have, however, given excellent results. While this tie weighs, in position in the ballast, about 330 pounds (metal and stone), an ordinary wooden tie only weighs about 154 pounds.

The inventor had the following objects in view in designing this form of tie: (1) the suppression of movable fastenings, so that the tie could be made complete at the works, the track men only requiring a hammer for the bent lug; (2) the same base and the same resistance to longitudinal and transverse motion as a wooden tie; (3) easy ballasting; (4) the maintenance of the gauge and the inclination of the rails; (5) easy placing and removing; (6) ease of manufacture. In regard to this last point, however, it may be noted that the ties in use, with eighteen rivets each, represent a good deal of shop-work.

These ties have been tried on the Belgian lines of the Northern Railway of France.

*The Bernard Ties* (See plate No. 10.)—Mr. Bernard, engineer of the Belgian division of the Northern Railway of France, has invented a cross-tie consisting of two channel-irons placed back to back, and with a broad bed-plate riveted to the bottom at each end, each plate having eight rivets, and the end of the plate being turned up to make a closed tie. Each rail rests on a chair secured to the top of the channels by bolts, the ⊥ heads of which are on the under side of the top flanges of the channels. A special form of nut is used, having part of its lower face plain and part indented; the plain part bears on a washer which is large enough to leave a space between it and the bolt. In this space is a spring nut-lock of one spiral; the lower part of the spring has a lug which fits into a hole in the rail clamp, and the upper part has a tooth engaging with the teeth on the lower face of the nut and so preventing it from working loose. The tie may be made with two Z-irons instead of channel-irons, the lower flanges being inward. They can also be adapted for double-headed rails by using the regular chairs for this form of rail instead of the flat chair for flange rails.

In a pamphlet upon his patent tie, Mr. Bernard says:

"The tie may be considered as formed of two ties united; it presents two bearing points for the rail, so that the distance between these ties is gained in the general spacing of the ties and their number can be reduced 33 per cent. The distance between the two bolts on each side of the rail is 12.16 inches. For eight ties to a rail length of 29.52 feet, the joints are suspended, and the arrangement is 11.2 inches center to center of bolts of joint-ties, and 34.2 inches between the adjacent bolts of intermediate ties, except that the distance between the two middle ties is 35.12 inches. For six ties to a rail-length of 29.52 feet, the joints are supported and the arrangement is 41.68 inches between the bolts of the joint and shoulder ties, and 50.92 inches between those of the intermediate ties. The weight is from 242 to 305.8 pounds, but as each tie of this type is equivalent to one and a half ordinary ties, the comparative weight would be about 160 and 203 pounds respectively. For the spacing of six ties to a rail-length of 29.52 feet, Mr. Bernard suggests a rail about 6.4 inches high, 4.2 wide over the flange, 2.48 wide at the head, and weighing about 86 pounds per yard. The sixteen rivets per tie represent a good deal of shop-work, as with the 'Severac' tie."

These ties have been tried on the Belgian State railways and the lines of the local railways company.

*The Coblyn Ties* (See plate No. 10).—These are steel cross-ties of approximately T-section, but with a deep groove along the middle of the top table; the edges of the top table are turned down slightly and the ends are closed. For standard gauge lines they are about 7.8 feet long, 9.6 inches wide over all, 3.64 inches deep in the middle, and 1.04 inches at the sides, .32 inch thick on top, and weighing about 112.2 pounds. The cost, with fastenings, complete for rails weighing about 72.33 pounds per yard is about $1.89 per tie. For meter-gauge lines they are about 5.9 feet long, 8 inches wide, 3.5 inches deep in the middle, and .96 inch deep at the sides, .32 inch thick on top, and weighing about 61.6 pounds. The cost, with fastenings, complete for rails weighing about 42.25 pounds per yard is about $1.26 per tie. A special form of fastening is designed to be used with the heavier flange rails. The rail rests on a chair riveted to the tie; the inner side of the flange is held by a lug projecting 1.6 inches over it; on the outer side is a high jaw inclined toward the rail; over this fits a loose cap, with its inner face also inclined, and having a vertical groove; a taper wooden key is driven between the side of the cap and the web of the rail and bears tightly against the under side of the rail head; the wood swells into the groove in the cap so that the key can not work loose. The several parts of the fastening are stamped at the works. This fastening may be used for wooden ties, and it is claimed that the use of the tie plate will increase the durability of wooden ties and enable soft woods to be used.

These ties have been tried on the Liege and Luxembourg Railway, and adopted on the Liege and Seraing Railway. The riding over metal ties with the fastening described is said to be as quiet as, if not quieter than, over wooden ties with ordinary clamp or spike fastenings holding the rail by the flange; this is attributed to the holding of the rail by the web and head with an elastic body, which absorbs the vibrations. These ties give a good bearing for the rail, make a stable track, are easily ballasted, and may be used with broken stone or slag ballast.

*The Z-Iron Ties* (See plate No. 10).—These ties are composed of two rolled beams of Z-section, with vertical web, placed side by side with the lower flanges inward. At each end is placed a cast-iron rail chair with wings projecting down into the tie between the two beams; three rivets passing through each chair and the webs of the beams hold the pieces firmly together. The Z-irons present a great resistance to vertical bending motion, and the tie is very strong. The weight, including fastenings, for ordinary track, is about 195.8 pounds, and for rails weighing 100 pounds per yard about 209 pounds. The Z-irons for these heavy ties are about 2.6 inches wide, 4.4 inches deep, and .28 inch thick. The rails are of flange section, and are given the usual inclination by the seat of the chair; there is a lug on each side of the plate; the outer lug fits over the outer side of the rail flange, and a taper key is driven horizontally between the inner lug and inner side of the rail flange; to prevent the key from slacking back the end is split, and may be opened with a chisel when driven home, and a small wooden or metal wedge may be driven into the split end. This makes a very tight and secure fastening; the rail is fixed as in a vise; the surfaces in contact being extended, there is no wear or play, and consequently no vibration or rattling. It is estimated that the proposed ties, weighing 209 pounds, would cost $2.45 each, or $4,740.75 per mile with 1,935 ties per mile; white oak ties would cost, with plates and fastenings, $1.90 each, or about $4,907 per mile with 2,580 ties per mile. The reduced annual cost for maintenance is a special advantage. It is calculated that the annual cost per yard for maintenance would be with the metal ties 21.7 cents for ten years, 17.15 cents for fifteen years, or 12.21 cents for thirty years. With wooden ties 8 feet 2 inches long, 12 by 6 inches section, it would be 30.62 cents for ten years, and 22.92 cents for fifteen years. The track can be more readily and quickly laid than with rails spiked or clamped to wooden ties. The weight of the tie in the track is increased to about 396 pounds by the ballast within it, and it is very easily tamped and ballasted. These ties are to be given trials in various countries. The Congo Railway Company (in the interest of the Belgian Government) has ordered these ties for 270 miles of road, from Matade to Stanley Pool. The chief engineer of the Ottoman Railway, of Turkey (owned by an English company), has recently been in Belgium with a view to replacing the wooden ties with "Z" ties. The following railways also intend to experiment with them: Loando and Ambaca, in the Portuguese territory of the Congo; Portuguese State railways; Minho and Douro Railway, Portugal; South and Southeastern Railway, Portugal; State railways, France; Egyptian railways; Bone and Guelma Railway, Algeria.

SUMMARY OF METAL TRACK FOR BELGIUM.

| Railway. | Metal cross-ties, (about). |
|---|---|
| | *Miles.* |
| State | 100.00 |
| Great Central | 5.00 |
| Northern | .75 |
| Local | 9.75 |
| Total | 115.50 |

## GERMANY.

General Remarks.—Germany has an extensive system of railways, most of which are State railways. The principal system of the German Empire is that of the Prussian State railways, which are owned and operated by the Prussian Government; the system is divided into divisions corresponding with the several provinces of the Prussian Kingdom. The railways of the other States of the empire, not belonging to Prussia, are owned by the governments of these States as a rule. There are also several private railways, some of which are under government control. The lines are principally of standard gauge, 4 feet 8½ inches.

In this country very extensive experiments with metal track have been made, the experiments extending over a number of years and including trials of various types of track. The experience has been in general in favor of the metal track, and has led to its being adopted in some cases. The first experiments were made in 1862, and in 1880-'81 there were 2,875.5 miles laid with metal track, equal to 8.1 per cent. of the total mileage then in operation. In January, 1885, there were 3,234.54 miles laid with metal cross-ties, and 3,145.26 miles with metal longitudinals, a total of 6,379.80 miles of metal track, representing 16.52 per cent. of the total length of single track, which was then 38,608 miles. The following table, showing the growth of different classes of track on German railways, from 1878 to 1884, is from the report of Mr. Bricka to the minister of public works (France), and to it I have added the official figures for 1888:

*Mileage of German railways*, 1878–1884.

| Year. | Main lines. | Local lines. | Total track. | Wooden ties. | Metal longitudinals. | Metal ties. | Stone, blocks, etc. |
|---|---|---|---|---|---|---|---|
| 1878 | 18, 645. 88 | 833. 28 | 33, 343. 60 | 32, 008. 74 | 902. 10 | 175. 46 | 257. 30 |
| 1879 | 19, 041. 44 | 1, 582. 86 | 34, 904. 76 | 32, 621. 30 | 1, 574. 18 | 489. 18 | 220. 10 |
| 1880 | 18, 886. 44 | 1, 988. 96 | 35, 522. 90 | 32, 399. 34 | 1, 980. 28 | 828. 32 | 314. 96 |
| 1881 | 18, 978. 82 | 2, 165. 04 | 36, 061. 68 | 32, 150. 72 | 2, 359. 72 | 1, 240. 00 | 311. 24 |
| 1882 | 19, 001. 76 | 2, 582. 92 | 36, 906. 12 | 32, 088. 72 | 2, 604. 00 | 1, 905. 26 | 308. 14 |
| 1883 | 18, 982. 54 | 3, 059. 70 | 37, 697. 86 | 32, 008. 74 | 2, 892. 92 | 2, 485. 58 | 310. 62 |
| 1884 | 18, 931. 70 | 3, 642. 50 | 38, 608. 02 | 31, 914. 50 | 3, 145, 26 | 3, 234. 54 | 313. 72 |
| 1888 | 19, 169. 16 | 5, 107. 56 | 41, 290. 76 | 32, 147. 62 | 3, 562. 52 | 5, 224. 12 | 356. 50 |

During the past decade there has been considerable activity in the introduction of metal track, and the results have been in general thoroughly satisfactory. This experience is of more practical value than that of the earlier experiments, as the earlier forms of track were naturally deficient in many ways, while the more recent forms have been designed in accordance with the teachings of experience and have been in service under modern conditions of traffic. Both longitudinals and cross-ties have been tried on an extensive scale, but the former are not being used to any extent for new work, while large quantities of cross-ties are being introduced continually. It is stated on authority that on new lines and on such old lines as are to be thoroughly repaired, the Hilf system of longitudinals is not to be used any more, and the Haarmann system of longitudinals only to a limited extent. The reasons given are that the maintenance is difficult and the construction and drainage of the road-bed especially difficult. As regards the life of the ties, that is a point as yet undetermined; the earlier forms of ties were too weak for modern conditions of traffic, and those fitted for such conditions have only been in service for from five to ten years. On the Elberfeld division of the Prussian State railways (Westphalia), it is considered that metal ties will not have a longer life than wooden ties (fifteen years maximum); but in view of the experience with the earlier ties and of the durability of steel rails, etc., this estimate can hardly be considered as correct. Mr. Gustav Meyer, chief engineer of the Prussian State railways, is of opinion that the life of metal cross-ties of modern design may be estimated as at least double that of the best wooden ties, or thirty to forty years. Metal ties have been definitely adopted on some lines.

Wooden ties are still used to a very great extent, partly owing to the policy of the government to foster and develop the forests and encourage the forest industries, and partly on account of their smaller first cost. The native forests can not supply nearly enough timber to meet the demands, and large quantities of wooden ties are imported annually. The appropriations for railways in 1888 included about $2,500,000 for wooden ties and only $1,000,000 for metal ties, and it was estimated that the importation of wooden ties amounted then to $450,000. This has roused the iron and steel manufacturers, who have called the attention of the government to the fact that metal ties are a success in point of efficiency and economy, and they have petitioned the government to provide for a more rapid introduction of such metal track in the interests of the iron industries. Large quantities of metal ties are made for export; according to a report by Mr. Tanner, United States consul at Chemnitz, Germany exported 26,991 tons of steel ties in 1885 as compared with 17,000 tons in 1884.

It has been stated sometimes in the technical and daily press that the metal track has not proved satisfactory, and is being either discontinued or actually removed. The perusal of the following pages will show clearly that the metal track is a success and that a supposed economy is the main reason for the comparative slowness with which it is being further introduced. The fact of the use of metal ties at switches and frogs on the Prussian state railways (see the end of the part of this report relating to Germany) is an evidence of the efficiency of the track and the favor with which it is regarded. In the only instance where metal track has been abandoned (on the Altona division of the Prussian State railways) it is officially stated that local conditions of the ballast and road-bed, and not any deficiencies of the track, have led to this action. The tracks laid with wooden ties are being improved by the extensive introduction of heavy metal tie-plates and improved fastenings for the rails. The wooden ties are usually treated with some preservative process. The administration of the Saxony State railways report that wooden ties are used almost exclusively upon these lines.

The extent of metal track on the Prussian State railways in 1886 and 1887 was as follows:

| | 1885-'86. | | 1886-'87. | |
|---|---|---|---|---|
| | Cross-ties. | Longitudinals. | Cross-ties. | Longitudinals. |
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| Main tracks | 2,480 | 2,232 | 2,870.60 | 2,275.40 |
| Side tracks | 248 | 124 | 260.40 | 124.00 |
| Total | 2,728 | 2,356 | 3,131.00 | 2,399.40 |

New material was used as follows:

| Year. | Iron ties and longitudinals. | | | Wooden ties. | | |
|---|---|---|---|---|---|---|
| | Tons. | Total cost. | Cost per ton. | Number. | Total cost. | Cost per tie. |
| 1885–'86 | 40, 214 | $1, 356, 067. 00 | $33. 75 | 1, 510, 806 | $1, 7[illegible]4, 246. 25 | $1. 18 |
| 1886–'87 | 31, 913 | 1, 041, 760. 75 | 32. 75 | 1, 581, 169 | 1, 876, 552. 50 | 1. 15 |

The following table gives the quantities of wooden and iron ties laid in 1886, 1887, and 1888:

*Prussian state railways.*

| Year. | Wooden ties. | Metal ties. | Wood. | Metal. |
|---|---|---|---|---|
| | *No.* | *No.* | *Per cent.* | *Per cent.* |
| 1885–'86 | 1, 507, 263 | 672, 086 | 69. 16 | 30. 84 |
| 1886–'87 | 1, 582, 877 | 522, 470 | 75. 18 | 24. 82 |
| 1887–'88 | 1, 654, 304 | 493, 623 | 77. 02 | 22. 98 |

*All railways in Germany.*

| Year. | Wooden ties. | Metal ties. | Wood. | Metal. |
|---|---|---|---|---|
| 1885–'86 | 2, 462, 004 | 1, 007, 152 | 70. 97 | 29. 03 |
| 1886–'87 | 2, 544, 992 | 868, 262 | 74. 56 | 25. 44 |
| 1887–'88 | 2, 677, 424 | 750, 670 | 78. 10 | 21. 90 |

The following table gives the comparative mileage of different classes of track from 1880 to 1885:

| Year. | Cross-ties. | | | Longitudinals—iron (mileage). | Total mileage. | |
|---|---|---|---|---|---|---|
| | Wood. | Iron. | Mileage. | | Cross-ties. | Longitudinals. |
| | *Per cent.* | *Per cent.* | | | *Per cent.* | *Per cent.* |
| 1880–'81 | 96. 73 | 2. 43 | 33, 442 | 2, 046. 5 | 94. 10 | 5. 76 |
| 1881–'82 | 95. 39 | 3. 74 | 33, 704 | 2, 422. 6 | 93. 18 | 6. 70 |
| 1882–'83 | 93. 51 | 5. 63 | 34, 270 | 2, 636. 5 | 92. 76 | 7. 14 |
| 1883–'84 | 91. 90 | 7. 23 | 34, 873 | 2, 957. 3 | 92. 10 | 7. 81 |
| 1884–'85 | 89. 97 | 9. 18 | 35, 416 | 3, 219. 3 | 91. 55 | 8. 32 |

NOTE.—Small balance of length not accounted for.

About June, 1889, the following note on this subject appeared in "Kuhlow's German Trade Review:"

*Metallic v. Wooden Ties in Germany.*—As far back as last year the North-German group of the German Iron and Steel Manufacturers' Union and the German Ironmasters' Union addressed a petition to the minister of public works, in which the latter was requested to take steps so that the use of wooden ties should not only not become greater, but that the substitution of iron or steel ties for wood might be continued, as was the case in the previous year, and to proceed with the view to having everything connected with the railway lines only of iron and steel. The societies above named have recently again addressed themselves to the minister with the request that the latter do all in his power to put an end to the importation of foreign wooden ties, and to supply the deficiency thus created by an increased use of iron ties. The petitioners assigned a number of reasons for their action. The increase in the use of iron ties, which on the Prussian railways was 11½ per cent. on the quantity in use in 1883-'84, was only .53 per cent. on the other railways of Germany, while the German forest owners derived no benefit therefrom, as can be proven by the figures representing the yearly importation from abroad of wooden ties. The amount of wages lost by German railway workmen consequent upon importing ties from abroad is calculated at $1,392,187.50 and the loss caused by the diminution in the traffic on the state railways at $371,250. A reply to the petition has just been received from the minister of public works, in which he states that he is very glad when he can encourage the use of iron ties on the Prussian railways as formerly, but he is not in a position to accede to the request of the petitioners to exclude as far as possible the wooden ties. The wooden ties, particularly after the new improvements in the tie-plates and track fastenings, have proved themselves to be especially suitable as supports for the rails, while the iron ties hitherto supplied have not sufficiently justified their use on those portions of the line in which a fine or impervious material for ballast has to be reckoned with. When iron ties are produced which will obviate the difficulties attendant on their use in the cases named a large increase in their application will take place even on those lines on which they have been hitherto used only to a limited extent.

PRUSSIAN STATE RAILWAYS.—*Berlin division (province of Brandenburg).*—Metal longitudinals of the "Hilf" and "Haarmann" types are used (See plate No. 12), and at the end of 1884 there were 473 miles of this class of track in service. The Haarmann longitudinal, as now used, is in lengths of 29.49 feet, weighing 508.95 pounds, or 51.75 pounds per yard; it has the middle part about 4 inches wide, 2.08 inches deep, and .36 inch thick, with a rib on each side of the top table, forming a groove for the flange of the rail; the flanges of the longitudinal are inclined downwards toward the outer edge at a slope of 1 in 12 and the edges are bent down vertically to a depth of 1.18 inches; the width over the flanges is 12.8 inches. The rail clamps are short channel plates (⊏), with the top flange bearing on the rail and the bottom flange on the inner side of the longitudinal; the two clamps are held together by a bolt .76 inch diameter passing through the clamps and through the upper part of the longitudinal, under the rail. At the joints the ends of the longitudinals rest on a saddle plate of inverted channel section, with a deep groove rolled in the top table, which is inclined so as to make the outer side of the longitudinals higher than the inner side, and so give the rail the usual inward inclination. The lower flanges of the rail clamps pass through the top of the saddle, taking a bearing on the under side of the top table. The saddle is secured to a bed plate 19.28 inches wide and .40 inch thick, by bolted clamps on the Ruppel plan (See plate No. 13). The rails are of flange section, weighing 59.7 pounds per yard; they are 29.52 feet long and 5 inches high, with a flange 3.40 inches wide. The rail joints are spliced by deep angle-bars having a vertical web projecting below the rail. The weight of the track complete is 1,616.55 pounds per rail length, or 179.63 pounds per yard. This system of metal track is used on the Berlin City Railway.

The Haarmann combined rail and longitudinal has also been tried for a length 3.1 miles. This compound rail (See plate No. 12) was a large flange rail composed of two pieces placed side by side; it was 8 inches high over all, 12 inches wide over the flange, with a head 2.4 inches wide; the two parts were connected by two rows of rivets, and the joints were spliced by angle-bars 16 inches long, with eight bolts in two rows. The two parts of each rail broke joint by 20 inches. Flat tie-bars, with ends bent at right angles and secured by bolts passing through the webs of the rails, were placed at intervals of 9 feet $10\frac{1}{8}$ inches. The weight of this track was 273 pounds per yard.

The following is Mr. Bricka's statement of the track of this division at the end of 1884:

| | Miles. |
|---|---|
| Main lines | 1,414.22 |
| Local lines | 163.68 |
| Total track | 2,762.72 |
| Wooden ties | 2,276.64 |
| Metal longitudinals | 473.06 |
| Metal ties | 1.24 |
| Stone blocks, etc | 11.78 |

Two systems of track are adopted for the bridges of the city railway, for the purpose of deadening the noise: (1) The rails rest on iron longitudinals, of the Haarmann type, connected by iron cross-tie connections, wooden packing blocks being placed between the two parts. A water-tight casing, hung below the floor, receives all water and drainage and is covered with a thin layer of gravel to deaden the noise from vibration. The wooden blocks are difficult to maintain. (2) The longitudinals are bedded in gravel laid in troughs along the bridge, the top of the longitudinal being level with the top of the trough. The floor is of buckle plates covered with gravel. This track is heavy and alterations cannot easily be effected for frogs and switches, while it is difficult to tamp the longitudinals properly.

PRUSSIAN STATE RAILWAYS.—*Elberfeld division (province of Westphalia).*—This division includes most of the lines in the industrial district of the Rhine, in Westphalia, and has a heavy traffic on its principal lines. It also includes the former Berg and Mark Railway, the name of which is well known in connection with metal track, this road having been one of the first to experiment on a large scale with such track. The following is Mr. Bricka's statement of the track for 1884:

| | Miles. |
|---|---|
| Main lines | 587.76 |
| Local lines | 159.96 |
| Total track | 1,590.30 |
| Wooden ties | 912.02 |
| Metal longitudinals | 41.54 |
| Metal ties | 629.30 |
| Stone blocks, etc | 7.44 |

The first trials made in Germany with metal ties were made on the old Berg and Mark Railway. The trials were commenced in 1869, with ties of the original "Vautherin" type; these were 3.2 inches wide on top, 6.8 inches wide inside on the bottom, and 9.2 inches wide over the flanges; 2.4 inches deep; the sides and top were .24 inch thick and the flanges .32 inch thick; the weight was 40.70 pounds; the ends were open. This type not proving satisfactory, changes were made which led to the designing of the "Berg-and-Mark" (or Bergisch-Markische) type of tie. It is a modification of the "Vautherin" type, doing away with the narrow horizontal flanges at the bottom, and having the lower part of the sides bent to a vertical position (See plate No. 12). The tie was 7.5 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the thickness was .24 inch at the bottom, increasing to .36 inch at the top, and on the under side of the top table was a rib 1.44 inches wide, making the thickness .52 inch to give extra strength at the holes for the fastenings. The tie was horizontal for a length of 3 feet 3$\frac{3}{8}$ inches at the middle, and then inclined upward 1 in 20 to the ends, which were closed by bending over the top table. The weight of the tie was 98 pounds, and of the fastenings 5.4 pounds, making a total of 103.4 pounds per tie. The rails were of flange section, weighing 66 pounds per yard, and having a flange 4 inches wide. The fastenings of each rail consisted of three gibs and a cotter (See plate No. 13). The outer flange was held by a gib, the lower side of which bore on the inside of the tie; a similar gib held the inner flange, and a small gib was placed against the opposite side of the hole in the tie, so as to give a good bearing for the cotter, which was driven down vertically between these two gibs. The cotter was about 6$\frac{1}{2}$ inches long, eleven-sixteenths inch thick—1$\frac{5}{32}$ inches wide at top and thirteen-sixteenths inch wide at 1$\frac{3}{32}$ inches from the end, thence tapering to a point; the side furthest from the rail was perpendicular to the top of the tie. The gibs were all eleven-sixteenths inch thick; the outer and the small inner gibs were made in three different widths, to allow for the adjustment of the gauge at curves, etc. At the rail joints the ties were spaced 20.4 inches apart, center to center.

Metal ties only are now used for main lines; metal and wooden ties are used for branch and local lines. The ties for main lines are of the modified Berg-and-Mark type (See plate No. 12). They are 8.2 feet long, 4.4 inches wide on top, 8.72 inches wide inside at the bottom, and 9.36 inches wide over the ribs on the bottom edges; they are 3 inches deep, with the sides nearly vertical for 1.5 inches from the bottom; the sides are .28 inch thick; the top table is .36 inch thick, with a strip along the middle .52-inch thick for a width of 1.44 inches, the extra metal being added on the under side. The middle part of the tie is horizontal for a length of 3 feet 3$\frac{3}{8}$ inches, and is then inclined upward 1 in 20 to the ends, which are closed by bending down the top table. The weight is 119.24 pounds per tie. There are 10 ties to a rail length of 29.52 feet; the joint ties are spaced 24 inches apart center to center, and the intermediate ties 37.04 to 37.08 inches apart. The rail fastenings are gibs and cotters arranged as above described; the outer gib weighs .75 pound, the inner gib .68 pound; the small gib .26 pound, and the cotter .97 pound. The rails are of flange section, 29.52 feet long, weighing 67.2 pounds per yard; they are 5.36 inches high, and have a flange 4.20 inches wide. The weight of the track is 2,696.93 pounds per rail length, or 274.08 pounds per yard. The ties for local lines are of the original Berg-and-Mark type; 8.2 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides are .28-inch thick, and the top table .36-inch thick, with a rib along the under side, making it .52-inch thick for a width of 1.44 inches. They are bent to shape and have the ends closed in the same way as the heavier ties. The weight is 106.26 pounds per tie, and the track weighs 2,567.13 pounds per rail length, or 260 pounds per yard.

The following is a detailed statement, furnished in July, 1888, by the officers of the division for the purpose of this report:

This division includes the former Berg-and-Mark Railway, and in 1887 it comprised about 806 miles of line, with about 1,649.20 miles of main and side tracks, laid as follows:

| | Miles. |
|---|---|
| Wooden cross-ties | 790.50 |
| Metal cross-ties | 762.60 |
| Metal longitudinals | 93.00 |

The lines are divided into two classes, according to their traffic; main lines, generally with double track, with a maximum grade (exceptionally) of 1 in 75, or 1.33 per cent., and a minimum curvature of 984 feet radius; local or branch lines, with single track, a maximum grade of 1 in 40, or 2.5 per cent., and a minimum curvature of 590.40 feet radius.

The first trial of iron cross-ties was made in 1869 by the Berg-and-Mark Railway. In 1874 they were used to a larger extent, and in 1877 a further introduction of them was commenced. Iron longitudinals have not been laid on the lines of this division, but in 1880, when all the Prussian railways were acquired by the Government, the boundaries were extended, and so included parts of some lines using these longitudinals. On main lines the traffic is about one hundred and sixty trains per day (on double track), at speeds of 46.5 miles per hour for passenger trains and 27.9 miles per hour for freight trains; the six-wheel engines weigh about 42 tons, with 7 tons on the driving wheels. On branch lines the traffic is from twenty-five to thirty trains per day, at a speed of 18.60 miles per hour for passenger and freight trains. The six-wheel engines weigh about 30 tons, with 5 tons on the driving-wheels.

The ties are now made of mild steel, and for their manufacture the basic process of Thomas Gilchrist has recently been used; no preservative process has been used; the ties are laid in the condition they leave the rolls, and there is very little trouble from rust. They are manufactured by a number of works, proposals being advertised for in the usual way. The cost at the mills in 1888 was from $27.50 to $30 per ton, or about $1.50 to $1.62½ per tie for main lines and $1.32½ to $1.45 per tie for branch lines. The gibs and cotters, being of wrought-iron, cost at the same time $72.50 per ton. The cost of maintenance of the ties is very small, as the works furnishing the ties must give a guaranty for two years, replacing every tie which becomes damaged during this time. If a tie has internal defects which escape notice at the inspection, they will show themselves within two years, and it is found that after that any failure of the ties now used is very rare. On the other hand, the labor for the maintenance of track on metal ties is considerable, and is greater as the ballast is less hard and less porous. This is especially the case during the first few years, until the track has settled to a firm bearing. It seems, therefore, that metal ties require the best broken stone ballast, and with this material the cost of maintenance of track on metal ties is scarcely greater than that of track on wooden ties, especially as the item of renewals (necessary for wooden ties in a few years) is eliminated. Exact comparisons between the cost of maintenance of track on metal and wooden ties on this division cannot be made, as the expenses are not separated, and there are wooden ties only on branch lines and on main lines with little traffic. All tracks having considerable traffic are now laid with metal ties. There has been no experience as to the life of metal ties. With the present form of tie there are no breakages under ordinary circumstances, and there is no weakening by rust discernible, not even with the older ties. Wherever a renewal has been necessary it has been on account of the enlargement of the holes in the tie by wear or of a crack between the holes. In no case can it be said that metal ties last longer than wooden ties.

[In this connection, however, it may be remarked that wooden ties in Europe have a much longer life than in this country, from fifteen to twenty years or more, owing to the use of rail chairs, broad tie-plates, and preservative processes.—E. E. R. T.]

As remarked above, metal ties require ballast of the best quality. On this division broken stone of a hard and durable character is used; this material costs from 62½ cents to $1.12½ per cubic yard according to locality, while gravel ballast for wooden ties costs only 25 to 62½ cents per cubic yard. The experience here is that metal ties have a tendency to grind the softer ballast to dust, which in wet weather becomes mud. If the ballast consists of soft clayey gravel, the cost of maintenance is proportionately greater. Without ballast metal ties could not be used at all. [They are, however, successfully used under such conditions in Australia. See "Queensland."—E. E. R. T.] On the other hand, ballast of hard broken stone forms a solid hard body in the interior of the tie, which contributes considerably to the firm bedding of the track. For main lines there is a bottom course of large stones and the smaller material is brought up level with the tops of the ties; it is 21.97 feet wide on top (for double track), with side slopes of 1 to 1½ and a depth of 14 inches at the middle; the subgrade is crowned to an inclination of 1 in 25. For local lines the style of construction is the same; 10.5 feet wide on top with side slopes of 1 to 1, and a thickness of 6 inches under the tie at the middle. The attachments of the rail do not cause any difficulty; on the contrary, the position of the rails is more securely maintained than with wooden ties, and any loose fastenings can be easily tightened by driving the cotters, while with wooden ties respiking would be necessary.

An impulse to the general use of iron ties on this division was given by the hard times of the home iron industry at the end of the last decade; in consequence of which the prices were so low that iron ties were actually cheaper than wooden ties, which had to be imported, as the home forests could not supply a sufficient quantity. The use of metal ties was also, partly from a patriotic motive, to help the iron industry. The experience with these ties was in general satisfactory, and their use was therefore continued. The dephosphorizing of the poorer German ores by the Thomas Gilchrist process has also been favorable to the use of metal ties by reducing the price for mild steel. Oak ties for main lines cost $1.37½ each, or $1.50 if impregnated with chloride of zinc; for branch lines some impregnated beech ties have been used, costing 96 cents each. The life of wooden ties varies between five and fifteen years; a life of ten years is rare even for oak ties, as on account of the occasional respiking they become weakened, even if still sound. The value of old material must be taken into account, for while old wooden ties are practically of no value, old iron ties can be sold for $11.25½ to $12.50 per ton, or about 62½ cents each. On the whole, metal ties appear to be as serviceable as wooden ties; a disadvantage consists in their less elasticity, as riding over them feels harder to the passengers; but they have the advantage of a firm and accurate rail fastening. The climate is uniform and moist, having about the same effect upon wooden and metal ties. On the strength of our experience we can consider metal ties only equal to the best wooden ties. It will depend upon local circumstances whether their use will be economical; if, as in our district, the first cost is not much higher, and if there is good material for ballast available at a low price, then the use of metal ties may be considered advantageous and economical on account of their longer life and their value as old material.

PRUSSIAN STATE RAILWAYS.—*Cologne Division, right bank of the Rhine (province of the Rhine, or Rhenish Prussia).*—Metal track of different types has been tried on this division since 1868. A longitudinal used was similar to the "Vautherin" type of cross tie; it was $8\frac{11}{16}$ inches wide on top, $11\frac{13}{16}$ inches wide on the bottom, $2\frac{3}{8}$ inches deep, five-sixteenths of an inch thick on top; the weight was 46.36 pounds per yard. Cross-ties of similar form were also used; they were 7 feet $4\frac{9}{16}$ inches long, $3\frac{15}{16}$ inches wide on top, $8\frac{11}{16}$ inches wide at the bottom, $2\frac{3}{8}$ inches deep, five-sixteenths of an inch thick on top; the weight was 77.16 pounds per yard, or 82.76 pounds including the fastenings. These were manufactured by the Gutehoffnung works at Oberhausen. The longitudinals were closed at the ends by angle-pieces bolted on; the gauge was maintained by means of tie-rods of round iron passing through the webs of the rails and having a washer and nut on each side of each rail; the rails were fastened by clamps and bolts. The rail joints were even and suspended, spliced by angle bars and channel bars. With the cross-ties, the rails of flange section were secured by bolts and clamps similar to the Ruppel plan (See plate No. 13). The ties were bent up at the ends to give the rails an inward inclination. For a rail length of 21 feet $8\frac{1}{4}$ inches, the ties were spaced $21\frac{3}{4}$ inches apart, center to center at the joints, $32\frac{7}{8}$ inches next to the joints, and $39\frac{3}{8}$ inches intermediate, giving eight ties to a rail length. The rail joints were even and suspended and were spliced by angle bars.

Cross-ties of the "Haarmann" type (See plate No. 12), have been in use for some years on the Cologne and Minden line; they are 7 feet $10\frac{1}{2}$ inches long, the middle part is $4\frac{5}{16}$ inches wide on top and $1\frac{15}{16}$ inches deep, the width over the bottom flanges is $9\frac{13}{16}$ inches, and the edges of the flanges are turned down for a depth of thirteen-sixteenths of an inch; the thickness of the top is three-eighths of an inch. The ends of the tie are bent upward, and the extremities are closed by bending down the top table, instead of by riveted pieces; the rail fastenings consist of bolts and clamps on the Ruppel plan. The weight per tie is 108 pounds, or 113.9 pounds including the fastenings. For a rail length of 30 feet the ties are spaced $20\frac{1}{8}$ inches apart, center to center, at the joints, $33\frac{5}{8}$ inches next to the joints, and 39 inches intermediate. The Haarmann system of longitudinals has also been used. The longitudinals were 3.92 inches wide at top and bottom of the "cap," 2.08 inches deep; the width over the flanges was 12.8 inches, and the total depth 3 inches; thickness of the flanges, sides and top table was .24, .28, and .36 inch. The weight was $47\frac{1}{2}$ pounds per yard. The track is similar to that of the Berlin Division, already described. The longitudinals were 29.52 feet long, laid with even joints, but breaking joint with the rails. At each joint was an angle iron cross-tie, 6.23 feet long; at each end of it was a saddle to which the ends of the longitudinals were fastened.

The following is Mr. Bricka's statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 920.08 |
| Local lines | 234.36 |
| Total track | 2,241.92 |
| Wooden ties | 1,758.94 |
| Metal longitudinals | 124.62 |
| Metal ties | 347.20 |
| Stone blocks, etc | 11.16 |

Iron cross-ties of the modified "Berg-and-Mark" type (See Plate No. 12) are now in use on this division. They are 8.2 feet long for heavy ballast, or 8.85 feet long for light ballast; 5.2 inches wide on top, 9.44 inches wide at the bottom, 3.2 inches deep, with the ends 3.6 inches deep; the thickness of the sides is .28 inch, and of the top table .32 inch. The tie is horizontal, but at each rail seat is a tie-plate giving the rail the usual inward inclination; the outer end of this plate has an S-shaped lug, the top part holding the outer side of the rail-flange, and the lower part passing through a slot in the tie and bearing on the underside of the top table. The inner flange of the rail is held by a bolt and clamp on the Ruppel plan, the lug of the clamp passing through the bolt-holes in the tie-plate and tie. The joint ties are spaced 26.68 inches apart, center to center; and the intermediate ties 37 to 37.04 inches. The rails are of flange section 29.52 feet long, 5.36 inches high, with a flange 4.20 inches wide; they weigh 67.2 pounds per yard. The rail-joints are spliced by deep angle-plates, having a web projecting below the rail, the ends of this web being cut to fit the slope of the side of the tie; there are four bolts to each joint. The track, with ties 8.2 feet long, weighs 2,750.09 pounds per rail length, or 305.58 pounds per yard.

In June, 1888, there were altogether 612.75 miles laid with metal track, 450.69 miles with cross-ties, 153.78 miles with longitudinals not having cross-tie connections, and 8.28 miles with longitudinals having such connections. There are also on one of the local lines 7.8 miles of the Hartwich system of combined rail and longitudinal, laid directly in the ballast.

PRUSSIAN STATE RAILWAYS.—*Cologne Division, left bank of the Rhine (province of the Rhine, or Rhenish Prussia).*—On this division metal track has been used very extensively, and several different forms of track have been tried. Metal cross-ties are now exclusively used for renewals and new work. The following is Mr. Bricka's statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 850.02 |
| Local lines | 168.64 |
| Total track | 2,117.30 |
| Wooden ties | 1,212.10 |
| Metal longitudinals | 252.34 |
| Metal ties | 639.84 |
| Stone blocks, etc | 13.02 |

Of longitudinals the "Hilf," "Rhenish," and "Haarmann" types have been used, but no new track of this kind is now laid. Of cross-ties the Vautherin type was first used, then the Rhenish, the original Berg-and-Mark, the modified form of the "Berg-and-Mark," and the "Haarmann" tie. The modified form of the Berg-and-Mark type was considered the best. The "Haarmann" tie was ordered by the minister of railways to be used on most of the divisions of the State railways, but it is reported that it has not given as much satisfaction as some other systems, and its use is not being extended. The ties of this type used on this division were 7.8 feet long, with the middle part horizontal, and the ends inclined upward 1 in 20 for a length of 26 inches. It was 4.4 inches wide on top and 4.8 at the bottom of the "cap," 2 inches deep; 10 inches wide over the flanges and 2.56 inches deep over all; the thickness varied from .28 inch to .36 inch. A piece of N-iron (or double-angle iron) was riveted inside at each end and at the middle. The weight of the tie was 110 pounds. With cross-ties of the modified "Berg-and-Mark" type the Haarmann system of combined tie-plate and fastening has been used, as already described for the Right Bank of the Rhine Railway.

A special return from this division was furnished in 1888 for the purpose of this report, as follows:

Of the 1,681.81 miles of line, 943.96 miles were laid with metal cross-ties and 241.45 miles with metal longitudinals, the remainder being still on wooden cross-ties. The track on longitudinals included 43.44 miles of the Rhenish type, 1.86 miles of the Haarmann type, and 200.57 miles of the Hilf type, a total of 245.87 miles, of which about 5 miles of the first two types were for experiment. The first longitudinals were laid in 1872 and the first cross-ties in 1876.

The division has 30 per cent. of its length horizontal and 70 per cent. on grades; the steepest grade is 1 in 37, or 2.7 per cent. In alignment there are 65 per cent. of tangents and 35 per cent. of curves; the sharpest curve has a radius of 590.40 feet. The traffic consists of passenger and freight trains, some of the former being express trains. The standard four-coupled passenger engines weigh 37 tons, having 24.4 tons on the two driving axles and 12.6 tons on the leading axle or truck; the tender weighs 27.5 tons. The standard six-coupled freight engines weigh 38.5 tons, and their tenders 27.5 tons. The standard six-coupled tank engines for branch or local lines weigh 29.2 tons.

The ties are of mild low-carbon steel, and are not painted or otherwise treated. They are manufactured by the Aachen Mills; the Phœnix Company, of Laar; the Union Company, of Dortmund; the Rhenish Steel Works, of Ruhrort; and the Good-Hope Works, of Oberhausen. The cost, delivered, is about $31.25 per ton. In regard to maintenance, every mile of track on metal longitudinals requires about 372.58 days' labor of one man per annum (231 days per kilometer), and every mile of track on metal cross-ties requires about 267.74 days' labor of one man per annum (166 days' labor per kilometer). The adjustment or widening of gauge at curves is effected by means of different sizes of rail clamps without varying the holes in the ties. The observations as to durability are not yet concluded. The ballast consists principally of river gravel, but broken stone is used in some places. It is satisfactory for cross-ties, but with longitudinals care must be taken to provide proper drainage. The principal reason for adopting metal ties was their advantage in maintaining the width of gauge accurately, and the convenience of track laying and tamping was also considered. In localities poor in wood the cheaper cost and at least the same, but probably longer, life than that of impregnated wooden ties must be taken into account.

The general results have been very satisfactory. There has been no trouble with maintenance, or with the rail attachments, which are much more secure than the ordinary spikes in wooden ties. No trouble has been experienced from breakages. With metal track the ties are more durable, so that the track is more economical; and the fastenings are more efficient, so that the track is safer than track on wooden ties.

Impregnated oak ties cost, exclusive of the value of old material, about $1.75 each, or about $3,104.84 per mile. They have an average life of about twenty years. The simplest testimony as to the opinion of the advantages of metal and wooden ties is that since 1879 no wooden ties have been purchased, iron ties having been used exclusively.

The drawings accompanying this communication show cross-ties of the "Haarmann" and the modified "Berg-and-Mark" types. The latter are 9.36 inches wide on the bottom, 3 inches deep over all, with the sides and top .28 and .36-inch thick respectively; the weight is 110 pounds. The former are 4.4 inches wide on top and 4.24 inches wide inside at the bottom of the "cap," 10 inches wide over the flanges; the middle part, or "cap," is 1.64 inches deep, and the flanges are turned down .80 inch, making the total depth over all 2.56 inches; the flanges are .24 inch thick, the sides .28 inch, and the top table .36 inch; the weight is 110 pounds. Both these forms of ties are 7.87 feet long, horizontal at the middle for a length of 3.6 feet, and then inclined upwards to the ends at an inclination of 1 in 20. No tie-plates are shown, the rails resting directly on the ties and being secured by bolted clamps on the Ruppel system. The rails are 5.36 inches high and 4.20 inches wide over the flange; the rail joints are even and suspended, and are spliced by deep angle bars, projecting below the rail, with four bolts. For a rail length of 29.52 feet the ties are spaced 26.68 inches apart, center to center, at the joints, 33.76 inches next to the joints, and the intermediate ties 38 inches.

Cross-ties of the "Hoerde" or "Post" type have also been used.

The system of rail attachment designed by Mr. Ruppel, of this division, is in extensive use and has given general satisfaction. (See Plate No. 13.) The rail is held by a clamp of such form that while the inner side bears on the rail flange the outer side bears on the top of the tie; on the under side of the outer edge is a lug or projection which fits into the bolt hole in the tie. The bolt passes up through the tie and clamp, and the nut is secured down on the latter; the head of the bolt is of ⊥-shape, so that the bolt can be put in or taken out without disturbing the ballast or the tie. The adjustment of the gauge at curves, etc., is effected by using clamps with lugs of different widths fitting into the bolt holes.

PRUSSIAN STATE RAILWAYS.—*Frankfort-on-Main division* (*province of Nassau*).—Metal longitudinals of the "Hilf" type were used in 1868 on the Nassau State Railway, now a part of this division of the Prussian State Railways. The following is a brief notice of the several different systems of metal track which have since been tried:

Cross-ties: (1) Ties of the original "Vautherin" type, with gib and cotter fastenings, open ends, and a piece of T-iron riveted across the bottom of the tie under each rail; (2) ties of similar section, but with bolted clamp fastenings and having the ends closed by riveted angle pieces (as on the left bank of the Rhine Railway; (3) ties of the "Berg-and-Mark" type, with bolted clamp fastenings and with an angle iron riveted inside the tie under each rail; (4) similar tie and fastenings, but with the ends closed; (5) ties of the original "Vautherin" type, with bolted clamp fastenings and with the top table bent down at the ends; (6) ties of Haarmann section, with bolted clamp fastenings and closed ends, 1881; (7) modified form of "Haarmann" tie, with the upper part wider and flanges narrow; bolted clamp fastenings, ends closed by riveted angle pieces, 1885; (8) similar to No. 7, but with the top table inclined at the rail seats.

This is the form of metal cross-tie adopted in 1887, as noted further on: Longitudinals, (1*a*) "Hilf" type, two forms of sections, one with middle rib, the other without the middle rib and resembling the original "Berg-and-Mark" cross-tie; the joints of rails and longitudinals coincided and round tie rods maintained the gauge; (1*b*) longitudinals with middle rib; they were not brought close to the rail joints, but a cross-tie of similar section was placed on each side of the joint; (1*c*) longitudinals and rails laid to break joint, with a cross-tie of similar section under the rail joints; (1*d*) similar track, but with the cross-ties placed back from the rail joints; (1*e*) joints of longitudinals and rails coincided; a cross-tie or similar section was placed under the joints and had a saddle support for the longitudinals; (1*f*) similar to No. 1*e*, but with the addition of a T-iron cross-tie at the middle of the rails. This is the form of metal longitudinal track adopted in 1888, as noted further on. (2) Longitudinals of Hilf section, with joints coinciding with rail joints, and an angle iron cross-tie fastened to the rails at the joints; (3*a*) similar longitudinals, with T-iron cross-ties under the joints and a saddle for the longitudinal; (3*b*) similar to No. 3*a*, but with a different seat for the longitudinals and with cross-ties of the Lasard section (**T**) under the joints; (3*c*) similar to No. 3*b*, but with a T-iron cross-tie on each side of the joints; (4) similar in general to No. 3*c*. The following is Mr. Bricka's statement of the track for the end of 1884:

| | *Miles.* |
|---|---|
| Main lines | 639.84 |
| Local lines | 37.20 |
| Total track | 1,468.78 |
| Wooden ties | 790.50 |
| Metal longitudinals | 634.88 |
| Metal ties | 37.82 |
| Stone blocks, etc | 5.58 |

Metal cross-ties and longitudinals are now in use for main lines. The former are of the "Haarmann type" (See Plate No. 12) 8.2 to 8.86 feet long, 6.4 inches wide on top, 7.2 inches wide at the bottom of the cap, 9.2 inches wide over all; the depth is from 2.8 inches at the ends and middle to 3.4 inches at the inclined rail-seat; the weight is 112.4 pounds per tie for the shorter, and 127.93 pounds for the longer, ties. There are ten ties to a rail length; the joint ties are spaced 28 inches, center to center; the next ones 33.12 inches, and the intermediate ties 37.96 inches. The rails are of flange section and the joints are spliced by deep angle-bars. The fastening for the rails consists of a bolt with a gauge-washer against which the rail flange abuts, and a channel-shaped clamp fitting over the washer and bearing on the tie and rail-flange. It is somewhat similar to the fastening used on the Baden State railways (See plate No. 13), but with the exception that the gauge-washer fits into the bolt-hole in the tie, having an eccentric head which rests on the top of the tie. This system of fastening appears to combine the advantages of the Ruppel and Baden systems; the gauge-washer by fitting into the bolt-hole adding greatly to the solidity of the fastening and reducing the strain on the bolt. The weight of this track is 2,815.30 pounds per rail length or 286 pounds per yard.

The longitudinals now used are of the Hilf type (See plate No. 12). They are 29.38 feet long, 7.2 inches wide on top, 12 inches wide at the bottom, 2.6 inches deep, with the top table .52-inch thick. The weight is 674.75 pounds, or 69 pounds per yard. The rails are of flange section, and the fastenings consist of bolted clamps of channel shape (⌐¬) which bear on the longitudinal and the rail flange. Under the rail-joint is a cross-tie of the same section as the longitudinal; it is 8.53 feet long, and weighs 196 pounds. The cross-tie is under the longitudinals, which are fastened to it by large angle clamps (—¬), with bolts passing through the cross-tie and the horizontal part of the clamp. Two channels are riveted across each end of the cross-tie and support the top table of the longitudinal from the inside. At the middle of the rail length is a T-iron cross-tie, 8.2 feet long, 5.6 inches wide, 6 inches deep, and weighing 154 pounds or 66.34 pounds per yard. On curves of less than 1,640 feet radius two of these cross-ties are used. The weight of this track is 3,040.75 pounds per rail length of 29.52 feet, or 337.85 pounds per yard.

In September, 1889, the officers of this division stated that the Hilf system of longitudinals will in future be used only to a small extent on a certain part possessing excellent material for ballast, which lets the water drain off quickly. Iron cross-ties are used on parts where stone ballast is readily obtainable. Where the road bed is in clayey or loamy sand wooden ties are used exclusively on new branch and local lines. For the renewals on all lines during 1889 about an equal number of iron and wooden ties were used.

PRUSSIAN STATE RAILWAYS.—*Erfurt division (province of Thuringia).*—Various systems of metal track have been tried on this line, both with longitudinals and cross-ties, but the latter have now been definitely adopted. In October, 1889, the officials of this division forwarded a detailed statement in regard to their experience with metal track.

Metal ties were first laid in 1879, and there are now 251.10 miles of track on seven sections of the line. The grades are from 0 to 1 per cent., and the curves down to 984 feet radius. The traffic consists of passenger and freight trains, the express passenger trains running at 43½ miles per hour. The heaviest six-coupled freight-engines weigh 40 tons in working order.

The ties are manufactured by the Hösch Iron and Steel Works, of Dortmund; the Mine and Mill Company, of Hörde, and the Queen Marie Works, of Cainsdorf, Saxony. The cost is $33.75 per ton at the works. No preservative treatment is employed, the ties being laid in the state in which they come from the rolls. It is estimated that the metal track will last thirty years, while wooden ties must be renewed every twelve or fifteen years. The reasons for the adoption of metal ties were as follows: (*a*) the maintenance is cheaper than that of track on wooden ties; (*b*) the price is cheaper, taking into consideration the durability of thirty years, than that of wooden ties; (*c*) the encouragement of the iron industry. The general results have been satisfactory, and there has been no trouble with maintenance, with the rail attachmnts, or from breakages. The wooden ties are of pine or oak; impregnated pine ties cost 87.5 cents per tie and last about ten to twelve years; oak ties cost $1.37½ each and are estimated to last fifteen to eighteen years.

Arrangements have been made for giving up entirely the use of the Hilf longitudinal system after a lapse of not more than five years. At the same time that the longitudinals were first laid, in 1879, the laying of metal cross ties was also commenced, and there are at present 251.10 miles of main track laid with them, equal to 17 per cent. of the total length of track of this division. In selecting the sections of the line to be laid with these ties, the quality of the ballast was taken into consideration, to provide proper drainage. The form of the tie now used has been arrived at by the development of the original form according to the experience obtained. The earlier ties were of the "Haarmann," "Hilf," and the original "Berg-and-Mark" types.

The "Haarmann" ties were 7.87 feet long, and weighed 113.65 pounds each; they were 4.4 inches wide on top, 4 inches wide inside at the bottom of the "cap," and 10 inches wide over the flanges; the sides of the flanges were bent down .8 inch, making the depth over all, 2.56 inches. The vertical parts of the flanges were .20 inch thick; flanges, .24 to .28 inch; sides, .28 inch, and top table, .36 inch thick. The ends were closed by riveted pieces of double-angle section (┌───┘), the upper web fitting inside the "cap" of the tie, the flange riveted under the flanges of the tie, and the lower web projecting below the end of the body of the tie; the total depth at the ends was 3.40 inches. The tie was horizontal at the middle, and inclined upward 1 in 20 to the ends; as this was found to render the track unstable, the tie was afterward made horizontal, with the rail-seat inclined 1 in 20 by the Hosch-Lichthammer system. (See "Holland.") The fastenings were of the Ruppel type, already described.

The Hilf ties were 7.87 feet long, and weighed 114.4 pounds each; they were 4.8 inches wide on top, 8.8 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.2 inches from the bottom; the sides were .32 inch and the top table .40 inch thick; the top table was bent down at the ends to a depth of 4 inches, and the sides were bent round outside at the end. The ties were of similar shape, longitudinally to the Haarmann ties, and the same fastenings were used.

The "Berg-and-Mark" ties were 7.54 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides were .28 inch thick, and the top table .36 inch; with a rib 1.44 inches wide on the underside, making the thickness .52 inch. The weight was 97.90 pounds per tie. The tie was horizontal at the middle and then bent up at an inclination of 1 in 20 to the ends, which were closed by bending down the top table. Gib and cotter fastenings were used.

The ties now adopted are a modification of the Haarmann type, having the "cap" wide and the flanges narrow. They are 8.85 feet long, and weigh about 126.50 pounds each; the ends are flared out and are closed by bending down the top table; they are horizontal throughout. They are 6.4 inches wide on top, 7.2 inches wide inside at the bottom of the cap, 9.2 inches wide over the flanges, and about 11.2 inches wide over all at the ends; the depth of the cap is 1.84 inches, and 2.8 inches over all; the depth at the ends is 4.8 inches. The sides are .28 inch thick, and the top table .32 inch. The fastenings are of the Haarmann type already described, the rail resting on a tie plate with a hooked lug at the outer end, and a bolted clamp on the inner end. The plate is 6 inches long and 7.08 inches wide over all; and from .28 inch to .5 inch thick. There are ten ties to a rail length of 29.52 feet; the joint ties spaced 26.68 inches center to center, and the intermediate ties about 37 inches. The weight of the track is 2,854 pounds per rail length, or 290.1 pounds per yard.

In renewals on existing lines on this division about 50 per cent. of the ties used are of iron and the balance of wood. On new lines, however, preference is given to wooden ties on account of their less cost. The wooden ties used are generally of pine, imported from foreign countries, as the forests of this country can not supply the great demand.

PRUSSIAN STATE RAILWAYS.—*Altona Division* (*Province of Schleswig-Holstein.*)—Trials of metal track have been made on a small scale, and some of the Hoerde or Post steel cross-ties have been tried. The following is the substance of a statement made by the officers of this division in August 1889:

On this division metal track has been tried only to a limited extent; but even on the short stretches of road where iron ties were used they have been replaced by wooden ties, because the ballast and road-bed of this division have proved to be unsuitable for iron ties.

This official statement suggests two comments: First, it has been reported from time to time in the technical and other papers that metal ties have not been a success in Germany and have been abandoned. This has been through ignorance in taking the experience on one division as representing that on the entire railway system. The other official statements which are given in this report show that on the whole the metal ties are giving good results and are being extensively adopted, after years of experience and experiment. Second, the statement shows very clearly that the metal ties will not of themselves necessarily make a good track, since their abandonment on this division is due primarily not to any defect in the ties (the type used is not stated), but to the material of the ballast and the road-bed.

PRUSSIAN STATE RAILWAYS.—*Hanover Division* (*Province of Hanover*).—Longitudinals of the "Hilf" type were first used in 1876 and "Haarmann" longitudinals in 1880. At the end of 1884 there were 340.38 miles of track on longitudinals, of which 154.38 miles were on the Hilf system. The track is similar to that of the Berlin division, already described. In 1888 there were 222.3 miles of the Haarmann and 142.84 miles of the Hilf type. Metal cross-ties were first used in 1878, and their use has been continued. The "Vautherin," "Rhenish," and "Haarmann" types of ties have been tried. The latter are similar to those on the Erfurt division, with the rail seat formed on the Hoesch-Lichthammer plan. The Haarmann fastenings, with the hooked tie-plate, and the Ruppel fastenings, with bolted clamps, are both used.

The following is Mr. Bricka's statement of the track for the end of 1884:

| | *Miles.* |
|---|---|
| Main lines | 1,124.68 |
| Local lines | 101.06 |
| Total track | 2,570.52 |
| Wooden ties | 2,117.92 |
| Metal longitudinals | 340.38 |
| Metal ties | 107.26 |
| Stone blocks, etc | 4.96 |

PRUSSIAN STATE RAILWAYS.—*Magdeburg Division* (*Province of Saxony*).—In 1879 trials were made with cross-ties of the same section as the Hilf longitudinal. Then the "Berg-and-Mark" tie of the Elberfeld division was tried, and later the Haarmaann tie. The latter weighed 112.2 pounds, were bent up at the ends to give the inclination to the rails, and had the Ruppel system of fastenings. The "Hoerde" or "Post" tie has been tried within recent years.

The following is Mr. Bricka's statement of the track for the end of 1884:

| | *Miles.* |
|---|---|
| Main lines | 858.08 |
| Local lines | 73.16 |
| Total track | 1,920.76 |
| Wooden ties | 1,780.64 |
| Metal longitudinals | 13.02 |
| Metal ties | 126.48 |
| Stone blocks, etc | .62 |

PRUSSIAN STATE RAILWAYS.—*Breslau Division* (*Province of Silesia*).—On this division, cross-ties of the modified Berg-and-Mark system have been tried. They are 8.2 feet long, 4.4 inches wide on top, 7.76 inches wide inside at the bottom, 9.12 inches wide over all at the bottom, 3 inches deep; thickness of sides, .32-inch, and of the top table .36 inch. The weight is 120 pounds per tie. The ends are inclined upward 1 in 20. The rail fastenings consist of clamps and bolts on the Ruppel plan. The joint ties are spaced 26.68 inches, center to center, and the intermediate ties about 37 inches. The weight of the track is 2,704.77 pounds per rail length, or 274.86 pounds per yard.

In November, 1888, a contract for 599 tons of metal ties was awarded to the Laurahutte Works at $31.25 per ton at the works.

PRUSSIAN STATE RAILWAYS—*Bromberg Division* (*Province of East Prussia*).—Metal cross-ties and longitudinals are in use on this division. Of the latter there were, in 1888, 116.12 miles of the Hilf system with heavy cross-tie connections; 43.64 miles of the Hilf system without these connections, and the ends of the longitudinals resting on a saddle plate, and 32.17 miles of the Haarmann system.

BAVARIAN STATE RAILWAYS.—Different systems of metal track have been tried on these lines, partly to reduce the expenses for maintenance and renewals, and partly in the interest of the iron industry of the State. The Hartwich system of track has been tried (see plate No. 12); also the Hilf and Rhenish systems of longitudinals. The types of cross-ties tried include the "Vautherin" (weighing 77 pounds per tie); the Haarmann (102.3 pounds;) the "Berg-and-Mark," with rail seat inclined on the Hosch-Lichthammer plan (114.4 pounds); and the "Heindl" (138.6 pounds). The engineers have recognized the superiority of cross-ties over longitudinals for main lines, but the latter are still used to some extent on secondary lines. In June, 1888, contracts were let for 11,100 tons of metal ties at about $29.10 per ton.

Mr. Bricka, in his report, gives the following statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 2,401.26 |
| Local lines | 327.98 |
| Total track | 3,727.44 |
| Wooden ties | 3,232.06 |
| Metal longitudinals | 275.90 |
| Metal ties | 10.54 |
| Stone blocks, etc | 208.94 |

The following different forms of tracks are in use on these railways:

(1) Main lines, (*a*) steel rails on iron ties of the Heindl system; (*b*) steel or steel-headed rails on wooden ties.

(2) Branch lines, (*a*) steel rails on iron ties of the Heindl system; (*b*) steel rails on wooden ties.

(3) Local lines of standard gauge, (*a*) steel rails on iron longitudinals of the "Rhenish" type; (*b*) steel rails on iron cross-ties of the Heindl system, but lighter than the ties for main lines; (*c*) steel rails with longitudinals or cross-ties, Hartwich system.

(4) Local lines of meter gauge, iron rails on iron ties of the Heindl system.

The Heindl system of track with cross-ties has now been adopted as the standard system of metal track for main lines, and it has also been applied (in a lighter form) for secondary lines. Up to the end of 1887 this track had been laid as follows:

| | Miles. |
|---|---|
| 1883 | .17 |
| 1885 | 19.10 |
| 1887 | 35.34 |
| 1887 | 31 |
| Total | 85.61 |

The Heindl system of track for main lines is described in full further on. Two lighter forms of this track have been designed for secondary lines of standard and meter gauge: (3*b*) 8.2 feet long, 7.2 inches wide at the bottom, 2.4 inches deep, with ends 3 inches deep, top table .36 inch thick; weight, 86.83 pounds; no tie plates are used, the ends of the tie being bent up at an inclination of 1 in 20; bolted clamp fastenings on the Ruppel plan are used; (4) 5.57 feet long, 6 inches wide at the bottom, 1.72 inches deep, with ends 2.40 inches deep, top table .32 inch thick; weight of tie, 43 pounds; the rails are fastened by bolts and clamps on the Roth-and-Schuler plan (see "Baden State Railways"). The longitudinals of the Rhenish type are similar to those on the Alsace-Lorraine Railways; they are 8.8 inches wide on top, 12 inches wide at the bottom, 2.4 inches deep; at the joints were cross-ties of T-section, 7.5 feet long, to which the longitudinals were secured by bolted clamps holding the flanges (See plate No. 12); the outer flange rested on packing pieces so as to give the rail the inward inclination of 1 in 20; round tie-rods 1.02 inches diameter were used, spaced one to each rail length; they passed through the webs of the rails. A lighter form of this longitudinal was 29.42 feet long, 6 inches wide on top, 8.4 inches wide inside at the bottom, and 9.2 inches wide over all at the bottom; 2.4 inches deep; sides .24 inch thick, and top table .32 inch; weight, 35.21 pounds per yard. The top table had a small rib along each edge, forming a channel for the rail flange. The rails were fastened by bolted clamps similar to those used on the Hesse-Louis Railway, but the bolts had not eccentric necks. The Hartwich system of combined rail and longitudinal has been tried on a length of 6.2 miles. The rails were 24.6 feet long, 6 inches high, with a head 1.8 inches wide and a flange 4.8 inches wide; the weight was 58.35 pounds per yard. They were connected by tie-bars 1.8 inches by .36 inch, turned and screwed at the ends, passing through the webs of the rails and secured by a nut on each side of the web. The weight of the track was about 136 pounds per yard. At joints the rails rest on grooved bed plates, to which they are fastened by bolted clamps similar to those of the Hesse-Louis Railway, but without eccentric necks on the bolts.

The following is from official statements and drawings furnished in April, 1889, for the purpose of this report:

The management of the Bavarian Government railways has made experiments for a number of years with different systems of metal track, both with iron longitudinals and iron cross-ties. Based upon the experience obtained by these trials a track with iron cross-ties, on the Heindl system, has been used since 1885, in combination with wooden ties, for all new construction and in the reconstruction of main lines. This track includes a method of fastening the rails patented by Mr. Franz Heindl, chief inspector of the Austrian state railways (see "Austria"). These Bavarian lines are of standard gauge, 4 feet 8½ inches.

Of the total length of the railways, comprising 4,063 miles, there were in 1889 the following systems of track:

| | Miles. |
|---|---|
| Wooden ties | 3,312 |
| Wooden longitudinals on bridges | 3 |
| Iron longitudinals | 399 |
| Iron ties, of different systems | 33 |
| Iron ties, Heindl system | 107 |
| Hartwich system and stone blocks | 209 |
| Total | 4,063 |

The following particulars refer to the Heindl system. The ties have been laid between 1885 and 1889; the maximum grade upon which they are placed is 2½ per cent., and the minimum radius of curves 984 feet. The traffic consists of express and ordinary passenger trains and freight trains. The amount of traffic on the different lines, per yearly average, is 200 to 1,400 passengers and 2,500 to 6,500 tons of freight per day. The express engines weigh 35.43 tons each, and have a weight of 12.32 tons on the driving wheels; the maximum speed is 43½ miles per hour. The freight engines weigh 41 tons each, have a maximum load per axle of 13.8 tons, and travel at a maximum speed of 25 miles per hour.

The ballast is partly gravel and partly of broken stone. It completely fills the interior of the tie and is compressed very firmly by the pressure of passing trains.

The ties are of wrought iron, and are used without any paint or other protection against rust. They are manufactured in Bavaria by the Maximilian Works, at Haidhof, and by Krämer Brothers, of St. Ingbert. They cost, in April, 1889, $30.50 per ton at the works. So far there had not been any appreciable wear. The reasons for adopting these ties were to obtain a firm and stable track, a long life for the ties, and a security of the rail fastenings. The general results have been very satisfactory, there having been no trouble with the fastenings, nor with the maintenance of track. No breakages have occurred and the rails only break the same as on wooden ties. An iron tie costs 96 cents, and a pine tie, impregnated with chloride of zinc, 67 cents. The latter lasts on an average about twelve years.

Besides the proper shape, a certain dead weight of the tie is absolutely necessary for the stability of the track, and the engineers of these lines consider a weight of 139 pounds per tie as the minimum admissible weight for track with ordinary traffic. Mr. Heindl recommends for main lines with a heavy traffic a weight of 175 pounds per tie. [While general experience does not seem to bear out the requirement of such weight, I would call especial attention to this point of minimum weight, as in many cases metal ties have been designed and invented in which every other feature has been sacrificed in order to secure the least possible weight and amount of material and consequent cheapness in first cost. Ties of such design cannot be efficient in service, and are likely to make a track very inferior to one laid with wooden ties, however desirable the use of the metal may be in itself. This is one of the pronounced defects of some of the ties patented in this country.—E. E. R. T.]

The engineers of these lines consider the horizontal tie to be superior to one having the ends inclined upward. A tie-plate is also considered advantageous with metal track, because it distributes the vertical pressure over a larger area, prevents the flanges of the rail from wearing into the tie, and gives also a wider bearing to resist lateral pressure. Good results are expected from the method of fastening the rails, especially on account of the separation of the part resisting the horizontal thrust from the part resisting the overturning of the rail. The former are firmly seated, and are not affected by the inevitable motion of the rail. [It has the disadvantage, however, of increasing the number of parts, but this appears to be a matter of very secondary importance in European track practice.—E. E. R. T.]

The ties are of inverted trough section (See plate No. 14), 8.2 feet long, 5.2 inches wide on top, 9.6 inches wide at the bottom. They are horizontal and of uniform section throughout; the ends are closed by bending down the top table to a depth of 4.8 inches, and in the older ties the sides were also bent round at the ends. The weight is 138.6 pounds per tie. The top table is .36 inch thick, and the sides from .3 inch near the bottom to .32 inch near the top. At each rail seat are two oblong holes 2.32 inches long by .92 inch wide, 4.08 inches apart in the clear. There are eleven ties to a rail length of 29.52 feet; the joint ties are spaced 20 inches center to center, the next 30.1 inches, the next two spacings 34 inches, and the remainder 36 inches.

The rails are of steel, of flanged section, 5.22 inches high, with a flange 4.20 inches wide, head 2.32 inches wide, top table 9 inches radius, top corners .56 inch radius, weighing 62.78 pounds per yard. Each rail rests on an iron tie-plate 4.64 inches long, 5.12 inches wide, with notches for the rail fastenings; the rail seat has an inward inclination of 1 in 20, and is from .22 inch to .44 inch thick; at the outer edge the plate is .68 inch thick, having a rib which resists the outward pressure of the rail flange. The weight is 2.16 pounds per plate. The fastenings consist of gauge-washers, clamps, and bolts; the former are 2.6 inches wide along the rail, and of different lengths according to the gauge; one end butts against the tie-plate, having a notch for the bolt, and the other end has a lug which fits into the hole in the tie. Upon this is the clamp, one end resting on the washer and the other on the rail flange. They are held together by a ⊥-headed bolt, .80 inch diameter, weighing .95 pound each, with the nut screwing down on the clamps. At one tie in each rail length a short piece of angle-bar is bolted to the rail, the flange bearing against the side of the rail fastening and preventing creeping of the rail. The fastening is similar to the "Ruppel" type (see Left-Bank-of-the-Rhine Railway), but with the rail-clamp of the latter divided horizontally into two parts. The rail joints are suspended and are spliced by a pair of angle-bars and four bolts: the bolts are .88 inch diameter, and are spaced 4.20 inches center to center, for the inner ones, and 5 inches for the outer ones. A space of .20 inch is left at the rail ends.

The weight of this track per rail length is given as follows:

[Per 29.52 feet.]

| Material. | Weight. | Material. | Weight. |
|---|---|---|---|
| | *Pounds.* | | *Pounds.* |
| 2 rails | 1,235.52 | 44 fastening bolts | 46.42 |
| 11 ties | 1,524.60 | 44 rail-clamps | 24.64 |
| 2 outer angle-bars | 39.16 | | |
| 2 inner angle-bars | 52.36 | Total | 3,011.14 |
| 8 splice-bolts | 10.12 | | |
| 22 tie-plates | 47.52 | Total per yard | 334.40 |
| 44 gauge-washers | 30.80 | | |

BADEN STATE RAILWAYS.—Mr. Bricka, in his report to the Minister of Public Works (France), mentioned the curious fact that on these lines the work of maintenance is done by contract; the railway administration furnishing the material. The work is said to be well done, and the method to have proved satisfactory. The plan has also been tried on the Wurtemberg State Railways, and on the Swiss Central Railway. He gives the following statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 701.84 |
| Local lines | 97.96 |
| Total track | 1,425.38 |
| Wooden ties | 1,239.38 |
| Metal longitudinals | 3.72 |
| Metal ties | 182.28 |

The following particulars are from an official statement received in September, 1889:

The total length of railways in operation is 857.888 miles, of which 343.288 miles are double track and 514.600 miles are single track. The total length of main track is 1,178.10 miles, and of this amount at the end of 1888 there were 569.878 miles, or 47.8 per cent., laid with metal track, including 2.604 miles with longitudinals and 567.274 with cross-ties. Iron cross-ties were first used in 1881, and the experience with them proved so satisfactory that they are being used exclusively for renewals for all main track now laid with wooden ties. During the last few years iron ties have also been used in the construction of new roads. The renewal of wooden with iron ties upon all the main tracks of these railways will be completed in eight or ten years.

The ties weigh 94.16 pounds each, but it is intended to use heavier ties as an experiment. They are not painted or otherwise treated, but no damage by rust has been observed. The time during which they have been in service is too short to allow of any observations being made as to their durability or life. As far as the experience goes, the iron ties are found to have considerable advantages as compared with wooden ties; they last longer, and so reduce the cost of maintenance; they also keep the track in line better and maintain the gauge more accurately. At first, however, the maintenance of track on iron ties is not cheaper than that of track on wooden ties. The adjustment of gauge is effected by a washer on the bolt, with the bolt hole placed eccentrically, allowing for each line of rails three side movements of .132, .268, and .40 inch, so that the gauge can be widened .80 inch.

The ballast is generally of coarse gravel or broken stone, in pieces upwards of 2.4 inches diameter, free from earth or sand. This material admits of proper drainage and has proved satisfactory. The heaviest locomotives weigh 107,800 pounds in working order, and have a maximum load of 15,400 pounds per driving-wheel. The traffic consists of passenger and freight trains.

The ties are of the original "Berg-and-Mark" type, as used on the Elberfeld division of the Prussian State Railways (see Plate No. 12); formerly they were of iron, but since 1883 they have been made of mild steel. The earlier ones were 7.38 feet long, which was considered too short. The ties now used are 7.87 feet long, 4.8 inches wide on top, 8.8 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.2 inches from the bottom. The thickness of the sides is from .24 to .28 inch, and of the top table .36 inch. The middle part of the tie is horizontal for a length of 3.28 feet. The rail seats are inclined upward 1 in 20 for a length of 25 inches, and then the tie inclines downward to the end. At the ends the top table is bent down and flared out, so that the closed ends are 4 inches deep and 10.8 inches wide over the bottom. The bolt holes are .84 inch square, with rounded corners. They are staggered at each rail seat instead of being placed opposite one another. The rails are of flange section, made of Bessemer steel. The fastenings consist of bolted clamps, on the Roth-and-Schuler plan. (See plate No. 13.) The bolt is .76 inch diameter, with a neck .80 inch square, and a round cup head 1.36 inches diameter; the bolt passes through a gauge-washer and rail clamp, and the nut screws down on the latter. The washer is 1.76 inches square and .56 inch thick; it has a bolt hole .80 inch in diameter, so placed as to be .28, .412, .548, and .68-inch from the four sides, thus permitting a close adjustment to gauge; the rail flange buts against this plate or washer. The clamp is of channel shape (┌─┐) and fits over the gauge washer; it is 2.84 inches by 2.6 inches, with an oval bolt hole .84 by 1.24 inches; it is about .52 inch thick; the shorter leg is .68 inch deep and bears on the rail flange; the longer one is 1.16 inches deep and bears on the tie. There are 11 ties to a rail length of 29.52 feet; the joint ties are spaced 22.8 inches apart, center to center, and the intermediate ties 33.72 inches. The weight of this track is 2,640 pounds per rail length, or 267.6 pounds per yard. Prices bid for ties in December, 1889, averaged about $38.20 per ton.

The road-bed is crowned at subgrade, and the ballast is filled in level with the tops of the ties. For double track lines the width over the bottom of the ballast is 26.24 feet, and the side slopes are 2 to 3, giving 18 inches of ballast beyond the ends of the tie; the depth of ballast is 18 inches at the side, and 12 inches at the middle. For single track the width at the bottom is 14.27 feet, side slopes 2 to 3, giving 18 inches of ballast beyond the ends of the tie; the depth of the ballast is 16 inches at the side and 12.8 inches at the middle. At stations the top of the ballast is level with the surface of the ground; it is 11.48 feet wide on top, 10 inches deep at the sides, and 16 inches deep at the middle, so that all water runs to the bottom at the middle, where there is a drain covered with broken stone of large size.

WURTEMBERG STATE RAILWAYS.—Metal cross-ties have been used since 1879, and several different forms have been used. Those now used are of the modified Vautherin section, with ribs instead of flanges on the lower edges, and with a rib 1.66 inches wide along the underside of the top table to strengthen it at the holes for the fastenings. The tie is 7.87 feet long, 5.2 inches wide on top, 10.4 inches wide at the bottom, 3.2 inches deep; the top table is .36 inch thick, and .52 inch at the thickened part. The weight is 130 pounds per tie. The tie is bent up at the rail seat, and then slopes down so that the end is at the same level as the middle. The ends are closed by riveted pieces. The rails are secured by gib and cotter fastenings, similar to those used on the Elberfeld division of the Prussian state railways, and they have given satisfaction. The work of maintenance is less than with track on wooden ties owing to the weight of the tie. At the end of 1884 there were 194 miles of metal ties, out of a total of 1,426 miles, and it was then expected to extend this about 37.2 miles per year.

The following is Mr. Bricka's statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 878.54 |
| Local lines | 78.74 |
| Total track | 1,404.92 |
| Wooden ties | 1,185.44 |
| Metal longitudinals | 16.74 |
| Metal ties | 194.06 |
| Stone blocks, etc | 8.68 |

ALSACE-LORRAINE STATE RAILWAYS.—A number of different systems of metal track have been tried, and in August, 1889, the management reported that there were in use eight kinds of metal track and four systems of attachments. Of the total length of track there were then as follows:

| | Miles. |
|---|---|
| Wooden ties | 888.931 |
| Metal longitudinals | 583.686 |
| Iron and steel ties | 312.015 |

The form of cross-tie adopted in 1887 is of the modified "Berg-and-Mark" type (See plate No. 12); 8.85 feet long, 5.2 inches wide on top, 10.52 inches wide over all, 3.6 inches deep; the sides are .28 inch thick and the top table .32 inch; weight 156½ pounds. The earlier form of the tie of this type was 7.87 feet long, 4.4 inches wide on top, 7.84 inches wide inside at the bottom, 9.2 inches wide over the ribs, 3 inches deep, top table .4 inch thick, weight 126.5 pounds; it was bent to a curve to give the rails an inward inclination. The rails were of flange section and were secured by clamps and bolts on a plan similar to the Ruppel plan. The newer ties are horizontal, and the "Haarmann" tie-plate and bolt fastening are used, as on the Cologne division of the Prussian State Railways. The ends are closed. With this newer form of track there are ten ties to a rail length of 29.52 feet; the joint ties are spaced 23.6 inches, center to center, the next 30.4 inches, the next 38 inches, and the intermediate ties 30⅜ inches. The weight of the track is 3,204.88 pounds per rail length, or 325.70 pounds per yard. The Hœrde or Post ties are also being tried.

A cross-tie of the "Haarmann" type has also been used; it was 7.87 feet long, 4.28 inches wide inside at the bottom, 10 inches wide over all; the edges of the flanges were turned down .80 inch; depth over all (not including the end plates) 2.56 inches. The end plates were of double angle, or ⌐┘ section, riveted to the horizontal flanges, closing the end of the "cap" of the tie and projecting 1.2 inches below the flanges. The weight was 106.7 pounds per tie. The "Haarmann" tie-plate and rail fastening were used, requiring only one bolt and clamp for each rail.

The Hilf system of longitudinals has been tried on this line. The longitudinals were 24.6 feet long, 12 inches wide at the bottom and 2.4 inches deep; the thickness of sides and top was .32 inch. The rails were secured by bolted clamps, on a plan similar to that used for the cross-ties on the Hesse-Louis Railway, but the bolts had not eccentric necks. The rail joints were spliced by one angle-bar and one channel-bar. At the joints of the longitudinals was a cross-tie 7.5 feet long, and the gauge was maintained by tie-rods passing through the web of the rail and secured by nuts; these were spaced 12.3 feet apart. Longitudinals of the "Rhenish" type were also used; they were 8 inches wide on top, 12 inches wide over the bottom ribs, 9.84 inches wide inside at the bottom; 3.6 inches deep; thickness of sides .32 inch, and of top, .36 inch. They were 24.6 feet long, and weighed 63.6 pounds per yard, a little more than those of the "Hilf" type. The ends were closed. The joints of the longitudinals were spliced by saddle plates 28.8 inches long, of almost similar section to them, fitting inside and secured by bolts. There were no cross-ties, the gauge being maintained by tie-rods placed at intervals of 12.3 feet. Longitudinals are now only used in exceptional cases. The Hartwich system of combined rails and longitudinals, consisting merely of deep flange rails, without cross-ties, has been used where local lines are laid in the streets or along roads. The rails were 29.52 feet long, 7.2 inches high, with a head 2 inches wide and a flange 4.8 inches wide; weight, 73.2 pounds per yard. They were connected at intervals of 9 feet $10\frac{1}{8}$ inches by round tie-rods, 1 inch diameter, passed through the webs and secured by a nut on each side of each rail; there were three tie-rods to each rail length. The rails were spliced at the joints by angle-bars with two rows of bolts. The weight of the track was 1,647.9 pounds per rail length, or 183.10 pounds per yard. Great care was taken to insure proper drainage. At subgrade a line of large rough stone blocks was laid under each rail, and upon this was a bed of broken stone in which the rail was bedded to the middle of the web. The ballast was filled in to the level of the rail heads, with a paving of blocks just under the tie-rods. Cross-drains were laid at intervals. These precautions, however, were expensive, diminishing any economy due to this system of track. This track was first laid about five years ago.

The weights of the engines in use in 1885 were as follows:

| Class of engine. | Total weight. | Maximum weight on one axle. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| Passenger | 80,000 | 32,230 |
| Freight | 86,240 | 30,140 |
| Mixed | 68,750 | 28,600 |
| For secondary lines | 55,880 | ........ |

The following is Mr. Bricka's statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 699.98 |
| Local lines | 109.12 |
| Total track | 1,516.52 |
| Wooden ties | 874.82 |
| Metal ties | 79.98 |
| Metal longitudinals | 559.86 |
| Stone blocks, etc | 1.86 |

MAIN-NECKAR RAILWAY (See plates Nos. 12 and 13).—On this line mild steel cross-ties have been used since 1880, and their use is being extended. The original Vautherin section is adhered to, with the rail-seats formed on the Hoesch-Lichthammer plan. Mr. Bricka in his report (1885) stated that wooden ties were not being used for new lines or general renewals. He reported the track as excellent. He examined ties that had been in service for three years and found no signs of wear under the rails or at the bolt-holes. The track behaved as well under the passage of trains as the best track on wooden ties, and cost less for maintenance. The following is his statement of the track for the end of 1884:

| | Miles. |
|---|---|
| Main lines | 58.28 |
| Total track | 148.94 |
| Wooden ties | 126.48 |
| Metal ties | 20.46 |

In October, 1889, I received the following report from this railway, with a letter stating that it would have been sent at an earlier date, but that having adopted that year a heavier section of tie they preferred to wait until particulars of these new ties could be given:

Up to the end of 1889, about 100,000 cross-ties on the Hosch-Lichthammer plan had been laid; equal to about 12,500 rail lengths of 24.6 feet, or 58.125 miles of track. Iron ties were first used in 1881, and each year, until now, 10,000 ties have been laid; in 1884 and 1885, however, 20,000 ties were laid each year. The ties are now of mild steel. The traffic is very heavy. The ties are manufactured by the Hoesch Iron and Steel Works, of Dortmund; the De Wendel Works, of Haizengen; and the Hoerde Mining and Rolling Mill Company, of Hoerde. The cost per ton (1,000 kilograms = 2,200 pounds) is from $33.10 to $35.90, delivered at the Darmstadt station. At present the life of the ties cannot be given, but it is estimated (from eight years' experience) that they will certainly last between thirty and fifty years. Formerly gravel ballast was used, but broken stone is now adopted as experience has proved its superiority, especially for the heavy ties of the section of 1889. The change from wooden to iron ties was made because at the same cost of iron and wooden ties the former give certainly more security and better gauge, and are also of longer duration. At first ties of .32 inch thickness were used, which, at the prices at that time, were hardly more expensive than oak ties. These light ties (weighing 84.414 pounds each) had the disadvantage that the entire track, rails and ties, was too light; it had to be frequently tamped and straightened or lined up. It was thought that this objection would be remedied by increasing the thickness of the tie to .40 inch, giving a weight of 106.75 pounds. The result was not as good as had been expected, and therefore, in

1889, ties weighing 135.3 pounds were adopted, but were not delivered until October of that year. The good results expected from the use of metal ties have been in the main realized, and the safety of the traffic is increased. The maintenance of track with the light metal ties was a little more expensive than with wooden ties. There is no more trouble with the rail joints on these ties than on wooden ties. Breakages of ties occur very rarely, and of rails hardly ever. The metal ties have maintained the gauge accurately, which was not always the case with wooden ties. Formerly two-thirds of pine and one third of oak ties were used, both impregnated with a solution of sublimate. They were 8.2 feet long, 5 to 5.5 inches wide, and 4 inches thick. The cost was $1.27½ per tie for oak, and 73¾ cents for pine. The adzing of the rail seat cost 2 cents, and the preserving 8¾ cents, so that the cost for tie complete was $1.38¼ for oak and 84½ cents for pine. The life is from fifteen to twenty years for oak, and from five to eight years for pine. The sharpest curve on which the metal ties are laid is of 1,148 feet radius, and the steepest grade is 1 in 333.

The ties of 1880 were of mild steel; they were 8.2 feet long, 4 inches wide on top, 2.4 inches deep, 8.8 inches wide over the bottom flanges, which were .6 inch wide; the thickness was from .24 inch at the lower part of the sides, to .32 inch at the top table. The middle portion of the tie was horizontal for 4.26 feet, the rail seats were inclined 1 in 20 for 8.52 inches, and the tie was then horizontal to the end. The weight was 81.41 pounds per tie. The fastenings were of the Ruppel plan of bolted clamps. The bolt holes at each rail seat were staggered. The rail joints were even and suspended, spliced by straight plates and four bolts. To a rail length of 24.6 feet there were nine ties; the joint ties spaced 21.6 inches apart, center to center, and the intermediate ties 34.8 inches. The ties of 1883 were similar to the above, but the thickness was from .26 inch to .36 inch. The ends and middle of the tie were in the same horizontal line, the rail seats being inclined and then sloped back to the normal level. At the rail joints one of each pair of clamps was long enough to cover the width of the flange of the rail. There were nine ties to a rail length of 24.6 feet; the joint ties were spaced 20.4 inches apart, center to center; the next 31.88 inches, and the intermediate ties 36 inches. The weight was 91.85 pounds per tie. These ties were of mild steel. The ties of 1886 were similar to those of 1883, but the thickness was from .32 inch to .40-inch. The rail joints were spliced by one channel bar and one straight bar, 27.2 inches long, with six bolts. The weight was 106.75 pounds. There were nine ties to a rail length of 24.6 feet; the joint ties spaced 26.08 inches center to center, the next ones 29.04 inches, and the intermediate ties 36 inches.

The ties of the type adopted in 1889 are of the same general type. They are 8.2 feet long, 5.6 inches wide on top, 2.8 inches deep, 10.4 inches wide over the bottom flanges, which are .72 inch wide. The thickness is .32 inch at the sides and .40-inch at the flanges and the top table. The rail seat is inclined for a length of 10 inches, and then slopes back in 6 inches to the horizontal line of the tie. The ends are bent to a depth of 4.8 inches. The weight is 135.2 pounds per tie. The fastenings are of the Ruppel system. The rails are of flange section, 5.2 inches high, with a flange 4 inches wide. The joints are spliced by one straight and one channel bar, with six bolts. For a rail length of 24.6 feet there are nine ties. The joint ties are spaced 26.08 inches center to center, the next ones 29.04 inches, and the intermediate ties 36 inches. For a rail length of 32.8 feet, there are twelve ties; the joint ties are spaced 26.08 inches center to center, the next ones 28.64 inches, and the intermediate ties 35.2 inches. The weight of the track for a rail length of 24.6 feet is 2,337.32 pounds, or 28.5 pounds per yard.

HESSE LOUIS RAILWAY.—On this line the Hilf system of longitudinals has been tried, but this system of track was abandoned, as the cost of maintenance on the 78 miles laid with it was found to be, during the years 1881 to 1886, 36 per cent. higher than that of track on cross-ties.

**The "Berg-and-Mark" type of cross-ties is now used. The following is Mr. Bricka's statement of the track at the end of 1884:**

| | Miles. |
|---|---|
| Main lines | 420.36 |
| Total track | 757.02 |
| Wooden ties | 484.46 |
| Metal longitudinals | 78.12 |
| Metal ties | 192.20 |
| Stone blocks, etc | 1.24 |

## The following is from a special report received in January 1890:

Metal track is in use to a greater or less extent on all the divisions of the road. The lines from Frankfort-on-Main to Eschhofen, from Wiesbaden to Niedernhausen, from Babenhausen to Hanau, and from Erbach to Eberbach, are laid entirely with metal track. At the end of 1888, there were 304.42 miles of main line, and 75.02 miles of local lines, laid with such track; making a total of 379.44 miles. The steepest grade on which the track is laid is 1.43 per cent. (1 in 70), and the sharpest curve has a radius of about 984 feet. The first metal track was laid in 1874. The traffic consists of passenger, freight and express trains. The heaviest locomotives weigh 48 tons, without the tender, and have a maximum load of 7 tons on the driving wheels.

At the end of 1888 the metal track included 300.08 miles of cross-ties and 79.36 miles of longitudinals. The longitudinals are of the Hilf type, with middle rib. The cross-ties are of similar section, but without the middle rib; they are 8.2 feet long and weigh 114.4 pounds. Both longitudinals and cross-ties are of rolled iron. They are not treated with any preparation to resist rust. They are manufactured by the Luxemburg Metal Works, the Saarbruck Iron Works, and the Burbach Forge Company, near Saarbruck. During 1888, the contract price for cross-ties averaged $28 per 2,200 pounds, at the works. Longitudinals have not been purchased since 1879. The cost of maintenance of the track on metal ties can only be given for the parts which are laid entirely with metal track; on the other parts the costs for wages, road-bed material, etc., for track on iron and wooden ties, are not kept in separate accounts. In 1888 the cost for maintenance of track, for material and wages, per kilometer, was as follows:

| | |
|---|---|
| (*a*) Frankfurt Station to Eschhofen | $108 |
| (*b*) Wiesbaden to Niedernhausen | 79 |
| (*c*) Babenhausen to Hanau | 87 |
| (*d*) Erbach to Eberbach | 85 |

The cost per car axle per kilometer is calculated as follows: (*a*) 6.25 cents; (*b*) 8.5 cents; (*c*) 7.25 cents; (*d*) 9.75 cents.

At curves, the holes in the longitudinals are drilled to correspond to the curves, and the gauge is kept by the cross connections and the cross-ties under the joints of the longitudinals. With cross-ties, the bolts which fasten the rails have eccentric necks which admit of an adjustment or widening of gauge at curves of .72 inch in nine movements. Tie-rods are used with the track on longitudinals. When first laid, only one tie-rod was placed to each pair of longitudinals, but experience proved that a second was desirable. These tie-rods are placed at the middle and ends of the rails, and are secured by bolts and nuts. As to the durability, the time during which the metal track has been in service to a large extent is too short to enable a definite statement to be made. The ballast consists of gravel and broken stone. Coarse gravel or broken stone are good; fine gravel or sand are not so satisfactory. The width of ballast is from 11.48 feet to 22.96 feet. The rails are of flange section; those on longitudinals weigh about 52 pounds per yard; those on cross-ties weigh 71.65 pounds per yard. In exceptional cases, rails weighing 71.65 pounds per yard will be laid on longitudinals. On longitudinals the rail joints are spliced by a pair of plain splice bars; on cross-ties they are spliced by a pair of angle-bars. On track with cross-ties the rail joints are suspended. Metal track was used principally because wooden ties were sometimes difficult to obtain, and also because with metal track a better track-laying and maintenance of gauge is insured than is attainable with wooden ties. The results with metal track thus far are thoroughly satisfactory. With good road-bed material the maintenance of the track gives no trouble, and neither is there any trouble with the rail fastenings. No transverse breakages have occurred with longitudinals or cross-ties; on the other hand cracks lengthwise of the tie are not uncommon between the bolt holes, and a stronger construction of the track was very soon required. An opinion can not yet be given as to the comparative durability or life of metal and wooden ties. An impregnated pine tie costs at present 86 cents; an impregnated beech tie, 84 cents to $1.27; and an oak tie, $1.30 to $1.42. The life of an impregnated pine tie averages ten years, that of an impregnated oak tie, twelve years. The life of beech ties is not yet determined. The temperature ranges between — 15° C. and + 25° C. in the shade. No effect of the climate upon wooden or metal ties has been observed. The cross-ties are considered better than longitudinals, as they give a better drainage of the road-bed, and consequently the work of maintenance of the track is less.

The following particulars are taken from the drawings accompanying the above communication:

The longitudinals are 29.39 feet long, for rails 29.52 feet long; the joints of rails and longitudinals corresponding. They are 7.2 inches wide on top, 12 inches wide at the bottom, 2.4 inches deep; the sides are vertical for 1.2 inches from the bottom and the middle rib is the full depth. The thickness is .32 inch; the middle rib is .8 inch thick at the upper part and .4 inch thick at the bottom. The cross-ties at the joints are of similar section; they are 8.53 feet long, with the middle portion horizontal and the ends bent up at an inclination of 1 in 20 to give an inward inclination to the longitudinals and rails. Each rail is secured to the longitudinal by twelve pairs of bolted clamps, spaced about 34 inches center to center, and 26.2 inches at the rail ends. The longitudinals are attached to the cross-ties by bolted clamps. The longitudinals and cross-ties weigh 59.1 pounds per yard, or 579 and 168 pounds each, respectively. The weight of the track is 2,484.5 pounds per length of 29.39 feet, or 276 pounds per yard. The ballast consists of a bottom course of large stone, and an upper course of ordinary broken stone, filled in to the tops of the longitudinals.

The cross-ties are 8.2 feet long, 4.8 inches wide on top, 9.6 inches wide at the bottom, 2.8 inches deep; the sides are vertical for 1.2 inches from the bottom. The thickness of the sides is from .24 to .36 inch; the top table is .4 inch thick. The middle portion of the tie is horizontal, the rail-seats are inclined for a length of 16 inches, and the tie is then horizontal to the ends, which are closed by bending down the top table to a depth of 4 inches. The bolt-holes are oblong, 1.24 by .88 inch; they are 3.6 inches apart in the clear and are staggered, being 1.6 inches center to center. The rails are secured by bolted clamps (See plate No. 13). The bolts have eccentric necks to permit of adjustments of gauge, and have hemispherical heads, so that they can not be put in from above. The clamps are of ┏ shape, the horizontal leg resting on the rail-flange and the vertical leg on the tie. There are eleven ties to a rail length of 29.52 feet; they are spaced 25.2 inches center to center at the joints, 31.4 inches next, and the intermediate ties 34 inches center to center. The rail-joints are spliced by angle-bars and four bolts; the bars bear against the clamps on the cross-ties, and creeping of the rails is thus prevented.

LOWER PALATINE (PFALZ) RAILWAY.—The following particulars are taken from a statement and drawings furnished in September, 1889, by the officers of the Pfalz Railway (Rhenish Bavaria) for the purpose of this report:

On the railways of the Palatine, iron cross-ties have been used since 1885; at first they were of wrought iron, but are now of mild steel, manufactured by the Thomas process. As far as experience goes, these ties have proved successful. They are now used not only in continuous stretches, but also singly in exchange for wooden ties in ordinary renewals. The total quantity, up to the end of 1889, is about 160,000 ties, and there are continuous stretches of track 63.86 miles long laid with them.

The ties are of the Hoerde type, similar to the "Post" type (See "Holland"), except that each side is in one plane instead of two, as in the latter. They are 7.87 feet long, and weigh 114.4 pounds. The top is horizontal at the middle, inclined upward 1 in 20 at the rail-seats, and then sloped down to the ends, which are closed. At the outer part of the rail-seat the tie is 4 inches wide on top, 9.4 inches wide over the bottom ribs, 3.56 inches deep, .44 inch thick on top; under the rail it is 4.4 inches wide on top, 9.4 inches wide over the bottom ribs, 3.26 inches deep, .44 inch thick on top; at the inner part of the rail-seat it is 4.8 inches wide on top, 9.4 inches wide over the bottom ribs, 2.8 inches deep, .28 inch thick on top; at the middle, it is of ∩ section, flat for about 1 inch on top, 3 inches wide just below the top, 4½ inches wide over the bottom, 5 inches deep, .28 inch thick. The top table is bent down at the end, projecting 2.8 inches below the bottom of the tie. The rails are fastened by bolted clamps, on the Ruppel system. The rails are of flange section, 5.36 inches high and 4.20 inches wide over the flange. There are nine ties to a rail length of 24.6 feet; the joint-ties are spaced about 22 inches center to center, the next 33 inches, and the intermediate ties 37.75 inches. The track weighs about 2,362 pounds per rail length, or 270 pounds per yard.

LUBECK AND BUCHEN RAILWAY.—On this line metal ties have been tried since 1878. Mild steel cross-ties of inverted trough section are now used; they are somewhat narrower and deeper at the middle than at the ends. The section at the rail-seat resembles that of the Hilf or the modified "Berg-and-Mark" ties, but the vertical part of the sides is very shallow, and has a small rib on the bottom edge; the section at the middle more nearly resembles that of the "Post" tie, but here too the change of plane of the sides is very low down. The tie is 7.87 feet long, and weighs 107.8 pounds; at the rail-seat it is 9.2 inches wide over the bottom and 3.2 inches deep, with the top table .36 inch thick, and the sides .3 inch thick at the top and .25 inch at the bottom; at the middle it is 8 inches wide at the bottom and 4 inches deep, with the same thickness. The rails are of flange section, weighing 70.42 pounds per yard, and are secured by clamps and ⊥-headed bolts; the bolt-holes are staggered. For a rail length of 29.52 feet there are eleven ties; the joint-ties are spaced 27.12 inches center to center, the next ones 33.24 inches, and the intermediate ties 33.32 inches. The weight of the track is 2,716.36 pounds per rail length, or 276 pounds per yard.

HALBERSTADT AND BLANKENBERG RAILWAY.—Cross-ties of the "Berg-and-Mark" type are used, with gib and cotter fastenings. They are 7.12 feet long, have the ends bent to an inclination of 1 in 20, and weigh 88 pounds each. The rails are of flange section, 21.62 feet long, 5.2 inches high, with a flange 4 inches wide. The weight of the track is 1,767.87 pounds per rail length, or 245.37 pounds per yard. This railway includes the rack-rail line, on the Abt system, from Blankenberg to Tanne. The ties are of similar section to the above, 7.21 feet long, 8 inches wide on the bottom, and weighing 90 pounds each. The ends are closed by riveted angle-irons, and other angle-irons are riveted inside at about 18 inches from the end. The ties are spaced about 35 inches center to center. The rack-rail is carried in chairs which are fastened to the ties by gib and cotter fastenings similar to those for the track-rails. The ballast is filled into the ends of the tie to the inner angle-irons, and the middle part of the track between the rails is left entirely clear of ballast.

MULHAUSEN, ENSISHEIM AND WITTENHEIM RAILWAY.—This is a country tramway line, built partly along the public highway, and the information given, which is taken from a report published in 1888, refers only to the section from Mulhausen to Ensisheim, the extension of 4.83 miles to Wittenheim not having been built at the time of the report. The line was opened in December, 1885, being built to develop the trade of the old city of Ensisheim, which had declined on account of its isolation from railway communication. The line is 10.22 miles long, 1 meter gauge; maximum grade 2.4 per cent. for 295.20 feet, with other grades of 1.2 to 2 per cent. for a total length of 1,459.60 feet. The sharpest curve is 65.6 feet radius, and the alignment is as follows: Tangents, 7.70 miles, or 76 per cent.; curves of 3,280 feet radius, .35 mile, or 3 per cent.; curves of 1,640 to 328 feet radius, 1.63 miles, or 16 per cent.; curves of less than 328 feet radius, .53 mile, or 5 per cent.

Three systems of track have been adopted: (1) The Demerbe track, consisting of a rail of saddle or inverted trough section, weighing 61.36 pounds per yard. On the upper surface is a groove for the wheel flanges. It is used for a length of 3.5 miles for passing through villages It requires no bolts, being secured by keys. On tangents the rails are 29.52 feet long, and on curves of 65.6, 98.4, and 114.8 feet radius they are 14.76 feet long, with two cross-ties. The rail is the same as that used on the Mulhausen street railway, but the attachments and splices are simpler. (2) Flange rails on oak ties. (3) Flange rails on iron longitudinals. This system, employed especially where the width of the road is not more than 22.96 inches from the center of the track to the side, is composed of a rail 3.4 inches high, bolted to an iron longitudinal. The joints are entirely suspended, the splice plates being clear of the ends of the longitudinals. The rails weigh 31.69 pounds per yard, the longitudinals 24.75 pounds per yard, and the track complete about 120.75 pounds per yard. The rails are 29.35 and 29.52 feet long, and the longitudinals 27.71 and 27.88 feet. The gauge is maintained by five tie-rods of round iron to each pair of longitudinals, secured by nuts at the ends; they are spaced 5.9 feet center to center. With this system of track, which is laid for a length of 2.32 miles, the minimum curvature possible is 328 feet radius, on account of the necessity of bending the longitudinals. For curves of 328 to 656 feet radius, the outer and inner rails are 19.68 and 19.51 feet long respectively, and the outer and inner longitudinals are 18.04 and 17.87 feet long respectively.

HOLLENTHAL RAILWAY.—This is a standard gauge railway between Freiburg and Neustadt, which was opened in May, 1887. It is $21\frac{3}{4}$ miles long, of which $4\frac{3}{4}$ miles are fitted as a rack railway. The rack used is of the Marsh (or so called Riggenback) ladder type. The track is laid with mild steel cross-ties of the Hilf type, with closed ends. The rails are of flange section, and are fastened to the tie by bolted clamps; the chairs for the rack rail are bolted to the middle of the tie. The rails are 29.52 feet long and weigh 72.84 pounds per yard. There are ten ties to a rail length. The ordinary track weighs 246.3 pounds per yard, and the rack and appurtenances 256.8 pounds per yard.

## TIES.

*The Hoerde Tie.*—This is practically the same as the "Post" steel cross-tie, already described (see Holland). In February, 1888, the manufacturing company (Hoerder, Bergwerks und Hutten Verein) stated that the following numbers of these ties had already been supplied: German railways, 500,000; Gotthard Railway, 160,000; Swiss Western Railway, 160,000; Sumatra Railway, 80,000; Dutch State railways, 100,000; total 1,000,000 ties. Besides these, about 200,000 had been laid in France and Belgium. The price then varied from $25.84 to $28.34 per ton, free on board at Antwerp, according to size and quantity.

The special features of this form of tie are that the inclination of 1 in 20 is given to the rail seat in the process of rolling, while at the same time an increased thickness is given to the same part to increase its strength and durability. The tie is also made narrower and deeper at the middle than at the ends. By the method of rolling just mentioned the metal is subjected to less working and fatigue than when the seat is stamped to shape by a subsequent operation; the thickness may be increased .12 to .16 inch, while at the same time it may be reduced at other parts of the tie without diminishing the efficiency of the tie. A reduction of 10 per cent. in weight is claimed, with equal strength and durability to a tie of uniform section. By making the tie deep at the middle its stiffness or rigidity is increased, and any buckling or bending which might alter the width of the gauge is prevented, even when the tie is improperly ballasted. For main lines it is not advisable to reduce the weight below 110 pounds, but it is claimed that for secondary railways the ties may weigh only 72.6 to 77 pounds where now ties weighing 99 pounds are used. The deepening at the middle also prevents firm tamping of the tie in the middle, and the trackmen are given special instructions to tamp only the part under the rails, leaving the middle free, to prevent "hogging" of the ties. Such motion as the tie may have in the ballast tends to drive the ballast from the middle toward the rail seats.

For main lines the tie is 8.53 feet long, 11.2 inches wide at the ends, 9.4 inches wide for about 26 inches from the ends, and then narrowing to 4.72 inches at the middle. The depth is 5.24 inches at the middle, 2.32 and 2.92 inches at the inner and outer parts of the rail seat; the ends are closed by bending down the top table to below the level of the body of the tie. On each of the bottom edges is a broad rib of triangular section. The section is generally polygonal, each of the sides being in two planes; in some cases the sides are in one plane only, forming an ordinary inverted trough. The thickness at the rail seat is .24 inch at the bottom of the sides, increasing to .34 inch at the upper part of the sides and .36 inch at the top table. The thickness at other parts of the tie averages .24 inch. The fastenings consist of tee-headed bolts with eccentric necks, which admit of adjustment of the gauge; the bolt passes through a clamp, one end of which rests on the rail flange and the other end on the tie, the latter having a rib on the under side to bring the top level; the nut is screwed down on the clamp. The clamps are 2.6 by 2.16 inches, about .4 inch thick, and .8 inch deep at the outer side; the bolt-hole is .96 inch diameter. Special bolts, with necks of different dimensions, are used for curves, and these bolts are marked as already described for the "Post" tie (See "Holland"). The widening of gauge of .32 inch and .4 inch, required in ordinary service, can be effected with the ordinary bolts, the special bolts being used at the points of change from one adjustment of gauge to the other, and at the ends of curves of less than 3,280 feet radius. The bolt-holes are in identically the same position on all the ties. Verona nut-locks are used for the fastening and joint bolts. The rail joints are suspended and are spliced with angle-bars. For rail lengths of 29.52 feet, the joint ties are spaced 26.8 inches center to center, and the intermediate ties about 37 inches. The weight of the track is given as follows:

| Materials. | Unit weight. | Total weight. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| 2 rails, 29.52 feet long ........ per yard.. | 67.2 | 1,322.64 |
| 10 ties, 8.52 feet long, 9.4 inches wide ........ each.. | 110 | 1,100.00 |
| 4 splice-bars, 22.8 inches long ........ do... | 25.30 | 101.20 |
| 8 splice-bolts, .88 inch diameter ........ do... | 1.21 | 9.68 |
| 40 rail-clamps ........ do ... | .66 | 26.40 |
| 40 track-bolts, .88 inch diameter ........ do... | 1.10 | 44.00 |
| 48 nut-locks ........ do... | .039 | 1.89 |
| Weight per rail length ........ | .......... | 2,605.81 |
| Weight per yard ........ | .......... | 264.825 |

The manufacturers give particulars of tests of the comparative strength of these types of ties: No. 1, Netherlands State Railways, narrow and deep at the middle; 8.52 feet long, 9.4 inches wide, and 2.32 inches deep at rail seats, 4.72 inches wide, and 5.24 inches deep at the middle, .24 to .36 inch thick, weighing 110 to 120 pounds. No. 2, of similar type, but of uniform section throughout, 9.4 inches wide at the bottom and 2.32 inches deep. No. 3, a tie of inverted trough section, used on the Right-Bank-of-the-Rhine Railway, Germany; 8.85 feet long, 4.8 inches wide on top, 9.44 inches wide at the bottom, 3.1 inches deep, with the inner part of the side vertical for 1 inch from the bottom, the outer part being a thickened rib; sides .28 inch and top .32 inch wide; weight 125.4 pounds. The ties were supported at the middle. A beam or rail was laid across the two track rails, and upon this heavy frogs were placed, the load being uniformly distributed. The bending down of the unsupported ends of the ties would widen the gauge. No. 1, the widening of the gauge was from .18 inch with 6,050 pounds to .39 inch with 12,100 pounds load. The only permanent set was with this last load. No. 2, with a load of 7,260 pounds, the tie failed at the middle, being entirely deformed. No. 3, the tie failed at the middle under a load of 9,680 pounds and was entirely deformed.

For light or portable railways of 24 inches gauge, the works manufacture two forms of ties: No. 1 is 32.8 inches long, horizontal and shallow at the ends, with the top table arched up at the middle to increase the depth and stiffness; the ends are closed. It is 4 inches wide and 1 inch deep at the ends, 2.24 inches wide, and 2.2 inches deep at the middle; thickness, .16 and .24 inch at the rail seats. No. 2 is of uniform section throughout. The rails are 6.56 feet long, of flange section, but with a narrower flange on the inner side of the rail; they are 2.6 inches high, 1.88 inches wide over the flange, with a head .92 inch wide. The fastenings consist of hook-bolts, the hook-head holding the rail flange and the nut being on the inside of the tie. The rail joints are spliced by straight plates riveted to one end of each rail of each section of track, the ends of the rails of the next section being inserted between the projecting plates. The ties are spaced 16 inches apart, center to center, at the joints, and 32 inches apart intermediate. The track is made in sections 6.56 feet long, each consisting of two rails, three ties, and four plates. The weight of one such section is about 88 pounds.

*The Good Hope Works ties.*—The Good-Hope Works, at Oberhausen, manufacture a number of different forms of ties and fastenings. One type is somewhat similar to that adopted for the Indian State railways. (See "India.") It is 8 feet long for standard gauge lines; at the middle it is 4½ inches deep and 8½ inches wide on the bottom; at the rail seat it is 9½ inches wide on the bottom, with vertical sides and rounded corners; the top table is horizontal and at the ends it is bent down and flared out to a width of 13 inches. The rails are of flange section and rest on metal tie-plates, which give them the required inclination. The fastenings consist of a gib to hold the outer flange and two gibs and a cotter for the inner flange. The plate from which the tie is made is 8 feet 5 inches long by 15½ inches wide, and weighs 9 pounds per square foot. The tie weighs 98 pounds, the two tie-plates weigh 12 pounds, and the fastenings 9½ pounds, making a total of 119½ pounds for each tie complete. Similar ties are made for gauges of 5 feet 3 inches (weighing 125½ pounds) and 5 feet 6 inches (total weight 128½ pounds). It is also made for the 3 feet 6 inches gauge, but is of arched section in the middle, and broader and shallower under the rails; the tie-plates are not used; the tie weighs 56 pounds, or 8 pounds per square foot, and the fastenings 3½ pounds. The rails are of flange section, weighing 41½ pounds for the narrow gauge and 53 pounds per yard for the wider gauges. Ties of the Haarmann and Vautherin types are also manufactured.

*The Burkhardt longitudinals.*—The following description of this system of track is abstracted from the Minutes of the Proceedings of the Institution of Civil Engineers (England), Vol. LXXXI, 1885:

"The longitudinal is of inverted channel section, 27 feet 10½ inches long, 9.76 inches wide on top, 2.36 inches deep, and 12.6 inches wide over the flanges. One of the ends is closed by a riveted plate and the other by the cross-tie connection. A space of 19½ inches is left between the ends of the longitudinals, and this space comes under the rail-joints. The rails are fastened at nine points by bolts and clamps. There are three cross-ties to each longitudinal; they are of angle or channel iron, 6 feet 7 inches long, 4 inches deep. The weight of the track is 268 pounds per yard."

*Ties made from old rails.*—A system has been designed by L. Schulke, of Dusseldorf, for utilizing old rails for ties. The rails, of flange section, are cut into lengths of about 7 feet 6 inches, and two of these pieces laid on the side, head to head, form one cross-tie. The heads and webs are cut away on the upper side at each rail seat for the metal tie-plates, upon which the rails rest. The track rails are secured by bolted clamps, different sizes of clamps being used for the adjustment of the gauge. It is stated that the average price for old rails in Germany in 1887 was about $10 per net ton for heavy iron rails and about $7.50 per ton for light steel rails. The weight of these ties is from 60 to 100 per cent. greater than that of wooden ties. It is claimed that while ten iron or wooden ties are used to a rail length of 29.52 feet, only eight of these ties would be required, especially if the two parts of each tie were placed further apart, and the tie plates lengthened accordingly. They may be spaced from 29.6 inches at the joints to 36 inches intermediate. The manufacture requires a considerable amount of shop work—sawing to length, cutting the seats for the tie-plates, making the bolt-holes, etc.—all of which is expensive. While the plan might be successful for light railways with small traffic, it is not likely to be practicable for main lines or heavy traffic. As to the supply of material, it will be noted that one rail 30 feet long will only make two ties.

These ties have been tried on two or three railways in Germany, and a few have been tried in Belgium. They are said to have given satisfactory results as to maintenance, but it is not probable that they will be adopted to any extent.

*Metal ties at switches and frogs.*—On the Prussian state railways the metal ties are employed at switches and frogs. The ties are of the modified "Berg-and-Mark" type, 11.2 inches wide over the bottom and 3 inches deep. Bolted clamp fastenings are used. For a length of 81.45

feet over a switch and frog, there are 40 ties of various lengths, from the ordinary length of 7.87 feet to 14.76 feet beyond the frog; this long tie holding all the rails. The tie to which the switch lever and apparatus is fastened is 12.46 feet long. The ties are variously spaced; 30 inches center to center at the frog, 32.4 inches at the switch, and up to 37.2 inches intermediate. At the switch there is a bed-plate 18.6 feet long by 14.8 inches wide under each line of rails, covering 8 ties. The frog and guard rails cover 5 ties. At crossings and slip switches the arrangement of the ties is rather more complicated.

The work of laying and fitting switches and frogs on these ties is probably more difficult than with wooden ties, but when once laid they require much less attention, owing to the secure fastenings and the accurate maintenance of the gauge, and the track is certainly much safer than with the ordinary arrangement of frogs and switches. The fact of the introduction of metal ties at these points is an evidence of the favor with which such ties are considered.

SUMMARY OF METAL TRACK FOR GERMANY.

| Railways. | Year. | Ties. | Longitudinals. | Total track. |
|---|---|---|---|---|
| Prussian state railways: | | *Miles.* | *Miles.* | *Miles.* |
| Berlin division | 1884 | 1.24 | 473.06 | 474.30 |
| Elberfeld division | 1887 | 762.60 | 93.00 | 855.60 |
| Cologne division (R) | 1888 | 450.69 | 162.06 | 612.75 |
| Cologne division (L) | 1888 | 943.96 | 241.45 | 1,185.41 |
| Frankfurt division | 1884 | 37.82 | 634.88 | 672.70 |
| Erfurt division | 1889 | 251.10 | ........ | 251.10 |
| Hanover division | 1884 | 107.26 | 340.38 | 447.64 |
| Magdeburg division | 1884 | 126.48 | 13.02 | 139.50 |
| Bromberg division | 1888 | ........ | 191.93 | 191.93 |
| Bavarian state railways | 1889 | 140.00 | 399.00 | 539.00 |
| Baden state railways | 1889 | 567.27 | 2.61 | 569.88 |
| Wurtemberg state railways | 1889 | 350.00 | 16.74 | 366.74 |
| Alsace-Lorraine railways | 1889 | 312.02 | 583.69 | 895.71 |
| Main-Neckar Railway | 1889 | 58.13 | ........ | 58.13 |
| Hesse Louis Railway | 1888 | 300.08 | 79.36 | 379.44 |
| Lower-Palatine Railway | ...... | 80.00 | ........ | 80.00 |
| Hollenthal Railway | ...... | 4.75 | ........ | 4.75 |
| Total included in this report | ...... | 4,493.40 | 3,231.18 | 7,724.58 |
| Official total at end of 1888 | ...... | 5,224.12 | 3,562.52 | 8,786.64 |

## AUSTRIA AND HUNGARY.

General Remarks.—Metal tracks of different kinds have been tried on the most important railways, and the two types which have been most widely experimented with are the Heindl type of cross-ties and the Hohenegger type of longitudinals. On the lines where wooden ties are used metal tie-plates are frequently employed to prevent the cutting of the wood by the flange of the rail; they are not generally used on every tie, except on very sharp curves; they are generally heavy plates about 5.25 by 7.50 inches and .40-inch thick under the rail, with a rib on one or both sides. The spikes pass through the plate, and hold both rail and plate. The following notes as to the track are taken from an article of mine, "The Austria-Hungarian railways," published in the Railroad Gazette, New York, August 19, 1887:

The iron rails are from 39.6 pounds per yard in lengths of 18.14 feet to 75 pounds per yard in lengths of 19.68 feet. The steel rails are 64.5 pounds per yard in lengths of 22.79 feet, 66.3 pounds per yard in lengths of 29.52 feet, and 76.5 pounds per yard in lengths of 22.79 feet; the second of these steel rails is the standard. Formerly insistent joints were used, the wooden joint-ties being 8.2 feet long, 10 inches wide on top, 11¾ inches wide at the bottom, and 6 inches thick. Suspended joints are, however, now being used. The ordinary ties are about 8.2 feet long, 6 inches wide on top and 11¾ inches wide at the bottom; in some cases both sides have a slope, in others one side is vertical and the other slanting, while others have the sides vertical, but with the corners beveled off to the top width. Gauge-rods are sometimes used on curves.

These countries are said to be among the most favored countries in Europe as regards the production of timber.

The following table, showing the growth of the railways and the steady increase in the use of metal track, is from the report of Mr. Bricka to the minister of public works, France, in 1885.

*Mileage of railways of Austria and Hungary.*

| Year. | Main lines | Local lines. | Total track. | Wooden ties. | Metal longitudinals. | Metal cross-ties. |
|---|---|---|---|---|---|---|
| 1878 | 10,600 14 | 625.58 | 14,977.96 | 14,966.18 | 11.78 | ........... |
| 1879 | 10,621.22 | 681.38 | 15,086.46 | 15,071.58 | 12.40 | 2.48 |
| 1880 | 10,668.34 | 718.58 | 15,237.74 | 15,219.14 | 16.12 | 2.48 |
| 1881 | 10,626.80 | 843.34 | 15,351.20 | 15,324.54 | 18,60 | 8.06 |
| 1882 | 10,970.28 | 859.94 | 15,860.22 | 15,821.78 | 27.28 | 11.16 |
| 1883 | 11,078.16 | 1,271.62 | 16,523.00 | 16,464.72 | 42.16 | 16.12 |
| 1884 | 11,647.32 | 1,607.04 | 17,681.78 | 17,606.76 | 47.74 | 27.28 |

AUSTRIAN STATE RAILWAYS.—Some years ago a few metal ties of the "Atzinger" type, designed by Mr. Atzinger, an engineer, were laid on a length of about 2.48 miles on the Francis Joseph Railway, which is now a part of the state railways system. They were similar to the "Berg-and-Mark" type of tie, with the Ruppel plan of fastenings (see Germany). In 1879 wrought-iron ties, weighing 154 pounds each, were laid for a length of about .85 mile between Nussdorf and Kahlenbergerdorf. In 1882 mild steel ties of the same type were laid for a length of 1.75 miles between the latter town and Klosterneuborg; these were 7.87 feet long, 4.8 inches wide on top, 9.6 inches wide at the bottom, 3.2 inches deep, weighing 118.8 pounds. The ends were closed. On this single-track line there was an ordinary traffic of forty trains per day, with seventy trains on fête days.

The Serres-and-Battig system of longitudinals (Plate No. 11) was also tried about ten or twelve years ago. They were laid in 1877–1879 for a distance of .62 mile on the line from Vienna to Bruck, .62 mile on the line from Oravitza to Anina, and also in the station at Budapesth. The longitudinal consists of two beams, forming a Λ or a ⅄ with a very short stem when assembled together. At the lower edge of each beam is a horizontal flange, and the upper part is vertical for a short depth; between these vertical parts rests the web of a flangeless T rail, secured by bolts passing through the web and the tops of the two beams. The objects of this system are as follows: (1) To make a track which the weight of trains will tend to keep together or consolidate; (2) to make the wearing part of the rail renewable; (3) to avoid the use of small pieces of material. The longitudinals are connected at their joints by flat plates bolted to the horizontal bottom flanges. The transverse connections consist of deep bars of ├─┼┼─┤ section passing through the longitudinals, notched to receive the web of the rails, and resting on the top of the horizontal flanges of the longitudinals. The head of the rail is 1.32 inches deep; the vertical part of the longitudinals upon which rests the head and between which lies the web of the rail, .60 inch thick, is 2.48 inches deep, and from thence to the level of the top of the horizontal flanges is 2.98 inches; these flanges are 2.48 inches wide. The width of the longitudinals at the bottom is 7.64 inches inside and 12.60 inches over the flanges. The thickness of the vertical and horizontal parts is about .60 inch and of the inclined parts about .24 inch to .38 inch. The tie-bars extend beyond the longitudinals and are placed about 7.87 feet apart; they are 4.48 inches deep, about .32 inch thick, with flanges about 1.8 inches wide, the two middle ones being rather narrower. The bolts holding the rails and longitudinals together are .76 inch diameter, with oval bolt holes to allow for expansion. The weight of the track was about 258 pounds per yard. The line was standard gauge, single track, with the ballast deep under the longitudinals and on the outside level with the bottom of the rail head. For curves, the parts are bent at the works. When tried in Belgium this track was unsatisfactory, owing to the poor quality of the iron and faulty construction, but in Austria it has given good results. A piece of track .62 mile long laid in 1879, near Temesvar and Oravitza, included curves of 374 feet radius and a grade of 2 per cent.; there was a heavy traffic, with trains hauled by engines having three and four coupled axles. This section of track was found by Mr. Bricka in 1885 to be in good condition; the repairs had been few, and the maintenance was reported as having been more economical than with wooden ties. Further experiments, on a more extended scale, were to be made. Some of this track was still in service in 1887. It is said to have given especially good results at stations, where the maintenance is difficult, and where it is necessary to avoid a frequent renewal of the ties. The comparison of cost has been given as follows:

| Materials. | Ordinary track with wooden ties. | Serres and Battig system of metal track. |
|---|---|---|
| Rails | $3.36 | $1.98 |
| Ties or longitudinals | 1.34 | 4.02 |
| Fastenings | .72 | .06 |
| Ballast | 1.30 | .86 |
| Laying | .36 | .14 |
| Total cost per yard | 7.08 | 7.06 |

The most extensive experiments, however, have been with the "Heindl" type of cross-tie (Plate No. 14), the invention of Mr. Franz Heindl, general inspector of the state railways. These ties have been laid as follows:

| Where laid. | Year. | No. of miles. |
|---|---|---|
| On three divisions | 1883 | 1.302 |
| In the Arlberg tunnel (first track) | 1884 | 6.634 |
| In the Arlberg tunnel (second track) | 1885 | 6.634 |
| On secondary railways | 1886 | 13.020 |
| Total | ...... | 27.590 |
| At stations (side-tracks, etc.) | ...... | 24.800 |
| Total to 1888 | ...... | 52.390 |

The ties are of steel, of inverted trough section, having the lower part of the sides vertical. They are 7.87 feet long, 6 inches wide on top, 10.4 inches wide at the bottom, 4 inches deep with the sides vertical for 2.4 inches from the bottom; .32 inch thick at the sides and .40 inch on top. The weight is 158.4 pounds per tie. The fastenings are rather complicated and are composed of a number of pieces. Each rail rests on a tie-plate which gives the inclination of 1 in 16; an angle clamp (⌐) is placed on each side, the top resting on the tie with its end fitting into a notch in the tie-plate and the lug fitting into the elongated bolt hole in the tie; the adjustment of gauge is effected by using different sizes of these clamps. Lying in a groove in the top of this clamp is another clamp with one end projecting over and bearing upon the flange of the rail. A ⊥-headed bolt, with the nut on top, holds these parts together. The tie is horizontal throughout its length. Formerly the top table was bent down at the end to a depth of 5.2 inches, and the sides bent round; now, however, the projecting end of the top table is cut to such a shape that when bent down it effectually closes the ends of the tie. For a rail length of 24.6 feet the ties are spaced 20 inches apart at the joints, 32 inches next to the joints, and 36 inches center to center of intermediate ties. The rails are of flange section, about 4.9 inches high, with a head 2.32 inches wide and a flange 4.48 inches wide. The joints are spliced by angle-bars with four bolts. The ballast is of earthy gravel. The weight of track complete is 2,833.58 pounds for a rail length of 24.6 feet, or 345.6 pounds per yard.

The ties for the secondary railways are of similar type to those already described; 5.2 inches wide on top, 9.2 inches wide on the bottom, 3.2 inches deep; thickness of sides .32 inch, and of the top .34 inch. The weight is about 123.2 pounds.

In Arlberg tunnel coke-burning engines are used. For particulars of this track, see a note on "The Heindl ties" further on.

NORTHERN RAILWAY.—In 1883 ties of the "Heindl" type were laid for a length of 1.24 miles between Vienna and Cracow, on the Emperor Ferdinand Northern Railway. Part was laid in gravel and part in broken stone ballast. Mr. Bricka states that he noted that the noise of the passage of trains was no more disagreeable on this track than on the parallel track laid with wooden ties. He notes this as an interesting point, as showing that with ties of proper section and sufficient weight the vibrations are not caused, or that with a good form of metal track as a whole they are considerably diminished. These ties are of similar dimensions and weight with those on the state railways.

AUSSIG AND TEPLITZ RAILWAY.—Steel cross-ties of the Heindl system were laid in 1883 for a length of .62 mile. They are of similar weight and dimensions with those on the state railways.

GALICIAN (CARL-LOUIS) RAILWAY.—A length of .62 mile was laid with the Heindl system of steel cross-ties in 1884. These also are similar to the ties in use on the state railways.

NORTHWESTERN RAILWAY.—On this railway metal longitudinals have been tried since 1876, and the following very complete description of the track was furnished in March, 1888, by Mr. Hohenegger, chief engineer, for the purpose of this report. (See plate No. 14.)

The line between Vienna and Tetschen has 59.51 miles laid with metal track, which have been laid as follows:

| Year. | Form. | No. of miles. |
|---|---|---|
| 1876 | I | 2.54 |
| 1877 | II | 2.45 |
| 1878 | II | 4.70 |
| 1880 | II | 3.33 |
| 1881 | II | 2.58 |
| 1882 | III | 7.87 |
| 1883 | III | 15.31 |
| 1884 | III | 6.20 |
| 1885 | III | 6.32 |
| 1886 | III | 4.33 |
| 1887 | III | 3.87 |

Of this length the alignment is as follows:

| | *Miles.* |
|---|---|
| On tangents | 37.21 |
| On curves of: | |
| 9,840 to 3,280 feet radius | 7.44 |
| 2,952 to 1,968 feet radius | 3.35 |
| 1,640 to 1,148 feet radius | 11.00 |
| 984 to 935 feet radius | .51 |

There are daily, in both directions, two fast express trains, two express trains, eight accommodation trains, and at least ten freight trains. The passenger engines weigh 42 tons each, in working order, and have a weight of 12.4 tons on the driving axle; the freight engines weigh 45 tons in working order and have a weight of 11.25 tons on the driving axle.

The track is laid with three forms of metal longitudinals: 2.54 miles of No. I 13.07 miles of No. II, and 43.90 miles of No. III. Those of forms No. I and No. II are made from old iron rails, and weigh 51.90 pounds and 60.95 pounds per yard, respectively; No. III are of mild steel, made by the Thomas process, and weigh 58.80 pounds per yard. There is no protection against rust, the longitudinals being laid in the state in which they leave the rolls; no rust has thus far been observed. The longitudinals are manufactured at the Teplitz Rolling Mill and Bessemer Works.

*Price.*—The prices are as follows, for delivery at railway stations: No. I, $5.94 per 220 pounds, or about $60 per ton; No. II, $3.46 per 220 pounds, or about $35 per ton; No. III, $4.56 per 220 pounds, or about $46 per ton. For the manufacture of Nos. I and II, the railway company furnished the necessary old rails, which were accepted and accounted for at $1.92 per 220 pounds, or about $20 per ton.

*Renewals.*—Of form No. I, after eleven years' service, one longitudinal was renewed on account of the opening of a welded joint; this is 0.0001 per cent. of the whole. Those of form No. II were made from old flange rails, which were simply welded together, and rolled in three sizes; of the first delivery, after ten years' service, 7.08 per cent. had to be renewed on account of imperfect welding. Those of form No. III are, so far, without defect or failure, and not one piece has been renewed.

*Curves.*—The longitudinals of forms Nos. I and II are rolled straight, and the holes for the rail-bolts were spaced according to the radius of the various curves; those of form No. III are bent, while hot, to the required curve. Those of form No. I were all of equal length, because, in consequence of the considerable distance left between the ends at the joints, a shortening on the curves can easily be effected by laying them closer together. Nos. II and III are made of shorter length for the inner side of curves, a certain number being laid according to the shorter rail length and the radius of the curve.

*Tie-rods.*—These were originally used for Nos. I and II, because the longitudinals were only connected at the ends by transverse ties, the distance between them being 31.81 feet for No. I and 15.83 feet for No. II. An experience of several years has proved that tie-rods are not necessary for preserving the accuracy of the gauge, the transverse connections under the longitudinals being sufficient for this purpose; these connections placed at intervals of 9.84 feet answer the purpose.

*Wear.*—The only wear observed has been with some longitudinals of form No. I, in which the flange of the inner rail on curves has worn slightly into the top table.

*Durability.*—The life of the longitudinals of form No. I is estimated at about fifty years; those of No. II, made of old flange-rails, will hardly last as long, as, being made simply by welding the old rails together, a gradual opening of the welded joints must be expected, especially in those parts which correspond to the former web of the rail; the pieces which have required to be renewed have shown this defect distinctly. Those of form No. III, being of steel, will certainly last even longer than those of form No. I.

*Fastenings.*—The rail fastenings for form No. III (See plate No. 14) effectually prevent creeping of the rail on the longitudinal by firm hold of the clamp on the rail-flange and the rib of the longitudinal. The inclined outer face of the clamp admits of an adjustment of the gauge; this is effected by slacking one nut, which allows the clamp to rise and also move back; the rail is then shifted, the opposite clamp pushed down to a corresponding extent, and both nuts then screwed tight. The rail-flange butts against a boss on the lower side of the clamp, which thus receives all the force of the lateral thrust caused by passing trains, and transfers it to the rib of the longitudinal, thus protecting the bolt from wear.

*Ballast.*—The ballast is of river gravel, excavated gravel, and broken stone. The core of ballast inside the longitudinal is compressed, by tamping and by the pressure of passing trains, to such an extent that it can only be loosened by means of a pick; this compression extends nearly 12 inches below the lower edge of the longitudinal and prevents the quick drainage of water from between the rails, this prevention of the drainage varying with the degree of compression of the ballast. For this reason it is recommended that the ballast should be clean and of a character which will allow of the water passing through; where this can not be had, however, sufficient means for drainage must be provided. No heaving by frost has been observed on this track.

*Rails.*—The rails are of one flange section, weigh 58.75 pounds per yard. The joints are spliced by an inner straight plate, and an outer double-angle or channel plate;

four bolts are used. The outer plate was of symmetrical shape for Nos. I and II, and served to hold the head of the rail in horizontal position as well as to support it vertically. At each end the splice-plate bore against a rail-clamp bolted to the longitudinal, and thus prevented creeping; in this way the tendency to creep caused by the passage of trains was transmitted to the longitudinal, which was itself prevented from moving by its rigid cross connections For form No. III the outer splice-plate is of unsymmetrical section, the upper flange being narrow; the edge of the lower flange bears against the rib of the longitudinal, thus increasing the resistance to the outward thrust of the rail. A bolt passing through this flange and the top of the longitudinal effectually prevents any creeping beyond that allowed by slight inaccuracies in drilling the bolt-holes. An inner angle-plate, bearing against the other rib of the longitudinal, completes the joint and makes a solid continuous track. With Nos. I and II the rail-joints are supported, but with No. III they are suspended.

The steadily increasing speed and weight of passenger trains made it necessary to employ heavier and more rigid locomotives, and this traffic nearly reached the limit of the power of resistance of the ordinary track with cross-ties. To strengthen this track by the use of oak ties, or even iron ties, in place of the usual pine ties, would have increased the expenses considerably without increasing in equal proportion the power of resistance of the track against lateral pressure on the many and sharp curves of the road. These reasons led to the adoption of track on metal longitudinals, after a preliminary trial had been made in 1876; but the great cost of such track made it necessary to study the matter more thoroughly. At the first, attention was directed to making use of old rails, which, in consequence of the increasing introduction of steel, would be obtained at very moderate prices. The success of the experiment permitted the adoption of iron track for other portions of the line in 1877, 1878, 1880, and 1881, but only to such an extent as old rails were taken up and welded together to form the longitudinals. These old iron rails becoming scarce, and the introduction of the Thomas-Gilchrist process for the manufacture of mild steel, which made the cost of this material very moderate, led naturally to the adoption of form No. III (See plate No. 14), made of mild steel. Another reason for adopting the longitudinal stringer system of track was the proportionately weak section of the flange-rails used, weighing only 64.38 pounds per yard. In view of the increasing weights of the locomotives, this gave the company and its engineer the alternative of increasing the weight of the rails to 100.43 pounds per yard, or of adopting a still lighter rail and obtaining the necessary strength by means of a strong longitudinal or stringer. Whether this method of obtaining a strong track is a correct one, the future will demonstrate.

The behavior of the track laid with form No. III has been very satisfactory. On the part laid with Nos. II and I, it was found necessary to remove the broad iron cross-ties which were laid under the joints of the longitudinals, according to the Hilf system (See Germany), and to replace them by plain angle-irons. Their purpose is merely to maintain the width of the gauge, and not to support the ends of the longitudinals like abutments. The track stands admirably and requires little or no labor for maintenance and surfacing, either on the straight portions, which are in lengths of 3.72 to 4.34 miles, nor on sharp curves. On the straight portions no such swinging and rolling motion of the cars can be observed as is the case on track laid with cross-ties. There is no trouble with the attachments, the nuts being held in position by nut-locks, and tightening up of the nuts is rarely necessary. The trackmen formerly required to redrive the spikes for track with wooden cross-ties can now be employed on other track work. In consequence of the continuous support of the rails, no rails or splice-plates on this metal track have been broken since the same has been in service. The economical value of the use of metal track has been worked out by calculation.

*Wooden ties.*—On the guaranteed system of this railway impregnated oak ties are used on all portions over which express trains are run; impregnated pine ties are used at stations, on side tracks, and on branch lines. The reason for this is that the terminus of the road is on the Donau River, so that the oak brought by water from Hungary can be bought at a comparatively low price. On the supplementary system of the railway, which requires in addition the cost of freight of oak ties to Vienna, a distance of 200 miles, oak ties had to be abandoned on account of the increased cost, and pine ties are therefore used. These conditions, as already stated, were the cause of the introduction of metal track, and at present, of the total length of 83.70 miles over which express trains are run, 64.3 per cent. is laid with this track. The remaining parts will be renewed with metal in accordance with the amount appropriated for this purpose. These parts are now laid with impregnated pine or spruce ties, but it must be remarked that metal tie-plates .4 inch thick are laid on each new tie that is put in; on curves of 1,640 feet radius, and less, these plates have a rib fitting into a groove across the tie, and the rail is fastened by bolted clamps. Oak ties cost at present (1888) about 84.96 cents each, not impregnated; this is in consequence of the high German duty on timber which prohibits its export, but only a few years ago the price was $1.08 per tie. Pine ties, not impregnated, cost from 38 to 43 cents each. Oak ties were impregnated with oil of creosote, on the Bethel process, at a cost of 22 cents per tie; chloride of zinc, of 1.5 degrees Beaumé density, by the Burnett process, is now used and costs 17 cents per tie. Pine ties are impregnated with tar oil or creosote on the Blythe system, and partly with a solution of chloride of zinc of 1.5 degrees density, Beaumé, by the Burnett process, at a cost of 17.28 cents per tie. The life of an impregnated oak tie is estimated at twenty years, and the life of an impregnated pine tie at twelve years.

The following descriptions of the three classes of track are from drawings furnished by Mr. Hohenegger:

No. I.—The longitudinal was of the "Rhenish" type (See plate No. 12). It was 8 inches wide on top, 11 inches over the bottom, 2.88 inches deep; thickness of sides .3 inch, and of top table .32 inch. The rails were held by clamps bearing on the rail flange and the top of the longitudinal, and fastened by hook or L headed bolts. For tangents and curves down to 1,230 feet radius, the rails and longitudinals were 31.98 to 31.81 feet long, the joints of the former being about 40 inches from those of the latter. The ends of the longitudinals rested on saddle plates riveted to the ends of a cross-tie 7.87 feet long, 8 inches wide on top, and 12.8 inches wide on the bottom. There were two tie-rods to each rail length. For curves of 1,226.72 to 492 feet radius, the rails and longitudinals were 21.32 to 21.15 feet long, with a cross-tie at the joints of the longitudinals and two tie-rods to each rail length. The cross-ties were inclined at the ends to give the rails the usual inclination, and the longitudinals were fastened to them by ┌ clamps holding the rib. The tie-rods were .88 inch diameter, with a bearing plate and nut on the outer side of the rail. The rail fastenings were placed at intervals of about 32 inches with the longer rails, and about 31.6 inches with the shorter rails; at the joints they were closer together.

No. II.—The longitudinal was of a section somewhat similar to the Hilf or the original "Berg-and-Mark" types (See plate No. 12), but with a semi-cylindrical rib along the middle of the under side of the top table. For rails 31.98 feet long, the longitudinals were 15.90 feet long, breaking joint with the rails by about 11 inches. The ends of the longitudinals rested on saddle pieces fastened to cross-ties 7.87 feet long, 8 inches wide on top, 10.8 inches wide on the bottom; the cross-tie was horizontal, but the outer side of each longitudinal rested on a packing piece to give it the required inclination. The ballast was brought up level with the top of the longitudinals.

No. III. (See plate No. 14.)—The longitudinal is of a section similar to that of the "Berg-and-Mark" cross-tie, but has a rib along each side of the top table. It is 6.72 inches wide on top, 12 inches wide on the bottom, 3 inches deep, with the sides vertical for 1.84 inches from the bottom; the sides are .32 inch thick and the top table is

.36 inch thick. The fastenings, as already described, consist of bolted clamps bearing on the flange of the rail and the inclined face of the rib of the longitudinal, while at rail joints the bolts pass through the lower flange of the outer splice bar, which is of channel section. The longitudinals are 29.43 feet long, and the rails 29.52 feet long. The joints of the rails and longitudinals coincide. The ends of the latter rest upon a saddle made of a plate .40 inch thick, bent to shape to fit the interior of the longitudinal, and bolted to the end of an angle-iron cross-tie, 6.56 feet long, 3.2 inches wide, 4 inches deep, and .4 inch thick. The saddle is 16 inches long and 17 inches wide; the top is inclined 1 in 16 to give an inward inclination to the rail. The bolts pass through the saddle, longitudinal and clamp. There are two intermediate cross ties, spaced 9.77 feet from each joint tie, center to center; they are of angle-irons of the same size as those at the joints, but the saddle for the longitudinal is only 4.8 inches long. There are three bolts on each side of every rail joint; the next fastening is 22.2 inches away, center to center and the others are 30.4 inches apart center to center. All the nuts are fitted with nut locks; the nut lock consists of a square flat plate, with a slit in one side; the plate is prevented from turning and when the nut is screwed down upon it the slit piece is bent up against the side of the nut, thus preventing the nut from turning. The weight of this track is 2,791.58 pounds per rail length, or 283.72 pounds per yard.

Mr. Bricka, in his report to the minister of public works, France, in 1885, speaks very favorably of this latter form of track. The cost is about \$5.31 per yard for No. III, \$5.22 per yard for No. II, \$6.60 per yard for No. I, and \$5.12 per yard for track on impregnated oak ties.

HUNGARIAN STATE RAILWAYS.—The following particulars were presented by Mr. Kowalski at the International Railway Congress at Milan, Italy, in 1887:

In 1887 there were 3,000 metal ties in service, which had been laid in 1882 and succeeding years. They were of the "Berg-and-Mark" type, with gib and cotter fastenings. Up to 1886 they were made of wrought-iron, but after that of Bessemer steel. The ties weighed 108.90 pounds each, and the fastenings 5.19 pounds per set; making a total weight of 114.09 pounds per tie. Up to 1886 they were employed only on the Mountain division between Piski and Petroseny, and they were all laid on curves of a radius of less than 984 feet. The speed of the trains was from 13.64 to 21.70 miles per hour. The track was laid with iron rails weighing 71.5 pounds per yard, and steel rails weighing 67 pounds per yard. The ballast was of broken stone. The metal ties cost \$2.82 each, and the wooden ties 67½ cents each. The advantages of the former were in the simplicity of the attachments and the stability of the track. In 1887 the company began the work of gradually replacing wooden ties with metal ties on curves of 984 feet and under. The price of oak ties was still too low to permit of the introduction of metal ties on a large scale for tangents and flat curves, but nevertheless, it was proposed to substitute metal for wooden ties at switches and the approaches to important stations, as the former were considered advantageous for such a locality.

HEITZING AND PERTCHTOLDSDORF STEAM TRAMWAY.—This is a standard-gauge country tramway, built partly along the public highway and partly across country. It is 6.43 miles long; 3.9 miles, or 60 per cent. of its length, are on roads and streets, and the remaining 40 per cent. is practically a light railway. Along the roads the track is laid on one side, next to the gutter. The track is on the Hartwich system, with flange rails carried on longitudinal steel stringers, connected at intervals by tie bars. The longitudinals are of a section similar to that of the original "Berg-and-Mark" cross-ties; they are 4.6 inches wide on top, 8.4 inches wide at the bottom, 2.4 inches deep, with the sides vertical for about .8 inch from the bottom. The weight is about 28.72 pounds per yard. At the joints the ends of the longitudinals rest on a saddle piece of such section as to fit the interior of the tie. The rails are of flange section, 4 inches high, flange 2.72 inches wide, head 1.52 inches wide, with the top table at an angle, higher on the outer than on the inner side; the weight is about 31 pounds per yard. The fastenings consist of a riveted lug for the outer flange, and a hook-headed bolt, with clamp washers, for the inner flange; the heads of the bolts are inside the longitudinal. The rail joints are spliced by straight splice plates. The tie-bar is 5.74 feet long, 2.4 inches deep, .32 inch thick; it is notched for the bottom of the sides of the longitudinal, and at each end is keyed a ∩ piece against which the outer side of the longitudinal bears. In the streets there is a guard rail attached to the longitudinal, leaving a groove 1.20 inches wide for the wheel flanges. In streets the longitudinals are laid on stone blocks and ballast is filled in nearly up to the under side of the rail-heads. In country roads a trench is dug for each line of rail, broken stone laid for the longitudinals to rest on, and ballast then filled in to the underside of the rail heads, the heads just projecting above the street level. The engines are ordinary steam motors, boxed in. The older ones had four wheels, all coupled, and weighed 29,700 pounds. The later engines have six wheels and weigh 39,600 pounds.

## TIES.

*The Heindl ties.*—The system of track with steel cross-ties, invented by Mr. Heindl (See plate No. 14), has already been described as used on the Austrian state railways. In 1888 Mr. Heindl sent a communication in relation to this track, which had been laid as follows, up to the end of 1887:

| Year. | No. | Railway. | Location. | Maximum grade. | Minimum curve. | Length. | Total. |
|---|---|---|---|---|---|---|---|
| | | | | *Per ct.* | *Feet.* | *Miles.* | *Miles.* |
| 1883.. | 1 | Austrian state | Breitenschutzung-Schwanenstadt. | .37 | 1,869.60 | .62 | ...... |
| 1883.. | 2 | ...... do | Kosten-Dux | 1.03 | 931.52 | .62 | ...... |
| 1883.. | 3 | ...... do | Grybow-Ptaszkowa | 1.80 | 984.00 | .06 | ...... |
| 1883.. | 4 | Bavarian state | Landshut-Neuenmarkt | 1.25 | 1,148.00 | .17 | ...... |
| 1883.. | 5 | Emperor Ferdinand's Northern. | Raigern-Durnkrut | .04 | 4,352.56 | 1.24 | ...... |
| 1883.. | 6 | Aussig-Teplitz | Ullersdorf-Dux | .86 | 1,554.72 | .62 | ...... |
| | | | | | | | 3.33 |
| 1884.. | 7 | Galician, Carl-Ludwig | Ulai-Bochnia | .06 | 3,109.44 | .62 | ...... |
| 1884.. | 8 | Austrian state | Arlberg Tunnel, track No. 1. | 1.50 | 984.00 | 6.63 | ...... |
| 1884.. | 9 | Alps Mountain Company | Leoben-Leegraben | 4.12 | 492.00 | .37 | ...... |
| | | | | | | | 7.62 |
| 1885.. | 10 | Austrian state | Arlberg Tunnel, track No. 2. | 1.50 | 984.00 | 6.63 | ...... |
| 1885.. | 11 | Bavarian state | Stockheim-Ludwigstadt | 2.50 | 984.00 | 19.10 | ...... |
| | | | | | | | 25.73 |
| 1886.. | 12 | Austrian state | Liveric-Knin | 2.00 | 934.80 | 13.02 | ...... |
| 1887.. | 13 | Bavarian state | (Renewals) | ...... | ...... | 35.34 | ...... |
| 1887.. | 14 | .....do | (Laying second track) | ...... | ...... | 31.00 | ...... |
| | | | | | | | 79.36 |
| | | Total | ...... | ...... | ...... | ...... | 116.04 |
| Side-tracks at stations on the Austrian state railways | | | | | | | 24.80 |
| Grand total at end of 1887 | | | | | | | 140.84 |

**The following is the principal part of Mr. Heindl's communication:**

The heaviest traffic has been on line No. 5, over which 20,000,000 gross tons had been hauled and express trains had run at a speed of 50 miles per hour. The traffic on line No. 6 has been about the same. The locomotives have a weight of 6 to 7 tons per wheel, except on lines No. 9 and No. 12; the former is a mountain line, and the latter is a part of the secondary railways. The cost of maintenance is greater than that of wooden ties only during the first year, and afterward it becomes considerably less. In 1886 the cost of maintenance of the metal track on line No. 5 was $164.63 per mile, while that of adjacent track on wooden ties was $266.25 per mile. The durability of the iron track depends principally upon the construction, because with a defective method of attaching the rails, a mechanical destruction and wear of the track at the fastenings is inevitable. Experience has shown that a light track with such defective fastenings will scarcely last more than a few years under heavy traffic. With a carefully constructed track, however, the durability of the ties and attachments will be greater than that of the rails, which are directly exposed to the shocks and wear from the wheels. The principal conditions for a superstructure with metal ties are as follows: First, sufficient weight of ties and rails to insure stability; and, second, the use of an efficient fastening for the rails. The ballasting for a track on iron ties does not require more attention than that for track with wooden ties. The same kind of ballast can be used, but care must be taken to keep it free from earthy or clayey matter. The material fills the interior of the tie and in time forms a compact body which adds considerably to the stability of the track. With a metal track there is a greater security in the track and greater safety in operation. The durability and the avoidance of repairs or other work except tamping must certainly lead to economical results even if the first cost be greater. A well-constructed track on metal ties is so superior to one on wooden ties, as regards safety for the traffic, that an increased first cost might well be incurred, especially for main lines with heavy traffic.

Whatever may be the advantages of this system, it is certainly lacking in simplicity, which is a very serious defect, as it must inevitably lead to difficulty in laying and maintaining track, unless well trained, skilled, and expensive labor is employed. As already noted, this important feature of simplicity is one which as a rule is apparently given little attention in Europe.

SUMMARY OF METAL TRACK FOR AUSTRIA AND HUNGARY.

| Railways. | Longitudinals. | Cross-ties. | Total. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| Austrian state | .62 | 52.39 | 53.01 |
| Northern | | 1.24 | 1.24 |
| Aussig and Teplitz | | .62 | .62 |
| Galician (Carl-Ludwig) | | .62 | .62 |
| Northwestern | 59.51 | | 59.51 |
| Hungarian state | | 1.50 | 1.50 |
| Heitzing and Pertchtoldsdorf | 6.43 | | 6.43 |
| Total | 66.56 | 56.37 | 122.93 |

## SWITZERLAND.

GENERAL REMARKS.—Metal track is in quite extensive use in this country and has been given a thorough trial with eminently satisfactory results, some of the railways having now definitely adopted metal ties. At present they are used mainly on lines having the heaviest traffic, as on these lines the ties give greater security than wooden ties, if they are of sufficient weight, have well proportioned dimensions, and if the right means of attachment are employed. Another reason for using metal ties is that it is getting more difficult year by year to obtain oak ties in sufficient quantity.

Mr. Bricka, in his report to the minister of public works (France) in 1885, gives the following statement of the mileage of the track of Swiss railways for 1883 and 1884:

| Year. | Main lines. | Total track. | Wooden ties. | Metal ties. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| 1883 | 1,165.60 | 1,695.08 | 1,633.08 | 62.00 |
| 1884 | 1,165.60 | 1,696.94 | 1,582.86 | 114.08 |

The chief engineer of the Jura, Berne and Lucerne Railway sent me in August, 1889, the following statement of the mileage of the railway track in Switzerland to date:

| | Inclusive of the Brunig line. | Exclusive of the Brunig line. |
|---|---|---|
| | *Miles.* | *Miles.* |
| Total length | 1,697.65 | 1,668.83 |
| Length in operation | 1,777.54 | 1,749.64 |
| Length of track with: | | |
| Wooden ties | 1,973.46 | 1,967.24 |
| Metal ties | 397.40 | 372.31 |
| Total length of track | 2,370.86 | 2,339.55 |

GOTTHARD RAILWAY.—During the first construction of this celebrated railway, from 1879 to 1882, timber ties were used. In the summer of 1883 experiments were made with different types of metal track. These experiments led to the adoption of metal ties, and in 1884 it was decided to use such ties only in future; after further experiments a form of tie was definitely adopted in 1887. (See plate No. 15). In the original construction, the track was laid with steel flange rails, weighing 73.65 pounds per yard, on wooden ties. The rails were 5.2 inches high, with a flange 4.4 inches wide and a head 2.4 inches wide; the top table was flat, with top corner curves of .56 inch radius. The ties were 8.2 feet long, 9.6 inches wide on the bottom, 6.4 inches wide on top, 6 inches thick, the upper edges being beveled to a depth of 1.6 inches.

The rail joints were suspended, and metal tie-plates were placed under the rails at the joint ties as well as on some of the intermediate ties on curves. These plates were 6 inches long, 7.6 inches wide, and .44-inch thick, with a rib on the outer side. There were three spikes to each plate; they were of octagonal section, with hooked heads, and were driven into holes bored through the ties. The inclination of 1 in 16 was given to the rails by adzing out a seat on the tie. The joints were spliced by angle-bars and four bolts.

Several systems of metal track have been tried, among them the following:

(1) "Vautherin" tie, of modified section, with heavy ribs instead of flanges on the bottom edges; 4.4 inches wide on top, 7.84 inches wide at the bottom inside and 9.2 inches wide over the ribs, 3 inches deep, top table .40 inch thick; weight about 123.2 pounds. There were ten ties to a rail length. These were laid for a length of 577.28 feet in the tunnel and about 1,968 feet on the line between Bellinzona and Giubiasco.

(2) Hilf tie; similar to the "Berg and-Mark" type, the lower part of the sides being vertical; 4.8 inches wide on top, 8.8 inches wide on the bottom, 2.4 inches deep; top table .4 inch thick; weight about 110 pounds. These were laid for a length of 2,296 feet.

(3) Hilf tie; of similar section to the above, but made of mild steel; 5.2 inches wide on top, 9.2 inches wide on the bottom, 2.4 inches deep, with sides vertical for 1 inch from the bottom; top table .4 inch thick and sides .36 inch; weight about 110 pounds. These were laid for a length of 984 feet.

(4) Lazar tie; this was of T section, with the sides bent down slightly; 10 inches wide on top, 8.8 inches being horizontal; middle rib 3.2 inches deep, edges turned down .8 inch; weight 134.2 pounds. These were laid for a length of 984 feet.

(5) Hohenegger system of longitudinals (See "Austria"). This track was laid for a length of 1,640 feet in the tunnel and on the line between Bellinzona and Giubiasco.

After these experiments a cross-tie of rounded trough section was adopted, with the top table thickened by adding metal on the upper side; 4.8 inches wide on top, 8.16 inches wide inside at the bottom, 9.336 inches wide over the ribs, 3.2 inches deep; corners, 1.6 inches radius; sides .28 inch thick, and top .36 inch thick; weight, 119.9 pounds. In December, 1889, Mr. Bechtle, the chief engineer, reported that there were 37.25 miles laid with metal track.

The preliminary trials, made about 1885, showed that with bad ballast the maintenance of track with metal ties cost more than that of track on new wooden ties, but that with good ballast the cost was less. The ballast now used is broken stone.

The type of tie definitely adopted in 1887 (See plate No. 15) is slightly modified from that last described, but is of varying width and depth, somewhat resembling the "Post" tie. At the rail seat it is 4.6 inches wide on top, 8.196 inches wide at the bottom inside, and 9.38 inches wide over the ribs; 3.4 inches deep; thickness of top table .40 inch, and of sides .28 inch; corner radius, 1.6 inches. Inside the rail seat it is of similar width, but only 3.24 inches deep, and the top .32 inch thick. At the middle it is of ∩ shape, 2.56 inches wide inside near the top, 3.46 inches wide inside at the bottom, 5.44 inches deep. The top table of the tie is horizontal at the middle, with a flat curve to the rail seat, which is inclined 1 in 20, and another flat curve from the outer side of the rail seat. At the ends the top table is bent down to a radius of .36 inch, and the depth is 4.8 inches. The total length of the plate from the bottom of one end to that of the other is 8.53 feet. The weight of the tie is 127.6 pounds. The bolt holes are 1.92 inches by .84 inch, with rounded corners, and 3.72 inches apart in the clear. The rail fastenings are on the Ruppel plan (See "Germany—Prussian state railways"); the inner side of the clamp bears on the flange of the rail, the outer side rests on the tie and has a lug fitting into the bolt-hole in the tie; tee-headed bolts are used, with the nuts screwing down on the rail clamps. For a rail length of 26.24 feet there are ten ties; the joint ties are spaced about 11.30 inches apart center to center, the ties next to the joints 30.5 inches, and the intermediate ties 34 inches apart. For a rail length of 39.36 feet there are fifteen ties; the joint ties are spaced about 11.30 inches apart, the ties next to the joints 29.15 inches, and the intermediate ties about 33.25 inches. The cost of maintenance, exclusive of renewals, is said to slightly exceed that of track on wooden ties.

Switches and crossings are laid on the steel ties. At the heel of the switch a tie of extra size is used, being 8 inches wide on top and 11.2 inches wide on the bottom, while the others are 4.8 inches wide on top and 9.336 inches on the bottom. With a stock rail 22.96 feet long, and a switch rail 16.40 feet long, there are eight ties, including one at the point and one at the heel, spaced 28.52 inches apart center to center. On these ties are bolted two plates 17.38 feet long and 18.4 inches wide, one on each side of the track, and on these are placed the rails. Hand-lever switch apparatus is bolted to a plate resting on the ends of two ties of extra length.

Mr. Bricka states in his report that in 1885 metal ties were laid for a length of 15.5 miles, and he gives the following statement of the mileage of the track in 1884:

| | Miles. |
|---|---|
| Main lines | 148.80 |
| Total track | 204.60 |
| Wooden ties | 202.12 |
| Metal ties | 6.82 |

NORTHEASTERN RAILWAY.—Metal ties were first used in 1880; the "Vautherin" and "Berg-and-Mark" types were tried, and the latter was adopted. They are 7.87 feet long, 5.2 inches wide on top, 9.2 inches wide at the bottom, and 3 inches deep, with the lower part of the sides vertical for 1.6 inches from the bottom; the top table was .32 inch thick, with a rib on the under side 1.6 inches wide, making the thickness .44 inch. The weight was 117.7 pounds. The ends were closed. At the middle the tie was horizontal, but at 22 inches from the middle they were bent up 1 in 16 for a length of 14 inches to form the rail-seat; thence the ends were horizontal, but higher than the middle portion. The rail fastenings are of the Roth-and-Schuler type, as used on the Baden state railways (Germany); a gauge washer on the bolt takes the thrust of the rail, and the clamp bears on the tie and the rail flange. In 1884 there were 42,358 ordinary ties and 2,512 special ties at switches; in 1885, 42,000 ties were laid. A modified form was adopted in 1885; it is of the same type, length and weight, but the top table is .36 inch thick instead of .32 inch; the sides are rather thinner, and there is a rib on each bottom edge. The rail joints are spliced by angle-bars 21.20 inches long, with four bolts. At the joints the ties are spaced 24 inches apart center to center, 32 inches apart next to the joints, 34 inches spacing for intermediate ties. These ties have given good results in regard to maintenance.

The ties used at frogs and switches are of the Hilf section, similar to the "Berg-and-Mark" type, but with a longitudinal middle rib, making them of ╓╖ section. They are 7.2 inches wide on top, 12 inches wide on the bottom and 2.4 inches deep, the sides being vertical for 1.2 inches from the bottom. The thickness averages .32 inch, and the weight is 58.5 pounds per yard. Between the switch and frog, ordinary Berg-and-Mark section ties are used, with bolt holes in the top table, and weighing about 45 pounds per yard. At switches the ties are spaced about 30.28 inches center to center. Under each line of rail is a plate about 18.76 feet long and 12.8 inches wide, to which the rails are bolted and which is itself bolted to the ties; upon this the switch rails move. The two ties at the point of the switch are about 13.12 feet long, extending outside the track on one side to hold the switch stand and lever. At a No. 9 frog there are four ties; the inner ones, at the frog point, are spaced 28.56 inches center to center, and the outer ones 26.60 inches. On these four ties is a plate 6.56 feet long, and 16.8 inches wide, to which the rails are bolted, and which is bolted to each tie by two bolts.

Mr. Bricka, in his report, 1885, gives the following statement of the mileage of this road for 1884; and 21.08 miles more were laid in 1885:

| | Miles. |
|---|---|
| Main lines | 403.62 |
| Total track | 596.44 |
| Wooden ties | 573.50 |
| Metal ties | 22.94 |

Western and Simplon Railway.—Steel ties of the "Berg-and-Mark" type and similar to those in use on the Elberfeld division of the Prussian State railways, were tried about 1881. They weighed about 100 pounds each. The engineers thought the maintenance expenses were greater at first, owing to the difficulty of ballasting, but the track was very elastic and the riding easy. In 1884 there were about 34.10 miles laid. Mr. Bricka stated that the introduction of metal ties had reduced the prices of wooden ties as follows: Oak, reduced from $1.20 or $1.30 to 90 cents per tie; larch, reduced from 80 or 90 cents to 60 or 70 cents per tie. For rails 19.68 feet long the ties were spaced 20.08 inches apart, center to center, at the joints, and 36.38 inches intermediate. Mr. Bricka gave the following statement of the mileage of track up to 1884:

| | Miles. |
|---|---|
| Main lines | 368.90 |
| Total track | 492.28 |
| Wooden ties | 473.68 |
| Metal ties | 18.60 |

The type of tie adopted in 1887 (See plate No. 15) is of inverted trough section, broad and shallow at the ends and narrow and deep at the middle, being of fish-bellied shape in elevation. The cross-section is similar to that of the "Berg-and Mark" type. The tie is bent to a curve with a radius of 49.26 feet to give the rails an inward inclination. It is 7.54 feet long over all, 9.2 inches wide over all at the ends, narrowing to 4.8 inches at the middle, and flaring out to 11.2 inches at the extremities; it is 4.4 inches deep at the middle, 2.4 inches deep for the greater part of its depth, and the ends are curved down and project below the body of the tie, being 4 inches deep. At the rail seat it is 5.2 inches wide on top, 9.2 inches wide at the bottom, 2.4 inches deep, with the sides vertical for 1.04 inches from the bottom. At the middle it is of ∩ section, with nearly vertical sides and round top corners; it is 4.8 inches wide at the bottom and 4.4 inches deep, with the top flat for a width of about 2.4 inches. The thickness is .28 inch at the sides, .36 inch on top, and .52 inch along the middle of the top table, the extra thickness being given by a rib 1.44 inches wide on the underside of the top. For rails 19.68 feet long, the joint ties are spaced 20.08 inches apart, center to center, and the intermediate ties 36.68 inches apart. The rails are of flange section, secured by gib and cotter fastenings. The outer flange is held by a gib; the inner flange is also held by a gib, and a third gib is placed back to back with the second one and the vertical cotter driven between them, the object of the third gib being to increase the bearing of the cotter. At each rail seat there are two holes in the tie; the outer one is 1.56 inches long at right angles to the rail and .72 inch wide; the inner hole is 2.624 inches long and .72 inch wide; they are 3.36 inches apart in the clear. The gibs are .68 inch thick. The cotter is 5.96 inches long, .68 inch thick, 1.07 inches wide at the top, and .76 inch wide just above the point. Inner and outer gibs of three different widths are used for the adjustment of the gauge; they allow a widening of .16 to .64 inch, and raised numbers on the side enable them to be easily distinguished. The gauge on tangents, and on curves of over 2,955.8 feet radius, is 4.71 feet; at the ends of curves of 1,315.28 feet to

2,952 feet, the inner rail is set out to give a gauge of 4.73 feet, and the gauge on the curve is 4.736 feet, the inner rail being again set out; on curves of 590.4 feet to 1,312 feet radius, the outer rail is set out to give a gauge of 4.75 at the end of the curve, and is set out again to give a gauge of 4.762 feet on the curve. This method enables very close adjustments to be made, and the gauge is accurately maintained, but it has the disadvantage of requiring the use of several different kinds and sizes of material in track work, and as the fastening of each rail to each tie requires four separate pieces (three gibs and one cotter) the result is an apparant complication, especially on a line having many curves, where different sizes of gibs are required. On the other hand, fastenings used with metal ties are expected to require very much less attention when once in place than fastenings used with wooden ties, and many bolt fastenings require a still greater number of pieces. In track work it is always desirable to have as few separate pieces and as great simplicity as possible.

The following particulars are taken from the company's book of "Instruction for the laying and ballasting of track having rails 39.36 feet long," issued in 1885:

The gauge of the road is 4.70 feet on wooden ties and 4.71 feet on metal ties. The rails are of flange section, weighing 66.40 pounds per yard; they are 5.08 inches high with a head 2.4 inches wide and a flange 4 inches wide; they have an inward inclination of 1 in 20. The joints are square and suspended, and are spliced by fish plates with four bolts; some of the plates have a lug which bears against the tie plate on wooden ties, or against the gib fastening on metal ties, the object being to prevent creeping of the rails. Changes of grade are effected by a vertical curve of 3,280 feet radius, giving a deflection of .32 inch for a rail length of 39.36 feet. The following spacing of ties for rails of this length was adopted in 1887: Wooden ties are spaced 24.8 inches apart at the joints, 29.2 and 32.8 inches next to the joints, and 36.8 inches for intermediate ties; metal ties have the ties at the joints spaced 20 inches apart, center to center, the next ones 30 and 34.4 inches, and the intermediate ties 36.8 inches apart. The width at subgrade for single track is 16.40 feet. With wooden ties the ballast is 14.8 inches deep at the middle, 16.8 inches deep at the sides, and 9.84 feet wide on top for single track; the subgrade is crowned, and the surface of the ballast is horizontal, just covering the ties. On curves the top of the ballast is given the same slope as the ties and on double track on curves the ballast between the two tracks is rounded off to a level with the top of the tie of the inner track and the top of the rail of the outer track. With metal ties the arrangement is similar, but the ballast is shallower, only level with the tops of the ties and not covering them; it is only 8.2 feet wide on top for single track. The volume of ballast per yard single track is as follows, the volume of the ties being deducted where wooden ties are used:

| | With wooden ties. | With metal ties. |
|---|---|---|
| | *Cubic yards.* | *Cubic yards.* |
| On tangents | 1.55 | .83 |
| On curves below 1,968 feet | 1.71 | .79 |

In April, 1888, Mr. Mayer, chief engineer of permanent way, stated that the laying of these ties was commenced in 1883; up to the date of his letter 52.70 miles had been laid, and 21.7 miles were to be laid during 1888. Some of the ties put down in 1883 were taken out in 1888 to see how they had behaved in service, and they were found to be in excellent condition. They weigh, he stated, 96.8 to 99 pounds each. The track keeps in good order, and the engineer was very well satisfied with the ties. The cost of maintenance was even more economical than with wooden ties. It is expected that these ties will last twice or two and a half times as long as the best oak ties; when rejected they will always be worth 40 to 50 cents each, while rejected oak ties are not worth more than 8 to 10 cents each. They are made from mild steel plates, and the railway pays $26.40 per ton of 2,200 pounds, or $1.16 per tie. An oak tie costs $1, and the two iron tie-plates for the same cost 10 cents. The ballast used with the metal ties consists of screened gravel, not too coarse, broken to pass through a ring of 1.6 inches diameter; broken stone of the same size is also used.

At the meeting of the International Railway Congress, at Paris, in 1889, Mr. Mayer presented the following information:

Since 1883 metal ties have been used in regular service, being introduced gradually as the wooden ties necessitate renewals The total length of track thus laid is as follows:

| | Miles. |
|---|---|
| 1883 | 6.738 |
| 1884 | 10.725 |
| 1885. | 10.131 |
| 1886 | 9.512 |
| 1887 | 13.036 |
| 1888. | 18.426 |
| Total at end of 1888 | 68.568 |

This represents a total of about 126,990 ties in the track. The work is being continued, and it is intended to lay about 15.5 to 18.6 miles of metal track per year. Contracts have been made for supplies for five years. This type of track, as already described, is now adopted as the standard track of the road. The ties first used were of uniform section throughout, but the form adopted in 1887 is narrow and deep at the middle (See plate No. 15); the objects being to give a better hold on the ballast, to increase the stiffness of the tie, and to prevent lateral motion of the tie. The ties are of mild steel, having a resistance to breaking of 56,000 to 65,000 pounds per square inch. The weight is 99 pounds per tie.

The maximum grades are 2.3 per cent. and the minimum radius of curves is 1,148 feet. The traffic varies on different parts of the line, being from eight trains in each direction per day, with a maximum speed of 28 miles per hour, on branch lines, to thirty trains in each direction per day, with a maximum speed of 40 miles per hour, on the main line. The heaviest locomotives weigh about 34 tons, with a maximum load of 12 tons on an axle, though some of the old four-wheel tank engines still in use have a load of 13 tons per axle. Up to 1884 the rails were 19.68 feet long, with seven ties to a rail length. They are now made 39.36 feet long, with thirteen, or in exceptional cases fourteen, ties to a rail length. The first cost of track on new wooden ties is about $47 per rail length, or about $3.58½ per yard. The first cost of track on steel ties is about $47.55 per rail length, or about $3.62½ per yard. The current prices, on which these estimates were made, were 87 cents each for oak ties and $1.31 each for steel ties ($1.16 for the tie and 15 cents for the fastenings). The cost of maintenance has not yet been established, but reports for the year ending

February, 1889, for twenty-two sections of track on steel ties and twenty-one sections of track on wooden ties, showed the maintenance expenses of the former to be slightly less than those of the latter. The company has found, and this is the general experience, that the maintenance expenses of track on metal ties are during the first two years rather higher than those of track on wooden ties, but after that time they decrease considerably for the former. The introduction of steel ties has reduced the price of oak ties from $1.25 to 87 cents each. A slight but scarcely perceptible metallic sound is heard when traveling over the steel ties. No difference in the wear of the rolling-stock has been noted. A few fastenings have been renewed, not on account of failure, but because they were considered to be too light, and were replaced with others of stronger make. The durability of the steel ties has not yet been determined, but those first put down in 1883 do not show any wear or cutting by the rail flange. Of the 126,990 steel ties laid, only 43 have been taken out on account of breakage (0.03386 per cent.), while it is estimated that with the same number of wooden ties the renewals would have amounted to 20,000 or 25,000 ties (15.75 to 19.7 per cent.).

JURA, BERNE AND LUZERNE RAILWAY.—Iron cross-ties are in use on this road, and the following statement in regard to the track was sent to me in August, 1889, by the chief engineer:

| | Inclusive of the Bodeli and Brunig lines. | Exclusive of the Brunig line. |
|---|---|---|
| | *Miles.* | *Miles.* |
| Total length of road | 216.24 | 188.44 |
| Length in operation | 228.16 | 200.26 |
| Length of track: | | |
| With wooden ties | 229.31 | 223.09 |
| With metal ties | 33.04 | 7.95 |
| Total length of track | 262.35 | 231.04 |

The ties are of iron and are of a somewhat similar type to those used on the Gotthard Railway, but the cross-section at the rail-seat more closely resembles the "Post" tie (See "Holland"), with a rib on each of the lower edges. The tie is 7.87 feet long; at the outer part of the rail-seat it is 4 inches wide on top, 9.4 inches wide over the ribs at the bottom, and 3.56 inches deep; at the inner part of the rail-seat it is 4.8 inches wide on top, 9.4 inches wide on the bottom, and 2.8 inches deep; at the middle it is of ∩ section, about 3.5 inches wide and 5.36 inches deep. The thickness of the sides is from .24 inch at the bottom to .32 inch at the top; the top table is .28 inch thick, except at the rail-seat, where it is .44 inch thick; the ribs on the edges are about .72 inch deep. The inclination of the rail seat is 1 in 20. The rails are secured by bolted clamps on the Ruppel system (See plate No. 13), the adjustment of the gauge being effected by the use of different sets of clamps.

On the Delle and Basle line a length of 1.55 miles has been laid with a rather different form of track, designed by Mr. Bieri, an engineer on this road. The rail rests on a tie-plate which gives it the inclination of 1 in 20; bolted clamps of ⌐ shape hold the rail flange, but the vertical leg does not fit into the bolt-hole. A hole in the middle of the tie-plate is over a smaller hole in the tie, and into these holes fits a metal plug of T section; the width of the projection of the head is different on each side, the leg not being in the middle, so that by turning the plug the position of the tie-plate, and consequently the gauge of the track, is altered. This is a somewhat similar plan to that tried in India by Sir Guilford L. Molesworth, consulting engineer for state railways, but in that case the plugs were used in cast-iron bowls and the legs engaged with notches in the tie-bars. On the Delle and Basle line there are twenty-nine trains per day besides a number of extra trains (often one or two per day) during the months of busiest traffic.

UNITED SWISS RAILWAYS.—In August, 1889, the chief engineer stated that on this line, which is 166.16 miles long, 1,843 mild steel ties were laid during 1887 and to the end of 1888. These ties were similar to those of the Gotthard Railway (See plate No. 15). They were manufactured at the Good Hope Works and the Hoerde Works, and cost $28.40 per 2,200 pounds, or $1.64 each. The ties are 8.2 feet long, and are narrow and deep at the middle; at the rail seat the cross-section is 4.8 inches wide on top, 9.28 inches wide over the ribs on the bottom edges, and 3.4 inches deep; the top corners have a radius of 1.6 inches, and the sides have an outward slope of 5 to 1; the thickness of the top table is .48 inch and of the sides .28 inch. Inside the rail seat the cross-section is similar, but only 3.24 inches deep, and the thickness of the top table is .32 inch. At the middle it is of ∩ section, 2.54 inches wide on top, with top corner curves of .88 inch radius; depth 5.52 inches; width inside at bottom, 3.46 inches. The weight is 127.6 to 134.2 pounds. The bolt holes are .84 inch square, with rounded corners. For rails 39.36 feet long, there are fifteen ties; the joint ties are spaced 21.6 inches apart center to center, the ties next to the joints 26.4 inches, the next 30.08 inches, and the intermediate ties 34.4 inches. For rails 29.52 feet long there are twelve ties; the joint ties are spaced 21.6 inches, the next 26.4 inches, the next 28 inches, and the intermediate 32.8 inches. For rails 19.68 feet long, there are eight ties; the joint ties are spaced 21.6 inches, the next 26.8 inches, the next 30.8 inches, and the intermediate ties 31.4 inches. The rail joints are square, suspended, and are spliced by angle-bars 26.8 inches long, extending over the joint ties and having the flanges notched for the rail clamps on the ties; the bars weigh 22.66 pounds each, and have four bolts. The rail fastenings are of the Roth-and-Schuler type (See plate No. 13); the bolts are .76 inch diameter, with a round head and a neck .8 inch square; the gauge washers are 1.76 inches square, with a hole .8 inch diameter so placed as to be .28, .38, .58, and .68 inch from the sides, allowing for the adjustment of the gauge of the track. A channel-shaped rail clamp with an oval bolt hole, .84 by 1.24 inches, fits over the washer, one leg resting on the rail flange and the other on the tie. The bolt passes through the tie, washer, and clamp, and the nut is screwed down on the latter.

The engines used have four coupled wheels, and weigh 110,000 pounds. The maximum grades are 2 per cent. and the sharpest curves are of 721.6 to 984 feet radius. No experience had then been acquired as to the cost of maintenance; the short time of observation had showed that the wear of the ties is small, but that the wear of the bolts and the gauge washers is considerable on the sharp curves of 721.6 to 984 feet radius with this (Roth and-Schuler) system of fastening. The ballast is of gravel, and is 16 inches thick under the ties. The rails are of flange section, weighing 74.43 pounds per yard. The steel ties were adopted because the neighboring roads have had satisfactory experience with them, and because the price of oak ties rose while that of steel remained cheap. It seemed, however, at the time of writing (August 1889), that the price of steel would also go up. Oak ties, 7.87 feet long by 9.6 inches by 6 inches, cost about $1.12 to $1.20 each, and have an average life of seventeen years. Larch (or tamarack or hackmatack) ties of the same dimensions cost 66 to 80 cents each, and have an average life of ten years.

SWISS CENTRAL RAILWAY.—Metal ties were first used about 1880; they are of the "Berg-and-Mark" type (Germany), resembling those in use on the Western and Simplon Railway (See plate No. 15). They are 7.87 feet long; the first ones used weighed 103.4 pounds each, but the later ones weigh 118.8 pounds. The gib and cotter fastenings are used. The earlier ties were of iron, the later ones are of steel. At the end of 1884 there were over 100,000 ties in service, and it was intended to lay about 30,000 per year until they had been laid over the entire system. The engineers were well satisfied with the results obtained, and they considered the track more elastic than track on wooden ties. The cotters are said to keep tight and do not wear the holes. At switches heavier ties are used, with the top table .52 inch thick, the purpose being to have them strong enough not to be broken by derailments, which occur more frequently at switches than on the open track. The ballast is of round, clear gravel, and forms a core in the tie. The engineers have found by experience that the metal ties require a better ballast than the wooden ties, but that when well settled, and after the first year of maintenance, one packing of the ballast each year is sufficient to keep the track in good condition. Mr. Bricka, in his report, (1885) gives the following statement of the track for 1884:

| | Miles. |
|---|---|
| Main line | 244.28 |
| Total track | 403.62 |
| Wooden ties | 333.56 |
| Metal ties | 70.06 |

MOUNT PILATUS RAILWAY.—This is a rack railway up Mount Pilatus. It is about 2¼ miles long, and has a maximum grade of 48 per cent. The rack is a flat steel bar with teeth on each side, and the driving or spur wheels of the engines are horizontal. The track is entirely of metal, and the ties are bolted down to the masonry substructure by bolts 1.08 inch diameter. The cross-ties are of channel section, inverted; they are 4 feet long, 5.6 inches wide, and $2\frac{1}{2}$ inches deep. The joint ties are spaced 15.2 inches apart and the intermediate ties 4.3 feet. In the middle of each tie is a chair built up of an inverted channel 10.2 inches wide and 2.88 inches deep, with an angle-iron 2.40 by 2.40 inches at each side, the angle-irons being riveted to the sides of the chair and the top of the tie by two rivets on each side. At the joints the chairs extend over the two joint ties, being 20.8 inches long. These chairs carry an iron longitudinal of approximately ∩ section, 8.4 inches wide, 4 inches deep, and on top of this is bolted the flat rack-rail, which is 5.2 inches wide over the teeth and 1.6 inches deep, made in sections 9.84 feet long. The gauge of the track is 32 inches. The rails are of flange section, about 4.8 inches high, with a head 1.64 inches wide and a flange 4 inches wide; they are 19.68 feet long. The rail joints are secured by angle-bars bolted in the usual way. The bars are 2.72 inches high, with a flange 3.2 inches wide having a rib on the underside of the outer edge of the flange. This rib bears on the tie while the flange bears on the rail. Each angle-bar is bolted to the tie and extends over the two joint ties; a short angle-bar fastening is used at each intermediate tie. The rails and rack are laid to break joint, so that each rail has two ties close together at the middle. The horizontal curves have a radius of 262.4 feet (about 22 degrees), the vertical curves, at changes of grade, have a radius of 1,640 feet.

BURGENSTOCK RAILWAY.—This is a short rack railway, on the Abt system, up the Burgenstock mountain. It is operated by a cable, the plant being driven by electricity generated by water power at a considerable distance; the rack gear is intended merely for safety, on account of the steep grade. The line is 3,070.08 feet long, with a grade of 32 per cent. for 1,148 feet from the bottom and 58 per cent. for the remainder of the distance. It is the steepest railway in existence. At the middle of the line is a curve 606.8 feet long, the tangents of which form an angle of 112 degrees. The cross-ties are angle-irons about 4.92 feet long; the vertical web is about 3.2 inches deep, and is imbedded in masonry; the horizontal web is about 4.8 inches wide and carries the rails. The gauge is 1 meter. The rails are of flange section, weighing 44.25 pounds per yard; they are 4.6 inches high, with a flange 3.96 inches wide, resting on a plate .20 inch thick between the rail and tie. The rails are fastened by bolted clamps, or by bolts passing through the rail flanges. The ends of the ties are closed by riveted angle-irons. In the middle of the track is a rack-rail of two bars, .8 inch thick and 1.12 inches apart, each bolted or riveted to an angle iron bolted to the tie.

SUMMARY OF METAL TRACK FOR SWITZERLAND.

| Railways. | Longitudinals. | Cross-ties. | Total. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| Gotthard | .25 | 37.00 | 37.25 |
| Northeastern | | 41.00 | 41.00 |
| Western and Simplon | | 68.57 | 68.57 |
| Jura, Berne, and Lucerne | | 33.04 | 33.04 |
| United Swiss | | 1.00 | 1.00 |
| Swiss Central (estimated) | | 120.00 | 120.00 |
| Mount Pilatus | | 2.75 | 2.75 |
| Burgenstock | | .62 | .62 |
| Total (compiled from returns) | .25 | 303.98 | 304.23 |
| Actual total in 1889 | | | 397.40 |

## SPAIN.

General Remarks.—In Spain, metal ties are in use to a moderate extent, but wooden ties, either of native fir or imported creosoted pine, are more generally used. In October, 1888, the following interesting statement from a Spanish correspondent was published in an English technical paper:

Very large quantities of the fir ties used by Spanish railways have been derived from the forest districts of Portugal north of Oporto. I have lately been visiting this district, and find that in places where, twenty-five years ago, fir trees of sufficient size for ties seemed innumerable, there are hardly any to be seen now which could be used for that purpose within twenty years. Espinho, Caminha, and Vianna, which are small ports from which the ties used to be shipped, have now scarcely any traffic of this kind at all. Considering that Spain may require within a comparatively short period 20,000,000 or 30,000,000 of ties for new lines, besides those required to replace decayed wooden ties on the existing lines, there can be very little doubt that steel ties will rapidly come into use in this country.

The gentleman whose statement is quoted above wrote to me in January, 1889, saying that the principal railway companies were still using wooden ties, of which a great number came from the north of Europe, and some from the Landes, in France. Prices have not been altered for some years, but in the country large timber for ties is very scarce. At one time he imported 1,000,000 ties from Portugal, but in 1887 he went over the district where the trees had been cut and found that it would be many years before other ties could be obtained from there. In the north of Spain, particularly toward the Pyrenees, oak ties are still to be had, but even for the lines decided to be constructed this source of supply will not be sufficient. He thinks the period is fast approaching when metal ties will be a necessity. In September, 1889, the same gentleman stated in a letter to the paper above mentioned that although a scarcity of wood for mining purposes was being felt in Asturias, wooden ties were being sold in other parts of the country at cheaper rates than had ever been known before.

The maximum life of Spanish pine ties, not creosoted, is reported as about five years. On the Rio Tinto Railway, creosoted Baltic ties are found more economical, lasting ten or twelve years.

During the discussion of a paper on "Metal Sleepers for Railways," by Mr. E. Benedict, read before the Institution of Engineers and Shipbuilders, Glasgow, in March, 1877, Mr. Peter Stewart stated that he had some experience on a short line in the south of Spain, half of which, or about 14 miles, was laid with rectangular cast-iron bowls, with tie-rods, in sand ballast. The rest of the line was laid with uncreosoted wooden ties. In running over the road there was a hard metallic ringing sound from the iron track. This portion of the line was very favorable as regarded grades and curves, but the difficulty and cost of general maintenance were so great that the iron ties had to be replaced with wooden ties, which, with ordinary care, were little affected by the climate, and gave very fair results.

Much interest in the subject of metal ties is said to be shown at Bilbao, that place being an important center of the iron industry. It was hoped that the Northern Railway would adopt cast-iron ties, as the productive capacity of the iron-works exceeds the demand for home consumption, but so far oak ties appear to be preferred.

BILBAO AND LAS ARENAS RAILWAY.—This line runs from the port of Bilbao to the town of Las Arenas at the mouth of the river; it is 7.10 miles long, one meter gauge; minimum radius of curves, 278.8 feet, and 360.8 feet maximum grade, 1.98 per cent. The main line and sidings are laid with steel cross-ties which were put down in June, 1887. (See plate No. 16.)

In a communication received in May, 1888, in regard to this line, it was stated to be believed that these ties would be cheaper than wooden ties. At first more attention has to be paid to such track than that laid on wooden ties. No difficulty had been experienced with the fastenings. The gauge had been maintained better than is possible with wooden ties. It was, however, considered advisable to increase the length of the ties and to space them more widely apart on any extensions of the line. The ties are of inverted trough section, being of the modified Vautherin type, with a rib on each of the lower edges. They are 4.92 feet long, 3.6 inches wide on top, 7.2 inches wide at the bottom, 2.4 inches deep. The thickness of the sides is .24 inch, of the rib .52 inch; the top table is .26 inch, but with a rib on the underside increasing the thickness at the middle to .32 inch. The tie is horizontal throughout except that the rail seats have an inclination of 1 in 17 for a length of 6.20 inches, and are then sloped down to the normal level. At each rail seat there are two rectangular holes, 1.64 inches long by .76 inch wide, 2.4 inches apart in the clear. The fastenings are on the Ruppel plan (See "Germany; Left-Bank of the Rhine Railway"), and consist of clamps which hold the rail flange and have a lug projecting downward and fitting into the bolt hole in the tie; these clamps are secured by tee-headed bolts, the heads being inside the tie, and the nuts screwing down on the clamps. The joint ties are placed 16.48 inches apart, center to center, and the intermediate ties are spaced 35.44 inches apart on tangents and 31.2 inches on curves. They were manufactured at the Bochum Works, in Germany, and were not painted or otherwise treated. The rails are of flange section, weighing 32.16 pounds per yard; they are 3.6 inches high, with a head 1.6 inches wide and a flange 3.8 inches wide. The rail joints are suspended, and are spliced by straight fish plates of curved section, fastened by four tee-headed bolts; the plates are 14.4 inches long; the inner holes are 4.56 inches apart, center to center, and the outer holes 3.28 inches. The ballast is of broken stone, which becomes pulverized. The weight of the locomotives is about 20 tons.

Another statement, received in January, 1889, gives the following particulars:

The ties were laid in 1886 under the supervision of Don Adolfo Ibarreta; they are 4.6 feet long on tangents and 5.25 feet long on curves, and are spaced 21.6 inches apart on curves and 25.6 inches on tangents. They are of mild steel, weighing 46.2 pounds each, and cost about 75 cents each. The ballast is of broken stone, of a rather soft character; it behaves well under the ties if the pieces do not exceed 2 inches in size. The rails weigh 34.2 pounds per yard. The traffic consists principally of passenger trains, and the engines, with six wheels, weigh about eighteen tons. The reason for adopting these ties was that wooden ties have a short life, owing to the wet nature of the ground; they have proved generally satisfactory, and the bolt fastenings hold much better than the spikes in wooden ties. There has been no trouble from breakage, and no difficulty with rail attachments or maintenance. The ties would have given better satisfaction if they had been heavier. The steel ties are considered to be very well adapted for use in wet climates, but track on metal ties takes some little time to settle down to a firm and permanent bearing. Wooden ties would have cost about 50 cents each, but none have been used on this line.

ALMANSA, VALENCIA AND TARRAGONA RAILWAY.—This line is 251.68 miles long, with a gauge of 5 feet 6 inches; the gauge is uniform on tangents and curves. The maximum grade is 1.55 per cent., and the minimum radius of curves is 583.84 feet. Cast-iron plate ties of the DéBergue system are used. (See plate No. 16.) They were laid between Valencia and Tarragona in 1860, and in 1873 they were laid on the line between Almansa and Valencia. The traffic is mixed, principally freight; and the trains are hauled by engines weighing about 50 tons, with tenders weighing 25 tons, in working order.

The ties consist of cast-iron plates arranged in pairs and connected by tie-bars; they were made in England and cost about 69.6 cents for each plate and 50.3 cents for each tie-bar. No paint or preservative is used. The plates are laid 34 inches apart, center to center of each pair, but the tie-bars are only put in every alternate pair. (This practice was originally followed on some of the railways in India, but after some experience tie-bars were put in for every pair of plates.) The cost of maintenance is about $3.77 per mile per year, including labor and material. The life of a pair of plates and a tie-bar is twenty years. This track is found more economical, and the gauge is maintained better than with timber ties. No difficulty is experienced with maintenance, and breakages only occur where plates are changed while trains are running

The climatic effects upon the metal ties are inappreciable, but they have a material effect upon timber ties. The rails are of Bessemer steel, weighing 63.30 pounds per yard, and having suspended joints fastened by four bolts. They are of flange section, 4.52 inches high, with a flange 3.28 inches wide, and a head 2.48 inches wide; the head is rounded, top table 4.52 inches radius, top and bottom corners .52 inch radius, with a vertical strip about one eighth inch deep between them; the flange is narrow but very thick, the top faces being at a steep angle. The ballast on single track is 10.82 feet wide on the top, 14.46 feet at the bottom; the width at subgrade is 16.9 feet in cuts and 19.68 feet in fills. In cuts there is a ditch on each side of the track 28 inches wide on top, 5.6 inches wide at the bottom, and 10.92 inches deep. The ballast is 16.8 inches deep, and average 1.107 cubic yards of gravel per linear yard.

Each plate is rectangular in shape, 19.6 inches long with the rail, 15.2 inches wide, with rounded corners. The bottom is flat, with a shallow rib along the middle, in the direction of the rail, having an opening at the middle of the tie-bar; a lug on the bottom of the plate engages with a notch in the top edge of the tie-bar. On the top of the plate are two longitudinal ribs, with four transverse ribs between them; these transverse ribs are not so high as the two longitudinal ribs, and are inclined so as to give the rail its inward inclination. A shallow rib runs round the edge of the plate, and four curved webs or fillets connect with the longitudinal ribs. The outer flange of the rail rests against the inner side of the rib, but is not held down; the inner flange is secured by a clamp which rests on the plate-rib and the rail flange and is fastened by a hooked bolt, the tie-bar resting in the loop and the nut being screwed on from the top, bearing on the rail-clamp. Each plate weighs 63.8 pounds. The tie-bar is 6.36 feet long, .52 inch thick, and 2.8 inches deep, weighing 28.6 pounds. It is placed edgeways under the plates, a notch at each end engaging with a lug on the bottom of the plate so as to insure the accuracy of the gauge, and it is held in place by the **U** bolts.

SUMMARY OF METAL TRACK FOR SPAIN.

| Railways. | Bowls. | Cross-ties. | Total. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| Bilbao and Las Arenas | ........ | 7.10 | 7.10 |
| Almansa, Valencia, and Tarragona | 251.68 | ........ | 251.68 |
| Total | 251.68 | 7.10 | 258.78 |

## PORTUGAL.

Royal Railways.—At the International Railway Congress, held at Milan, Italy, in 1887, Mr. Kowalski stated that forty pieces of the MacLellan system (See "England") had been put down as an experiment, but the trial had been too short for any conclusions to be drawn.

## ITALY.

GENERAL REMARKS.—The railways in Italy are owned by the state, but are leased to operating companies under government supervision. The railways are divided into two main systems, the Adriatic system and the Mediterranean system, each operated by a separate company.

Metal ties have not yet been introduced except in a very small way for experiments, as oak ties can be obtained at a much lower price, 80 cents to $1 each. It is probable that the extension of the railway systems and the increasing destruction of oak trees will change this state of things eventually, but the time is in the distant future, as the growth of the railways is not rapid or extensive. It was at one time reported that the Mediterranean Railway Company proposed to introduce metal ties upon one of its divisions, at an estimated cost of about $115,200, but this report has not been confirmed, and in answer to an inquiry the engineer merely replied that metal ties are not used. The director general of the Adriatic Railway Company stated, in May, 1889, that metal ties have not been used on the lines operated by that company; he stated further that the use of such ties is not advisable for the present, because the difference in cost of metal and wooden ties is considerable, and he does not think they will be adopted in the near future, as the Italian forests will furnish very good timber for many years yet.

A few steel ties of the type used on the Northeastern Railway, England, have been imported for experimental trial. The Italian Government has laid steel ties on about 13 miles of the line from Massana to Sahati, in Africa, and particulars of these will be found under the heading of Africa.

According to information sent me in May, 1888, by an engineer connected with one of the technical papers of Italy, there are a great many short old lines of railway, the greater part of which have been united to form four principal systems. Renewals have not been carried out as fast as was desirable, and therefore there were a great number of different tracks, old and new. In May, 1888, a commission, composed of representatives of the more important railway companies, proposed to the secretary of state for public works a new type of track, to be adopted gradually in renewals. Its principal features were as follows: Steel rails of flange section, 39.36 feet long, 5.2 inches high, 4.4 inches width of flange, 2.56 inches width of head, .56 inch thickness of web; weight, 76.45 pounds per yard. Suspended joints, spliced by angle-bars with four bolts. There were to be thirteen or fourteen wooden ties to a rail length, and the rails were to be fastened by screws. Tie-plates of iron, 7.6 inches by 6 inches and 7.6 inches by 7.2 inches, .6 inch thick, were also to be used. This project was examined by the superior council of public works, which decided that under existing circumstances, considering chiefly the money side of the question, it was not advisable to adopt a new form of track.

## SWEDEN AND NORWAY.

GENERAL REMARKS.—The only trial made with metal ties in Sweden or Norway has been for a short distance on the Swedish state railways, a description of which trial is given herewith.

The following general information relating to the railways of these countries is taken from a communication received in May, 1888, from Mr. John Johnson, manager and engineer of the Swedish Central Railway:

Timber ties, unpreserved, are generally used; they are principally of fir, with a small proportion of oak in the south of Sweden; for standard gauge lines they are 8.75 feet long, 9 inches wide, and 6.4 inches thick; fir ties have an average life of 10 to 12 years, and cost 27 to 30 cents each. The rails are of steel, of flange section, and are of the C. P. Sandberg standard patterns, weighing 56.5 to 60.36 pounds per yard for the standard gauge, and 30.10 to 34.2 pounds per yard for narrow-gauge lines. The rails are fastened direct to the ties by spikes 5.4 inches long, and no tie-plates are used. The rail joints are suspended, the joint ties being placed only half as far apart as the intermediate ties. The rail joints are spliced by two angle-bars each, or one straight and one angle bar. There are nine ties to a rail length of 23.94 feet. The ballast is usually of gravel, and blast-furnace slag is used where gravel is scarce; it is laid flush with the top of the ties, and is 12 to 14 inches deep. The mileage of the railways in 1888 was as follows: Sweden, 1,547.52 miles of government lines and 3,025.60 miles of private lines; all the former are of standard gauge (4 feet 8½ inches), but 908.92 miles of the latter are of gauges varying from 4 feet to 32.08 inches. There are only 1.86 miles of double track. Norway, 968.44 miles, of which 926.28 miles are owned by the government and 42.16 miles by a private company. The government lines include 324.88 miles of standard gauge and 601.40 miles of 3 feet 6 inches gauge. The private lines are of standard gauge. All the lines are single track.

SWEDISH STATE RAILWAYS.—In June, 1888, Mr. Storckenfeldt, assistant chief engineer of the state railways, sent me some information in regard to experiments made on a small scale on this system of railways, and notes of these experiments were presented at the International Railway Congress held at Milan in 1887. Up to July, 1887, the trials had been in progress for eleven months. The ties are of the "Berg-and-Mark" type. They are placed for a length of 2,645.6 feet near the station at Akarju; they are on a tangent, with a grade of 1 in 147; part of the track is in a cutting and the remainder is on embankment. The traffic averages twenty freight and passenger trains per day; of these, four are freight trains with an average of forty cars, weighing 610 tons loaded, and sixteen are mixed and passenger trains with an average of fourteen cars, weighing 264 tons loaded. The speed varies from 30 to 34 miles per hour for express trains, 30 miles per hour for mixed trains, and 25 miles per hour for freight trains. The weight of locomotive and tender is about 43 tons.

The ties are of iron, of the original "Berg-and-Mark" type (see Plate No. 12). They are 7.54 feet long, 5.2 inches wide on top, 9.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical for 1 inch from the bottom. The thickness of the sides is from .24 inch at the bottom to .28 inch at the top; the top table is .36 inch thick, with a rib in the middle on the underside increasing the thickness to .52 inch for a width of 1.44 inches. They are of uniform section throughout their length. The middle part is horizontal for a length of 3.28 feet, and the ends are bent up at an angle of 1 in 20. The ends are closed by bending down the top table. At each rail seat there are two holes 1.72 by .84 inch, and 3.42 inches apart in the clear. The tie itself weighs 95.91 pounds, the attachments 2.61 pounds, and the bolts, nuts, and washer 2.68 pounds, making a total weight of 101.20 pounds per tie. They were manufactured by the Union Iron and Steel Company, of Dortmund, Germany. The rails are of steel, of flange section, and the fastenings are bolted clamps on the Ruppel plan (see Plate No. 13). The ballast is of poor quality, being composed of a mechanical mixture; 30 per cent. of broken stone, 27 per cent. of gravel, 38 per cent. of coarse sand, and 5 per cent. of fine sand, clay, and particles of soil. The ballast is poor even from a mineralogical point of view as it contains among other kinds of disintegrated rock 8 to 9 per cent. of burned limestone, or the refuse from the lime kilns.

The metal ties were laid as an experiment to test their advantages under the conditions prevailing in this country. The cost of track laying and of maintenance were about the same as with wooden ties. In regard to the durability of the tie and the fastenings it was stated that the fastenings of the rails to the ties had remained in good condition. This track does not appear to have a bad effect upon the rolling stock; the elasticity of the track is good, and no complaints have been made by passengers as to any discomforts in traveling over it. While the trials, up to July, 1887, had been satisfactory, the following recommendations were made: The ties should be a little longer and deeper, as it has been found that they do not offer sufficient stability, and the track has to be put in condition as to line and surface several times. No relations were established between the price of wooden and metal ties, on account of the short time since the latter had been put in.

## DENMARK.

General Remarks.—In this country there are 996.34 miles of railway owned by the state and 250.40 miles owned by private companies; they are all of standard gauge and all single track with the exception of 27.9 miles. The rails are of steel, of flange section; on the main lines the weight is 62.88 pounds per yard, but on secondary lines it is only 44.87 pounds, and on one line it is only 35 pounds per yard.

Danish State Railways.—April, 1888, I received a communication from the general director of state railways in regard to experiments made with metal ties. On the line from Tommerup to Assens (island of Fiona or Funen) there is a length of 18.1 miles laid with cross-ties of Martin mild steel. The ties were laid in 1883-'84, under the supervision of Mr. O. Hoyer, engineer. On this division 34.73 per cent. of the length is level, 4.95 per cent. has grades of 1 in 1,000 to 1 in 200, and 60.32 per cent. has grades of 1 in 200 to 1 in 100. As to curves, 73.54 per cent. of the length of the division is straight, 24.19 per cent. on curves of more than 1,640 feet radius, and 2.27 per cent. on curves of 1,640 feet radius and less. The traffic consists of eight trains daily (passenger and freight). The locomotives weigh 17.9 tons each, with 9 tons on the driving wheels.

The ties are of inverted trough section; they are 7.2 feet long, 3.2 inches wide on top, 7.2 inches wide on the bottom, and 2.4 inches deep, with the sides vertical for .8 inch from the bottom. The thickness of the sides and top is .24 inch, with a rib 1.6 inches wide on the under side of the top table, increasing the thickness to .32 inch. Each end is closed by a riveted angle piece, and two cross pieces are riveted inside at about one-third of the length from each end. The section is uniform throughout. The ties are horizontal at the middle for 4.26 feet, then inclined up at an angle of 1 in 20 for 8 inches at the rail-seat, and then again horizontal for 10 inches to the end. At each rail-seat there are two rectangular holes 1.56 by .84 inch, and 3.22 inches apart in the clear.

The fastenings are of the Ruppel plan (see Plate No. 13); they consist of two clamps holding the sides of the rail flange, and having a lug fitting into the hole in the tie. A bolt .76 inch in diameter passes up through the tie and clamp and the nut is screwed down on the clamp. The bolt has a tee-head .76 by 1.4 inches, inside the tie; the part in the hole in the ties is of circular section, but the part in the hole in the clamp is rectangular, .76 by .96 inch. The clamps are 2.4 inches long and their bolt-holes are .82 by 1.04 inches. The adjustment of gauge at curves is effected by the use of clamps of different sizes. The ties are manufactured by the Union Steel and Iron Company, of Dortmund, Germany; they weigh 53.28 pounds each and cost $38 per 2,200 pounds. They are tarred at the works. The experience has been insufficient for information to be given in regard to durability, cost of maintenance, and efficiency as compared with wooden ties. The rails are of flange section, 3.8 inches high with a head 2.16 inches wide and a flange 3.42 inches wide; the weight is 45 pounds per yard. They are 21 feet long and there are 8 ties to a rail length, spaced 18.4 inches apart, center to center at the joints with the next ties 32.52 inches and the intermediate ties 34.52 inches apart. The rail joints are square, suspended, and fastened by angle splice bars. The width at subgrade is 15.41 feet; width over bottom of ballast-bed, 13.45 feet; the ballast is 8.4 inches deep under the ties; at the middle and ends it is 3.2 inches deep over the ties, sloping down to the rail flanges. The ballast is of gravel.

These metal ties were adopted for experiment, and the general results have not been quite satisfactory. There was trouble with the maintenance, frequent lifting of the track being necessary. Breakages were rare and occurred generally at the hole for the outer bolt and clamp. The weight and strength of the tie were reported to be insufficient. When the gravel bed under the ties is frozen, water is retained in the interior of the ties, and during the passage of trains water and gravel spurt through the holes in the ties and cover the rails and wheels.

The wooden ties used are of Pomeranian fir (pine), costing $6.30 to $6.97 per cubic meter in 1888. They last from eight to ten years. The climate is about the same as in Germany.

## RUSSIA.

GENERAL REMARKS.—Metal ties have been tried in this country on a very small scale. In May, 1888, General Possiet, then minister of ways and communications, stated that they had only been used to a very limited extent on two branch roads; these were the Kursk-Kiev road and the Donets road, and even there they had not been sufficiently used to enable him to give any conclusions respecting them.

Mr. Hugh Carlile, chief engineer of the Dunaberg-Witepsk Railway, stated in February, 1888, that good red pine ties, 9 feet by 10 inches by 6 inches, would be obtained at about 40 cents each. A difficulty which would be met with in the part of Russia traversed by this railway in using metal ties would be in repairing the track for frost blisters in winter, which is usually done by inserting wooden wedges or packing between the rail and tie ("shimming," as it is termed in American railway track-work), the wedges being spiked to the ties to prevent them from moving.

MOSCOW-KURSK RAILWAY.—Some metal ties were laid on this line, but were taken up again, as they proved too expensive in maintenance, so it is said; their maintenance being more expensive than that of wooden ties. In the spring and fall seasons especially the cost of surfacing was found to be much higher than with wooden ties. The cost of iron being greater and that of wood being less in Russia than in some other European countries, it was claimed that at the prices of material in 1888 the iron ties cost one and a half times as much as oak ties not treated, and two and a half times as much as pine ties treated with chloride of zinc. The basis of comparison was a life of thirty-five years for iron ties weighing 112 pounds, and a life of ten years for treated and six years for untreated wooden ties. Conditions in Russia, however, are exceptional as regards material and labor.

## TURKEY.

EASTERN RAILWAYS.—The following particulars were presented by Mr. Kowalski at the International Railway Congress, held at Milan, Italy, in 1887:

The track laid with metal ties comprised 61.38 miles on which the ties were adopted for regular service, and 9.3 miles on which the ties were laid for experiment. The ties were of mild steel, and were of two types, viz, the original "Vautherin" type, with horizontal flanges on the lower edges, and the original "Berg-and-Mark" type (see plate No. 12). They were 7.22 feet long; the ends were closed by riveted pieces or by the bending of the top table of the tie, and the rail fastenings consisted of bolted clamps. The weight of fastenings for each tie was 3.3 pounds for the four clamps, and 3.3 pounds for the four bolts. The "Vautherin" ties weighed 77 pounds each, and the "Berg-and-Mark" ties 83.6 pounds each, exclusive of fastenings. The ties are placed in cuttings and on embankments, on different kinds of ground and on grades as steep as 1.5 per cent. On 47.74 miles of the line between Kutchuk-Tchekmedje and Kouleli-Bourgas, they have been laid on curves of 1,968 feet radius and on tangents connecting two curves; on the remaining 22.94 miles they were laid on tangents and on curves of different radius. These lines have a light traffic, averaging for both directions one to four mixed or loaded freight trains per day. The suburban line from Constantinople to Kutchuck-Tchekmedje is an exception, having nearly thirty trains per day in both directions. The maximum speed allowed is 26 miles per hour. The locomotives have three axles and weigh 36 tons. The track is laid with steel rails weighing 41.16 miles per yard, having the ties spaced 32 inches, center to center, and iron rails weighing 68.5 pounds per yard, having the ties spaced 3.28 feet, center to center. The ballast is of different materials, from fine sand to broken stone; the use of metal ties has shown the necessity of replacing the fine ballast, or at least mixing it with a coarse ballast.

The experiments date from 1879, when the first 600 ties were laid; since then ties have been laid as follows:

| Type. | Year. | Ties. |
|---|---|---|
| | | *No* |
| Vautherin | 1880 | 13,300 |
| Do | 1881 | 7,800 |
| Do | 1882 | 6,700 |
| Berg-and-Mark | 1883 | 13,400 |
| Do | 1884 | 31,400 |
| Do | 1885 | 31,000 |
| Do | 1886 | 16,500 |
| Do | 1887 | 9,300 |

With fine ballast, the maintenance expenses are higher than those with wooden ties; but with coarse ballast the maintenance expenses of tracks on metal and wooden ties are about equal (allowance being made for the expense of renewing wooden ties). The trials with fine ballast have also been unsatisfactory, because with a spacing of 3.28 feet between the ties the resistance to lateral motion is too little unless good ballast is used, preferably broken stone. No wear of the body of the tie had been observed, so that no limit of the life of the tie could be determined. With a good seat for the rails the tracks with wooden or metal ties present the same advantages as to the preservation of the rolling-stock, the elasticity of the track and the comfort of the passengers.

The company reported that the intention was to continue the use of the "Berg-and-Mark" type of ties, if the price could be made suitable. They were not able to establish a relation between the prices of wooden and metal ties to enable them to decide that the use of the latter was more advantageous. They were of the opinion, however, that the use of metal ties was not an advantage when the net cost was double the cost of wooden ties; but, on the other hand, they considered it to be an advantage to use metal ties when the price was only one and a half times that of wooden ties. For the comparative calculations respecting the two forms of track, they took pine or beech ties, treated with chloride of zinc, and each provided with two tie-plates; they only counted the value of one of these plates, however, because they last much longer than the wooden ties.

SUMMARY OF METAL TRACK FOR SECTION NO. 1.

| Countries. | Bowls. | Longitudinals. | Cross-ties. | Total. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| England | | | 70.00 | 70.00 |
| France | | | 52.12 | 52.12 |
| Holland | | 8.06 | 321.36 | 329.42 |
| Belgium | | | 115.50 | 115.50 |
| Germany | | 5,224.12 | 3,562.52 | 8,786.64 |
| Austria and Hungary | | 66.56 | 56.56 | 122.93 |
| Switzerland | | .25 | 303.98 | 397.40 |
| Spain | 251.68 | | 7.10 | 258.78 |
| Portugal | | | .02 | .02 |
| Italy | | | | |
| Sweden and Norway | | | .50 | .50 |
| Denmark | | | 18.10 | 18.10 |
| Russia | | | | |
| Turkey | | | 70.68 | 70.68 |
| Total | 251.68 | 5,298.99 | 4,578.25 | 10,222.09 |

## SECTION 2.—AFRICA.

### EGYPT.

GENERAL REMARKS.—In this part of Africa metal track has been in service since 1854. The type of track generally used consists of ties made of a pair of cast-iron bowls connected by a transverse tie-rod. This form of tie was originally used for a railway line in Egypt; the greater part of its length was through the desert, and it answered very well, as the fine loose sand made a ballast especially adapted for this type of tie. Now, however, this track is unfavorably considered by the consulting engineer of the railway administration, as noted in the following paragraph. It has been generally understood, however, that wooden ties were not suitable for the climatic and other conditions existing in Egypt, being destroyed rapidly by the heat, by insects, and by other influences.

EGYPTIAN RAILWAYS.—Through the courtesy of Mr. George H. Wright, of London, engineer for the railway administration, I am enabled to give the following details of the track, from a statement prepared from notes taken in 1887. Mr. Wright, in a communication received in August, 1889, stated that wooden ties only are now imported into Egypt; in his opinion they are much to be preferred to the iron bowl ties, as they make a better road and cost less to maintain. He stated, however, that the steel plate ties (presumably of the type used on the Indian state railways) would probably prove better than either the wooden or bowl ties.

*Track of Egyptian Railways.*

| Lines. | Opened. | Miles. | Track. Rails. | Track. Ties. | Notes of 1887. |
|---|---|---|---|---|---|
| *District No 1.* | | | | | |
| Cairo to Tanta | 1856 | 53½ | D. H. | Bowls | 37¾ miles iron rails, old bowls, 15¾ miles, steel rails, new bowls, laid in 1887. |
| Tanta to Kafr-Zayat | 1855 | 12½ | D. H. | do. | Steel rails on new bowls, laid in 1885. |
| Cairo to Callioub | 1861 | 8¾ | D. H. | do. | Rails iron, worn, ties fair condition. |
| Callioub to Benha | 1866 | 19½ | D. H. | do. | Do. |
| Benha to Tanta | 1865 | 25¼ | D. H. | do | Do. |
| Tanta to Kafr-Zayat | 1859 | 12½ | D. H. | do. | Steel rails and bowls, laid in 1886. |
| Benha to Mitbeneh | 1861 | 5½ | D. H. | do. | Iron rails, and ties in good order. |
| Barrage Branch | 1865 | 6¼ | D. H. | do | Do. |
| Cairo to Heloan Junction | 1876 | 7¾ | D. H. | do. | Iron rails some wooden ties. |
| Heloan Line | 1876 | 5 | D. H. | do | Do. |
| | | 7 | D. H. | Vautherin | Some ties in bad condition. |
| | | 3 | F. | Wood | |

*Track of Egyptian Railways*—Continued.

| Lines. | Opened. | Miles. | Track. Rails. | Track. Ties. | Notes of 1887. |
|---|---|---|---|---|---|
| *District No. 2.* | | | | | |
| Kafr-Zayat to Millaha ......... | 1854 | 57 | D. H. | Bowls..... | 22 miles, steel rails, old bowls, laid in 1880-'81. |
| Kafr-Zayat to Millaha, second track | 1855 | 57 | D. H. | ....do...... | 92 miles, steel rails, new bowls, laid in 1882-'85. |
| Millaha to Sidi-Gabir ....... .. | 1876 | 1½<br>1¼ | D. H.<br>D. H. | Wood ....<br>Bowls..... | Old wooden ties in good condition.<br>New steel rails and bowls, laid in 1887. |
| Sidi-Gabir to Alexandria ...... | 1876 | 3¼ | D. H. | ...do. .... | Do. |
| Sidi-Gabir to Alexandria, second track. | 1876 | 3¼ | D. H. | ....do ..... | New steel rails and bowls, laid in 1885. |
| Millaha to Gabbay.............. | 1854 | 6¾ | D. H. | .. do ..... | A few wooden ties. |
| Millaha to Gabbay, second track | 1855 | 6¾ | D. H. | ....do . ... | |
| Gabbay to Mex ............... | 1862<br>1875 | 3½ | D. H. | ....do ..... | A few wooden ties. |
| Rosetta Line. ............. .. | 1876 | 39½<br>1 | F.<br>D. H. | Wood.... | Extensive renewals required. |
| *District No. 3.* | | | | | |
| Tanta to Cheibin-el-Com....... | 1866 | 17½ | D. H. | Bowl . ... | In good condition. |
| Tanta to Mehallet-Roh......... | 1857 | 8½ | D. H. | .. .do ..... | New bowls laid to replace wood, to do away with a mixed track. |
| Tanta to Mehallet, second track | 1877 | 8½ | D. H. | ....do ..... | 1 mile of new rail and bowls laid in 1886. |
| Mehallet-Roh to Samanoud .... | 1859 | 7½<br>2<br>1<br>2½ | D. H.<br>D. H.<br>D. H.<br>D. H. | Wood.....<br>Bowls ....<br>Wood. ..<br>....do . .. | <br>Bowls laid to replace wood, to do away with mixed track.<br><br>Being relaid with iron bowls. |
| Samanoud to Damietta......... | 1869 | 38¾<br>2¾<br>9½ | D. H.<br>F.<br>F. | Bowls ....<br>Wood.....<br>Vautherin | 17¼ miles of ties, much corroded.<br>Pine, replacing old iron trough ties.<br>Ties in bad condition. |
| Zifteh Branch ................ | 1865 | 18¾ | D. H. | Bowls . .. | |
| Dessoub Branch................ | 1865 | 32½ | D. H. | ...do...... | |
| Kafr-Sheik Branch............. | 1875 | 11 | F. | Wood..... | Ties in good condition. |
| *District No. 4.* | | | | | |
| Benha to Zagazig .............. | 1860 | 21½ | D. H. | Bowls .... | Tie-bars too long. |
| Benha to Zagazig, second track | 1870 | | D. H. | ...do .... | |
| Zagazig to Suez and docks..... | 1868 | 60¼<br>39<br>4¼ | D. H.<br>D. H.<br>D. H. | ....do .....<br>Wood.....<br>Steel...... | <br><br>Buckled steel. |
| Callioub to Zagazig.... ... .. | 1865 | 38 | D. H. | Bowls ... | |
| Zagazig to Mansourah......... | 1865 | 44 | D. H. | ...do..... | |
| Salhiel Branch................. | 1869 | 2<br>19 | D. H.<br>D. H. | Wood....<br>Vautherin | 5 miles must be renewed before 1889. |
| *District No. 5.* | | | | | |
| Tchad-el-Baroud to Boulak-Dakrour. | 1872 | 43<br>26<br>5 | D. H.<br>D. H.<br>F | Bowls ....<br>Wood.....<br>....do . ... | |
| Boulak-Dakrour to Wasta ..... | 1867 | 51 | D. H. | Bowls ... | 5¾ miles of new bowls, laid in 1884, 1886. |
| Wasta to Fayoum.............. | 1868 | 24¼ | D. H. | ....do .... | |
| Fayoum to Abouxa ............ | 1869 | 14¾ | D. H. | ....do ..... | |
| *District No. 6.* | | | | | |
| Wasta to Minieh............... | 1867 | 97 | D. H. | Bowls ... | |
| Minieh to Millaui .............. | 1870 | 29½ | D. H. | ....do .... | |
| Millaui to Assiout ............ | 1874 | 2½<br>19 | D. H.<br>F. | ....do .....<br>Wood .... | |

SUMMARY OF MILEAGE.

| District. | Iron bowls. | Vautherin cross-ties. | Steel plates. | Wood. | Total metal. | Total. |
|---|---|---|---|---|---|---|
| No. 1 ................................ | 157½ | 7 | .......... | 3 | 164½ | 167½ |
| No. 2 ................................ | 138¾ | .............. | .......... | 42 | 138¾ | 180¾ |
| No. 3 ................................ | 126½ | 9¼ | .......... | 24¾ | 135¾ | 160½ |
| No. 4 ................................ | 163¾ | 19 | 4¼ | 41 | 187 | 228 |
| No. 5 ................................ | 132 | .............. | .......... | 31 | 132 | 163 |
| No. 6 ................................ | 129 | .............. | .......... | 49 | 129 | 178 |
| Total ................................ | 847½ | 35¼ | 4¼ | 190¾ | 887 | 1,077¾ |

The total length of lines, including sidings, in 1887, was 1,228¼ miles.

EGYPTIAN AGRICULTURAL RAILWAYS.—A type of metal track used on these lines consisted of ties made of a pair of wrought-iron plates connected by tie-bars. (See plate No. 17.) The plates were rectangular in shape, 18 inches long, about 15½ inches wide, and seven thirty-seconds of an inch thick. When bent to shape each plate is flat for its whole length and for a width of about 5½ inches; the sides are bent down, flaring out to a width of 13 inches over all at the bottom, and the corners are bent in to a width of 10¾ inches over all. The depth is then about 2¾ inches. Each pair of plates is connected by a transverse tie-bar, 6 feet 2 inches long, 1⅞ inches deep, and three-eighths inch thick, placed on edge; it is secured by a key or cotter on the inner and outer side of each plate. The keys are 6 inches long, 1¼ inches wide at the ends, 1½ inches wide at the middle, and three-eighths inch thick; the edge bearing against the plate is beveled to the same slope as the side of the plate. The holes in the tie-bar are 1¾ inches long by three-eighths inch deep. The hole in the outer side of each plate is slightly lower than the hole in the inner side, so that the top of the plate is inclined and gives the rail the usual inward inclination. The track is 4 feet 8½ inches gauge. The joint-ties are spaced 2 feet 4 inches apart, center to center of tie-bars, and the intermediate ties are spaced 3 feet 1½ inches apart. The rails are of flange section, weighing 42 pounds per yard; they are $3\frac{1}{32}$ inches high, with a flange 3¼ inches wide and a head 2 inches wide. The joints are suspended, and are spliced by a pair of straight, flat splice-bars 15 inches long, weighing 9.60 pounds per pair; there are four bolts three-fourths inch diameter, and the weight of the nuts and bolts is 3.24 pounds per set. The rail-fastenings consist of three clips; on the outer side there are two clips 3 inches long, each fastened by a rivet eleven-sixteenths inch diameter; on the inner side is a similar clip, secured by a bolt three-fourths inch diameter, with a ⊥ head on the under side of the plate. The weight of each tie complete is 60 pounds. The average weight of the track per yard is 140 pounds.

The following is the weight of material per mile of single track:

| | Tons. | Lbs. |
|---|---|---|
| Rails | 66 | ..... |
| Ties | 47 | 320 |
| Splice plates and bolts with rails: | | |
| 24 feet long | 2 | 1,170 |
| 21 feet long | 2 | 1,976 |
| 18 feet long | 3 | 812 |

SUAKIN RAILWAY.—During the English campaign in Egypt in 1885, a short section of light railway was laid near Suakin for military purposes. According to information received from the war office, the track was of the type manufactured by John Fowler & Co., of Leeds, England, for portable and light railways. The line had a gauge of 18 inches. The ties were of steel, 3 feet 9 inches long, of shallow inverted channel section, with a deep groove or corrugation lengthwise of the middle of the tie. At each end of the tie were two brackets, each secured by two rivets; the outer pieces were angle irons, with the upright web inclined toward the rails; the inner pieces were made to fit the web and flange of the rail. The ties weighed 35 pounds each, complete. The rails were of flange section, weighing 24 pounds per yard, and were secured by oak keys or wedges driven between the web of the rail and the outer angle bracket. A number of these ties were laid, but the line was taken up at the end of the campaign, and the time during which they were in service was too short for any opinion to be formed as to their durability.

## ALGERIA.

ALGERIAN RAILWAYS (*Paris, Lyons and Mediterranean Railway*).—The Paris, Lyons and Mediterranean Railway, of France, which has not had success with metal ties on its home lines (see "France") has used them with very satisfactory results on the Algerian lines which it owns. These lines are from Oran to Algiers, 264.12 miles; and from Phillipville to Constantine, 53.94 miles. The conditions, however, are by no means the same; the burning climate of Africa causes the very rapid destruction of wooden ties, while the metal ties stand very well under the comparatively light traffic, and effect a decided economy over wooden ties by their greater durability.

During 1867, 1868, and 1869 between 90,000 and 100,000 (reported as 93,762) iron ties of the original "Vautherin" type, with short flanges on the lower edges, were rolled at the Fraisant Works in France, and were laid on the Algiers and Oran line. They were 7.87 feet long, 5.2 inches and 3.2 inches wide on top for joint and intermediate ties respectively; about 7.2 inches wide inside at the bottom, and 10.4 inches wide over the flanges, which were 1.4 inches wide and .32 inch thick; the sides and top table were .18 inch and .28 inch thick respectively. The ends of the tie were open. The weight was about 77 pounds. The rails rested on tie plates which gave them the required inward inclination of 1 in 20, and were secured by a gib and cotter fastening; there was a gib holding each side of the rail flange with a cotter driven vertically at the back of the inner gib; the fastenings passed through the tie plate and tie. The number of renewals in seventeen years was 3,200, caused principally by cracks due to bad metal or improper tamping. The cracks were generally in the angles, and went from the ends toward the rail seats. There was no trouble from rust, and the experience of these seventeen years was favorable to the metal track. The metal was of inferior quality, and the attachments of the rails were defective. In 1885 there were still 91,000 of these ties in service. The average age of the ties in 1885 was 17 years, and the total of renewals during that period was 3½ per cent., while the renewals of wooden ties are about 10 to 12 per cent. per annum. Owing to this difference the iron ties had repaid the extra cost of establishment incurred by their use (principal and interest) in the fifth year, and the remainder of their service was a net gain in maintenance. From their state of preservation in 1885 it was estimated that they would give twenty-five years of service. From this trial it was concluded that metal ties behaved well in the ballast, that they do not rust or fail, and that the few renewals are due to defects in the ties or track, and not to a short average life of the ties. They cost less for maintenance, but up to the third year it is necessary to tamp the ballast and inspect the fastenings frequently; after that the attention is not required.

In 1885, 20,000 steel ties of the "Hilf" or original "Berg-and-Mark" type were laid. (See plate No. 17). They were manufactured in France by the Société de Denain et d'Anzin. These ties are 7.5 feet long, of uniform section throughout; 4.4 inches wide on top, 8.4 inches wide on the bottom, 2.4 inches deep, with the sides vertical for 1 inch from the bottom; the sides are .28 inch thick; the top table is .32 inch thick, with a rib on the underside 1.44 inches wide, making the thickness .52 inch. The weight is 85 pounds, or 96.8 pounds including the fastenings. The tie is horizontal for 3 feet 3⅜ inches at the middle, and is inclined upwards at an angle of 1 in 20 to the ends, which are closed by bending down the top table to a depth of 4 inches. The rails are of flange section and rest directly on the tie. Gib and cotter fastenings are used, but a third gib ("guard-gib") is now used, to increase the bearing area at the back of the cotter. The holes at each rail seat are 1.36 inches and 2.48 inches long, spaced 3.48 inches apart in the clear. In May, 1887, 35,000 ties of the "Vautherin" type were ordered, and in February, 1888, 60,000 steel ties were being laid.

Mr. Mazieres, the engineer, made a report to Mr. Bricka in 1884, stating that in spite of defects in the earlier ties the general results of the track had been satisfactory. On the Algiers and Oran line not a single derailment had occurred.

The following information was presented at the International Railway Congress at Milan, Italy, in 1887, by Mr. Kowalski:

There were 68.82 miles of metal track in service, including 91,000 iron ties of the Vautherin type and 20,000 steel ties of the Hilf type. The fastenings were of iron, weighing 5.28 pounds per tie for the former and 5.46 pounds per tie for the latter, making a total weight per tie of 82.28 pounds and 100.98 pounds respectively. The line was principally on low embankments; there were curves of 1,640 feet radius and upwards, long tangents, and grades of 2 per cent. The traffic consisted of passenger and freight trains running at various speeds; 54,000 trains had passed over the Vautherin ties; the speeds varied from 18.60 to 34 miles per hour. The engines weighed from 30 to 35 tons. The rails were of flange section, of iron, weighing 72.4 pounds per yard for the Vautherin ties, and of steel, weighing 68.8 pounds per yard for the Hilf ties. The ballast was of river sand mixed with sand and clay of poor quality. The steel tie cost about 60 cents more than the wooden tie, but effected an economy of 20 cents in the ballast, a smaller amount being required. When the track is well settled the work of maintenance is about a fourth less than with wooden ties. The life of the steel tie was estimated at treble that of wooden ties, but this could not be considered as determined. The life of fastenings was about the same for metal as for wooden ties. As to the elasticity of the track, the comfort of passengers, and the effect on the rolling stock, these were the same as with wooden ties. The results had been satisfactory and it was intended to extend the use of the Hilf steel ties.

Bône and Guelma Railway.—In 1885 this road had had in service for more than two years 3,500 cross ties of the Severac type (see Belgium), and 2,500 ties of the Boyenval Ponsard type (see France).

## ABYSSINIA.

Massana and Sahati Railway.—In May, 1889, the state inspector general of railways of the Italian Government furnished a detailed statement in regard to this line, which was built by that Government for military purposes, but which has been in operation for too short a time to enable any conclusions to be drawn as to the durability of the track. The line is 14.26 miles long, of 3.12 feet gauge, with a maximum grade of 2.3 per cent. and sharpest curves of 328 feet radius. It is a military line, with a traffic of water, supplies, and troops. The track was laid in March, 1888, under the supervision of Mr. Vernan. The engines weigh from 20 to 30 tons. They have four driving wheels, with a weight of about 5 tons in each wheel. The ties are of steel, of the Vautherin type, but without flanges on the lower edges, the sides being nearly vertical for .40 inch from the bottom. They are 4.92 feet long, 3.6 inches wide on top, 7.2 inches wide at the bottom, and 2.4 inches deep. The sides and top are about .25 inch thick, but a rib on the under side of the top table increases the thickness to .32 inch for a width of 1.44 inches. The ends are closed by bending down the top table. The tie is horizontal, but at the rail seats the top table is inclined 1 in 20, to give the rails the usual inward inclination. It is bent on the Hosch-Lichthammer plan (see Holland), the outer part of the rail seat sloping back to the normal level of the tie. The ties weigh 39.6 pounds each. They are not painted or otherwise treated for protection against rust, etc. They were manufactured by Tardy & Benech, of Savona, and the prices were \$35 per ton for ties, \$56 per ton for clamps, \$76 per ton for bolts and nuts, all delivered at Naples. In the track the ties are spaced 32.8 inches apart, center to center. The rail attachments are of the Ruppel type (see Germany), consisting of ⊥-headed bolts .64 inch diameter, with clamps 2 inches wide, one side of which holds the rail flange and the other bears on the tie, having a lug which fits into the bolt-hole in the tie. Adjustment of gauge is effected by the use of clamps with different widths of projection of the lugs. Two sizes of clamps are used at each rail, and the gauge on tangents and easy curves is 3.12 feet. By transposing the two clamps of one rail the gauge is widened .24 inch for curves of 984 to 656 feet radius, and by transposing the two clamps of both rails the gauge is widened .48 inch for curves of 656 to 460 feet radius. At each rail seat are two holes 1.6 inches long by .72 inch wide, spaced 3.28 inches apart in the clear. The rails are of flange section, 4 inches high, with a flange 3.2 inches wide and a head 2 inches wide. The weight is 46.26 pounds per yard. The joints are suspended and are spliced by plain bars. The ballast is of broken stone or gravel 14 inches deep, with the top level with the under side of the rail heads The passage of the first trains packs the ballast well into the ties. The width at subgrade, for single track, is 11.48 feet. These ties were adopted on account of the short life of wooden ties in the tropical climate. The general results have been satisfactory. The system is very simple, the track is easily laid, and maintenance, renewals alignment, etc., are easily effected. For surfacing, whenever depressions occur the track can readily be elevated by tamping gravel under the ties. The gauge also is always accurately maintained, while with the wooden ties spreading of the rails occurs on curves of short radius. Wooden ties would have cost 60 cents each at Naples.

## SOUTH AFRICA.

*(Portuguese territory.)*

Delagoa Bay and East African Railway.—This line runs inland from the port of Lourenco Marques, or Delagoa Bay, to the boundary between the Portuguese territory and the Transvaal, a distance of 50.22 miles. A report from Mr. Thomas Rumball, of London, the consulting engineer, in April, 1889, stated that 42.16 miles were then laid with steel cross-ties and the remainder with wooden ties; the reason for this was that the manufacturers could not keep up the supply of steel ties, and as the contract required the completion of the road within a certain time wood had to be used. An extension of 5.58 miles, however, was then being laid with steel ties. The track was laid between April and November, 1887, under the superintendence of Mr. A. B. Rumball. The steepest grade is 1 in 40, and the sharpest curve is 1,320 feet radius. There are comparatively few curves, 45.26 miles of the line being straight and only 4.96 miles on curves. The gauge is 3 feet 6 inches. The locomotives are six-wheel "bogi" tank-engines (*i. e.*, with trucks), weighing 33 tons in full working order, and having a weight of 10 tons on the driving wheels, The freight consists of gold-crushing and other machinery, colonial produce, hides, etc.

The ties are of similar type to those adopted for the Indian state railways. They are 6 feet long over all, horizontal in the middle, bent up at the rail seats to give the rails an inward inclination, and have the ends curved down and flared out to a width of 13 inches (see Plate No. 17). At the middle the sides are vertical and the top is arched; at this point the tie is $8\frac{1}{4}$ inches wide at the bottom and 5 inches deep; the sides are eleven-sixty-fourths inch thick, and the top is slightly thicker for a width of $4\frac{1}{2}$ inches, the extra thickness being added on the upper side. At the rail seat it is flat for a width of $4\frac{1}{2}$ inches on top, $9\frac{1}{2}$ inches wide at the bottom, and $4\frac{1}{2}$ inches deep; the sides are slightly curved and flare outward; the sides are one-fourth inch thick and the top is seven-sixteenths inch thick, the extra thickness being added on the upper side for a width of $4\frac{1}{2}$ inches and on the lower side for a width of 4 inches. There is a clip 3 inches long stamped out of the top table of the tie for each side of each rail, and the taper steel split keys are driven between the outer clips and the rail flanges. The ties are of steel, weighing 70 pounds each, and the keys weigh 1¼ pounds per pair. The joint ties are spaced 2 feet apart, center to center, and the intermediate ties are spaced 3 feet 3 inches apart. They were manufactured by the Moss Bay Hematite Company, of Workington, Cumberland, England, and cost 90 cents each at the works. The ties are dipped in a boiling solution of Dr. Angus Smith's composition, and the keys are dipped in boiling linseed oil. An improvement in these ties has been patented by Mr. H. Law.

The rails are of flange section, weighing 56 pounds per yard; they are 4 inches high, and 4 inches wide over the flange; the joints are suspended and are spliced in the usual way. The road is ballasted with sand and broken stone; the ties are considered to be better adapted for sand, as the ballast packs well into the tie. The durability of the ties had hardly been tested, as the road had only been open for about two years at the time of Mr. Rumball's communication, but it is confidently expected that they will not require renewal for thirty years. The cost of maintenance can only be arrived at so very approximately as to be of no value, since the line has been subject to severe floods. The labor for track-laying was entirely unskilled, but it was found in practice that the Kaffirs very quickly got into the way of "threading" the ties on the rails. The steel ties were adopted on account of timber-ties being eaten away by the white ants in a short time. They are very satisfactory, and the running over them is very smooth. The engineer thinks that in a country like Africa steel ties should be used in preference to wood.

## CAPE COLONY.

Cape Government Railways.—These lines aggregate 1,523.75 miles in length. They are of 3 feet 6 inches gauge, and have maximum grades of 1 in 40 and minimum curves of 400 feet radius. The following particulars in regard to the track are abstracted from a paper by Mr. Wm. Geo. Brounger, presented to the Institution of Civil Engineers (London) in 1885. (Proceedings; Vol. LXXXI; session 1884-'85; Part III.)

Steel rails of flange section are used weighing 45 and 60 pounds per yard, with suspended spliced joints, and spiked or bolted to creosoted Baltic ties, 7 feet by 9 inches by 4½ inches for the lighter rails, and 7 feet by 10 inches by 5 inches for the heavier rails. With a view to check the tendency to spread of gauge round the sharp curves of the Hex River Mountain, on the Western division, bowl ties of Livesey's pattern were ordered for a few miles for the sake of the wrought-iron tie-bar, all the different kinds of fastenings employed being found to yield in the case of wooden ties, even where hard wood was used, though the latter checks the tendency to some extent. This piece of track has answered well under a trying traffic. Most of the ties were of cast-iron, but a length of 1 mile was laid with wrought-iron. Of the latter not a single tie had to be replaced, but many of the former were broken during the process of packing. In consequence of the difficulty and uncertainty in obtaining wooden ties, the increase of their price, and the delay in procuring them, it was decided to try iron ties on a more considerable scale, and 36½ miles of wrought-iron trough ties and 73½ miles of wrought-iron bowls, both of Livesey's patterns, had been laid down. They had only been recently laid, so that little could be said as to the results, but the following particulars were given:

*First.* Both types require careful packing. In the case of the bowls, if this is not done, they are apt to get out of level transversely, and the result is a cant, which throws the line out of gauge.

*Second.* Special care is essential in the manufacture of both kinds, particularly in the fixing of the jaws, otherwise the gauge is affected.

Where irregularity occurs in the spacing of the holes in the bars, adjustment of gauge on curves is given with bowls by placing the cotter on the inner side, instead of the outer side, of the bowls; on sharp curves this may be done with both bowls. With the iron trough ties it is desirable that special ones should be provided for sharp curves, with allowance for slack, such ties having unmistakably distinctive marks to prevent confusion, or otherwise some safe means of adjusting the jaws for gauge.

[The use of special ties for curves is not to be recommended, as it is probable that the right ones will not be at hand when wanted, and they complicate the track-laying. There are better means of adjusting the gauge by means of the fastenings.—E. E. R. T.]

*Third.* More care is requisite as regards ballast, and this has been a source of trouble. It is undesirable that the ballast should be coarse for these ties, but it is often difficult to obain it fine, it being sometimes necessary to use broken stone for top as well as bottom ballast.

Various kinds of timber have been tried in order to test their durability as ties. Some varieties from colonial forests have given favorable results, but their cost has been prohibitory. A species of timber from Madagascar proved durable, but its export was attended with difficulty. The timber which has hitherto proved the most durable is that of the camphor tree, which has been taken up after being in the ground for twenty years, without any preparation, and found perfectly sound through heart and sap wood. The Government, therefore, decided to make plantations of this tree, which, under favorable conditions, attains a large size in the Colony,

The following particulars are from a communication received in December, 1889, from Mr. H. C. Litchfield, and referred to the Junction or Hanover line, built in 1883–'84:

The Hanover line is, approximately, an east and west line, over an open, treeless and bushless, undulating country, 300 miles from the coast, and with an average elevation of 4,500 feet above sea-level, crossing at right angles the main streams flowing northwards to the Orange River. It is about 70 miles in length, with maximum grades of 1.25 per cent., and sharpest curves of 8° 40′. The ties were spaced 2 feet at the (all opposite) joints, the intermediate ones being spaced (to the nearest inch) 2 feet 9 inches for wooden ties, 2 feet 5 inches for iron trough ties, and 3 feet 2 inches for bowl ties. The wooden ties were all 7 feet long, and of two sections, the heavy being 10 by 5 inches and the light 9 by 4½ inches; they were all imported Baltic red fir creosoted with not less than 10 pounds per cubic foot of timber of the best creosote oil, weighing not more than 10 pounds per gallon. The weight of each heavy tie when dry was 110 pounds, or 80 tons per mile. The rails were fastened by spikes. The weight of the iron trough tie was 66¾ pounds, or 68.1 pounds with the keys. The weight of a pair of bowls was 74 pounds, and of the tie-bar 12 pounds; the weight complete, with the keys, gibs, and cotters, was 88.27 pounds per tie. The weights per mile of these two kinds were 62 and 62.21 tons, respectively. The prices in 1883–'84, landed at the nearest port, Port Elizabeth, were $1.32, $1.84, and $2.26 each, respectively, or $2,608 (including spikes), $3,833, and $3,625 per mile. Steel rails were then $35 per ton, free on board, and freight to South Africa about $6.25 per ton. The rails were mainly 24 feet long, and 23 feet 10 inches long for curves; none were longer than 24 feet. With regard to the bowl ties, on tangents the gibs were placed inside, and the cotters outside, of the track, giving a gauge of 3 feet 6 inches on flat curves one gib was placed outside, giving a gauge of 3 feet 6¼ inches, and on sharp curves both gibs were placed outside, to give a slack gauge of 3 feet 6½ inches. In order to insure the bowls being packed, a mound or hillock of ballast was first made for each to rest upon; when the ties were placed in position a rail was laid in and keyed up on one side of the track first, and the opposite rail put in and keyed up afterward. The large lug of the bowls was tapered to suit the corrugated key, and the key was driven by the right hand of a man standing between the rails, so that all keys on the left hand rails pointed backwards, and those on the right hand rails pointed forwards, with the mileage.

## NATAL.

NATAL GOVERNMENT RAILWAYS.—These lines are also of 3 feet 6 inches gauge. Originally the track consisted of iron rails laid mainly on imported creosoted ties, the average life of which was about seven years. Since about 1884 native yellow-wood ties have been tried, but their life is only about two and one-half years, and soaking them in mineral oils was not found to be of much service. Good ballast is difficult to obtain, and poor grades of disintegrating shales, quartzites, and crystalline rocks are frequently used. Steel rails are being laid on some parts of the line, and on some of the extensions a track of steel rails on plate ties had been laid.

Mr. Kielland, an engineer who had some experience with the early railways of the Colony, informs me that with the exception of a small piece of line from Durban to the Umzemi River, about 4 miles, no railways had been constructed previous to 1876, when the location of the first Government railways was commenced. In 1878–'79 regular trains began to run. The ties used on these first roads were of creosoted pine, about 7 feet by 6 inches by 6 inches. It is reported that there is very little timber in Natal or the Cape Colony which is suitable either for ties or railway structures, the timber, as a rule, being hard and crooked. In the country north of Zululand, Mozambique, and Madagascar there are said to be immense tracts of swampy land, covered with a very lasting magnolia or mangrove tree, which is thought to be suitable for ties.

## SOUTH AFRICAN REPUBLIC.

(*Transvaal.*)

The Dutch company owning the railways awarded a contract in October, 1889, for 71,430 steel ties of the Post type (see Holland).

## CONGO FREE STATE.

CONGO RAILWAY.—This road is to be built by a Belgian company, and it is reported that Belgian works will supply steel rails and steel ties. The latter will probably be of the Post type.

## SENEGAL.

About 5,000 cross-ties of the Severac type (see Belgium) have been used in this French colony.

## ISLAND OF REUNION.

On the Island of Reunion, off the east coast of Africa, a French possession, there is a meter gauge railway 77.5 miles in length, built in mountainous country, at a cost of $48,000 per mile. The track consists of steel rails of flange section, weighing 28.2 pounds per yard; these were originally laid on preserved pine ties, imported from France, spaced 28 inches apart, center to center, but iron bowls arranged in pairs, on the Livesey system (see England), as employed with success in South America, have been substituted, and so far have given satisfactory results. The bowls are laid in broken stone ballast. The locomotives weigh 15 tons in working order, and can haul a load of 50 tons over the steepest grades. The traffic consists of about five trains per day, at an average speed of 15.5 to 18.5 miles per hour. For the sake of economy the location follows the surface of the ground as nearly as possible; this necessitates numerous curves; but these have caused no inconvenience in operation on account of the slow speed necessary to satisfy the demands of the traffic. There are curves of 351, 410, 492, and 656 feet radius. The steepest grades are 2 and 2.5 per cent. The conditions of the traffic led to the adoption of a light track. The imported pine ties only lasted two years, and trials with native wood from Madagascar, even with mangrove, not having been successful, metal ties were adopted.

Each tie (Livesey) consists of a pair of cast-iron bowls flattened on the upper part to form a seat for the flange of the rail, and having lugs between which the rail is held by a corrugated key. The gauge is maintained by means of a wrought-iron tie-bar connecting each pair of bowls and secured by keys. The spacing of the keys, and consequently the length of the tie-bar, can be varied at will, thus permitting an adjustment of the gauge at curves, etc. The ties are spaced about 3.28 feet apart, center to center of tie-bars. For over three years (up to 1888) 62 miles of track had been laid with this track and had not required any maintenance. The ballast is of broken stone. The cars run smoothly, without jarring, and passengers can not distinguish this part of the line from that on which wooden ties are still used.

The following particulars were presented by Mr. Kowalski, at the International Railway Congress, held at Milan, Italy, in 1887:

The Livesey system of cast-iron bowl ties was then in use on 62 miles, including a tunnel. Each tie, complete, weighed 128.4 pounds; the tie-bars weighed 2.8 pounds, and each key .71 pound. The rails were of flange section, weighing 28.2 pounds per yard. The ballast was of sand and broken stone. The traffic consisted of six to eight trains per day. The ties were laid in 1881, and have given good results, but the jaws on the bowls have to be made heavier than at first, as they broke frequently. The price in London was $1.40 each, or $2 each delivered at Reunion. Wooden ties cost $1. The cost of maintenance was very small. There was no bad effect on rolling stock, and no unpleasantness to passengers, but this might have been due to the low speed. The only renewals have been of a few bowls broken by derailments. The use of these ties is to be continued. It is considered that the advantages of metal ties in tropical countries are indisputable. Native and imported preserved wooden ties only last two and a half years, while the iron ties last indefinitely, and the maintenance is very much less than with wooden ties.

SUMMARY OF METAL TRACK FOR SECTION NO. 2.

| | Bowls. | Cross-ties. | Plates. | Total. |
|---|---|---|---|---|
| Egypt | 847.50 | 35.25 | 4.25 | 887.00 |
| Algeria | | 120.00 | | 120.00 |
| Abyssinia | | 14.25 | | 14.25 |
| Portuguese territory (South Africa) | | 47.75 | | 47.75 |
| Cape Colony | 80.00 | 36.50 | | 116.50 |
| South African Republic | | 40.50 | | 40.50 |
| Senegal | | 2.50 | | 2.50 |
| Island of Reunion | 62.00 | | | 62.00 |
| Total | 989.50 | 296.75 | 4.25 | 1,290.50 |

# Section 3.—AUSTRALASIA.

## AUSTRALIA.

General Remarks.—The railways of each of the five colonies of Australia (South Australia, Queensland, New South Wales, Victoria, and West Australia), are for the most part owned and operated by the separate governments of these colonies, and are under the control of railway commissioners. A very complete account of these railways will be found in Engineering News, New York, March 30, 1889. It is of interest to note that metal ties have been introduced into this new country, of which comparatively little is known here, and that their use is likely to be extended. In one case (South Australia) they have been introduced on account of the destructiveness of white ants, and in another case (Queensland) they have been adopted, after a partial trial, for an up-country line for motives of economy. One feature of this latter case is that the system adopted is claimed to be specially adapted for light and economical construction and to be suitable for some of the western sections of the United States. Hard-wood ties are in general to be obtained in abundance, but they are liable to be attacked and rapidly destroyed by white ants.

## SOUTH AUSTRALIA.

South Australian Government Railways.—In July, 1888, there were 1,500 miles of railway in operation, and two lines, aggregating 324 miles, under construction. The railways are of 5 feet 3 inches and 3 feet 6 inches gauge. The colony extends from the north to the south coast, and a north and south transcontinental line is to be built, some small sections of which are already in progress.

On the Palmerston and Pine Creek line (3 feet 6 inches gauge) steel cross-ties are being used; full details have been furnished by Mr. A. B. Moncrieff, engineer in chief of the Government railways, and are given further on.

As this railway was not completed at the time of Mr. Moncrieff's report to me, and therefore sufficient information was not obtainable to answer some of the questions asked, he kindly sent the following particulars from a report of Mr. J. C. B. Moncrieff, M. Inst. C. E., the resident engineer of the Adelaide and Terowie line (5 feet 3 inches gauge), who had been directed to lay twenty-seven ties of the same design, but of the requisite size for the wider gauge, at the entrance to the Adelaide station yard, where they would sustain the heaviest traffic. The expense of maintenance was not greater than with wooden ties, but they had not been tested long enough to enable a decided opinion to be formed as to their durability. Gravel ballast was used, and it packed well, giving no trouble. The packing did not, however, fully drive up the ballast into the hollow of the tie, so that the chief weight had been carried by the flanges.

[This was one of the troubles with the original form of the Vautherin tie, and led to the substitution of a thickened rib instead of the horizontal flange on each of the lower edges.—E. E. R. T.]

There was no trouble with maintenance, but as the length of the track in use with these ties was only 40 feet, it was impossible to say whether they would keep the line straight. The rail attachments had given no trouble. Mr. J. C. B. Moncrieff thought very highly of these ties and considered that if they were a little stronger, especially around the rail seats, they would be a really serviceable article. From the results of these experiments he reported as follows:

> These ties are of the same thickness as those for the Palmerston and Pine Creek Railway (3 feet 6 inches gauge) and are, therefore, too slight for the heavier track with 61-pound rails, of these lines of 5 feet 3 inches gauge. They were twenty-seven in number, and were placed on the up and down tracks at the entrance to the Adelaide station. They were laid on April 19, 1886, and have been in use until now, June 3, 1889, except during a few days when they were taken out for inspection. Three have been removed on account of cracks in the rail seats, and round the holes for the attachments. There are now twenty-four in the track and these are in fairly good order, although some of them are showing cracks similar to those in the rejected ones. Apparently these cracks were originally started in the creasing of the steep angles round the rail seats. They have been in use for one hundred and fifty-three weeks, and have had a traffic of 6,500,000 tons over them during that time.

Wooden ties, of jarrah, red gum, or sugar gum, cost about 84 cents each, and last about twenty years, under favorable conditions, in the southern part of the colony, but their durability in the northern or tropical part remains to be seen.

*Palmerston and Pine Creek Railway.*—In June, 1889, I received a very complete and interesting statement from Mr. A. B. Moncrieff in regard to a government line of 3 feet 6 inches gauge being built from Palmerston to Pine Creek, in the northern territory of South Australia, a distance of 146 miles. The works are in general moderately light; there are 3½ miles of curves of 660 feet to 1,320 feet radius, the rest being of larger radius; the grades include 12 miles of 1 in 60 (1.66 per cent.) 15 miles of 1 in 60 to 1 in 80 (1.66 to 1.25 per cent.), and 12 miles of 1 in 80 to 1 in 100 (1.25 to 1 per cent.). The bridges are up to 100 feet span. The road was not then completed. The object of the road is to develop a mineral country, and the traffic is generally light. The locomotives weigh 24¼ tons, and have a weight of 6¾ tons on each driving wheel; the tenders weigh 17 tons. Track laying was commenced in July, 1887, under the superintendence of Mr. J. W. James.

Metal ties were adopted on account of the destructiveness of white ants. The ties are transverse, of steel, of the type known as MacLellan and Smith's patent embossed stamped steel ties. (See plate No. 18.) They are manufactured by Ibbotson Bros. & Co., of England, and cost \$65 per ton, free on board, at an English port. They are coated with Dr. Angus Smith's composition. The general form is that of an inverted trough, with closed ends, and having a horizontal flange all round the lower edges. The trough part is formed with corrugations at the ends and near the rail seats; this part is narrow at the middle, the top table and bottom flanges being of equal width; at the rail seats it is wide and flat, with narrow flanges; and at the ends it is wide, and is corrugated where it slopes down to the horizontal flange. The tie is 6 feet 3 inches long, 12 inches wide in the body, 14 inches wide at the ends and about $2\frac{3}{4}$ inches deep. The top table is about 3 inches wide at the middle and 7 inches wide at the rail seats. The length of the trough is about 5 feet 7 inches on the bottom, leaving 4 inches of flat plate at each end; the top is slightly arched or curved. The tie has a uniform thickness of three-sixteenths inch, and weighs 56 pounds; the fastenings weigh $6\frac{1}{2}$ pounds per set. It is horizontal at top and bottom, but at each rail seat there is a depression $3\frac{3}{32}$ inches wide and about one-fourth inch deep on the outer side, forming a groove for the rail flange and having an inward slope of 1 in 26. This depression is an objectionable feature, as it is almost certain to cause cracks to start in the sharp angles, and this has been found to be the case. Experience in other countries has shown that proper fastenings are in themselves amply sufficient to hold the rails in place and prevent spreading of the track, so that this form of rail seat is therefore unnecessary. The expense and extra labor expended on this part may be dispensed with and a better and more durable tie obtained which will be fully as efficient in service as the tie with the depressed rail seat. The fastenings consist of two clips and one patent Ibbotson "twin" or **U** bolt for each rail. The horizontal part of the bolt rests inside the tie, under the rail seat, and the two vertical parts pass up through the top table and clips; these vertical parts are threaded and a nut is screwed down on each clip. The bolts are $4\frac{13}{16}$ inches long, center to center of the vertical parts, which are three-fourths inch diameter; the horizontal part is three-fourths inch wide and five-eighths inch deep, with the upper face flat, to bear against the under side of the top table. The clips are $2\frac{1}{4}$ inches long on the rail, $2\frac{3}{4}$ inches wide, and five-eighths inch thick at the middle. A groove is made in the outer clip and on the top of the outer side of the bolt, so that the track inspectors, when walking along the track, can see that the bolts and clips have been put in correctly. The ties are spaced as follows: For a rail length of 21 feet 2 inches, the joint ties are 1 foot 11 inches apart, center to center, the ties next to the joints 2 feet 4 inches, and the intermediate ties 2 feet 11 inches apart. For a rail length of 18 feet 5 inches, the joint ties are spaced 1 foot 11 inches apart, the next ones 2 feet 5 inches, and the intermediate ties 2 feet 11 inches apart. On curves they are laid radially.

At switches and frogs, wooden ties are used; they are 8 inches by 4 inches section, and 6 feet 6 inches to 13 feet long. The rails are fastened by steel spikes one-half inch square, $4\frac{1}{4}$ inches long, with heads 1 inch long by $1\frac{1}{8}$ inches wide.

The rails are of steel, of flange section, weighing 41 pounds per yard. They are $3\frac{1}{2}$ inches high, $3\frac{1}{4}$ inches wide over the flange; the head is $1\frac{7}{8}$ inches wide, with a top radius of 6 inches and three-eighths inch radius of top corners. They are mostly 21 feet 2 inches long (20 feet $10\frac{1}{4}$ inches for short rails on curves), and some of them (not more than 5 per cent. of the contract lots) are 18 feet 5 inches long. The joints are suspended and are fastened by splice plates 15 inches long, with four bolts three-fourths inch diameter, spaced $3\frac{3}{4}$ inches center to center. The outer plate is flat, five-eighths inch thick, with bolt holes seven-eighths inch square, The inner plate is of a deep pattern, having a vertical web projecting below the flange of the rail, being $4\frac{1}{4}$ inches deep over all, and having the ends of the lower web cut to fit the slope of the sides of the ties; it is five-eighths inch thick in the upper web, and three-eighths inch thick in the flange and lower web; the bolt holes are seven-eighths inch diameter. The bolt holes in the web of the rails are oval, seven-eighths inch vertical by $1\frac{1}{16}$ inches horizontal. A space of three-sixteenths inch is left between the rail ends at the joints. The ballast is of broken stone or clean gravel; it is 6 inches deep under the ties, 7 feet 6 inches wide on top, 10 feet 6 inches wide over the bottom; between the rails it is level with the tops of the ties, but outside it is nearly even with the level of the rail head, rounded down alongside the rail to the underside of the head. The minimum quantity of ballast, for single track, is 1,480 cubic yards per mile. The height from subgrade to top of rail is 12 inches.

There has not yet been sufficient experience to enable positive opinions to be given as to the value of these steel ties, but it is thought that they are rather too light, as they are found to crack slightly at the rail-seats and bolt-holes. The following particulars respecting the line are extracted from a report of the resident engineer, Mr. James:

> The steel ties are exceedingly strong, they stand well in the track and keep a good line. When traveling on an engine the road seems as elastic as if the line were laid with wooden ties. The contractors are highly pleased with them. They give no trouble when laid, and the cost for maintenance is very much lighter than with wooden ties.

The climate is tropical but it can not be said yet whether it will have any effect upon the ties.

## QUEENSLAND.

QUEENSLAND GOVERNMENT RAILWAYS.—The lines in this colony are divided into ten divisions, and the condition of the railway system at the end of 1887 was as follows: Open for traffic, 1,895 miles; under construction, 208 miles; proposals invited for construction, 38 miles; plans approved, 197 miles; total, 2,338 miles. The gauge of the railway is 3 feet 6 inches. The average cost for construction has been about $32,070 per mile, and the average cost for maintenance for the years 1884–'85–'86 was $704 per mile per annum. The lines are laid principally with steel flange rails weighing 41¼ or 60 pounds per yard. There is said to be an abundant supply of iron-bark timber for ties. In September, 1886, a contract for 12,000 wooden ties for the Northern line was let at $8,250, or about 69 cents per tie. Sawn wooden ties cost from $65 to $90 per 100, and last from ten to fifteen years. The railway commissioner has condemned the further cutting of timber for ties, fences, etc., and has recommended the home manufacture of steel ties.

Some years ago (about 1882) 1,000 wrought-iron cross ties of the Livesey pattern were laid on the Sandgate branch; they were 5 feet 6 inches long, made of metal three-sixteenths of an inch thick, and had closed ends. They lasted for five years under moderate traffic, but generally fractured under the rail seats, owing to defective fastenings of the rails. The oxidization was not serious. They were laid in ordinary broken stone ballast. In October, 1887, a contract for stamping 80,000 ties of the Phillips type was let to the Toowoomba Foundry Company, of Queensland, at $35,833.30. In December, 1887, a contract for 2,000 iron ties for the Southern and Western line was let at $4,156.25. In June, 1888, 100,000 ties of the Phillips improved type, weighing 84 pounds each, were being manufactured by the Toowoomba Foundry Company for the first section of the Normanton and Cloncurry Railway.

The ties designed by Mr. George Phillips, superintending engineer, late inspector of railway surveys, are intended especially for up-country lines; they dispense with ballast, the ground being plowed and the soil tamped into and around the ties. They are made of steel, and are of inverted trough section, with open ends (see Plate No. 19). These ties were first tried on the Harrisville branch of the Fassifern line, 80,000 being ordered. Of this first lot the plates were rolled in England and shipped flat, and were pressed cold to shape in the colony, as Mr. Phillips wished to inspect the work. They were imported by the Government at a cost of about $30 per ton, and the Toowoomba Foundry took the contract to do the shaping at 43 cents per tie. The work was to be done under very strict specifications, but after a time the contractors claimed that the plates were not delivered to them in a workable condition, and they applied for extra compensation. It was said that owing to careless inspection in England the plates were sent out warped, twisted, and sometimes so unevenly cut that they would not go into the pressing machine. Two dippings in tar were specified, but the contract was modified to permit the contractors to make one dipping only, on condition that they would forego their claim for extra compensation. The first ties for the experimental line weighed 60 pounds; those now made weigh 84 pounds.

Mr. W. A. Cross, engineer of existing lines, in his report dated April 9, for the year 1887, stated as follows:

An experimental line 65 chains 71 links long [4,336.86 feet if the English chain of 66 feet is used.—E. E. R. T.] was laid down in June last on the Harrisville branch, upon Mr. George Phillips's system, viz, a surface line having metal ties and without ballast, and has been tested by the whole of the traffic for the district having been worked over it for a period of ten months, with the result that a fair measure of success had been obtained for this description of light lines. The system merits consideration in opening up the vast plains of the interior of the colony.

In October, 1888, when the question of extending the Croydon branch railway from mile No. 13 to mile No. 42, from Normanton, a length of 29 miles, came before the legislature, there was quite a heated discussion as to the proposed use of metal ties. The contract for building a part of the line had been let by a previous administration to Mr. Phillips, who was to use his metal ties; as might be expected, the new administration disapproved of what had been done by the opposite party when in power, and this gave rise to considerable discussion. As shown further on, however, the line is being laid with these ties.

In May, 1889, the following particulars were furnished by the commissioner of railways in regard to the Phillips ties. They were laid on the Fassifern branch of the Southern and Western Railway, and on the first section of the Normanton and Croydon Railway. The length of track laid was 37 miles 1,980 feet, including sidings, and the laying of 60 miles more had been authorized. The maximum grade was 1 in 66 and minimum curve 660 feet radius. The ties were laid in 1887–'88 under the supervision of Mr. George Phillips and Mr. W. A. Cross, engineers. The traffic was mixed, passenger and freight, and the maximum of trains was six per day. The engines weighed 34⅗ tons, with 9 tons on the driving-wheels. The ties were transverse, of trough section, 5 feet 6 inches to 5 feet 9 inches long, 5 inches to 6 inches deep, and weighing from 60 to 84 pounds each. They were of wrought-iron and steel, and were manufactured by Springall & Frost and the Toowoomba Foundry Company in the Colony, from imported plates. They were dipped in a composition of coal tar and asphaltum, and cost $1.99½ to $2.50 each. The cost of maintenance was about $350 per mile per annum. They had not been done long enough to test their durability. The fastenings consisted of one riveted and one bolted clip to each rail. No special arrangement was made for curves. The lines are purely surface lines, with the exception of a few banks, the longest of which is only 1,980 feet in length; the ties are laid directly in the earth, no other ballast being used; the ballast behaves excellently under the tie. The rails are of flange section, 41¼ pounds per yard, with suspended spliced joints. The ties were adopted for economy in construction and maintenance, and so far the results had been perfectly satisfactory. There had been no trouble with the rail attachments, with maintenance, or from breakages.

FASSIFERN RAILWAY.—The following information relating to the first experimental line is condensed from a pamphlet issued by Mr. Phillips.

The Government having consented to lay down a short length of railway with wrought-iron ties (see plate No. 19), in order to test the practicability of working and maintaining railways laid on the surface of even country, without ballast or drainage of any description, the experimental line was laid in the form of a deviation near Harrisville, on the Fassifern branch of the Southern and Western Railway, upon a piece of even, black soil, melon-hole country, liable to be flooded after heavy rains to a considerable extent. The actual length of the experimental track was 4,336.86 feet, and on it were laid 1,988 wrought iron ties. The ties were made from plates 66 inches long, 19 inches wide, and one-eighth inch thick; they were 5 feet 6 inches long, 6 inches wide on top, 9½ inches wide on the bottom, and 6 inches deep. At each rail seat a wrought-iron tie-plate, 12 inches by 8 inches by three-sixteenths inch thick, was fastened to the tie; on the outer side of the rail it was fastened by a three-fourths inch rivet which also held the clips for the outer side of the flange of the rail, and on the inner side by a three-fourths inch bolt which also held the loose clip for the inner side of the flange of the rail. The ends were open, and the ties were tamped from the ends. The rails were of steel, of flange section, weighing 41¼ pounds per yard. The total cost of the deviation, including the approaches (total length, 4,898.52 feet), was $10,350.25, of which $2,000 was due to the excessive price of the ties, which were manufactured (under contract) in the colony, at a cost of $2 each, or about $77.50 per ton, or about 100 per cent. of the value if they had been imported from England; steel ties were then, it was said, being manufactured in England for India at $22.76 per ton. The line was opened to traffic on June 11, 1887, and up to June 11, 1888, it had carried a gross traffic of 150,000 tons. It had been repeatedly submerged and in one instance trains were run over it at a speed of 25 miles an hour while the flood waters were running across the rails. The results were so satisfactory that the Government let a contract in June, 1888, to the Toowoomba Foundry Company for 100,000 ties of a heavier pattern for the Normanton and Cloncurry Railway. These ties were made from steel plates 5 feet 9 inches long by 18 inches wide and three-sixteenths inch thick; they were 5 feet 9 inches long, 7 inches wide on top, 10 inches wide at the bottom, and weighed 84 pounds each, complete. After the bending and riveting, they were dipped vertically, for about twenty minutes, into a caldron containing a composition of refined Trinidad asphaltum and coal-tar at a temperature of about 300° Fahr. It has been shown that this experimental surface line can stand the test of recurring heavy rain-falls without its stability being seriously affected.

CROYDON AND NORMANTON RAILWAY.—The ties for this line are made from steel plates 6 feet long, 18 inches wide before bending to shape, and three-sixteenths inch thick, with a strip 6 inches wide along the middle three-eighths inch thick; this extra metal may be on the upper or under side of the plate, at the option of the manufacturer (see plate No. 19). The tie is 6 feet long, 7 inches wide on top (or 6 inches if the extra thickness is on the upper side); 10 inches wide at the bottom, inside; 5 inches deep (or $5\frac{3}{16}$ inches if the extra thickness is on the upper side). The top corners are 1 inch radius, and the sides flare slightly outward. The top table of the tie is horizontal and the cross-section is uniform throughout. The rails are of flange section, of steel, weighing $41\frac{1}{4}$ pounds per yard; the flange is $3\frac{1}{4}$ inches wide. The outer flange of the rail is held by a riveted clip $4\frac{1}{2}$ inches long, $2\frac{7}{16}$ inches wide, three-eighths inch thick, projecting seven-sixteenths inch over the flange. This clip is fixed at the exact place, with regard to the flange of the rail, to give the correct gauge, and it is secured by two five-eighths inch rivets, $2\frac{1}{4}$ inches apart. The inner flange of the rail is held by a loose clip, $2\frac{1}{2}$ inches square, seven-sixteenths to nine-sixteenths inch thick, projecting one half inch over the flange; the outer part has a rib on the under side which rests on the tie and so keeps the top of the clip horizontal. The bolt hole is thirteen sixteenths inch diameter. The bolt hole in the tie is kite-shaped, the point being turned toward the middle of the tie; it is $\frac{13}{16}$ by $1\frac{1}{16}$ inches. The bolt is $1\frac{3}{4}$ inches long under the head, three-fourths inch diameter, with the Whitworth thread, and has an eccentric neck 1 inch long, fitting into the narrow part of the bolt hole so as to prevent the turning of the bolt.

In January, 1889, Mr. Phillips sent the following report of his ties, and his statement, together with the other information given, shows that under certain circumstances, at least, steel ties are adapted not only to replace wooden ties on the main lines with heavy traffic, but also for an economical construction of railways with small traffic in even country:

I have just returned from North Queensland, where I have been constructing a section of railway 36 miles in length on my system. The country I am dealing with is between the port of Normanton, in 17° 45′ south latitude and 141° 10′ east longitude, and a new gold field by the name of Croydon, situated about 85 miles east-southeast from Normanton. The country is almost uniformly even, and the Norman River is the only important river crossed. The first 4 miles are over gravel ridges, when a descent of 1 in 70 for half a mile brings the line down to the level of the river flats; the soil is dark clay with a slight admixture of alluvial sand. This description of country extends to 14 miles, where the river is crossed with a low, level timber bridge (principally 20-foot spans) on a sandstone-rock bottom. Thence to Croydon the country is very uniform in character—fine sandy soil, covered with a more or less thick forest of inferior and stunted timber, sometimes dense enough to be called brush or scrub. There is no forest timber of sufficient dimensions in the district available for ties or bridge work, neither is there any stone for ballast, except by quarrying below the surface, and that is sandstone of an inferior and very soft description. The country is almost uniformly even, except at the 4-mile peg, where there is a cutting of about 5 feet and an embankment of equal height. I commenced track laying July 7, and completed 32 miles on December 29; fully seven weeks were lost through non-delivery of ties, so that the average rate of progress was $1\frac{3}{4}$ miles per week of six working days. The number of men employed in (*a*) clearing track 66 feet wide, (*b*) grubbing central width of 10 feet, (*c*) plowing, harrowing, and rolling the same, (*d*) track laying, (*e*) lifting and packing ties, and (*f*) straightening track, never exceeded 65, with one team of bullocks (12), and one horse. Cost per mile for labor only, $630; wages for laborers, $2.50 per day; gaugers, $3.15. The plowing, harrowing, and rolling cost $75 per mile, and is included in the $630. The total cost was under $15 per lineal foot. The best day's work was 2,772 feet, or 0.525 mile, and the best week's work a little over 2 miles. No ballast has been provided and no side or cross drains cut; the only water-ways are at well-defined and water-worn channels. The total timber bridging on the 36 miles is 1,108 linear feet, and only one box-drain has been put in. From $20\frac{1}{4}$ miles to 36 miles there is not a single water-way of any description.

The material train has never failed to run to the head of the road daily from the commencement of track laying, although there have been some very heavy thunderstorms with 1 to 2 inches of rain-fall in an hour. The track is laid with steel flange rails, $41\frac{1}{4}$ pounds per yard, 26 feet long, fastened to mild steel cross-ties, weighing 84 pounds each, 11 ties to a rail length. The average gross load of the material train is 100 tons. The locomotive employed is a six-wheel engine, built by Dübs & Co., of England; this description of engine has a greater average weight per foot of wheel base than any other class of locomotives in use in Queensland. The country passed through is believed to be the softest in wet weather to be found in Australia, but so far no trouble has been experienced with the line. The country is infested with white ants (termites), and ties of the best hard wood of the colony will not last more than three years in the form of ties. The government now in power are not very favorable to my system, but I hope to be able to induce them to complete the Croydon Railway on my system. I believe my system might be applied with advantage to your prairie country, subject to heavy rain-falls; that is to say, south of the snow regions.

The steel tie and special construction of track, as already described, was designed by Mr. Phillips with a special view to its adaptability for economical construction and maintenance, particularly for up-country lines. He is an advocate of a simpler form of construction for such railways, in suitable country, than that generally employed, and he thinks that this is rendered possible when "such a very superior article as a metal tie is used, which can be pressed into any desired shape." His system is peculiarly adapted to conditions existing on the Australian continent, the country being generally very even, and not subject to snow-fall. Mr. Phillips thinks that it would also be applicable in the more southern parts of the western plains of the United States, and in Mexico over even country which is liable to heavy floods. The more or less open ends of the ties are an essential of this system, on account of providing for the drainage of the earth in which the ties are embedded and packed. On the experimental line no tendency to lateral displacement was observed on a curve of 660 feet radius. If, under any other circumstances, such a tendency shall be observed, it would probably be met by using a transverse web inside at the middle of the tie. In regard to a suggestion that the use of bolts would be cheaper, by reducing the shop work, it has been stated that the difference in cost would be small, and that rivets are preferred as giving a more exact and accurate gauge. The outer clips are bolted on templets while being riveted, so as to insure accuracy in fitting. No ballast is intended to be used with this system of track, the ties being simply packed with surface soil. The Phillips ties for the Fassifern line were the first metal ties manufactured in Australia. Up to October, 1888, no ties of the type having a strip of extra thickness along the top table had been manufactured, owing to delays caused by the political circumstances already referred to.

This system is only applicable to level country. The principle which the inventor works upon is that surface soil, when subjected to compression, will sustain a very much greater weight than when loose or in its normal condition, and he instances the fact that well-beaten roads in soft country remain firm even when entirely covered with water. The effect of the passage of trains will be to compress the soil along the line, and the natural surface drainage can escape under the rails and between the ties; in certain cases cross drains may be used. The life of the tie is estimated as at least thirty years.

## NEW SOUTH WALES.

New South Wales Government Railways.—The lines in this colony are of standard gauge, 4 feet 8½ inches. In July, 1888, there were 2,102 miles in operation and 66 miles under construction. The number of wooden ties used during 1887 was 77,451; of this number 66,407 were for renewals and 11,044 for new side tracks, etc. Mr. E. M. G. Eddy, the chief commissioner of railways, states that experience with metal ties in that colony has been too limited to allow of any opinion of value being given yet. I have not received any particulars of such limited experiments as have been made.

Mr. George Cowdery, one of the engineers of the government railways, has designed a steel cross-tie, which is fitted with a tie plate at each end to give the rails the usual inward inclination and to compensate for the weakening of the tie by the stamping of lugs or clips up from the top table. A stud-bolt secures the rail and tie-plate to the tie, and a split taper steel key is driven between the rail and the head of the bolt.

## VICTORIA.

Victoria Government Railways.—At the end of 1888 there were 2,167 miles of railway in operation in this colony. These lines are of 5 feet 3 inches and 3 feet 6 inches gauge. The maximum grades of the different lines range from 1 in 23 to 1 in 206, but average 1 in 40 to 1 in 50. The average cost per mile for construction, exclusive of rolling stock, has been from $124,880 to $396,370 for double track, and from $16,130 to $79,660 for single track. The blue-gum ties used cost 96 cents each. The agent-general in London states that he does not know of any metal ties being used.

## NEW ZEALAND.

At the end of 1888 the colonial government owned 1,751 miles in operation, and there were also 92 miles owned by companies. The lines are of 3 feet 6 inches gauge. The agent-general in London states that metal ties are not used, and that it is not likely that the use of wooden ties will be abandoned. Mr. J. P. Maxwell, the general manager of the government lines, states that there is an abundance of durable timber available. The wooden ties are 7 feet by 7 inches by 5 inches, cost 48 to 96 cents each, and have a life varying from ten to twenty years.

## TASMANIA.

In June, 1889, there were 375 miles of railway open to traffic, of which 171½ miles were private lines, the remainder belonging to the colonial government. The gauge is 3 feet 6 inches. The agent-general in London states that metal ties are not used and are not likely to be used.

Mr. Fincham, M. Inst. C. E., engineer-in-chief of the government railways, writing in June, 1889, stated that no metal ties are used in the colony, as there is an abundance of excellent timber, which enables the government to obtain ties 6 feet 6 inches by 9 inches by 4½ inches at prices from 36 to 48 cents each, including long carriage.

SUMMARY OF METAL TRACK FOR SECTION NO. 3.

| | Miles laid with steel ties. | Total mileage. |
|---|---|---|
| South Australia | 146 | 1,824 |
| Queensland | 40 | 2,103 |
| New South Wales | | 2,168 |
| Victoria | | 2,167 |
| West Australia | | 160 |
| New Zealand | | 1,843 |
| Tasmania | | 375 |
| Total | 186 | 10,640 |

# SECTION 4.—ASIA.

## INDIA.

*Railway mileage.*—The following table is condensed from a table in the administration report on "The Railways of India" for 1888-'89, by Lieut. Col. L. Conway-Gordon, R. E., director-general of railways. The figures represent conditions at the end of March, 1889:

*The railways of India.—(March 31, 1889.)*

| Railways. | Gauge. | | Total authorized. | Total open. | Total double track. |
|---|---|---|---|---|---|
| *State imperial.* | Ft. | In. | *Miles.* | *Miles.* | *Miles.* |
| East Indian | 5 | 6 | 1,513.25 | 1,513.25 | 474.25 |
| Patna Gya | 5 | 6 | 57.25 | 57.25 | ... |
| Dildarnagar Ghazipur | 5 | 6 | 12.00 | 12.00 | ... |
| Rajputana Malwa | 3 | 3⅜ | 1,672.50 | 1,664 50 | 1.25 |
| Bengal-Nagpur | 5 | 6 | 827.00 | 293.00 | ... |
| Southern Mahratta | 3 | 3⅜ | 1,041.75 | 854.00 | ... |
| Southern Mahratta (Mysore section) | 3 | 3⅜ | 296.25 | 219.75 | ... |
| Indian Midland | 5 | 6 | 679.25 | 514.50 | ... |
| Villupuram Dharmavaram | 3 | 3⅜ | 383.75 | 82.75 | ... |
| Bezvada extension | 5 | 6 | 21.50 | 21.50 | ... |
| Dhond Manmad | 5 | 6 | 145.50 | 145.50 | ... |
| Bhopal Itarsi (British section) | 5 | 6 | 13.00 | 13.00 | ... |
| Total in the hands of companies | ... | | 6,663.00 | 5,391.00 | 475.50 |
| Northwestern | 5<br>3 | 6<br>3⅜ | 2,396.50 | 2,381.25 | 2.25 |
| Sind-Pishin, Chaman extension | 5 | 6 | 27.00 | ... | ... |
| Oude and Rohilkund | 5 | 6 | 739.25 | 692.25 | ... |
| Bengal Central | 5 | 6 | 125.25 | 125.25 | ... |
| Wardha Coal | 5 | 6 | 46.50 | 46 50 | ... |
| Jammu and Kashmir (British section) | 5 | 6 | 8 75 | ... | ... |
| Toungoo Mandalay extension | 3 | 3⅜ | 223.50 | 222.00 | ... |
| Total in the hands of the State | ... | | 3,566 75 | 3,467.25 | 2.25 |
| *State provincial.* | | | | | |
| Bareilly Pilibhit | 3 | 3⅜ | 36.00 | 36.00 | ... |
| Total in the hands of companies | ... | | 36.00 | 36.00 | ... |
| Eastern Bengal | 5<br>3<br>2 | 6<br>3⅜<br>6 | 770.00 | 673.25 | 29.25 |
| Nalhati | 4 | 0 | 27.25 | 27.25 | ... |
| Tirhoot | 3 | 3⅜ | 273.25 | 273.25 | ... |
| Lucknow-Sitapur-Sihraman | 3 | 3⅜ | 124.00 | 106.00 | ... |
| Jorhat | 2 | 0 | 30.75 | 30.75 | ... |
| Cherra Companyganj | 2 | 6 | 15.00 | 7.50 | ... |
| Amritsar-Pathankot | 5 | 6 | 64.75 | 64.75 | ... |
| Burma | 3 | 3⅜ | 335.75 | 333.00 | ... |
| Total in the hands of the State | ... | | 1,640.75 | 1,515.75 | 29.25 |

*The railways of India.—(March 31, 1889)*—Continued.

| Railways. | Gauge. | | Total authorized. | Total open. | Total double track. |
|---|---|---|---|---|---|
| *Guaranteed companies.* | *Ft.* | *In.* | *Miles.* | *Miles.* | *Miles.* |
| Madras | 5 | 6 | 839.25 | 839.25 | 42.50 |
| South Indian | 3 | $3\frac{3}{8}$ | 654.50 | 654.50 | ........... |
| Great Indian Peninsula | 5 | 6 | 1,288.25 | 1,288.25 | 323.75 |
| Bombay, Baroda, and Central India | 5 | 6 | 461.00 | 461.00 | 60.00 |
| Total guaranteed companies | | | 3,243.00 | 3,243.00 | 426.25 |
| *Assisted companies.* | | | | | |
| Darjeeling-Himalayan | 2 | 0 | 51.00 | 51.00 | ........... |
| Tarakeshwar | 5 | 6 | 22.25 | 22.25 | ........... |
| Deoghur | 3 | $3\frac{3}{8}$ | 4.75 | 4.75 | ........... |
| Dibru-Sadiya | 3 | $3\frac{3}{8}$ | 77.50 | 77.50 | ........... |
| Bengal and Northwestern | 3 | $3\frac{3}{8}$ | 510.25 | 276.25 | ........... |
| Rohilkund and Kumaon | 3 | $3\frac{3}{8}$ | 54.50 | 54.50 | ........... |
| Delhi, Umballa and Kalka | 5 | 6 | 162.00 | ........... | ........... |
| Thaton-Duyinzaik | 2 | 6 | 8.00 | 8.00 | ........... |
| Total assisted companies | | | 890.25 | 594.25 | |
| *Foreign.* | | | | | |
| Pondicherry | 3 | $3\frac{3}{8}$ | 7.75 | 7.75 | ........... |
| West of India Portuguese | 3 | $3\frac{3}{8}$ | 51.00 | 51.00 | ........... |
| Total foreign | | | 58.75 | 58.75 | ........... |
| *Native States.* | | | | | |
| H. H., the Nizam's guarantied | 5 | 6 | 489.25 | 329.25 | ........... |
| Khamgaon | 5 | 6 | 7.50 | 7.50 | ........... |
| Amraoti | 5 | 6 | 5.50 | 5.50 | ........... |
| H. H., the Gaekwar's | 2 | 6 | 71.25 | 58.75 | ........... |
| H. H., the Gaekwar's, V. M. H | 3 | $3\frac{3}{8}$ | 64.50 | 27.50 | ........... |
| H. H., the Gaekwar's, A. P | 5 | 6 | 22.50 | ........... | ........... |
| Bhopal Itarsi (Native State section) | 5 | 6 | 44.00 | 44.00 | ........... |
| Total in the hands of companies | | | 704.50 | 472.50 | ........... |
| Bhavnagar G., J., Porbandar | 3 | $3\frac{3}{8}$ | 328.75 | 259.75 | ........... |
| Morvi | 2 | 6 | 93.00 | 68.00 | ........... |
| Jodhpore | 3 | $3\frac{3}{8}$ | 123.75 | 123.75 | ........... |
| Rojpura Bhatinda | 5 | 6 | 113.25 | 15.25 | ........... |
| Kolhapur | 3 | $3\frac{3}{8}$ | 28.75 | ........... | ........... |
| Jammu and Kashmir (Native State section) | 5 | 6 | 16.00 | ........... | ........... |
| Total in the hands of the State | | | 703.50 | 466.75 | ........... |

## SUMMARY.

| Railways. | Total authorized. | Total open. | Total double track. |
|---|---|---|---|
| *State Imperial.* | *Miles.* | *Miles.* | *Miles.* |
| In the hands of companies | 6,663.00 | 5,391.00 | 475.50 |
| In the hands of the State | 3,866.75 | 3,467.75 | 2.25 |
| *State provincial.* | | | |
| In the hands of companies | 36.00 | 36.00 | ........... |
| In the hands of the State | 1,640.75 | 1,515.75 | 29.15 |
| Guaranteed companies | 3,243.00 | 3,243.00 | 426.25 |
| Assisted companies | 890.25 | 594.25 | ........... |
| Foreign railways | 58.75 | 58.75 | ........... |
| *Native States.* | | | |
| In the hands of companies | 704.50 | 472.50 | ........... |
| In the hands of the State | 703.50 | 466.75 | ........... |
| Total | 17,506.50 | 15,245.25 | 933.25 |

GENERAL REMARKS (*Forms of metal ties*).—Experiments with various types of metal ties have been made during the last twenty-years on different lines, the first trials having been made on the State railways, about 1873, and some of these types have been in service for a sufficient time to enable reliable data to be gathered and conclusions drawn as to their merits in point of efficiency and economy. The principal types used may be divided into the following classes: (1) Cast-iron and steel bowls and cast-iron plates (all arranged in pairs and connected by the rods or tie-bars; (2) Wrought-iron and steel cross-ties. Various forms of these types have been used and various methods of rail fastenings have been tried with them, while the different systems of track have been tried under various conditions of road-bed and traffic. Large orders for cast-iron plate ties and steel ties are given out from time to time for the State and private lines. The cast-iron bowls are said to be becoming obsolete, having been found unsuitable under fast traffic; although they have done good service in the past, they are not being used much now on new work, and on lines where they have been in use they are gradually being replaced. One objection to them is the difficulty of getting them properly packed with ballast so as to keep the track in proper line and surface. Sand is the only satisfactory material, but it must be covered with stone or other coarse material to prevent dust, and it is liable to be washed out. The cast-iron plate ties ("Denham-and-Olpherts" type) have given very excellent results and are in extensive use, while large numbers are being manufactured. Until recently these plate ties were nearly all imported from England, but are now being manufactured by at least two iron works in India, at Jamalpur and Burraakur; the home manufacture seems likely to become an important industry. Details of the manufacture are given elsewhere. Another type of tie which has been extensively used within the last few years, and which is giving satisfactory results, is the steel cross-tie designed for the lines of the State railways system, and used for lines of 1 meter gauge and the Indian gauge of 5 feet 6 inches. They have been used on frontier lines with heavy traffic, and appear to be the standard type of the future.

The following is from a communication from Mr. T. W. Jones, of the East Indian Railway, dated in October, 1889:

Very few metal ties are used on our meter-gauge lines; most of them use sal or deodar wood. I have had charge of from 70 to 100 miles of track for the last twenty years, and have had experience with oval and round cast-iron bowls, Barlow's longitudinals, Denham ties, and three patterns of Denham-Olpherts ties. Bowls do well in side-tracks, but are not suited for high speeds, as when well packed they make a very unyielding track, while, if loosely packed, they break. Barlow's system is a longitudinal with two chairs cast on it, and an angle-iron tie bar is bolted to the plates at the middle; these also do well in side-tracks, but break lengthwise, under the rail, when run over at high speed. The Denham cast-iron plate ties give good results but have three weak points: First, the wooden key for the rails; second, the wooden block under the chair; third, the tie-bar, which does not hold the rails together after the plates break. It can, however, be packed with any sort of ballast, and makes a smooth track; the number of breakages is also very small. I have had experience with all classes and weights of the Denham-Olpherts cast-iron plate ties, and think the present shape is far the best cast-iron tie that has been made up to date. The first Denham-Olpherts tie was of a much lighter section, and the rail instead of being suspended, as now, by the top-table, rested on wooden blocks; as the blocks became crushed and also on account of the lightness of the outer jaws, the number broken in the first year was larger than it is now. This explains the average of .84 per cent. on page 15 of your report [preliminary report; Bulletin No. III—E. E. R. T], although I have never heard of the percentage being more than .70 per cent., and this only where light plates were used and the men were careless. The average now is about .40 per cent., I believe. The Indian Midland Railway has only used the latest type, and this explains the small number of breakages on that line. Bowls of corrugated steel have been largely used on the Oude and Rohilkund Railway, where they are packed with sand; but although better than the cast-iron bowls, they are not satisfactory where the speed is high and rolling-stock heavy. Tozer's steel cross-tie (see England) has been used on some of the state lines with double-headed rails. With flange rails a steel cross-tie similar to that in use on the Northeastern Railway of England has been tried. This latter type has been adopted as the standard on the new Bengal-Nagpur Railway, but engineers of experience are of opinion that the metal will soon be rusted away, especially on the sandy plains, where there is a good deal of salt in the earth.

The advantages of using the Denham-Olpherts ties in India are as follows: (1) Every part can be made in the country by uneducated native workmen, and without very expensive machinery, at a lower price than is paid for good, hard wood ties. The cost of good sal ties is 5 rupees to 5 rupees 4 annas ($1.67 to $1.75); chairs, spikes, keys, etc., 48 cents, or a total of 6 rupees, 8 annas to 6 rupees 12 annas ($2.16 to $2.24) per tie, while the metal tie costs 5 rupees 8 annas ($1.83) complete. The wooden ties when removed from the track can be sold for 8 to 16 annas, while the cast-iron ties, which cost 55 rupees ($18.33) per ton when new, are worth 30 rupees ($10) per ton as scrap; a new tie can almost be made out of the remains of an old one. At present we have no appliances for working up old steel ties into new ones. (2) There is no danger from fire, and in a country where on a May morning three or four ties sometimes catch fire on a mile of track, this is an important point. (3) There are no wooden keys to keep tight or renew. (4) There are no spikes to work loose or break, or for the villagers to steal. (5) The gauge is always preserved and does not require constant adjusting. I find that Denham-Olpherts ties require to be carefully packed at least three times before the ballast is boxed up. In this respect they are at first a little more trouble than wooden ties, but once they get a good bearing they stand three times as long as wooden ties. The rails do not creep nearly as fast where Denham-Olpherts ties are used, and the lower table of the rails does not get marked or indented as on track where it is supported in chairs, and it is consequently available for service after the upper table is worn out. About two years ago a young inspector on a state railway, who was then using Denham-Olpherts ties for the first time wrote to me in great distress; the ballast was very poor, and he said that do what he would the ties were continually loose. I replied that a little patience was necessary and that when once he had his Denham-Olpherts ties properly bedded he would find little trouble with them and could reduce his maintenance gangs. Twelve months later he wrote again, saying that his down track, which was laid with the Denham-Olpherts ties, gave 25 per cent. less trouble than the up-track, which was laid with wooden ties, and he only wished the chief engineer would allow him to relay the up-track. The saving in labor is even more apparent after the fourth year when a track on wooden ties begins to need a lot of repairs, unless the renewal of ties has gone on systematically and carefully all the time. Even where wooden ties are changed monthly, there is generally an extra large number to renew after a certain period and this continual pulling about of the track does not conduce to smooth running. During the hot months it is almost impossible to keep wooden keys in the chairs, even with a man to every 2 miles of rails; and the villagers being very fond of iron spikes, which they find useful for making agricultural implements, a great number are stolen annually; I have known 200 taken in one night from a mile of track. This explains why I prefer metal ties.

We use the hardest stone procurable, broken from three-fourths inch to 2 inches diameter, or cube, for ballast, and when a road is laid with at least 6 inches of this under the ties, the Denham-Olpherts tie gives as elastic a track as can be desired. Most cast-iron ties are unpleasantly rigid, and thus damage the rolling stock. One of the gravest defects in many of the steel ties used with flange rails is that a rail can not be renewed without bending one of the clips, which fit over the flanges, and this forcing of the clips upwards often results in breaking them and the tie is then comparatively useless. With mild steel this ought not to occur, but there is no gainsaying the fact that large numbers may be seen which have been damaged in this way. One type of tie did not admit of the rail being taken out at all, and the only way in which a defective tie could be removed was by taking off the fish-plates, slewing the rails out of line, and then slipping the ties off the end one by one. Most of the steel ties are also made of metal far too thin for the heavy strains which ties have sometimes to bear, when improperly packed or when owing to the bank sinking they are left partially unsupported. Of course this is done to lower the price, but such ties can not be economical, and railway engineers would do well to refuse to have anything to do with ties which are only three-eighths inch thick. Plates one-half inch thick give much better results and are cheaper in the end.

*Ballast for metal ties.*—Different materials have been used; sand, gravel, burnt clay, broken brick, and broken stone; the first two are principally used with metal ties. According to a paper on Stone ballast in India, in the Railroad Gazette, New York, May 3, 1889, the cast-iron bowls were not found suitable for fast traffic on account of their making a very rigid road and the large number of breakages. For packing these bowls, fine sand was generally used, and in some cases where they were packed with gravel or broken brick the results were very bad, "from 25 to 40 per cent. having failed in two years under moderate traffic." Where sand was used an upper layer of brick or stone about 3 inches thick was found necessary in order to prevent the sand from flying up and damaging the machinery and bearings of the engines and rolling stock. In one or two cases where hard stone 1 to 1½ inches in diameter was used, very good results were obtained, and the track was more elastic than with sand or any other description of ballast. The Denham-Olpherts cast-iron plate ties are usually packed with hard stone ballast, but where double-headed rails are used (the rails being suspended by the head instead of resting in the chairs) the track is as elastic as track on wooden ties. Sand, gravel, and stone are used with the steel cross-ties.

*Wooden vs. metal ties*—The wooden ties used are mainly of imported creosoted fir, or of native sâl or deodar, the sâl being the best for the purpose. There has naturally been considerable controversy over the respective merits of wooden and metal ties, the former being indorsed by some few engineers, but mainly by parties interested in private forest properties. The testimony of numerous eminent and practical engineers in favor of the latter, and the steady increase of their use after years of experiment and experience, brings the balance of competent opinion decidedly in favor of the metal ties. In February, 1888, the following prices were given by a correspondent of Indian Engineering, a Calcutta paper, the prices for the wooden and cast-iron ties being those of the East Indian Railway and that of the steel ties of the Oude and Rohilkund Railway: Sâl and deodar ties cost 5 rupees ($1.66) and 3 rupees 8 annas ($1.16) each, respectively; but as the iron chairs and fastenings cost 1 rupee 13 annas 9 pice (60 cents), the total cost per tie was 6 rupees 13 annas 9 pice ($2.26) and 5 rupees 5 annas 9 pice ($1.76) each, respectively. The Denham-Olpherts cast-iron plate ties cost 5 rupees 13 annas ($1.91) each complete, and the steel ties 9 rupees 4 annas ($3.05) each, imported. The average life of a deodar tie is about ten years and of sâl about eighteen years; other authorities give the life at twelve years for sâl, seven years for deodar, and five years for creosoted pine. The number of renewals has been put at about 10 per cent. per annum for wood and 1 per cent. per annum for Denham-Olpherts iron ties. Jungle-wood ties have been tried on the Rohilkund and Kumaon Railway, but the wood was found unsuitable for this purpose, as it can not stand exposure to wet and rain, and decays very rapidly. At the beginning of 1887 there were 70,000 of these ties in the track, but during that year 21,000 were renewed, and in the first half of 1888 over 17,000 were renewed, that is to say, in eighteen months more than half the ties on the line had been renewed. Sâl was used in place of the jungle wood, and the company's report of November, 1888, stated that there were at least 5 sâl ties under every rail. The weight of the heaviest wooden tie, with chairs, spikes, etc., complete, is about 240 pounds; and of deodar ties 180 pounds.

It has been claimed that in case of derailment there is likely to be less damage to track and rolling stock if the accident occurs where wooden ties are used than would be the case where metal ties are used; while this may be true to some extent, the metal tie is likely to give a better and safer track and less liable to derailment than a wooden tie. European experience has shown that a steel-tie track can be made to withstand derailments, and the Sind-Pishin Railway in India has put in a hydraulic press for reshaping steel ties, and steel ties damaged in this or other ways, have been repaired at small cost and put in service again.

The following comparative estimates of the cost and expenses of wooden and metal ties appeared in the Indian Engineer during 1888. The first is for deodar wood and Denham-Olpherts cast-iron ties in main track; and the second is for sâl wood and cast-iron bowls for sidings.

| | Rupees. | United States currency. |
|---|---|---|
| *No. 1 (wood).* | | |
| 1,760 deodar ties, with fittings, at 5 rupees 1 anna | 8,910 | $2,970.00 |
| 79,200 cubic yards ballast, at 5 rupees per 100 | 3,960 | 1,320.00 |
| | 12,870 | 4,290.00 |
| Less value of 1,760 fire-wood ties, at 4 annas (8 cents), when taken out of track | 440 | 146.66 |
| Balance | 12,430 | 4,143.34 |
| *No. 1 (iron).* | | |
| 1,760 Denham-Olpherts ties, complete, at 6 rupees | 10,560 | 3,520.00 |
| 55,440 cubic feet of ballast, at 5 rupees per 100 | 2,772 | 924.00 |
| | 13,332 | 4,444.00 |
| Less value of 3,520 plates and 3,520 jaws when broken, less 5 per cent. for loss of small pieces = 148½ tons, at 30 rupees ($10.) | 4,455 | 1,485.00 |
| Balance | 8,877 | 2,959.00 |

This shows a saving of 3,553 rupees ($1,184.34) per mile by using iron instead of wooden ties, supposing the life of each to be the same; but as the former will last at least twice as long as sâl, and three times as long as deodar, the economy is still greater.

| | Rupees. | United States currency. |
|---|---|---|
| *No. 2 (wood).* | | |
| 1,600 sâl ties, at 5 rupees each | 8,000 | $2,666.66 |
| 3,200 cast-iron chairs (21 pounds) 8 annas each | 1,600 | 533.34 |
| 6,400 wrought-iron spikes at 1 anna each | 400 | 133.33 |
| Total | 10,000 | 3,333.33 |
| *No. 2 (iron).* | | |
| 1,600 bowl ties, complete, at 7 rupees each | 11,200 | 3,733.33 |
| Extra cost of laying | 100 | 33.33 |
| Total | 11,300 | 3,766.66 |

The saving in first cost would, therefore, be 1,300 rupees ($433.33) per mile in favor of the wooden ties. Under the most favorable conditions the cost of the track with wooden ties for 50 years would be as follows:

| | Rupees. | United States currency. |
|---|---|---|
| First cost | 10,000 | $3,333.33 |
| Two renewals, 1,600 by 2 new ties, at 5 rupees | 16,000 | 5,333.33 |
| Total | 26,000 | 8,666.66 |

The value of the wooden ties taken out would not more than pay the cost of labor in taking out the old and putting in new ties, and may therefore be left out of consideration. The cost of the track with iron ties for the same period would be 11,300 rupees ($3,766.66) per mile for first cost and labor, or a total saving of 14,700 rupees ($4,900) per mile in favor of the metal ties. In such side-tracks, except in case of accident, the life of these metal ties may be estimated at fifty years, while wooden ties require renewal every twelve or fifteen years, it being an undoubted fact that white ants, wet and dry rot, etc., destroy wooden ties much faster in sidings than in the main track.

There are materially different conditions in different parts of so large a country; but, speaking generally, wood is not procurable in quantity as a rule, and must therefore be transported from one section to another to a certain extent. In Bengal wooden ties last about five years, as they soon split under the intense heat and rot during the rainy season. In Burmah iron-wood and teak ties are used; the former is not attacked by the white ants and is little affected by dry rot, the latter is softer and lasts about 8 or 10 years. Native hard and soft woods cost too much and are not obtainable in sufficient quantity; imported creosoted pine is cheaper but not durable. The tropical climate is hard on wood, and the white ants destroy large quantities of timber in a very short time. Metal in some form or other is surely taking the place of wood. Sir A. M. Rendel, consulting engineer of state railways, states that the cast iron plates and steel crossties, though dearer in first cost than imported Baltic timber, and in Upper India than sâl or deodar, are cheaper in maintenance than any kind of wood. Metal, taking durability into account, is certainly more economical, and in Bengal steel ties are used for cheapness and because timber is not procurable with facility or in sufficient quantity. The advantages of metal are eminently in economy. Comparisons made by engineers on the state railways between tracks with metal and tracks with wooden ties show decidedly in favor of the former. But metal ties are also more efficient, and one of these engineers stated in his report that, in his opinion, metal ties should be used in preference to wooden ties even if the latter were obtainable sufficient in quantity and quality at the existing prices. It is difficult to obtain a large and regular supply of wooden ties, and the price of timber is said to have been doubled during the last twenty years.

*Tie-bars.*—When separate pieces are used, connected by a transverse tie-bar or tie-rod, as in the case of cast iron bowls or plates, experience has shown that each pair should be so connected. In the case of floods on the Northwestern Railway in November, 1887, at a part where only the alternate pairs of bowls were connected by tie-rods, the sinking or softening of the embankment allowed the disconnected bowls to part when the weight of an engine came upon them, and a train was thereby derailed and wrecked. After that it was decided to put a tie-bar to every pair of bowls.

*Bowl-ties.*—In The Indian Engineer, January 16, 1889, it was stated that about twenty-three years previous this type of track was not in favor on the Madras Railway, and large stocks were allowed to lie on the beach at Royapuram for months together; now it is the standard for the whole line. More than twenty years ago the East Indian Railway Company found that this same form of tie was unsuited for a line with high speeds and heavy loads, and they were either replaced by some other type or used in sidings only; in the face of this the Great Indian Peninsula Railway still adheres to it as its standard tie, and is not only using it for maintenance, but also on the doubling of the line which is being pushed on vigorously. The Indian Midland Railway is also using it, and the Sind, Punjab, and Delhi section of the Northwestern Railway is still laid with bowls for some distance, although in this part of the country they are not held in such high estimation as formerly. The Oude and Rohilkund Railway is now using a bowl-tie of corrugated steel. Mr. Ernest Benedict, in a paper on Metal Sleepers for Railways, read before the Institution of Engineers and Shipbuilders, Glasgow, Scotland, in March, 1877, mentioned the following roads as using cast-iron bowls: Madras Railway, 800 miles; Oude and Rohilkund Railway, 444 miles; Great Southern of India (South Indian), 86 miles; Scinde, Punjab, and Delhi Railway; Bombay, Baroda, and Central India Railway; East Indian Railway; Eastern Bengal Railway; Calcutta and Southeastern Railway.

The Government, in 1875, decided against cast-iron bowl sleepers (ties) on the Madras Railway and in Bengal, on the ground of their extra cost as compared with wooden sleepers. They, however, made a proviso that if iron sleepers could be made in India of native iron this conclusion might be reversed. The question of the comparative advantage of wooden and iron sleepers should, they said, be treated from a purely financial point of view; that is, all payments whether in first cost, renewals, or interest on both, should be taken as part of the money spent on the sleepering. Supposing the bowls to last twenty-four years, the total amount spent on them (including prime cost, renewals, and interest) would come to 36,846 rupees a mile at the end of the twelfth year, and 74,063 rupees at the end of the twenty-fourth year. Taking the bowls to last fifty years, the figures would be 32,734 rupees and 62,574 rupees. With wooden sleepers lasting twelve years, the cost would be 23,530 rupees and 52,551 rupees, respectively.

Mr. Benedict believed at that time in a comparatively small bowl, of circular form, with the bearing in the center; plenty of these ties to be used and each pair connected by a tie-bar. He considered them stronger, handier for the natives, and more firm in the ballast. While they had not been tried on lines with very heavy traffic, he believed they would answer on all other lines, and in side tracks would be practically everlasting. In regard to the white ants, he stated that they work in a covered way of clay; they could not bear the shaking of a railway which destroyed their covered way, and, therefore, did not attack ties in the main track.

In some cases the bowls were found to make too rigid a track, and in some rock cuts it became necessary to put a greater depth of ballast under them.

*Manufacture of ties in India.*—Cast-iron ties are now manufactured at the Burrakur Iron Works, Burrakur, Bengal, and at the works of the East Indian Railway Company, at Jamalpur, Bengal. The engineering press advocates the establishment of more extensive works, so as to make the manufacture of ties and other material for railways and general use a home industry, instead of importing so largely from England as at present. There is abundance of good ore, with coal and limestone, all practically unworked, while thousands of tons of cast-iron ties are brought from England every year, and the railways have large stocks of old rails on hand. Experience at the railway shops and foundries has shown that native labor can be utilized. The Government has been urged to assist in this enterprise, and there have been propositions to establish steel works at Burrakur. The Burrakur Iron Works supply pig-iron and manufacture large quantities of railway chairs and ties. In February, 1888, it was reported that they were carrying out a large order for Denham-Olpherts plate ties, at the rate of 10,000 per month. The prices of chairs and ties was about 3 rupees, 8 annas per 112 pounds (about 97 cents per pound); or 55 to 58 rupees ($18.33 to $19.33) per ton. From Mr. Ritter von Schwarz, superintendent of the works, I have received a very full report. Jamalpur is practically a railway town, having the works of the railway company, while the majority of the inhabitants are employed in the offices or workshops. At the foundries, attention has been given to the production of the Denham-Olpherts plate ties, the company using its own scrap, supplemented by pig-iron from the Burrakur Iron Works. About 10,000 tons of castings have been worked up into 100,000 of these ties. During the year ending March 31, 1889, 100,000 of these ties were made, and the men were then at work on a number for the Patna-Gya Railway. At the end of 1888, the shops turned out 400 or 500 complete ties per day. A large quantity of the Burrakur iron was used, the use of imported iron having been suspended. The wrought-iron for the tie-bars, keys, etc., is made from old rails and other scrap, and rolled by the company's rolling-mill, which is said to be the only one in India and is worked with marked success. Having found that considerable economy would result from manufacturing the ties for its own lines, the company has engaged an inspector from England to superintend the work and to carry out the tests required by the specifications adopted for similar ties manufactured in England.

*Cast-iron* vs. *steel ties*.—There is naturally considerable difference of opinion between the advocates of cast-iron and steel ties, and the matter of breakages and damages to track in cases of derailment of trains is one of the disputed points. A correspondent of Indian Engineering, March 24, 1888, stated that in February, 1888, a spare tender was derailed at a crossing and dragged for 200 feet over a track laid with Denham-Olphert's cast-iron plate ties without doing any damage; the track was fully ballasted. He also instances a case in which the middle car of a train was derailed and dragged nearly one-fourth of a mile over a track laid with wooden ties; every deodar and fir tie was damaged, many being broken in two, and having to be taken out; the track had been opened out for repairs, and the ties were uncovered. In this connection it should be noted that, while accidents are among the points to be considered, they are of comparatively minor importance to the question, and it must be remembered that the results of accidents are very variable. In one case a derailed wheel may cause very little damage to the track, while in a similar case, and under apparently similar conditions the track may be practically destroyed. As a rule, cast-iron is not considered by engineers as a suitable material for such use in railway track, owing to its liability to fracture under sudden or heavy shocks; and, while under certain conditions, this material has given good results and has been extensively used, the general experience—including that of India—points to steel as the metal most suitable in every way for railway ties. The correspondent above referred to is an advocate of cast-iron ties, and claims that steel ties can not be made in India, have little if any value as scrap, and are difficult to tamp. He thinks the minimum weight of a steel tie should be 160 pounds. The future growth of industry in India may include the establishment of steel works, as noted in the preceding paragraph, and certainly the steel ties are very highly spoken of by competent authorities. It is said that the Indian Government has adopted the steel tie for the State and frontier lines, on account of the danger, from a military point of view, attending the use of cast-iron bowls. Experiments have shown that a road on the latter can be destroyed in a very short time with a few sledge-hammers. It would seem, however, that the same sledges might be used to knock out the key fastenings of the steel ties for a few rail lengths and the rails removed; but, of course, with cast-iron, the jaws would be knocked and the bowls cracked, rendering them quite useless. As regards the cast-iron plate ties, it is said that cracked plates have been kept in the track without showing any tendency to shift.

*Steel ties.*—The steel ties which are now so extensively used were designed by Sir A. M. Rendel, consulting engineer for State railways, and have given excellent results, while the key or wedge fastening used has proved very successful in service. The ties are of mild steel, and are manufactured by most of the large steel works in England. Mr. Rendel states that any danger from rust is very remote, and that the ties will stand under heavy traffic. Up to 1888 about 525,000 tons of steel ties had been sent out from England, and about 70,000 or 80,000 tons have been sent out since that time. An objection which has been made against some of these ties is that there is extra trouble in renewals; the arrangement of the clips or lugs is such that the rails have to be canted in order to fit the flange of the rail on to the seat, and the objection is that to renew one tie two rails must have the joints unfastened, the keys all driven out, and must then be lifted out; the old tie is then removed, the new one put in its place, the rails put back, keys re-driven and joints fastened. One way of avoiding this trouble is to bend back one of the lugs of the tie sufficiently to allow the tie to drop from the rail when the ballast is removed, but it is difficult to get a purchase on the lugs while the tie is in place. The trouble may be reduced by taking out one rail only, and then tilting up the free end of the tie until the other end can be slipped off the rail-flange. The objection does not, of course, obtain with ties which have the clips sufficiently wide apart to admit the rail-flange horizontally. The engineers of the roads using these ties have reported very favorably of them. (Notes of special reports will be found included in the matter relating to the Northwestern Railway, Southern Mahratta Railway, Sind-Pishin Railway, Nizam's Railway, and South Indian Railway.) Mr. Bull, of the Cuddapah-Nellore Railway, (Villupuram-Dharmavaram system), and Mr. Lyle, of Nizam's Railway, have suggested that small holes on the top, at the ends, would facilitate proper tamping. Sir Juland Danvers, in a paper on "The Progress of Railways and Trade in India," read before the Society of Arts, England, in March, 1889, said: "A steel sleeper is used and found very serviceable." Some steel ties of the "Post" type (Netherlands State Railways) have been designed for India, but not yet introduced.

*Contracts for metal ties.*—The following is a list of some of the contracts awarded during the last two or three years; it is by no means complete, or even approximately so, but will serve to show that these ties are now firmly established in India, and that the experimental stage has been passed, the ties being ordered from time to time like any other track material:

Indian State Railways: Steel ties, July 19, 1887, December 4, 1888; steel and cast-iron ties, August 27, 1889.

East Indian Railway Company: Cast iron plate ties, April 7, 1887, January 26, 1888, February 14, 1889, November 14, 1889; steel ties, October 31, and November 12, 1880.

Bengal and Nagpur Railway Company: Steel ties, May 23, 1887 (180,000), February 28, 1888, October 30, 1888 (216,000), June 4, 1889 (375,000).

Southern Mahratta Railway Company: Steel ties, November 28, 1888, April 17, 1889.

Indian Midland Railway Company: Cast-iron bowls, June 7, 1888.

Madras Railway Company: Cast-iron bowls, December 7, 1888.

South Indian Railway Company: January 31, 1888 (12,684 tons of cast-iron bowls), November 27, 1888 (23,965 tons of steel ties), February 5, 1889 (9,513 tons of cast-iron bowls), July 2, 1889.

Bombay, Baroda and Central India Railway Company: October 18, 1887, and February 11, 1889 (steel); July 9, 1889 (cast-iron).

Delhi, Umballa and Kalka Railway Company: February 27, 1889 (100,000 pairs of cast-iron plate ties.)

INDIAN STATE RAILWAYS.—About twelve or fourteen years ago, according to a statement by an engineer formerly connected with these roads, the state railways were using on the meter-gauge lines an iron rail 3.52 inches high, and weighing 40 pounds per yard; the fish-plates were 14½ inches long, weighing 1½ pounds. These rails were laid on ties of creosoted Norway pine, or Indian teak; these were spaced 34 inches, center to center, and 22 inches at joints. The most common metal ties then in use were the inverted bowls of cast-iron, with chairs cast on top; each pair of bowls was connected by a light wrought-iron transverse tie-rod. There was also a wrought-iron longitudinal support, with chairs bolted on top; the longitudinals were of inverted trough section, and were connected by wrought-iron tie-rods. In both bowls and longitudinals there were holes in the upper part, through which sand was poured and rammed to give a firm bearing. (Whether the longitudinals were used on the state railways is not definitely stated.)

A brief report, giving a summary of the trials of metal ties on these lines, was made in 1885 by Sir Guilford L. Molesworth, consulting engineer for state railways. His conclusions were in favor of bowls, or Denham-Olpherts plate-ties of cast iron, with vertical wedge fastenings, capable of alteration of gauge on sharp curves. Of other types he preferred the rolled wrought-iron Vautherin tie to the stamped steel MacLellan tie. Considerable progress has, however, been made since the date of his report, and the new steel tie has, as already stated, come into extensive use.

The first metal ties tried were Mr. Greaves' cast-iron inverted bowls, laid in 1873. They were laid on stone, broken small, and proved fairly satisfactory. (See plate No. 20.) A similar tie was laid on the Porada branch, without ballast, the soil of the embankment being earth and clay mixed. The plan answered well in a district where ballast would have been expensive. The "Greaves" bowls were of circular form, about 22 inches in diameter across the bottom, and 15 inches long on top under the rail. The depth under the rail was $4\frac{5}{8}$ inches; height $8\frac{1}{4}$ inches from the bottom of bowl to top of jaw of rail-chair; $9\frac{3}{8}$ inches from bottom of bowl to top of rail. The thickness varied from three-eighths inch to one-half inch, and the weight of each casting was 79 pounds. The rail chair was in the middle of the top, and on each side was a pocket in the metal for a wooden packing-piece, or cushion, $3\frac{3}{16}$ by $2\frac{1}{4}$ inches, and 1 inch thick, upon which the rail rested. In each bowl were two holes three-fourths inch in diameter, for tamping the sand-ballast. The rails were of double-headed section, $4\frac{3}{4}$ inches high, weighing 68 pounds per yard. Each pair of bowls was connected by a wrought-iron tie-bar 2 by one-half inches, and 7 feet $9\frac{3}{4}$ inches long; the bar was placed on edge and passed through each bowl, being secured by a gib on one side and a cotter on the other, passing through slots in the bar. A complete tie, therefore, consisted of two bowls, one tie-bar, two gibs and two cotters. The following was the weight per mile in tons of 2,240 pounds for 1,760 pairs of bowls:

| | Tons. | Pounds. |
|---|---|---|
| Cast-iron in bowls | 124 | 336 |
| Wrought-iron in tie-bars, gibs, and cotters | 21 | 1,344 |
| Total | 145 | 1,680 |

In 1876 a few cast-iron ties of De Bergue's patent were sent out from England and were tried experimentally on the meter-gauge. (See plate 20.) They consisted of a pair of shallow "saucers," placed bottom down, and connected by a wrought-iron tie-bar 2½ by three-eighths-inch, the upper edge of which engaged with a groove in the bottom of the "saucer," while the lower part projected down into the ballast. Flange rails were used, and were fastened by iron clamps bearing on the tie and the inner flange of the rail, with a hooked bolt passing through the clamp; the hook held the bottom of the tie-bar, and the nut was screwed down on the clamp. The weight per tie was 54½ pounds, and it was intended to use eight complete ties to a pair of 40-pound rails 21 feet long.

In the same year a few wrought-iron cross-ties of the "Vautherin" type were also tried experimentally on the meter-gauge. (See plate 20.) They were 5.9 feet long, about 2⅝ inches deep, 3⅛ inches wide on top, 6½ inches wide inside at the bottom, and about 9 inches wide over the bottom flanges; the thickness was about one-fourth or five-sixteenths of an inch. (These dimensions, except length, are measured from half-size lithograph drawings, and are therefore only approximate.) The ties were curved to a radius of 19.05 meters (62.5 feet), giving the rails an inward inclination of 1 in 20; they were curved as soon as they left the rolls, and the exact curve was afterwards given when the metal was cold. The weight was about 12 kilograms per meter, or 24.15 pounds per yard. The rails were of flange section, weighing 40 pounds per yard; the outside flange was held by a gib and the inner flange by a gib held in place by a vertical cotter, with a second gib or packing-piece inserted between the back of the cotter and the metal of the tie.

In 1878 two types of Livesey's wrought-iron ties were tried on the Western Rajputana line; one consisting of a pair of bowls of improved form, and the other consisting of a pair of corrugated plates of inverted trough section, the trough being parallel with the rails, with the corrugations at right angles with them. (See plate No. 20.) In both types the pieces were connected by tie-bars 1½ by three-eighths-inch, passing through and secured by a gib on the outer side and a cotter on the inner side of each piece. The gauge was 1 meter. The rails weighed 40 pounds per yard, and were generally secured to the bowls by a riveted clip on the outer side, and a bolted clip on the inner side; while to the corrugated plate-ties they were secured by two riveted clips on the outer side, and a bolted clip on the inner side; in some cases a gib and cotter fastening, similar to that of the Vautherin tie, was used. The patentee proposed to lay six complete ties to a pair of rails 21 feet long, and the weight of track complete was estimated at 40 tons per mile. These were reported upon unfavorably.

The MacLellan steel cross-ties used in 1882 were of similar type to the new standard steel ties, and were used for meter gauge lines with rails weighing 41¼ pounds per yard. They were 5 feet 3 inches long over all, each stamped from a plate 5 feet 6 inches long, 14 inches wide, and three sixteenths inch thick. The thickness was uniform, but the cross-section of the tie varied; at the rail-seat it was flat for about 5 inches, $3\frac{1}{2}$ inches deep, and $9\frac{1}{2}$ inches wide over the bottom; at the middle it was of arched section $4\frac{1}{2}$ inches deep and $8\frac{1}{2}$ inches wide at the bottom, while at an intermediate point it was $4\frac{1}{2}$ inches deep and $8\frac{3}{4}$ inches wide. The ends were bent to give the rails an inward inclination, and the extremities were closed by rounding off the top table. The fastenings were of the gib and cotter type, above described. The tie weighed 50 pounds and the fastenings $3\frac{1}{2}$ pounds. The ties for lines of 5 feet 6 inches gauge were 8 feet 6 inches long, made from plates 8 feet 9 inches long, 15 inches wide, and seven thirty-seconds inch thick, the finished tie being three-sixteenths inch thick; the cross-section was nearly identical with the above, but at the rail-seat it was flat on top for a width of 6 inches, $9\frac{1}{2}$ inches wide at the bottom, and 4 inches deep; the tie weighed 100 pounds, and the fastenings 5 pounds.

The cast-iron bowls designed by Mr. Molesworth in 1878 were for meter gauge lines with flange-rails, and were of a generally similar form to those first described (1873); they were 18 inches in diameter, with radial ribs on the outside; one flange of the rail was held by a projecting lug or jaw, and the other by a wrought-iron gib and cotter. The thickness was five-sixteenths inch in the web, and the depth inside was $3\frac{5}{8}$ inches. The tie-bar was 2 by $\frac{3}{8}$-inch and 5 feet 1 inch long; it was laid on edge, and passed through the bowls, being secured to each by a gib on the inner side and a cotter on the outer side of the track. An adjustment of one-fourth inch at curves could be obtained by reversing the positions of one gib and cotter, or one half inch by reversing both gibs and cotters. The modification of 1882 consisted in the use of a vertical cast-iron gib and cotter fastening for the rails. The tie-bar was of wrought iron or steel, $1\frac{1}{2}$ by $\frac{3}{8}$ inch, and 4 feet $7\frac{3}{8}$ inches long; it had notches thirteen-sixteenths inch wide by three-eighths inch deep, accurately punched to templet to give the gauge; a plug in a hole in the top of each bowl under the rail engaged with the notch in the bar; the faces of this gauge-plug were not vertical, and there was thus a difference of gauge according to the different positions of one or both plugs. By this arrangement the gib and cotter fastenings at the end of the tie-bar are dispensed with. These ties were tried on the Tirhoot Railway and the Fazilka Branch of the Rajputana-Malwa Railway.

The Denham-Olpherts cast-iron plate ties are described fully later on. Mr. Molesworth devised a modification, consisting in the use of a cast-iron wedge with one of its faces corrugated; this is driven between a fixed lug and the loose jaw which holds the inner flange of the rail. (See Plate No. 21). The shape of these wedges is such that when the corrugated face of each wedge in a complete tie is towards the middle of the track the gauge is 3 feet $3\frac{3}{8}$ inches (1 meter); when one wedge is turned with its corrugated face to the outside of the track the gauge is three-eighths inch slack, and when both wedges are so turned the gauge is three-fourths inch slack. This arrangement has not been very successful, owing to the difficulty of accurate fitting in casting; while such fitting could probably be secured by careful work, the system is more complicated than the ordinary fastening. A simple plan, suggested by Mr. Schwarz, of the Burrakur Iron Works, is to use at the ends of the tie-bar gibs of different widths, arranged in offsets; the gauge would be tight or slack according as the gibs were put with the wide or narrow part in the slot.

In 1881 proposals were advertised for cast-iron bowls slightly different from those made in 1878 for the Patna-Gya Railway. They were oval in plan, 23½ inches long by 20½ inches wide on the bottom, 5 inches deep in the middle, 11 inches center to center of the wooden bearing pieces; the thickness was about ¾ inch. The tie-bars were 7 feet 10 inches long, 2½ by ½ inch, placed on edge, and secured by gibs and cotters driven horizontally. The rails were of double-headed section, secured between the jaws of the chair by a wooden key driven on the outside of the rail.

The new type of steel tie now in extensive use, and which is the standard metal tie of the state railways, is a cross-tie of rounded trough section, with closed ends, and having an extra thickness of metal in the top table; in its general form it resembles half a pea-pod. They are modified from the older type of MacLellan steel ties, to meet the objections made by Sir Guilford L. Molesworth, consulting engineer, as to the want of metal at the fastenings. They were first made for the frontier lines, but are now adopted for all classes of lines, both of meter gauge and the Indian gauge of 5 feet 6 inches. (See plate No. 22.) They are made of mild steel plates rolled flat to the desired thickness and then pressed or stamped while red-hot between dies in a press, which operation turns down the sides and shapes the ends (which are curved down and flared out), gives the rail-seat an inclination of 1 in 20 and presses out the two clips or lugs for each rail. The steel is specified to be equal to a tensional stress of between 26 and 31 tons per square inch, with a contraction of 30 per cent. of the tested area at the point of fracture. The space between the edges of the lugs is slightly narrower than the width of the rail-flange, so that the rail has to be canted or tilted to one side to put it into place. This has the disadvantage of preventing the removal of one tie independently of the rest of the track, as in order to take out one tie the two rails must be loosened for their whole length and tilted over, or one rail loosened and the tie tilted up. Each rail is secured by a taper key with a split end, which is driven between one of the lugs and the rail-flange overlapping the flange. They are usually on the outer side of the rail, but one or both may be placed on the inner side if the gauge is to be widened. After the key is driven the split end is opened with a chisel, to prevent the key from slacking back or working loose. The ties are dipped in a black-varnish solution. They are not patented.

For the 5 feet 6 inches gauge, the ties are made from plates 9 feet long and 15 inches wide, with the middle thirteen thirty-seconds inch thick for a width of $4\frac{1}{2}$ inches, and the sides about seven thirty-seconds inch thick (specified to be of such thickness as will make the tie weigh 120 pounds). The finished tie is 8 feet 9 inches long; at the rail seat it is $9\frac{1}{2}$ inches wide at the bottom and $4\frac{1}{2}$ inches deep; at the middle it is $4\frac{7}{8}$ inches deep and $8\frac{1}{2}$ or 9 inches wide at the bottom, while at an intermediate point it is $4\frac{1}{2}$ inches deep and 9 inches wide; the ends are 13 inches wide. The lugs are 3 inches long and the keys 8 inches long. The tie weighs 120 pounds and the keys 1 pound each, making a total of 122 pounds for each tie, complete. The rails are of flange section, $4\frac{15}{16}$ inches high, 4 inches wide over the flange, and weighing 75 pounds per yard. For the meter gauge the tie is made from a plate 5 feet 9 inches long and 14 inches wide, with the middle part three-eighths inch thick for a width of 4 inches, and the sides about three-sixteenths or one-fourth inch thick (specified to be of such thickness that the tie will weigh 69 pounds). The finished tie is 5 feet 6 inches or 5 feet 7 inches long; at the middle it is flat on top for a width of 4 inches, and the bottom width is $9\frac{1}{2}$ inches; at the middle it is of arched section, $8\frac{1}{2}$ inches wide at the bottom and 5 inches deep. The ends flare out to a width of 13 inches. The lugs are 3 inches long, spaced $2\frac{7}{8}$ inches apart in the clear, and the keys are 6 inches long. The tie weighs 69 pounds and the two keys 1.25 pounds, making 70.25 pounds for the tie complete. The rails are of flange section, $3\frac{1}{2}$ inches high, $3\frac{1}{4}$ inches wide over the flange, and weighing $41\frac{1}{4}$ pounds per yard. The price of the broad-gauge ties is said to be about 6 rupees ($2) each in India. It has been stated (The Indian Engineer, March 31, 1888) that after two or three years' experience the general opinion was that these ties were too thin, especially for the northwest provinces, where the soil and the ballast are of a peculiarly corroding character. Sir A. M. Rendel, consulting engineer in England for the state railways and guaranteed lines, who introduced these ties, prefers them to the cast-iron plates. In February, 1888, there were over 3,000 miles of this track (including Mexico), on lines of all descriptions as regards grades, curves, etc. They had been laid during the past ten years, but principally during the previous four years. The traffic was not then very heavy. The weight of the broad-gauge locomotives was up to 45 tons in all and 36 tons on three pair of wheels, which would be increased to 42 tons; the engines of the meter gauge lines had a weight of 24 tons on six coupled wheels. The ties are spaced about 3 feet apart center to center, or eleven to a rail length of 30 feet. The cost was then about $20 per ton delivered at a port in England, and the expense of maintenance had been very low. As to durability, it is known that steel ties in another form have lasted for sixteen years on the Oude and Rohilkund Railway without injury. All kinds of ballast are used, but gravel or fine sand is the best; the behavior of the ballast under the tie is very good, particularly during floods and rainy seasons. The road-bed is of ordinary type, generally well ballasted. There is no trouble with maintenance of track nor with the rail attachments, nor from breakages.

The following statement, showing the quantities and various descriptions of metal ties which have been sent to India for the state railways since 1874, by the India office, was furnished me in September, 1889, by Mr. Abercrombie Jopp, director-general of stores, India office, London.

*Statement of iron and steel ties sent to India by the India office during years* 1874 *to* 1889.

| Description of ties. | Number supplied. | Miles of single track. |
|---|---|---|
| Meter gauge: | | |
| DeBergue's system; cast-iron bowls ............ pairs.. | 7,040 | 4 |
| Vautherin; wrought-iron cross-ties ............ number.. | 6,332 | 4 |
| Cast-iron bowls ............ pairs.. | 39,018 | 20 |
| Wrought-iron bowls ............ do... | 36,000 | 18 |
| Wrought-iron cross-ties ............ number.. | 286,000 | 143 |
| Steel cross-ties ............ do.... | 723,829 | 361¾ |
| Denham-Olphert's cast-iron plates ............ pairs.. | 347,000 | 173½ |
| Total ties for meter gauge ............ | 1,445,219 | 724¼ |
| Indian gauge (5 feet 6 inches): | | |
| Cast-iron bowls ............ pairs.. | 364,361 | 183½ |
| Steel cross-ties ............ number.. | 1,941,398 | 988½ |
| Denham-Olphert's cast-iron plates ............ pairs.. | 245,347 | 122½ |
| Total ties for 5½-foot gauge ............ | 2,551,106 | 1,294½ |
| Total of complete cross-ties ............ | 3,996,325 | 2,018¾ |

East Indian Railway.—The line was originally laid almost entirely with wooden ties, but cast-iron plate ties are now extensively used. The Sinhgharon branch is laid partly with Greaves cast-iron bowls and partly with creosoted fir ties. Creosoted fir and sâl ties are used generally on the other branches. Cast-iron bowls have been used, but several years ago they were found unsuitable for a line with high speed and heavy loads, and they were afterwards only used in sidings. In 1877 Mr. Benedict, in a paper on "Metal sleepers for railways," read before the Society of Engineers and Ship-builders, Glasgow, Scotland, stated that thus far the bowls had not done well, but that a further trial would be made. The steel cross-ties have been used, but the standard metal tie on this road is the Denham-Olpherts cast-iron plate tie. In the company's report for the half year ending December 31, 1889, it was stated that the lavish expenditures during the past few years upon renewals of the line, replacing iron rails with steel rails and wooden ties by metal ties, were then taking effect, as there was no longer the heavy maintenance which had formerly burdened the road, and it was predicted that these maintenance expenses would continue to decrease with the gradual extending of the improvements.

The length of this system open for traffic on December 31, 1888 (exclusive of sidings), was as follows:

| | Miles. | Feet. |
|---|---|---|
| East India Railway, proper | 1,513 | 2,376 |
| Tarakeshwar Railway | 22 | 1,214 |
| Patna-Gya State Railway | 57 | 1,056 |
| Ghazipur-Dildarnagar Prov. State Railway | 11 | 5,239 |
| Sindia State Railway | 74 | 4,657 |
| Total | 1,677 | 3,982 |

The standard type of track consists of double-headed steel rails 30 feet long, weighing 75 pounds per yard, laid on Denham-Olpherts cast-iron plate ties weighing 227 pounds each; eleven ties to a rail length. The total number of these ties had increased from 413,000 at the end of 1882 to 1,311,000 at the end of 1887, the latter amount representing about 680 miles of track. At the prices of iron in April, 1888, the cost of track laid with these ties was less than that of a track on wooden ties. The breakages since 1885 averaged about .84 per cent. per annum. These ties are described in full farther on. (See plate No. 23.)

In January, 1888, the Government called for an exhaustive report on the behavior of the Denham-Olpherts plate-ties on various sections of the line, and also for the opinions of the engineers who had such ties in their districts. During the half-yearly inspection made in January and February, 1888, very careful examinations were made in order to form an opinion as to the relative merits of the track on cast-iron and on wooden ties, and in April, 1888, Major W. H. Coaker, deputy consulting engineer for railways, presented his report. He stated that the excessive oscillation complained of on some sections was due to the rounded shape of the head of the new rails and not to irregularity in gauge caused by the use of the metal ties, as had been alleged. On the whole he was of opinion that these plate-ties make an excellent track, and notwithstanding the use of stone ballast, which is generally unsuited for cast-iron ties, the track was fairly elastic, owing to the rail being suspended by its head: he advised the use of twelve ties instead of eleven to a 30-foot rail length, and this has been adopted in some cases where the rails are laid to break joint. As to irregularities in gauge, there is little difference between track on cast-iron and on wooden ties, as will be seen by the following summary of a number of gauge tests made early in 1888 and included in Major Coaker's report:

| | Denham-Olphert's | Wooden. |
|---|---|---|
| Tight | 15 | 14 |
| Slack | 13 | 5 |
| Correct | 3 | 4 |
| Varied | 2 | 7 |
| Total | 33 | 30 |

In regard to the question as to the reported difficulty in insuring accuracy of gauge with the cast-iron ties, Mr. Denham, chief engineer of the railway and one of the inventors of the tie, stated that this was due, *First*, to letting separate contracts to different parties for the cast-iron and wrought-iron work; *Second*, to faulty packing or tamping, as if tamped too much on the outside the plates will dip inwards and narrow the gauge, or if tamped too much on the inside the gauge will widen; this trouble can be avoided by having the work carefully done; *Third*, to the difficulty in manufacturing the pieces so as to render the gauge exact at all times, although careful work has reduced this source of trouble to a minimum. Mr. Denham, as one of the patentees, preferred not to make a statement of his opinions as to the merits and demerits of the tie, but sent in a number of reports from the district engineers. While differing in opinion and as to details, the impression given by these reports is that the ties are very satisfactory; rather frequent packing is required; but as there is not the trouble with the fastenings that there is with the wooden ties, the track-men have more time to attend to the packing, and the net result is a reduction of the maintenance expenses. The number of renewals is also very considerably reduced below that of wooden ties, effecting an economy of over 6½ per cent. per annum. The saving in maintenance on the Allahabad division is estimated at 821 rupees ($273.80) per mile per annum in favor of cast-iron over sâl ties; on this division there were in January, 1888, 276¾ miles laid with these ties; on 103½ miles the rails rest on wooden cushions, and on 173¼ miles they are suspended in the jaws of the chairs; the ties were first laid on this division in 1880 for a length of 5 miles.

The following table is taken from the report of the chief engineer, Mr. Denham, for the half year ending December 31, 1888, and shows a record of the tie work during that period:

| | Ties in track, including sidings. | | Removed. | | | Laid. | Removal on total. | | Total removal of each class. |
|---|---|---|---|---|---|---|---|---|---|
| | July 1, 1888. | December 31, 1888. | Defective. | Other causes. | Total. | | Defective. | Other causes. | |
| | | | | | | | *Per cent* | *Per cent* | *Per cent* |
| **Wooden transverse:** | | | | | | | | | |
| Fir (10 ft. by 10 by 5 in.)..No.. | 423,793 | 394,346 | 19,622 | 12,773 | 32,395 | 3,948 | 4.63 | 3.01 | 7.64 |
| Sal (10 ft. by 10 by 5 in.)..No.. | 1,597,021 | 1,560,852 | 34,868 | 39,787 | 74,655 | 38,486 | 2.18 | 2.49 | 4.67 |
| Others......do.. | 896,372 | 892,909 | 11,726 | 10,422 | 22,148 | 18,685 | 1.30 | 1.17 | 2.47 |
| Total.....do.. | 2,917,186 | 2,849,107 | 66,216 | 62,982 | 129,198 | 61,119 | *2.26 | *2.16 | *4.42 |
| **Iron:** | | | | | | | | | |
| Denham-Olphert's plate ties (227.37 lbs. each)..pairs.. | 1,451,076 | 1,524,999 | 5,747½ | 1,313 | 7,060½ | 80,983½ | .39 | .09 | .48 |
| Denham's plate ties...pairs.. | 82,695 | 82,621 | 78 | 58 | 136 | 62 | .09 | .07 | .16 |
| Bowl ties (228 lbs. each).. pairs.. | 237,592½ | 238,095½ | 1,147 | 72 | 1,219 | 1,722 | .48 | .03 | .51 |
| Others....No... | 34,448 | 34,444 | 4 | ...... | 4 | ........ | .01 | ........ | .01 |
| Total.......... | 1,805,811½ | 1,880,159½ | 6,976½ | 1,443 | 8,419½ | 82,767½ | *.38 | *.08 | *.46 |
| Grand total... | 4,722,997½ | 4,729,236½ | 73,192½ | 64,425 | 137,617½ | 143,886 | *1.55 | *1.36 | *2.91 |

*Average.

The next table shows the total length of single track laid with wooden and iron ties on December 31, 1888:

| | Wooden. | | Iron bowl. | | Iron plate. | | Wood and iron and timber intermixed. | |
|---|---|---|---|---|---|---|---|---|
| | *Miles.* | *Feet.* | *Miles.* | *Feet.* | *Miles.* | *Feet.* | *Miles.* | *Feet.* |
| East Indian Railway proper | 1,294 | 4,148 | 79 | 2,903 | 735 | 1,630 | 265 | 5,030 |
| Other lines | 101 | 1,329 | | | 26 | 5,051 | 59 | 3,231 |
| Total | 1,396 | 197 | 79 | 2,903 | 762 | 1,401 | 325 | 2,981 |

As already stated, the company has undertaken the manufacture of cast-iron-plate ties at its Jamalpur works, and early in 1888 the Burrakur Iron Works were turning out 10,000 of the same class of ties per month for this road.

The following is the substance of a detailed statement in regard to the Denham-Olpherts cast-iron-plate ties, which was sent to me in February, 1888, by Sir A. M. Rendel, consulting engineer. There were about 900 miles in all on the East Indian, Eastern Bengal, and branches, and further supplies had been ordered. The divisions laid with these ties were, as a rule, level and straight; the traffic was heavy and slow, hauled by engines weighing 40 to 44 tons, with 14 tons on each pair of wheels, say 28 tons on two pair and 40 tons on three pair of coupled wheels. A detailed description of these ties is given further on. They are spaced about 3 feet apart center to center of tie-bars. The plates, with their jaws, weigh 109 pounds each, or 218 pounds per pair; the tie-bar and accessories weigh 28 pounds. The cost for one tie complete, including tie-bar and fastenings, was then about \$2.16, delivered at an English port. The labor of maintenance was normal and the breakages were not serious. The results as to durability have been good. Various kinds of ballast have been tried, including broken stone, brick, sand, and kunker (this latter is a kind of nodular limestone, commonly burnt for lime in India; it is rather soft). The road-bed is of ordinary construction, well ballasted, and the ballast behaves well under the ties. The rails are of double-headed sections, weighing 75 pounds per yard; the joints are suspended. The reason for adopting metal ties was that native hard or soft woods cost too much and were not obtainable in sufficient quantities, while imported creosoted pine was cheaper but not so durable. The general results are satisfactory, and there is no particular trouble with maintenance. As compared with wooden ties they are more durable but less elastic. Various kinds of wooden ties are used, but the tropical climate is very bad on timber. A good sâlwood tie, which is the best to be got in India and is sometimes very good, costs 5 rupees to 5 rupees 5 annas (\$1.61 to \$1.83.) Mr. Rendel prefers the steel cross-ties.

A cast-iron-plate tie designed by Sir Bradford Leslie, formerly chief engineer of the road, was used on a short branch line crossing the

Hooghly River and proved quite a success; it could be easily and quickly laid and had but few breakages. The plate is 24 by 17 inches, the greater length being parallel with the rail. There are two fixed jaws on the outer side of the track and a loose jaw on the inner side; this loose jaw has a projection which passes through a slot in the plate and straddles the tie-bar; it is held in place by a flat taper key driven through it and through webs on the rail chair. The plate has a segmental rib on the lower side with two transverse ribs or webs on each side. The tie-bar is 2 inches deep; it is set on edge and is under the plate, passing through a slot in the longitudinal rib; at each edge is a notch in the upper edge which engages with a downward projecting flange on the outer edge of the plate. Double-headed rails are used, and are supended in the jaws, as in the Denham-Olpherts ties.

PATNA-GYA RAILWAY.—This line is now operated as a part of the East Indian railway system. Cast-iron bowls were in use in 1877. (See State Railways and East Indian Railway).

RAJPUTANA-MALWA RAILWAY.—This line is leased by the Bombay, Baroda and Central India Railway Company and forms a part of its system. Wooden ties of deodar and creosoted pine were originally used, but as the latter perished very rapidly they were replaced with deodar. The Fazilka Branch (50 miles long) of the Rewari-Ferozepore section is laid with steel rails on Molesworth's and Denham-Olphert's iron ties. (See State Railways.)

BENGAL-NAGPUR RAILWAY.—This road is to be about 800 miles long, and at a meeting of the company in London in June, 1889, it was stated that 294½ miles were then open for traffic; track had been laid on 260 miles more, of which 45 miles were ready to be put in operation as soon as the rainy season was over. Some of the older sections of the line, built about 1880–1881, were of 1-meter gauge, but the Indian gauge of 5 feet 6 inches having been adopted, these lines are being converted to the broad gauge.

The type of track adopted consists of steel flange rails on steel cross-ties, except in those places where timber can be readily obtained from neighboring forests. In April, 1888, there were 180 miles laid with steel ties (See plate No. 25). These ties are of the type now adopted for the State railways (already described). They are 8 feet 9 inches long, bent to give the rails an inclinatien of 1 in 20, and have the ends curved down with a radius of 9 inches and flared out to a width of 13 inches. They weigh 120 pounds each or 122 pounds, with two keys. The rails are secured by clips stamped up out of the top table of the tie; for the meter-gauge sections two sets of clips are made, one set for each gauge, the object being to permit of converting the gauge of the line, while keeping the meter-gauge open for traffic. The rolled section from which the ties are made is of trough shape, 9 feet long, flat on top for a width of $5\frac{7}{8}$ inches, $11\frac{5}{8}$ inches wide at the bottom, $3\frac{13}{16}$ inches deep; the thickness is seven-thirty-seconds inch, with the middle part of the top table three-eighths inch thick for a width of $4\frac{1}{2}$ inches; the corners are bent to a curve of 1 inch radius. At the middle the cross-section is $4\frac{7}{8}$ inches deep, 8 inches wide at the bottom; the top is curved to a radius of $10\frac{1}{2}$ inches, and the corners to a radius of $1\frac{7}{8}$ inches; the distance between the centers of the corner curves is $3\frac{5}{8}$ inches, and the sides flare outward slightly towards the bottom. At the rail seats the top is flat, giving a width of $4\frac{1}{2}$ inches; the section at the inner rails (meter gauge) is $8\frac{1}{2}$ inches wide at the bottom and $4\frac{5}{8}$ inches deep; at the outer rails (broad gauge) it is 10 inches wide at the bottom and $4\frac{5}{8}$ inches deep. The clips are 3 inches long and the keys 8 inches and 6 inches long for the broad and narrow gauges respectively. The adjustment of the gauge is effected by driving one or both of the keys on the inside instead of the outside of the track. The ties are steeped while hot in linseed oil and tarred. They were manufactured by Bolckow, Vaughan & Co., of England, and cost \$24.54 per ton, or about 4 rupees 8 annas (\$1.48) each in India. The ties are spaced 3 feet center to center, 1,760 to the mile. They are laid in ballast of broken stone $1\frac{1}{2}$ inches size; this behaves well under the ties, does not crush, and is elastic and clean. It has also been proposed to lay some Denham-Olpherts cast-iron-plate ties as an experiment.

These steel ties were adopted on account of the low cost of steel and because timber was not procurable in sufficient quantity. Wooden ties last about five years; they soon split from the intense heat, and rot during the rainy season. The climate has no effect on the metal ties. Wooden ties are used to some extent, and the rails are secured to them by spikes five-eighths of an inch square in the shank and 5 inches long under the head, with a notch cut in the sides at a distance of $1\frac{3}{4}$ inches from the point. The meter-gauge line was laid with 40-pound rails on teak, sâl, and creosoted pine ties. One advantage of the steel ties is that the number of separate pieces is small and the fastenings are simple, which makes the track very easy to lay with rapidity and accuracy. It is said that rust is liable to form at the rail-seat, but the engineers have no anxiety on this account. The space between the clips being narrower than the flange of the rail, the rails have to be canted when being put in or taken out, and this causes a good deal of extra work when tie renewals are to be made. It is said by outside authorities that the ties are of too light section, the finished thickness being about three-sixteenths of an inch. The road being new, there has not yet been time to ascertain their durability or the expense of maintenance, but up to the date of the reports received (April and May, 1888), the general results have been satisfactory; not one tie had been damaged and the engineers were well satisfied with them. Mr. T. R. Wynne is chief engineer and Mr. P. T. Large is superintending engineer.

The rails for the meter-gauge weigh $41\frac{1}{4}$ pounds per yard. They are $3\frac{15}{32}$ inches high, with a head $1\frac{27}{32}$ inches wide (having inward flaring plane sides), and a flange $3\frac{7}{32}$ inches wide; the clear distance between the clips for these rails is $2\frac{7}{8}$ inches. The rails for the broad gauge weigh 75 pounds per yard; they are $4\frac{15}{16}$ inches high, with a head $2\frac{11}{32}$ inches wide (having inward flaring rounded sides), and a flange 4 inches wide; the clear distance between the clips for these rails is $3\frac{3}{4}$ inches. The joints are suspended and are spliced by angle splice-bars 26 inches long, with a very narrow horizontal flange; there are six bolts, the inner ones spaced 6 inches and the outer ones 4 inches, center to center. The ruling grade is 1 in 150 and the sharpest curve 1,000 feet radius. The engines are all of one class with six coupled wheels; total weight, without tender, 45 to 50 tons; weight on a pair of wheels, $11\frac{1}{2}$ to 12 tons. In addition to the passenger traffic there is a heavy traffic in grain; also in hides, salt, timber, and bamboos.

SOUTHERN MAHRATTA RAILWAY.—Steel cross-ties of the state railway type are now being substituted for the creosoted pine ties. In the report for the half year ending June 30, 1888, it was stated in regard to the renewals of ties that some part of the line was built as a famine relief work by the Government before the railway company came into existence, and the Government provided also some of the tract, which the company laid down. On the older state lines of meter-gauge half-round creosoted pine ties had been largely used, but they proved a failure and had to be renewed. The greater portion of this line, about 80 per cent., is laid with teak or steel ties, and it was hoped that the renewals would be less expensive than on other roads. About 10 per cent. of the ties in the line were then of creosoted pine. The number would be about 200,000, and 27,000 had been renewed during the half year.

*Mysore section.*—The track is laid with $41\frac{1}{4}$-pound rails, on teak and creosoted pine ties.

*Bellary-Kistnah section.*—Early in 1888 reports on the new type of steel ties (state railway type) were made by the district engineers to Mr. La Touche, the engineer-in-chief, who reported to the director-general of railways in September, 1888. The old pattern of tie, of somewhat similar form, but with gib and cotter fastenings, was objectionable on account of the number of small pieces—eight to each tie—while the metal was so thin as to be easily broken by derailed cars or split by driving the keys home. There was no adjustment for curves. The close spacing of the clips of the new ties was objected to. In stone or clean gravel ballast they do very well, but in soil banks the edges cut down into the material and a good deal of extra raising and packing was required. The increased thickness of the top table greatly increased the strength and efficiency of the tie. (See State Railways.)

INDIAN MIDLAND RAILWAY.—The older parts of this line are laid with double-headed rails, weighing 75 pounds per yard, on Denham-Olpherts cast-iron plate ties. The remainder of the main line and branches are laid with steel flange rails weighing 80 pounds per yard, on cast-iron bowl ties (See plate No. 23.) These bowls are an improvement upon those of the state railways. They are oval in plan, 25 inches long by 20 inches wide, and $2\frac{5}{16}$ inches deep under the rail. In the top there are two holes $2\frac{1}{2}$ inches in diameter, for tamping. The tie bar is of wrought iron 7 feet 7 inches long, 2 inches deep by one-half inch thick; it is secured to each bowl by a cotter on the outer side and a gib on the inner side of the track. There are eleven pairs of ties to a rail length of 30 feet; they are spaced 2 feet $9\frac{1}{4}$ inches center to center of tie bars, and 1 foot $1\frac{3}{4}$ inches at the joints. The spacing of the ties is slightly modified with a rail length of 29 feet $7\frac{1}{2}$ inches, but the three middle ties are spaced as above—2 feet $9\frac{1}{4}$ inches—for the reason that holes are drilled in the outside flange of the rail and at the tie on each side of the middle tie, for a pin five-eighths inch diameter and $1\frac{3}{8}$ inches long; these pins are to prevent the creeping of the rails. The rails are of flange section, resting on a piece of felt packing on the rail seat; the rail seat has an inclination of 1 in 24. The outer flange of the rail is held by a projecting lug, cast on the bowl. The inner flange is held by a cast-iron clamp 4 inches long, the upper part of which has a projection which bears on the rail flange, the lower part being dovetailed so that there is no vertical motion. This key is dropped into place, the lower part fitting into a pocket or recess in the bowl, and a wrought iron taper key $6\frac{1}{4}$ inches long is driven between it and the jaw of the chair; the split end ot this key is then opened out to prevent the key from slacking back. The bowls weigh 92 pounds each and the rails 80 or 82 pounds per yard. The desirability of using the creosoted felt under the rails in a hot country like India, is an open question and practically the method has fallen into disuse. The adjustment of the gauge is effected by means of the tie bar fastenings; with both cotters on the outer side and both gibs on the inner side of the track, the gauge is 5 feet 6 inches; if the gib on one bowl is placed on the outer side of the track the gauge will be widened one-eighth inch; if both cotters are placed on the inside and both gibs on the outside, the gauge will be widened one-fourth inch. The ballast used is of stone broken very small, and there are about $15\frac{1}{2}$ cubic feet of ballast per foot run of tract. The rail joints are suspended, and are spliced with ordinary flat-fish plates and five bolts; the ends of the webs of the rails are notched to admit the middle bolt, which thus keeps the ends of adjacent rails at the same horizontal plane, and thus reduces the pounding of the joints by the wheels of trains. It has been reported to me that the track is one of the smoothest in the country; so smooth that on passing over the line the joints are scarcely perceptible, even before the bowls are finally tamped. Denham-Olpherts cast-iron plate ties were laid on the Cawnpore and Jhansi Railway, which is now a part of the Indian Midland system.

VILLUPURAM-DHARMAVARAM RAILWAY.—The state railways steel cross-tie has been tried on the Cuddapah-Nellore line, now a part of this system. Mr. Bull, superintendent, in a letter to the director-general of railways in February, 1888, stated that the ties are lighter than those of the Denham-Olpherts type, and the simplicity and small number of parts makes the track-laying very easy. The trough shape of the tie renders the track more difficult to align, but once in line it also prevents its moving. It is difficult to pack but may be considered self-packing; a hole might be punched at each end so that it can be seen if the tie is properly packed. Pebble or coarse sand ballast should be used. He considered it on the whole an excellent tie and superior to the Denham-Olpherts type.

DHOND-MANMAD RAILWAY.—The track of this line, which is operated by the Great Indian Peninsula Railway Company, consists of double-headed steel rails weighing 70 pounds per yard laid on ties of cast-iron bowls weighing 94 pounds each.

BHOPAL-ITARSI RAILWAY.—This line is also operated by the Great Indian Peninsula Railway Company. The rails are of steel weighing 62 pounds per yard, and the ties are partly of steel and partly of creosoted pine and other kinds of wood.

NORTHWESTERN RAILWAY.—This system includes the Sind, Punjab and Delhi, the Punjab Northern, the Indus Valley, the eastern section of the Sind-Sagar, and the southern section of the Sind-Pishin railways, on which different kinds of wooden and metal ties are used. These lines have all been amalgamated into one system under the name of the Northwestern Railway, with a total length of nearly 2,500 miles. Three types of metal track are used, viz, cast-iron bowls, Denham-Olpherts cast-iron plates, and the state railways steel cross-tie (See Plate No. 24). Mr. F. R. Upcott, the engineer-in-chief, has furnished me with a detailed statement, dated in July, 1889, in regard to this line, referring principally to the steel ties, as they are to be the future standard, the cast-iron bowls and plates becoming obsolete. The types of track include double-headed and bull-headed rails on wooden ties, flange rails on wooden ties, double-headed and bull-headed rails on cast-iron bowls. These are being gradually replaced by the 75-pound rails on steel ties.

There are about 600 miles laid with these steel ties; of this length 400 miles are in easy country, the remainder being on grades of 1 in 40 and 1 in 25, with curves of 800 feet radius and upwards. They were laid in 1886 and 1887 under the supervision of Mr. Upcott. The traffic is light; on the level plains the trains are hauled by engines weighing about 50 tons, and on the heavy grades by engines weighing 62 tons, with 14 tons on the driving axle. The ties are of the type adopted on the state railways, but are of two patterns, one of which has the ordinary form of clips, while the other has clips strengthened by a corrugation lengthwise of the tie, forming a rib and reducing any tendency to force open the clip or split the tie; it is not, however, thought to be an advantage. They are 8 feet 9 inches long, of rounded trough section, bent up at the rail seats to give an inward inclination to the rails, and having closed ends rounded and dished. The ties with corrugated clips are $4\frac{1}{8}$ inches deep and $8\frac{1}{2}$ inches wide at the middle, $3\frac{3}{8}$ inches deep and $9\frac{1}{2}$ inches wide at the rail seat, and 12 inches wide at the end. They are made from plates 1 foot $1\frac{1}{2}$ inches wide, 9 feet long, one-fourth inch thick at the sides, and one-third inch thick for a width of $4\frac{1}{2}$ inches at the middle, but the thickness is increased gradually. The other ties are $4\frac{5}{8}$ inches deep and $7\frac{1}{2}$ inches wide at the middle, with the top table 12 inches radius and top corners $1\frac{1}{4}$ inches radius; the width is 10 inches at the rail seats and 13 inches at the ends, which are closed by a vertical curve of 7 inches radius. The top table has an extra thickness for a width of $4\frac{1}{2}$ inches. The sizes of the clips and keys are the same as on the state railways, and the adjustment of gauge is made in the same way as on those lines. In the track the ties are laid 3 feet apart, center to center. Their durability so far has been good. Some have been laid in very saline soil, which has stripped off the preservative coating, but the steel has not suffered much in the two years it has been in the track. Experiments are being made as to corrosion, etc. The ties are manufactured by the principal steel-making firms in England, and are dipped in Dr. Angus Smith's composition at the works. The cost is from \$23.75 to \$25 per ton. As regards expense for maintenance, for ordinary roads the average is $2\frac{1}{2}$ men per mile of single track, costing 7 rupees (\$2.33) per man per month; for frontier and hilly roads, 3 to 4 men per mile, costing \$3.30 per man per month.

The rails are of steel flange section, weighing 75 pounds per yard; $4\frac{15}{16}$ inches high, $2\frac{11}{32}$ inches width of head, 4 inches wide over the flange. For 200 miles the ballast is of sand covered with 3 inches of broken stone or brick; at the rails it is 12 inches deep and covers the flanges of the rail; in the middle of the track it is 9 inches deep, leaving the top of the tie exposed; the side slopes are 2 to 1, and the width of the ballast at sub-grade is 15 feet. This method answers very well where the rain-fall is small and high winds do not prevail. Stone, either in a natural state or broken up by hand, is also used, and answers very well after the track has been laid for some months; at first a good deal of packing is required to get the ballast up into the hollow of the tie.

The steel ties were adopted for reasons of economy and progress, track with wooden ties not being satisfactory in India. The general results may be said to be satisfactory, but the element of durability has not yet been fully established. There is no trouble with maintenance except that more attention has to be given to keeping the middle of the ties free. In laying for the first time the rails have to be canted to get them into the seat between the lug, and it is difficult to take out any single tie without unduly pinching back the lip of the lug. The key never shifts after driving and opening out the split end. As to breakages, Mr. Upcott says he has only seen half a dozen broken ties out of half a million, but they get crumpled up under an engine derailment, especially if not well backed up. A steel die is used to bring these distorted ties into shape. The wooden ties cost about 3 rupees ($1) each; they are mostly of deodar or *pinus excelsior*, growing in the Himalaya; it lasts from ten to fifteen years, if properly managed. The steel ties cost about 6 rupees ($2) at a mean distance from the port, and they are better able to stand the climate than the wood. Mr. Upcott is satisfied that the only point to be urged against the ties is possibility of fast corrosion. His three years of experience with them leads him to think that the mild steel of which they are made will not corrode so fast as the wrought-iron and cast-iron now corrodes on the worst places on the line, where the soil is saturated with chlorate of sodium. In a report to the director-general of railways in March, 1888, Mr. Upcott stated that the new type of steel ties (state railway pattern) laid in sand ballast on the Sind-Sagar line, answered very well; they were easy to pack, and the keys held quite tight, even when not split at the ends. Only one or two cases of hogging had been reported, which were due to the tie riding on hard material at the middle. The rusting was slight, and no breakages had occurred. The rails did not creep, and this was attributed to the absolute fixture of the rail on the tie and to the latter being anchored in the ground by its sides.

The cast-iron bowls used are of oval form, 25 inches long by 21 inches wide, the greater length being parallel with the track; the thickness was about seven-sixteenths to one-half inch. The rails are of double-headed section resting on two wooden cushions, and fastened between the jaws of the chair by a wooden key. The tie-bars are $2\frac{1}{2}$ inches deep by five-eighths inch thick, passing through both bowls and secured by a gib on the inner side and a cotter on the outer side of each bowl. The ballast is sand covered with 3 inches of broken brick or stone; the bowls are imbedded nearly up to the chairs. The depth of ballast is 14 inches under the rails, decreasing to 12 inches at the top of the side slopes of $1\frac{1}{2}$ to 1, and 8 inches between the rails. The width of ballast bed over the toe of the slopes is 13 feet 6 inches.

The Denham-Olpherts cast-iron plate ties are of the type adapted for double-headed rails, the rails being suspended by the head in the jaws which form the chair. The plates are 2 feet 10 inches long and 12 inches wide, the greater length being transverse to the track; a rib runs across the middle of the plate on the bottom side, thus giving a hold in the ballast to resist lateral motion of the track. The rail chairs are $7\frac{3}{16}$ inches long. The tie-bars are 2 inches by one-half inch, 7 feet long. They are secured by a gib on the outer side of the track, and a large cotter on the inner side, this cotter passing through the webs which run from the chair to the edges of the plate, and holding the loose jaw of the chair in its place. The webs are transverse to the track, 3 inches high at the rail-seat and tapering down to the edges of the plate.

Mr. Croudace, superintendent of way and works of the Sind section, wrote me in May, 1889, that he thought the Denham-Olpherts plate-tie, with the cast-iron jaws supporting the upper head of the rail, to be the most satisfactory, in spite of its having a tie-bar passing through a flat cast-iron table. The pressed steel ties he considered are difficult to pack, but have the advantage in simplicity and a minimum number of parts; there is, however, a leverage of the rail to break the clips.

The report of the director-general of railways for the year ending March 31, 1888, makes mention of about $630\frac{1}{2}$ miles of metal track on the Punjab section, out of a total of $1,489\frac{3}{4}$ miles; this includes 259 miles of steel ties, about 242 miles of oval bowls, 85 miles of round bowls, $39\frac{1}{2}$ of bowls (not described), and 5 miles of old bowls (on a branch). On the Sind section the same report mentions about 400 miles laid with Denham-Olpherts plate-ties; the length of this section is 895 miles.

The Sind, Punjab and Delhi Railway, now a part of the Northwestern Railway, is still laid with cast-iron bowls for a considerable distance, but it is said that they are not now considered so favorably as formerly in that part of the country. Bowls were used on this line more than twenty-years ago. In 1877 it was stated by Mr. Ernest Benedict, in his paper on "Metal sleepers for railways," read before the Society of Engineers and Ship-builders, at Glasgow, Scotland, that the general opinion of the engineers, based upon the experience of ten years, was decidedly favorable to iron bowls in preference to wooden ties, though some thought that they should only be used in certain kinds of ballast. The former cost about $86\frac{1}{4}$ rupees ($28.75) per ton, and the latter 4 rupees ($1.33) each. Owing to the use of sand and earth ballast (which when boxed with bricks broken fine came to 2,950 rupees ($983.33) a mile, as against 12,040 rupees ($4,013.33) for the ballast of broken brick throughout, used with wooden sleepers), the cost of the iron road compares favorably with the wooden one, being 37,000 rupees ($12,334) a mile for the wood and 34,000 rupees ($11,334) for the iron.

SIND-PISHIN RAILWAY.—On this line the steel ties of the state pattern are used. Mr. F. L. O'Callaghan, engineer in chief of the northern section, made a report on these ties to the director-general of railways in April, 1888. He gave the following comparison of the weights and numbers of parts of different ties:

| | Weight. | Parts. |
|---|---|---|
| | *Pounds.* | *No.* |
| (*a*) Steel tie | 120 | 3 |
| (*b*) Deodar | 143 | 5 |
| (*c*) Teak | 160 | 5 |
| (*d*) Denham-Olpherts | 229 | 9 |
| (*e*) Bowl | 180 | 9 |

*a*, tie and 2 keys; *b* and *c*, tie and 4 spikes; *d*, 2 cast-iron plates, 2 cast-iron jaws, 1 wrought-iron tie-bar, 2 wrought-iron gibs, and 2 wrought-iron cotters; *e*, 2 bowls, 1 tie-bar, 2 gibs, 2 cotters, 2 keys.

The track, he stated, is easily and rapidly laid, but somewhat difficult to pack up in the first instance. The practice was to put the ballast in two parallel heaps about 6 feet apart center to center, and about 18 inches high; the ties spanned these two stacks and were forced down into them by the first passage of an engine; the space under the rail was thus solidly filled and the space between the stacks of ballast was then filled in with sand, as any hard material under the middle of the tie is liable to cripple it. The narrow space between the lugs was complained of, but it was stated that if made wide enough to admit the rail flange horizontally, four keys would be required on curves instead of two; and "the remedy, by introducing special parts, seems worse than the disease." The turned down ends of the ties hold the ballast so firmly that very little is required beyond the ends. Some cases were reported in which the lugs were cracked off, and an increase in the thickness of the top table, by adding metal to its under side, was recommended. As to the strength of the ties, it was stated that under ordinary circumstances they are as strong as timber; a heavy derailment distorts them, but under similar circumstances wooden ties are generally smashed up, and any kind of cast-iron ties so broken as to be useless, the tie-bars only being repairable. Other reports, made about the same time, suggested the use of a loose-bolted clip on one side of each rail, and also that the lugs should be made stronger. A number of objections were urged against the old form of steel tie (state railways pattern, 1885).

Oudh and Rohilkund Railway.—This road is laid with metal track throughout. In March, 1888, there were 432 miles of cast-iron oval bowl-ties, 75 miles of wrought iron saddle-ties, and 182 miles of MacLellan and Smith's patent Bessemer steel corrugated bowl-ties. The Cawnpore branch, 45½ miles long, of which 42 miles were built in 1867, was originally laid with 36-pound rails, on corrugated iron bearing plates, but has been relaid with the cast-iron oval bowl-ties and the 60-pound flange-rails used on other parts of the line. The corrugated or embossed steel bowl-tie made by P. & W. MacLellan, of Glasgow, is said to be the standard type of tie now for this line, and it was of these that Sir A. M. Rendel, consulting engineer for state railways, wrote in 1888 that they had lasted sixteen years without injury. These bowls are also in use on the Calcutta Port Railway. At the beginning of 1875, as stated by Mr. Ernest Benedict in his paper on "Metal sleepers for railways" (already referred to), 1877, there were 444 miles laid with oval cast-iron bowls, having recessed pocket for wooden cushions; 60-pound flange-rails were used, secured by iron keys; the principal defect was in the jaw which held the key, 75 per cent. of the breakages occurring at this point. A bowl and fastening, exclusive of tie-bar, weighed 87¼ pounds. In the discussion of this paper Mr. J. E. Wilson stated that the wrought iron saddle-tie had been adopted on this road in 1869, and notwithstanding its weak form it had given such satisfaction that its use was continued, 25 miles being laid in 1876. After a series of tests the use of iron for ties had been abandoned and embossed steel ties adopted; these were only three-sixteenths inch thick, as it had been found that there was no danger of corrosion. A pair of these steel bowls would weigh about 90 pounds, while a pair of cast-iron bowls would weigh not much less than 224 pounds. The steel bowls could be struck out of a steel plate at one blow.

JAMMU AND KASHMIR RAILWAY.—In the report for the year ending March 31, 1888, of the director-general of railways, it was stated that the track was to be of the most improved type in use on the North-western Railway (presumably 75-pound flange-rails on steel cross-ties of the state railways type.)

EASTERN BENGAL RAILWAY.—The report of the director-general of railways, for the year ending March 31, 1888, mentioned 34 miles laid with cast-iron bowls, 20 miles with Denham-Olpherts cast-iron plate-ties, 10 miles with Denham's plate-ties, and one-fourth mile with Greaves' cast-iron bowls; also Vautherin wrought-iron and De Bergue cast-iron ties (length of track not stated) on the northern section (see State Railways); and Denham-Olpherts plate-ties on the Assam-Behar section. On the Goalundo extension, opened about 1871, 8 miles of the main line were laid with spheroidal cast-iron bowls, packed with the ordinary sand of the country. Mr. Ernest Benedict, in his paper on "Metal sleepers for railways" (1877), already referred to, stated that they were laid in sandy earth packing and the grass allowed to grow over it, except within 6 inches of the rails, thus protecting the sand from being washed away by the rain or blown away by the wind. This was expected to save the cost of burning clay or brick for ballast, about $7,500 per mile, and to effect a great economy in maintenance. These views were found in practice to be correct. There were eight pairs of bowls to a rail length of 20 feet, as compared with seven wooden ties; they were first laid on brushwood and packed with sand, but later the ordinary sandy loam only was used, packed from below by wooden beaters and then tamped through the holes on top. The bowls were 22½ inches in diameter, nine-sixteenth inch to 1 inch thick; the tie-bars were 2½ inches by ½-inch section, 7 feet 4½ inches long, and weighing about 31½ pounds; they were secured by cotters on the outside and gibs on the inside of the track. The rails were of double-headed section, weighing 74 pounds per yard. Particular attention was paid to the drainage; besides the ordinary trench between the rails, four cross drains were cut to each pair of rails, two to the right and two to the left between alternate ties; the embankment itself was rounded off and there was not a square foot of level surface upon its top. There were seven trains each way per day, with four-wheel freight cars weighing 16 tons (10 tons of freight) and heavy engines with four coupled wheels. Mr. Benedict gives the following figures in regard to renewals:

In the half year ending June 30, 1876, 14,130 wooden ties were renewed, or at the rate of nearly 10 per cent. per annum of the main line ties, bringing the total renewals, which have been mostly on the main line, to 34.33 per cent. of the whole number of ties, and leaving 40 per cent. of all the ties in the line fifteen and one-half years old; but these are mostly in sidings. Taking, then, that nearly all the renewals have been on the main line, the yearly average so far (1877) has been 3.44 per cent.; but it may also be taken as certain that another 33 per cent. of the total number of wooden ties will have to be removed from the main line during the next two years (to 1879). This would give a yearly average of 6 per cent., or a life of sixteen and one-half years to the old ties now in the track, of which two years passed before the line was open for traffic. Against this we have 364 or 1.25 per cent. of bowls renewed in the half year, making a total of 6.17 per cent., all on the main line, and giving a yearly average of a little over 1 per cent., or a life of eighty-nine years to the bowls.

TIRHOOT RAILWAY.—In 1878, Sir Guilford L. Molesworth designed some cast-iron bowls for this line (See State Railways). There are now in use the Denham-Olpherts and Denham's cast-iron plate-ties; also sâl and deodar wood ties.

JORHAT RAILWAY.—Fowler's patent portable track, with 14-pound steel flange-rails on corrugated steel cross-ties, is laid for 3 miles; the rest of the line is laid with 18-pound rails on wooden ties.

CHERRA-COMPANYGANJ RAILWAY.—On this line 7½ miles are laid with 25-pound steel flange-rails on Fowler's patent steel ties for light railways. The ties are flat, with a middle corrugation forming a deep groove along the upper surface of the tie. The outer flange of the rail is held by a clip secured to the tie by two bolts; the inner flange is held by the hooked end of a bolt which lies in the groove under the rail, with a nut screwed up against the end of the tie. The ties are 45 inches long, and there are eight to a rail length of 21 feet. This part of the line is worked by locomotives. On the mountain inclines, worked by steel wire ropes, wooden ties are used.

BURMAH RAILWAYS.—Until very recent years the ties used in Burmah were almost exclusively of iron-wood, or teak. The former is an excellent timber, impervious to white ants, and little troubled with dry-rot. The teak is softer, and lasts eight or ten years. Steel ties, however, have been experimented with, and are now being introduced, as they economize in the expense of spikes, and are claimed to last forty or fifty years. Recent low prices have greatly aided the introduction of steel rails and steel ties.

MADRAS RAILWAY.—The track of this road is laid almost entirely with cast-iron bowls, carrying rails weighing 65 to 84 pounds per yard. The southwest section was originally laid with ties of indigenous woods, but as early as 1853 the then chief engineer, Mr. G. B. Bruce, suggested that an experiment should be made by using stone blocks 2 feet by 2 feet by 1 foot. The Government acceded to the proposal and sanctioned the purchase of 60,000 stone blocks. Apparently, however, only about 800 yards were laid in this way, and, as the experiment proved to be unsatisfactory, the blocks were all removed in 1857. Jungle-wood ties were found to be very short-lived, and in 1861 it was decided to replace them by Greaves's patent cast-iron bowls. This alteration has proved to be economical and satisfactory. The northwest section, 308 miles long, and the Bangalore Branch, 87 miles long, are laid with iron ties. In 1877 it was stated by Mr. Benedict, in his paper on "Metal Sleepers for Railways," already referred to, that nearly the entire line was laid with the bowls, except about 70 miles laid in laterite rock-ballast, and in that part trenches were being made in the ballast to be filled with sand, so that the bowls could be put there also. When the bowls were carefully packed they made a smooth track, easy to ride over, and safe for high speeds. At one time tie-bars were only used to every alternate pair of bowls, but now they are used for every pair. The cost of maintenance, as compared with jungle-wood ties, was found in five years to be as 3 to 1 in favor of the bowls. Creosoted pine ties have been tried, but are not preferred to the iron. About 1886, there was a period in which this form of tie, however, fell into disfavor, but it has survived up to the present time.

From a paper, with illustrations, by Mr. E. W. Stoney, chief engineer, on "The Creep of Rails on Double Lines of Railway," published in The Indian Engineer, Calcutta, October 29, 1887, the bowls were of the Greaves pattern (See State Railways); they were about 24 inches in diameter, arranged in pairs, and connected by transverse tie-rods; the ties were spaced 2 feet 6 inches apart, center to center of tie-rods, at the rail-joints, and 3 feet 6 inches apart intermediate. The distance between the near rails of the two tracks is 6 feet. The rails are of double-headed section, weighing 75 pounds per yard; they are 20 feet long, connected by splice bars and four bolts, the joints being even and suspended. The ballast is of sand. The taper of the keys and the jaws of the bowls was in the direction of the traffic for the outside rails of each track, and in the opposite direction for the inside rails. The creeping of the track in the direction of the traffic, therefore, tended to tighten the keys of the outside rails and to loosen those of the inside rails; consequently, the creeping of the inner rails was much greater than that of the outer rails. In regard to this creeping, which is a matter of importance to railway engineers, Mr. Stoney states that it is in the direction of the traffic; the joints are sometimes drawn out as much as 5 inches, when the fish-plate came against the jaws of the bowl; but even then the force was sufficient to pull the bowl through the ballast, sometimes bending the tie-bars, shearing or breaking three-fourths inch splice bolts, and breaking the jaws of chairs which were immovably fixed on girder bridges.

SOUTH INDIAN RAILWAY.—This line was formerly the Great Southern of India Railway. It was commenced in 1859, and was built to the Indian gauge of 5 feet 6 inches, but during the years from 1875 to 1879 it was converted to meter gauge. Cast-iron bowls were made for this road in 1877 (as described under State Railways). In that year the road had 86 miles laid with these ties in sand ballast; they were laid with seven pairs to a rail length of 21 feet. At first tie-bars were only used at every alternate pair of bowls, but now at every pair. Each bowl had a teak cushion on which the rail rested. On the broad-gauge line, about half was laid with iron and half with wooden ties. As the latter decayed they were replaced with iron. The track was laid with 40-pound rails and light ties, but it is being rapidly relaid with 50 pound rails and heavier ties. In October, 1889, the consulting engineer, Sir Douglas Fox, informed me that there were about 140 miles laid with cast-iron bowls, and extensions aggregating 300 miles were being laid with steel ties of the State Railways pattern for meter-gauge, large numbers of which were sent to India. In his opinion, the cast-iron tie is by far the best under most circumstances. The grades and curves of the road are easy. The engines have a weight of about 3½ tons on the driving wheels, and they haul the trains at a speed of about 25 miles per hour.

The bowls are 20 inches long at the bottom, at right angles to the rail. The thickness of the metal averages eleven-thirty-seconds inch, and the weight is 70 pounds each. The height from the bottom of the bowl to the top of the jaws, forming the rail-chair, is 7⅜ inches, and 7⅝ inches for the inner and outer jaws respectively. The tie-bar is of wrought-iron, 1⅝ by three-eighths inch section, 5 feet 6¼ inches long, and weighs 11 pounds. It is placed on edge, and passes through the bowls, being secured on the outer side of each bowl by a split cotter, and on the inner side by a gib. The cotters weigh 43½ pounds per hundred, and the gibs 17 pounds per hundred. The rails are of steel, of bull-headed section, weighing 50 pounds per yard. The lower table rests on a wooden packing-piece, or cushion, and a compressed oak key, or wedge, is driven between the web of the rail and the outer jaw of the chair, the jaw being corrugated so as to bite into and hold the key. The rails have an inward inclination of 1 in 20. The ballast is of a stone called laterite. The cost of construction of the road is said to have been about $33,500 per mile.

A special feature of some of the steel ties used (not the state railways pattern), was that the clips were not stamped out of the metal of the tie, but two wrought-iron plates with jaws were secured to each tie by four rivets, each rail resting on a plate. They were laid in April, 1885, to replace creosoted pine ties, and in October, 1888, Mr. David Logan, chief engineer, reported that some had been found cracked round the plates, the weight of the traffic appearing to have a tendency to punch the plates through the tie. The cracked ties weighed about 62 to 64 pounds each, while the average weight of ties of this class was about 70½ pounds. The rails were of flange section, weighing 40 pounds per yard, and were secured by wooden keys in the same way as a double-headed rail in a chair.

Great Indian Peninsula Railway.—On this line, cast-iron bowls are extensively used. They have been adopted for the standard track of the road as a form of bowl which gives good satisfaction, arrived at by gradual improvement. They are of oval shape, and are spaced 2 feet 9 inches apart, center to center. They are being used not only for maintenance and renewals, but also on the double tracking of the lines. As laid in 1877, there were eight pairs of bowls to a rail length of 24 feet. The rails were of iron, and weighed 68 pounds per yard. The rails now used are of steel, and weigh 69, 82, and 86 pounds per yard. At a meeting of the company in June, 1889, the president, in presenting the report for the half year ending December 31, 1888, made the following remarks in regard to the ties used:

When the railway was first worked wooden sleepers were very largely used. We found in very early days that it would be advantageous to introduce iron sleepers in substitution for wood. It was done in some degree tentatively, but with some rapidity after a little while. In 1872, just after the railway had been completed throughout, our road consisted of 1,110,000 iron sleepers and 1,638,000 wooden sleepers. Many of the wooden sleepers have been replaced, and we have now 2,190,000 iron sleepers as compared with 977,000 of wood; and the advantage of this is that while one represents the renewal of iron sleepers per hundred, it takes 5.09 of teak wood sleepers and pine sleepers to do as advantageously as the iron does, and the effect is that you get done with 1 per cent. that which takes more than 5 per cent. in the case of the teak sleepers, which are the next durable we have.

BOMBAY, BARODA AND CENTRAL INDIA RAILWAY.—In September, 1889, Mr. J. M. Sleater, the chief engineer, forwarded me a statement in regard to this road. There were then 77.48 miles laid with the cast-iron bowls; they were laid at different dates, under the supervision of the late Mr. A. F. W. Forde and the late Mr. F. Matthews, who were successively chief engineers of the road. The steepest grade is 1 in 100; ruling grade, 1 in 500; sharpest curve, 1,500 feet radius. There is a heavy traffic, with freight trains of fifty cars. The total weight of engine and tender is about 62 tons, with 14 tons on the driving wheels. The bowls are oval in plan, about 21 inches by 26 inches, the major axis being parallel with the rail; the depth of the bowl (inside) is about 5 inches, and the total depth from the top of the jaws which form the rail chair to the bottom of the bowl is about 9½ inches. The thickness varies from about one-half inch to three-fourths inch. At the middle, between the jaws, the top is flat for a width of 6 inches; on this the rail does not bear, resting on two wooden cushions about 5½ inches long, 2½ inches wide, and 1 inch thick, in sockets of the casting, one on each side of the flat portion. There are two tamping holes 2¾ inches in diameter in the top of the bowl. They weigh 87 pounds each and cost 53 rupees 1 anna 8 pice ($17.25) per ton, delivered in Bombay; ten years ago the price was 64 rupees 2 annas 8 pice ($21.15) per ton. The tie-bars are 7 feet 7¼ inches long, 2 by ½ inch section, placed on edge; they pass through the bowls and are secured by a cotter on the outer side and a gib on the inner side of each bowl. The ties are spaced about 3 feet 5 inches apart, center to center of tie-bars. The rails are of double-headed section, of steel, weighing 69 pounds per yard; they are secured in the chairs by wooden keys or wedges. The rail joints are suspended and are spliced by deep splice bars, the lower part curved to clear the lower head of the rail. The ballast is of stone and gravel, but must not be more than 1 inch in size. The width of the ballast bed is 14 feet at the bottom, or at subgrade; 11 feet on top, with side slopes of 1 to 1; the top surface is flat, and is level with the under side of the rail heads. The width of embankments at subgrade is 18 feet. The ballast behaves fairly well under the ties. The reason for adopting metal ties was their supposed cheapness, and the general results have been fairly satisfactory; there is no trouble with the rail attachments, nor with maintenance; breakages, however, occur where the stone ballast is larger than 1 inch in size. Mr. Sleater considers the track not as good as that on wooden ties. The wooden ties used are of creosoted pine, cost 2 rupees 8 annas (80 cents) apiece, and have a life of about eight years. The following table shows the quantities and weights of the metal track per mile:

*Material and weight, metal track.*

| Material. | Actual requirements. | | Allowance for waste. | Weight per mile. |
|---|---|---|---|---|
| | Unit weight. | Number. | | |
| | | | *Pr. ct.* | *Tons.* |
| Rails (30 feet long) ........ pounds.. | 690 | 352 | ...... | 108.42 |
| Bowls .. ........ do.... | 87 | 3,168 | 2 | 125.50 |
| Tie-bars ........ do.... | 26 | 1,584 | ...... | 18.39 |
| Cotters ........ ounces.. | 10½ | 3,168 | 5 | .97 |
| Gibs ........ do.... | 3½ | 3,168 | 5 | .32 |
| Fish-plates ........ pounds.. | 10 | 704 | 5 | 3.30 |
| Bolts and nuts ........ do.... | 1½ | 1,408 | 5 | .99 |
| Total ........ | ........ | ........ | ...... | 257.89 |
| Oak cushions ........ ounces.. | 10 | 6,336 | 5 | 1.85 |
| Wood keys ........ pounds.. | 1 | 3,168 | 5 | 1.48 |

In his paper on "Metal Sleepers for Railways" (1877), already referred to, Mr. Ernest Benedict stated that on this line some thought that bowls were superior to wood wherever coarse sand or tolerably firm gravel was procurable, while others said that they should only be used where durable timber can not be obtained at a moderate cost. There were six pairs of oval bowls or seven wooden ties to a rail-length of 24 feet, giving about the same bearing surface, and, taking the cushions into account, about the same distance between the points of support. This very nearly equalized the original cost of the tracks, and it was found that the track on metal ties could be kept in order at about the same cost as that on the ordinary wooden ties. With broken stone, coarse shingle, or any ballast that cakes or hardens, the bowls were liable to be broken. In this respect circular bowls, ribbed, were found stronger than oval bowls. On the Nagpoor district there were many breakages, through allowing the track to run "hard," while in other districts, in sand ballast, the breakages did not exceed 2 per cent. per annum.

TARAKESHWAR RAILWAY.—This line is operated as a part of the East Indian Railway system, and is laid with Denham-Olpherts cast-iron plate ties of the latest type. (See East Indian Railway.)

DELHI, UMBALLA AND KALKA RAILWAY.—This is a new line now under construction, on which the Denham-Olpherts cast-iron plates are to be used, but up to June, 1889, no track had been laid. The rails will be of steel, double-headed section, weighing 75 pounds per yard. The ballast will be partly of brick and partly of stone, and the general type of track throughout will be in accordance with the standards of the East Indian Railway.

The southern division of 130 miles is over easy country, with a ruling grade of 1 in 300, while the northern division has a ruling grade of 1 in 40. The minimum radius of curves of the two divisions is one half mile and one-fourth mile, respectively. Mr. R. A. Way is chief engineer and Mr. William Duff Bruce is consulting engineer. The cost is estimated at $32,500 per mile, exclusive of rolling stock. The cost of the East Indian Railway, including equipment, is given as about $110,000 per mile, and that of the Scinde, Punjab and Delhi Railway as about $80,000 per mile. The State will provide all rolling stock and will operate the line for 50 per cent. of the gross receipts. It will be worked by the East Indian Railway Company under a contract with the State.

THATON-DUYINZAIK RAILWAY.—The track of this road consists of steel flange rails on steel and wooden ties.

H. H. THE NIZAM'S RAILWAY.—Some cast-iron bowls of a type used on the state railways were in use on this road in 1877. At the end of March, 1888, 109¾ miles were laid with 66¼-pound steel rails on steel cross-ties of the state railways pattern, 87 miles with 68-pound rails on cast-iron bowls purchased from the South Indian Railway, 6 miles with 66¼-pound flange rails on Bessemer-steel ties, and the remainder with 60-pound flange rails on creosoted pine and jungle-wood ties. Mr. W. A. Lyle, chief inspector of maintenance, who has had nearly thirty years' experience with metal and wooden ties, wrote me in September, 1889, stating that, in his opinion, cast-iron ties were not reliable; wooden ties, he thought, cost too much to preserve, and even when preserved they were not reliable, as the gauge spreads under the lateral pressure of the wheels of trains, and the ties split and rot. In August, 1889, Mr. Lyle made a report to Sir A. M. Rendel, the consulting engineer, upon the State Railways type of steel tie, of which he had six years' experience, three years having been with the new pattern. He found this latter pattern superior to anything else he had ever tried, for the following reasons:

(1) It is easily handled and laid in the track.

(2) It holds well in line and surface.

(3) The gauge can be easily and uniformly adjusted on curves.

(4) The lugs are not too rigid, and the key is kept in place when once properly driven.

(5) The maintenance is easy when the track has become consolidated.

(6) If damaged by a derailment the tie can be repaired and made serviceable at a small cost.

He had not found the preservative coating to come off or the ties to rust except in a few rare cases, due to the use of bad ballast, impregnated with saltpeter, etc. Sand ballast he considered best, while broken stone he thought scratched the preservative coating and consolidated to too hard a bed, like macadam. To lessen the labor of packing and tamping he suggested the making of a packing hole $1\frac{3}{4}$ inches in diameter at each end of the top of the tie, the holes to be so punched as to leave a rib or burr around them. The cost would be small, and he estimated that he could carry on the maintenance with five men less for every 4 miles of line. He thought the ballast should be only level with the tops of the ties, not covering them.

In February, 1889, Mr. W. C. Furnivall, chief engineer, reported to the director-general of railways that his experience with the improved pattern of the State Railways steel ties was very favorable to their use. They can be easily and quickly laid, are preferable to timber in diversions on rough temporary roads, except only where stone and rock occur, and then only a sand packing must be employed. A line laid with these "pea-pod" ties is cheaply maintained; the ties keep their position well, and do not oxidize where the ballast is good. The slight friction caused by the passage of trains pressing the sand in stone ballast against the under side of the tie suffices to brush off any particles of oxidation which might otherwise exist. In cases of derailment he had found the ties easy to repair.

KHAMGAON RAILWAY.—The track of this line is laid with 60-pound flange rails on oval bowls. The road is operated by the Great Indian Peninsula Railway Company.

AMRAOTI RAILWAY.—This line is laid with 68-pound rails on iron ties. It is operated by the Great Indian Peninsula Railway Company.

H. H. THE GAEKWAR'S RAILWAY.—The Viramgam-Mehsana-Vadnagar Railway is laid with $41\frac{1}{4}$-pound steel rails on steel cross-ties. The line is owned by the Gaekwar of Baroda, and is operated by the Bombay, Baroda and Central India Railway Company. The other line, known as the Gaekwar's Railway, is laid with wooden ties.

BHAVNAGAR, GONDAL, JUNAGARH AND PORBANDAR RAILWAY.—The extension to Porbandar will be laid with $41\frac{1}{4}$-pound steel flange rails on steel cross-ties; this line will be 69 miles long. Of the $259\frac{3}{4}$ miles in operation, $193\frac{1}{4}$ miles are laid with similar rails on half-round pine ties, and $66\frac{1}{2}$ miles with similar rails on jungle-wood ties from a local forest.

MORVI RAILWAY.—Part of this line runs along a highway. The track is laid with about 90 miles of 19-pound steel rails on Kerr and Stuart's patent steel ties, which are similar to the state railways type. (See Kerr and Stuart, England.)

JODHPORE RAILWAY.—The Pachpadra extension, $59\frac{3}{4}$ miles long, is laid with 36-pound rails on steel cross-ties. The main line is laid with similar rails, 19 miles on creosoted pine ties, and 45 miles on jungle-wood ties.

CALCUTTA PORT RAILWAY.—This is a line of 5 feet 6 inches gauge, owned by the port commissioners. The following report was kindly prepared for me by Mr. E. Desbruslais, assistant engineer, at the instance of the commissioners:

The line is in three sections: No. 1, from Chanpal Ghat, Calcutta, to the government gun foundry, Ghat, 4.085 miles, laid with three tracks; No. 2, from Chanpal Ghat to Kidderpore docks, including the dock lines, 7.25 miles; No. 3, from the Kidderpore Docks to brick fields at Akra, 3.50 miles. Sections No. 1 and No. 2 are laid with steel bowls; No. 3 is only a temporary line. On section No. 2 the curves are very slight and the lines run generally level, except on each side of the level crossing at the approach road to the Hooghly floating bridge, where the grades are 1 per cent. for 600 feet. On No. 2 the sharpest curve is of 1,000 feet radius, and the line is nearly level. No. 1 was laid in 1875 with iron rails, which were replaced in 1885 with steel rails 30 feet long. No. 2 was laid in 1885–1886. Mr. William Duff Bruce was the engineer to the port commissioners when these works were carried out. No. 1 was intended to do away with as much as possible of the cart traffic on the Strand road and at the jetties; there is quite a heavy freight traffic. No. 2 is principally for conveying materials for the construction of the docks. The engines are tank engines, with four wheels, all coupled; wheel base, 6 feet; they were built by Dübs & Co., of Glasgow, and weigh 20 tons empty or 23 tons with tanks and bunkers full, giving 11½ tons on each pair of wheels. Each tie consists of two of MacLellan's patent steel embossed bowls, connected by a tie-bar; the bowls are of rectangular form, with all sides fluted; they weigh 33 pounds each (See plate No. 25). They are spaced 3 feet apart, center to center, and the rails are laid with suspended joints. The cost was £14 ($70) per ton delivered, and the average cost of maintenance (labor only) on section No. 1 is 26 rupees ($8.22) per mile of single track. The rails are of flange section and rest directly on the bowls, to which they are fastened by two bolted clips on the outer side and one clip on the inside; the outer bolts are seven-eighths inch in diameter and the inner bolts 1 inch in diameter. At curves a larger number of tie-bars is put in and the gauge is left one-half inch slack. The tie-bars are of angle-iron with adjustable clips and bolts at each end; they are spaced 6 feet apart, center to center. Ordinary freight cars are used, but the speed does not exceed 6 miles per hour. The materials appear to be wearing satisfactorily, but there has not been time enough to judge of their durability. Section No. 1 is ballasted with cinders, which are easily procurable and answer remarkably well for packing the bowls; the cinders are walled in by the curbstone of the road, the rails being level with the top of the curb; all rain-water drains through the cinders and is carried away in the roadside surface drain, so that the road-bed is well drained. Section No. 2 is ballasted with old bricks, broken to pass in any direction through a 2-inch ring; being rather soft they answer very well, but hard burnt brick would not be suitable. The cinders do not cake or harden into a mass under the bowls, but the brick ballast seems to be doing this. The suspended rail-joints on section No. 1 being very springy, Mr. Desbruslais designed a joint tie, which has been laid throughout this section with satisfactory results. The joints on section No. 2 are suspended. The general results of this track have been satisfactory so far, and there is no trouble with maintenance or with the rail attachments. When once the clips are fastened and the bolts tightened up they do not require any further looking after, as they get jammed up in a few weeks, and a difficulty is experienced if the bolts are required to be unscrewed. The fish-plate bolts, however, constantly require tightening. There is no trouble from breakages on the main line; it is only at switches and frogs that engines or cars get derailed, and, as the speed is slow, little damage is done. The switches and frogs are laid on wooden ties, with the ordinary cast-iron chairs; some of the chairs get broken and occasionally a switch rail and coupling-rod bent. The cost of the track laid complete, including the cinder ballast, is about 18 rupees ($6) per yard. The speed being only 6 miles per hour, the results that may be obtained on this line can not be assumed as similar to those that will be obtained from the use of this description of track on lines where high speeds are attained.

The rails are of steel, of flange section, and weigh 60 pounds per yard; they are 4¼ inches high, 4 inches wide over the flange, with a head 2¼ inches wide, having top corners of one-half inch radius. The bowls are about 30 inches long, 18 inches wide, and 4½ inches deep; the greater length is in the direction of the track. The rail joints are even and come between the bowls. The joint support designed by Mr. Desbruslais consists of a cast-iron plate and chair under each joint, without tie-bars. (See plate No. 25.) The plate is 24 inches by 12 inches, the greater length being transverse to the track. The bottom is flat, but at the middle of the upper surface is a support 6 inches high, forming the rail-seat. From each side of this two webs run to the edge of the plate. The splice-plates are double angle-bars, having a vertical web below the horizontal flange; on the inner edge of the bottom of this lower web is a rib, so that when brought together by the splice-bolts these ribs fit under the projecting top of the rail-seat and thus prevent vertical motion of the rails at the joint. The splice plates are 18 inches long, with four bolts. The tie-bars are of angle-iron, 2¼ by 2¼ by ¼ inch; they are placed between the pairs of bowls and connect the rails instead of the bowls, the latter being left quite independent of each other. At each end of the bar are two lugs, one fixed at the extremity of the bar, the other loose; the tops of these lugs are bent over to hold the rail-flange; when the rails are in place the lugs are held together by a horizontal bolt passing under the flange. In the middle of and between the tracks the ballast is level with the top of the rails, sloped down at the rails to the under side of the head. The space between the rails of adjacent tracks is 7 feet.

MISCELLANEOUS LINES.—The following railways are laid with wooden ties:

Dildarnagār-Ghazipur; 65-pound steel rails, on bearing plates and creosoted pine ties.

Bengal Central; 62-pound flange rails, on creosoted pine ties.

Wardha Coal; creosoted pine, teak, and sâl ties.

Toungoo-Mandalay (Burmah); flange rails, on teak and pyingado ties.

Bareilly-Pilibhit; 4¼ pound flange-rails, on deodar and sâl ties.

Nalhati; 31 and 41¼ pound flange-rails, on teak, sâl, and pine ties.

Lucknow-Sitapur-Sihraman; 41¼-pound steel rails.

Amritsar-Pathankot; 62-pound rails.

Darjeeling-Himalayan; 30 and 40 pound rails, on wooden ties.

Deoghur; 36 pound steel rails, on wooden ties.

Dibru-Sadiya; 41¼ pound steel rails.

Bengal and Northwestern; 41¼-pound steel rails, on sâl and creosoted pine ties.

Rohilkund-Kumaon; $41\frac{1}{4}$-pound steel rails, on sâl and jungle-wood ties.

Pondicherry; 40.3-pound rails, on wooden ties.

West of India Portuguese; 62-pound rails, creosoted pine, sâl, and teak ties.

H. H. the Gaekwar's; 30-pound flange rails, on wooden ties.

Rajpura-Bhatinda; 68-pound steel rails on deodar ties.

## TIES.

*Denham-Olphert's cast-iron plate ties* (See plates Nos. 21 and 23).—This tie consists of a pair of cast-iron plates, each having a chair for one rail, with a wrought-iron tie-bar connecting them. It is interesting to note the extent to which cast-iron has been employed with successful results—as on the East Indian Railway. On the guaranteed railways of 5 feet 6 inches gauge the plates are oblong, 34 inches by 12 inches, the greater length being transverse to the track. The thickness at the middle is three-fourths inch, tapering to three-eighths inch near the edges, while at the edge it is five-eighths inch. On the bottom, parallel with the rail, is a segmental rib $1\frac{1}{2}$ inches deep at the middle. At the middle of the plate are the jaws which form the rail chair, from each of which run two ribs $3\frac{1}{16}$ inches high at the jaw and curving down to the edge of the plate. The rails are of double-headed section and are suspended in the chair by the under side of the head resting on the jaws of the chair. The outer jaw is a part of the plate casting, but the inner jaw is loose and is held in place by a flat taper key or cotter driven horizontally through slots in the plate ribs, the tie-bar and a web projecting from the back of the jaw; the cotter is 10 inches long, 2 inches and $1\frac{5}{8}$ inches wide, and three-eighths inch thick. With this fastening no wooden keys are used to fasten the rail, which is an important feature in hot countries. The tie-bars are flat, $2\frac{1}{2}$ inches deep by one-half inch thick; they rest on the upper surface of the plates and pass under the rails through both jaws of each plate. They are secured on the outside of each plate by a gib, and on the inner side by the cotter, which holds the several parts together and brings the loose jaw firmly home against the rail. The height from the top of plate to the top of the jaw is $7\frac{3}{8}$ inches, and the metal in the jaw is about five-eighths inch thick.

For the meter-gauge lines the plates are 24 inches by 10 inches, with a tie-bar $1\frac{1}{2}$ by $\frac{1}{2}$ inch; the plates are nine-sixteenths inch thick at the middle, three-eighths inch at the sides, and one-half inch on the edges. The rails being of flange-section, the chairs are of different shape from the above; the outer side of the chair has two lugs which hold the rail flange, while the loose jaw on the inner side is of ┏ form, the horizontal portion bearing on the rail flange; the jaw is held in place by a key, as above described. The weight is as follows:

| | Pounds. |
|---|---|
| Cast-iron: | |
| Two plates | $89\frac{1}{2}$ |
| Two jaws | $5\frac{1}{4}$ |
| Wrought-iron: | |
| Tie-bar | $11\frac{1}{4}$ |
| Two cotters | $2\frac{1}{4}$ |
| Two gibs | $\frac{1}{2}$ |

In another form of the tie for meter-gauge lines each rail rests on a block of wood 5 inches long, 7 inches wide, and $2\frac{1}{2}$ inches thick. The top is cut to give the rail an inward cant of 1 in 20. The rail is fastened by two bolts; the heads are on top, with washers, which hold the rail flange, and the nuts are on the under side of the plate, being prevented from turning by lugs on the plate. The bolt is screwed down through the nut. The tie-bars are only 2 feet $7\frac{3}{8}$ inches long, resting on the inner side of the plate and having a notch which engages with a projection on the plate. On the inner edge of each plate is a lug with a slot, through which the tie-bar passes, and a taper key placed on edge is driven into this slot along the top of the tie-bar.

The "Denham-Olpherts-Molesworth" tie for meter-gauge lines is similar to the first type described for this gauge, but has the corrugated wedge fastening designed by Sir G. W. Molesworth and described under the heading of the Indian State railways. Another modification in these ties is the mode of adjusting the gauge by means of the tie-bars. Under the raised rail seat are two studs in the plate. They are placed side by side and are of different dimensions. The end of the tie-bar projects under the rail and has a notch on the lower edge to fit over the projections or studs. When the tie-bar is placed with its ends fitting on one diagonally opposite pair of studs the gauge is 3 feet 3⅜ inches for tangents. When the ends fit over two opposite studs the gauge is 3 feet 3¾ inches for easy curves. When the ends fit over the other diagonally opposite studs the gauge is 3 feet 4⅛ inches for sharp curves. The weight is as follows: 2 plates, 100 pounds; 2 jaws, 5 pounds; 2 wedges, 4 pounds; 1 tie-bar, 10 pounds; total, 119 pounds. This type is also suitable for broad-gauge lines.

The ties take the same depth and level of ballast as the wooden ties, so that by inserting a plate tie whenever a wooden tie is removed the renewal can be carried out gradually without closing the line in sections or in any way interfering with the traffic. The ties have a very long life, and some have been exhibited at Calcutta over which 16,000,000 tons of traffic had passed without causing appreciable wear or injury. The percentage of breakages is very small, and when broken or worn out the plates have still the value of scrap iron, about 30 rupees ($6) per ton at any large foundry. The price in India, when imported, is about 6 rupees 8 annas ($2.16), but when of home manufacture the price will be about $2 per tie complete. The ties are said to make a very smooth and easy riding track, with no jolting or rattling with trains traveling at high speed. Some of the ties on a broad-gauge line, with 74-pound rails, were carefully examined after three years' service and found to be in perfect condition, though about 12,000,000 tons of traffic had passed over them at various speeds.

As regards maintenance, it has been stated that during the first year the amount of labor is slightly greater for track laid with "Denham-Olpherts" ties than for a good track on wooden ties; during the second year it is about equal, or a little in favor of the metal track, while during subsequent years it is much less for the track on metal ties than for that on wooden ties. The following are stated to be the comparative proportions of the cost of renewals per mile per annum:

| | |
|---|---|
| Creosoted pine | $750 |
| Deodar | 625 |
| Sâl | 500 |
| Denham-Olpherts | 40 |

The breakages in handling are said to be less than one eighth of 1 per cent., and one-half of 1 per cent. per annum in the track, against 2 or 3 per cent. for bowl ties.

The ties are generally laid eleven to a rail length of 30 feet; the ballast is usually 2-inch to 4-inch hard stone, but broken brick, ashes, gravel, dirt, etc., are used. The ties are found to be sufficiently elastic for smooth running of trains at high speeds. The weight of the ties for broad-gauge lines laid with 75-pound rails is about as follows:

| | Pounds. |
|---|---|
| 2 cast-iron plates | 175 |
| 2 cast-iron jaws | 22 |
| 2 wrought-iron cotters | 2½ |
| 2 wrought-iron gibs | ⅝ |
| 1 tie-bar | 22⅛ |
| Total | 222¼ |

The following is an abstract of a statement submitted to me in June, 1888, by Mr. Browning, the London agent for the patentees:

Mr. C. H. Denham is the engineer-in-chief of the East Indian Railway and Mr. Olpherts was a district engineer on the same line. Several years ago large quantities of cast-iron bowls were sent out from England for use on the East Indian Railway, having been already used with success on the Egyptian railways and in parts of India where the ballast was of sand or light gravel. The East Indian Railway was ballasted for a great part of its length with hard red iron stone mixed with clay. This ballast soon shaped itself under the bowls and became hardened into solid concret-cakes, so that it was found that the bowls were constantly getting broken by concussion with the solid blocks of ballast on which they rested. To obviate this trouble Mr. Denham designed a cast-iron tie of about equal weight with the bowls, but formed of flat plates with vertical ribs so arranged on the upper surface as to strengthen the plate and form a seat for a wooden cushion to which the ordinary chair was bolted. Such plates laid in pairs connected by wrought-iron tie-bars were tried, with satisfactory results. The under side of the plate being flat admitted of easy and solid packing, and the proportion of breakage in the track was at once reduced to about one-one-tenth of that of the bowls, while the trains were found to run more smoothly. The principle of a flat iron plate tie having been thus established, improvements in detail rapidly followed. The formation of the outer jaw on the plate and the keying up of a loose inner jaw against the rail by a cotter passing through it and the webs of the rail seat were designed by Mr. Olpherts, and finally the wooden cushions upon which the rails rested were abandoned and the rails were suspended by the under side of the head resting upon the tops of the jaws. In this form the tie had, in June, 1888, been in use for about seven years on the East Indian Railway and other railways in India. The tie is also adapted for flange rails and has been used on the meter-gauge railways of India, which are laid with steel flange rails weighing 41¼ pounds per yard. Up to June, 1888, more than 2,000,000 pairs of plates for double-headed rails, and about 600,000 pairs for flange rails had been made, and their use was extending rapidly. The saving in cost of maintenance on the main track of an Indian railway laid with 75 or 80 pound double-headed steel rails on these ties as compared with the same road laid on the best wooden (sâl) ties has been found by experience, extending over several years, to be about $400 per mile per annum. Some engineers still prefer the original form of the plate ties on the ground that the wooden cushions give elasticity to the track, but the general opinion is in favor of the latest pattern, in which the rail is suspended and which is free from the serious defects due to the shrinkage and rapid destruction of wood in hot climates. No trouble is experienced in maintaining a good track, and the difficulty of preserving an accurate gauge, which is unavoidable in a track laid with wooden ties, hardly exists in a track carefully laid with the metal ties. Actual renewals are reported to be rare. The plates require rather more frequent packing than wooden ties, but the ballast to be moved is much less. It is generally concluded that the economy found to result from the use of these plates is due to the renewals being so much less frequent than the renewals of wooden ties, and to the fact that a broken cast-iron tie is worth about three-fourths of its original value, while a worn-out wooden tie is almost worthless. About 900 miles of track are now laid with these ties.

*Moore's cast-iron ties.*—Mr. George E. Moore, deputy consulting engineer for railways, has designed some forms of cast-iron plate ties, the special feature of which is that the ends of the tie-bar support the rails on the inside of the track, the gauge depending on the accuracy of the length of the tie-bars instead of upon the accuracy of the casting. The plates for broad-gauge lines are rectangular, about 33 inches by 12 inches, the greater length being transverse to the track. The tie-bars are of **T** section, resting between lugs on the plate and secured by keys driven through the lugs and bar. With double-headed rails the end of the bar abuts against the web; with flange rails the end is cut to fit the web and flange. The plates for double-headed rails have a grooved depression, forming a seat for the lower head, and a jaw on the plate holds the rail on the outside; for flange rails there is a flat seat with a cast clip to hold the outer flange of the rail. No arrangements are made for alterations of the gauge. For light-meter gauge lines the tie may consist of the plates and tie-bar only, dispensing with all loose pieces. These ties are placed diagonally to the track, with the rails in place; the plates are then shifted to bring the tie-bar at right angles to the rails, when the notches and lugs engage and make the fastenings.

A suggested form of cast-iron tie somewhat resembles the steel tie of the state railways; it is of shallow inverted-trough section, deeper at the ends, and with a rib under each rail. The middle of the top table is cut away to reduce the weight and facilitate packing. Another suggested form consists of two plates shaped like tennis rackets, but with parallel sides. On the top of the end of the narrow part, or "handle," is a lug, and when brought together these ends abut against one another and are secured by a bolt passing through the lugs. No loose fastenings are used, each plate having two clips for the rail flange; the plates are put diagonally in the track, with the rails resting between the clips; they are then swung around till at right angles to the track, bringing the narrow ends together and causing the clips to overlap the rail flanges. For light lines the narrow part of the plates may be dispensed with and a tie-bar used to connect the plates. It has been suggested that ties of this kind might be made of pressed-steel plates, but Mr. Moore is in favor of cast-iron, as the ties can then be of home manufacture. The plan of using a tie made in two pieces connected in the middle of the track is not new, although Mr. Moore's designs may have some originality; such ties were patented in the United States as early as 1878 (Nos. 207320, 254802, 312881). (See Preliminary Report, Bulletin III, Forestry Division.)

Mr. Moore's latest form of tie (March, 1889) is a cast-iron cross-tie of shallow inverted-trough section, with closed ends, and having a deep corrugation along the middle of its length, and making a groove on top and a rib below. The tie is 10½ inches wide on the bottom, 9 inches wide on top, and 1½ inches deep at the sides and middle groove; the groove is 1 inch wide. The sides and groove are one-fourth inch thick and the top three eighths-inch thick. At each end of the tie are two rigid rail clips, no loose pieces being used, and the fastening being effected through a certain amount of spring in the rail. This plan is claimed to be particularly suited to light railways of narrow gauge, as the rails can be easily sprung into place by the use of a bar. For broad-gauge lines with heavy and stiff rails one of the two lugs at each end of the tie must be made to turn to some extent round a bolt or rivet, but here, also, the locking is to be done by springing the rail. The movable clip has a projection on the side opposite to the rail to enable a claw-bar to be used to move the clip on or off the rail flange. Arrangements may be made for adjusting the gauge at curves, but Mr. Moore does not consider that this is necessary in ordinary country. For heavy lines it is proposed to use an outer fixed clip 2¼ inches square clear of the rail, with a lip one-half inch by one-half inch projecting over the rail flange; the inner clip is of the same size, fastened by a three-fourths-inch rivet with a one-eighth-inch washer under the tie; this clip turns slightly on the rivet. An oval hole for tamping is provided on each side of the rail.

*Bell's cast-iron tie.*—The tie designed by Mr. Horace Bell is a flat cast-iron plate tie, intended for meter-gauge lines with flange rails. The plates are 24 inches long and 10 inches wide, the greater length being transverse to the track; the thickness is five-eighths inch at the middle, tapering to three-eighths inch, and on the under side of the plate are two ribs 6 inches apart, parallel with the rail. The rail rests on an elevated seat with a projecting lug on each side; a key of malleable cast-iron of ┏ section, tapered 1 in 100, is driven between the lug and flange on one or the other side of the rail according to the gauge; the vertical web of the key rests in a notch in the rail seat and tie-bar. The tie-bar is of ⊥ section, 1½ inches deep, 1 inch wide, and one-half inch thick; it rests above the plate, passing through lugs and under the rail; when in position the lower leg of the key engages with a notch in the upper edge of the bar. In another of Mr. Bell's ties there is but one rib on the bottom, and on the top are four ribs running from the raised rail seat, one to each corner of the plate. The tie-bar is flat, $1\frac{1}{2}$ by $\frac{1}{2}$ inch.

*Denham's cast-iron tie.*—This consists of two cast-iron plates, 34 by 12 inches; a wrought-iron tie-bar 4 feet 6 inches by 2 inches by $\frac{1}{2}$ inch; two ordinary rail chairs weighing 27 pounds each, and a wooden cushion 14 inches by 7 inches by $1\frac{1}{2}$ inches. The usual wooden keys are used for fastening the rails, and instead of spikes two bolts (with the nuts on top) pass through the plate, cushion, and chair. The tie-bar passes through a lug in each plate and fits over a small stud cast on the plate; it is kept from shifting by means of a split pin. Of 4,000 ties, only one breakage occurred during three years, and that was owing to bad drainage. Stone, gravel, and dirt ballast has been used. These ties are said to give better results than the "Denham-Olpherts" ties for lines where good ballast is not attainable, owing apparently to the use of the wooden cushion between the chair and plate.

SUMMARY FOR INDIA OF METAL TRACK.

| Railway. | Bowls. | Cross-ties. | Denham-Olpherts plates. | Total |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| State railways | $225\frac{1}{2}$ | $1,497\frac{1}{4}$ | 296 | $2,018\frac{3}{4}$ |
| East Indian | $79\frac{1}{2}$ | | 160<br>$762\frac{1}{4}$ | $1,001\frac{3}{4}$ |
| Rajputana-Malwa | | | 50 | 50 |
| Bengal-Nagpur | | $554\frac{1}{2}$ | | $554\frac{1}{2}$ |
| Southern Mahratta | | 500 | | 500 |
| Indian Midland | 300 | | 214 | 514 |
| Dhond-Manmad | $145\frac{1}{2}$ | | | $145\frac{1}{2}$ |
| Bhopal-Itarsi | | 6 | | 6 |
| Northwestern | 370 | 600 | 40 | 1,010 |
| Oude and Rohilkund | 692 | | | 692 |
| Eastern Bengal | 34 | | 30 | 64 |
| Jorhat | | 3 | | 3 |
| Cherra-Companyganj | | $7\frac{1}{2}$ | | $7\frac{1}{2}$ |
| Madras | 800 | | | 800 |
| South Indian | 140 | 300 | | 440 |
| Great Indian Peninsula | 622 | | | 622 |
| Bombay, Baroda and Central India | $77\frac{1}{2}$ | | | $77\frac{1}{2}$ |
| Delhi, Umballa and Kalka | | | 162 | 162 |
| H. H. the Nizam's | 87 | $175\frac{1}{4}$ | | $262\frac{1}{4}$ |
| Khamgaon | $7\frac{1}{2}$ | | | $7\frac{1}{2}$ |
| Amraoti | $5\frac{1}{2}$ | | | $5\frac{1}{2}$ |
| H. H. the Gaekwar's | | 50 | | 50 |
| Bhavnagar-Porbandar | | 69 | | 69 |
| Morvi | | 90 | | 90 |
| Jodhpore | | $59\frac{3}{4}$ | | $59\frac{3}{4}$ |
| Calcutta Port | 12 | | | 12 |
| Total | 3,598 | $3,912\frac{1}{4}$ | $1,714\frac{1}{4}$ | $9,224\frac{1}{2}$ |

These figures are most probably considerably below the actual mileage, owing to the lack of complete returns and to the fact that the returns received do not always give the latest mileage laid. The 160 miles of the East Indian Railway are estimated as the proportion of $325\frac{1}{2}$ miles laid with iron and wooden ties intermixed.

## FARTHER INDIA.

In Selangor, one of the protected States of the Malay Peninsula, the native hard-wood ties have not worn well, and in 1888 it was proposed to try some wrought-iron or steel ties. The colonial secretary at Singapore wrote me, however, in June, 1889, that no metal ties had then been laid on the Selangor Government Railway. In 1887, 20 miles of line were completed by the State; the meter gauge Government railway was opened for light traffic in September, 1886, and for regular traffic in January, 1887. There are railways in others of these States (Perak and Sunjei-Ujong), but no returns as to the ties used have been received; probably they are of wood.

### CEYLON.

Mr. F. J. Waring, chief resident engineer, wrote in October, 1889, that no metal ties are used. All the ties are of Baltic fir or native or Australian hard woods.

### SUMATRA.

On the railway of this island, which is a Dutch possession, steel cross-ties are used. They are of the "Post type" (Netherlands State Railway), and are imported from Holland. At first they were laid only upon the rack-rail section of 16.42 miles, but are now being laid over the entire length of the line 90.20 miles. Early in 1889 a contract was reported to have been made with a firm at Oberhausen for 121,000 ties (4,750 tons) at 2.55 gulden ($1.02) each, free on board, at Rotterdam or Amsterdam, but the agent of the manufacturers of these ties in a list of sales up to September, 1889 (see "Holland"), gives only 100,000 for Sumatra. The railway is of meter gauge, and was built to develop an extensive coal basin in the interior. The rack-rail section crosses a range of mountains, and has grades of 4 and 5 per cent. The engines on this section weigh 20 tons each, and two engines (one at each end of the train) can take a train load of 250 tons over the section at a speed of $6\frac{1}{4}$ to $7\frac{1}{2}$ miles per hour. The sharp curves on the line necessitate a widening of gauge of .96 inch, which is obtained by the use of three sizes of bolts with eccentric necks.

### CHINA.

The only railway at present existing is the line from Kaiping to Tientsin, 85 miles, which is owned by the China Railway Company. It is a standard gauge road (4 feet $8\frac{1}{2}$ inches), with maximum grades of 1 to 300 on the main line and curves of 3,000 feet radius. The track is laid with rails of the Sandberg standard sections, 60 and 70 pounds per yard, with angle-bar joints. The ballast is of broken limestone 2 to 3 inches in size and 9 inches to 12 inches deep under the ties. The ties are of chestnut, costing 60 cents each, and having a life of about seven years. The engines have a weight of 6 tons on each driving-wheel. The traffic is general passenger and freight. The climate is reported to be like Canada. In October, 1888, Mr. C. W. Kinder, the chief engineer, stated that a few steel cross-ties were to be imported from England and tried as an experiment. They were of the type adopted on the Indian State Railways, of inverted-trough section with closed ends, and having two clips stamped up out of the metal for each rail; a serrated steel key holds the rail, being driven between one lug and the flange. The steel is five-sixteenths inch thick, and the weight of the tie 80 pounds. They were coated with tar-paint. The cost was $1.20 each at the works and $1.70 in China. They were thought to be too light for the traffic, and were only to be placed on trial. They were manufactured by Messrs. Bolckow & Vaughan, of England.

A few steel ties of the Tozer type (See "England") were reported as being sent out for trial.

In 1887, when there was considerable talk of American companies intending to build railways in China, a form of track was suggested consisting of metal ties of "Berg-and-Mark" section (See "Germany"); they were to be 6 inches wide on top, 9 inches at the bottom, $2\frac{1}{2}$ inches deep, with the sides vertical for 1 inch from the bottom; top table one-half inch thick, with a rib one half inch thick at the middle, sides one-fourth inch thick. The fastening was to be an adaptation of the Fisher rail-joint fastening; it consisted of a U-bolt with the horizontal part inside the tie and the lugs projecting through it, one on each side of the rail-flange, with washers bearing on the rail-flange and secured by nuts. At joints the washers would hold the flange of the angle-bars, the joints being supported on a tie.

## JAPAN.

In May, 1888, Mr. C. A. W. Pownall, chief engineer of the imperial Government railways, stated that a few cast-iron bowl ties were laid when the first lines were built, about seventeen years previous, but they have nearly all been taken up again and hardly any remain in the track. For new lines; timber ties are used exclusively.

SUMMARY OF METAL TRACK FOR SECTION 4.

| | Bowls. | Cross-ties. | Denham-Olpherts plates. | Total. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| India | 3,598 | 3,912¼ | 1,714½ | 9,224¾ |
| Sumatra | ....... | 90 | .......... | 90 |
| Total | 3,598 | 4,002¼ | 1,714½ | 9,314¾ |

## SECTION 5.—SOUTH AMERICA, CENTRAL AMERICA, AND MEXICO.

### ARGENTINE REPUBLIC.

GENERAL REMARKS.—Metal track is the standard form of track in this country, owing to the difficulty of obtaining suitable timber in sufficient quantities. The most generally used type consists of cross-ties composed of cast-iron bowls arranged in pairs and connected by a transverse tie-bar. Within the last few years, however, steel cross-ties have been introduced. Since 1888, about 700,000 steel ties of the "Post" type (See "Holland") and about 20,000 tons of the Tozer steel ties (See "England") have been contracted for. Mr. Griswold, writing from Buenos Ayres in July, 1888, said in regard to metal ties: "We use nothing else here, except in the far north and west." The timber ties used in the northern part are principally of "quebracho colorado," which is a very hard timber; the spike holes are bored, and square spikes with rounded ends are driven in. It is almost impossible to draw these spikes. The timber, however, is very inflammable, and the ties are therefore covered over with the ballast. Suitable material for proper ballast not being available, the surface soil is generally used, being well tamped and packed into and around the bowls, and with ample provision made for drainage. Between the rails it is about 1 inch below the top of the rail head, and outside the track it is nearly level with the top of the rails. The want of proper ballast is especially felt in the rainy seasons, when the earth soil ballast is frequently saturated or washed out, entailing considerable expense for repairs. The usual gauge of the railways is 5 feet 6 inches.

BUENOS AYRES GREAT SOUTHERN RAILWAY (See plate No. 26).—The following particulars are taken from a full and complete report, accompanied by drawings, furnished in May, 1888, for the purpose of this report by Mr. Sam. Abbott, general manager, and Mr. Henry G. Sketchley, chief resident engineer:

The road has 13.75 miles of double track and 819.50 miles of single track laid with metal ties. The steepest grade is 1 in 91 for a length of .77 mile approaching Buenos Ayres. Generally the ruling grade is 1 in 200, but by far the greater portion of the railway is either level or has very flat grades. The sharpest curve has a radius of 820 feet, but this is quite exceptional, and is close to a station. Generally the curves are extremely easy, being of very long radius. The embankments and cuttings are generally small, owing to the extreme flatness of this country; the highest bank is 21 feet and the deepest cut 13 feet. The various sections of the line were opened to traffic as follows:

| From— | To— | Opened. | Length. |
|---|---|---|---|
| | | | *Miles.* |
| Buenos Ayres | Jeppener | Aug. 14, 1865 | 47.85 |
| Jeppener | Chascomus | Dec. 14, 1865 | 22.60 |
| Altamirano | Ranchos | Mar. 1, 1871 | 14.88 |
| Ranchos | Salado | May 19, 1871 | 19.84 |
| Salado | Las Flores | July 1, 1872 | 40.17 |
| Chascomus | Dolores | Nov. 10, 1874 | 55.71 |
| Las Flores | Azul | Sept. 8, 1876 | 67.93 |
| Dolores | Ayacucho | Dec. 7, 1880 | 79.50 |
| Azul | Olavarria | Mar. 15, 1883 | 27.10 |
| Ayacucho | Tandil | Aug. 19, 1883 | 39.10 |
| Olavarria | La Gama | Oct. 2, 1883 | 58.00 |
| La Gama | El Puerto | May 7, 1884 | 162.00 |
| Tandil | Juarez | Feb. 1, 1885 | 53.00 |
| Juarez | Tres Arroyos | Apr. 2, 1886 | 56.12 |
| Maipu | Mar del Plata | Sept. 26, 1886 | 79.76 |
| Hinojo | Sierra Chica | June 1, 1887 | 4.21 |
| Hinojo | Sierra Baya | ...do | 3.48 |

There is considerable passenger traffic, especially on the double track. The freight traffic consists chiefly of wool, hides, grain, stone (the latter from the Sierras of Tandil and Hinojo), cattle, horses, and sheep. The locomotives are of various types and weights; the heaviest are built by Beyer & Peacock, of England, and weigh 162,680 pounds, with a weight of 24,808 pounds on the driving-wheels.

Mr. Henry G. Sketchley, is the engineer in charge. The ties consist of cast iron bowls on the Livesey system (See "England"); they are of the forms patented in 1870 and 1882. The new pattern is a great improvement upon the old one, which had not sufficient lateral bearing surface, the outer jaws cutting into the flange of the rail and in some places eating it away right up to the web. In the old form of bowls there were recesses carrying hard-wood cushions for the rails to rest on; these became rotten in course of time, and the rail then bore upon the edges of the recess, which cut into the under side of the flange of the rail. The sectional area of the rail being then reduced in two places, the rail became unfit for use much sooner than it otherwise would have done. The inner jaws (for the keys), also being made of cast-iron, frequently broke. All these weak points have been remedied in the new pattern of bowls. The bowls are of cast-iron and weigh 82 pounds each. The joint ties are spaced 3 feet 4½ inches apart, center to center of tie-bars, and intermediate ties 3 feet 7½ inches. No preservative treatment is considered necessary; cast-iron rusts very slowly and the metal is pretty thick. They are manufactured by the Anderston Foundry Company, of Glasgow, Scotland, and the cost in 1888 was $18.50 per ton, delivered free on board at Glasgow. For curves the adjustment of gauge is effected by having the holes in the tie-bars punched a little farther apart to give a widening of from one-quarter to one-half inch, according to the radius of the curve. The tie-bars can be bent, but this is a bad practice. It is certain that the ties have a very long life, but there is not sufficient data at hand to say how long.

The ballast is of black earth, on which the grass is allowed to grow. During the times of floods the grass is a great protection; and during dry weather it also reduces the dust, which is a great annoyance to travelers. The ballast becomes very highly indurated by the compression and vibration of the passing trains, so much so that during floods the earth under the bowls stands up like small pillars, all the intermediate and surrounding earth having been washed away. It becomes necessary, however, to pack the rails with hard-wood ties at such times, as nothing can be done with the earth that has become saturated with water. The rails are of steel, of flange section. As the 58-pound rails become too much worn to allow of their remaining in the track they are being replaced with 70-pound rails. The rail-joints are suspended.

The reasons for adopting metal ties were the difficulty of procuring good hard-wood ties in sufficient quantities, and their greater expense; also, because a more rigid and more satisfactory construction can be made with iron ties. The general results are considered to be most satisfactory. In very wet weather there is certainly trouble with the maintenance of track, but so there would be in the case of wooden ties; the reason being that the earth when wet can not be used for packing in either case. There is no trouble with the rail attachments. Breakages seldom occur. The iron ties are considered more efficient than wooden ties, but as none of the latter are used on this line there is no certain data for a definite conclusion. Wooden ties of "quebracho colorado" cost about $2.25 each. The climate is very variable and humid; consequently wood, especially pitch pine, soon becomes rotten. The rails are certainly too light for the heavy traffic that passes over them, but this will be generally remedied by the introduction of a heavier section of rail. Generally speaking, the road is considered a good one.

The drawings show bowls oval on plan, 26 inches long, parallel with the rail, and 18¼ inches wide transverse to the track (See plate No. 26). The length on top is 21 11/16 inches, and the middle is depressed like a saucer. The thickness is five-eighths inch on top, five-sixteenths inch on the sides and eleven thirty-seconds inch in the middle. The rail is secured on the outer side by two lugs which hold the rail-flange; the inner flange is held by a cast-iron taper corrugated key, which bears on the web and flange of the rail, and is driven between the rail and a corrugated steel jaw which is let into a socket in the bowl and is inclined toward the rail. This jaw was formerly of iron, cast on the bowl. The tie bar is of wrought iron, 1 15/16 inches deep by one-half inch thick; it passes through the upper part of the bowl and is secured by a curved cutter 1⅜ inches wide, five-sixteenths inch thick, 6¼ inches long on the arc and about 5¾ inches radius. The cotter is under and parallel to the rail, and lies in the saucer-shaped depression in the middle of the bowl. There are eight pairs of bowls to a rail length of 25 feet. The rails now being used are of steel, flange section, weighing 70 pounds per yard; they are 25 feet long, but are to be 30 feet in future; they are 5 inches high, head 2.4 inches wide, 3.45 inches wide over the flange, radius of top table 15 inches, and of top corners one-half inch. The splice plates are of steel, of deep pattern, having a vertical web projecting below the flange of the rail, and being 5 inches deep over all. The plates are 18 inches long, and have four bolt-holes, spaced 4½ inches center to center; the inner plate has the holes 15/16 inch by 1 5/16 inches to fit the shape of the neck of the bolt; the outer plate has holes fifteen-sixteenths inch diameter; the holes in the rail are oval, 1⅛ by 1 inch. The Ibbotson patent bolt and nut is used; a bolt seven-eighths inch diameter, with hexagon nut and round washer 1⅞ inches diameter. The rail joints are even and suspended. The older rails were of steel, and of similar form; they were 4¼ inches high, with a head 2 3/16 inches wide, and a flange 3½ inches wide. The joints are as above described, but the splice plates are only 4⅜ inches deep.

The material necessarily used for ballast requires that great care be taken to dispose it so as to drain easily and rapidly. On the outer side of the track it is level with the under side of the rail head, and is then gradually sloped off by three planes at different angles to a width of about 18 feet at subgrade. Between the rails the ballast, at a distance of about 6 feet from the ends of the rail, forms a ridge across the track level with the under side of the rail head; from this ridge it slopes downward in all directions to the drainage channels at the middle and ends of the rails. The channels at the ends are cut right across the road-bed, but those at mid-rail length only run from the middle of the track to one side, being to right and left alternately. In this way a form of surface is given which tends to throw off water and drains rapidly. The greatest depth of ballast, from under the rail heads, is 18 inches; sloping down to 15 inches at the center line of the track, with channels about 6 inches deep. At the rail ends the ballast is about 12 inches deep under the rails.

CENTRAL ARGENTINE RAILWAY (See plate No. 26).—In 1889, the consulting engineer, Sir Douglas Fox, of London, stated that about 640 miles were then laid with metal track. The line is almost entirely laid with ties composed of cast-iron bowls of Livesey's pattern. The extensions which were under construction in April, 1888, were being laid with these ties. There is no ballast proper, the bowls being packed with the black loam of the country. The grades and curves are easy. Speed of trains, about 30 miles per hour. Weight on driving wheels of locomotives, about 6 tons to each wheel. The gauge is 5 feet 6 inches.

The following particulars are from a statement furnished in January, 1889, by Mr. Malcolm Graham, the resident engineer:

The line is from Rosario to Cordoba, with branches under construction from Cañoda de Gomez to Pergamino and Las Yerbas. The total length was 245.52 miles. The line is very straight and level, having maximum grades of .5 per cent. and curves of 6,560 feet radius. Construction was commenced in 1864 and finished in 1870, the work being done under the supervision of Mr. Graham. The traffic consists of passengers and general freight. The locomotives weigh about 60 tons. The ties are of cast-iron bowls, on Livesey's system, weighing 90 pounds each. They are manufactured in England, are not treated with any preservative process, and cost delivered $1.05 (gold). They are spaced 5 feet 8¼ inches apart, center to center; no special arrangements are made for curves. They are spaced 3 feet 9 inches apart, center to center of tie bars, giving eight ties to a rail length. Their durability is very good. The ballast is of black earth, which is good except in wet weather. The rails are of steel, of bull-headed section, 30 feet long, and weigh 66 pounds per yard; the joints are suspended, and are fastened by straight splice-plates 18 inches long, with four bolts three-fourths inch diameter. The reason for using metal ties is the difficulty of obtaining wood; the general results of the metal track are satisfactory. The climate has no perceptible effect. There is more trouble with maintenance of the metal track than of track on wooden ties, especially in wet weather. Breakages occur in shipment and in cases of derailment. The track on wooden ties is considered to be better, if the wood was only obtainable. The difference in cost depends upon the distance the material has to be carried.

Each bowl is 19¼ inches long, at right angles to the rail, and the depth under the rail is 5 inches. (See plate No. 26.) The tie-bar is of wrought iron 2 inches deep, one-half inch thick, and 7 feet long; it is secured by a flat, curved cotter, 1¼ inches wide and one-fourth inch thick, driven parallel with the rail through the bowl and a notch in the lower edge of the tie-bar. No more bull-head rails are being used, but the extensions are being laid partly with steel flange-rails weighing 80 pounds per yard (on the suburban portion near Buenos Ayres), and partly with similar rails weighing 67 pounds per yard; the latter are $4\frac{13}{16}$ inches high, with a flange $3\frac{1}{2}$ inches wide; they have an inward inclination of 1 in 20. The track was being relaid in 1887-'88 with steel rails 25 feet long, replacing the old iron rails. With this work an extra pair of bowls was put in for every rail length. The outer flange of the rail is held by a lug on the bowl; the inner fastening consists of two pieces, a loose steel jaw and a cast-iron key. The steel jaw is $3\frac{1}{2}$ inches square, three-eighths to five-eighths inch thick; the inner face is corrugated vertically and there are two vertical ribs on the back; this jaw is let into a socket in the bowl and inclines inward at an angle of about 55 degrees, the top being about 1 inch from the web of the rail. The cast-iron key is driven between the jaw and the rail, bearing on the web and flange of the rail.

The weight of the ties is as follows:

| | Unit weight. | Total. |
|---|---|---|
| | *Pounds.* | *Pounds.* |
| Cast-iron bowls with steel jaws | 90.00 | 180.00 |
| Cast-iron keys | 5.00 | 10.00 |
| Wrought-iron tie-bar | 23.00 | 23.00 |
| Wrought-iron cotters | 0.84 | 1.68 |
| Total weight per tie | ........ | 214.68 |

The dimensions of the cross section of the line on double-track are as follows: Width at subgrade, 29.50 feet; outside of this at each side is a ditch 18.4 inches deep, 14 inches wide at the bottom, and 22 inches wide on top. The distance between the inner rails of the two tracks is 7.31 feet, and the distance center to center of outer rails is 18.66 feet; the ballast is 12 inches deep between the rails and 18 inches outside, sloping down 3 to 1 to form a drain between the tracks; and on the outer sides it slopes down 3 to 1, the slope being 3 feet 6 inches wide, and leaving a strip 12 inches wide between the toe of the ballast and the ditch.

In regard to the earth ballasting, Mr. Walter Morrison, president of the company, made the following remarks at the annual meeting in London, in May 1889:

> You know that in this country there is no ballast. The sleepers (ties) are just put down on the soil, and when it rains the soil, saturated with water, works up into a puddle, and it is impossible then for the permanent-way (track) men to do anything with the line. It is no use to put more soil under the sleepers to pack them up, because the soil becomes a puddle; and I am afraid that when the rain stops we shall have a heavy bill to pay for damages to the line at the time of the rain-fall.

The rain-fall of the season of the early part of 1889 was said to have been extraordinary in its persistence. Allowance must be made for Mr. Morrison being unacquainted with railway construction when he said that "the sleepers are just put down on the soil." This might convey the idea that the line was very roughly and cheaply built; but, as has been shown in the description of the Buenos Ayres Great Southern Railway, great care is generally taken to make the best possible roadbed with poor material. From the particulars given above it is probable that similar care has been taken on this line, and Mr. Morrison was only unfortunate in his manner of expressing himself.

BUENOS AYRES AND PACIFIC RAILWAY.—This is one of the railways which is to connect with the Chilian railways and form a transcontinental line. The gauge is 5 feet 6 inches. It is about 426 miles long; for the first 18.6 miles wooden ties (of quebracho-colorado) are used, and the remainder is laid with cast-iron bowls. The bowl, or "copa," is oval on plan, 26 inches long by 18 inches wide across the track, 8 inches deep, and about five-eighths inch thick; they are spaced 4 feet 8 inches apart, center to center of tie-bars. The rails are of double-headed section; the outer side is supported by two lugs, and on the inner side is a wrought-iron lug with a key driven between it and the web of the rail; they are spliced in the usual way.

The following notes are from letters from Mr. F. L. Griswold, published in the Railroad Gazette, New York, May 1 and August 28, 1885.

*February* 15, 1885.—Track-laying under good organization can be done a third more rapidly than with wooden ties, at least I think so. The rail weighs 56 pounds per yard and is 4 inches high and 3 inches base; it has a bearing of 16 inches on each tie and is clamped at each end of the bearing on the outside and at the middle on the inside. The wrought-iron lug that holds the cast-wedge is corrugated on the inside and the wedge or key on the outside. The tie-rods are put in and keyed up on the ground. Between Buenos Ayres and the foot of the Andes the location is easy; there is one tangent 211 miles long. There are no bridges. The deepest cut is about 3.28 feet and the highest fill about 6.56 feet. The grades are, say, 0.5 per cent., or 26 feet per mile as an outside maximum. Only 96 miles are as yet completed and in operation.

*June* 29, 1885.—We are using a 50-pound English steel rail, with Livesey's patent iron bowls, which give 21 inches of support to 28 inches of suspension, or, in other words, the supports are 21 inches long, and the clear distance between supports is 28 inches; all loam ballast. Over this track we are using engines of about 40 tons on a wheel-base of about 18 to 20 feet as an average of the different styles. The east end of the road has been in use for about twenty months and shows good track and the rails in good condition.

In a personal letter to me in July, 1888, Mr. Griswold stated that he had a deep interest in the movement for forest protection and in the metal tie question. He gave as his opinion that iron or steel ties will supersede wood in nearly all countries, and that a track may be built with them that will possess equal efficiency in all respects with a track on wooden ties.

EAST ARGENTINE RAILWAY.—The following particulars are from a report sent to me in August, 1889, by the president of the Argentine Republic Society of Civil Engineers:

The line runs from Concordia to Ceibo, a distance of 99.20 miles. There are 12,500 metal cross-ties in use, 2,500 being of iron and 10,000 of steel; metal ties are also used in renewing old wooden-ties. The ties have been laid at different times since 1880 and the work has been done under the supervision of Mr. Oliver Budge, chief engineer of the railway. The locomotives weigh 30 tons each, and have a weight of 11 tons on the driving-wheels. The iron ties are made by the Le Grange Works in France, and weigh 81.4 pounds each. The steel ties are of the type adopted on the Indian State Railways and are manufactured by the Ebbw Vale Iron and Steel Company, of England; they are 8 feet long by 8 inches by 4 inches; three-eighths inch thick; they weigh 90 pounds each, and 92½ pounds with fastenings. They are spaced 3 feet apart, center to center. They are given a coat of coal tar, and the cost at the works is $1.35 each in gold. On curves eight ties are used to a rail length of 21.32 feet. There is little expense for maintenance, and the ties laid in 1880 are still in good condition. The ballast is of gravel, which becomes consolidated under the ties. The width at subgrade is 16 feet. The rails are of flange section, 4 inches high and 3⅞ inches wide; they are spliced by fish-plates and 4 bolts. For 37.20 miles the joints are suspended, and for the remaining 62 miles they are supported on the ties. The metal ties were adopted on account of their greater durability than wood, and the results have been very satisfactory. There is no trouble with the rail fastenings, and breakages are very rare. The steel ties effect a saving of 4 inches of ballast. Hard-wood ties are also used, and cost $1.20 (gold) each. The climate is mild and has very little destructive effect on the ties. The line is 4 feet 8½ inches gauge, has a maximum grade of 1 in 80 (1.25 per cent.,) and a minimum curve of 1,640 feet radius. The rails are secured to the ties by riveted and bolted clips, the inner clip of one rail and the outer clip of the other rail being riveted; the holes are punched cold.

Santa Fé and Cordova Great Southern Railway.—This line, which will run from Villa Constitucion to La Carlota, a distance of 186 miles, is now under construction. The track will consist of steel rails of flange section, weighing 65 pounds per yard, laid on steel cross-ties; 21,000 tons of rails and 20,000 tons of steel ties were ordered in 1889. The ties are of inverted trough section, weighing 120 pounds each, and the rails are secured by lugs and keys. They are spaced eleven to a rail length of 32 feet. The rail joints are suspended. The ballast is of earth. Schultz, Tozer & Co., of London, supplied the 365,000 steel ties (20,000 tons), which are for mixed gauge. The two outer rails, for the gauge of 5 feet 6 inches, are of flange section, and are secured to the tie in the same way as on the Indian state railways; the middle rails, for the meter gauge, are of bull-headed section, secured to the self-fastening chairs patented by this firm (See "England"). The steel used is of the quality generally used for the Indian ties; it is equal to a tensile strain of between 26 and 31 tons to the square inch, with a contraction of 40 per cent. at the point of fracture. Mr. E. H. Woods is the engineer.

Buenos Ayres and Ensenada Port Railway.—This line is 37 miles long, 5 feet 6 inches gauge, and the track consists of steel rails weighing 68 pounds per yard, carried on cast-iron bowls, which are ballasted with the black earth of the country. The line connects the city of Buenos Ayres with the new docks and port at Ensenada; the cost was about $95,000 per mile, there being some expensive works on the first 5 miles and at the crossing of the Riachuelo River. It passes through agricultural and grazing country, and has a large passenger traffic; from Buenos Ayres there is a large traffic of suburban trains. The following note on the respective merits of steel cross-ties and cast-iron bowls (or pots) is taken from the report of Mr. A. R. Brown, general manager, made in October, 1889:

*Main line.*—This is in good running order throughout. It is interesting to note the superiority of the new transverse steel sleepers that you have sent for the double line over the "pots." I have laid half a kilometer (.31 mile) of the new rails and ties between Barracas and General Mike; they have been down since April, and have hardly required any touching. It is difficult to estimate the enormous saving that may be effected by the use of these sleepers in the personnel of the permanent way; they are especially adapted to the mud ballast of this country, as after rain there is beneath them a tie composed of dry earth, which forms a very rigid road. Their great superiority over the pot is in that they do not sink on one rail which is invariably the case with the pots, which carries a nasty oscillating movement to the train; also that they are not so easily broken."

BUENOS AYRES AND ROSARIO RAILWAY.—On this line cast-iron bowls are said to be used as far as Sunchales, a distance of 341 miles, beyond which ties of "quebracho-colorado" wood are used.

BUENOS AYRES NORTHERN RAILWAY.—This line has $5\frac{1}{1}\frac{3}{6}$ miles of single track laid with metal track, which was put down between 1877 and 1886. There is ordinary passenger and freight traffic, hauled by locomotives weighing 26 to 48 tons in working order. Mr. T. E. M. Marsh, of England, is consulting engineer. The line has now been absorbed by the Central Argentine Railway. The ties consist of a pair of cast-iron bowls of oval shape 27 by 20 inches, weighing 100 pounds each. They were manufactured by the Anderston Foundry Company, of Glasgow, Scotland, and are treated with Dr. Angus Smith's preservative solution. There are eight pairs of bowls to a rail length of 23 feet. The bowls are connected by transverse tie-bars, with a gib and cotter fastening to each bowl; the gauge can be adjusted or widened by transposing the gibs and cotters. Up to August 15, 1889, the date of Mr. Marsh's communication, no breakages had been reported. The parts of the line where these ties are used are badly provided with good ballast for ordinary wooden ties, and the metal ties are adopted because the ballast is soft and bad for wooden ties of ordinary dimensions. Where wooden ties are used they are of native hard wood, which is good and durable. The rails are of steel, of flange section, weighing 68 and 75 pounds per yard; they are secured by patent cast-iron corrugated keys. The rail joints are suspended, and are spliced by fish-plates 16 inches long, with four bolts.

WESTERN OF BUENOS AYRES RAILWAY.—This line is about 620 miles long, 5 feet 6 inches gauge. There are Barlow iron rails weighing 88.5 pounds per yard; double-headed rails weighing 64.38 pounds per yard, and steel flange rails weighing 56.34 pounds per yard. The track now used consists of steel rails 26.24 feet long, carried on nine cross-ties of hard wood (quebracho or urunday), or upon seven pair of Livesey's cast iron bowls.

ANDINE RAILWAY.—This line is 476 miles long, 5 feet 6 inches gauge. The track consists of rails weighing about 54 pounds per yard, carried on cast-iron bowls.

SANTA FÉ AND NORTHERN COLONIES RAILWAY.—This line is 62 miles long, 1 meter gauge. The rails are of steel, weighing 45 pounds per yard. Some of the ties are of the "quebracho-colorado" wood, brought from the Chaco and from Corrientes, but the majority are of cast-iron bowls.

NORTHERN CENTRAL RAILWAY.—This line is about 548 miles long, 1 meter gauge. Iron ties are extensively used.

SUMMARY OF METAL TRACK FOR THE ARGENTINE REPUBLIC.

| Railways. | Cast-iron bowls. | Cross-ties. |
|---|---|---|
| | *Miles.* | *Miles.* |
| Buenos Ayres Great Southern | 833. 25 | ........... |
| Central Argentine | 640. 00 | ........... |
| Buenos Ayres and Pacific | 407. 40 | ........... |
| East Argentine | ........... | 7. 10 |
| Santa Fé and Cordoba Great Southern | ........... | 186. 00 |
| Buenos Ayres and Ensenada Port | 36. 69 | 0. 31 |
| Buenos Ayres and Rosario | 341. 00 | ........... |
| Buenos Ayres Northern | 5 81 | ........... |
| Western of Buenos Ayres (estimated) | 250. 00 | ........... |
| Andine | 476. 00 | ........... |
| Santa Fé and Northern Colonies | 60. 00 | ........... |
| Northern Central (estimated) | 300. 00 | ........... |
| Total | 3, 350. 15 | 193. 41 |

## CHILI.

GENERAL REMARKS.—In November, 1889, "Industries," and some other European engineering journals, reported that the Chilian Government, through its legation at Paris, France, was negotiating for 739,400 metal ties 9 feet long, and 725,100 ties 4.25 feet long. Mr. Henry Budge, chief engineer of the State railways, has stated that there must have been some mistake, no such proposals having been asked for by the Government. Mr. C. M. Seibert, secretary of the United States legation at Santiago, stated in January, 1889, that there were 679.52 miles of lines owned by the Government, and 965.96 miles owned by private parties or companies, a total of 1,645.48 miles. Some new lines are being built. He also stated that Chili possesses abundance of forests in the southern part of her territory, sufficient for supplying railway ties for many years.

COQUIMBO RAILWAY.—In a letter dated August 4, 1888, Mr. Henry A. Vivian, chief engineer, stated that in 1887 he received from England sufficient steel ties to lay one mile of track, but so far very few had been put in. They were steel cross-ties, of the type adopted for the Indian State Railways, 9½ inches wide at the bottom, and having an extra thickness of metal on the top. They were for a gauge of 5 feet 6 inches, and weighed 120 pounds each. They were not what he wanted, and as their weight made them very expensive he decided not to ask for any more. They cost $8 each, in Chili currency, while timber ties, having an average life of about five or six years, could then be bought for $1.30. Cypress ties are used.

## BRAZIL.

General Remarks.—In this country, metal ties have only been tried to a limited extent. Mr. Jason Rigby, chief engineer of the Great Western of Brazil Railway, in a letter dated May 17, 1889, stated that there were two reasons for the non-employment of metal ties: First, because the Government, wishing to encourage the use of native material, has objected to their use; second, because the native hard wood can be obtained at a very low price. Mr. O'Meara, of the Brazil Great Southern Railway, stated that no iron or steel ties are in use on that road, as native timber of good quality is obtainable at moderate prices along the Uruguay River. The following table of the mileage of Brazilian railways is from the official returns for December 31, 1887:

| Railways. | In operation. | Under construction. | Surveyed. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| State lines | 1,248.06 | 155.00 | 1,463.82 |
| General Government, guaranteed lines | 1,602.70 | 118.42 | 13.02 |
| Provincial government lines | 58.90 | .......... | 93.00 |
| Provincial government guaranteed lines | 962.24 | 301.32 | 475.54 |
| Companies without guarantee | 1,337.34 | 286.44 | 184.76 |
| Total | 5,209.24 | 861.18 | 2,230.14 |

Great Western of Brazil Railway.—Mr. Rigby, the chief engineer, stated as follows in a letter dated May 17, 1889:

A short time since, when building an extension of this line, I thought of introducing steel ties as even the best native hard wood only lasts in this climate from six to seven years. I got some samples of different systems sent out, but all were, in my opinion, objectionable either from complication of the rail-fastenings or want of sufficient length outside the rail to give stability in the very soft sand ballast which is all we can obtain here; and then the price, with freight and duties, put their use quite out of the question. I pay here 50 cents for a squared tie, 7 feet by 9 inches by 5 inches, all hard wood, delivered on the line.

Southern Brazilian Rio Grande do Sul Railway.—The following particulars are from a statement furnished in December, 1889, by the consulting engineer, Mr. Charles Neate, of London:

The line has curves of 328 feet to 6,560 feet radius, and grades from 3 per cent. to .025 per cent. About .62 mile of metal track was laid between 1880 and 1884. Mr. A. Duprat is the general manager and Mr. Baras de Holleben is resident engineer. The engines are of two classes: (1) ten-wheel engines with tenders, with six coupled wheels and a four-wheel leading truck; 23 tons total weight with 5,936 pounds on each driving-wheel; (2) eight-wheel engines, with tenders, with six coupled wheels and a two-wheel leading truck; 23 tons 448 pounds total weight, with 7,504 pounds on each driving-wheel. The ties are of steel, of the Indian State Railway pattern, for 1 meter gauge. They are 5 feet 6 inches long, $8\frac{3}{4}$ inches wide, with closed ends $4\frac{1}{2}$ inches deep; 12 inches wide, $1\frac{3}{8}$ inches thick on top: the weight is 70 pounds per tie. The rails are secured by lugs and keys. The ties are spaced 24 inches apart, center to center, at joints, and $31\frac{1}{2}$ inches apart, intermediate. There are 5,000 ties manufactured by the Darlington Steel Company, England; they are given a coat of paint and cost about $1 each. The rails are of flange section, weighing 40 pounds per yard; the joints are suspended, and are fastened by splice bars and four bolts. The ballast is of coarse sand, and occasionally small stone; no gravel proper is to be had; it is about 13 inches deep. With wooden ties it is very liable to be washed away by the tropical rains, but there is no sufficient experience yet with the hollow metal ties. The steel ties were tried on account of the early decay of native hard-wood ties, the life of which rarely exceeds five years in the northern provinces, and eight to ten years in the southern provinces. The general results are satisfactory, so far as is known, especially for preserving the gauge on sharp curves, but the time of the test has not been long enough to enable any definite opinions to be formed. Careful maintenance is necessary, but there is little trouble with the rail fastenings. Native hard-wood ties cost 60 to 72 cents each, delivered.

Although the forests of Brazil undoubtedly furnish hard wood of the finest quality, ties from which would be very durable, the cost of obtaining such ties for the whole line would be almost prohibitory; whereas with metal ties uniformity of quality can be obtained at a moderate cost, and it is expected that the steel ties will prove durable. Cast-iron bowl-ties will undoubtedly last well, but on railways of 1 meter gauge, where the rolling-stock is necessarily wide in proportion to the gauge, cross-ties are found to give more lateral stability than bowl-ties. The Indian pattern of steel cross-ties admits of a certain widening of gauge round curves, if necessary, by shifting the keys to the outer side of the rails, or by the use of special keys.

CONDE D'EU RAILWAY.—The following particulars are from a statement furnished in December, 1889, by the consulting engineer, Mr. Charles Neate, of London. (For general notes see the preceding paragraph on the Southern Brazilian Rio Grande do Sul Railway.)

The line has a maximum grade of 2.22 per cent., and the minimum curves of 328 and 394 feet radius. There are about 20.46 miles of metal track, laid between 1880 and 1884, under the supervision of Mr. I. H. P. Dunsmure, general manager and resident engineer. There are three classes of locomotives: (1) new tank engines, four coupled wheels and a four-wheel truck, 26 tons weight in working order, with a maximum weight of 4½ tons on each wheel; (2) tank engines, with four coupled wheels and a Bissel or pony truck, 21 tons in working order, with 4 tons on each coupled wheel; (3) eight-wheel engines with tenders, four coupled wheels and a four-wheel truck, 21 tons in working order, with 3½ tons on each coupled wheel. The ties consist of a pair of cast-iron bowls weighing 65 pounds each; each bowl is oval, 22½ inches long, 18½ inches wide, 4¾ inches deep, with a metal three-eighths inch and one-half inch thick on the sides and three-quarters inch on top. The tie-bar is secured by a gib on the inner side and a cotter on the outer side of each bowl. The rails are of steel, of flange section, weighing 50 pounds per yard, they rest on two wooden cushions on each bowl; the inner side of the flange is held by a lug, and on the outer side an elm key is driven between the web of the rail and a high lug on the bowl. The ties are spaced 3 feet 10 inches apart. The bowls are manufactured by Head, Wrightson & Co., of Stockton-on-Tees, England, and cost about 68 cents each. They were used by the contractors owing to the scarcity of native timber.

DONNA THEREZA CHRISTINA RAILWAY.—The following particulars are from a statement by Mr. Charles Neate, of London, the consulting engineer, furnished in December, 1889. (See also the two preceding railways.)

The line has minimum curves of 328 feet to 392 feet, and maximum grades of 2.22 to 1.66 per cent. About 2.48 miles were laid with metal track between 1880 and 1884, under the supervision of Mr. E. J. Brown, general manager and resident engineer. The engines are eight-wheel tank engines, with six coupled wheels and a two-wheeled leading truck with radial axle boxes; they weigh 22 tons in working order, with 2½ tons on each coupled wheel. Two patterns of cross-ties have been used; in the first instance, 1,000 steel ties manufactured by Howard & Company (See "England") were sent out, and subsequently 5,000 steel ties of the Indian pattern, as already described for the Southern Brazilian and Rio Grande do Sul Railway. The "Howard" ties were 5 feet 6 inches long, 10 inches wide on the bottom, and 3 inches deep with metal three-sixteenths of an inch thick; they weighed 40 pounds each and cost $1.20 each. The spacing weight, maker, and cost of the Indian pattern ties are as already described. The rails are of flanged section, weighing 40 pounds per yard. The reasons for trying metal ties were the same as on the Southern Brazilian line.

The Howard tie was not of the heavy type for main lines; a corrugation or rib was formed along the top of the tie, and pressed down at the rail-seat to allow the flange of the rail to rest on the flat portion of the top of the tie; the sides of the rail-seat formed clips for the rail flanges, and the rails were secured by steel keys driven between one clip and the rail flange.

RECIFE AND SAO FRANCISCO PERNAMBUCO RAILWAY.—Ties of iron and native hard wood are used on this line.

DOM PEDRO SEGUNDO RAILWAY.—On this line (now known as the Central Railway of Brazil, since the change of government from an empire to a republic) some wrought-iron or steel cross-ties of inverted trough section, similar to those of the original Vautherin section, were in use as an experiment near Rio, in 1888, and were there noticed by Mr. Rigby, of the Great Western of Brazil Railway.

SAN PAULO RAILWAY.—This line runs from Santos to Jundiahy, about 62 miles, and has two grades of $2\frac{1}{2}$ per cent., and curves of 984 feet radius. The traffic is chiefly heavy freight; the engines weigh 44 tons, with 11 tons per axle. Mr. John Barker is the engineer. The ties used are of the old form of Greaves's cast-iron bowls, arranged in pairs and connected by tie bars. The bowls are 22 inches in diameter, with metal one-half inch thick, and weigh 176 pounds per tie. They are coated with tar. They are spaced 2 feet 9 inches apart and are connected by tie bars 2 inches deep by three-eighths inch thick. They are manufactured in England and cost $22.50 to $24 per ton. Their average life is twenty-five years, and the expense of maintenance is small. There is no trouble with the rail attachments, nor from breakages, and the efficiency is said to be five times as great as that of wooden ties. The rails are of bull-headed section weighing 66 pounds per yard and have suspended joints. Metal ties were adopted on account of the economy resulting from their use, and the general results have been satisfactory. They make a rigid but very economical track, although the first cost is double that of wooden ties.

MINAS AND RIO RAILWAY.—In a letter dated May 27, 1889, Mr. F. E. Fenn, general manager, stated that there were no metal ties then in use, but that an experiment was about to be made with steel ties. Messrs. Brunlees & McKerrow, of London, the consulting engineers, report that these ties will be of the type adopted on the Indian State railways, and will be laid for a length of about .62 mile.

SUMMARY OF METAL TRACK FOR BRAZIL.

| Railways. | Bowls. | Cross-ties. |
|---|---|---|
| | *Miles.* | *Miles.* |
| Southern Brazilian Rio Grande do Sul | | .62 |
| Conde d'Eu | 20.46 | |
| Donna Thereza Christina | | 2.48 |
| San Paulo | 62.00 | |
| Minas and Rio | | .62 |
| Great Western of Brazil* | | |
| Recife and Sao Francisco Pernambuco* | | |
| Dom Pedro II* | | |
| Total | 82.46 | 3.72 |

*Experimental trials.

## VENEZUELA.

General Remarks.—The contractors who built the Puerto Cabello and Valencia Railway and the Bolivar Railway (Messrs. Perry, Cutbill, and De Lungo, of London), and who have had large experience in railway construction in South America, state that their general impression is that track constructed with iron ties is more expensive to keep in order, but at the same time is certainly more durable than track with wooden ties. The engineer of this firm considers that for sharp curves heavy wooden ties are the best, if of hard and durable timber. Steel he considers better than creosoted pine, but inferior to vera, jarrah, and similar hard woods. His opinions as to the comparative work of maintenance with track on metal and wooden ties differ from those usually expressed. Mr. James T. McGawran, resident engineer for railways being built by a French company, stated in August, 1889, that while he had not been connected with any railway using metal ties, he considered that they would prove useful where timber is scarce (as in the Argentine Republic), or in places like Venezuela, provided that lignum-vitæ and one or two similar timbers can not be obtained, where the white ant (comahen) will make short work of any ordinary wooden tie. He is fortunate in being able to get a wood (curarire) which lasts from twenty to thirty years. It is true that each tie has to be bored, but as the system of track-laying is that adopted extensively in Europe, the rails being secured by screw-spikes, this makes no difference, as the holes would have to be bored in any case.

Puerto Cabello and Valencia Railway.—On this road (also known as the Venezuela Central Railway), which is 34 miles long, steel cross-ties are used on an incline $2\frac{1}{4}$ miles long, with a grade of 8 per cent. and curves of 500 feet radius. This incline is operated on the Abt rack-rail system; the rack-rail being carried in chairs fastened to the ties. The traffic consists of passengers and freight, and the trains are hauled by locomotives weighing 40 tons, with a load of 13 tons per axle. The ballast is of broken stone. The rails weigh 56 pounds per yard. Metal ties are used to avoid renewals, and the general results have been satisfactory. There has been no trouble with the rail attachments, nor from breakages, but there has been trouble with the maintenance. It is reported that the track with wooden ties is more easily kept in condition, but the difference is not very great.

BOLIVAR RAILWAY.—This line (known also as the Quebrada Railway) was built in 1875; it is 55 miles along, with generally very easy grades and curves. The traffic is heavy, principally mineral; the engines weigh 20 tons and have a load of 7 tons per axle. The steel cross-ties originally laid are reported to be still in good condition. There is no proper ballast. The rails weigh 30 pounds per yard. No trouble has been experienced from breakages or with the rail attachments. There has, however, been trouble with maintenance, and it is reported that the track is more easily kept in order with wooden ties, but the difference is not great. The line is of 24 inches gauge. The ties were made by Kerr and Stuart, and have riveted clips which support the outer side of the rail head like rail braces. (See "England.")

LA GUAYRA AND CARACAS RAILWAY.—This line is 23 miles long. It has been stated that cast-iron bowls are used for ties; but no returns have been received, no reply has been made to requests for information, and no reliable or definite information on this point has been obtained. As Mr. James Livesey is the consulting engineer, it is quite probable, in view of the statement above referred to, that the Livesey system of track with cast-iron bowls is employed. (See "England.")

*Summary for Venezuela.*

| Railways. | Bowls. | Cross-ties. |
|---|---|---|
| | *Miles.* | *Miles.* |
| Puerto Cabello and Valencia | | 2.25 |
| Bolivar | | 55.00 |
| La Guayra and Caracas | 23 | |
| Total | 23 | 57.25 |

## UNITED STATES OF COLOMBIA.

GENERAL REMARKS.—Mr. F. J. Cisneros, an engineer who is connected with the Bolivar Railway of Colombia and a number of other railways, stated in May, 1888, that he was an advocate of metal ties and had thought of employing them, but so far he had no experience with them.

PANAMA RAILWAY.—Metal ties have not been used, as hard and long-lived wooden ties are available. An engineer who has been over the road remarked that in such a climate, and with the class of labor available, there would probably be trouble with the maintenance and fastenings of metal ties for the first few years, owing to the indolent and careless nature of the trackmen. It may be remarked, however, that after the first few years the maintenance is generally found to be considerably less with metal ties than with wooden ties. Mr. W. F. Dennis, acting general superintendent, wrote as follows in June, 1889:

On our road, 47 miles, we have never had either steel or iron ties under our track. Our main line has lignum-vitæ ties about 6 by 8 inches in sections, which are supplied from the surrounding countries at a cost to us of from $1.50 to $1.80 gold each. These ties are so hard as to necessitate boring holes for spikes, but after the preliminary difficulty is overcome they make an extremely solid and durable track. It is difficult to get exact information as to the life of these ties, but it is a common saying among trackmen that these ties are good for twenty-five years, and there are instances where ties have been recently taken up which have been in track a long time; it is even claimed that they have been in use since the opening of the road, nearly thirty-five years ago. Ordinary timber, such as pine and oak, when subjected to exposure, is not good for more than three years at the utmost.

## GUATEMALA.

Guatemala Central Railway.—Under the ownership of Mr. C. P. Huntington it had been proposed to try metal ties, but no definite steps were taken, and the road having now passed into other hands it is not probable that any such steps will be taken in the near future. The following are extracts from a detailed communication from Mr. William Nanne, general manager, dated in May, 1889:

The subject to which you are applying your energies certainly deserves the attention of all true railroad men, not only on the continent but all over the world, because it is only a question of time everywhere when the time-honored wooden substructure will have to give place to the iron age. We Central American railway constructors, in tropical jungles, with any amount of hard or soft wood ties presumably at our disposal, make a poor show in this important question of economical construction and operation, and nowhere, perhaps, has the adoption of metal cross-ties been more seriously considered than on our lines, but we have not as yet arrived at the practical application, for reasons given later. For these reasons I have held back from the experiments suggested by Mr. Huntington and Mr. Mahl. We are using about half California redwood ties, 8 feet by 8 inches by 7 inches and 7 feet by 7 inches by 6 inches; and the balance native hardwood ties 6 feet by 7 inches by 6 inches, and 6 feet by 8 inches by 6 inches. All of these have an average life of six years under new track. On the mountain division we are rising on our present location 2,600 feet in 12 miles, with curves of 15 degrees and on several trestles 150 feet high. By great care we have operated this without the slightest accident, but it is such costly operation that we are now lengthening the division to 16 miles, with a maximum grade of 3 per cent.; we are about two-thirds through with the work. In preparing for this work the question of the use of metal track was seriously considered, and Mr. Huntington seemed to favor the use of steel cross-ties. But much as I appreciate the "Post" system (See "Holland") as the best so far brought out, I have objected to even an experiment on our crooked line and heavy grades, which in many places are on the borders of tremendous precipices. In none of the metal ties do I see how the proper widening of the gauge or curves is to be carried out, and this is the main obstacle I see to our adopting metal ties. Another consideration is that the cost of transportation of material to our Central American lines, via Cape Horn, comes to about 200 per cent. on the original invoice, with heavy landing expenses of $10 to $20 per ton at our Pacific terminal station; bringing the cost of a Post steel tie, placed on our line, to about $3 to $4 silver (35 per cent. discount on United States gold). You will agree with me, as our board has agreed already, that under these circumstances, when we can get good wooden ties for about $1 silver per tie (or say

75 cents United States gold), lasting six years on an average, we are not yet up to the metal track question. Nevertheless the question is watched very closely by me and I am always open to conviction if I can see my way clear. So far I shall stick to the time-honored wooden ties for elasticity and safety generally.

The road is 75 miles long, with maximum grades of 3 per cent. and minimum curves of 15 degrees. The ties are spaced 24 inches apart, center to center, and are laid in broken stone and blue gravel ballast. The rails are of steel, weighing 54 pounds per yard; the joints are even and suspended, spliced by angle bars 20 inches long. Ajax steel braces are used on curves. The engines weigh 45 tons. Mr. Albert J. Scherzer is the engineer in charge. In regard to the question of adjustment of gauge I have already referred to the importance of this matter, and it will be seen that a wide range of adjustment combined with very secure fastenings is required on such a crooked road. Probably the Ruppel system of fastening, as used in the Prussian state railways (See "Germany") would meet the requirements.

## COSTA RICA.

General Remarks.—Mr. Manne, of the Guatemala Central Railway, states that he believes that steel ties are being used on these lines. Over 100 miles of railway are in operation, and several lines are under construction.

## SAN SALVADOR.

General Remarks.—It has been reported that it is proposed to use steel ties of American design and manufacture on a new railway to be built.

## MEXICO.

General Remarks.—Metal ties have been tried and have given such good results that their use is being extended.

Mexican Railway.—The Mexican Railway (Vera Cruz line) has now in service several miles of track laid with steel ties of the type designed by Sir A. M. Rendel, and adopted for the Indian state railways. The length of the main line is 265 miles. At the end of June, 1888, there were $46\frac{1}{4}$ miles laid with steel-ties, and at the end of June, 1889, there were 77 miles laid with them. While they have not been in service long enough to test their durability they have given great satisfaction, particularly by their behavior in times of flood. In regard to breakages, I am credibly informed that in one case a Baldwin consolidation engine left the rails and traveled about 100 yards over the ties without breaking a single one; some were bent, but were easily put into shape at the shops. The line has grades of 2 per cent. The locomotives are Fairlie (double-boiler, double steam-truck) engines, weighing 80 tons, and Baldwin consolidation engines. The ties are made in Wales, weigh 112 pounds each, are treated with a coal-tar preservative composition, and are spaced in the track 2,000 to the mile. The rails are of flange section, weigh 62 and 82 pounds per yard, and are secured by steel keys, as on the Indian state railways. The joints are supported on the ties, and are spliced by ordinary fish-plates. The general results have been satisfactory, the efficiency being much higher than with wooden ties; there has been no trouble with maintenance of rail attachments nor from breakages. In August, 1889, proposals were opened at the London office of the company for 10,000 of these ties, to be used with 62-pound rails. Mr. J. F. O'Brien, general manager of the Mexican National Railway (since resigned), stated in August, 1889, that no experiments had been made on his road, but that on the Mexican Railway the results of the steel-ties seem so very satisfactory that it has been decided to substitute them for wood entirely. He has been over the line several times, and states that the track on metal ties seems to be very smooth and perfect, even in the rainy season, and he sees no reason why they should not be a success after the experience of this railway. There is said to be even less noise and greater smoothness in riding over the track with steel ties than the track with wooden ties.

The following is taken from a paper on "The Railways of Mexico," by Mr. W. B. Parsons, read at the annual convention of the American Society of Civil Engineers in June, 1889:

The most interesting thing in connection with the track is the use of metal cross-ties. Wooden ties, expensive in first cost, were found to last only four or five years, so that metal was adopted for economy. The ties are of mild steel, and weigh 110 pounds each. The rail is held by clamps punched up from the tie, and is secured by a key weighing 1 pound; so that a tie and two keys weigh about 112 pounds. In section they are channel-shaped, with an extra thickness of metal on the top. The ends are splayed and turned down so as to retain the ballast, while the tie is bent upwards toward the ends so as to give the rails an inward cant. Their price varies with the price of steel, but is now about 5 shillings (English), or say \$1.25 per tie, free on board, at English ports. The ballast is of sand and gravel, and in places on the heavy grade an attempt at broken stone is found. The ballast is laid flush with the top of the tie. The results of experience have been most gratifying. The track is found to remain in better surface and line than when wooden ties are used, and certainly the track in best condition to-day is that portion where metal ties are laid. Practically it has been found that the track thus laid requires so much less work that section gangs on metal tie sections have been reduced about one-half. The Mexican Railway is therefore laying the steel ties as fast as possible, there being enough on hand to finish about 150 miles of road.

The following is the statement of Mr. George Foot, the general manager, furnished in 1887:

Our experience with these ties, of which some 30,000 have been in the line since September, 1884, is so satisfactory in every respect, that we are now about to lay down 40,000 more, and our intention is to gradually relay the entire line with metallic sleepers. The type of tie we are about to lay down is about the same as that employed on the State Railways of India for both the 5 feet 6 inches and 1 meter gauges, but arranged for our gauge, which is 4 feet 8½ inches. The price of the new ties under contract in England is 4*s.* 4*d.* (\$1.05) each, including steel keys, free on board in Cardiff, and their weight with keys 112 pounds each. The metallic ties in use here for the last two years are almost of the same pattern, excepting the fastenings, which are much more complicated and expensive. The tie represents the latest improvements in steel sleepers suggested by experience on railways in India, where millions of them are employed, and I think that the tie in question leaves little to be desired either in general form, simplicity of fastenings, weights, or price. The metal is thickened where strength is most required, and the rail clips are formed from the solid plate, the rail being kept in place by a simple steel key which can be driven either on the inside or outside of the rail when increased width of gauge is required on sharp curves. So far we have no disadvantage to record, but many and very important advantages, which are as follows:

(1) No spikes are required.

(2) The rails are kept to gauge with almost mathematical accuracy and the result is that the oscillation of a train running at high speed over this track is reduced to a minimum, and is very marked when it runs on to a length laid with ordinary timber sleepers.

(3) The difference in the cost of maintenance is enormous, because a track once properly laid with these steel ties and well ballasted requires no permanent road gangs and can be maintained in good order by a traveling gang going over it once or twice a year.

This is our experience here, but it must be remembered that on this railway we have no frost or snow to contend with and very light traffic. In the United States these conditions would of course be altered, but I see no good reason why these ties should not bear frost well; they are extensively used in Germany, and I am not aware that frost has proved an objection to their use. From personal experience I can not say how metallic ties behave in cases where trains run off the line, as we very seldom on this line have such accidents, and have had none on the portions of track laid with them. In India the experience is that in a bad run-off a great number of ties are bent and injured, but that very few are so badly damaged as to be past repairs, and that, as a general rule, they are repaired in the shops and replaced in the line. I must add, however, that metal sleepers require a very solid and perfect road-bed, and a much larger quantity of ballast than timber ties. The Mexican Railway is laid throughout with 62-pound steel rails, except on the Cumber 4 per cent. incline, where we are now laying down 82-pound rails. Our metal ties are laid under the 62-pound rails, the number being 2,000 per mile, but we find that this number is not necessary, and in future we propose to lay only 1,850 per mile. I may say in conclusion, that in my opinion the steel tie is the tie of the future, and that our experience here points with their use to substantial economies in repairs and maintenance and at the same time to a very perfect track.

The following notes are from The Mexican Financier. The first one refers to the serious and disastrous floods of 1887:

The management of the Mexican Railway has reason to congratulate itself on the success which has attended the introduction of steel ties on its line. The recent washout, caused by the bursting of a water-spout on the track, afforded a test of the utility of metal ties than which nothing could have been more satisfactory. On the section where the spout burst there were both wooden and metal ties. The wooden ties were completely washed away and the track badly torn up, but on that portion having the steel ties the bursting spout was unable to do any harm to the track, the ties retaining their place and the line of rails remaining at their original level. General Manager Foot, who made a personal inspection of the washed track, could not find that the section having the metal ties had been sensibly damaged; only the gravel between the ties had been carried away, leaving them in their original place and preserving as has been said, the level of the track just as it was before tons of water had swept down upon it. The bursting spout carried much débris on the track and loaded an iron bridge with bowlders, some weighing fully 6 tons, in fact so heavy that they had to be blasted to accomplish their removal, and this fact will indicate the tremendous force of the waters and demonstrate convincingly the merits of the Rendel steel ties which kept the submerged track in such good order.

The road began using steel ties in 1884, and has now some 20,000 of them on its bed. So satisfactory has the experiment been that 40,000 more have been ordered from England for use this year, and it is proposed to put in from 40,000 to 50,000 per year hereafter. The "life" of a steel tie is considered as indefinite, but it may safely be set at from thirty to fifty years, the former being an American estimate by a competent metallurgist. The steel tie is now produced in England where the manufacture has been so extended as to make the product for 5*s.* apiece, or $1.25 gold, or very much cheaper than formerly. By chartering its own vessels the company can land its steel ties at a cost which permits their extensive use. It may be set down that the outside cost will not exceed $2 each, Mexican silver. The wooden ties which the steel ties are replacing on the Vera Cruz line range in price, according to the quality of wood, from 90 cents to $1.62, silver. The latter price is paid for the zapote tie, a very hard and durable wood. The best white-oak ties last from five to six years, the red oak about three years.—(1889).

The policy of the management has, for a long time past, been directed toward making the road-bed exceptionally solid, and a large amount of money has been invested in steel ties which have proven well suited to the requirements of the line, known to be one of the most difficult of maintenance in the world, on account of its tremendous gradients. The good results of this wise building up of the line will be seen when the competition of the Interoceanic Railway begins, for then it will be made evident that, by having got its road-bed into a condition where it can be kept in repair at a comparatively small expense, the line can sustain a sharp rivalry.—(1889).

MEXICAN CENTRAL RAILWAY.—In February, 1888, Mr. Max E. Schmidt, then chief engineer of the Tampico division, wrote me as follows:

We have not yet used metal cross-ties on this line, but are considering the advisability of introducing them on our mountain division. In that case we will probably adopt the steel tie of the Indian State Railways lately introduced on the Vera Cruz Railway. This tie has the advantage of a most simple mode of fastening the rail to the tie, the rail being placed between two clips turned up from the bearing surface of the tie itself, only one wedge being required to hold each rail in place. Steel ties have two main advantages: (1) They last much longer than wooden ties; (2) they keep the track in perfect gauge. The question not yet settled is the kind of ballast which will keep the tie immovable in place.

SUMMARY OF METAL TRACK FOR SECTION 5.

| Countries. | Bowls. | Cross-ties. | Total. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| Argentine Republic | 3,350.15 | 193.41 | 3,543.56 |
| Chili | | 1.00 | 1.00 |
| Brazil | 82.46 | 3.72 | 86.18 |
| Venezuela | 23.00 | 57.25 | 80.25 |
| Costa Rica (probably experimental) | | | |
| Mexico | | 77.00 | 77.00 |
| Total | 3,455.61 | 332.38 | 3,787.99 |

## Section 6.—NORTH AMERICA.

### UNITED STATES.

General Remarks.—In this country very little practical attention has been paid by railway men to the use of metal track until within the last few years. The indifference displayed has been largely due to the increased first cost for metal and the apparently inexhaustible supply of timber. But with the steady improvement in the tracks of the principal lines and with the knowledge, as disseminated by the Forestry Division, of the actual condition of the timber resources there is a noticeable increase in the attention paid to this matter, and this will probably continue to increase. The metal track question, however, has been extensively considered by inventors, and much time, energy, and money have been spent in demonstrating, on paper, the positive efficiency of numerous new designs of track. The list of patents given with my preliminary report, in Bulletin No. 3, was surprisingly large, showing a total number of about two hundred and sixty patents from 1839 to 1889.* Very few of these patented tracks have been designed by railway men or men experienced in railway work, and the number of those which have practical merit is very small. Many of them are utterly impracticable, complicated, and costly, while others are carried to the opposite extreme of simplicity, with the result of sacrificing such efficiency as they might otherwise possess. The natural result of all this, combined with the large claims made from time to time in behalf of some of these impracticable systems, has been to render engineers, managers, and railway men generally somewhat doubtful as to the final solution of the metal track question. While some of the systems tried in actual service have not yet proved entirely satisfactory, it should be thoroughly understsood that no such system can be expected to give satisfactory results until it has been tested by trial and modified in accordance with experience obtained. Practical trial alone can show the actual results of any system of metal track.

The following remarks are taken from the report for 1888 of the railway commissioners of Connecticut:

We have in former reports mentioned the experiments made in the use of metal ties, and we refer to the subject now not as one requiring legislative action, but simply as a matter of practical and scientific interest. The supply of wood has so far continued so abundant in this country that the first cost of ties has not very materially increased, but the average life of a tie has considerably decreased, both because of inferior quality and greater wear upon them. We are not aware that experiments with

* The list of patents appended to this report contains 491 numbers.

metal ties of any account have been made in this country, but on the continent of Europe, where experiments began nearly twenty-five years ago, their use may be said to have passed the experimental stage, some companies having practically adopted this kind of tie and using them in all renewals. The most thorough experiments were made on the Netherlands State Railway, and the adoption there has been the most complete. In England, though used to some extent, they have not been at all generally adopted, as they do not seem to be well adapted to the double-headed rail so much used in in that country. The material found to be best adapted for this use is steel of a mild type, and the advantages claimed, apparently with reason, are such as to make it worth while for the managers of our principal roads to consider whether the adoption of this kind of tie would not be advantageous, even at the present price of wooden ties. The crowding outward of the spikes in wooden ties and the cutting of the spikes by the rail flanges on sharp curves constantly affects the gauge, and the cutting of the outer flange into the tie often seriously changes the position of the rail on wooden ties and requires constant watchfulness and respiking and readzing of old ties and the substitution of new ones. As traffic increases the loss of time thus occasioned in itself becomes a very serious item of expense. This is avoided by the use of metal ties, as the bolts do not cut like the spikes and the bolt-holes do not enlarge, neither do the ties wear or cut under the rail flange; so that the expense of maintenance is very much lessened, and instead of increasing as the road-bed gets settled it is said to decrease. The most approved form for the tie is like an inverted trough, and when the ends are closed there is very little lateral displacement of track, even on the sharpest curves. The first cost of metal ties and their fastenings is, of course, very much more than that of wooden ties and spikes, but their durability in itself, it is believed, far more than compensates for the additional cost.

New York Central and Hudson River Railway (See plate No. 27).—The chief engineer of this road, Mr. Walter Katté, having recognized the importance of the metal track question to the great trunk lines of railway, became desirous of obtaining some reliable data based upon experiments made under his own supervision. The company authorized an expenditure of $2,500 for the purpose of procuring such ties and testing them upon its own track. Various forms of ties used in foreign countries were examined, none of which, however, were considered to meet entirely and satisfactorily the conditions of American railway practice. The "Hartford" tie, with certain modifications to be made at his suggestion, seemed to Mr. Katté the best suited of any he had examined, and as it could be made in this country under his own observation as to manufacture, test of material, etc., he concluded it was the best one he could get, at least to start with, in investigating practically the question of metal ties. It is intended to conduct a close investigation of the comparative cost of maintenance, expenditures, renewals, etc., as compared with ordinary wooden ties. About eight hundred of the steel ties were purchased and were laid in double track on the main line. The company's standard system of track is used, consisting of good broken-stone ballast, with 80-pound flange rails, three-tie supported joints, and six-bolt angle-bar splices 40 inches long. The rails are laid to break joint. As stated in my preliminary report (Bulletin No. 3), it was expected to have these ties laid in April, 1889; owing to delays in manufacture, etc., they were not put in the track until November, 1889. They are laid for about a quarter of a mile on the main line, just south of Garrison's Station, Hudson River division. They are of two lengths, 8 feet and 8 feet 6 inches. They were at first laid in gravel ballast of mediocre quality, but this has been replaced with broken stone, in accordance with the company's approved form of track. The flanges of the angle-bars are notched to allow the clamps to bear on the rail flanges.

The following particulars are from a statement and drawings furnished in January, 1890, by Mr. Katté:

The ties were laid in November, 1889, on an experimental section of double track about a quarter of a mile long. The section is level and straight. The line has the heaviest kind of freight and passenger traffic. Passenger engines, with a weight of 36 tons, on four driving-wheels and a driving-wheel base of 6 feet, pass over these ties at speeds of 40 to 55 miles per hour. The ties have not been in use long enough for the expense of maintenance to be determined. Apparently, however, it is thus far no greater than with wooden ties. The arrangement for curves is the same as for tangents, any adjustment of gauge being effected by the fastenings. The rails weigh 80 pounds per yard and have supported joints. The reason for using these ties was the desire to secure economy over wooden ties and to obtain a superior attachment of the rails to the ties. The results have so far been quite satisfactory. There has been no trouble with maintenance nor with the rail-fastenings. No breakages have occurred. The attachment of the rails to the ties is much superior to the ordinary system of spiking. The wooden ties are of Southern yellow pine. They cost 55 cents each, delivered in New York, and have a life of from seven to ten years. The climate is variable, humid, with extremes of temperature. There is no record of the effects of the same on metal or wood.

I am of opinion that the rolled metal tie is essentially a requisite for first-class permanent way in this country. Having investigated the relative economy of metal and wooden tie systems for a term of fifty years, I am led to believe as the result thereof that upon the basis of 55 cents for a wooden tie and $3 for a steel tie, and under the conditions of traffic and maintenance expense existing on this line the relative economy is from 8 to 12 per cent. in favor of the metal system. The general advantages which I recognize in the metal system are: (1) Superior and more effective fastening of rail to tie. (2) Better hold of metal cross-tie with curved ends in the road-bed ballast, thereby preserving alignment both in straight line and curves much more effectively than with wooden ties. (3) Increased and effective resistance to tangential pressure on curves, with overturning tendency, and resistance to creeping of rails, especially on steep grades. (4) The clip and bolt fastening to the tie avoids the necessity of double-spiking the rail braces on curves. (5) Immunity from destruction of wooden ties by fire from coals dropped from locomotives and other causes. (6) The greater commercial value of the scrap material when worn out.

The ballast is about 24 inches deep; it consists of a 6-inch bottom course of rough quarry spawls, 4 to 6 inches diameter, and an 18-inch upper course of crushed rock 2 inches diameter. The ballast is brought up level with the tops of the ties. From the center of the rail to the outer edge of the ballast is about 6 feet 6 inches. The drawings show the rail joints spliced with plain splice-bars 22 inches long, with four bolts. Angle-bars are actually used, as already stated. Four arrangements of spacing of the ties are being tried; the rails are laid to break joint in all cases, with supported joints: (1) Thirteen lengths of 30-feet rails, with twelve ties to a rail length; the three-joint ties are spaced 18 inches, center to center, and the intermediate ties 3 feet. (2) Fourteen lengths of 30-feet rails, with twelve ties to a rail length; uniform spacing of 30 inches center to center. (3) Fourteen lengths of 30 feet rails with fourteen ties to a rail length; the three joint ties are spaced 18 inches, center to center, and the intermediate ties 2 feet $4\frac{13}{16}$ inches. (4) Fourteen lengths of 30-feet rails, with fourteen ties to a rail length; uniform spacing of 2 feet $1\frac{11}{16}$ inches, center to center. The close spacing of the ties at the rail joints is considered necessary for the existing severe conditions of traffic.

The cast-iron bowls designed in 1885 by Mr. John M. Toucey, general superintendent of the road, were intended for yard service and are still in use at the Grand Central station, New York City. (Description of the Hartford and Toucey ties will be found a few pages further on.)

CHICAGO AND WESTERN INDIANA RAILWAY (See plate No. 28).—About 1,000 feet of track near Chicago, Ill., have been laid with the "Standard" steel tie for experimental purposes, and up to the end of 1889 they had been in service about three months. It was then reported that they appeared to be satisfactory, but that it was too soon to express a decided opinion in regard to them. The traffic is about eighty trains per day; all in one direction. The locomotives weigh 96,000 pounds, and have a weight of 15,000 pounds on the driving-wheels. The track is as firm as could be expected for the open winter that has been experienced. It makes very easy riding and causes very little noise. The ballast is of light gravel. The ties are spaced $23\frac{1}{3}$ inches apart, center to center. They are 7 feet long and 3 inches deep; joint ties, 10 inches wide; intermediate ties, 7 inches wide. There had been no trouble with the rail fastenings, but a little rust had been noticed where the bolts come in contact with the clamp. The rail joints are square (or opposite), and are supported; they are spliced with plain splice-bars weighing $18\frac{1}{2}$ pounds per pair; angle-bars could not be used as the flange would interfere with the rail clamp. The company which is introducing this tie claims that the clamp fastening will obviate the necessity for the use of splice bars and bolts, the clamps holding the rails firmly by the flange. Many railway men, however, consider that it is not sufficient to hold the rail by its base. In view of the fact that rails are not always vertical in the web, and are liable to bend, especially under heavy traffic, it may be found inadvisable to dispense generally with the use of splice-bars, which serve to keep the rail ends in line. Particulars of the "Standard" tie will be found a few pages further on.

The following is a letter written to the Standard Metal Tie and Construction Company of New York, in January, 1890, by Mr. J. W. Clarke, roadmaster of the Chicago and Western Indiana Railway Company and the Belt Railway Company of Chicago:

Answering your inquiry as to the condition of the Standard steel ties now in our track on main line, north of Seventy-first street, I beg to say that these ties were laid on the 1st of October, 1889, and, as you are aware, they were put in at the above location on south-bound track for the reason that at this point the ballast is very light gravel, which would make the test much more severe than if they had been put in at another location of the road. The traffic on this section is eighty regular trains in one direction every twenty-four hours; the heaviest engine weighs 96,000 pounds, with 15,000 pounds on each pair of drivers.

So far the ties have given perfect satisfaction, requiring but slight attention, and that only when first laid. There are no loose bolts, clips, or nuts, and so far there have been none. It would be impossible for me to estimate correctly at the present time the saving in maintenance, as the ties have not been in service long enough. I believe, however, that there will be a great saving in maintenance, as the only things to need attention are the bolts and clips, and so far they have shown no indication of weakness in any particular. There has been no upheaval of the ties where the ground is frozen, and from present indications I hardly believe that such will occur. The ties are in good line and surface, and hold the rails in an upright rigid position, so that the wear on the rail head seems to be more uniform and even than where wooden ties are used. I am free to say that the ties have so far surpassed all my expectations.

There seems to be no possibility of spreading of the rails. Should a rail break there would be less liability to accident, for the reason that the fastenings hold the rail absolutely firm and rigid. I believe that the saving in maintenance that will eventually be shown, and the absolutely safe, permanent way which these ties make, to say nothing of their greater life, will show greatly in their favor.

DELAWARE AND HUDSON RAILWAY.—Steel ties are to be tried on this road. An order for 1,500 "Standard" ties was given in April, 1890, to the Standard Metal Tie and Construction Company, of 15 Cortlandt street, New York, and they will be laid north of Ballston on what was originally a part of the old Saratoga and Schenectady Railroad. The ties are to be 7 feet long and 7 inches wide; they will be in gravel ballast and will be spaced 2 feet, 2 feet 6 inches, and perhaps 3 feet apart for experimental purposes. The rails weigh 67 pounds per yard and rest on blocks of compressed wood. The joint is of a new type; a channel-bar 4 inches deep is placed under the rail ends, and a clamp on each side takes hold of the rail flange and the bottom of the flange of the channel. Four bolts, with the Harvey grip-thread, pass through the clamps and channel-bar under the rail. No ordinary splice-bars are used, the rails being held by the flanges only. The joint ties are spaced 2 feet apart, and the channel-bar and clamps are as long as the distance between these ties. The order for the ties was given through Mr. H. G. Young, second vice-president of the road, and Mr. A. J. Swift, chief engineer. The Standard ties are in experimental use on the Chicago and Western Indiana Railway, and are described further on.

PENNSYLVANIA RAILWAY (See plate No. 29).—Mr. William H. Brown, chief engineer, stated in February, 1889, that the iron ties tried on this line had not been satisfactory. Four or five different kinds had been tried but there was not one that gave any satisfaction, and they had all been taken out with the exception of the steel ties obtained from the London and Northwestern Railway, England; and it was supposed that these also would be taken out in a year or two. In October, 1889, Mr. Brown stated that a few metal ties had been in service for about nine years, but that they had all been taken out of the main track, with the exception of small lots. They were made of channel iron, from designs prepared by the engineer, and cost $4 each. As will be noticed by the description given further on, the construction of these ties involved considerable shop-work. One bolt on each side of the track might, however, be dispensed with. Some of these ties were laid on the Filbert street extension in 1880, and in 1885 about 400 or 500 were laid on the 4½-degree curve in the West Philadelphia yard, where 134 fast passenger trains passed over them in 24 hours. They had no elasticity and were very hard to keep in line. It was concluded that as long as good oak ties could be procured at a price not exceeding $1 each, it would be cheaper to use wooden than iron ties. The price being paid for oak ties in October, 1889, was 65 cents per tie, delivered on the line of the road. In a letter published in 1886, Mr. Brown stated that the iron ties gave perfect satisfaction and were no more trouble to keep in line and surface than wooden ties, but in October, 1889, he stated as follows:

> In our experience a metal tie is not worth half as much as a wooden one, and as long as we can get first-class white-oak ties at our price of 65 to 75 cents each, it would be very foolish for us to use metal ties that cost $3 and $4.

This road has two sections of track laid with the standard metal track of the London and Northwestern Railway (See "England"), consisting of steel cross-ties with steel rails of bull-headed section, weighing 90 pounds per yard, secured in the chairs by steel keys. This track is said to be more easily kept in line than track on the company's own iron ties, in spite of the English ties having open ends. This is attributed to the greater stiffness of the rails. One of the sections of track is near Harrisburg, Pa., the other is on the New York division, west of the station at Menlo Park, N. J. On the latter location they are laid on the most southerly of the four tracks, which is the track for east-bound freight trains. There are about eight hundred ties in all, spaced 3 feet, center to center, giving ten ties to a rail length of 30 feet. The track is on tangents, one curve and one short bridge; on the bridge the ties are placed on wooden cross-ties having beveled edges. The rails are laid to break joint, and the joints are spliced by deep bars with four bolts. The ballast is of broken stone; and fine broken stone is filled in, covering the ties. This covering is not used on the other tracks, which are laid with wooden ties. I examined this section of track in November, 1889.

CHICAGO, SANTA FÉ AND CALIFORNIA RAILWAY (See plate No. 30).—On the Illinois division of this line the Taylor tie (described further on) has been in use on a few rail lengths for over two and one half years. They are reported to have been laid in poor ballast, and to have carried heavy traffic.

Official reports made to me in February, 1890, speak unfavorably of these ties. There are twenty-two of them at Streator, Ill., in the yard west of Main street, between the crossings of the Wabash Railway and the Chicago and Alton Railway. They were laid in August, 1887, and are on a length of about 40 feet on a level and straight track. Mr. R. R. Coalman was the engineer in charge. There is a train every hour. The locomotives weigh 85,000 pounds. The bowls of the joint ties are 8 inches by 19 inches; those of the intermediate ties are 8 inches by 14 inches. They are of steel, five-eighths inch thick, and weigh 50 pounds. The joint and second ties are spaced 20 inches, center to center; the others are spaced 24 inches, center to center. The fastenings consist of lugs on the bowls and on the ends of the tie-bars as described further on. The expense of maintenance is said to be 50 per cent. more than with ordinary ties, and the durability is "not very good." The rails are of flange section, weighing 70 pounds per yard; the joints are supported, and are spliced by angle-bars. The ballast is of cinders and gravel, and does not behave well under the tie. The general results are not satisfactory. There is trouble with maintenance of track and with the rail attachments, but no trouble from breakages. In January, 1890, when the ties were examined for the purpose of this report, the track was found to be 2 inches lower than the other part of the track; it had been raised 3 inches above the level of the other ties, but would not stay up. The ties were hard to tamp and the gravel worked out from under them. From the experience with these ties it is thought that they will not last any longer than good wooden ties, while the cost for maintenance is much greater.

LONG ISLAND RAILWAY (See plate No. 30).—A few ties of the "International" type, described further on, were sent by the inventor for trial, and up to the end of 1889 had been in service for about two years. They were laid for a length of about 40 feet, and were spaced 2 feet apart, center to center. The rail joints are suspended. The track is ballasted with cinders, filled in level with the tops of the ties. The track is said to be not more firm than that with wooden ties, and its length is too short to enable its riding qualities to be determined. The ties are 8 feet long. The average amount of traffic is 100 trains per day. The heaviest locomotives weigh 146,050 pounds with a weight of 59,000 pounds on the driving-wheels. The number of ties is too small and time of trial too short for any definite conclusions to be drawn as to maintenance, but it is thought it would cost as much as, or more than, the track with wooden ties to keep in good line and surface, and for maintenance. The rail fastenings have given no particular trouble. Several ties have cracked under the rails. On the whole, the results are not considered to be very satisfactory, but, as already stated in the "general remarks," a few pages back, the metal tie question is quite in its infancy in this country, and ties which have not thus far met the requirements and conditions to be fulfilled may be improved in the light of actual experience so as to be ultimately efficient. These remarks apply also to the ties described in the previous paragraph.

BOSTON AND MAINE RAILWAY (See plate No. 30).—A few steel ties of the "International" type have been tried on this line. They were laid at Somerville, Mass., in July, 1885. Different patterns were used, most of them in two pieces, riveted together at the middle rib or web; others in one piece with riveted angle-pieces to which the rail clamps were bolted. They all had the top table crowned at the middle. Some had only half the width of each end closed; others had a part of the side at each end cut away. This was to facilitate tamping. I visited the track in September, 1889, but the ties had all been taken out (and piled near the line), as the notch in the rib was not wide enough for the flange of the new rails which are being put in. Some were cracked at the rail-seats. The section-master in charge of this section spoke well of the ties; he considered that there was but little more trouble in tamping, especially with the ties having a part of the sides cut away. The ties gave a bearing of 14 inches for the rail, and were spaced 28 inches, center to center.

MAINE CENTRAL RAILWAY—(See plate No. 30).—On this line also a few "International" ties have been tried, and have been in service since 1885. I examined them in September, 1889. There are only fifteen ties, or one rail length, and they are laid in the freight-yard at Portland, Me. They were put in at the request of the inventor. The ties have half of each end open. In a freight track, where a good deal of switching is carried on, the rib would be bad in case of derailment, as it might strip the trucks from a car which otherwise might have been got back on the rails without injury. As the rib would also be dangerous to brakemen in coupling cars, etc., being likely to trip them up, the space between the rails is filled in with gravel. The yard-master stated that these ties had not been touched since they were laid, which could not be said of any of the wooden ties during the same time.

DENVER AND RIO GRANDE RAILWAY.—A very limited trial of metal ties has been made on this road. In October, 1889, Mr. R. E. Briggs, chief engineer, stated that there had never been a trial made of a character to afford information of value. A few years ago a few iron ties (probably a dozen) were laid in the track near Denver, but were taken out after a short time, and no record of them has been kept. From another source I learn that the ties were probably of trough section with a wooden block under each rail, and that probably a larger number was tried than above noted.

PHILADELPHIA AND BALTIMORE CENTRAL RAILWAY.—On this line, which is now a part of the Philadelphia, Wilmington and Baltimore Railway, trials of the Travis iron ties were being made in 1879. The following is from the Railroad Gazette, New York, of March 28, 1879:

At the meeting of the Engineers' Club of Philadelphia on March 15, 1879, C. E. Buzby exhibited a model of the Travis iron tie, which was then being tried on the Philadelphia and Baltimore Central Railway, near Lamokin. It dispensed with all spikes, bolts, nuts, or fish-plates, and drilling or punching rails. Each tie was recessed under the rails, and along the bottom of the recess wedge-shaped pieces were cast transversely. At the sides of each recess are creosoted blocks, which form a cushion and a fulcrum for two clamps, which grasp the flange and web of the rail above, bearing upon opposite faces of the wedge below. The weight of the train forces the clamps upon the wedge, spreads them out at the bottom, and causes the upper part to grip the rails. The first cost was somewhat greater than that of the wooden ties, but it was said to offset this in durability.

In January, 1890, Mr. H. F. Kenney, general superintendent of the Philadelphia, Wilmington and Baltimore Railway, wrote me as follows:

In 1878 one hundred iron cross-ties of the Travis pattern were placed in the track, on our Maryland division, and were removed after having been in use for a period of four years and seven months. The results obtained were not at all satisfactory, the expense of surfacing and lining amounting to considerably more than with wooden cross-ties. A number of these cross-ties, of a similar pattern, were laid on the Chester Creek branch, on our central division, during 1879. These ties, like those in use on the Maryland division, failed to give satisfactory results and were removed from the track after a period of about four years' service.

DELAWARE, LACKAWANNA AND WESTERN RAILWAY (See plate No. 30).—On this line six ties, of a type designed by Mr. Hicks, of New York, have been in use for some months in the yards at Hoboken, under heavy drilling and switching traffic. Mr. Neafie, the roadmaster, states that they behaved well; better, in fact, than had been expected. The tie as at present made is not considered suitable for main tracks, as the wooden blocks are liable to split, the grain being parallel with the rail. In dry weather, too, the wood would shrink and might become loose. The ties are in cinder ballast. (See "Hicks'" system.)

Mr. Neafie has designed a metal tie especially for use at road crossings. Two pieces of old rail with a chair secured at each end, form the tie. There is no intention of applying this plan to ordinary track, but it is intended especially for the crossings as above mentioned.

It is claimed that these experiments were not conclusive, and that with certain modifications the tie would prove successful. An improved form of tie of this type, designed to meet the objections experienced with the original Travis tie, has been invented by Mr. E. Brandwood, of Philadelphia, Pa. (See Brandwood Tie, page 289.)

## TIES.

*The Hartford Tie* (See plate No. 27).—This is a rolled Bessemer-steel cross-tie, of inverted-trough section, with a channel or groove along the middle of the top table for the entire length of the tie. The dimensions are as follows: Length, 7 feet 6 inches to 8 feet 6 inches; width on top, 8 inches; width at bottom, $10\frac{1}{4}$ inches; depth, $2\frac{1}{2}$ inches. The metal is three-eighths inch thick at the sides and five-sixteenths inch on top. The channel or groove is $2\frac{1}{2}$ inches wide and five-eighths inch deep. The ends are closed by curving the whole tie to a depth of $5\frac{1}{2}$ or 6 inches. The weight is 150 pounds, including the fastenings. The ties are treated with Dr. Angus Smith's asphaltum process, applied at a temperature of 300° Fah. The fastening for each rail consists of two clamps five-eighths inch thick; the clamps are wedge-shaped in plan and lie under the rail in the channel of the tie. At the broad end of each clamp is a hooked projection or lug, which holds the flange of the rail. A bent bolt, seven-eighths inch diameter, with its head at an angle of 53 degrees with the body, is used on each side of the rail; the head is on the under side of the top table of the tie, and the body passes up through the tie and clamp. The neck is oblong, $\frac{7}{8}$ by $1\frac{3}{16}$ inches. The nut screws down on the inclined face of the end of the clamp. At first the clamp had a hole for the bolt, but as now made it has a slot to receive the bolt;

by this means the clamps can be shifted, so that the track may be adjusted accurately to gauge, with any variation in the width or thickness of the rail flanges. The gauge can also be thus easily widened at curve or contracted at frogs and switches, and rails with worn heads may be shifted in to maintain a uniform gauge. The bolt being at an angle, a strong grip is secured. Lock-nuts are not used, but the bolts have the Harvey grip-thread, which in itself forms a nut-lock. Powerful wrenches must be used, as the security depends upon the upsetting of the threads within the nut. Under exceptionally severe conditions of traffic, however, nut locks may be used as an extra precaution. This is the fastening as improved in accordance with suggestions made by Mr. Walter Katté, chief engineer of the New York Central and Hudson River Railway, who is now conducting a careful trial of these ties, as already noted. The ties cost $3 each, including fastenings. They are manufactured by the Pennsylvania Steel Company, of Steelton, Pa., for the A. J. Hartford Steel Railway Tie Company, of Temple Court, New York city. Their life is estimated at fifty years.

Ties of this type, but flat on top, without the groove or channel, have been designed. The special object is to permit of shimming up the track, which becomes necessary with the disturbance of the ballast by frost in certain sections of the country. The impossibility of shimming has been an objection to metal ties, which has frequently been urged by practical track men.

*The Standard Tie* (See plate No. 28).—This is a steel cross-tie of channel section (|___|), stamped to shape from a plate. The intermediate or ordinary ties are 7 feet long, 7 inches wide over all, and 3¼ inches deep over all. They weigh 82 pounds each and cost $2.50. The joint ties (for supported rail joints) are 7 feet long, 10 inches wide, and 3¼ inches deep. They weigh about 105 pounds, and cost $3.50 each. The metal is three-eighths inch thick throughout. The bottom of the channel is cut loose from the sides at the middle portion of the tie, and the parts bent up at an angle, so as to offer resistance to lateral motion, the ends of the tie being open. The tie is intended to be filled with ballast. Each rail rests upon a block of preserved and compressed wood placed with the grain vertical. It is expected that this block will give a firm support to the rail, will not be cut by the flange, and will be durable. Each block is 4½ inches wide by 6½ inches long (or 9½ inches for joint ties) and 2⅝ inches deep. The rail rests only on the block, the sides of the tie being cut away to a depth of one-half inch for the width of the rail flange. The fastenings consist of Z-shaped clamps, the upper rib holding the rail flange, while two projections forming the lower rib pass through holes in the bottom of the tie and take a bearing against the under side of the bottom. The upright web is nearly vertical, but curved so as to grip the wooden block. The clamps are as long as the inside width of the tie. At intermediate ties the clamps are screwed up to a bearing on the rail flange by a bolt three-fourths inch diameter, passing horizontally under the rail through both clamps and the wooden block. The center of the bolt is one-half inch below the top of the block. At joint ties two bolts are used. It is claimed that this fastening will obviate the necessity for the use of splice-bars and bolts, but as already noted, in view of the fact that rails are not always vertical in the web and would have a tendency to be bent at unsupported ends, it may be that the use of splice-bars will be found desirable, especially for track with heavy traffic. These ties are said to be especially adapted for roads with a narrow width of ballast, as the resistance to lateral motion is at the middle instead of at the ends of the tie. They are also claimed to be suitable for bridge floors and elevated railways. In the latter case, the bottom of the channel would be cut away entirely between the wooden blocks, so as to offer as little obstruction to light as possible; they would in themselves form the cross-bracing of the structure. The ties are manufactured at the Homestead Steel Works of Carnegie, Phipps & Co., at Homestead, Pa. They are stamped from steel plates by a hydraulic press designed by Mr. Aiken, of Pittsburgh, and built by the Scaife Foundry and Machine Company of Pittsburgh. They are being introduced by the Standard Steel Tie and Construction Company, of 15 Cortlandt street, New York City. They are being given a trial on the Chicago and Western Indiana and on the Delaware and Hudson Railways.

*The Pennsylvania Railway Tie* (See plate No. 29).—The channel tie designed by the engineer of the Pennsylvania Railway consists of an ordinary channel-iron (⊓), 8 feet 6 inches long, 7 inches wide, 2¼ inches deep, weighing 13½ pounds per foot. Each end is closed by an angle-iron 3½ inches by 5 inches, 7 inches long, weighing 7 pounds per foot. The shorter leg rests on the top table of the tie and is secured by two rivets. A piece of angle-iron 3 inches by 3 inches, 5½ inches long, weighing 6 pounds per foot, is also riveted inside of the channel just under the flange of the rail. The fastenings for each rail consist of a riveted brace on the outer side and a bolted clamp on the inner side. The brace on the outer side is a piece of angle-bar 7 inches long, secured to the tie by the two rivets which hold the angle-iron in the interior of the tie; this angle-bar or brace bears on the flange and under side of the head of the rail. The clamp on the inner side is a flat piece of iron 7 inches long, secured by two bolts; one bolt may be dispensed with in some cases. This clamp bears on the tie and flange of the rail.

*The Toucey Tie* (See plate No. 29).—This tie was designed by Mr. John Toucey, general superintendent of the New York Central and Hudson River Railway, expressly for laying in the Grand Central Station, New York City, where it was desired to pave. Each tie consists of a pair of cast-iron "bowls" of **H**-section, with outward, flaring sides. The bowls are connected by a tie-rod five-eighths inch diameter, the ends of which are bent down at right angles to fit into a hold in the middle web, the rod passing through the side of the bowl. The bowls are 18 inches long, 9¾ inches wide on top, 16½ inches wide at the bottom, and 8$\frac{5}{16}$ inches deep. The thickness is from one-half to 1 inch. The upper part of the bowl is fitted with an oak block, to which the rail is secured by a pair of Bush interlocking bolts. The ties are laid 3 feet apart, center to center of tie-rods, giving 18 inches clear between the bowls. The weight of each bowl is about 100 pounds. The track was laid in 1885, and no breakages have occurred. There is a distance of about 3,000 feet laid with these ties. They are economical in that the track has not to be dug up and disturbed for renewals of ties. The wooden block is not vulcanized, creosoted, or otherwise treated; but it is considered that Georgia pine would last a long while, as it is away from dampness. The ties were also laid at the same time for several rail lengths at the entrance of the yard. Mr. Toucey stated in January, 1890, that these also are still in service. There have been no renewals or breakages.

*The International Tie* (See plate No. 30).—This is a rolled-steel tie, the cross section of which resembles a printer's "brace" (⏞). Originally it was made in two pieces riveted together at the upper flanges, but it is now made in one piece. Some of the earlier ties were in one piece, but had not the upper flange, a short piece of angle-iron being riveted at each side of each rail seat; the rail clamps were bolted to these angle pieces. To facilitate tamping, half of each end was left open or a piece of the side cut away at each end. As now made, however, the ends are open, and a transverse plate inside the tie, nearly under the rail seat, is secured by a rivet to each side. The usual dimensions are now as follows: Length, 8 feet; width, 10 inches; side flanges, 3 to 3½ inches deep; middle flange, 2 inches high. The thickness is from three-sixteenths inch at the bottom of the side flanges to three-eighths inch on top. At first the top table was slightly curved at the middle, but it is now made horizontal for its entire width. The middle flange is cut away in two places to admit the rail flanges. The weight of the tie is about 100 pounds. The price is about $1.50 to $2.50, according to length, etc. The fastenings consist of flat wrought-iron clamps bolted to the middle flange of the tie, one on each side of each rail. These clamps have projections which bear upon the flange of the rail, and these projections are so made as to give four different clearance heights between the tie and the clamp; this allows for rails with flanges of different thickness, and also for some amount of shimming. Some of these ties have been tried, as already noted, on the Long Island

Railway, Boston and Maine Railway, and Maine Central Railway. They are manufactured by the Cambria Iron Company, of Johnstown, Pa., for the International Railway Tie Company (of which the inventor of the tie, Mr. Higley, is treasurer), 45 Broadway, New York City.

*The Taylor Tie* (See plate No. 30).—This is an iron or steel cross-tie on the "bowl" system, each tie consisting of a separate piece under each rail, connected by a third piece forming a tie-bar. The bowls or rail-bearers are of inverted-trough section, placed lengthwise of the rail, and having a vertical transverse slot through which the deep flat tie-bar passes. At rail joints (supported joints) the rail-bearers are of extra length and two tie-bars are used, one to each rail end. With this system, as with the Standard system, the use of splice bars and bolts is intended to be avoided. The inner side of the rail flange is held by lugs stamped up from the metal of the top table of the bowl; the outer side is held by the hooked end of the tie-bar. No bolts or other loose parts are used. The rail-bearers are of sheet steel 14 inches long, 9 inches wide, 7 inches deep, five-sixteenths inch thick. The tie-bar is 6 feet long and one-half inch thick. The weight of the tie complete is about 90 pounds. With ballast that is fine or of poor quality it is proposed to use a tie-bar of ⊥ section (as shown on plate No. 30 (instead of the flat bar; the ⊥ bar would be 3 inches by 3 inches, vertical web three-eighths inch thick, horizontal flange five-sixteenths inch thick. The object is to give additional bearing surface. These ties (with flat bars) have been tried on the Chicago, Santa Fé and California Railway, as already noted. The inventor is Mr. E. L. Taylor, of 682 Brooklyn street, Philadelphia, Pa. He stated in January, 1890, that he had received several inquiries from foreign countries, and hoped soon to make arrangements for manufacture.

*The Hicks Tie* (See plate No. 30).—The ties already noted as being tried on the Delaware, Lackawanna and Western Railway are composed each of two angle-irons, so placed as to form an inverted channel. At each end two angle-pieces are riveted across the top of the tie; between these two pieces rests the oak block to which the rail is secured by spikes. The angle-pieces are not as high as the block, and as the latter has the grain parallel with the rail, it is liable to be cut by the rail and to be split by the spikes. The block is also liable to become loose in dry weather. The tie weighs about 100 pounds. Mr. Neafie, the road-master, suggests that it would be an improvement to make the angle-pieces as high as the wooden block, with the upper edges bent over. The block would be driven to a tight fit and would not be liable to be split. The ties are spaced 15 inches apart in the clear, or 27 inches center to center. Mr. Hicks proposes several modifications of the tie as now in use. One plan is to have the wooden blocks only 4 inches thick and long enough to reach from tie to tie, forming a continuous support for the rail, and the ends of the adjacent wooden blocks being on the ties. With this form of track an improved clamp fastening of simple form would be used instead of a spike. Another system designed by the same inventor consists of longitudinals carrying cross-ties, which are placed diagonally instead of at right angles to the rails. The ties are of channel section, with a wooden block under each rail. The object of placing the tie diagonally is to increase the length of bearing of the rails on the blocks. The cross-tie was invented by the late Capt. H. O. Cook, and has been modified and improved by the present owner, Mr. James M. Hicks, 19 Park Place, New York City.

*The Durand Tie.*—This tie is of inverted-trough section, somewhat resembling the "Post" tie (See "Holland"). It is narrow and deep at the middle. Lengthwise corrugations on the top table of the tie at the railseat are intended to give additional strength; vertical corrugations may also be made in the sides. The width of the railseat is 10 inches on top and 12 inches at the bottom. The thickness may be either three-sixteenths inch, giving a weight of 65 pounds per tie, or five-sixteenths inch, giving a weight of 100 pounds per tie. The cost is claimed to be $1 or $1.35, respectively. The ends are open, but can be closed by a special cap, which is to be put on after the tie is laid, and which can be removed to permit access to the bolts, etc. Experience has shown the advantages of closed ends for ties, and the proposed movable ends are not likely to be introduced. The fastenings consist of four bolts, with the heads welded to the under side of the top table of the tie. The nut-lock consists of a washer of soft metal; an indentation fits into a recess in the tie, preventing the washer from turning, and when the nut is screwed down one side of the washer is turned up against it. Various other fastenings are also proposed by the inventor in connection with his ties. It is proposed to roll old rails into sheets, from which the tie would be stamped by special machinery; any special arrangement of tie for curves, switches, etc., would be effected by interchangeable pieces in the machinery. The plant for rolling and stamping is estimated to cost $5,000, and the cost of manufacture is estimated at 30 cents per tie. The ties have been tried on a private trial line in the French Alps. The inventor is A. Durand, of Alexandria, Va., and Atlantic Building, Washington, D. C. (Patent No. 386,389; July 17, 1888.)

*The Maloney Tie.*—This is a cross-tie of cruciform section, the upper vertical flange being cut away in two places to allow the rail to rest on the horizontal web. The dimensions are as follows: Length, 6 feet 6 inches; width, 9 inches; top and bottom flanges each 1½ inches high. The thickness is one-fourth inch, increased to one-half inch at the rail seats. The rails are fastened by flat clamps, which are bolted to the top flange of the tie. The ties are to be rolled, the cutting for the rails and holes for bolts being made during the operation, so as to turn out a finished tie from the rolls. The four clamps for each tie weigh about 3 pounds, and the fastening of the rail is claimed to be very efficient. This tie was invented by Mr. M. Maloney, of Ironton, Ohio. He reported in January, 1890, that he was negotiating for its manufacture, and hoped to have it in service during the present year. (Patent No. 395,447; January 1, 1889.)

*The Flower-Heller Tie.*—This is a cross-tie in the form of a hollow box of rectangular section, with a wooden block inside under each rail. The top of the box is cut away to allow the rail flange to rest on the wooden block, and the rail is spiked to this block as to a wooden tie. For curves the tie is made shallower at the middle than at the ends, so as to form shoulders to resist lateral shifting in the ballast. The patents for these ties are owned by the American Metallic Railway Tie Company, 230 South Fourth street, Philadelphia, Pa. (Patents Nos. 386,119, July 17, 1888, and 370192, September 20, 1887.)

*Phœnix Iron Works.*—In June, 1889, Mr. Amory Coffin stated that metal ties were being used on all the new track being built around the works. There are several miles of narrow-gauge track, and as fast as the wooden ties give out they are renewed with metal. Channel-bars are used 6, 8, or 9 inches wide; of ordinary weight per yard, say 40 to 60 pounds.

*The Price system.*—This system consists of a longitudinal under each rail, made of a strip of steel bent or corrugated to form a series of troughs, open alternately at top and bottom. The sides of the troughs are flaring, the open parts being widest. The strip has a rib on each edge. The rails are secured by bolted clamps. The length of each stringer or longitudinal is about 30 feet. Light steel cross-ties are placed at intervals. The ballast is intended to be filled in to the top of the longitudinal. This system is owned by Mr. James M. Price, 1719 North Eighteenth street, Philadelphia, Pa.

*The Hoffmeier system.*—This system consists of cross-ties with arms at each end. The arms of adjacent ties dovetail together, forming a continuous stringer or longitudinal under each rail. The ties and longitudinals may be of various sections, and various forms of fastenings may be used. The inventor is Mr. A. K. Hoffmeier, of Lancaster, Pa.

*The Holland system.*—This consists of round or elliptical castings, with a dome-shaped diaphragm in each. The space above the diaphragm is filled with concrete or asphalt. The castings are not placed opposite one another in the track, but are staggered. They are connected by tie-bars. The system is the invention of Mr.

Robert M. Holland, of Philadelphia, who also has a patent on a cross-tie. (Patent No. 66,711; July 16, 1867.)

*The Schofield Tie* (See plate No. 30).—This cross-tie is of iron or steel, of deep inverted-trough section, with horizontal flanges on the bottom edges. Each rail is fastened by two clamps three-eighths inch by 2¼ inches, fastened by two five-eighth-inch bolts each. The tie is 5 feet 6 inches long, one-fourth inch thick, and weighs 50 pounds. It is estimated to have a life of fifty years and to be worth 50 cents when worn out. It is proposed to use three iron ties to a rail length of 30 feet, replacing three wooden ties, in order to increase the safety of ordinary track at small expense. It is reported that they are to be used in some special places on the Lookout Mountain Railway, near Chattanooga, Tenn. These ties are being manufactured by the Schofield Metal Cross-Tie Company, of Chattanooga, Tenn. (Patent No. 230,826; August 3, 1880.)

*The Brandwood Tie.*—This is a cross-tie of iron or steel with a section at its middle part of the form of a cross + and with the ends turned down. At each end of the tie is formed a hollow "box" deeper than the other portions of the tie, and the horizontal part of the tie is widened at the ends to form a plate around each box and to give ample bearing on the ballast. The bottom of the box is closed and has a rib of Λ section under the rail. Each rail is carried on two clamps, the top of which is of ⊏ shape to hold the rail flange, and has a long lower leg of wedge form which fits into the box. The rib in the bottom of the box forces the lower legs of the clamps apart, causing the upper part to grip the rail tightly, especially when the weight of a train comes upon the rails. Wooden blocks are placed between the backs of the wedges and the sides of the box. At rail joints the upper part of the clamps is made of extra length, to give a good hold on the rail ends. No splice bars or bolts are used. The "box" is rather wider at the middle than at the sides, so that in renewals the clamps may be easily knocked loose from the sides of the box and withdrawn, thus obviating one of the defects said to exist with the Travis tie, that the clamps became wedged so tightly in the boxes that they could not be removed. This tie was designed as an improvement on the Travis tie. (See p. 283 and patent No. 206,647) by Mr. E. Brandwood, of Philadelphia, Pa., and patented December 9, 1890. (No. 442,416.)

SOUTHERN PACIFIC RAILWAY.—It is reported that trials of metal track are likely to be instituted on the Southern Pacific system.

LOOKOUT MOUNTAIN RAILWAY.—On this standard-gauge road up Lookout Mountain, near Chattanooga, Tenn., some metal ties are to be tried in special places. (See "Scofield" tie.)

## CANADA.

Metal track has not been introduced, and in fact has probably never been considered with a view to its introduction or a practical trial. A prominent engineer, Mr. Thomas C. Keefer, writes as follows:

> I do not believe metal ties have been used in Canada. We have not even creosoted ties yet. With white oak ties at 50 cents, and tamarack and cedar at 20 cents, our railways, always living from hand to mouth, have never thought of anything else.

## TABULAR SUMMARY OF METAL TRACK.

The following is a table giving a summary of the figures presented in the first parts of the report, showing that of the total length of railways in the world (exclusive of the United States and Canada) about 13.21 per cent. of the mileage is laid with metal track. The figures of the totals given can only be approximate, in consequence of omissions, incomplete data, and lack of figures brought up to the same recent date. The totals are, in all probability, considerably below the actual mileage, as shown by the figures for Germany and Switzerland. In the latter case the total compiled from data relating to the several railways, as given in my report, is nearly 100 miles below the actual total officially reported. It must also be borne in mind that the use of metal track is being continually extended.

*Section 1.—Europe.*

| Countries. | Longitudinals. | Bowls and plates. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| Great Britain | | | 70.00 | 70.00 | 20,000 |
| France | | | 52.12 | 52.12 | 21,700 |
| Holland | 8.06 | | 321.36 | 329.42 | 3,216 |
| Belgium | | | 115.50 | 115.50 | 3,544 |
| Germany* | 3,562.52 | | 5,224.12 | 8,786.64 | 25,144 |
| Austria and Hungary | 66.56 | | 56.37 | 122.93 | 14,942 |
| Switzerland | .25 | | 303.98 | *397.40 | 1,810 |
| Spain | | 251.68 | 7.10 | 258.78 | 5,772 |
| Portugal | | | .02 | .02 | 1,120 |
| Italy | | | | | 7,292 |
| Sweden and Norway | | | .50 | .50 | 5,544 |
| Denmark | | | 18.10 | 18.10 | 1,248 |
| Russia | | | | | 17,682 |
| Turkey | | | 70.68 | 70.68 | 865 |
| Roumania | | | | | 1,491 |
| Servia | | | | | 321 |
| Greece | | | | | 380 |
| Totals of Europe | 3,637.39 | 251.68 | 6,239.85 | 10,222.09 | 132,071 |

*Official statement of totals.

*Section 2.—Africa.*

| Countries. | Bowls and plates. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| Egypt | 851.75 | 35.25 | 887.00 | 1,228 |
| Algeria | | 120.00 | 120.00 | 1,538 (Algeria and Tunis) |
| Tunis | | | | |
| Abyssinia | | 14.25 | 14.25 | 14 |
| Portuguese Territory (South Africa) | | 47.75 | 47.75 | 56 |
| Natal | | | | 217 |
| Cape Colony | 80.00 | 36.50 | 116.50 | 1,736 |
| South African Republic (Transvaal) | | 40.50 | 40.50 | 45 |
| Reunion | 62.00 | | 62.00 | 78 |
| Senegal | | 2.50 | 2.50 | 290 (Senegal and Mauritius) |
| Mauritius | | | | |
| Totals for Africa | 993.75 | 296.75 | 1,290.50 | 5,202 |

*Section 3.—Australasia.*

| Countries. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| South Australia | 146 | 146 | 1,824 |
| Queensland | 40 | 40 | 2,103 |
| New South Wales | | | 2,168 |
| Victoria | | | 2,167 |
| West Australia | | | 160 |
| New Zealand | | | 1,843 |
| Tasmania | | | 375 |
| Totals for Australasia | 186 | 186 | 10,640 |

*Section 4.—Asia.*

| Countries. | Bowls and plates. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| British India | 5,312.25 | 3,912.25 | 9,224.50 | 15,245 |
| Ceylon | | | | 182 |
| Sumatra | | 90.00 | 90.00 | 90 |
| Java and Dutch Possessions | | | | 720 |
| Malay States | | | | 31 |
| China | | | | 85 |
| Japan | | | | 896 |
| Asia Minor | | | | 372 |
| Asiatic Russia | | | | 960 |
| Cochin China | | | | 525 |
| Totals for Asia | 5,312.25 | 4,002.25 | 9,314.50 | 19,106 |

*Section 5.—South America, Central America, and Mexico.*

| Countries. | Bowls and plates. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| Argentine Republic | 3,350.15 | 193.41 | 3,543.56 | 4,650 |
| Paraguay | | | | 90 |
| Uruguay | | | | 345 |
| Chili | | 1.00 | 1.00 | 1,650 |
| Peru | | | | 837 |
| Bolivia | | | | 43 |
| Brazil | 82.46 | 3.72 | 86.18 | 6,070 |
| Ecuador | | | | 94 |
| British Guiana | | | | 22 |
| Venezuela | 23.00 | 57.25 | 80.25 | 182 |
| United States of Colombia | | | | 164 |
| San Salvador | | | | 25 |
| Costa Rica | | | | 115 |
| Nicaragua | | | | 32 |
| Guatemala | | | | 105 |
| Honduras | | | | 37 |
| Mexico | | 77.00 | 77.00 | 5,000 |
| Totals | 3,455.61 | 332.38 | 3,787.99 | 19,461 |

*Section 6.—North America.*

| Countries. | Cross-ties. | Total metal track. | Total track. |
|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* |
| United States | 2.00 | 2.00 | 161,000 |
| Canada | | | 13,165 |
| Totals of North America | 2.00 | 2.00 | 174,165 |

*Summary of totals.*

| Section. | Longitudinals. | Bowls and plates. | Cross-ties. | Total metal track. |
|---|---|---|---|---|
| | *Miles.* | *Miles.* | *Miles.* | *Miles.* |
| No. 1 | 3, 637. 39 | 251. 68 | 6, 239. 85 | 10, 222. 09 |
| No. 2 | | 993. 75 | 296. 75 | 1, 290. 50 |
| No. 3 | | | 186. 00 | 186. 00 |
| No. 4 | | 5, 312. 25 | 4, 002. 25 | 9, 314. 50 |
| No. 5 | | 3, 455. 61 | 332. 38 | 3, 787. 99 |
| No. 6 | | | 2. 00 | 2. 00 |
| Total | 3, 637. 39 | 10, 013. 29 | 11, 059. 23 | 24, 803. 08 |

NOTE.—The use of longitudinals is being abandoned. The bowls and plates are mainly in service in hot countries, with special conditions of traffic, as in India and South America. The cross-ties are used under conditions of climate, traffic, etc., most nearly according to the conditions obtaining in this country.

*Percentage of metal track mileage.*

| | Total metal track. | Total track. | Percentage of metal track. |
|---|---|---|---|
| Section: | *Miles.* | *Miles.* | |
| No. 1 | 10, 222. 09 | 132, 071 | 7. 74 |
| No. 2 | 1, 290. 50 | 5, 202 | 24 80 |
| No. 3 | 186. 00 | 10, 640 | 1. 75 |
| No. 4 | 9, 314. 50 | 19, 106 | 48. 75 |
| No. 5 | 3, 787. 99 | 19, 461 | 19. 46 |
| No. 6 | 2. 00 | 174, 165 | |
| West Indies | | 1, 241 | |
| Total | 24, 803. 08 | 361, 886 | 6. 85 |

| | | |
|---|---|---|
| Total mileage of railway with metal track | miles.. | 24, 800 |
| Total mileage of railways of the world (exclusive of United States and Canada) | miles.. | 187. 721 |
| Percentage of railway with metal track (exclusive of United States and Canada) | per cent.. | 13. 21 |

# PART II.

# GENERAL REVIEW OF THE METAL TRACK QUESTION.

General Remarks.—In view of the information and statistics presented in this report, there can be no doubt that the use of metal track for railways has reached a stage beyond that of mere experiment, and that satisfactory results may be obtained with such track under certain conditions. Experience (under various conditions) has conclusively demonstrated the fact of the practicability of employing metal as a substitute for wood, for supporting the rails of railways. Not only has the practicability of using such track been shown, but also its advantages in economy, efficiency, and safety. That the experimental stage has been passed is shown by the extent to which this kind of track is in use, and its steadily increasing introduction. It remains now for us to profit by the experience already on record, making use of the improvements, modifications, and warnings suggested thereby in our actual practice. The main advantages presented by a good system of metal track are as follows: (1) Reduced expenses for maintenance and renewals, owing to the solid construction and the greater durability of the parts; (2) a better class of track, owing to improved fastenings, etc., and the fact that the road-bed is not torn up (as with wooden ties) for frequent renewals, so that it gives the best road with the least amount of work for maintenance; (3) increased safety for traffic, owing to the superiority of the fastenings over those used with wooden ties. Metal tie-plates and improved fastenings are being introduced in this country and abroad, to increase the efficiency of track on wooden ties, but the standard track of the future, for main lines with heavy traffic at least, will probably be laid with metal ties. It has been pointed out that the use of metal ties would have a beneficial effect on the iron trade, as the ties (except, perhaps, some lots imported for experiment) would be manufactured in this country.

In nearly all the principal countries of the world, and in many of the smaller countries, experiments have been made on a sufficiently large scale to enable reliable conclusions to be drawn as to the merits and demerits of the numerous systems of track which have been experimented with. It may be noted as of special significance that in Holland, a country without home manufacture of metal ties, but possessing ample resources of native and foreign timber at cheap rates, all the railway companies have used metal ties for a number of years, and that without pressure from the Government; the companies having considered this step to be in their own interest. Mr. Bricka, in his report to the minister of public works, France, in 1885, stated that the progress in this direction had been such that already some railways in Germany, Holland, and Switzerland had decided to abandon the use of wooden ties. In connection with the favorable opinions expressed by engineers in these countries, it is to be considered that in Switzerland and some parts of Germany where metal ties are used there are no iron or steel works, and, therefore, the fostering of a local industry had no influence on the opinions expressed, while Switzerland especially has plenty of timber. Mr. Post, in a paper written in 1885, stated that if, in comparing the costs of different systems of track, account was taken in each case of the different details (first cost, transportation, laying, maintenance, renewals, interest, selling price of old material, etc.) it would be seen that there are few countries where the exclusive use of wood for ties is really economical in the broad meaning of the word. This is specially evident as to hot countries where insects and atmospheric influences effect a rapid destruction of wooden ties.

In this country, railway men are very generally indifferent to this matter, or are waiting for a perfect tie to be brought to them. Among the reasons for this indifference has been the apparent abundance of our timber resources. But attention has now been drawn, especially by the Department of Agriculture, to the great destruction of these resources and the serious results of the denudation of large tracts of forest land. Other reasons have been the greater first cost of metal ties and the need of cheapness in railway construction. These considerations have some weight still, but on main lines, with heavy traffic, economical construction has become the main consideration rather than cheap construction.

A few practical experiments with different forms of cross-ties have been made and are now in progress. Other trials have also been made from time to time with a small number of ties, but these experiments are on too limited a scale to allow any definite conclusions and are generally conducted without much regard to practical results. If a metal tie could be designed and constructed that would meet at once all the requirements and answer all the objections, it would have a fair chance of being adopted. But it must be remembered that engineering is to a great extent the science of development. As the metal rail has been developed from the wooden rail, so has the metal tie been developed from the wooden tie. These developments have been by "trial and error," and it is practically an impossibility for a metal tie to be devised at once that will be successful in every way.

The ties that are now used with success in other countries are modifications and improvements of those first tried, and thus by degrees a really efficient tie has been obtained. In this country there have been discussed in the technical press various claims made by inventors for forms of ties existing only on paper or in miniature. It is probable that few of the ties designed and patented here have much real merit, as so many are invented by persons unacquainted with the requirements to be met or the conditions to be considered. Of the few that possess merit it may be said with reasonable certainty that actual trial will result in considerable modifications being made of the original design. Such trial may show that an apparently poor type of tie may be made valuable by some modifications, or that a tie of apparently good type is a failure in practice.

Among the requirements for a successful tie may be enumerated the following: (1) Heavy enough to hold the rails down well and make a firm track; (2) light enough to be of reasonable cost; (3) metal enough to stand wear and tear and give ample strength; (4) easy of manufacture, and requiring a minimum of shop-work; (5) not liable to lateral motion in the ballast; (6) easy to be laid, removed, or ballasted; (7) fastenings simple and efficient, with as few parts as possible, capable of adjustment for widening the gauge at curves etc.; (8) price such as to enable an actual ultimate economy to be shown to the engineers and financial officers; (9) proper quality of metal to sustain shocks without injury; (10) elasticity enough to give an easy-riding track. The following is a partial summary of the conclusions of the report made by Mr. Bricka in 1885:

(1) The ties should be of mild steel, to the exclusion of wrought iron.

(2) Ties of the original Vautherin type may be employed for sand and fine gravel ballast, but for coarse gravel or broken stone they should be without the bottom flanges. The Post and Berg-and-Mark ties are the best modifications of this type.

(3) They should be at least 8.2 feet long and 8.8 or 9.2 inches wide. The ends should be closed, but the use of extra cross-pieces inside is not necessary.

(4) The thickness should not be less than .28 or .32-inch, and should be at least .40 inch under the rail; it may be reenforced by a longitudal rib under the top table, or, better, by the Post system of rolling the rail-seat of extra thickness. The extra thickness must not involve unreasonable expense. The ties are rolled and punched.

(5) For flange rails the inward inclination is best given by an extra thickness of metal at the rail-seats; the use of tie-plates is considered preferable to bending the tie at the rail-seats.

(6) The weight should not be less than 110 pounds, but it has beeu proposed to reduce it below this reasonable minimum. A weight of about 121 or 132 pounds, or even more, is preferable for main lines.

(7) The best systems of fastenings for flange rails are the Ruppel system, used on the Prussian State Railways, and the Heindl system, of the Austrian State Railways; nearly all the bolt systems have given good results.

(8) The use of metal ties does away with use of the chairs for double-headed rails, and the combination of flange rails on these ties is simpler and less expensive.

(9) The price of the ties should not exceed $32 to $34 per ton, and that of the small material $50 to $70 per ton. (These prices are for France, 1885.)

(10) The life of metal ties is at least thirty years, or double that of oak ties. It can be shown that the use of steel ties weighing 121 to 132 pounds is not more expensive than oak ties when the latter cost $1.10 each and the former $32 per ton.

(11) The track on metal ties is as stable as but no harder than that on wooden ties, and it behaves better in case of derailment. When the track is established in good condition the labor of maintenance does not cost more than with track on wooden ties; it is probably more economical.

(12) The ties may be laid in ballast of any permeable material. A good splicing of the rail-joints is necessary with this form of track.

Mr. Bricka considered that engineers should make themselves thoroughly acquainted with results already obtained before introducing metal track for themselves. For careful comparisons of maintenance expenses he suggested trial sections of 6 or 9 miles, with varying conditions of alignment, profile, ballast, etc.; the expense of such trials would be small in comparison with the end to be attained.

Elasticity is necessary to make an easy-riding track and prevent any additional wear of the rolling-stock. Ties of polygonal or trough section, such as those of the Post and Vautherin types, are said to be especially elastic. The track on metal ties on the Central Railway of Switzerland is said to be even more elastic than that on wooden ties. It has been stated that a metal track would be too severe on the rolling-stock and too rigid for rapid traffic, but experience does not support this statement. In England trains run at a speed of nearly 60 miles an hour on metal track; on the European continent the speed varies from 37 to 45 miles per hour.

Rust is only experienced to a comparatively limited extent with wrought-iron ties and hardly at all with mild steel. It is mainly produced, as with rails, in damp tunnels or in cinder ballast, owing to the sulphuric acid and carbonic acid in the smoke and ashes. Wearing at the rail-seats, and longitudinal cracks at the same place, are not experienced with mild steel as with iron. The greatest probable trouble is from the wear of the holes for the fastenings, but this may be reduced to a minimum by proper construction.

Simplicity in design, manufacture, fastenings, and the arrangement of parts is especially to be aimed at, with due regard to practical requirements for strength, etc.; and the simplest system designed with such regard will probably give the best results in economy and efficiency. In some systems, however, this principle of simplicity has been carried too far, allowing no loose parts at all; the rails are either held by tie-bars with hooked ends or are sprung into place between fixed lugs or the ties are laid diagonally to let the rail fit onto its seat and are then shifted to their proper position, bringing the lugs to overlap the rail flange. Such methods may do for very light rails, but are hardly adapted for heavy traffic. With some forms of track special ties are required at curves; this is a very serious objection, as it not only increases the shop-work and expenses, but also makes more work and is likely to cause continual trouble in track-laying. All the ties, except those at frogs and switches, should be of precisely the same size and form, and adjustment of the gauge should be effected by means of the fastenings of the rails. In some European countries this question of simplicity appears to be a very secondary consideration, and there is a growing tendency towards the greater complication of the track by various forms of tie-plates, clamps, etc. The steel cross-ties of the Indian State Railway and the local railways of Belgium, however, make a track which is very simple in construction and which has shown its efficiency in actual service.

Metal ties will have a much longer life than wooden ties, and the old material will have a considerable market value. The actual life of metal ties has not been determined, as the older forms were not adapted to the conditions of modern traffic and rolling stock, and the newer forms have, as a rule, only been in service from five to ten years. Some of the older ties have been in service for fifteen to twenty-five years, as in Holland and Algeria. In Germany their life is estimated at between thirty and forty years, although on the Elberfeld division of the Prussian state railways it is not considered that they will last more than fifteen years, or the same time as the best oak ties. A life of fifty years is sometimes estimated, and it is possible that ties of good design and material and under favorable conditions may come up to this estimate. The steel ties now being tried on the New York Central Railway are estimated to have such a life. The life of rails, however, is said to be less when laid on metal ties than on wooden ties, owing to more rapid wear. Mr. Couard, of the Paris, Lyons and Mediterranean Railway, France, has compiled statistics showing this result, and similar results, but to a less extent, have been noted on the Northern Railway of Austria. The quality and character of the material of the rails, however, is a point of very great importance in consideration of this question.

The question of metal track was among the subjects considered at the International Railway Congress, in 1885 and 1887. The conclusions of the congress held at Brussels, Belgium, in 1885, were as follows:

(A) The congress is of opinion that tracks on metal cross-ties, considered from a technical point of view, can compare favorably with tracks on wooden ties, both for lines with heavy traffic and for lines with light traffic. The congress is also of opinion that the tracks on metal ties can also compare favorably with those on wooden ties from a financial point of view; but it is well in each particular case to make a comparison between the two types of tracks, taking into account the cost of materials, the cost of labor for maintenance, and the probable durability of the materials; the result of the comparison will show which type of track should be adopted.

(B) The congress is of opinion: (1) That for main lines with continuous and heavy traffic, and for strategic lines, it will be well to adopt a stronger tie than that for secondary lines, or lines with lighter traffic, at least for such of the latter tracks as are not likely to become main lines within a short time. For lines which are only secondary provisionally, the resistance of the track may be diminished until the line becomes a main line, by increasing to a certain extent the spacing of the ties. (2) That for secondary or light lines, it is well to employ ties lighter and less expensive than those adopted for main lines, lines with heavy traffic, or strategic lines.

(C) As to the most favorable form and dimensions to be adopted for a metal cross tie, the congress is of opinion that the results of experience, so far, are not sufficiently conclusive to allow of the recommendation of one type to the exclusion of others.

The opinions of the congress held at Milan, Italy, in 1887, were as follows:

(A) The opinion expressed by the congress of 1885, as to the relative merits of metal and wooden ties from a technical point of view, is not weakened by the experience of the last two years; and the use of metal ties is increasing.

(B) As to the relative cost of the two systems, taking into account the net cost and the durability, the result is a question of the type of tie, and depends entirely upon local circumstances and the state of the metal market.

(C) As to the maintenance expenses, for lining and surfacing, the question does not appear to be sufficiently demonstrated for lines with heavy traffic and fast trains. For lines with moderate traffic and slow trains the opinion of the majority is that the metal ties present advantages, especially after sufficient time has elapsed for the earthwork and road-bed to have settled to a good bearing and for the fastenings to have become well consolidated.

(D) For ties of the Vautherin or inverted trough type, it appears well to state that the use of a homogeneous metal is desirable.

The congress held at Paris, France, in 1889, arrived at the following conclusions:

While metal ties present many favorable and advantageous points, the experience with them has not been sufficient to justify any final decision in their favor against wooden ties. Recommendations were made that each management should select two trial sections, 1,640 to 3,280 feet in length, and lay one with metal ties and the other with wooden ties; both sections to have as nearly as possible the same conditions of grade, alignment, road-bed, ballast, and traffic. The trials should last long enough to enable definite conclusions to be arrived at. The special points to be considered and reported upon would be as follows: First cost; cost of maintenance; cost of renewals; approximate life of ties; effect on the rails; best types or forms of ties; general cost, taking renewals into account.

Mr. Bricka, chief engineer of the French state railways, estimated that at the end of 1884 there were 12,400 miles of metal track throughout the world, of which 6,200 miles were in Europe. The tables which I have compiled for this report show a total of 24,800 miles of metal track.

While the general adoption of any one form of tie can not be predicted with any certainty, yet the combination of heavy steel flange rails and steel cross-ties may be considered as the standard type of track of the future for main lines at least. At a meeting of the Cleveland Institution of Engineers (England), in June, 1889, Mr. Jeremiah

NOTE.—In a paper on "The Improvement of Railway Track," presented at a meeting of the American Society of Railway Superintendents in April, 1889, I called attention to the importance of the metal track question, and also suggested that the committee on roadway should consider, among other matters, the question of the advantages of steel ties for main lines with heavy traffic and for prairie lines, with the desirability of making any recommendations on this point as also on the question of metal tie plates on wooden ties. I have also discussed this question in a paper on "The Improvement of Railway and Street Railway Track," read at the annual convention of the American Society of Civil Engineers at Seabright, N. J., in June, 1889.

Head, M. Inst. C. E., the eminent engineer, prophesied that the standard track of the future would consist of 100-pound rails, laid on steel cross-ties.

Apart from its use for ordinary railway purposes, however, metal track is very extensively used for military railways; for light railways for general purposes, such as feeders to main lines, etc.; for street railways; for portable railways on plantations, etc.; and for contractors' temporary lines. Metal ties are also used in mines and collieries.

TYPES OF TRACK.—In considering the results obtained by past experience with metal track, the various forms already tried may be divided into three classes, as follows:

1. Cross-ties.
2. Longitudinals.
3. Bowls or plates, arranged in pairs and connected by tie-rods transverse to the track.

(1) *Cross-ties.*—This is by far the most extensively used of any of these types, and it has been more rapidly and more widely introduced and extended than either of the others. From this and from the results attending the trials under varying conditions, it may be considered that this is the most advantageous type, and will be the standard type for metal track. In saying this, it must be clearly understood that it is the *type* only which is referred to, as there are innumerable forms and patterns of cross-ties, with which various results have been obtained, as will be seen from this report. Track of this type has been tried in many countries and has proved satisfactory under conditions of the most widely varying character, from European railways with good road-beds and heavy rails, carrying heavy traffic, to prairie and hill country lines. It is especially significant that it has given excellent results and has been widely introduced under conditions of track, traffic, etc., which are practically similar to the conditions which would obtain in service in this country. This type of track has been so widely used that the various forms of ties can not well be summarized here, but some notes are given further on, and full particulars are given in the descriptions of the experiments made on different railways, as shown in Part I.

(2) *Longitudinals.*—This type of track is only used to a limited extent, and, as shown by special reports and other information, their use is not increasing. The construction of the track is more difficult and requires more labor than that with cross-ties. Maintenance, renewals, and repairs are less easily managed, and greater care must be paid to the ballasting and drainage. On the other hand, it has the advantage of giving the rails a continuous support, and, consequently, with a well-packed road-bed, would make a very smooth-riding track, but probably at a higher cost than an equally good track of another type. The construction of the road-bed and arrangement of the ballast involves con-

siderable care and cost, as, owing to the difficulty of drainage, special means have to be taken, by the use of courses of large rough stone or drain-pipes, to carry water away quickly. Longitudinals have been adopted for the city railway of Berlin, Germany, having been proved the best for reducing the noise of passing trains on this viaduct line connecting main lines of railway. It was originally thought that longitudinals would make a better and cheaper track, avoid shocks at the rail-joints, and, by their long bearing in the ballast, require less work of maintenance. Also, that lighter rails could be used with the continuous bearing. It is, however, difficult to maintain the ballast so as to keep a continuous and even bearing inside the longitudinal. The economy in material by the use of longitudinals is reduced or negatived by the necessity of using transverse connections of ties or tie-rods to hold the track together and maintain the gauge. This system is awkward on curves, and renewals are difficult. Each piece must be bent hot at the works, or have the holes for the rail fastenings made to fit a certain radius of curve. In a report on a derailment accident, in May, 1889, on the East Somerset Division of the Great Western Railway (England), the track of which was laid with bridge rails on longitudinal timbers connected by transoms, Colonel Rich, the government inspector, stated that it is difficult to know if longitudinals are thoroughly packed until the trackmen watch an engine passing over the places which have been under repair, as the stiffness of the rail and longitudinal keeps the latter level when it may not be properly packed with ballast underneath.

(3) *Bowls and plates* have been extensively used and have given good results, but only under certain conditions. They have been used in India, South America, South Africa, and Egypt. The bowls were originally designed for sand ballast, which answered very well; in India trouble was experienced from the sand flying up through the tamping holes and causing injury to the running gear and journals of the rolling stock, but a few inches of broken stone or brick reduced this trouble. With broken-stone ballast, however, this track did not answer well. In the Argentine Republic, where the surface soil or black loam is the only material available for ballast, the bowls have been used with great success; but even there steel cross-ties are now being introduced. The objections to the bowls in India led to the designing of a form of plates (Denham-Olpherts system) with which good results have been obtained. It is not likely that this type of track will be adopted to any extent. The type, however, is said to be the most economical in material, giving ample bearing to each rail and eliminating unnecessary metal between the rails. This may be correct under certain conditions, as with very light traffic, but under even moderately heavy traffic such track can not be as firm or stable as track in which both rails are securely attached to the same piece of metal. The transverse connection is necessarily imperfect, and does not insure the correct re-

lation of level of the two lines of rails. The track is relatively cheap, easily laid and maintained; the latter are important features in countries where skilled labor is not plentiful. Bowls were first designed by Mr. Greaves, and early experience showed that care was necessary to have the holes and attachments cast accurately as to size and position, and the holes in the tie-bars also accurately placed; carelessness in this respect has caused serious trouble on some roads in India.

MATERIAL.—The question of the material to be used for metal track is one of very great importance. Cross ties were at first made of wrought iron, but with the introduction of processes for making mild steel at a low cost this material began to be used, and has now practically superseded iron. The engineer of the Great Central Railway of Belgium, however, considers iron preferable. The steel used is made by the Bessemer, Thomas, or Siemens-Martin processes, and must be of a mild grade. This material possesses the qualities of homogeneity, malleability, and ductility. (As several translators have erred on this important point, I may mention here that "flusseisen" is the German technical term for "mild steel.") Mr. Post, of the Netherlands state railways, considers that the metal should be capable of resisting a tensile strain of 25.4 to 28.6 tons per square inch, with a minimum contraction of 30 to 40 per cent. The steel for ties of the Indian State Railway pattern, for India, for the Mexican Railway, and for the Santa Fé and Cordoba Great Southern Railway in the Argentine Republic, is specified to be equal to a tensional strain of between 26 and 31 tons per square inch, with a contraction of 40 per cent. of the tested area at the point of fracture. Mr. F. L. Delano, of the bureau of rail tests, Chicago, Burlington and Quincy Railway, states that he considers that the kind of metal which it would be safe to use depends considerably upon the shape of the tie; whether from its shape it sustains much flexure in use or is pretty stiff and rigid; for the shapes which appear likely to come into general use he thinks that a .25 per cent. carbon Bessemer steel would answer the purpose well, but that for ties which are liable to considerable flexure a milder steel would probably have to be used.

Mr. Bricka, in his report to the minister of public works (France) in 1885, stated that the tendency to fracture, which was for a long time considered as one of the fundamental objections to metal ties, had disappeared since the employment of mild steel; the ties do not break even in cases of derailment. In some such cases the damaged steel ties were straightened out to proper shape and put back in the track where they continued to give good service. As showing the malleability and ductility of the steel, he quotes a clause generally inserted in German specifications for mild steel ties, which explains the facility with which certain forms of ties requiring bending of the metals are made in Germany. Some engineers consider that the operations mentioned do not affect the strength of the tie, but Mr. Bricka thinks it doubtful if the metal does not suffer. The clause referred to is as follows:

A tie is to be flattened out cold under a steel hammer, and then bent double at the middle, so that the diameter of the circle at the part bent shall not exceed three inches. During the operation the metal must not show any break, crack, or lamination, but must remain intact.

In a note appended to his report and dated October, 1886, Mr. Bricka gives some interesting particulars of tests made on ties manufactured from hard steel, suitable for rails, showing that mild or soft steel is not so necessary as is generally believed. The tests were made at the St. Nazaire Works, with ties of the latest type for the Northeastern Railway of Switzerland, but with the top table .4 inch thick throughout. The drop tests were made with a tie resting on supports 3.508 feet apart, which sustained without breaking or cracking, successive blows of a ram of 660 pounds with heights of drop of 10 inches to 6 feet $6\frac{3}{4}$ inches; the final bends were only 6.08 inches. The pressure tests were as follows:

(1) Tie resting flat on an iron surface, the load applied through the flange of a rail. The tie sustained no sensible permanent deformation up to a load of 33,000 pounds; then the deformation began and continued steadily up to a load of 63,800 pounds; when the load reached 77,000 pounds the tie was flattened, but the metal showed no signs of failure.

(2) The tie rested on supports $19\frac{1}{16}$ inches apart and was loaded at the middle as before, but with the head of the rail; the load was raised to 35,000 pounds without permanent set; then the bending began, and with 44,000 pounds was .20 inch; under a load of 45,100 pounds, deformation began and continued until the tie was flat at the middle, the arrangement of the apparatus not permitting a bend of more than 6 inches. The upper table was then put into shape in a press and the sides bent till the tie assumed somewhat its original shape; the metal showed no cracks or other signs of injury. These tests show that ties of hard steel will support, like those of mild steel, the shocks of engine and car wheels in a derailment without breaking and without being made unfit to be continued in use, except temporarily. Hard steel would have the advantage of increased rigidity and would give, if proper care were taken in piercing the holes for the fastenings, almost a complete guarantee against distortion of the holes by wear.

In regard to the injury to mild steel ties in case of derailment, at least one railway in India has put up an hydraulic press for the purpose of bending to shape any ties that may be bent or distorted by such accidents. A thickness of .52 inch for the top table is considered to be sufficient to withstand the blows of derailed wheels. A cast-steel tie, known as the Sampan tie, has been patented in England. For longitudinals, wrought-iron is used almost exclusively, though perhaps mild steel may be employed to a small extent. Bowls are usually of cast-iron, but pressed steel has been used in India. The plates used in India are of cast-iron. Wrought-iron plates, bent to form practically bowls, have been used in Egypt. Cast-iron is generally considered unsuitable for such work, but it has been very extensively employed for bowls and plates in India, South America, and elsewhere, with satisfactory results and a low percentage of breakages.

FORM AND DIMENSIONS.—Different methods have been tried for giving the inward inclination of 1 in 17 to 1 in 26 of the rails, in accordance with the very general practice in most countries. Cross-ties were at first bent to a curve, but that resulted in a tendency of the track to rock if the ballast was packed too hard in the middle or not hard enough under the rails; the tie also tended to straighten, which thus widened the gauge. To obviate these objections, the ties were then made with the middle part horizontal and then bent up toward the ends, which bending could easily be done with steel ties: this was a great improvement, but the ties still had a tendency to rock under the trains. The horizontal tie gives the best results in stability of the track, and to allow it to be used, while avoiding the necessity for tie-plates, the Hosch Lichthammer plan was designed in Germany, in which advantage was taken of the malleability of mild steel, and the top table of the tie pressed to the desired inclination at the rail seat. In the Post tie, extra metal at the rail seat gives the inclination and adds to the strength. In the steel ties for the Indian state railways, which are stamped to shape, the top table is bent up at the rail seat in the operation of stamping. Mr. Bricka suggested, in his report, that it would be simpler to modify the shape of the rail-flange to give the rail the desired inclination. This idea has been suggested by other engineers at various times. Ties with the top table horizontal and with tie-plates to give the rail this inclination are used in Holland, Germany, and Austria, but generally add to the complicated character of the track. With longitudinals the inclination is usually given by tie-plates, or by tilting the longitudinal by means of packing pieces or saddles on the cross-tie connections. With bowls the rail seat is cast at the required inclination. In this country, where the rails are laid without such inward inclination, no bending or tie-plates would be required for this purpose.

The cross-section of nearly all the cross-ties employed to any extent is derived from the type invented by the French engineer, Vautherin, the first trials of which were made about twenty-five years ago, on the Paris, Lyons, and Mediterranean Railway (France). This type has a flat-top table, inclined sides flaring outward from the top and with narrow horizontal flanges on the bottom edges; it formed with closed ends an inverted trough filled with ballast. The flat-top table furnished a good seat for a rail flange, tie-plate, or chair, but the lower flanges were objectionable, reducing the stability of the track by preventing the proper settling of the tie in the ballast and not being wide enough to give any bearing in the ballast; this objection was not felt with fine sand ballast. To obviate this difficulty some engineers, including those of the Alsace-Lorraine railway and Wurtemburg state railways, in Germany, modified the original plan by substituting for the flange a rib of triangular section; this did not diminish the moment of inertia of the tie, but it protected the edges from damage by blows when being tamped. Another modification, forming what was known as the Berg-and-Mark type of tie (Prussian state railways), consisted in abandoning the bottom flange or rib, and bending the lower part of each side to a vertical position; this answered very well, the tie bedding itself well in the ballast and having less tendency to shift than if the sides were inclined for their whole depth. This again was modified by inclining the vertical part of the side slightly outward, the change in direction being made by curves instead of angles, and adding a rib to the bottom edges. In the Haarmann system the top table is comparatively narrow and the sides nearly vertical, with wide flanges at the bottom; the edges of these flanges are turned down slightly to retain the ballast. The ends are closed by riveted plates. Mr. Bricka, in his report, stated that the objections were, the difficulty of ballasting the raised part, the chance of breakage, and the less height for equal weight than ties with inclined sides. The Hilf type has a middle flange or rib along the under side of the top table. The Post type has the sides flaring out in two planes, the cross-section being a portion of a polygon. The Indian type is rounded, having a flat top and curved sides at the rail seat, and an arch section at the middle. The ties of these types on different railways vary of course in details of section, thickness, etc. The tie of the Standard Metal Tie Company, New York, and one tried on the Eastern Railway of France, are channels laid in the normal position with the open side upward; the bottom is flat and the sides are vertical in each case. The Bernard, Severac, Lavalette, and some other cross-ties are built up of angles, channels, beams, and plates.

The system of metal longitudinals includes the Macdonnell, in England; the Hartwich, Haarmann, Hilf, and Rhenish, in Germany; and the Hohenegger and Serres-and-Battig in Austria.

In regard to the thickness of the metal, this has been too often reduced so much, in order to reduce weight and cost, that the tie cracks or splits after being in service for a comparatively short time. It has been customary to make the metal of uniform thickness throughout the length of the tie, but Mr. Post's tie (Holland) has been designed to give an economical distribution of metal; the rail seats are of extra thickness to insure ample strength, additional metal is added at the holes for the fastenings, and the middle of the tie is made only thick enough to give the necessary strength and stiffness; these variations of thickness are given during the operation of rolling.

Mr. J. W. Jones, of the Indian state railways, writes as follows in regard to this point:

> Railway engineers would do well by refusing to have anything to do with ties which are only three-eighths inch thick; one-half inch thick give much better results and are cheaper in the end.

A thickness of 0.52-inch is now very generally used in Germany for the middle portion of the top table of the cross-ties. Experience on the Wurtemburg state railways (Germany) is said to have shown that an iron cross-tie with metal one-half inch thick stood an ordinary derailment very well without alteration of the gauge or any serious deformation, while ties in which the thickness of the body had been reduced to eleven-thirty-seconds inch, with strengthening rib, were so badly deformed by the same derailment as to require to be renewed. In his report of 1885, Mr. Bricka (France) stated that the thickness averaged about 0.32 or 0.36 inch, but was as low as 0.24 inch in the parts subjected to the least strain; at the rail seat it was rarely less than 0.32 inch, and was sometimes as much as 0.40 inch. The tendency has been to increase these dimensions, as it has been observed that under the passage of trains there is less vibration and noise with the heavier than with the lighter ties; and this stability, which causes greater economy of maintenance, is attributed largely to the extra thickness of the metal. Special advantages in stability and in maintaining a good bed or ballast under the rail seats are claimed for the Post and other systems in which the tie is made narrow and deep at the middle.

WEIGHT.—This is too frequently sacrificed to mistaken ideas of economy, with expensive results. In the first place, the metal must be thick enough to stand the shocks and vibration to which the ties are subjected in service without cracking. In the second place, the tie must be strong enough as a beam; otherwise it will give way and become distorted under the traffic. In the third place, the tie must have weight enough to hold the track down firmly, making it solid and stable. In several designs of ties the metal is very thin, the metal being strengthened by corrugations. The designers probably lost sight of the third requirement above mentioned or did not understand its significance. It is probable that the corrugations might in themselves be the cause of failure of the tie, cracks starting at the angles of the corrugations, as has been found to be the case in South Australia and elsewhere. The cause of these attempts to reduce weight is the eagerness of inventors to produce a cheap tie which will appeal to the financial side of railway companies. If the reduction in weight is carried too far, and a very little may be too far, the tie will be a dear one, as, even if it does not crack or otherwise fail, it will make a loose track, requiring continual attention and tamping, instead of effecting a reduction in maintenance. This point is briefly discussed in my remarks on Mr. Post's paper on "Steel Ties" (Bulletin No. III, page 35). It may be noted with advantage that in Germany it has been found generally desirable to use ties of greater weight than those first adopted, as the cost of maintenance was thereby reduced. In England too it has been found that a certain weight is necessary in order to give the tie a holding or anchorage in the ballast. This is the general experience elsewhere. These results of experience show that the various attempts made by inventors to reduce the material and weight to a minimum, without considering some imperative conditions, are not steps in the way of improvement, but tend to throw discredit on metal track in general and to render inefficient some forms of ties which might otherwise be of some merit. A very large number of failures of metal ties are due to too light weight.

The engineers of the Bavarian state railways consider that a weight of 139 pounds should be the minimum for ties for lines with ordinary traffic. Mr. Heindl, the inventor of the ties used on the Austrian state railways, considers 175 pounds the minimum under heavy traffic on main lines. In view of experience elsewhere, however, this seems to be too heavy. Both Mr. Post and Mr. Bricka consider that the steel ties of the Post type in use on the Belgian State Railways are too heavy, but I am informed that they were adopted on account of the great weight of some enormous locomotives which haul over these lines the "overland" train between Ostend and Brindisi. In a paper published in the bulletin of the society of civil engineers, France, April, 1885, Mr. Post stated that some engineers sent to England to examine the railways attributed too great an influence to the weight of the track, and arbitrarily condemned metal ties because they calculated that the wooden ties were heavier. But in order to give the correct value of this argument, it is necessary to know the actual weights of ties of different ages, and some lots of oak ties, taken at random from the tracks of the Belgian state railways and the Netherlands state railways, were therefore weighed. The new ties showed a variation of 42 per cent., the heaviest weighing 173.8 pounds and the lightest 99 pounds, or 11 pounds lighter than the 110-pound steel ties which had been in service for some years. Of the old wooden ties at the end of their service there was a variation in weight of 32 per cent., the heaviest weighing 114.4 pounds and the lightest 77 pounds, or 33 pounds less than the steel ties. The weight of the wooden ties diminishes materially with age, by losing the sap, etc., by which the width of the tie and the bearing of the rail are reduced, and the average weight is only 129.8 pounds for new and 99 pounds for old ties. These figures show the weakness of the argument in favor of wooden ties on account of their weight.

Mr. Bricka, in his report of 1885, stated that at first cross-ties had a weight of only about 77 to 88 pounds, owing to a desire for cheapness, but experience showed this to be insufficient. German and Dutch engineers have estimated that the work of maintenance is less with heavy ties than with light ones, and have increased the weight to 99 or 110 pounds. Ties weighing 129.8 pounds have been used on the Würtemberg state railways, 138.6 pounds on the Bavarian state railways, and 132 to 154 pounds on the Austrian state railways. According to the opinion of many engineers, flange rails on 110-pound steel ties make a very satisfactory track; superior to track on wooden ties. The standard weight might be between 110 and 132 pounds, and even the latter figure might be exceeded in exceptional cases of heavy and fast traffic. He comments upon the heavy Heindl ties used on the Austrian state railways, that the noisy, destructive, and unpleasant vibrations are not experienced with ties of sufficient weight. This is an important point, as the absence of such vibration tends to lessen the disturbance of the track and consequently the work of maintenance.

According to an article in the Indian Engineer, of Calcutta, August 1, 1888, ten ties—the usual number for a rail length of 30 feet—weighing 126 pounds each, will cost, at $30 per ton, or $1.68 each, $16.80; while by increasing the weight to 168 pounds per tie the ten ties would cost, at the same rate per ton, $22.50; but if the latter will last thirty years under conditions of traffic which will wear out the former in twenty years, the cost of material for the heavier track for sixty years will be $45 against $50.40 for the lighter track, or a saving of nearly $1,000 per mile, besides the saving in renewals and the advantage of a more stable track by the use of the heavy ties.

Ties open at the top and filled with or buried in the ballast have their weight in the track very largely increased. Of this type are the Severac, Bernard, and "Z" ties in Belgium; the channel tie of the Eastern Railway of France, and the "Standard" tie now being tried in this country.

Manufacture of Cross-ties.—Cross-ties of trough section are either rolled or stamped to shape. The wrought-iron and many of the steel ties are rolled, but large numbers of steel ties are stamped to shape in hydraulic presses from flat or bent plates. The steel ties of the Indian state railways pattern are made of plates rolled to the rounded channel section, which are cut into lengths; each length is then put into one press which shapes the ends, and then into another press which stamps the lugs for rail fastenings. The Phillips steel ties used in Queensland are stamped to shape from flat plates. Of the steel ties now being used in this country the "Hartford" and "International" ties are rolled, while the "Standard" ties are stamped by hydraulic presses.

There should be as little working of the metal as possible, as all such working tends to disturb the molecular construction of the metal and to reduce its strength. Annealing has been tried on the Netherlands state railways with success from a technical point of view, but the operation is generally too expensive.

In designing a tie its manufacture should be taken into account, as all handling and all additional shop-work adds considerably to the cost of its manufacture. Ties in which much riveting is required, as in the Webb tie in England, the Severac and Bernard ties in Belgium, etc., are not likely to come into general use. As has already been stated, the ties of the simplest form have the best chance.

In Germany and Holland, and probably in other countries, the contracts for metal ties contain a "guarantee" clause similar to the European contract system of guaranteeing rails. This clause requires the manufacturer to replace all ties which break or show defects during a certain term of years; generally three or five. This helps to secure better material and more careful manufacture, and any hidden defects which escape notice during inspection will almost certainly show themselves within the guaranty term.

PRESERVATIVE TREATMENT.—In some cases the ties are used as they come from the rolls or press; in other cases they are dipped in or painted with tar, oil, or some composition. The object of this treatment is to prevent rust or corrosion. In open line and in ordinary ballast there is not much danger of corrosion, but it is liable to occur in tunnels or damp places, and in slag or cinder ballast; this is due largely to the sulphuric acid and carbonic acid in the ashes, slag, and smoke. In a paper on "Steel Ties," by Mr. Munday, A. M. Inst. C. E., read before the Civil and Mechanical Engineers' Society (London), in January, 1888, it was stated that all ties should, if possible, be dipped while hot in a preservative solution. But as this can not be done with rolled ties without reheating them, the solution should be kept at boiling point by a steam coil. Rapid drying is an advantage obtained by dipping hot, as wet, dirty freight and the smell of the wet solution are objected to on board ship (for export), while in some cases the dock laborers have refused to handle the slimy metal sent down from the works. Pressed ties can be taken hot from the press to the bath, care being taken not to set fire to the inflammable mixture. If dipped cold it should be done some time before shipping, so that a sufficient quantity for a cargo may be stacked and dried. A solution recommended for ties and rails is as follows: Two gallons of boiled tar, one-half gallon of mineral turps, 1 gallon of vegetable oil. The tar is boiled first, and the other ingredients then well mixed in. The turps constitute the drier, and the larger the proportion of this the quicker the drying is effected; but as it is highly inflammable great care must be taken in dipping hot metal. The composition invented by the late Dr. Angus Smith (England) and well known by his name, is a solution of coal pitch in coal tar naphtha; it may be used as a paint or bath, and the metal should be hot. There is also a composition consisting of pitch and tar with a little tar oil and dry lime; rock asphaltum melted up and mixed with this gives body and sets hard like enamel. A black varnish solution is used for the steel ties of the Indian state railways pattern. The "Hartford" ties, on the New York Central Railway, are treated with Dr. Angus Smith's asphalt composition, applied at a temperature of 300 degrees Fahrenheit.

FASTENINGS.—In any system of track it is desirable to have as few separate parts, and as few different or special kinds of parts, as possible. An increase in the number not only increases the labor and cost of track-laying and maintenance, but it is the general experience of the perverseness of things that the right pieces are not at hand when wanted. The forgetting or delaying to send a keg of special bolts, clamps, etc., such as are sometimes required at curves or in other places, may seriously interfere with the work. In this respect the steel track of the Indian state railways, and of the local railways of Belgium, presents many advantages; the ties and two steel keys to each tie being all the material required on any part of the line. Where different degrees of adjustment of the gauge are effected by different sizes of clamps, washers, etc., the system is still more troublesome and complicated, but at the same time it must be remembered that with metal ties the fastenings are supposed to require far less attention than those with wooden ties. With a proper fastening there should be no vibration to cause noise, rattling, and wear; and experience has shown that such fastenings can be made. Where double-headed rails are used, they may be carried in special chairs, as on the London and Northwestern Railway (England), and the Western Railway (France,) or in ordinary chairs, as on the Midland Railway (England), the state railways, (France), etc. Little need be said on this point, as the double-headed or bull-headed sections of rails are never likely to be introduced into this country for regular service, and their use in other countries is comparatively limited.

The ordinary flange rails may be secured direct to the ties by different forms of fastenings, as follows:

1. Bolts and clamps.
2. Bolts, rivets, and clamps.
3. Keys.
4. Gibs and cotters.
5. Rivets.

(1) *Bolts and clamps.*—With many systems of metal track the fastenings consist of bolted clamps. The heads of the bolts are usually tee-shaped (⊥), so that they can be inserted from above, through a slot in the top table of the tie. The bolt passes through a loose clamp which holds the flange of the rail, and the nut is screwed down upon the clamp; a washer or nut-lock is usually interposed, but by the use of a grip thread on the bolt the nut-lock may perhaps be dispensed with, except under severe conditions of traffic, making four pieces less to each tie. The bolts are usually seven-eighths inch or 1 inch in diameter, and the nuts should be of ample depth, so as to give a large thread-bearing. Various forms of clamps are used; in some cases the clamp bears on the rail and the top of the tie, leaving the bolt to resist the thrust of the rail; in other cases, as in the Ruppel system, widely used in Germany, a lug on the clamp fits into the bolt hole in the tie, and so relieves the bolt. In the Roth-and-Schuler system, used on the Baden state railways and with the latest form of tie on the Netherlands state railways, a rectangular washer rests on the tie and transmits the thrust of the rail to the bolt, and a clamp holds the rail and keeps the washer in position. The advantage of a bolt fastening is that it gives a firm hold and can be easily slackened or tightened.

(2) *Bolts, rivets, and clamps.*—In some systems of metal track one side of the rail is held by a riveted clamp and the other by a bolted clamp, the latter being generally on the inner side of the track. This plan is in use in Queensland, Australia.

(3) *Keys.*—A fastening which has been found very efficient consists of a taper steel key driven horizontally between the rail flange and a lug on the tie or on a chair carrying the rail. The other side of the flange is held by a lug. The end of the key or wedge is split, so that it can be opened out or expanded by a chisel after it has been driven to a bearing, and so prevented from slacking back. This fastening is used with steel ties in Belgium, India, Africa, and Mexico, and has given excellent results as to security and noiselessness. A similar style of fastening is used with cast-iron bowl ties in South America, an iron, wooden, or coiled steel key being driven between the rail and a lug cast on the bowl; as the lug was liable to be broken, a loose lug of wrought iron or steel is now used, being inserted in a socket in the bowl; a cast-iron key is used and bears against the web and flange of the rail.

(4) *Gibs and cotters.*—Gibs held up to the rail by a vertical cotter driven into a slot in the top of the tie, were among the earliest forms of fastenings used in Germany; they did not then prove satisfactory, as the vibration jarred the parts sufficiently to loosen them, so that there was considerable noise and rattling under passing trains, while the jarring frequently resulted in the cracking of the tie. In India, fastenings of this pattern sometimes rusted together, so that they could not be moved without breaking them off; a fastening with cast-iron gibs was designed there, but never introduced to any extent. In Germany and Switzerland, improved fastenings are now used, with an extra gib to give a good bearing for the back of the cotter, and as the metal of the tie is thickened at the holes for the fastenings, there is no trouble from breakage; these improved gib and cotter fastenings are reported to give satisfaction. With the Denham Olpherts plate tie, used in India, there is a fixed lug or jaw on one side of the rail and on the other side is a loose jaw which is held in place by a horizontal cotter which secures the tie-bar.

*Rivets.*—Riveting the rails direct to the ties is only practicable for portable railways, but some systems of metal track have been designed in which riveted clips are used, the rails being sprung into position. A fastening described in "Les Annales des Travaux Publics," Paris, April, 1888, consisted of two rail clamps of eccentric form, riveted to the tie in such a way that they could turn on the rivet. The rail being put in place the clamps are turned round by a special wrench or bar, bringing the projecting part over the rail flange; when in position, a projection on the outer side of the clamp fits into a notch in a horizontal spring on the top of the tie. A somewhat similar plan of loose riveted clips has been designed by Mr. Moore for use with cast-iron ties in India.

Tie Rods.—With bowl or plate ties, transverse tie-rods or tie-bars are required, to hold the parts together and to maintain the gauge. Flat wrought-iron bars are generally used, placed on edge and passing into or through the bowl or plate; they are secured by gibs and cotters or by cotters only. These are used in India, Africa, and South America. In the De Bergue system, used in Spain, (and tried in India) the tie bar is underneath the bowls, being held by lugs and U-bolts. In the plate ties used in India, the bars pass through the upper part of the plate which forms the rail seat, and are secured by a horizontal flat cotter. On the Calcutta Port Railway, India, the tie bars are fastened to the rail flange by bolted clamps, being quite independent of the bowls.

With metal longitudinals, the two lines of longitudinals have to be tied together, and various forms of cross-tie connections have been used in Germany and Austria. In some cases T or angle-irons are used, while heavy cross-ties of the same section as the longitudinals have been used at the joints of the latter. These heavy connections, however, have been found to make the track too rigid, causing a battering of the rails at the joints and an increased wear of the rolling-stock. Tie rods are also used to maintain the gauge; they are tapped into or passed through the webs of the rails and secured by nuts; in some cases they are of round iron and in other cases flat with round ends.

Metal Contact.—A common objection is that metal track will be noisy and unpleasant to ride over, owing to the metal contact of the rails and ties. Various methods have been tried and suggested to obviate this, but where good fastenings which will keep tight are used, there is not found to be any necessity for such precaution. Mr. George E. Moore, deputy consulting engineer of railways, India, states that wooden packing, asbestos sheets, tarred canvass, etc., have been tried and found of no value. The Great Indian Peninsula Railway, after several years of experiment, has gone back to iron on iron, and finds the results quite satisfactory. It is principally a matter of getting the fastenings tight and keeping them so. Linoleum has been suggested in Belgium. With the steel ties of the London and Northwestern Railway, England, tarred paper, forming a tough leathery material, is used between the riveted plates. Some of the bolt-fastenings used are found to keep sufficiently tight, and with the key fastenings of the Indian State Railway steel ties and the Z-iron ties in Belgium, the fastening is found to be very efficient in this respect. On a section of the Northern Railway, Austria, where one track was laid with wooden ties and the other with metal ties, it is reported that the noise of the passing of trains was no more disagreeable with one system than with the other; showing that with metal ties and fastenings of good shape and proper weight no trouble from noise or vibration need be experienced. In several cases it is specifically reported that there is no trouble from noise or uneasy riding of the cars.

ADJUSTMENT OF GAUGE.—Where metal ties are to be applied to any great length of track it is necessary to provide some means for widening the gauge at curves, etc. With bowls this widening is effected by the use of different sizes of cotters in the ends of the tie bars; this has the objection of increasing the number of separate pieces required, but to obviate this Mr. Schwarz, of the Burrakur Iron Works, India, proposes to use cotters or keys made of different widths in "steps" or "offsets," so that one set of cotters will give the required variation in gauge. With longitudinals the adjustment is effected usually by means of the rail fastenings. With cross-ties, where bolts are used, the adjustment is effected either by eccentric necks on the bolts, as on the Netherlands state railways; by eccentric washers, as on the Baden state railways and Netherlands state railways; or, where the clamps have lugs fitting into holes in the tie, by means of rail clamps with different sized lugs, as on several German railways. With the first plan mentioned two sets of bolts are required, one for tangents and on curves, and the other at the extremities of curves, etc. The bolts are marked on the ends, so that the ordinary and special bolts can be easily distinguished, and in such a manner that the inspector walking along the track can see if the proper bolts are used and are properly placed. With the clamp fastenings on some of the German railways six sizes of clamps are used, and are distinguished by stamped figures: No. 0, on the outside of the rail, has no projection on the lug in the bolt-hole; No. 1, has a projection of one-twelfth inch; No. 2, one sixth inch; No. 3, one-fourth inch; No. 4, five-sixteenths inch; No. 5, five-twelfths inch. This makes a very complicated arrangement, and can only be successfully carried out where the trackmen and section bosses are carefully instructed and trained. In this country, with the class of labor frequently employed, it would almost certainly be a failure. Even with skilled labor such a system is not to be recommended, as under any circumstances the simplest arrangement possible, with due regard to efficiency, is the most desirable. With gib and cotter fastenings the adjustment is effected by using gibs of different widths. It is usually the outer gib and the small gib at the back of the cotter which are made in diffierent sizes. On the Elberfeld division of the Prussian state railways the outer gib is either $\frac{15}{16}$, $1\frac{1}{16}$, or $1\frac{1}{4}$ inches wide, and the small gib either $\frac{7}{8}$, $\frac{3}{4}$, or $\frac{5}{8}$ inch wide. The above remarks as to complication apply almost equally to this plan. With key fastenings the adjustment is effected by putting one or both of the keys on the outer side of the rail.

CLOSED AND OPEN ENDS.—In regard to the question of open or closed ends for cross-ties, the general and most approved practice is to close them. The reasons for this are apparent; a wooden tie when buried in the ballast presents an end area of about 5 by 8 inches or 6 by 10 inches, equal to 40 or 60 square inches, to resist the lateral motion induced by the passing of trains, especially on curves. Metal ties with closed ends offer a similar resistance, but an open ended tie presents only its thin cross-section, say one half inch by 14 inches, or 7 square inches, to resist this movement. Trough ties with closed ends offer in fact a much greater resistance to lateral motion, as not only has the outer end to push against the thickness of ballast beyond it, but the other end has to pull against the ballast within the tie and drag the entire core of ballast inside the tie over the ballast below it, which would require very considerable force, especially with broken stone. The ends of metal ties frequently project below the bottom of the body of the tie. Well packed and tamped ties of this kind will keep the track in good line. The open-end ties of the London and Northwestern Railway, England, are said to give no trouble in this respect; these ties are dipped in tar and then in sand, to give them a rough surface to increase the friction in the ballast, but it does not seem as though such a method would be very effectual. It seems only reasonable, however, that closed ends should give the best results. They may make tamping more difficult at first, but when once thoroughly tamped the track is very substantial. With some of the "International" ties used in this country, only half the end was closed, in order to facilitate tamping. The "Hartford" tie, on the New York Central Railway, has its ends bent below the bottom of the tie. The channel tie used on the Eastern Railway, France, has the bottom bent down, the channel itself being open at the ends. The "Standard" tie, on the Chicago and Western Indiana Railway, has the bottom cut loose from the sides at the middle and bent up inside the tie, which is filled with ballast, so that the resistance to lateral motion is at the middle instead of at the ends of the tie, a feature which is claimed to be advantageous on tracks with narrow width of ballast. The ends may be closed by a riveted plate, by stamping to shape while hot, or by cutting the top corners and bending the top table and sides cold.

Mr. Post, in his paper in the Bulletin of the Society of Civil Engineers, France, April, 1885, gives the following account of trials made to determine the efficiency of closed ends: A certain number of ties with closed ends were divided into three compartments, by riveting two plates on the inside of the trough; the two outer compartments were well ballasted, while the middle one was simply filled. An equal number of ties with closed ends were put in service at the same time. It was soon ascertained that the intermediate plates were superfluous, the ends affording all necessary resistance.

COST.—As to the cost of ties, while prices are given in several cases in this report, yet the prices of foreign ties are not of much practical value in considering the use of such ties in this country, as the conditions of the various foreign metal markets may differ so much from one another and from the conditions prevailing in this country. Mr. Post stated in 1885 that the cost of a good steel tie should not be more than 125 or 150 per cent. of that of a wooden tie. According to Mr. Meyer, of the Prussian state railways, iron ties weighing 110 pounds and costing $1.73 each, must last twenty-five years, in order not to involve an annual charge of more than 9.8 cents,* which is the average annual charge for wooden ties on German railways.

ECONOMY.—The economy effected by the use of metal ties lies in the great life of the ties, the reduction in maintenance expenses, and the higher value of worn-out metal ties over wooden ties. The economy of the metal longitudinals may be doubted, on account of the extensive preparation of the road-bed to secure proper drainage, and of the work of maintenance required to maintain free drainage. The Mexican railway "will feel the good results of its track with steel ties when the competition with the Interoceanic Railway begins, as the track will be kept in first-class condition at comparatively small cost, enabling the road to sustain a close competition." Mr. Katté, chief engineer of the New York Central Railway, estimates that the use of the steel ties now being tried on that line will effect an economy of 8 to 12 per cent. in renewals, repairs, and maintenance. (See also "Maintenance" and "Conclusion."

EFFICIENCY.—That metal ties act efficiently in making a good track has been conclusively and satisfactorily proved, while by the firm seat and secure fastenings the danger of accident from spreading of the track or overturning of the rails is very considerably reduced. The gauge is also maintained more accurately and the track is kept in better line and surface than track on wooden ties.

SPACING OF TIES.—The question of the spacing of the ties is one which should be given careful consideration, and the distance will depend to a considerable extent upon the character of the traffic. On a busy main line with fast and heavy traffic, the ties should be spaced closer than on a line with lighter traffic. The average is about 30 to 36 inches. To secure the best results and the most easy riding track, the ties should be spaced farthest apart at the mid-length of the rail and closest together at the rail-joints. Different arrangements of spacing of steel ties are being tested on the New York Central Railway.

TRACK-LAYING.—This work is generally very simple, except in the case of systems with complicated fastenings. The ties are sent out on the cars, with the fastenings in kegs, or in some cases where bolts are used, the bolts are put into the holes and the nuts screwed on, so that when the tie is put in the track the fastenings are all ready to be adjusted to the rail. With many forms of track the work can be efficiently done by unskilled labor, but it is of course always better to have experienced trackmen, or at least an experienced foreman to see that the work is done carefully and correctly. Careless or inaccurate work will cause subsequent trouble, which will tend to create a prejudice against the track. Poor work will reduce the good results which would otherwise

* This charge is figured even too low. See table for computing annual charges on p. 39 of this report. The metal tie, to be within an annual charge of 9.8 cents on first cost alone, must not cost more than $1.40.—B. E. F.

be obtained. A point to be considered is the grade of track labor available. In Europe the grade is, on an average, pretty high. An engineer who has made an inspection of the Panama Railway stated that if wooden ties had not been available and metal ties had been used, there would have been trouble with the fastenings and attachments, owing to the indolent and careless nature of the negro trackmen.

It is well to issue to the section men printed instructions as to track-laying and maintenance, illustrated, if necessary, by diagrams prepared with the special aim to make them clear and readily understood. The instructions should be clear, concise, and to the point.

BALLASTING.—Various materials for ballast are used for metal track on different roads. In Queensland, the Phillips tie is intended to be used without ballast, being packed with the surface soil of the country, and in South America the road-bed is carefully built up with the surface soil or black loam as ballast. For ordinary circumstances, such as would obtain in this country, gravel, slag, or broken stone may be used, but care must be taken to consider whether the material, especially slag, is likely to cause corrosion. (See page 26.) The ballast must be clean and free from clay, allowing free drainage. It is essential that the ballast should be thoroughly packed into the tie, and a little work with the tamping bar in the first place will save a good deal of subsequent work in maintenance. The material should only be packed hard at the ends and extending some inches in beyond the rail-seats, leaving the middle of the tie only loosely filled; if the middle is packed hard and the ends not carefully attended to, the tie will have a tendency to bend or "hog," and cause an unstable track. In some cases the ballast is laid in two rows of heaps; one tie is put across each pair of heaps and an engine run over the track forcing them down into the ballast, which is then packed and tamped and loose ballast filled in between the rails. The ballast should generally be flush with the top of the tie; in some cases it is filled in over the tops of the ties, and this practice is carried out with the London and Northwestern steel ties on the Pennsylvania Railway, which are covered with fine broken stone. Particular attention should be given to keeping up the road-bed for the first few months, until the ballast under the ties becomes well consolidated; this work should be charged to construction rather than maintenance. The objection has been made that it is difficult to tamp and pack the hollow ties generally used; experience has shown, however, that while it presents some difficulty at first, yet the ballast, being confined within the tie, is soon compacted by the passage of trains, and requires little subsequent attention. The saving in the quantity of ballast required is shown by the official figures given for the Western and Simplon Railway, Switzerland.

RENEWALS.—With cross-ties, bowls, or plates, renewals are as a rule easily effected, but with longitudinals the work is more difficult. In most cases the fastenings of any one tie can be removed, the ballast dug away, the tie dropped from the rail and removed, and a new tie put in place. Where, however, as on some railways in India, the rails have to be tilted to get the flanges under the lugs when being laid, all the fastenings and both joints of one rail must be removed and the rail tilted and taken out; the free end of the tie can then be raised until the opposite end can be slipped off the rail. In some cases the lugs can be pried back to free the rail flange, and in other cases both rails may be required to be taken out. Renewals of mild steel ties are expected to be very few; the material does not rust to any extent, does not wear under the rail, and is not liable to crack at the holes. Of ties laid on the Netherlands State Railways in 1865, the renewals up to 1887 were only 5 per cent. One of the great advantages of a metal track is that it is not disturbed frequently by renewals, and is thus left in good condition for running.

MAINTENANCE.—It is generally found that the work of maintenance for metal track, during the first two to four years, is as much as, if not more than, that for track in wooden ties; after that period, however, the work becomes less and less, as the track gets well settled together, the fastenings firm, and the ballast consolidated, while with wooden ties the work increases year by year until renewals are necessary. The fastenings being secure, do not require constant watching and frequent attention as with spikes in wooden ties; and an occasional surfacing of the ballast and inspection of the ties and fastenings is all that will be required; nor will, as stated, the frequent disturbance of track for renewals be occasioned, as is the case with wooden ties. It is estimated that on the Algerian lines of the Paris, Lyons, and Mediterranean Railway, the adoption of metal ties has effected a saving of one-fourth of the maintenance work, or $62 per mile per annum. According to Mr. Post, the cost per mile allowed on some of the German secondary railways in 1885, for the renewal of steel ties, was only about one-sixth of the sum for replacing old wooden ties per mile per annum. The amounts were deduced from the statistics of the Rhenish Division of the Prussian State Railways, which has been using metal ties since 1868.

One of the division engineers of the Netherlands state railways, in his annual report for 1884, stated that in order to make a test of the metal track (Post ties), he left one of the trial sections, having a grade of 1 in 83 and a curve of 2,460 feet radius, near Glons, Belgium, for twenty-two months (February, 1883, to December, 1884) without lining or surfacing, only employing one man for thirty-four days' work to inspect and tighten the nuts; the traffic over the line was very heavy, but the track was in good condition at the end of the test. On this division the cost of maintenance per mile of track on steel ties, after three and one-half years' service, was the same as of track on oak ties, but at that time the maintenance expenses of the former commenced to decrease, the track being by that time firmly settled, while it would begin to increase with the oak ties. In Germany the cost of maintenance has been found to vary from \$38 to \$360 per mile with longitudinals, and from \$47 to \$107 per mile with cross-ties; the road-bed, ballast, and class of track cause these great differences. On the Rhenish division of the Prussian state railways, the work of maintenance per 100 miles in 1879, was two hundred and seventy-one days' work for track on wooden ties, two hundred and nine days' work with metal longitudinals (23 per cent. less), and 164.5 days' work with metal cross-ties (35 per cent. less).

For the calculation of the annual cost for maintenance and renewals, the following points must be considered:

(1) Annual interest on first cost.
(2) Annual sum laid aside for depreciation.
(3) Value of old material, lessening the depreciation.
(4) Cost of labor in renewals.
(5) Cost of rail fastenings.
(6) Cost of maintenance of the road-bed.
(7) Influence of the track upon the life and repairs of rolling stock.

FROGS AND SWITCHES.—With metal track, wooden ties are very generally used at frogs and switches, but metal ties can as well be used and will give a safer track. These metal ties will cost rather more than the ordinary metal ties, on account of their greater length and weight, and the extra number of holes required. The work of track laying will also be more expensive than the mere spiking of rails, guard-rails, and frogs to wooden ties. But when once well laid and tamped, the track put in good line and surface, and the fastenings tightened up a few times until they take a good bearing, the maintenance of such parts of the track will be light, while the safety will be very considerably increased. Metal ties are in use at frogs and switches in Germany and Switzerland, and their use is to be specially recommended, as at these points the track requires to be kept in excellent condition.

RECORDS.—It is very desirable, wherever metal ties are placed, either for a small experiment or with a view to general adoption of the system, that careful records should be kept of the date of laying, construction of the track, amount of traffic, amount of work done and money spent, notes of inspection, results observed, etc., so that it may be seen if the track is satisfactory and economical. In this way an intelligent idea may be obtained as to the general results of the experiments, from a financial and technical point of view. For convenience in keeping notes, some plan of numbering the ties might be adopted, reckoning between mile-posts, by which individual ties could be located and identified in case of breakage, renewals, tests of different fastenings, etc.

TIES MADE FROM OLD RAILS.—Several devices have been patented for the utilization of old rails for ties, but it does not seem probable that they will be used to any extent. In the first place, it is doubtful that the supply of old rails would be at all adequate to the demand, as rails rejected from main tracks may be safely used for side tracks, and are often so used until very badly worn. The uneven wear of the rails would be an objection in some of these devices, and in others the amount of shop work is quite considerable, entailing an expense which is perhaps overlooked when economy is claimed. Cross-ties of this class have been tried in France and Germany, and longitudinals rolled from old rails have been tried on the Northwestern Railway of Austria. Old rails are proposed for the manufacture of the Durand tie in this country. Where the rails are to be worked and submitted to such treatment as rolling into plates and stamping into shape, it may be doubted if the metal would stand this working successfully, or make a safe and durable tie. It would be especially likely to crack at any corrugations, corners, etc., and at any welded parts; this has been the experience in Austria. There might be a limited field for the use of such ties on lines with light traffic, but it is not probable that they would prove efficient, safe, or economical on main lines and under heavy traffic. Any apparent cheapness in first cost would probably be entirely covered by additional work upon the track.

COMBINATIONS OF WOOD AND METAL.—A very large number of ties have been invented in which blocks of wood are placed under the rail as bearing-blocks, and many inventions of this kind will be found in the list of United States patents accompanying this report. The object is, of course, to combine the elasticity of the wood with the strength and durability of the metal; but the weight of experience seems to show that the combination, or the method of obtaining it, is unnecessary or undesirable. Metal ties can be made which will be in themselves sufficiently elastic, and fastenings can be made which will hold the metal surfaces of rail and tie rigidly together. The use of wooden bearing-blocks has been found unsatisfactory in France, Holland, and India. In regard to the metal ties with wooden bearing-blocks tried on the Eastern Railway, France, Mr. Bricka stated in his report, in 1885, that results obtained with ordinary fastenings did not justify the interposition of a block of wood between the rail and the tie, and that it was probable that there would be a play of the pieces after a time. The "Standard" steel tie, in this country, in experimental service on the Chicago and Western Indiana Railway, is of this class; but it differs from the ordinary plan in using blocks of preserved wood, which are compressed before being used, and are placed with the rails resting on the end grain. The claims made are that the preservative process will prevent rotting of the wood, while the compressing and manner of placing will prevent flange cutting. By this compression, the block of wood would be practically as rigid as the metal, but it is of course less vibratory.

TIE PLATES.—A method extensively employed in Europe, and recently in this country, to increase the durability of wooden ties, is to use metal plates between the rail and the tie. This method is extensively adopted in Germany.

The use of metal tie-plates with metal ties adds considerably to the cost, and while they may be of some benefit for ties of light section, yet as a general thing, with ordinarily heavy ties, it is found better to place the rail directly upon the tie, as this plan with good fastenings is less liable to cause noise and rattling. Tie-plates on metal ties are used in Germany and Austria.

GLASS TIES.—Glass ties were made by Dr. Siemens in Germany some years ago, and were reported to have given excellent results as to strength. At a meeting of the Cleveland Institution of Engineers, England, in June, 1889, during a discussion on rails and railways, the president stated that some years previous a number of glass ties had been put down, and the inventor had recently informed him that they were still in service. The reason why they do not generally find favor, he stated, is not that they fracture, but because they were very expensive and there was a difficulty in attaching the rails to the ties.

## RACK RAILWAYS.

For rack railways which are to carry ordinary traffic, and which form part of through lines of railway and are not merely lines for excursion travel, steel ties are generally used, as they give a more secure and stable track. Mr. Rinecker, M. Am. Soc. C. E., of Germany, who contracts for the construction of rack railways on the Abt system, stated as follows in a letter acknowledging the receipt of Bulletin III, with my preliminary report:

> I fully concur with the views expressed by Mr. Tratman. Being engaged in the construction of rack railways, I am using only steel ties, on account of their reliability in keeping gauge and of their better hold in the ballast against sliding down grade. Where steel ties fail it is on account of errors in shape or size.

## MILITARY RAILWAYS.

Light railways for the conveyance of supplies, etc., are much used in Europe at arsenals, fortifications, etc. The majority of these lines are of the portable type, made in sections, so as to be readily and rapidly laid, removed, and relaid. In France very heavy cannon are transported over such tracks; special cars being used to distribute the weight over a number of wheels. In Germany tracks of this kind are used in field-work and manœuvring. The English army in the Soudan campaign had a light railway at Suakin, and the Italians have also a line, but of a more permanent type, in Africa. In the Turkestan war of 1883 the French army had 66 miles of portable railway, 20 inches gauge, with steel rails, weighing 14 pounds per yard; the track was of the Decauville type. In the Tunis war of 1883 the French army had 43 miles of similar track, but with 24 inches gauge and with rails weighing 19 pounds per yard; this was found to be the more suitable and efficient track for the purpose.

## LIGHT AND PORTABLE RAILWAYS.

A class of railway with metal ties which is much used in Europe and in countries where work is carried on by European engineers, is that of light and portable railways. They are of various classes, from the permanent line of 42 inches gauge, operated by locomotives and adapted for country railways, feeders to main lines, etc., down to the really portable lines of 12 inches gauge, operated by horse, mule, or bullock power, and adapted for plantation and contractors' work, etc. Railways of this kind would not only be beneficial by means of the advantages possessed, but would also effect an appreciable saving in wooden ties of the small and cheap kind. The track is made in sections of convenient length, built up at the manufactory, which have merely to be carried by one or two men to the required site, laid end to end, and connected, to form a track capable of carrying considerable traffic. One man can carry a section of the lighter portable class. For the more permanent lines some amount of grading and ballasting is desirable. Curves, switches, etc., are all made in sections, as well as the straight track, and the lines can be laid by unskilled labor. Several firms in Europe have extensive works engaged in the manufacture of track, appurtenances, and equipment for this class of line. English prices a few years ago varied from $1,450 to $1,550 per mile of single track, straight line, of 16 and 24 inches gauge, suitable for animal traction; and from $2,500 to $2,700 per mile for lines of 18 and 30 inches gauge, suitable for locomotive traction. In the well-known system of the Decauville Works, France, light steel flange rails were riveted to steel ties of channel section. (See France.) In England various forms and modifications of this class of track are manufactured by the following firms: Dick, Kerr & Co., Kerr, Stuart & Co., Bolling & Lowe, J. Fowler & Co., W. G. Bagnall, J. & T. Howard, the Darlington Steel and Iron Company, and others. (See England and France.) A form of the Post steel cross-tie is manufactured by the Hoerde Works, Germany, for light railways of 24 inches gauge. The ties are of the usual form, except that the lower part is horizontal and the increased depth at the middle is obtained by bending up the top table. They are 33 inches long, 4 inches wide, and 1 inch deep at the ends, 2.24 inches wide, and 2.2 inches deep at the middle; the thickness is .16 inch, and .24 inch at the rail seats. Some of the ties are of uniform section throughout. The rails are of flange section 6.56 feet long; they are secured to the ties by hook-bolts, the nut being inside the tie. Projecting splice plates are riveted to one end of each rail. Each section of this track consists of two rails, three ties, and four splice-plates; the weight of the section complete is 88 pounds. For further particulars of these railways, see an article of mine on "Light and Portable Railways," in Engineering News, New York, September 6, 1884.

STREET RAILWAYS.

In European practice the use of wood in street railway, or tramway, tracks has been very generally abandoned, especially in the cities. For city streets, the track usually consists of grooved steel rails resting on cast-iron chairs or steel cross-ties or longitudinals. A concrete foundation is almost invariably used for such streets, and quite frequently for suburban and country roads. This system of construction is also adopted by English engineers in other countries, as at Honolulu, Hong-Kong, and Buenos Ayres. Similar systems are being introduced in this country, but to a comparatively limited extent, the style of track with flat rails spiked to wooden stringers resting on wooden cross-ties being still the ordinary practice. Notes on street railway tracks and descriptions of different American and foreign systems of construction will be found in my paper on "The Improvement of Railway and Street Railway Track," read at the convention of the American Society of Civil Engineers, in June, 1889.

CONCLUSION.

In this report information has been given, as shown by the tabular summary, covering experience on nearly 25,000 miles of metal track on railways in foreign countries, or 13.21 per cent. of the total mileage (187,721 miles) of the world, exclusive of the United States and Canada. This percentage is steadily increasing, as indicated by the reports from several railways, in which it is stated that metal ties are being substituted for wooden ties, either in large sections of track or by replacing wooden ties with metal ties as renewals are required. In the face of such figures, based upon official returns and statements, it can no longer be claimed that the metal track question is still upon an experimental basis. The official returns from some countries—Germany, Switzerland, and India, especially—show that the results of experience extending over several years have led in several cases to the adoption of metal track, and that this is becoming the standard track of railways in those countries.

In regard to the statements which have appeared in print from time to time, to the effect that the use of metal ties in Germany has been unsatisfactory and is being abandoned, I may refer to the official statements in this report from the leading railways in that country. These statements show that the results have been sufficiently satisfactory to lead to the entire adoption of metal ties on some lines and their continued and extended use on other lines. The only instance in which they have been abandoned is on the Altona division of the Prussian state railways, and there, as stated in the official return, the reason has been in the nature of the road-bed, etc., rather than in the ties. The agitation made a few years ago by the iron industries in Germany, asking for the increased use of metal ties, only showed that the Government was not putting in these ties on its lines in sufficient quantity to suit the iron trade people, and not that the use of metal ties was being discontinued.*

The most extensive introduction of metal track has been in Germany, India, and South America. In the first two countries steel cross-ties are practically the generally adopted type, although different forms of this type are in use in Germany. Cast-iron is still extensively used in India. In South America the metal ties used are mainly composed of a pair of cast-iron bowls connected by a tie-bar, but even there steel cross-ties are being introduced. The weight of evidence and the results of experience point towards the steel cross-tie, as making the best track and giving the best results in other ways, for heavy service at least, and therefore are destined to become the standard tie for first class track. As to the weight of these ties, it may be considered that for lines with heavy traffic it should be between 120 and 150 pounds, according to traffic and other conditions.

The following brief synopsis will give a general idea of the widespread use of metal track:

*England.*—Steel cross-ties are being tried on a practical scale on the London and Northwestern Railway and the Northeastern Railway. Experiments on a small scale have been made on other roads.

*France.*—Trials with different forms of cross-ties are in progress on the state railways. Five of the principal companies have also made experiments, and some of the trials are still in progress.

*Holland.*—Extensive trials of iron and steel cross-ties have been made on the Netherlands State Railway. The use of the Post steel tie is being extended. Other roads are also using metal ties.

*Belgium.*—The State has directed the carrying out of extensive trials of metal ties, and the trials are now in progress. The Northern Railway and Great Central Railway are also using metal ties. They are being adopted on some of the local and narrow-gauge lines.

*Germany.*—On the several state railways extensive trials with metal ties and longitudinals have been in progress for several years, and several hundred miles of metal track are now in service. The use of longitudinals is being abandoned, but the use of cross-ties is rapidly extending, and on some lines they have been entirely adopted. On the whole the results have been very satisfactory.

*Austria and Hungary.*—Two principal systems of metal track are in service. The Heindl system of cross-ties and the Hohenegger system of longitudinals.

*Switzerland.*—Metal ties are in service to a considerable extent. The results have been satisfactory and the use of these ties is being extended.

*Spain.*—Steel cross-ties are in service on a narrow-guage railway, and cast-iron bowls on a broad-gauge railway.

*Portugal.*—An experiment on a small scale has been made on the state railways.

*Italy.*—No metal ties are in regular service, but a few have been imported for experiment.

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*Objections to the use of metal ties in Germany come also from the forest administration, for the reason that the market for one of its staple products, beech railroad ties (creosoted), which have been grown in excess, has been limited by the substitution of metal, and hence an unfavorable showing on the balance sheet of many forest districts. Unlike the conditions in our country, in Germany a proper forest policy does not require this substitution —B. E. F.

*Sweden.*—A few steel ties are in service for experimental purposes on the state railways.

*Norway.*—No metal track has been tried.

*Denmark.*—Steel ties are in service on the state railways. The results are fairly satisfactory.

*Russia.*—Experiments have been made on a small scale, but have apparently been abandoned.

*Turkey.*—Several miles of track near Constantinople are laid with metal ties.

*Africa.*—In North Africa cross-ties are in use in Algeria and Egypt, and bowls in Egypt. Bowls and cross-ties are in use in South Africa. Steel cross-ties are reported as to be used on the projected Congo Railway.

*Australia.*—Steel ties are being used quite extensively in South Australia and Queensland. In the latter colony the track is of a type designed especially for cheap construction of railways in even country.

*New Zealand and Tasmania.*—No metal track is used.

*India.*—Metal track is in very extensive use and is being constantly laid. Cast-iron bowls are becoming obsolete, but cast-iron plates (in pairs, connected by tie-bars) are largely used and with satisfactory results. A special form of steel cross-tie is in extensive service on the state railways and other lines, and seems likely to become the standard form of track. It has given very good results.

*China.*—A few metal ties are to be tried as an experiment.

*Japan.*—Metal ties were used some years ago, but they have all been taken out.

*South America.*—In the Argentine Republic cast-iron bowls are very extensively used and with satisfactory results. Steel cross-ties are also beginning to be introduced. Limited trials have been made in Brazil.

*Mexico.*—Steel ties similar to those now adopted in India for the state railways are in service on the Mexican Railway. The results have been very satisfactory.

The principal point of view from which the metal track question is considered in this country, and the one which was of course specially taken by the Department of Agriculture in calling for the preparation of this report, is that which considers it in relation to forest conservation and the reduction of the consumption of timber. But there are other points of view, from which the subject will be presented in rather different relations. Leaving out of consideration the necessity for reducing the timber consumption, metal track will still present many advantages, which will be especially apparent to railway men. In the first place, it has been proved to be more economical in maintenance than track on wooden ties, and there can be no doubt as to the superiority of a well designed system of metal track in regard to efficiency and safety. A better track may be made, and with such secure fastenings as are in general use, there will be a minimum of danger with a minimum of track work for the running of trains. The overturning or spreading of the rails, which causes so many accidents, can scarcely occur with a well designed system of metal track. There need be little if any extra noise with the passage of trains, and the riding of trains may be as smooth and quiet as on track with wooden ties. In general it may be stated, that steel ties should be adopted as the standard for first-class track on lines with heavy traffic. Steel ties should be introduced as an advancement in railway engineering, and as a step towards practical economy. A good metal track, when once well laid and settled, is in itself a measure of safety and a source of economy in maintenance and operation. This is in relation to the main line, but metal track presents also special advantages for use at stations and yards. A metal track at such places, when once well laid and settled, is practically permanent, and there is a great reduction in disturbance and expense for repairs and in the chances for derailments, which are specially troublesome at terminals, yards, stations, etc. Metal track is also adapted for light and portable railways, street railways, etc.

As regards the relations of first cost and economy, Mr. Walter Katté, chief engineer of the New York Central and Hudson River Railway, has estimated and closely calculated that if the steel ties now being tried on his line last for fifty years, which he estimates as their life, there will be a relative economy of from 8 to 12 per cent. in favor of these ties. The economy is in renewals, repairs, and general maintenance. I have examined Mr. Katté's figures, and have calculated that even if the life be taken as only thirty-three years, there will still be a material saving per mile per annum.

I am particularly pleased to be able to show in this report that this subject is being practically considered and tested in this country, some fairly extensive trials being now in progress. From the results of several years' experience in foreign countries, it can not be doubted that it is entirely practicable to successfully introduce metal track into the United States. American ingenuity and skill will probably produce ties of equal or greater efficiency than those in use in other countries.

This report will show, I think, to railway financiers as well as to practical railway men, the advantages attending the use of metal track. In regard to the desirability of introducing such track, I quote as follows from an interesting letter to me from Mr. C. P. Huntington, of the Southern Pacific Railway Company, in January, 1890:

> I have for several years advocated the use of metal ties along the timberless regions of our lines, and while none of them have as yet been put in use, I think they will be given a trial in the near future. You have no doubt experienced that time and considerable patience is necessary to direct the minds of men into fields of investigation differing from those in which they have been educated, and in the practice of which they have spent a large part of their lives. To this fact I attribute much of the apathy manifested in giving metallic ties a trial; but now, as their merits and those of the various designs in use are being discussed by American writers and engineers, there will be a quickening of opinion about them, which is likely to make them in the next few years a factor of some importance in the discussion of railroad economies.

This report certainly shows the practicability of the matter and its desirability from several points of view. It may fairly be reasoned that what has been successfully accomplished abroad may be accomplished with equal success in this country. I have reported with pleasure that more and more attention is being paid to this matter, and that since the presentation of my preliminary report in February, 1889, really practical trials have been instituted. It is my wish that the present report may prove of some service in keeping alive and increasing the present interest in the matter, and that it may prove instrumental in furthering the practical work in this important direction.

Finally, while I can not predict any general or extended movement in this direction in the near future, I can certainly state that there has been a marked advance within the last year or two, and that this advance appears likely to continue. I think it highly probable that the question of the use of metal ties for railways as a substitute for wooden railways will gradually, steadily, and surely become one of the live problems of railway economics.

# PATENTS RELATING TO METAL RAILWAY TRACK.

BY E. E. RUSSELL TRATMAN.

The following list of United States patents relating to metal railway track and other substitutes for wooden ties will be found useful by persons interested in the subject. It could not practically be made anything more than a descriptive index, giving sufficient information to enable any one who wishes to investigate more fully to form some idea of the different types patented, and to find the specifications.

No. 1262; date, July 26, 1839; J. Stimpson.—Transverse frames resting on longitudinal timbers, with inclined braces to hold them in position, and sockets at the top to receive the web of a rail with a very narrow flange.

No. 7799; date, November 26, 1850; H. H. May.—A cast-iron column under each rail; broad circular base; top formed to make a chair for a double-headed rail, and having a projecting arm forming half of a transverse tie-bar.

No 16898; date, March 24, 1857; H. Carpenter.—A short hollow post under each rail, connected by a tie-plate; T-shaped fastening fitting into hollow of post. (See Nos. 35198, 99531.)

No. 18494; date, October 27, 1857; S. A. Beers.—Continuous longitudinal structure, with transverse tie-bars. Saddle-rail of section.

No. 19704; date, March 23, 1858; S. H. Long.—Cross-ties of channel section or T section (the latter made of two angle-irons.) Continuous flat plate under ordinary rail.

No. 20620; date, June 22, 1858; W. Bryent.—Combined longitudinal grooved rail and iron pavement.

No. 29693; date, August 21, 1860; Alexander Hay.—A deep support to be driven into the earth under each rail; either flat or twisted into a spiral; flat head, with chair to support rail.

No. 32794; date, July 9, 1861; B. C. Smith.—Wide longitudinal channel sleeper and rail combined, with transverse rods. A raised rib lengthwise of the sleeper forms the rail. (See No. 36579.)

No. 35198; date, May 6, 1862; H. Carpenter.—A cylindrical casting with a wide rectangular base is under each rail; the pairs connected by transverse tie-bars. The flange rails are held in chairs, the bottom of which fits into the cylindrical casting or embraces it like a cap. (See No. 16898.)

No. 35879; date, July 15, 1862; Herman J. Lombaert.—A continuous metal stringer is laid on wooden cross-ties; the flange rails rest on metal tie-plates with one end bent to a hook to hold one side of the flange of the rail. The other side is held by a gib and cotter. Object, to separate the wearing and bearing parts of the rail.

No. 36579; date, September 30, 1862; B. C. Smith.—Longitudinal cast-iron continuous bearing, of channel section, connected by transverse tie-rods. Rail secured to chairs. (See No. 32794.)

No. 38274; date, April 28, 1863; J. Anthony.—Metal chair and tie-plate for flange rails on wooden ties.

No. 53507; date, March 27, 1866; Franz Vester.—Flat cross-tie, with two deep corrugations along its whole length. Ends turned down.

No. 58563; date, October 2, 1866; Swain Winkley.—A corrugated plate of  shape under each rail, connected by a tie-bar.

No. 59112; date, October 23, 1866; Swain Winkley.—A corrugated or buckled iron plate under each rail, connected by a tie-bar; rails held by clamps and keys.

No. 63161; date, March 26, 1867; B. B. Hotchkiss.—A combined track and pavement. Cast-iron frames the width of the track are fitted to receive wooden blocks, to which flat rails are spiked.

No. 66711; date, July 16, 1867; R. M. Holland.—Cross-tie of Λ section. Flange cut away for rails. Hinged wedge fastening.

No. 70731; date, November 12, 1867; Henry McCan.—Broad flat transverse base-plates, with longitudinal girders held together by tie-rods. Rails resting on top of girders.

No. 71063; date, November 19, 1867; Leonard Repsher.—Wrought-iron cross-tie, bent up at ends to embrance flange and web of rail, angle-clamp bolted to tie on inside of rail. Bolt through clamp, web of rail, and end of tie.

No. 79016; date, June 16, 1868; William F. Serjeant.—Deep flat tie-bars connect the rails, which rest on, but are not spiked to, wooden ties. At each end of the bars are jaws to hold the base of the rail.

No. 83880; date, November 10, 1868; J. Potter.—Flat transverse base-plate, with two uprights which support continuous stringers, to which flangeless T-rails are bolted.

No. 84023; date, November 10, 1868; A. Van Guysling.—A hollow iron column under each rail; the rail is secured to a chair keyed to the top of the column. The columns are connected by tie-bars at the top; or they may be cast in combination with a hollow transverse base, in one piece.

No. 92874; date, July 20, 1869; W. J. Cockburn Muir (England).—Hollow inverted bowls, connected by transverse tie-bars; the rails are secured by lugs and keys.

No. 94856; date, September 14, 1869; C. G. Wilson.—Two channel irons placed back to back form a continuous stringer, and rest on wooden stringers. The web of a flangeless T-rail rests between the channel irons. The iron stringers are connected by tie-bars.

No. 97020; date, November 16, 1869; A. Van Camp and M. M. Hodgman.—For street railways. A deep rail with flat head and a web corrugated longitudinally is bedded in asphaltic or concrete composition. A groove is made in this composition along the side of the rail.

No. 97224; date, November 23, 1869; John H. Phillips.—Inverted bowls or saucers, having a chair for the rails and being connected by tie-bars.

No. 99531; date, February 8, 1870; H. Carpenter.—A hole is bored at each end of a wooden tie for the stem of a T-shaped metal support; the rail rests on a T-shaped plate, having lugs to hold the flanges of the rail and a stem underneath to fit into the hollow stem of the seat. (See No. 16898.)

No. 101751; date, April 12, 1870; Edward G. Markley.—A cast-iron column, in the form of a truncated cone, is under each rail. On top is a chair for the rail. Tie-bars connect the pairs of columns.

No. 107643; date, September 20, 1870; C. H. White.—Flat transverse bed-plates laid on wooden stringers or cross-ties. The rails are of ∩ or bridge section, and rests on tie-plates having a rib which fits into the rail.

No. 109504; date, November 22, 1870; C. Fisher.—Cross-tie of inverted trough section, with closed ends. Two pockets for wooden bearing blocks. Rail fastened by flat plates resting on tie and rail flange, screwed to the wooden blocks.

No. 112805; date, March 21, 1871; S. M. Guest.—A railway joint chair, combined with an iron cross-tie of T section.

No. 118260; date, August 22, 1871; Elijah Myrick.—A ring-shaped tie-plate, with three studs or pins to be driven into the wooden tie.

No. 121956; date, December 19, 1871; J. Newton.—A rail fastening for iron ties. Flat tie with end turned up, wooden wedge between rail and end of tie, vertical jib and cotter fastening (with serrated cotter) on inside of rail.

No. 123526; date, February 6, 1872; L. E. Towne.—Cylindrical cross-tie with a flat base-plate at each end, secured by a strap passing round the tie.

No. 124521; date, March 12, 1872; R. M. Upjohn.—Longitudinals under each rail, of ⊥ section, with very high vertical web. The rail is of _∩_ section, and rests upon the flanges of channel irons bolted to the vertical web of the longitudinals.

No. 127553; date, June 4, 1872; and No. 130010; date July 30, 1872; John L. Boone.—Ties made of a composition of fiber or other material, saturated with asphaltum and shaped under pressure.

No. 128120; date, June 18, 1872; Joseph H. Connelly.—A longitudinal of concrete is laid under each rail and covered with a continuous iron plate. The rails rest on wooden tie plates and are supported by chairs.

No. 134418; date, December 31, 1872; James Calkins.—The continuous longitudinals of channel sections have lugs to hold the outer flange of rails; transverse plates project over the inner flange and are bolted to the longitudinals.

No. 135667; date, February 11, 1873; Alexander D. Rock.—Castings of "frying-pan" shape; the rail is secured to a chair on the bowl, and the "handle" forms half of a transverse tie-bar; the ties are connected by diagonal rods.

No. 136067; date, February 18, 1873; J. W. Kern.—A continuous road-bed of Λ section, with the rails laid on the horizontal flanges. Transverse base-plates at intervals. The bed to be of ¼-inch boiler iron.

No. 139031; date, May 20, 1873; William H. Sterling.—Ties of a compressed asphaltic or other composition, with wooden plugs embedded in the material to receive the rail spikes.

No. 139518; date, June 3, 1873; W. Peck and H. C. Richman.—Two chairs connected by a horizontal flat tie-plate. Wooden bearing-blocks in the chairs.

No. 140411; date, July 1, 1873; C. W. Gulick.—A flat wrought-iron cross-tie with ribs, to form a channel for the flange of the rail. Fastenings of iron $\frac{4}{10}$ inch diameter under tie, passing up through holes in the same, with ends bent over rail flange. Ties about 5 inches wide and ½ inch thick.

No. 142668; date, September 9, 1873; J. R. Beckett.—Street railways. Transverse rods forming tie-plates for the rails and braces for the wooden stringers.

No. 143407; date, October 7, 1873; P. S. Devlan.—A cross-tie made of two iron plates on edge, fastened together at the middle and widening out to hold a wooden block at each end.

No. 144207; date, November 4, 1873; George Keech.—Longitudinal plates under each rail, with lugs to hold outside of rail flange. Transverse tie-plates project over the inner flange and are secured by horizontal bolts passing through lugs on the base plate.

No. 145250; date December 2, 1873; T. R. Timby.—Bowls of different forms cast on the ends of a deep flat steel or wrought-iron tie-bar. In the end of the bar are holes through which the metal flows and thus secures the casting of the bar. (The method is similar in principle to that of the Chappée tie now being tried on the Western Railway of France.) (See the report.)

No. 145991; date, December 30, 1873; H. L. De Zeng.—Wrought-iron cross-tie of \|___\|, U U, or other section. A clip stamped out of the metal holds outer flange of rail; loose clip, secured by vertical key or cotter holds inner flange. (See Nos. 155369; 334696; 380623; 400643.)

No. 146376; date, January 13, 1874; G. H. Blaisdell.—A cast-iron cross-tie of Λ section, with wide flat deep ends, having sockets for wooden blocks. A bolt passes through both blocks and the whole length of the tie.

No. 147563; date, February 17, 1874; P. Kendrick and J. Stokes.—A cross-tie made of two old rails laid parallel, with a wooden block between them at each end, and base-plates if desired.

No. 148242; date, March 3, 1874; George Potts.—Continuous bearing of wood held between two continuous iron stringers of ⊥ section, the top of the web being bent over to hold the rail flange. Bolts pass through the three pieces.

No. 152469; date June 30, 1874; Abram Dehuff.—The rails are spiked at the tops of short wooden piles or stakes, and are connected by iron tie-bars.

No. 155369; date, September 29, 1874; H. L. De Zeng.—A cross-tie of inverted trough section, with open ends, but with projecting wings at ends to prevent lateral displacement. (See No. 145991.)

No. 158437; date, January 5, 1875; S. L. Porter and Duane Peck.—Kite-shaped metal bowls, with the pointed ends between two diagonal tie-bars which form an X. The rails are held by lugs, keys and screws.

No. 161153; date, March 23, 1874; S. L. Porter and Duane Peck.—Modifications of the previous patent, No. 158437.

No. 163187; date, May 11, 1875; S. H. Hamilton.—An iron or steel cross-tie of square hollow section throughout or only at ends. Fixed lugs hold the inner flange of rail, and bolted plates hold the outer flange.

No. 163254; date, May, 1875; H. Reese.—A rolled iron cross-tie of T section; lugs stamped out while hot from the rolls. Bent clip and horizontal wedge fastening for outer flange of rail. (See Nos. 214192; 215675; 272477; also July 13, 1880.)

No. 164793; date, June 22, 1875; Ramon Bañolas.—Cross-ties of I section, carrying longitudinal stringers of ⊥ section, to which flangeless rails of ˥ section are bolted.

No. 166625; date, August 10, 1875; R. E. Nichols.—A continuous hollow bearing, section similar to lower half of letter A; bottom closed; top open with horizontal flanges to carry the rail flange, cross-ties of ⊔ section. Longitudinals and cross-ties filled with broken stone.

No. 171422; date, December 21, 1875; John Quigley.—A cast-iron cross-tie with chair combined, for street-railway track.

No. 172041; date, January 11, 1876; E. E. Lewis.—A cross-tie of + section, with the top vertical flange cut away for the rails, which are secured by wedges. (See Nos. 183, 766; 198, 464.)

No. 176213; date April 18, 1876; George D. Blaisdell.—A cast-iron cross-tie, with wide ends and loose bearing-blocks, all held together by a bolt running through the whole length of the tie.

No. 182984; date, October 3, 1876; Leonora Yates.—Cross-ties of ˥⊔˥, ⌄, or ⌣ section, the latter being semi-cylindrical, with flanges. The rails are fastened by bolted clamps.

No. 183766; 183767; 183768; date, October 31, 1876; E. E. Lewis.—A cross-tie of + section; rails of different forms. Also a joint tie of ⊥⊥ section. (See 172041.)

No. 185808; date, December 26, 1876; D. S. Whittenhall.—A cross-tie of /\/\/\ section; the rails resting in notches in the top ridges. (See No. 227602.)

No. 186710; date, January 30, 1877; George W. Chandler.—Clay, stone, or concrete ties in two or more pieces; a flat iron strap is laid in a groove along the top and another along the bottom; these plates are bolted together. The rails are held by clamps screwed to the iron plates.

No. 187652; date, February 20, 1877; Walter MacLellan and John P. Smith (Scotland).—Fluted, corrugated, or embossed rectangular bowls, connected by tie-bars; the rails are held by bolted clamps. (These ties are manufactured in Scotland and are in use in India and Australia.) (See the report.)

No. 188087; date, March 6, 1877; H. S. Wilson.—A cross-tie of I section, with fixed and movable rail-clips.

No. 188710; date, March 20, 1877; N. S. White.—A continuous bed-plate under each rail, with cross-ties.

No. 190739; date, May 15, 1877; A. H. Campbell.—A cast-iron cross-tie, with sockets for wooden bearing-blocks.

No. 192842; date, July 10, 1877; A. W. Serres.—A continuous bearing of Y section (in two pieces) under each rail with transverse tie-bars. The web of a flangeless rail lies between the two vertical webs. (This track has been used in Europe; see Engineering News, New York, January 28, 1887, page 73; also Railroad Gazette, New York, August 19, 1887. See report; "Belgium" and "Austria.")

No. 197300; date, November 20, 1877; John Turner.—Street railways. The wooden stringers are connected by tie-rods which have flat plates or washers, held tight against the stringers and rails by nuts. No wooden cross-ties are used.

No. 198060; date, December 11, 1877; John B. Ward.—A longitudinal pipe (for conveying water) under each rail; the bottom of rail curved to fit pipe.

No. 198370; date, December 18, 1877; Josiah Foster.—Hollow box castings, with top and bottom flanges, are bolted to stone blocks; the rails rest on spring plates and are held by hook bolts to the top flanges of the castings.

No. 198464; date, December 25, 1877; E. E. Lewis.—A cross-tie consisting of an old rail with two notches cut to the level of the flange to admit the track rails. Two rails with wooden bearing-blocks used at joints. (See 172041.)

No. 198618; date, December 25, 1877; D. Horrie.—A transverse truss of cast or wrought iron. Horizontal hook bolt fastenings.

No. 200737; date, February 26, 1878; Gustav Lehlbach.—Street railways or ordinary railways. Deep foundation columns under each rail.

No. 201667; date, March 26, 1878; H. A. Haarmann.—Continuous bearing for each rail, with cross-ties. This track has been extensively used in Europe. (See Engineering News, New York, January 29, page 74.) (See No. 219856.) (See Report, "Germany.")

No. 206647; date, July 30, 1878; T. W. Travis.—A hollow cross-tie, with boxes at the ends open on top. The rails are held between two ⊂ clips; the groove holds the flange rail; the upper web lies against the rail web, and the lower web is wedged into the box. See Nos. 214208 and 224808. (Tried on the Philadelphia and Baltimore Central Railway.) (See Report, "United States.")

No. 207242; date, August 20, 1878; J. A. Bonnell.—An inverted trough cross-tie with closed ends and corrugated top. Bolted clips or angle-bar fastenings for rails.

No. 207320; date, August 20, 1878; J. H. Thompson.—A cross-tie made in two pieces, dove-tailed together in the middle. The rails rest on wooden blocks.

No. 210681; date, December 10, 1878; George F. Folsom.—A continuous cast-iron bearing under each rail, connected by iron ties and having sockets for round wooden blocks.

No. 207719; date, September 3, 1878; W. E. Curtiss.—A wrought-iron cross-tie of inverted trough section with flaring sides, having a brace of the same section inside under each rail. The ends are open. Rails secured by bolted clips.

No. 210774; date, December 10, 1878; F. B. Freudenberg.—A wrought-iron cross-tie of somewhat similar section to the preceding one. Hooked clips are riveted on for inside and outside flange on alternate ties, the rails being sprung into place. Long ties for double tracks. Patented in Germany, January 18, 1878.

No. 211697; date, January 28, 1879; Hamilton L. Bucknall (England).—Glass bowls, cross-ties, and stringers.

No. 212127; date, February 11, 1879; James Buckner, jr.—For street railways. Metal saddle plates on the stringers, to carry the rails, and metal tie-bars.

No. 214182; date, April 8, 1879; George P. Osborne.—Safety plates to keep spikes from working loose when driven into sound-deadening material, to be used for elevated railways.

No. 214192; date, April 8, 1879; H. Reese.—A cross-tie of T-section, with the ends of the horizontal table turned down at an angle. Clip and wedge fastening. (See No. (163254.)

No. 214208; date, April 8, 1879; T. W. Travis.—A cast-iron box under each rail, with broad rectangular base. Tie-bar connections. The rails rest on and are held by vertical wedge clamps. (See No. 206647.)

No. 215675; date, May 20, 1879; H. Reese.—Improvements upon No. 214192.

No. 216846; date, June 24, 1879; L. A. Gouch.—A cross-tie of —|— section, the longitudinal web being the widest and having its edges turned up or down.

No. 218442; date, August 12, 1879; John Keller.—The wooden ties are spaced far apart, and at intermediate points there are bolted to the rail angle-plates with wide flaring flanges which project below and beyond the rail-flange, forming a sort of bowl.

No. 218559; date, August 12, 1879; S. Nicholls (of England.)—A continuous broad bed-plate under each rail, for street railways. The rail is formed of two channels, leaving a space between for the wheel-flange ] [.

No. 218603; date, August 12, 1879; A. P. Whiting.—A cross-tie of H section, the top flange cut away for the rails. Bolted clips hold the inner flanges of rails.

No. 218648; date, August 19, 1879; C. F. Wagner (of Austria).—A cross-tie composed of two parallel pieces of T-section, fastened together by cross-strips. Bolted clip rail fastenings.

No. 218878; date, August 26, 1879; C. Hanshaw.—A cross-tie made in two pieces lengthwise; on one piece are clips for the inner flange of one rail and the outer flange of the other, and on the other piece are clips for the outer and inner flanges, respectively. The two pieces are held together by a flat horizontal key driven between other clips in the middle of the tie.

No. 219856; date, September 23, 1879; H. A. Haarmann of Prussia—(See No. 201667).—A cross-tie of inverted trough section with flaring sides, and a flat or grooved top table. The rail fastenings are [ shaped, with a bolt passing under the rail.

No. 220026; date, September 30, 1879; H. T. Livingston.—A tubular cross tie of oval section with a flat surface under each rail. Rails fastened by bolts screwed into the tie. Interior of tie packed hard with straw, grass, etc.

No. 221596; date, November 11, 1879; O. E. Mullarky.—A cross-tie of channel section ┌──┐ with wooden bearing-blocks wedged inside under the rails. The rails are fastened by bolted clips.

No. 223187; date, December 30, 1879; J. R. Sullivan.—Two separate cast-iron bearing pieces connected by a tie-bar. Each rail is secured by a cast-iron wedge.

No. 224808; date, February 24, 1880; T. W. Travis.—A bridge support is placed between the ties, the top supporting the rail and the ends resting on adjacent ties. The object is to enable ties to be spaced farther apart than usual. See No. (214208).

No. 226308; date, April 6, 1880; A. Greig (patented in England, March 25, 1879).—Flat cross-ties, with one or two grooves along the whole length. A brace or clip is riveted to hold the outside of the rail, and the rail is held against it by a hook-bolt, the body of which lies in the groove and has a nut at the end of the tie. (This system is much used for portable railways manufactured in England.)

No. 227602; date, May 11, 1880; D. S. Whittenball.—Improvements on No. 185808.

No. 9292 (re-issue); date, July 13, 1880; H. Reese.—(See No. 214192.)

No. 230816; date, August 3, 1880; William Rainbow.—Cast-iron bowls of different forms, of approximately conical shape; they are connected by tie-bars.

No. 230826; date, August 3, 1880; Lewis Scofield.—A cross-tie of _∩_ section. Riveted and bolted clips for rail fastenings. (See Report; "United States.")

No. 231755; date, August 31, 1880; William Brown.—A hollow cross-tie of rectangular section, with concave bottom and open ends. A rib at the ends keeps the rail in position, and is fastened down by hooked bolts with nuts inside the tie.

No. 233528; date, October 19, 1880; W. C. Lutz.—A cross-tie of ⊥ section, with the rails secured by flat hooked clips bolted to the side of the vertical web. (See No. 241389.)

No. 235078; date, December 7, 1880; G. H. Gilman.—A cast-iron cross-tie of rectangular section, with grooves to reduce the weight. The rails are held by fixed and movable lugs.

No. 235321; date, December 7, 1880; F. A. Williams.—The two broad bearing plates, on which the rails rest, are connected by two transverse tie-plates, placed on edge.

No. 235706; date, December 21, 1880; S. F. Seely.—Metal longitudinals of rectangular form, with flaring sides and ends. Flangeless **T**-rails are used, with the web bolted against the leg of a **T**-iron on the longitudinal.

No. 239511; March 29, 1881; Joseph Kindelan.—Rail brace and tie-bar for curves.

No. 240511; April 26, 1881; D. R. V. Goetchius.—A flat tie-bar with wide ends is bolted on to a wooden tie; the ends have lugs for the rail flanges.

No. 240987; date, May 3, 1881; I. W. Fleck.—A cross-tie made of an ordinary rail, head down, with strengthening sections and a broad base-plate bolted to it. It is curved into an arched form, high in the middle, with the ends level for the track rails.

No. 241389; date, May 10, 1881; W. C. Lutz.—A cross-tie of cylindrical form, with flat bearing surfaces for the rails; or with a vertical web on top, with notches for the rails. (See No. 233528.)

No. 241724; date, May 17, 1881; J. C. Rupp.—The tie consists of a block under each rail, with a connecting tie-bar. (See No. 245222.)

No. 242850; date, June 14, 1881; H. Thielsen.—Cross-tie of **T**-section; in two halves, one under each rail. Bent clips formed out of the metal of the tie. The two pieces keyed together at the middle. (See No. 317244.)

No. 244003; date, July 5, 1881; George W. Vroman.—Each tie is in two pieces, each of which consists of a rectangular plate and half a tie-bar. Lugs are placed diagonally on the plates. The plates are put under the rails, so that the latter will rest between the lugs; the plates are then swung round, bringing the ends of the rods together, and bringing the lugs over the rail flanges. (This is similar to the ties proposed by Mr. Moore in India. (See Report.)

No. 245222; date, August 2, 1881; J. C. Rupp.—The block under each rail is of **I**-section; and each pair is connected by two tie-rods, forming an **X**. (See No. 241724.)

No. 245440; date, August 9, 1881; Thomas Breen.—A cast-iron chair or support is placed under each rail, and the pairs are connected by tie-bars. The rails are secured by bolted clamps. (See Nos. 272850 and 294191.)

No. 246888; date, September 13, 1881; G. A. Jones.—A cross-tie of ⊥ section, with the ends formed into a chair. The rail is held in the chair and spiked to a wood block.

No. 247248; date, September 20, 1881; Levi Haas.—A cross-tie made of an old rail with the ends resting on wood blocks; the track rails are secured to the top of the tie. (See 253374, 257572, 282309, 315771, 389464, 391704, 406346, 420299.)

Nos. 249270 and 249271; date, November 8, 1881; E. H. Tobey.—Cross-ties of ⊔ or **V** section; the rails are held in chairs resting on wooden blocks.

No. 249503; date, November 15, 1881; J. Clark.—A cross-tie of semi-circular section, the bottom fastened to a flat bed-plate the whole length of the tie; the top of the arch cut away for the rail. (See 256199, 259095, 270637, 358144, also August 5, 1884.)

No. 251251; date, December 20, 1881; C. F. Kreuz.—A flat cross-tie with thickened ends to hold the outer flanges of the rails and a flat cross-tie with another flat piece resting on it to hold the inner flanges of the rails. These ties are placed alternately. (See No. 263919.)

No. 251625; date, December 27, 1881; William Morris (England).—Concrete chairs and blocks for railways and street railways.

No. 253374; date, February 7, 1882; Levi Haas.—Iron ties in two pieces, connected by a tie-bar. It is designed to be made of old flange rails. (See No. 247248.)

No. 253381; date, February 7, 1882; Charles F. Herbst.—Cast-iron bolts, rectangular and pyramidical; each pair of bowls is connected by a tie-rod, having a nut on each side of each bowl. The rails are held by wedged and bolted clamps.

No. 254802; date March 14, 1882; J. Conley.—A flat cross-tie in two pieces, with the inner end of each turned up so as to be bolted together. Under the rails the sides are turned down. Clips are stamped out of the metal. (See No. 332384.)

No. 255554; date, March 28, 1882; F. A. Williams.—A cross-tie of shallow inverted trough-section, with broad ends. The rails are held against fixed clips by plates the whole length of the tie, placed on edge, underneath, with a hooked end to hold the rail flange. These plates are secured by a horizontal key in the middle of the tie.

No. 256199; date, April 11, 1882; J. Clark.—Improvements upon No. 249503.

No. 257437; date, May 2, 1882; H. De Zavala.—A cross-tie of ∧ section, with U-bolts passing under the rail and having nuts screwed down on the rail flange.

No. 257572; date, May 9, 1882; Levi Haas.—A cross-tie consisting of two cast-iron bed-plates, with bearing-blocks to which the rails are bolted. A tie-bar connects the two bed-plates. See Nos. 247248, 282309, 315771, 389464, 406346, and 420299.

No. 259095; date, June 6, 1882; J. Clark.—Further improvements on No. 249503.

No. 259726; date, June 20, 1882; Daniel Smith.—A transverse tie-bar with wide flat ends, having lugs to hold the rail flange; but the rails have to be slipped into these chairs, there being no loose or adjustable parts. Each end rests on a wooden block of white oak, 8 inches square and 2 inches thick, which rests on a stone block.

No. 259823; date, June 20, 1882; A. L. Cubberlery.—A flat cast-iron cross-tie, with concave bottom, and dovetail grooves on top, for sliding rail fastenings into place.

No. 259891; date, June 20, 1882; J. H. Meacham.—A cross-tie of ⊥ section, with end boxes for wood blocks, to which the rails are secured by hook-bolts.

No. 260231; date, June 27, 1882; J. Parr.—A cast-iron cross-tie with fixed and movable lugs for the flanges of the rails. (See No. 277333.)

No. 260724; date, July 4, 1882; A. L. Withers, jr.—Each rail rests in a groove on a metal block; the blocks have dovetailed recesses for rail-clamps and tie-bars.

No. 263078; date, August 22, 1882; Francis Tunica.—The rails rest in T shaped chairs, secured to circular blocks of metal resting on a concrete base. Each block has two tie-rods, which run not to the opposite block, but to the blocks to the right and left of the opposite block; so that the rods form horizontal triangular bracing or trussing.

No. 263919; date, September 5, 1882; C. F. Kreuz.—A cross-tie of H section, the rails resting on the web and secured by wedges. An improvement on No. 251251.

No. 265543; date, October 3, 1882; E. D. Samain.—A flat tie-bar with lugs on the ends, and a bolted plate with lugs to hold the inner side of the rail flange.

No. 265760; date, October 10, 1882; M. I. Cortright.—A cross-tie with two grooves or corrugations in its length, and with notches to receive the flange of the rails.

No. 267930; date, November 21, 1882; G. L. Putnam.—A cross-tie of square-section, hollow or solid, with hooked spikes put in place from the bottom and tapering upwards. (See No. 285842.)

No. 269442; date, December 19, 1882; R. B. Meeker.—Cross-ties of T section, with broad table. Flat horizontal bars with turned up ends, used alternately with the ties. The rail to be of extra height, bolted to chairs.

No. 270637; date, January 16, 1883; J. Clark.—A flat cross-tie with arched bearing-plates and chairs. (See No. 249503.)

No. 272477; date, February 20, 1883; Henry Reese.—A cross-tie of inverted trough sections, having flaring sides and a middle interior rib; carries longitudinal plates of similar section to which the rails are secured by gibs. The gibs are held in place by a horizontal screw and nut placed between the gib and counter-gib. (See No. 163254.)

No. 272850; date, February 27, 1883; T. Breen.—A flat cross-tie, twisted spirally in the middle and having the ends turned up. (See No. 245440.)

No. 274309; date, March 20, 1883; W. H. Gibbs and George Snook.—A cross-tie of ⊥ section, with supports for a rail-chair of inverted trough sections, with a wooden block, to which the rail is secured by hooked clamps.

No. 276414; date, April 24, 1883; E. B. Hungerford.—A cross-tie of shallow channel section. The flanges are cut away and notched to hold the rail-flange, and the rail rests on a loose bed-plate with a clip to hold the other flange; the plate being held in place by a horizontal key driven through holes in the tie-flanges.

No. 277000; date, May 8, 1883; T. J. Bronson and A. Armstrong.—The rails rest in grooves on separate blocks, and are held together and in place by tie-bars and bolted clamps. (See No. 289806.)

No. 277333; date, May 8, 1883; J. Parr.—A hollow cast-iron cross-tie. The rails are secured to loose chairs having long projections which run nearly through the tie and are secured by a vertical bolt at the middle of the tie. (See No. 260231.)

No. 279280; date, June 12, 1883; Fridolf Schaumann (England).—Concrete blocks with prepared cork tie-plates. Chairs are secured by bolts; or flange rails resting direct on the cork plates are secured by clamps held by bolts passing through the concrete block.

No. 280110; date, June 26, 1883; S. B. Wright.—A cross-tie of inverted trough section, with the inside of the top arched. (See No. 298539.)

No. 280200; date, June 26, 1883; J. Mahoney and D. W. Shockley.—A cross-tie of section, with wooden bearing blocks. (See No. 370634.)

No. 281806; date, July 24, 1883; A. R. Spaulding.—A cross-tie of channel section, to which the rail is fastened by a series of flat horizontal keys or wedges in dove-tailed grooves.

No. 282309; date, July 31, 1883; Levi Haas.—Heavy cast-iron chairs, connected by tie-bars. (See No. 247248.)

No. 283076; date, August 14, 1883; J. L. Chapman.—Cross-ties of shallow channel, or of two flat plates, one above the other, separated by distance-blocks. Each rail is secured by bolted clips to a bed-plate.

No. 283230; date, August 14, 1883; H. F. Flickinger.—A cross-tie of I section, to which the rails are secured by ∩ bolts, with the nuts on the under side of the top flange of the tie.

No. 284157; date, August 28, 1883; J. W. Young.—A hollow open-sided, elastic cross-tie of section; to be filled with ballast or earth on surface lines. Two or more of these plates to be placed inside one another, with one side open, or to form a closed tie. It is claimed to be adapted to elevated roads.

No. 285833; date, October 2, 1883; John Newton.—Channel-iron stringers with flat cross-ties fastened to the top.

No. 285842; date, October 2, 1883; George L. Putnam.—A cross-tie of T section, depressed in the middle to hold a water trough for supplying locomotives. The rails are secured by bolted clips. (See No. 267930.)

No. 285986; date, October 2, 1883; Clark Fisher.—A bent plate cross-tie of U section in the middle with flat ends. A U bolt passes under the rail, and washers are screwed down on the rail-flange by the nuts.

No. 286651; date, October 16, 1883; E. L. Taylor.—Separate rail bearers or bowls connected by tie-bars. Lugs or clamps on the bowl hold the inner flange of the rail, and a lug on the end of the tie-bar holds the outer flange. (See report "United States.") Wooden or stone blocks may be used. (See No. 371993 and No. 382470.)

No. 287418; date, October 30, 1883; J. J. Clarke (of Peru).—A flat plate tie for portable railway track, with special joint fastenings. (Assigned to A. W. Colwell, New York.)

No. 289806; date, December 11, 1883; T. J. Bronson and A. Armstrong.—An iron or steel cross-tie of approximately semi-cylindrical section ∩, with lugs struck up by means of dies. (See No. 277000.)

No. 290793; date, December 25, 1883; L. O. Orton.—A flat inverted trough cross-tie, with wedge-shaped boxes projecting above and below to hold the bearing blocks and fastenings.

No. 291514; date, January 8, 1884; H. R. Holbrook.—A hollow cross-tie of oval section with thickened portions under the rails; rails secured by bolted clips.

No. 291523; date, January 8, 1884; John G. Krichbaum.—Large, deep castings connected by tie-bars; rails held by bolted clamps.

No. 292421; date, January 22, 1884; J. J. Du Bois.—A cross-tie with dove-tailed groove for rail and a wedge fastening.

No. 293194; date, February 5, 1884; J. Reven.—A flat tie-bar to keep rails from spreading; one end bent up to hold rail, the other end having thread and nut with movable clamp.

No. 293302; date, February 12, 1884; George W. Bloodgood.—Bolted clips for fastening rails to ties of inverted-trough section.

No. 294191; date, February 26, 1884; T. Breen.—A cross-tie made in two pieces, lengthwise; placed side by side, holding the rail chairs and fastenings between them. (See No. 245440.)

No. 296725; date, April 15, 1884; W. T. Carter.—A hollow cross-tie, with flat top and bottom and concave sides.

No. 298539; date, May 13, 1884; S. B. Wright.—Fastening rails to inverted cross-ties by clips and T-headed bolts. (See No. 280110.)

No. 299345; date, May 27, 1884; Joseph Chater (India).—Cast-iron plates with jaws forming a rail chair; the plates are connected by tie-bars. The general design is similar to that of the Denham and Olpherts ties, used in India. (Patented in India, December 8, 1883; England, January 8, 1884; France, February 1, 1884; Germany, February 7, 1884.)

No. 299557; date June 3, 1884; J. Lockhart.—A clamp or tie-rod, to be used in connection with wooden ties. A tie rod, running across the track, has clamps to hold the rail flanges, the inner clamps being held by set-screws. It is claimed that soft wood ties can be used, as there will be no tendency for the rails to spread. (See No. 327285.)

No. 302664; date, July 29, 1884; Joseph Monier (France).—A metal skeleton or framework covered with concrete, artificial stone, etc.

No. 302965 and No. 302966; date, August 5, 1884; C. S. Westbrook.—A cross-tie of section, with parts of the horizontal table cut away. The rails are held by riveted and keyed angle-plates.

Nos. 10504 and 10505 (re-issues); date, August 5, 1884; J. Clark.—Improvements in No. 249503.

No. 303373; date, August 12, 1884; E. G. Holtham (of England).—Patented in England December 22, 1883.—Broad longitudinals under each rail, with transverse tie-rods, and with additional side plates to increase the bearing on the ballast.

No. 303540; date, August 12, 1884; W. G. Olpherts (India).—The tie consists of cast-iron plates connected by a tie-bar. The rails are held by jaws secured by cotters driven through the plate, tie-bar, and jaw. Patented in India, July 24, 1877; England, February 17, 1879. (See report "India.")

No. 304622; date, September 22, 1884; Charles H. Denham (India).—Somewhat similar to No. 303540, but having the rail or chair bolted to a wooden block. Patented in India, November 6, 1876; England, June 28, 1877. (See report "India.")

No. 304746; date, September 9, 1884; G. W. B. Neal.—A cross-tie made of triangular section, with the rails carried in and bolted to chairs fastened to the apex of the tie.

No. 305156; date, September 16, 1884; A. N. D. Delffs.—A concrete tie, with wooden blocks to which the rails are spiked.

No. 306090; date, October 7, 1884; Robert Moffly.—A cross-tie made of three pieces the full length of the tie, bolted together so as to form a ⊥-slot along it, in which the rail fastenings slide.

No. 306139; date, October 7, 1884; B. W. De Courcy.—A cross-tie of section, with the rails resting on the top, and secured by hooked clamps bolted together below the rail.

No. 309428; date, December 16, 1884; J. H. Williams.—A cross-tie of U-section, with wooden blocks to which the rails are spiked.

No. 310269; date, January 6, 1885; Abraham Gottlieb.—A cross-tie of inverted trough section, with a groove along its top table. The rail is fastened by bolted clips or a special form of locking plate or chair.

No. 310794; date, January 13, 1885; John K. Clark.—Each tie consists of two ⊥ (tee) shaped supports, with triangular wings; the supports are connected by a tie-rod. (See Nos. 323275, 350478, and 362608.)

No. 310878; date, January 20, 1885; John T. Campbell.—Metal longitudinals, with ribs on top forming a channel for the web of a flangeless T-rail. Transverse tie bars.

No. 312566; date, February 17, 1885; W. H. Knowlton.—Cross-ties of different sections.

No. 312717; date, February 27, 1885; E. N. Higley.—A flat cross-tie, with sides and ends turned down and with a vertical rib along the middle. This rib cut away for the rails, which are fastened by bolted clips. General section thus ⌒. (See Nos. 334228 and 353028.) Manufactured by the International Railway Tie Company, of New York. (See report, "United States.")

No. 312881; date, February 24, 1885; W. McVey.—A metal cross-tie in two pieces, mortised together at the middle and secured by a bolt.

No. 313072; date, March 3, 1885; A. A. Harrison.—A combined flat longitudinal and cross-tie; the cross-tie having plate at right angles, and being laid so that these plates of adjacent ties meet.

No. 313260; date, March 3,1885; L. O. Vanderbilt and M. E. Company.—Each tie consists of a pair of hollow inverted bowls, connected by a tie-bar. The rails are held by bolted clamps.

No. 313512; date, March 10, 1885; A. J. Moxham.—Cross-ties of inverted trough section, with riveted angle-irons on top, to which rail (principally girder street rails) are bolted or riveted. (See Nos. 319010 and 355778.)

No. 313778; date, March 10, 1885; C. M. Seltzer and O. T. Moock.—For street railways. Improvements in rail fastenings and stringers.

No. 314158; date, March 17, 1885; C. M. Van Orman.—A cross-tie of semi-circular section ⌒ with a cast-iron saddle at each end; the saddle has a lug fitting into a hole in the tie and two diagonal holes for rail spikes.

No. 314757; date, March 31, 1885; C. H. Van Orden.—A cross-tie of T section, with a rail chair at each end, the rails being secured by bolts which have hooked ends passing through the top of the tie.

No. 315047; date, April 7, 1885; M. A. Martindale.—Longitudinals of inverted trough section, with rails forming a part of or bolted to the top table. Connected by transverse tie-plates. Claimed to be adapted for laying along highways.

No. 315771; date, April 14, 1885; L. Haas.—A cross-tie made of two pieces the full length of the tie, with the section of figure 1, having wooden bearing blocks, to which the rails are spiked. (See No. 247248.)

No. 317244; date May 5, 1885; H. Thielsen.—A cross-tie of T section, the sides of the top table being turned down. (See No. 242850.)

No. 317763; date, May 12, 1885; M. A. Glynn (of Cuba).—Cross-ties of ⊓ or T section; also longitudinals of inverted trough section.

No. 317988; date, May 19, 1885; T. H. Gibbon.—Longitudinals with short spaces between them and connected by transverse tie-bars. The rails are held by clamps and lugs. (See Nos. 320869 and 347236.)

No. 319010; date, June 2, 1885; A. J. Moxham.—A cross-tie made of two angle-irons, with distance plates at the ends and middle ┌ ┐; the rails are bolted to high chairs. The tie is intended for street railways, and is shown with a center-bearing girder-rail. (See No. 313512.)

No. 319813; date, June 9, 1885; G. C. H. Hasskarl—A hollow box cross-tie, with a Y-shaped web inside; the small middle space receiving the T-heads of the track-bolts. It is also to be used as a longitudinal sleeper for street railways, the two large side spaces being used as conduits for telegraph wires, etc.

No. 320231; date, June 16, 1885; E. D. Dougherty and George B. Bryant.—A cross-tie of rectangular section, with an opening in the top table to receive a smaller cross-tie to which the rails are fastened, and which rests on springs placed in the larger box.

No. 320869; date, June 23, 1885; Thomas H. Gibbon.—A modification of former patent; adapted for street railways. (See Nos. 317988, 347236, 363513, 403465.)

No. 322621; date, July 14, 1885; Petherick Davey.—A tie composed of two plates and chairs connected by a tie-bar. The rails are held by keyed clamps.

No. 323275; date, July 28, 1885; John K. Clark.—Separate rail supports of T form, connected by a broad flat tie-bar, having the ends turned up and bolted to the rail support. (See No. 310794.)

No. 323356; date, July 28, 1885; G. Murray.—A flat cross-tie thickened under the rail, and having a rib at the bottom under each rail and in the middle; the rails secured by bolted plates.

No. 323430; date, August 4, 1885; J. K. Lake.—A combined metal stringer and chair for street railways.

No. 323809; date, August 4, 1885; William B. Henning.—A longitudinal plate lies under each rail; with cross-ties having deep ends, with T slots to receive the web and flange of the rails. (See No. 376884.)

No. 325020; date, August 25, 1885; R. R. Shepard.—A cross-tie of channel section ⊓ with one outer and one inner lug for each rail, and two ┌ slots for clips of ⊔ shape with eccentric heads.

No. 326874; date, September 22, 1885; P. Kirk (of England).—A cross-tie with increased thickness at the rail seats, and with two lugs or clips punched up to hold the flange of each rail; the rail being secured by a wedge driven between the flange and one of the lugs (patented in England, France, Belgium, and Spain in 1885).

No. 327285; date, September 29, 1885; J. Lockhart.—An improvement upon No. 299557.

No. 327667; date, October 6, 1885; P. H. Dudley.—Separate rail supports connected by tie-bars. Each support consists of a hollow rectangular box, open on top, set on a wide rectangular base or bowl. The box has a partial filling of sand, upon which rests a block of compressed wood or wood-pulp; the rail rests on this block and is secured by bolted clamps. The heads of the bolts are inside the bowl. One object is to enable the rails to be raised or "shimmed" without disturbing the ballast. At the joints the bowl is long enough to carry two or three "boxes," according to whether the rail-joint is suspended or supported.

Nos. 327745 and 327843; date, October 6, 1885; L. E. Whipple.—A cross-tie of X section, made of two curved plates placed back to back and having flat plate across top and bottom.

No. 328632; date, October 20, 1885; J. S. Ammon.—A cross-tie of Λ section with rail chairs secured to the top ridge.

No. 329429; date, November 3, 1885; G. E. Baldwin.—A pair of rail chairs of _∩_ shape, resting on wooden blocks and tied together by a rod. The top table has a groove to receive the web of a rail of T section, having no bottom flange. Intended especially for city railways.

No. 329821; date, November 3, 1885; P. Davey.—A cross-tie of channel section, to which the rails are secured by keys and Z-shaped clamps, the lower part of the latter lying inside the tie.

No. 332384; date, December 15, 1885; J. Conley.—A fastening for attaching rails to metal ties, which have lugs to hold the outer flange of rail. The fastening is a bar inside the tie, with a hook at one end projecting through a hole and holding the rail flange, while the other end is bent up against the end of the tie. (See No. 254802.)

No. 332707; date, December 22, 1885; Jacob Frysinger.—Wooden stringers are connected by metal cross-ties of I section, having the web cut away at the ends to admit the stringers. The rails are secured by bolts passing through the stringers and the flanges of the ties. (See No. 400558.)

No. 333015; date, December 22, 1885; J. Howard and E. T. Bousfield (of England).—A cross-tie of section, with a U-shaped depression for each rail, the rail being secured with a wooden wedge. See report, "England." (These ties have been used with the English double-headed rail; patented in England.) (See No. 335523.)

No. 333480; date, December 29, 1885; L. B. Prindle.—A steel cross-tie three-eighths to 1 inch thick; channel section ; at each end is a slot to receive a tenon at the bottom of a rail chair.

No. 334228; date, January 12, 1886; E. N. Higley.—An improvement on No. 312717.

No. 334696; date, January 19, 1886; H. L. De Zeng.—An improvement in fastenings. (See No. 145991.)

No. 335523; date, February 2, 1886; J. Howard and E. T. Bousfield (of England).—A cross-tie made of a metal sheet or plate, with one or more corrugations lengthwise, the rails being held in chairs made by cutting away the corrugations. (See No. 333015.)

Nos. 335804 and 335805; date, February 9, 1886; E. P. J. Freeman.—A cross-tie made of a sheet of metal bent to form a rectangular box. A wooden block is placed inside under each rail, and a spike is driven into the wood through a hole in the metal. The spike may be split so as to flare like Λ when driven in combination, a guard-rail of a plate bent to Z shape, the rail lying on the bottom flange and all fastened to the tie.

No. 338057; date, March 16, 1886; J. Gearon.—A continuous road-bed made of channel cross-ties placed alternately and , with the vertical flanges overlapping one another.

No. 339275; date, April 6, 1886; J. De Mott.—A cross-tie with a rail-chair at each end. The end of the tie is rounded on plan, and is embraced by a clamp with the ends turned up to hold the rail flange.

No. 339938; date, April 13, 1886; F. F. Scott.—A cross-tie with a chair for each rail; one-half of chair fixed, the other fastened by bolts. Pins driven through the web of the rail prevent vertical movement.

No. 340118; date, April 20, 1886; H. Howard.—A deep channel cross-tie for street railways. The rails are keyed to chairs resting on the top of the flanges.

No. 341286; date, May 4, 1886; James Smith.—Bowls of V section, connected by tie-bars. The rails lie inside the bowls.

No. 341416; date, May 4, 1886; F. V. Greene.—For street railways. A continuous cast-iron hollow bearing (preferably 10 feet long and weighing 140 pounds per yard) under each rail. The rails are grooved, and are screwed to the top of the longitudinal.

No. 342987; date, June 1, 1886; A. N. Warner and T. J. Deakin.—A cross-tie of channel section with T-shaped rail chairs fitting into it. The rail secured to chairs by bolts with hooked ends, the nuts being under the flange of the chair.

No. 344011; date, June 22, 1886; C. H. Sayre.—Flat or arched cross-ties with pieces punched out of the top and bent to embrace the flange and web of the rail.

No. 344185; date, June 22, 1886; W. Kilpatrick.—A cross-tie of section with a slot along the flat top to receive the bottom of the rail chairs.

No. 344826; date, July 6, 1886; I. F. Good.—A flat cross-tie thickened and widened at the ends to form rail chairs, and having flanges projecting down under the chairs. The rails secured by keys.

No. 345054; date, July 6, 1886; Samuel Hyman.—Hollow columns, with caps forming rail-seats. For street railways.

No. 345733; date, July 20, 1886; C. Sailliez.—A cross-tie of channel section , with lugs to hold the rail flanges. The flanges are cut away at the ends to allow of wooden stringers being used under the rails.

No. 346998; date, August 10, 1886; D. Kaufman.—Flat cross-ties with chairs at the ends, and longitudinal continuous flat plates beyond the chairs. The space between the rails is covered by a continuous arched plate.

No. 347236; date, August 10, 1886; Thomas Gibbon.—Hollow inverted trough stringers. For street railways. (See No. 317988.)

No. 348877; date, September 7, 1886; Henry P. Adams.—Each tie consists of two rectangular plates, connected by a tie-bar. Alternate ties have lugs on the outer and inner sides of the rails. (See No. 361199.)

No. 349524; date, September 21, 1886; E. Schmidt (of Prussia).—A cross-tie made of two old flange rails laid flat, head to head, forming a tie of H H section. The rails rest on the web and are fastened by bolted clips. (Patented in Germany.)

No. 349846; date, September 28, 1886; Edward Jones.—Hollow iron boxes, with high raised seats for the rails, and connected by deep plates set on edge.

No. 350478; date, October 12, 1886; John K. Clark.—Separate rail-supports, connected by flat tie-bars. (See No. 310794.)

No. 350692; date, October 12, 1886; T. L. Mumford and H. Moore.—A cross-tie of inverted trough section, wider at the ends, with fixed lugs and movable clamps for fastening the rails.

No. 351002; date, October 19, 1886; A. T. Stevens.—A hollow rectangular box tie, with bottom flanges at the ends, and the top flanges along the sides; the rail clamps are bent to take hold of these flanges.

Nos. 351498 and 351499; date, October 26, 1886; E. C. Davis.—A cross-tie made of two old rails placed side by side. Each track rail rests on a bearing-block in two pieces, with a lip at the end to engage the rail flange. The blocks are slid into place between the tie rails and bolted through the tie.

No. 351996; date November 2, 1886; Charles Netter.—Cross-ties of ⊔ section, with hook bolt fastenings; the hook of the bolt fits into a hole in the side of the tie, and the nut is screwed down on a rail clamp. (See No. 372864.)

No. 352002; date, November 2, 1886; E. F. Reynolds.—A cross-tie of /\/\/\ section. The rails rest in notches cut in the top, and are held by hinged clips and locking clips.

No. 353028; date, November 23, 1886; E. N. Higley.—Improvements upon Nos. 334228 and 312717.

No. 353691; date, December 7, 1886; S. D. Locke.—A channel cross-tie ⊓, with inclined ends and a transverse rib in the middle. The rails are fastened by bolted clips. (See No. 356002.)

No. 354147; date, December 14, 1886; F. G. Johnson.—Cross-ties of ⊓ section, with the bottom edges turned in to retain a concrete filling or a filling made of loose stone with melted iron poured over it, the casting being done inside the tie. The rails are held by bolted clamps; the clamp having lugs which fit into the holes in the ties, and these lugs as well as the bolts are long enough to enable the rail to be shimmed up when necessary. The shims extending under the rails and clamps.

No. 354250; date, December 14, 1886; R. S. Sea.—A cross-tie of T section with enlarged ends forming rail chairs. (See No. 375005.)

No. 354433; date, December 14, 1886; R. Morrell.—A cross-tie made of a plate bent to form a hollow rectangular box, with the top and bottom cut away at the middle. The rails are fastened to wooden bearing-blocks placed inside the tie. (See No. 365932.)

No. 355778; date, January 11, 1887; A. J. Moxham.—For street railways. A steel plate, 24 inches long 6 inches wide and one fourth inch thick, is twisted spirally, and is embedded in concrete. Angle-irons are riveted to the top to form a rail-seat, and the two columns are connected by a tie-bar. (See No. 313512.)

No. 356002; date, January 11, 1887; S. D. Locke.—An improvement on No. 353691.

No. 357301; date, February 8, 1887; J. J. Anderson.—Metal chairs with one fixed jaw, and one loose jaw for supporting the rails. Adapted for street railways.

No. 358144; date, February 22, 1887; J. Clark.—A cross-tie of channel section, with chairs for the rails. (See No. 249503.)

No. 358981; date, March 8, 1887; J. C. Lane.—An iron bridle-rod, made in two pieces, bolted together at the middle, to prevent rails from spreading at the curves.

No. 359115 and No. 359117; date March 8, 1887; W. Wharton, jr.—A cross-tie of ⊥ or L section, with the bottom flange bent up to make a chair for the rails. To be used on street railways with girder rails.

No. 359440; date, March 15, 1887; T. Gleason.—A cross-tie of trough section ⌊⌋, with interior cross-pieces or webs to which the rail clamps are fastened.

No. 359854; date, March 22, 1887; Henry C. Draper.—A compound tie, consisting of two channel irons placed back to back with a wooden tie between them. The three pieces are bolted together, and one end of the bolt is bent up and over so as to hold the rail flange.

No. 360397; date March 29, 1887; M. Y. Thompson.—A flat cross-tie, with a U-shaped depression at each end to receive a wooden bearing-block. The rails are fastened by keys.

No. 361199; date, April 12, 1887; H. P. Adams.—A cross-tie of T section, with chairs keyed to it. (See No. 348877.)

No. 361330; date, April 19, 1887; P. J. Severac (of Paris).—A cross-tie of I section, with the horizontal flanges bent at the ends. In some cases a broad plate is riveted to the bottom flange. The rails are fastened by clips or keyed to chairs. (This system is in use in Europe.) Patented in France, Belgium, England, Italy, and Spain, in 1884–'85. (See Report: "Belgium.")

No. 382608; date, May 10, 1887; John K. Clark.—A cross-tie consisting of two rail bearers or bowls, connected by a tie-bar. The rails are held by bolted clamps. (See No. 310794.)

Nos. 362786 and 362787; date, May 10, 1887; J. Riley (of Scotland).—A cross-tie of inverted trough section, with the rail chairs stamped or pressed by dies, the rails being secured by wedges. (Patented in England and Belgium; 1885–'86.)

No. 363020; date, May 17, 1887; L. Taylor.—A hollow box cross-tie, with outward-flaring sides and concave bottom. The rails are fastened by hook bolts with the nuts inside the tie.

No. 363513; date, May 24, 1887; Edgar S. Fassett.—Hollow inverted trough stringers, connected by tie-bars which maintain the gauge. For street railways. Improvements on the Gibson patents. (See Nos. 317988, 320869, and 347236.)

No. 365169; date, June 21, 1887; George de Beaulieu.—Two rail-bearers connected by a tie-rod. Each rail-bearer has one fixed jaw and one bolted jaw to support the rail.

No. 365350; date, June 21, 1887; A. Roelofs.—A cross-tie of channel ⌈⌉ or inverted trough section. The rails are fastened by fixed lugs on the outside, and a tie-bar which is sprung into place on the inside. Also a flat tie with a rib under each ail and a slot along the middle for the bent tie-bar.

No. 365511; date, June 28, 1887; F. X. Georget.—A cross-tie or longitudinal, of channel section ⌊⌋, built up of a base plate and two concave side plates with the tops flanged outward horizontally. The ties or longitudinals are connected by tie rods. (See No. 381125.)

Nos. 365932 and 365933; date, July 5, 1887; R. Morrell.—A hollow cross-tie, made of a plate bent to an oblong section, with straps around it at the rail fastenings. The metal is cut away to let the rails rest on a wood block inside the tie; the metal straps keep the spikes from working loose and allowing the rails to spread. Also a tie for elevated roads, made of two plates on edge, fastened together at the middle, and flaring apart to admit wooden bearing-blocks between them. (See No. 354433.)

No. 366546; date, July 12, 1887; N. S. White.—A cross-tie of channel ⌈⌉ or inverted trough section, with a base plate at each end, with a bearing-block of wood or other material inside under each rail. The rails are fastened by locking clamps.

No. 367325; date, July 26, 1887; John Splane.—A cross-tie of ⌈⌉ channel section, with the bottom of the sides flanged outwards. The rails are let into apertures in the top and rest on the hooked ends of two tie-bolts, the inner ends of which are connected by a turnbuckle which is tightened by a wrench, there being a hole in the middle of the top table of the ties.

No. 367383; date, August 2, 1887; J. Fitzgerald.—The rails are fastened to a cast-iron cross-tie by hook-headed spikes, which are secured by horizontal keys fitting into corresponding notches in the tie and spike.

No. 369591; date, September 6, 1887; J. H. Coffman.—A solid tie with a groove along the top and lugs for the inner flanges of the rail; hooked rods hold the outer flange, and the inner ends of the rods are attached to a spring at the middle of the tie.

Nos. 369755 and 369756; date, September 13, 1887; William L. Van Harlingen, sr.—A box cross-tie made of an inverted trough fastened to a base-plate; inclined and closed ends. It incloses a wooden tie or wooden bearing-blocks. The rail is fastened by wood screws with wide heads. Also a metal tie with end boxes to contain springs on which the rails rest.

No. 370072; date, September 20, 1887; R. C. Lukens.—A cross-tie of **T** section, with slots in the web for attaching weights or anchors to keep the track in position. The rails are fastened by lugs and bolts.

No. 370164; date, September 20, 1887; H. L. Stillman.—A street-railway track, with wooden stringers connected by metal tie-bars of **I** section, secured by keys.

No. 370192; date, September 20, 1887; D. C. Heller.—A hollow box-tie of rectangular section, with the top cut away under the rails. The tie is filled with concrete and has two wooden blocks to which the rails are spiked.

No. 370226; date, September 20, 1887; C. W. Yost.—A flat tie with lugs, and a separate bed-plate, with lugs, for each rail.

No. 370,634; date, September 27, 1887; J. Mahoney and D. W. Shockley.—A cross-tie of section, with a saddle plate for each rail seat. The plate has a lug for one flange and a clip is bolted on the other. (See No. 280200.)

No. 370837; date, October 4, 1887; John B. Williams.—The tie consists of two rectangular iron frames or boxes connected by a tie-bar; lugs or two of the sides form a seat for the rail. A block of wood or other material is fitted into the frame and has to this the rail is spiked.

No. 371110; date, October 4, 1887; W. H. Troxell.—A cross-tie with raised rail seat and outer lugs. Hooked bolts, with nuts on the outer side of the chair, hold the inner flange of the rail.

No. 371780; October 18, 1887; J. Moser and E. Moeckel.—A cross-tie of **T** section, with a chair at each end; each chair has an inclined rail-brace and two hook-bolts.

No. 371993; date, October 25, 1887; Enoch L. Taylor.—Two rail-bearers of inverted trough section, connected by a flat tie-bar, placed on edge, which passes through a slot in each rail-bearer or bowl. Lugs on the bearers hold the inner side of the rail flange, and lugs on the ends of the tie-bars hold the outer side. (See No. 286651; see Report; "United States.")

No. 372,230; date, October 25, 1887; A. McKenney.—Cross-ties of channel section, with one end cut off at an angle to allow of a diagonal tie to the next transverse tie, each set of three ties making a letter N on plan. Arranged continuously.

No. 372525; date, November 1, 1887; J. A. Dunning.—A hollow rectangular cross-tie, with open inclined ends; bottom and sides have corrugations, transversely and vertically. Bolted clip fastenings.

No. 372703; date, November 8, 1887; I. A. Perry.—A cross-tie made of two old rails, with saddle chairs fitting over the heads of these rails. Track rails fastened by chair and sliding wedge, being held by flange and web.

No. 372864; date, November 8, 1887; C. Netter.—A cross-tie of **T** section, with the ends beyond the rails bent down vertically and then horizontally. Rails fastened by bolts having hooks which take hold of the bottom of the web of the tie. (See No. 351996.)

No. 372879; date, November 8, 1887; S. H. Stull.—A cross-tie made of a plate bent to a semi-circular form, and semi-cylindrical at the ends. Rails fastened by clamps. Open ends.

No. 373656; date, November 22, 1887; W. P. Hall and C. C. Barnett.—A cross-tie of semi-circular section, with open ends. Shoulders pressed out to prevent spreadings. Rails fastened to saddles or straps. (See No. 375996.)

No. 375005; date, December 20, 1887; R. Sea.—A cross-tie of channel section, with closed ends. A strengthening plate is bolted to the under side of the top table, and the side flanges are deeply notched to give elasticity. A metal block is bolted under each rail, and the rails are secured by bolted plates. (See No. 354250.)

No. 375763; date, January 3, 1888; T. B. Moore.—A cross-tie of inverted channel section. The rails are held by clamps and hook-bolts; the hook end is inside the tie, and the nut is screwed down on the clamp, which has a lug fitting into the bolt hole.

No. 375856; date, January 3, 1888; R. T. White.—A cross-tie of ⊥ section, with high chair at each end to receive the web of a girder rail. Intended for street railways. (See Nos. 385395 and 386420.)

No. 375996; date, January 3, 1888; W. P. Hall.—A hollow cross-tie, made of a plate bent almost cylindrical, but with the bottom open and flat on top. The rails are fastened to saddle straps. (See No. 373656.)

No. 376214; date, January 10, 1888; J. W. Smith.—A hollow rectangular cross-tie, with holes in the top to admit the rail chairs, which rest on coiled springs inside the tie.

No. 376250; date, January 10, 1888; N. M. Marks.—The two rail-bearers are of section, with ratchet teeth on the outer faces; over the upright leg fits a saddle ∩, also with ratchet teeth, so that the height of the rail can be adjusted. The rails are secured to the saddles, which are connected by flat tie-bars.

No. 376884; date, January 24, 1888; William B. Henning.—A flat bar, bent up at the ends to embrace the flange and web of rail. Loose angle clamps on inside of rail. (See No. 323809.)

No. 377162; date, January 31, 1888; G. Kelton.—A cross-tie of channel section, with a separate bottom, having projections on its inner side to give a hold to the pulp with which the tie is to be filled. The rails are fastened by hooked bolts, with nuts inside the tie, cavities being left in the pulp filling.

No. 378133; date, February 21, 1888; James M. Gibberson.—Stone or other blocks with flat tie-bars, having lugs which can be bent over the flanges of the rails.

No. 378280; date, February 21, 1888; F. L. Barrows.—A cross-tie of inverted trough section, with clips struck up on the outside of the rail to hold its flange, and clips lengthwise on the inside of the rail to hold a rail fastening.

No. 378930; date, March 6, 1888; J. Hill.—A flat cross-tie, corrugated lengthwise top and bottom. The rail is keyed to a chair. The inventor proposes to use a double-headed rail.

No. 379312; date, March 13, 1888; S. B. Jerome.—A hollow rectangular cross-tie, made of a bent plate. It is to be filled with straw, sawdust, etc., and has a narrow bearing-block along the underside of the top, to which the rails are spiked. The ends are closed by wood or cement blocks.

No. 379399; date, March 13, 1888; J. Jacobs.—A cross-tie of channel section with closed ends; a top plate is bolted on by side clamps to form a rail seat. The tie is to be filled with concrete, etc.

No. 379574; date, March 20, 1888; C. P. Hawley.—A cross-tie of I section, with the top flange bent to make a rail brace. A longitudinal bridge is used under the rail at joints.

No. 379575; date, March 20, 1888; C. P. Hawley.—A combined metal and wooden tie, consisting of a metal beam of ⊥ section, resting on a wooden tie or plank.

No. 379576; date, March 20, 1888.—A cross-tie of ⊥ section, with slots for the web of a T girder, forming a rail seat, or which can be made a longitudinal bearing.

No. 379612; date, March 20, 1888; C. G. Singer.—A cross-tie of + cruciform section, with the top flange cut away at the rail seats. The rails are held by horizontal U clamps, the end being in a hole in the top flange of the tie, with the two legs resting on the rail flange. A key or plug, driven horizontally through the tie, holds the clamp down on the rail.

No. 380274; date, March 27, 1888; George E. Blaine and Edward Hill.—Anchor-blocks or bowls of terra cotta or earthenware, of frusto-conoidal or frusto-pyramidal form, connected by metal tie-bars. The rails rest on wooden plates.

No. 380623; date, April 3, 1888; H. L. De Zeng.—Improvements upon No. 145991, etc.

No. 381059; date, April 10, 1888; W. H. Donaldson.—A cross-tie of ╥╥ section. The rails are held by gibs with long ends within the tie, which are to be secured by a cotter driven through the tie parallel with the rail.

No. 381125; date, April 17, 1888; F. X. Georget.—Improvements upon No. 365511,

No. 381860; date, April 24, 1888; E. R. Stiles.—A cross-tie of channel section └──┘, with a wooden block under each rail.

No. 382134; date, May 8, 1888; W. H. Britton.—A cross-tie of T section, with the vertical web corrugated vertically. The rails are secured by lugs and clamps.

No. 382394; date, May 1, 1888; J. B. Sutherland.—A cross-tie of approximately Y section; curved like the section of a yacht, and with the top edges bent in to form horizontal flanges for the rail-chairs.

No. 382470; date, May 8, 1888; R. M. Hunter.—A modification of the Taylor patents. (See Nos. 286651 and 371993.)

No. 382855; date, May 15, 1888; F. Barhydt.—A hollow box cross-tie, with closed ends. There is a wooden block the full size of the face of the tie at the top, and another at the bottom; both inside. Coil springs are interposed between the top and bottom sections,

No. 383118; date, May 22, 1888; M. Fitzgerald.—A cross-tie of channel section ┌──┐, with solid ends. Fixed lugs and hooked spikes are the rail fastenings.

No. 384785; date, June 19, 1888; Jacob Reese.—A cross-tie of ∩ section, with a groove along its top table; rail seat bolted on top. The rail is secured by a bolt passing under it and through the chair, having Γ washers to hold the rail flange. It is to be rolled from a plate of No. 7 steel 24 inches wide; bedded in ballast.

No. 385395; date, July 3, 1888; R. T. White.—A channel cross-tie of U section, with rails secured to saddles by bolts and clips. (See No. 375856.)

No. 385492; date, July 3, 1888; D. Y. Wilson.—A cross-tie made of two angles _┘ └_, with a base plate and channel plate for rail seat at each end. Rails bolted through top and bottom plates.

No. 386064; date, July 10, 1888; H. T. Ferris.—Rails, ties, etc., of a composition of 500 parts of paper pulp, 25 parts of silicate soda, and 10 parts of barytes.

No. 386119; date, July 17, 1888; R. W. Flower, jr., and S. L. Wiegand.—A hollow cross-tie of rectangular section, with part of the bottom cut away and turned down to prevent lateral movement. The rails are spiked to wood blocks inside the tie. (See No. 420485. See Report ; "United States.")

No. 386156; date, July 17, 1888; J. A. Ogden.—A cross-tie of channel section └──┘, wide at the bottom, with bearing blocks and hook-fastenings for the rails.

Nos. 386356 and 386357; date, July 17, 1888; H. Shultzen.—A channel tie └──┘, with the middle part of the bottom cut away and turned up to prevent lateral movement. The rail is fastened to a wooden block by Z-clips and a longitudinal bolt under the rail, or by diagonal bolts. (Now being manufactured by the Standard Steel Tie Company, of New York.) (See Report; "United States.")

No. 386389; date, July 17, 1888; A. Durand.—A cross-tie of inverted trough section, with clips and channels stamped in it. (See Report; "United States.")

No. 386420; date, July 17, 1888; R. T. White.—Hollow box cross-ties of different sections, made of bent plates. Cross-section intended to give elasticity. (See 385395.)

No. 387602; date, August 7, 1888; Peter Semonin.—Cross-ties of inverted trough section. The rails are held by a fixed lug on the outer side and a gib and cotter with serrated faces on the inner side. (See No. 421769.)

No. 388266; date, August 7, 1888; George Cowdery and E. R. Thomas, (Australia).—A cross-tie of inverted cross-section, with closed ends, and with lugs stamped up at each rail seat. Each rail rests on a bed-plate placed between the lugs, and is secured by a split key. (Patented in England, June 30, 1886.) (See Report; "Australia.")

No. 388277; date, August 21, 1888; A. J. Hartford.—A flat cross-tie, with end turned up, and a bent plate tie bridge, arched in the middle, bent to form a shoulder for inner flange of rail; the rail rests on this plate and the end is turned over the outer flange and secured by a bolt through both plates. (See No. 401949.)

No. 388296; date, August 21, 1888; James R. Millhouse.—A cross-tie made of a sheet of metal, forming a deep tie-bar on edge, and bent to form a box or frame under each rail.

No. 389464; date, September 11, 1888; L. Haas.—A cross-tie of rectangular section; top cut away at ends and middle. Wooden block under each rail. (See No. 247248.)

No. 390014; date, September 25, 1888; R. P. Faddis.—Wooden stringers, with flat iron tie plates across top and under rail, with U bolts embracing the stringers. For street and steam railways. (See No. 391131 and No. 398037.)

No. 390370; date, October 2, 1888; I. G. Howell.—A cross-tie of channel section ┌──┐, with blocks under the rails. The top is cut away for the rail, and the rail clamps are fastened by hooks.

No. 391131; date, October 16, 1888; R. P. Faddis.—Four or more short pieces of ties in a frame with distance pieces and bolts. These sections are held together by tie-bars. (See No. 390014.)

No. 391492; date, October 23, 1888; W. J. Stifler.—A flat cross-tie with diagonal grooves on the under side near the ends to receive the heads of the bolts of the two plates, each with a lug, which form one rail seat.

No. 391704; date, October 23, 1888; L. Haas.—A cross-tie of channel section └──┘, higher at the rail seats, with notched flanges for the rails. (See No. 247248.)

No. 391999; date, October 30, 1888; A. H. Ames.—A flat cross-tie, with flaring ends of channel section ┌──┐, having riveted and bolted clips for rail fastenings.

No. 392849; November 13, 1888; J. Cabry and W. H. Kinch, (of England).—A rolled steel cross-tie of inverted trough section, with lugs stamped out. Rails secured by keys driven between flange and lug. (In use on the Northeastern Railway, in England.) (See report, "England.")

No. 393515; date, November 27, 1888; D. M. McRae.—A wooden or iron tie, with metal sockets at ends forming rail seats.

No. 394426; date, December 11, 1888; David Wilson, (England).—A tubular tie of concrete or other composition cast round a core of wire netting. Blocks of wood are placed inside. Patented in England, May 15, 1885, and February 17, 1886; France, March 16, 1886; Belgium, March 17, 1886; Spain, July 20, 1886.

No. 394738; date, December 18, 1888; G. W. Thompson.—A hollow cross-tie of rectangular section, with a metal bearing-block inside under each rail. Bolted clip rail fastenings.

No. 395134; date, December 25, 1888; M. Hagarty.—A cross-tie made of two channels placed back to back ℶ C, inner lug on one, outer lug on the other. The bolt holes in vertical web are elongated to allow the channels to be shifted to let rail in.

No. 395304; date, December 25, 1888; C. F. Yarbrough.—Hollow cross-ties of rectangular section, with open ends and openings at sides. Wood blocks may be used, or the ties may be filled with ballast.

No. 395447; date, January 1, 1889; Michael Maloney.—A cross-tie of cruciform section, +. Upper web cut away at rail seats to let rails rest on horizontal web. Rail clamps bolted to upper web.

No. 396160; date, January 15, 1889; H. Hipkins, (of England).—A stamped metal cross-tie of section, with lugs and rib stamped out of top table. (Patented in England, 1888.)

No. 396473; date, January 22, 1889; C. P. Espinasse, (of France).—A cross-tie of ⊥ section, with vertical web cut away for rail chair to which rail is secured by wooden wedge.

No. 398004; date, February 19, 1889; S. U. Smith.—A cross-tie of channel section, with closed ends. The rails rest on the ends of a separate cross-plate, with fixed lugs inside, and bolted plates outside.

No. 398037; date, February 19, 1889; R. P. Faddis.—Short pieces of ties connected and braced together to form a sort of crib. (See Nos. 390014 and 391131.)

No. 400558; date, April 2, 1889; Jacob Frysinger.—A cross-tie of I section in three pieces. The web is short and the flanges embrace a wooden stringer at each end, and are secured by bolts. (See No. 332707.)

No. 400643; date, April 2, 1889; H. L. De Zeng.—Cross-ties of channel section; with T a-iron bolted inside under each rail, forming an anchor plate. The rails are secured by bolted clamps. (See No. 145991.)

No. 401949; date, April 23, 1889; Arthur J. Hartford.—A rolled cross-tie of inverted trough section, with a longitudinal channel on the top table. Rails secured by bolts and clamps. (See Report; "United States"; see No. 388277.)

No. 402818; date, May 7, 1889; Karl L. Gocht (Germany).—A cross-tie of inverted trough section, with bottom horizontal flanges. A rail chair is secured to lugs on the tie.

No. 403464; date, May 14, 1889; E. J. Devens.—A cross-tie of channel section. The rails are held by bent clamps, which hold the flange of the rail and the sides of the tie.

No. 403465; date, May 14, 1889; Thomas H. Gibbon.—For street railways. Stringers having one side higher than the other, to fit the shape of a special side-bearing rail; the rail has a vertical web on its under side, to fit into the stringer, where it is held by the tie-bars. (See No. 317988.)

No. 403741; date, May 21, 1889; Robert Dansinger.—For street railways. Separate blocks connected by tie-bars. The rails are secured by cotters and keys.

No. 404043; date, May 28, 1889; Pierre Kolgraf (Belgium).—Cross-ties, formed of two bars of Z section, with a rail chair riveted between them at each end. The rails are held by keys driven between the rails and the lugs on the chairs. (See Report, "Belgium.") (Patented in Belgium December, 1885; France, January 5, 1886; England, March 16, 1886; Italy, July 12, 1886.)

No. 404401; date, June 4, 1889; Jacob Haish.—Cross-ties made of old rails laid head down. The track rails are to be of bridge section and secured by lugs.

No. 406129; date July 2, 1889; T. R. Dunning.—A hollow box cross-tie of rectangular section, with the top projecting beyond the sides forming flanges to which the rails are fastened. An iron block is placed inside under each rail.

No. 406346; date, July 2, 1889; Levi Haas.—A cross-tie of channel section. The rails rest in notches cut in the sides, and are secured by springs and clamps. (See No. 247248.)

No. 408255; date, August 6, 1889; C. B. Palmer.—A cross-tie of ⊥ section. The rails are held by clamps, the lower part of which straddles the web of the tie, and is secured by a pin and split key.

No. 409860; date, August 27, 1889; A. C. Nickloy.—A cross-tie of rectangular box section, made by coiling a steel plate spirally.

No. 410176; date, September 3, 1889; John R. McCartney.—A broad shallow cross-tie of section, with horizontal flanges. The rails are secured by clips made by turning up a strip of the flange of the tie, or by bolted clamps.

No. 410236; date, September 3, 1889; A. B. Fitch.—A cross-tie of inverted trough section, similar to the Haarmann type (Germany), having a narrow upper part and wider lower part. The upper part is cut away at each rail seat to let the rail rest on the lower part. The rails are secured by dove-tailed keys or wedges driven horizontally, one side being in a notch in the tie, and the other side bearing on the rail flange.

No. 410684; date, September 10, 1889; B. W. Ellicott.—A cross-tie of channel section, ⊔, with rail chairs of ⊂ shape; the rail is bolted to the upper leg, which is prolonged so that the legs of the two chairs meet and are secured by bolts. The chairs are bolted to the tie.

No. 410933; date, September 10, 1889; Edward Samuel.—A cross-tie of I section, with the top flanges cut and bent to form lugs between which the rail flange is held and secured by keys. A flat bar or plate, as deep as the web of the ties, is laid between the the ties at the middle, parallel with the rails.

No. 411959; date, October 1, 1889; Robert Forsyth.—A cross-tie of rectangular box section, with a rib or flange under the lower side; it is made by bending a plate to the required form and riveting together, the ends turned down to form the longitudinal rib.

No. 412000; date, October 1, 1889; John M. Robbins.—Longitudinals of ⊥⊥ section, with a continuous stringer of wood placed inside.

No. 412260; date, October 8, 1889: E. A. Jenks.—A flat tie-bar, with the ends bent up to hold the outer flange of the rails; used with a metal plate under each rail, having lugs to hold the inner side of the rail. The object is to maintain the gauge of track and prevent spreading of rails.

No. 416050; date, November 26, 1889; C. F. Z. Caracristi.—A cross-tie of I section, fitting into a chair of box shape, with concave sides at each end.

No. 416081; T. F. Thomas.—A cross-tie in two pieces, spliced at the middle by plates and bolts. The inner end of one piece has a semi-circular groove, which receives a semi-cylindrical rib on the end of the other piece; forming a horizontal hinge joint.

No. 417426; date, December 17, 1889; Richard Jones.—A cross-tie having a deep recess at each end to receive the rail up to its head; the rails are held by jaws secured by keys driven horizontally through the tie.

No. 418052; date, December 24, 1889; William Partridge and James McCutcheon, jr.—A hollow cross-tie of triangular section, laid with the apex downward. A brace of similar form is placed inside the tie under each rail. The ends are closed by blocks of preserved wood. The rails are secured by bolted clamps.

No. 418158; date, December 31, 1889; B. Boyer.—A cross-tie of cruciform section +, with the top web cut away at each rail-seat, and sloping away from the rail-seat to the middle and ends of the tie. The rails are held by angle-bar clamps and keys.

No. 419101; date, January 7, 1890; William H. Bagby.—A cross-tie of shallow channel section ⊔, with lugs on the sides to hold the inner flanges of the rails. A loose block or seat, secured by bolts, is under the rail, and has lugs for the flanges.

No. 420299; date, January 28, 1890; Levi Haas.—A cross-tie of inverted trough section. The rails are fastened by bent clamps, with the ends secured inside the tie. (See No. 247248.)

No. 420352; date, January 28, 1890; William MacManes and George E. Lum.—A cross-tie made of two plates of < section (thus <>), with a wooden block of hexagonal section at each end. Bolts pass through the plates and blocks. Between the two blocks the plates have longitudinal flanges, to form a closed bottom.

No. 420485; date, February 4, 1890; S. L. Wiegand.—A cross-tie of inverted trough or channel section, with roughened top and corrugated sides. The rails are held by hook-bolts; the hook end holds one flange, and at the other end is a nut and clamp for the other flange of the rail. (See No. 386119.)

No. 420674; date, February 4, 1890; Isaac Brown.—A cross-tie of ⊔ section, either in one piece or in two pieces bolted together at mid-length. The rails are held in chairs.

No. 420895; date, February 4, 1890; J. B. Wilson.—A cross-tie of ⊥ section, with a chair and lug for each rail. A loose clamp is put on the inner side of each rail and secured by the head of a long spike-shaped rod driven through the tie into the ground.

No. 421769; date, February 18, 1890; Peter Semomin.—Cross-ties of inverted trough or channel section, with a depression in the top at each end to form a rail seat. The rails are secured by bolted clamps. (See No. 387602.)

No. 422830; date, March 4, 1890; M. H. Pierce.—A cross-tie of ⊥ section, with a saddle-chair under each rail.

No. 423447; date, March 18, 1890; Percy W. Ross.—A cross-tie of channel section ⌴, with corrugated bottom. At both ends an angle-iron is secured on the outer side of each side. Each rail rests on a block of wood.

No. 423586; date, March 18, 1890; John M. Bailey.—A cross-tie made of a plate, bent to approximately a double tubular section ∞, of different forms. The rails are secured by bolted clamps.

No. 423852; date, March 18, 1890; Lewis Barnes.—A cross-tie of flat channel or curved section, with the ends bent to form a brace for a wooden stringer. An angle-iron is riveted to the tie at the inner side of each stringer.

Total number of patents from July, 1839, to March, 1890: 491.

Patents for cross-ties or track of concrete, clay, compositions, etc.: Nos. 127553, 130010, 186710, 251625, 279280, 302664, 305156, 380274, 386064, 394426.

Patent for glass ties: No. 211697.

# TIMBERS USED FOR TIES IN SOME FOREIGN COUNTRIES.

The following notes are extracted from the correspondence of Mr. Tratman on the species of wood used in some foreign countries. Some further particulars will also be found in the special returns of the various railways in the foregoing report:

*Turkey.*—Smyrna and Cassaba Railway. Oak and Pine.

*Egypt.*—Early in 1889 the Government was negotiating for 500,000 ties from Australia; probably of jarrah wood.

*India.*—The principal woods used are the native säl and deodar and imported creosoted pine. It is stated that there is always a market for good wooden ties, the cost of which is not much affected by the extensive introduction of metal. They appear to be used at frogs, switches, sharp curves, bridges, etc., and one writer estimates that 6 per cent. of the mileage would still be laid with wooden ties, even if all the railways should introduce metal ties as rapidly as possible and discard wooden ties except where their use is "imperative" (?). Deodar is a soft wood, with which accurate gauge can not well be maintained, and with which the risk from fire in dry seasons is 50 per cent. more than with säl ties. Curves of 1,000 to 1,500 feet radius, laid with deodar ties, require to be respiked about every three months, and under very heavy traffic the gauge has been one-half inch wide in three months with new ties. Under similar traffic the gauge is only one-eighth to one-fourth inch wide in two years where säl is used, and remains correct under ordinary traffic. Säl wood weighs about 53 to 70 pounds per cubic foot. The best ties are of good sound Nepal säl well matured, and not cut out of small trees with a great proportion of sap-wood. The writer mentioned above states that he has tried deodar, teak, asna, iron-wood, jarrap, and red gum from Australia, English oak, creosoted fir, yellow pine, etc., and has not found any, except the oak, to approach the durability of säl, the life of which is estimated at eighteen years. The creosoted fir ties are liable to dry-rot. The Rohilkund and Kumaon Railway has tried jungle-wood, but with very unsatisfactory results. The wood answers well for buildings, but rapidly rots in the track. At the beginning of 1887 there were 70,000 in use, and in eighteen months 38,000 had been replaced with säl, while the rest were being gradually replaced. The jungle-wood was to be had for the cutting when the road was built, but though cheap it was not economical.

*Ceylon.*—Owing to the weight of the native woods and the difficulty of hauling to the railway, etc., it has been found to be cheaper to import ties from Europe. There seems to be a movement now, however, in favor of utilizing the native supplies or for the forest department to turn its attention to the propagation of suitable trees. At the beginning of 1889 there were 182½ miles of railway, 5 feet 6 inches gauge, laid with 72-pound flange rails. The ties are of creosoted Norway pine, buried in the ballast, to protect them from the direct heat of the sun. They are 9 feet 9 inches long, 10 inches by 5 inches section, spaced about 3 feet apart.

*New Zealand.*—According to the official report of Mr. J. P. Maxwell, M. Inst. C. E., general manager of the government railways, there were 1,758 miles of railway, 13 feet 6 inches gauge, in operation in March, 1888. The rails are of iron, 40 and 52 pounds per yard, and steel, weighing 52 and 53 pounds per yard. Several native timbers are used. The contract prices for wooden ties are 72 cents, or by other contracts 56 to 60 cents, hewn or sawn, for birch and black pine; 36 to 46 cents for Kamai, 46 to 52 cents for totara, 59 cents for silver pine. There are about 2,100 ties per mile or 3,518,238 in all. The renewals during the year ending March 31, 1888, were 122,027 ties.

*Tasmania.*—The track consists of 43-pound steel flange rails on ties of stringy bark, iron bark, blue gum, or peppermint. The ties are 6 feet 6 inches long, 9 inches wide, 4½ inches thick; laid 2,450 to the mile, 24 inches apart at joints. They are in 6 feet of bottom ballast, with 4½ inches of boxing and top ballast.

*Argentine Republic.*—East Argentine Railway, handerbay; Western of Buenos Ayres Railway, quehacho and urunday.

*Uruguay.*—Uruguay Northwestern Railway, creosoted pine.

*Brazil.*—Herobo and native hard woods.

*Chili.*—Antofagasta Railway, Chili oak; Copiapo Railway, Chili oak; Coquimbo Railway, cypress; Taltal Railway, white oak.

*Peru.*—Pisco and Yca Railway, California redwood.

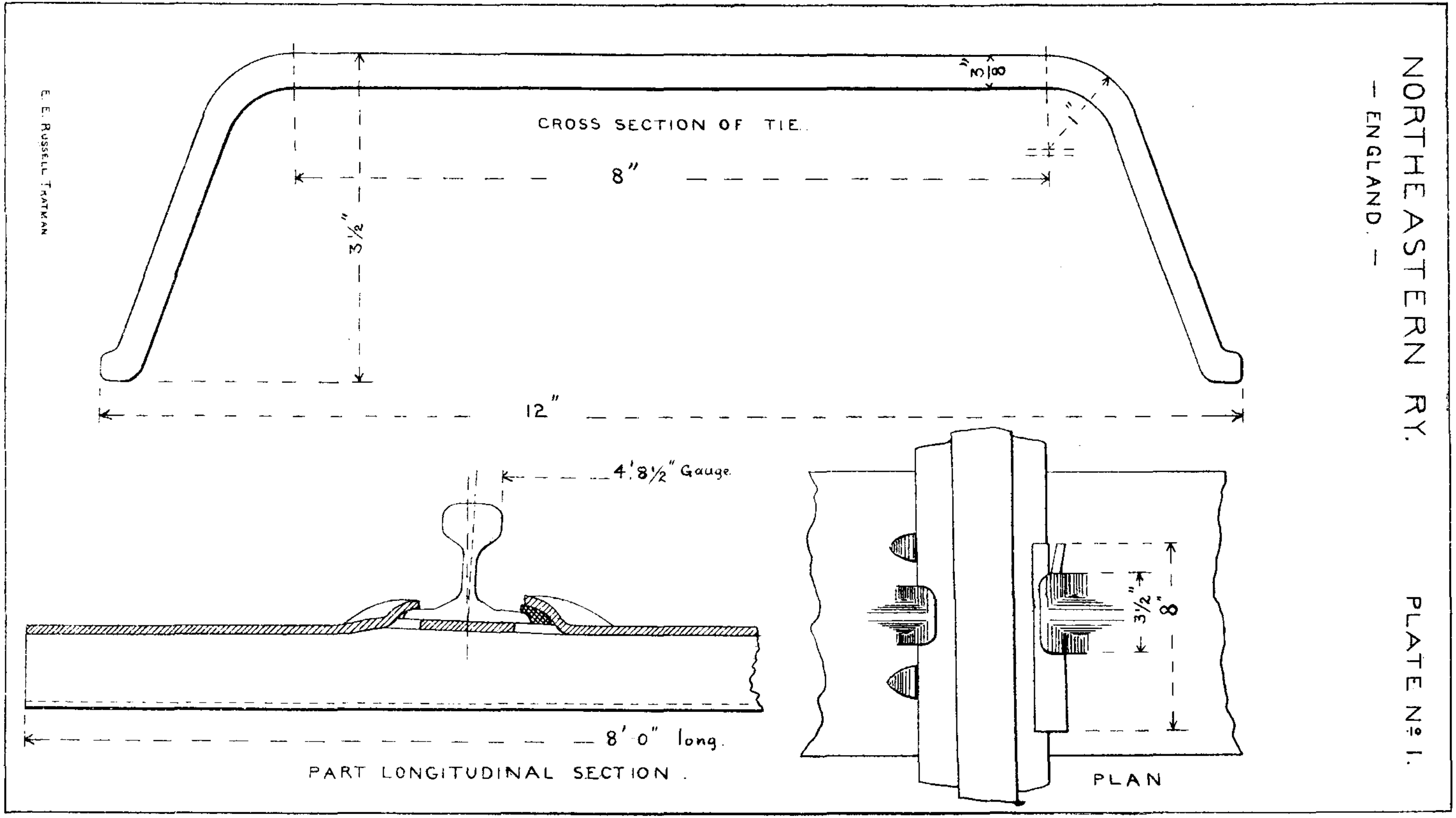
*Venezuela.*—La Guaira and Caracas Railway, lignum-vitæ

*United States of Colombia.*—Lignum-vitæ.

*Mexico.*—Merida and Progreso Railway, iron-wood.

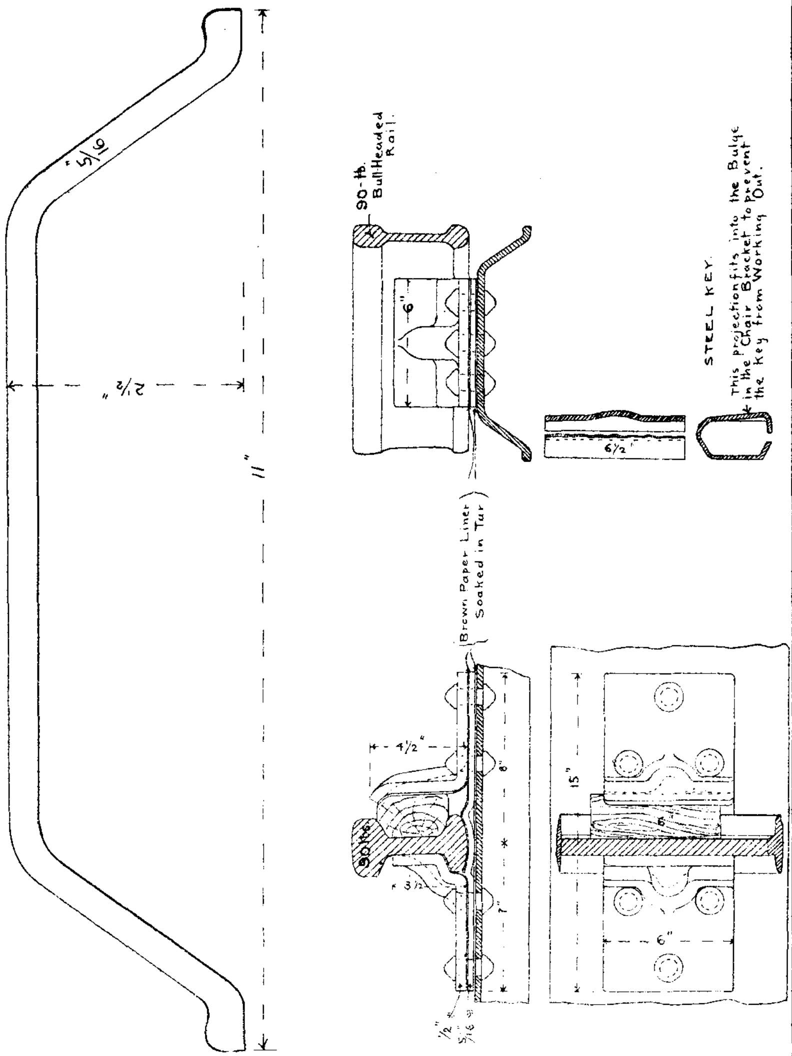
*Cuba.*—Jequi and native hard wood.

*Hawaii.*—California redwood.


NORTHEASTERN RY.
— ENGLAND. —
PLATE No. 1.
CROSS SECTION OF TIE.
8"
3½"
3/8"
12"
4' 8½" Gauge.
8' 0" long.
PART LONGITUDINAL SECTION.
3½"
8"
PLAN
E. E. Russell Tratman

ENGLAND. PLATE No. 2.

LONDON & NORTHWESTERN RY.




E. E. RUSSELL TRATMAN

# MIDLAND RY.

— ENGLAND. —

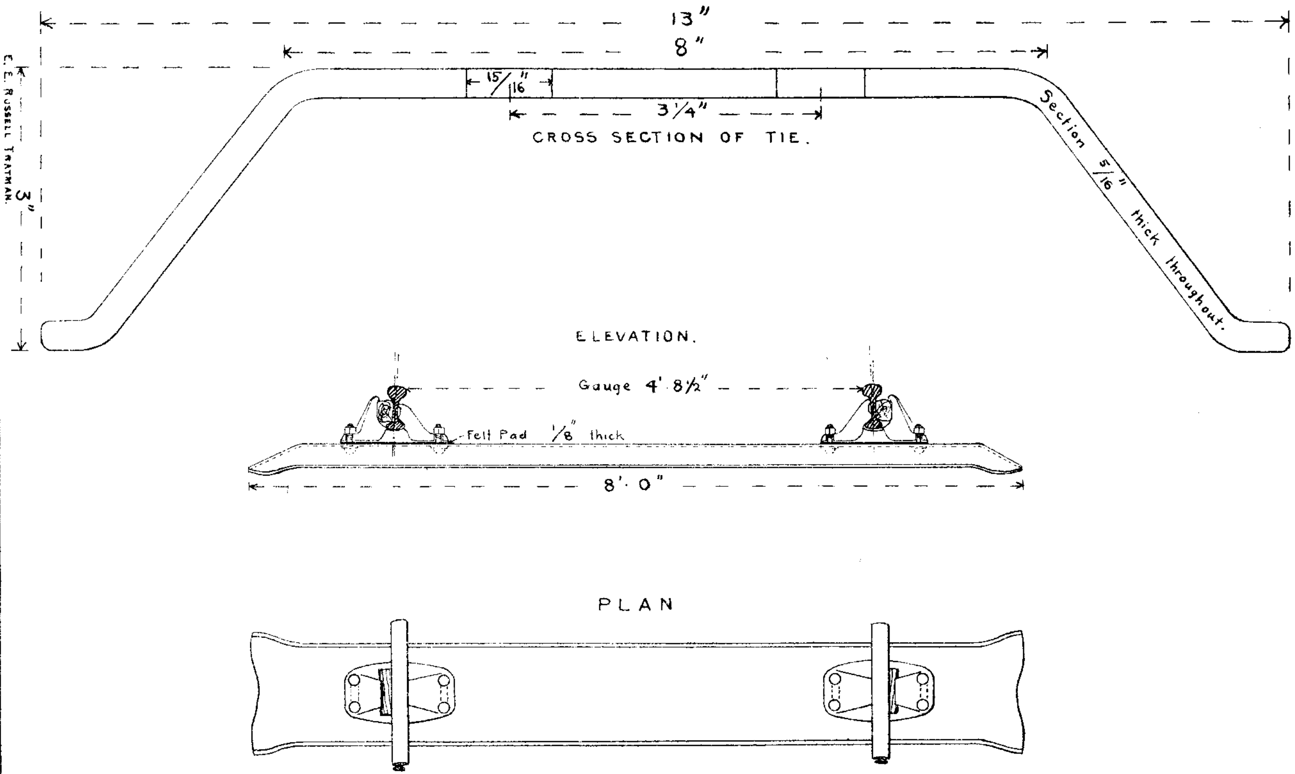
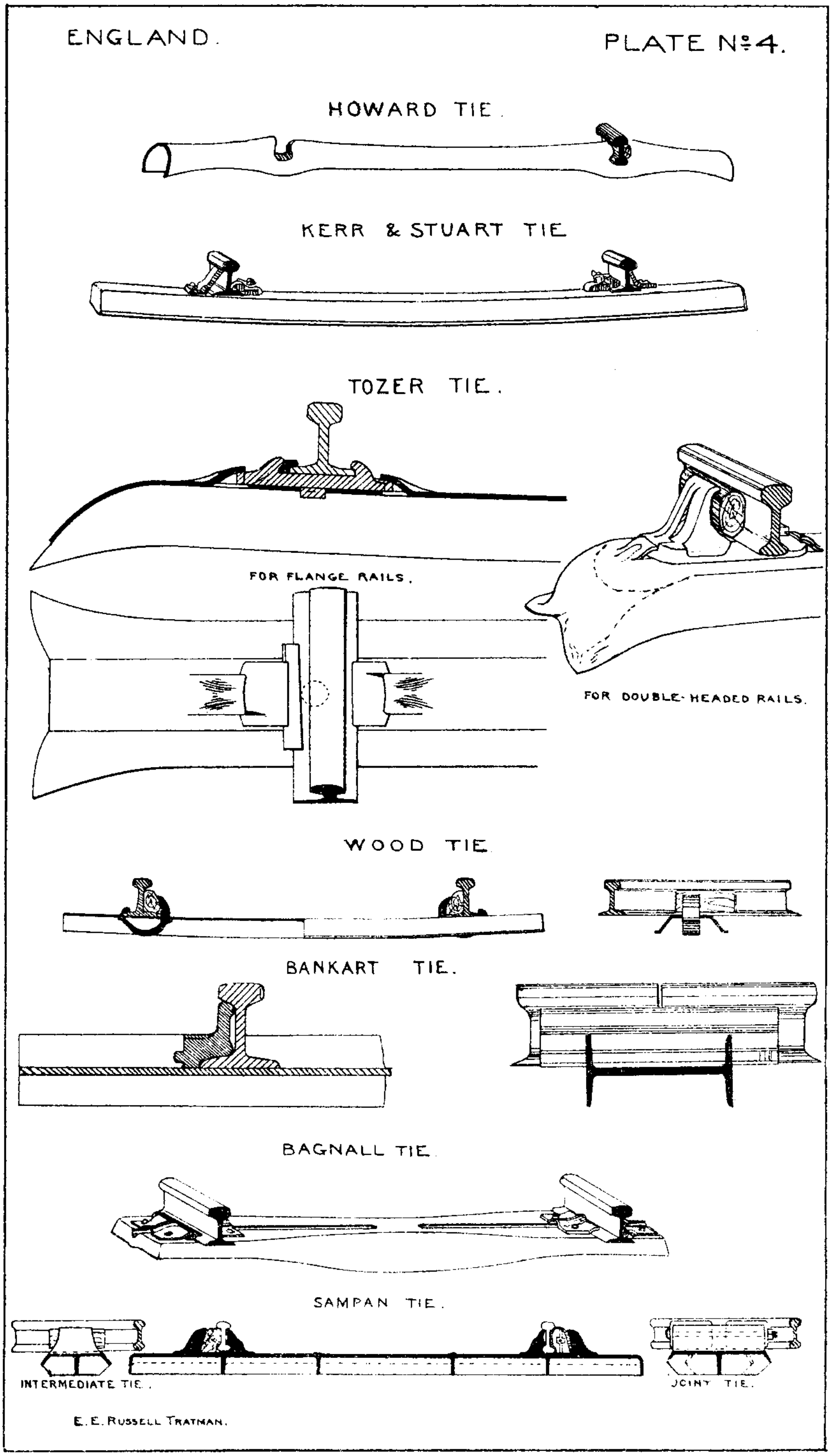
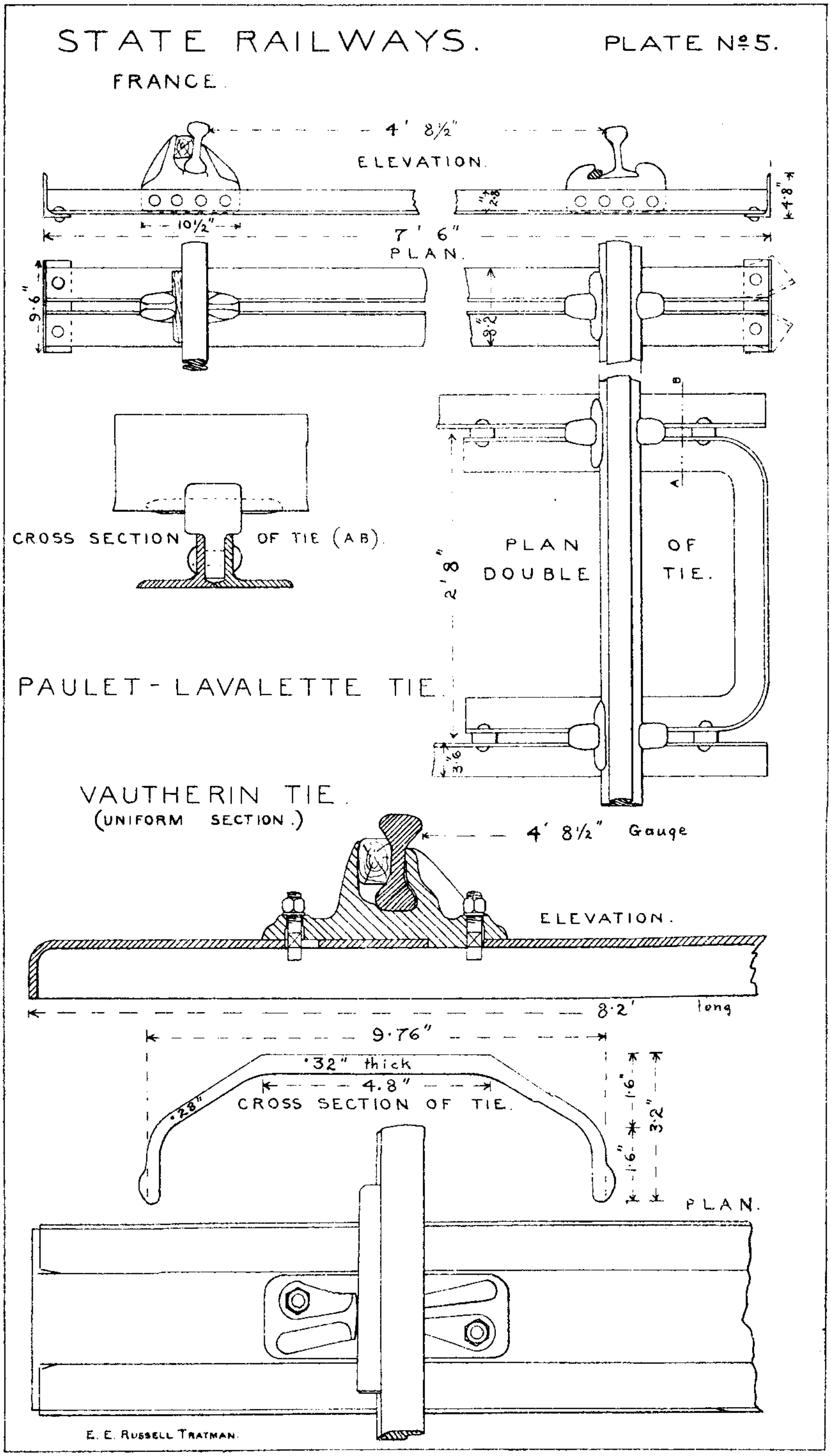
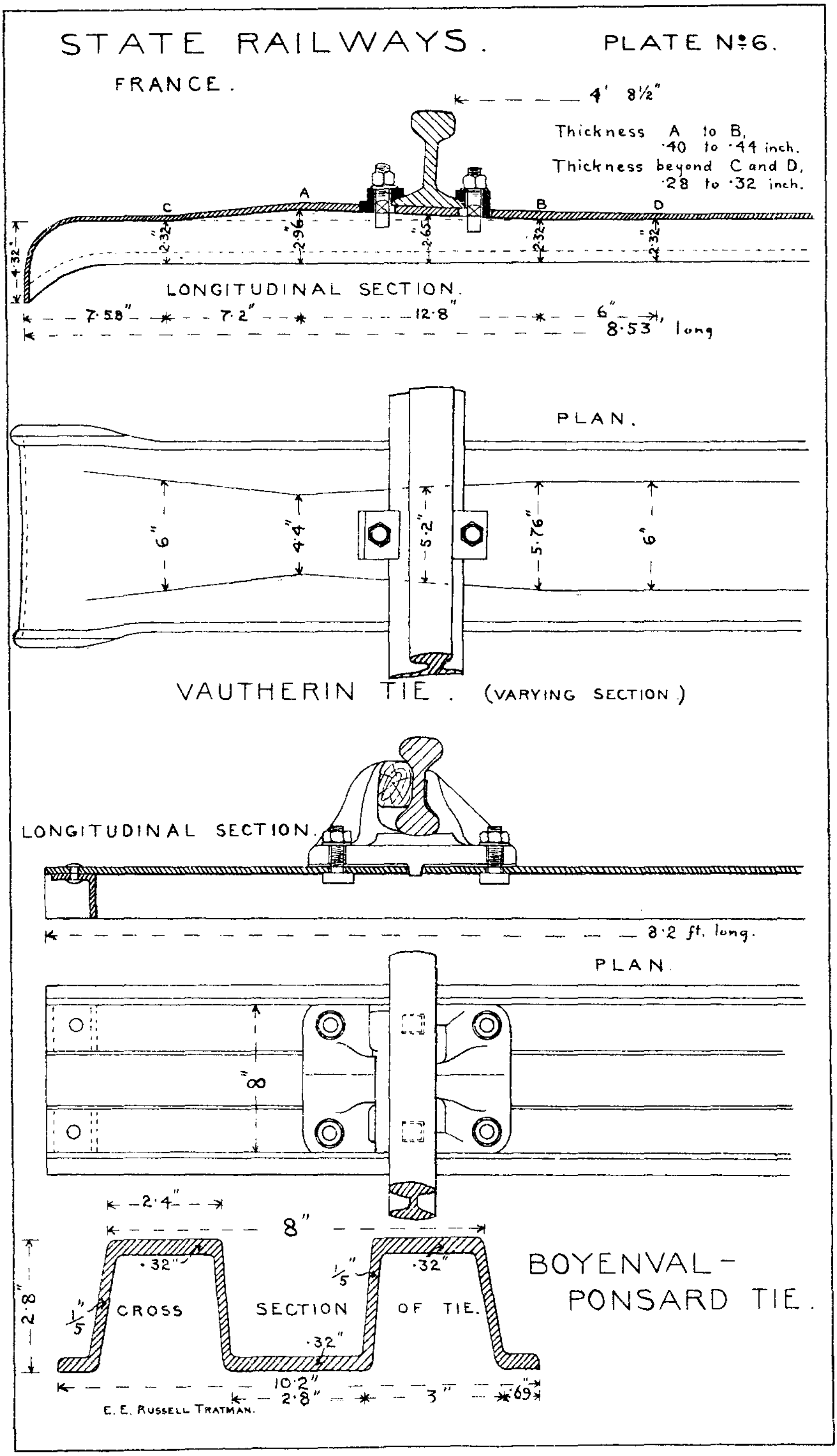
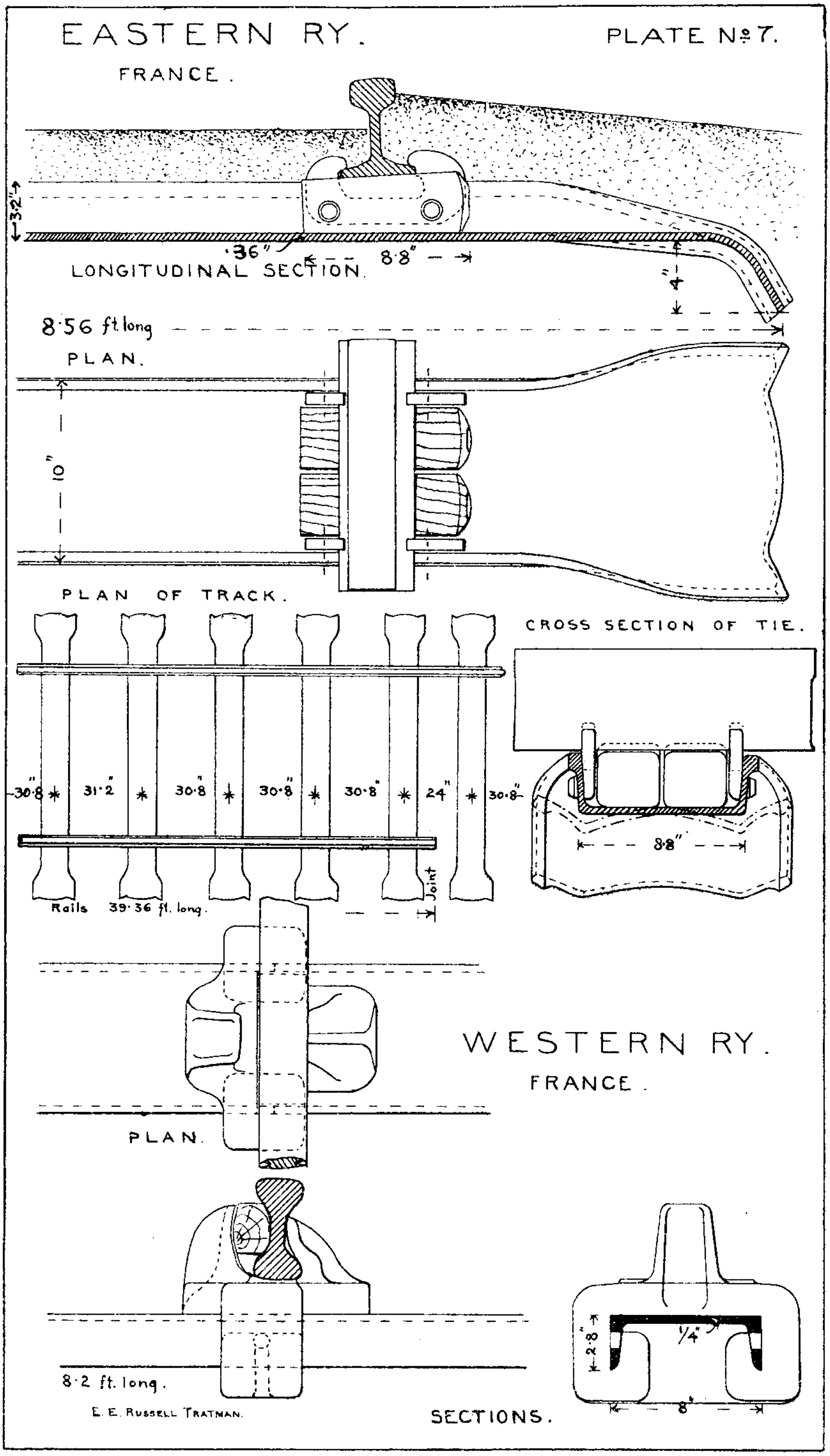


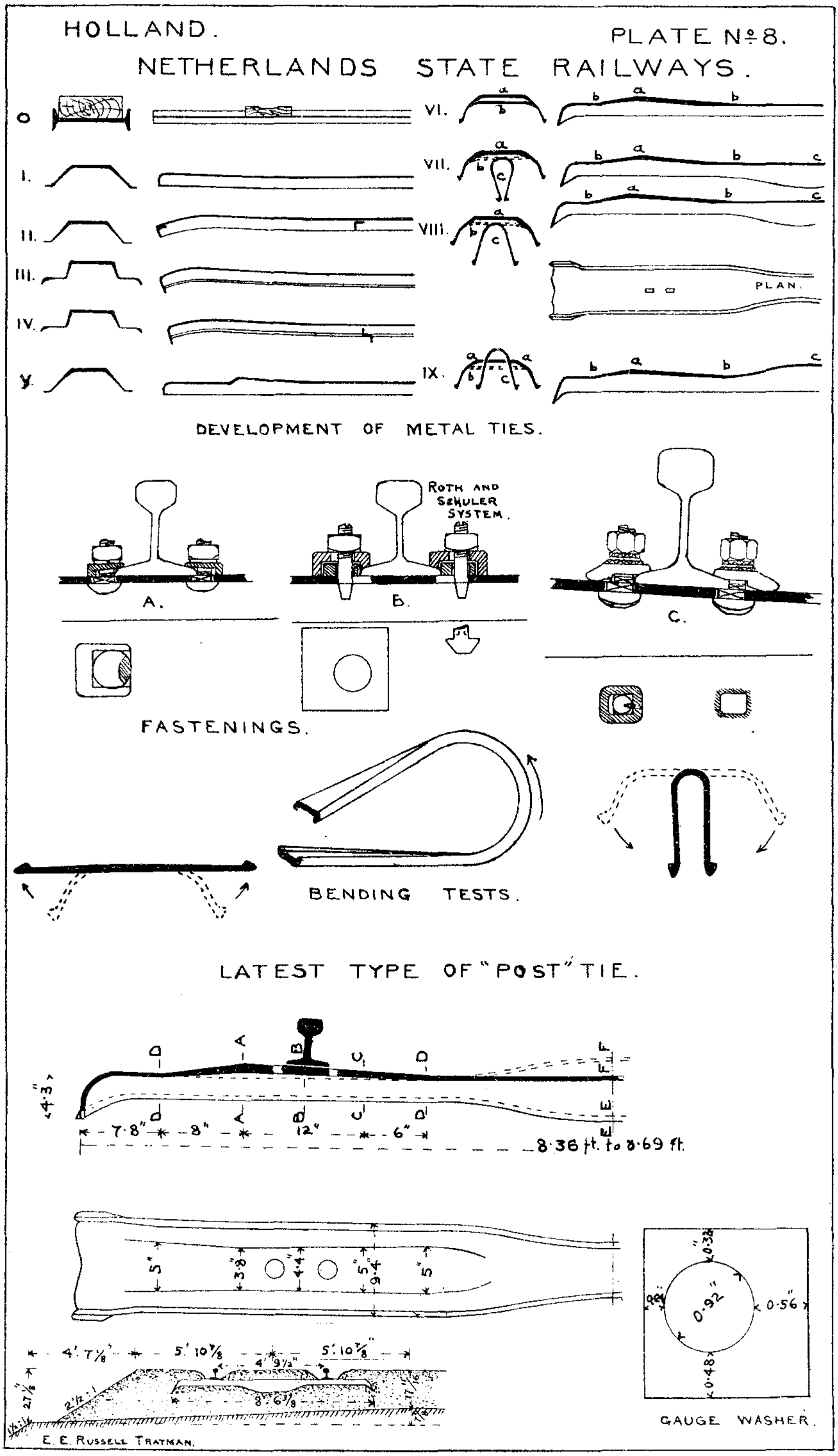

PLATE No. 3.


ENGLAND.
PLATE No. 4.
HOWARD TIE.
KERR & STUART TIE
TOZER TIE.
FOR FLANGE RAILS.
FOR DOUBLE-HEADED RAILS.
WOOD TIE.
BANKART TIE.
BAGNALL TIE.
SAMPAN TIE.
INTERMEDIATE TIE.
JOINT TIE.
E. E. RUSSELL TRATMAN.


STATE RAILWAYS.
PLATE No. 5.
FRANCE.
4' 8½"
ELEVATION.
10½"
2.8"
4.8"
7' 6"
PLAN.
9.6"
8.2"
B
A
CROSS SECTION OF TIE (AB).
PLAN OF DOUBLE TIE.
2' 8"
3.6"
PAULET-LAVALETTE TIE.
VAUTHERIN TIE.
(UNIFORM SECTION.)
4' 8½" Gauge
ELEVATION.
8.2' long
9.76"
.32" thick
4.8"
.28"
CROSS SECTION OF TIE.
1.6"
3.2"
1.6"
PLAN.
E. E. RUSSELL TRATMAN.


STATE RAILWAYS.
PLATE No. 6.
FRANCE.
4' 8½"
Thickness A to B, ·40 to ·44 inch.
Thickness beyond C and D, ·28 to ·32 inch.
C
A
B
D
4·32"
2·32"
2·96"
2·63"
2·32"
2·32"
LONGITUDINAL SECTION.
7·58"
7·2"
12·8"
6"
8·53' long
PLAN.
6"
4·4"
5·2"
5·76"
6"
VAUTHERIN TIE. (VARYING SECTION.)
LONGITUDINAL SECTION.
8·2 ft. long.
PLAN.
8"
2·4"
8"
2·8"
·32"
1/5"
CROSS SECTION OF TIE.
1/5"
·32"
·32"
10·2"
2·8"
3"
·69"
BOYENVAL-PONSARD TIE.
E. E. Russell Tratman.

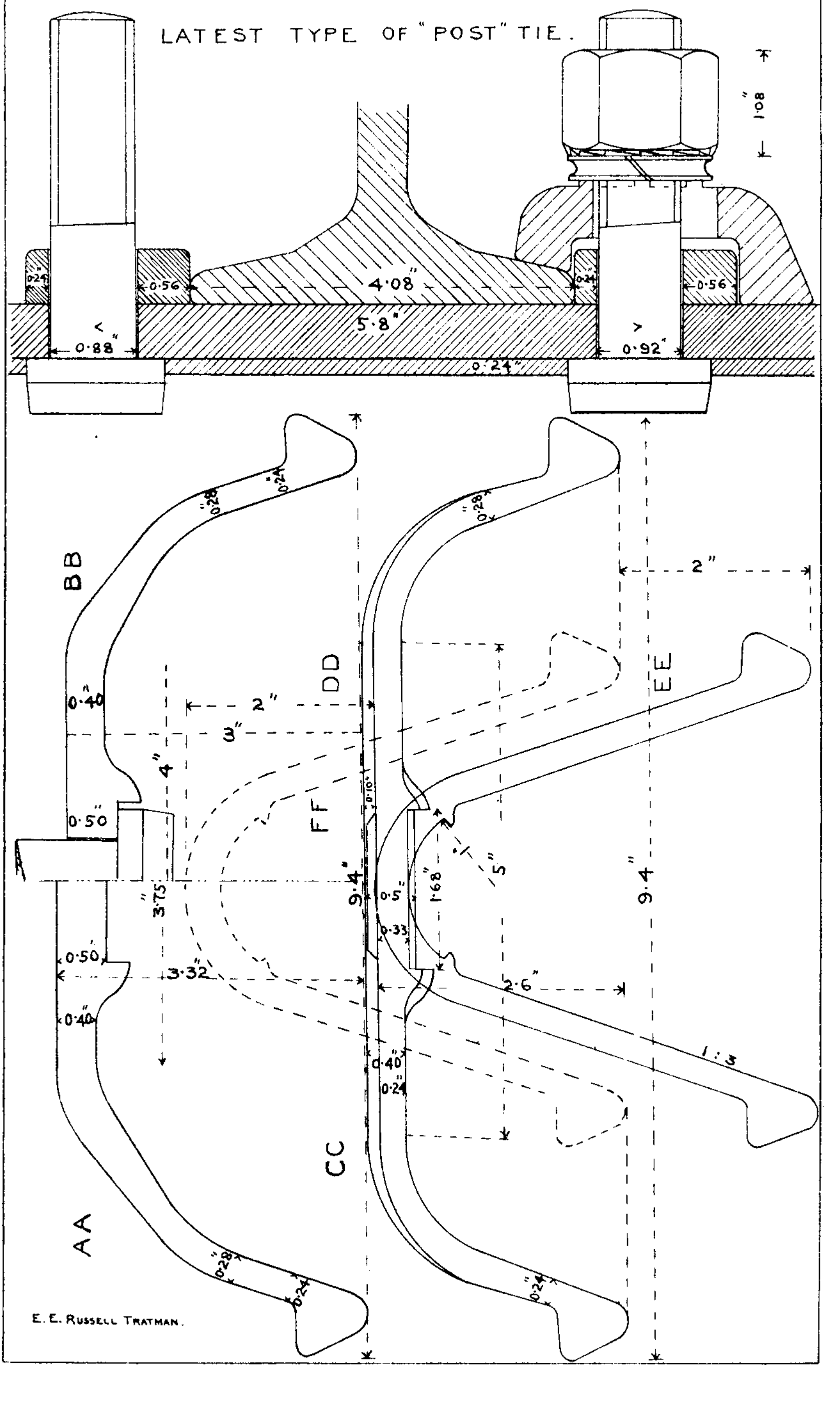

EASTERN RY.
FRANCE.
PLATE No 7.
3·2"
·36"
8·8"
LONGITUDINAL SECTION.
4"
8·56 ft. long
PLAN.
10"
PLAN OF TRACK.
CROSS SECTION OF TIE.
30·8"
31·2"
30·8"
30·8"
30·8"
24"
30·8"
8·8"
Joint
Rails 39·36 ft. long.
WESTERN RY.
FRANCE.
PLAN.
2·8"
1/4"
8"
8·2 ft. long.
E. E. Russell Tratman.
SECTIONS.

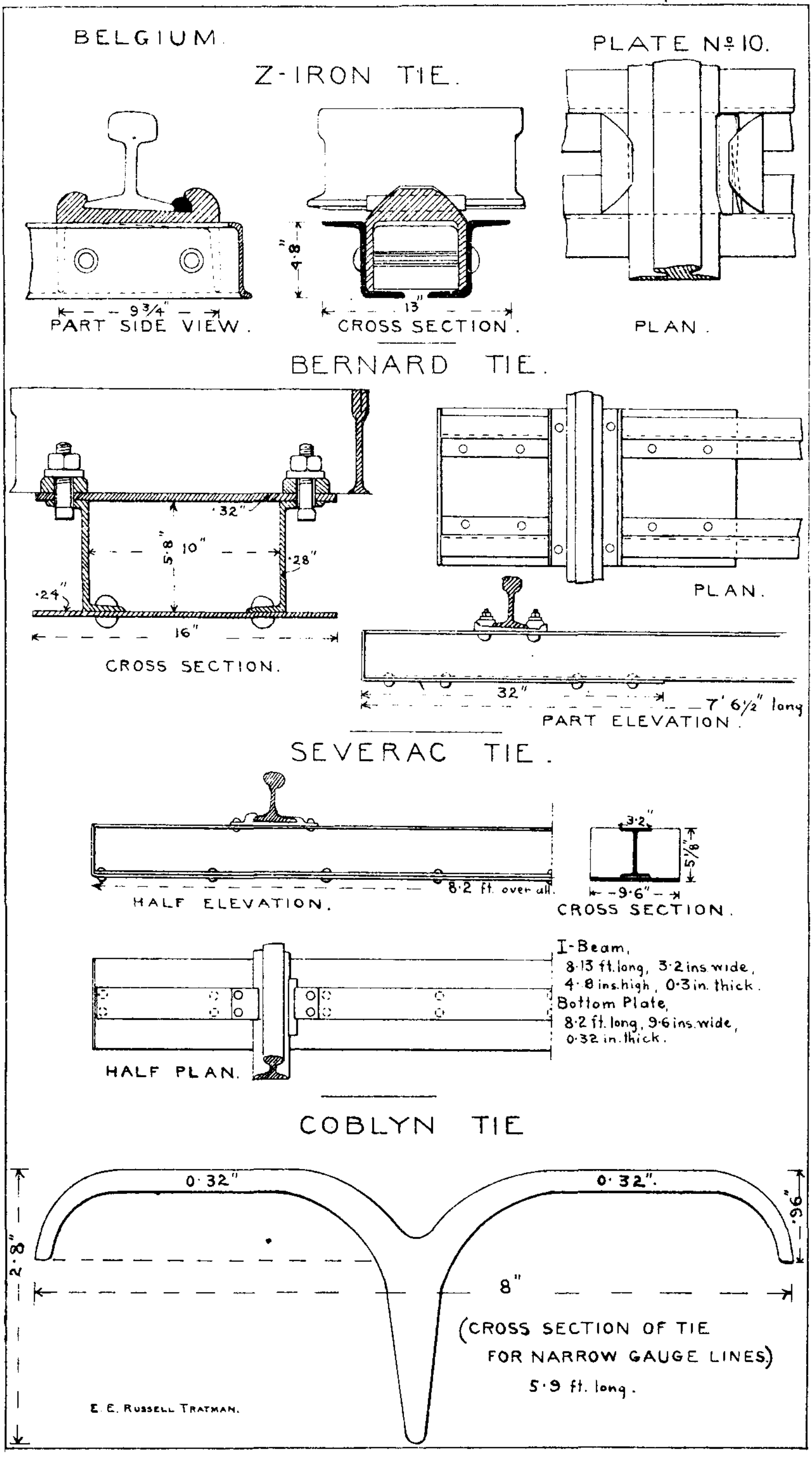

HOLLAND.
PLATE No. 8.
NETHERLANDS STATE RAILWAYS.
0
I.
II.
III.
IV.
V.
VI.
VII.
VIII.
IX.
a
b
c
PLAN.
DEVELOPMENT OF METAL TIES.
ROTH AND SCHULER SYSTEM.
A.
B.
C.
FASTENINGS.
BENDING TESTS.
LATEST TYPE OF "POST" TIE.
4·3"
7·8"
8"
12"
6"
8·36 ft. to 8·69 ft.
5"
3·8"
4·4"
5"
9·4"
5"
4' 7⅛"
5' 10⅞"
5' 10⅞"
4' 9½"
2½ : 1
8' 6⅜"
0·32"
0·92"
0·56"
0·48"
GAUGE WASHER.
E. E. Russell Tratman.

HOLLAND. PLATE No. 9.

NETHERLANDS STATE RAILWAYS

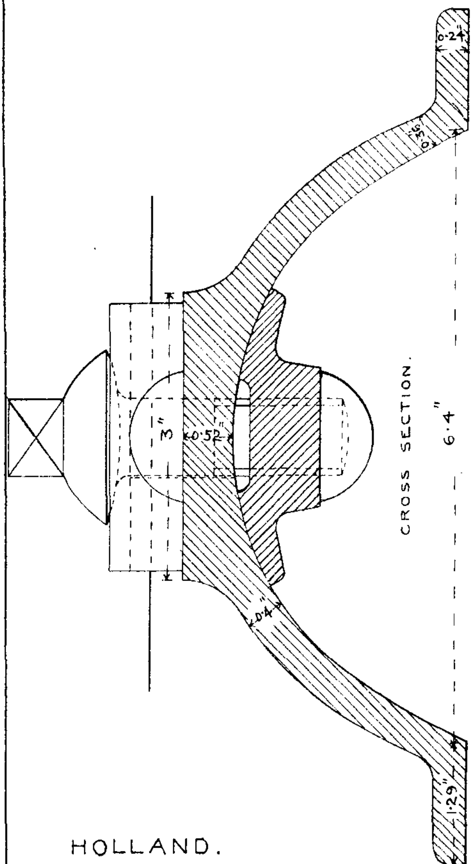
LATEST TYPE OF "POST" TIE.

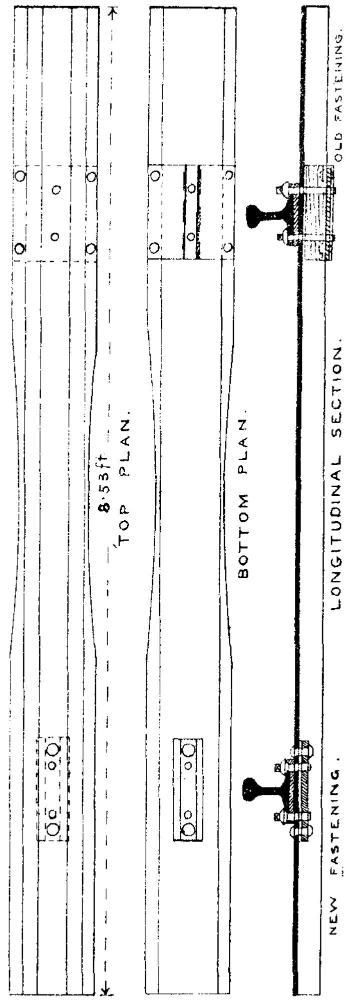



BELGIUM.
PLATE No. 10.
Z-IRON TIE.
9 3/4"
PART SIDE VIEW.
4·8"
13"
CROSS SECTION.
PLAN.
BERNARD TIE.
·32"
5·8"
10"
·28"
·24"
16"
CROSS SECTION.
PLAN.
32"
7' 6½" long
PART ELEVATION.
SEVERAC TIE.
8·2 ft. over all.
HALF ELEVATION.
3·2"
5⅝"
9·6"
CROSS SECTION.
I-Beam,
8·13 ft. long, 3·2 ins. wide,
4·8 ins. high, 0·3 in. thick.
Bottom Plate,
8·2 ft. long, 9·6 ins. wide,
0·32 in. thick.
HALF PLAN.
COBLYN TIE
0·32"
0·32".
·96"
2·8"
8"
(CROSS SECTION OF TIE
FOR NARROW GAUGE LINES)
5·9 ft. long.
E. E. Russell Tratman.

BELGIUM. PLATE No. 11.

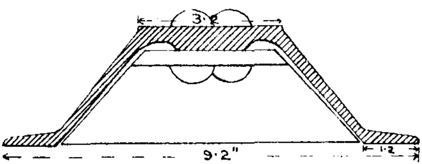
## GREAT CENTRAL RY.



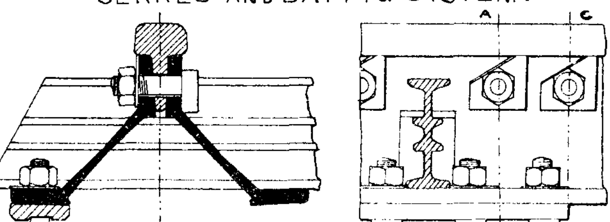

## HOLLAND.

## DUTCH RYS

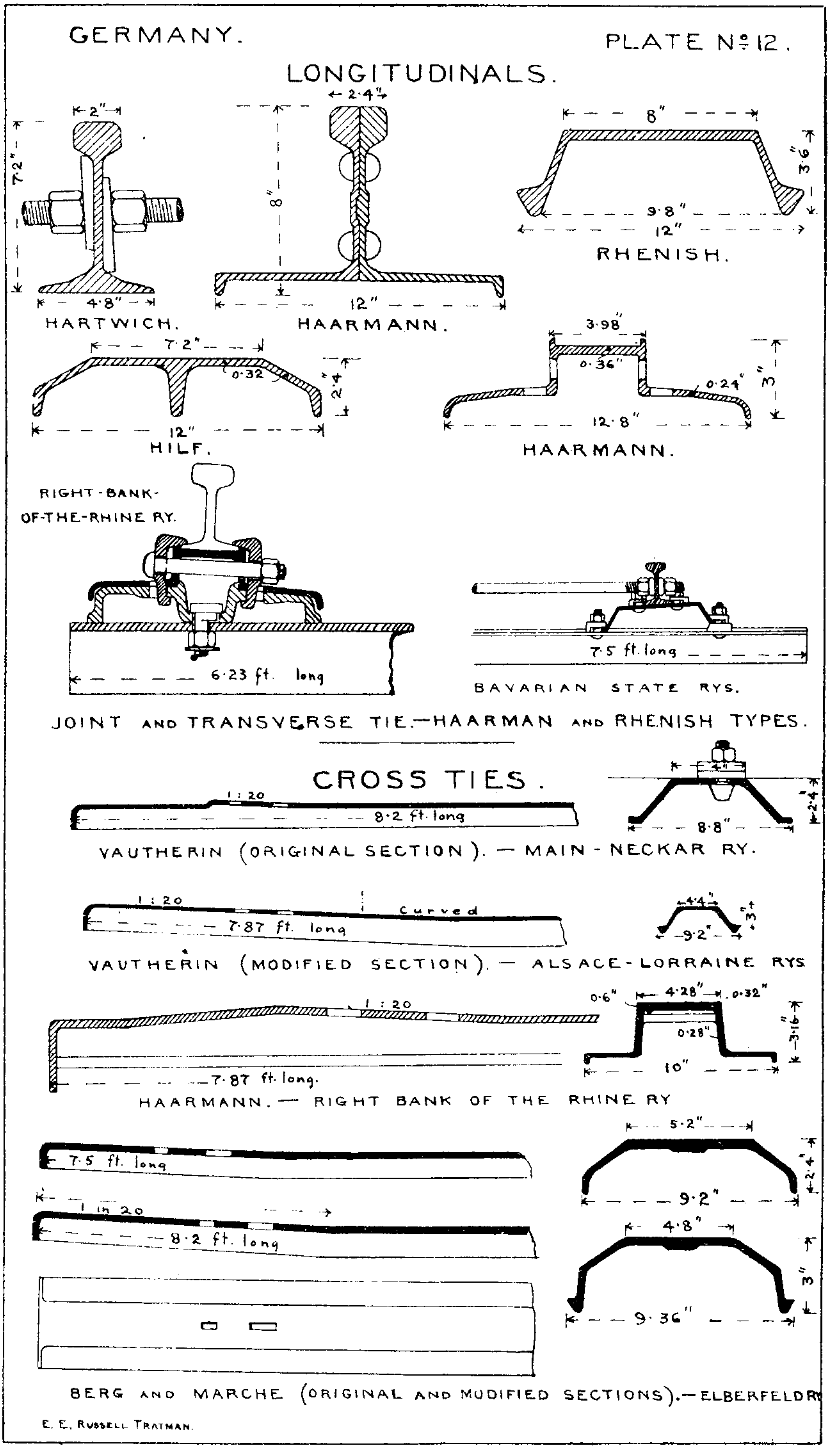



## AUSTRIA AND BELGIUM.

## SERRES AND BATTIG SYSTEM.

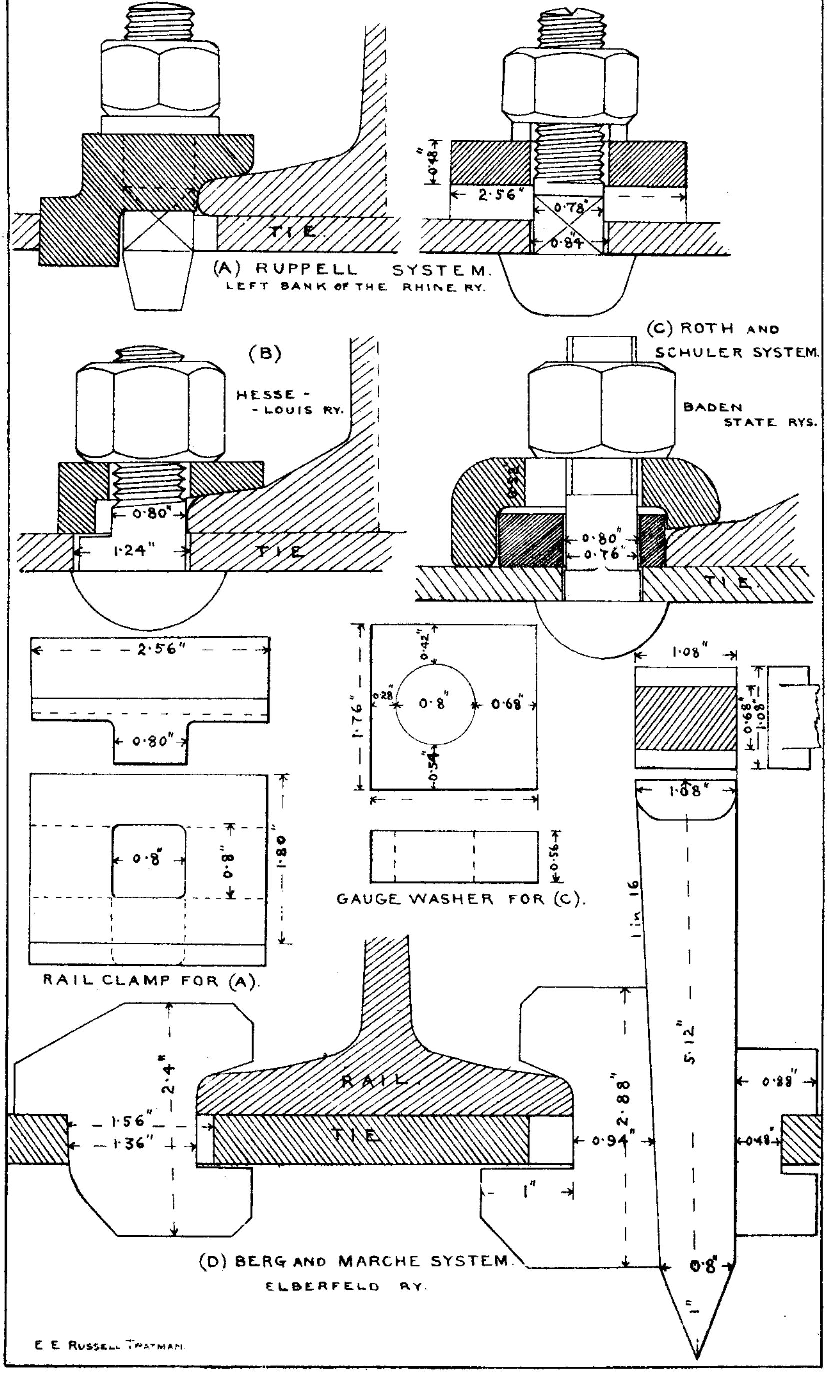


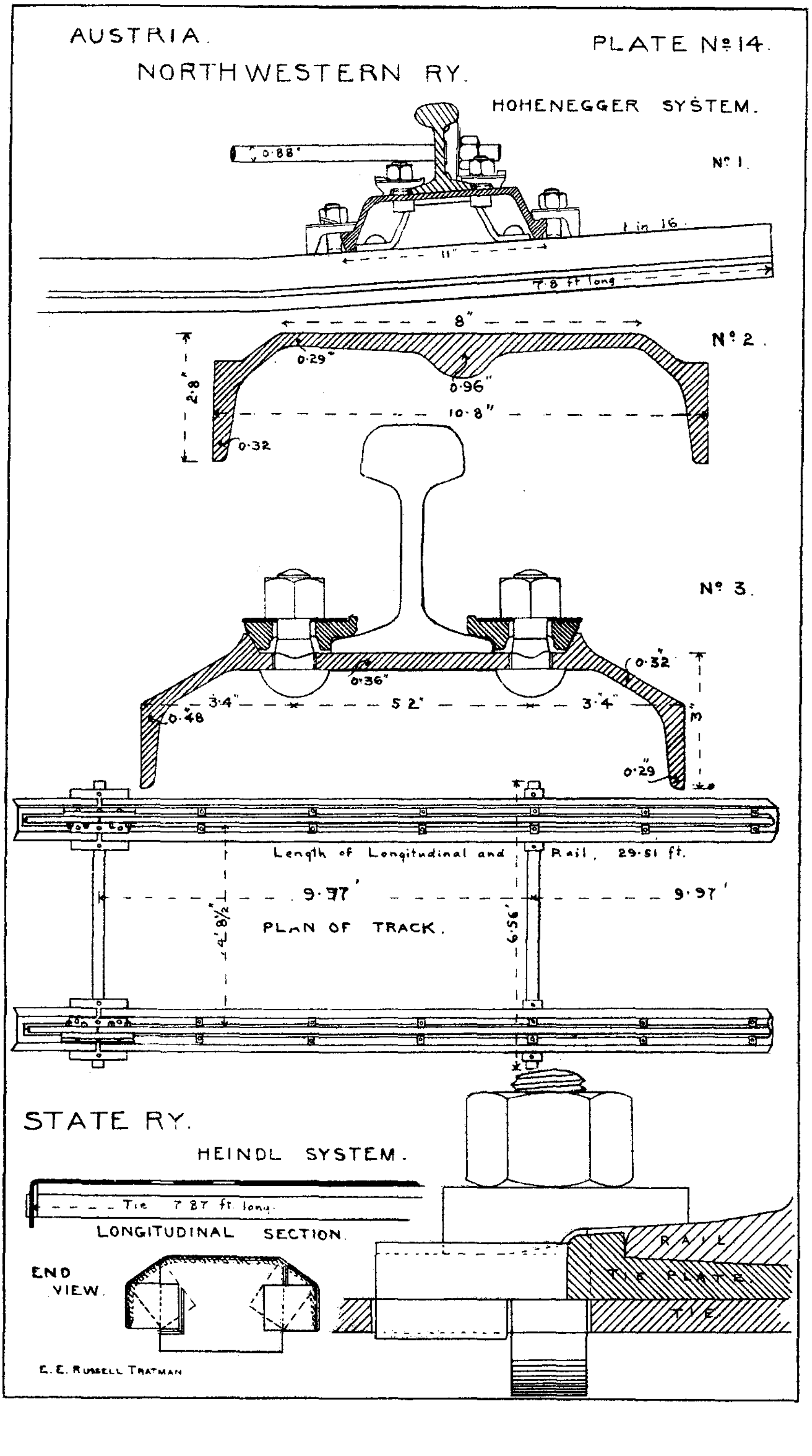

E. E. RUSSELL TRATMAN. SECTION A-B. SECTION C-D.

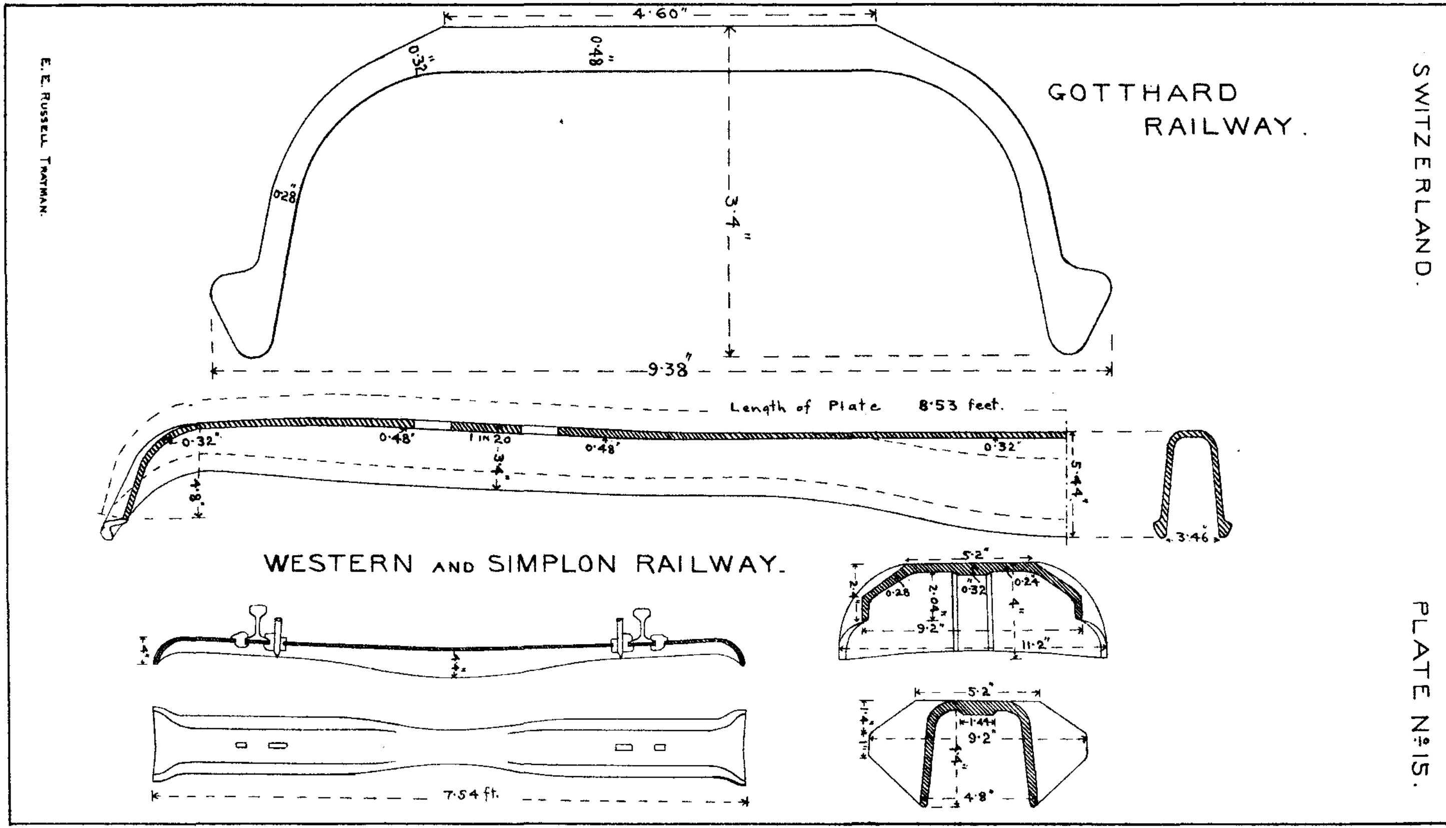

GERMANY.
PLATE No. 12.
LONGITUDINALS.
2"
7.2"
4.8"
HARTWICH.
2.4"
8"
12"
HAARMANN.
8"
3.6"
9.8"
12"
RHENISH.
7.2"
0.32
2.4"
12"
HILF.
3.98"
0.36"
0.24"
3"
12.8"
HAARMANN.
RIGHT-BANK-OF-THE-RHINE RY.
6.23 ft. long
7.5 ft. long
BAVARIAN STATE RYS.
JOINT AND TRANSVERSE TIE.—HAARMAN AND RHENISH TYPES.
CROSS TIES.
1:20
8.2 ft. long
4"
2.4"
8.8"
VAUTHERIN (ORIGINAL SECTION).—MAIN-NECKAR RY.
1:20
curved
7.87 ft. long
4.4"
3"
9.2"
VAUTHERIN (MODIFIED SECTION).—ALSACE-LORRAINE RYS.
1:20
0.6"
4.28"
0.32"
0.28"
3.16"
10"
7.87 ft. long.
HAARMANN.—RIGHT BANK OF THE RHINE RY
7.5 ft. long
5.2"
2.4"
9.2"
1 in 20
8.2 ft. long
4.8"
3"
9.36"
BERG AND MARCHE (ORIGINAL AND MODIFIED SECTIONS).—ELBERFELD RY
E. E. RUSSELL TRATMAN.

GERMANY. PLATE No. 13.

# FASTENINGS.

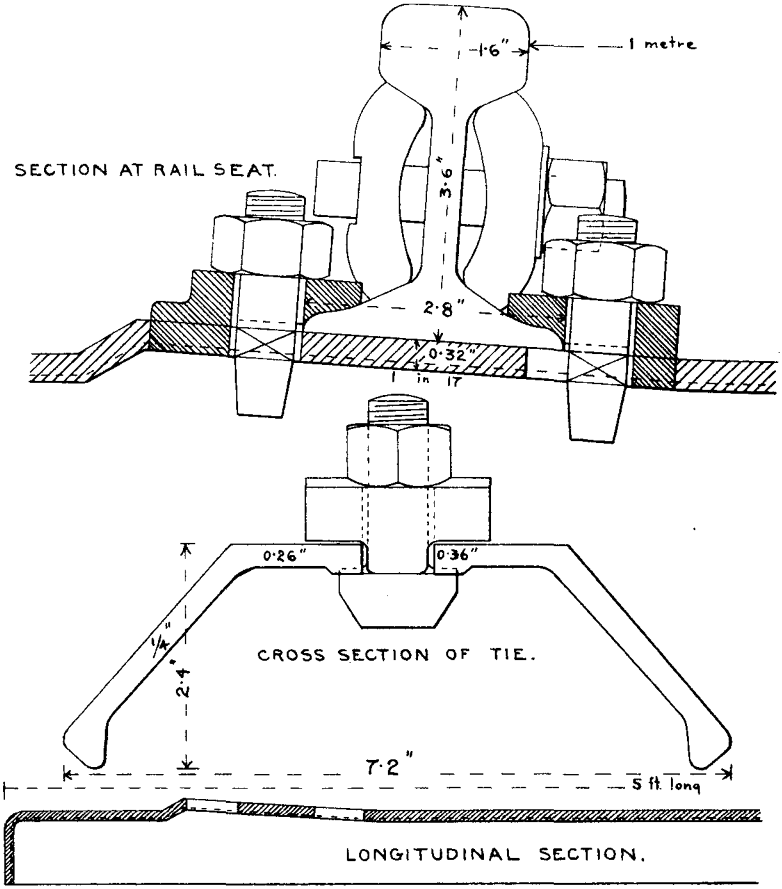



AUSTRIA.
PLATE No. 14.
NORTHWESTERN RY.
HOHENEGGER SYSTEM.
No. 1.
0·88"
1 in 16.
11"
7·8 ft long
No. 2.
8"
0·29"
0·96"
2·8"
10·8"
0·32
No. 3.
0·32"
0·36"
3·4"
5 2"
3·4"
0·48
3"
0·29"
Length of Longitudinal and Rail, 29·51 ft.
9·97'
9·97'
4' 8½"
6·56'
PLAN OF TRACK.
STATE RY.
HEINDL SYSTEM.
Tie 7·87 ft. long
LONGITUDINAL SECTION.
END VIEW.
RAIL
TIE PLATE
TIE
E. E. Russell Tratman

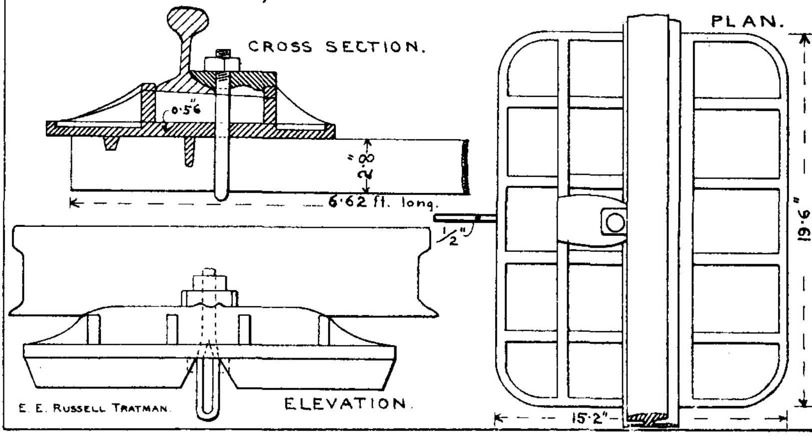

SWITZERLAND.
PLATE No. 15.
E. E. RUSSELL TRATMAN.
GOTTHARD RAILWAY.
4·60"
0·32"
0·48"
0·28"
3·4"
9·38"
Length of Plate 8·53 feet.
0·32"
0·48"
1 IN 20
0·48"
3·4"
0·32"
4·8"
5·44"
3·46
WESTERN AND SIMPLON RAILWAY.
5·2"
2·4"
0·28
2·04"
0·32
0·24
4"
9·2"
11·2"
4"
4"
7·54 ft.
5·2"
1·4"
1·44
9·2"
4"
4·8"

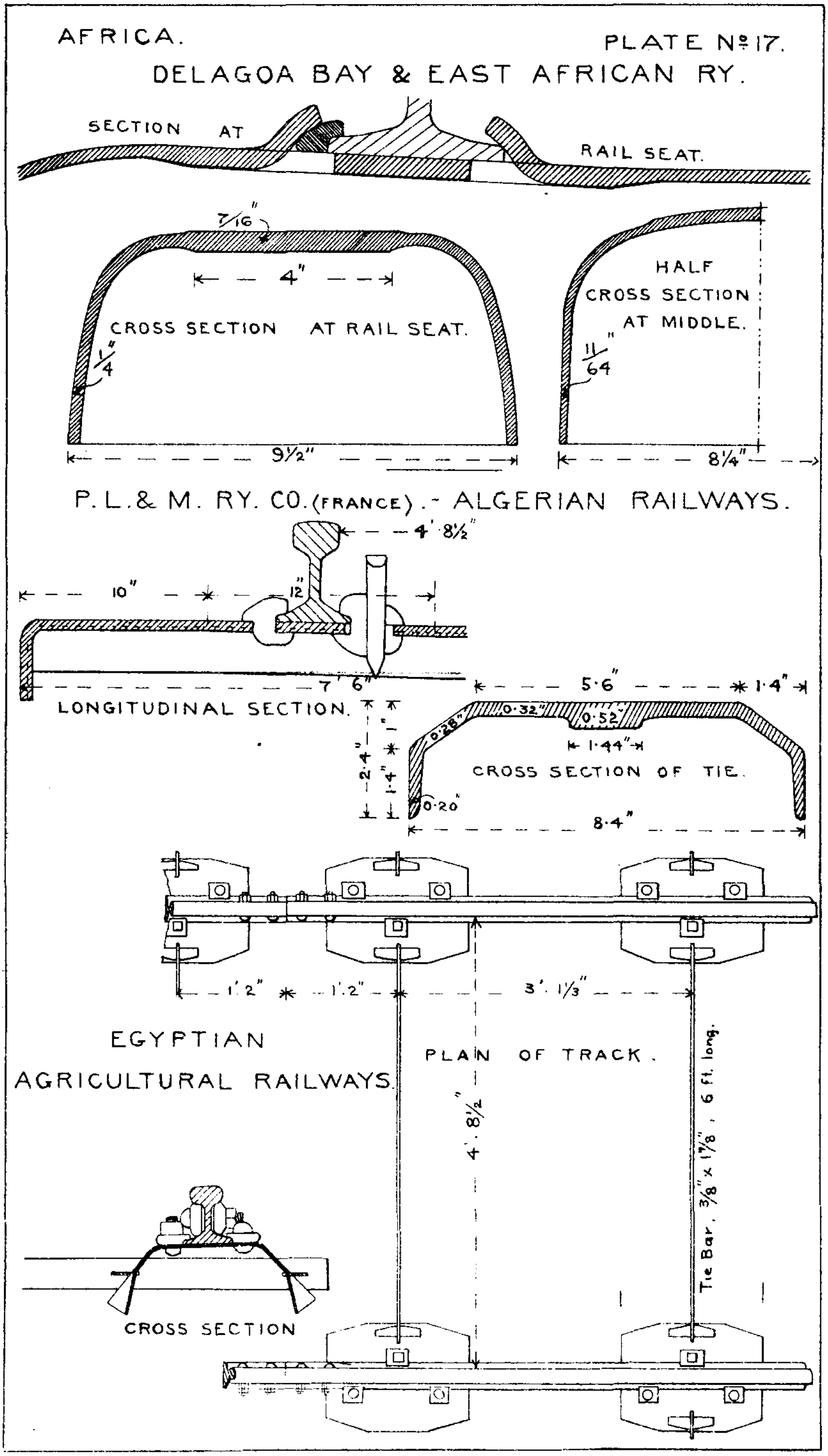
SPAIN. PLATE No. 16.

## BILBAO & LAS ARENAS RY.

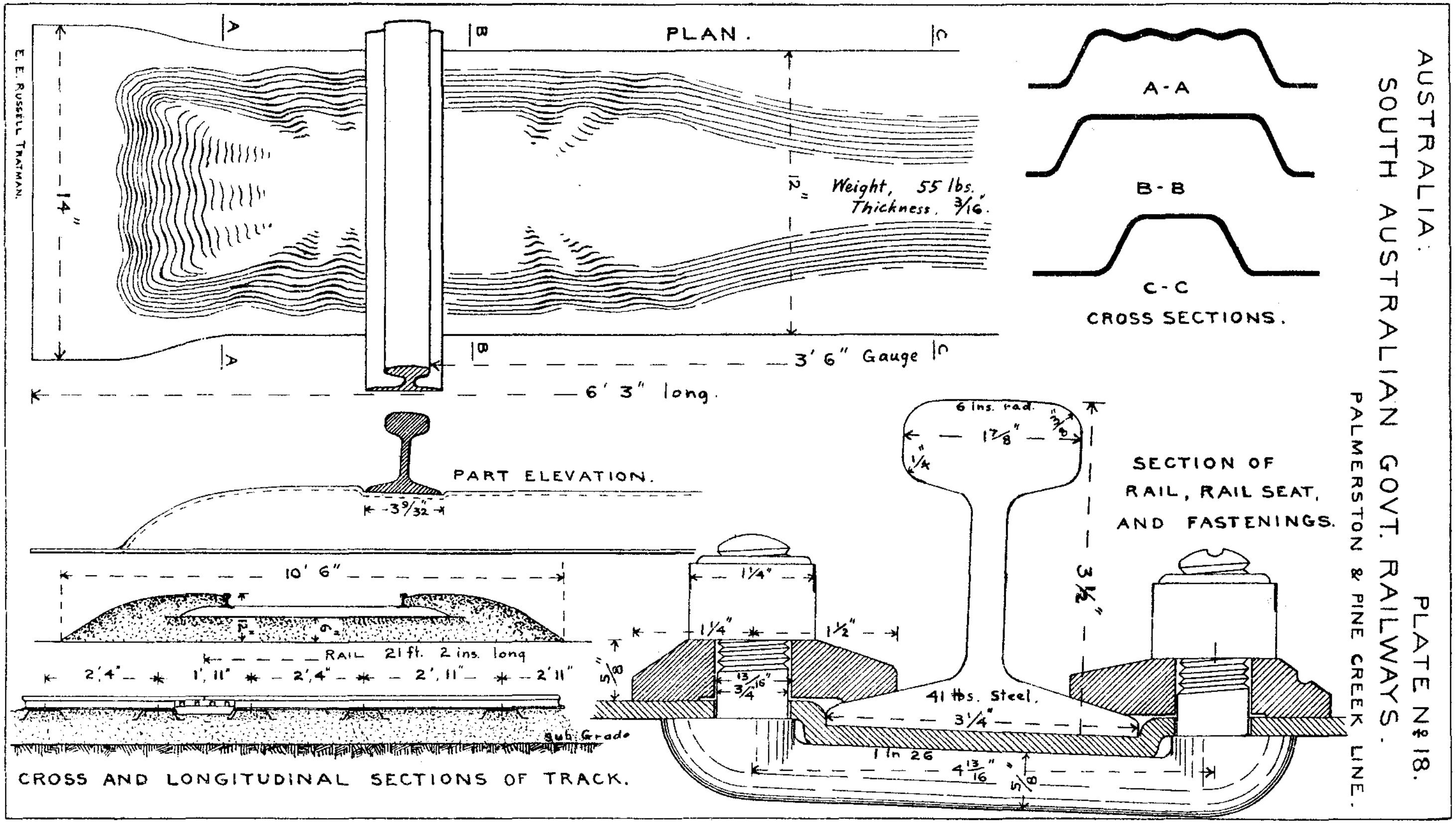



## ALMANSA, VALENCIA & TARRAGONA RY.

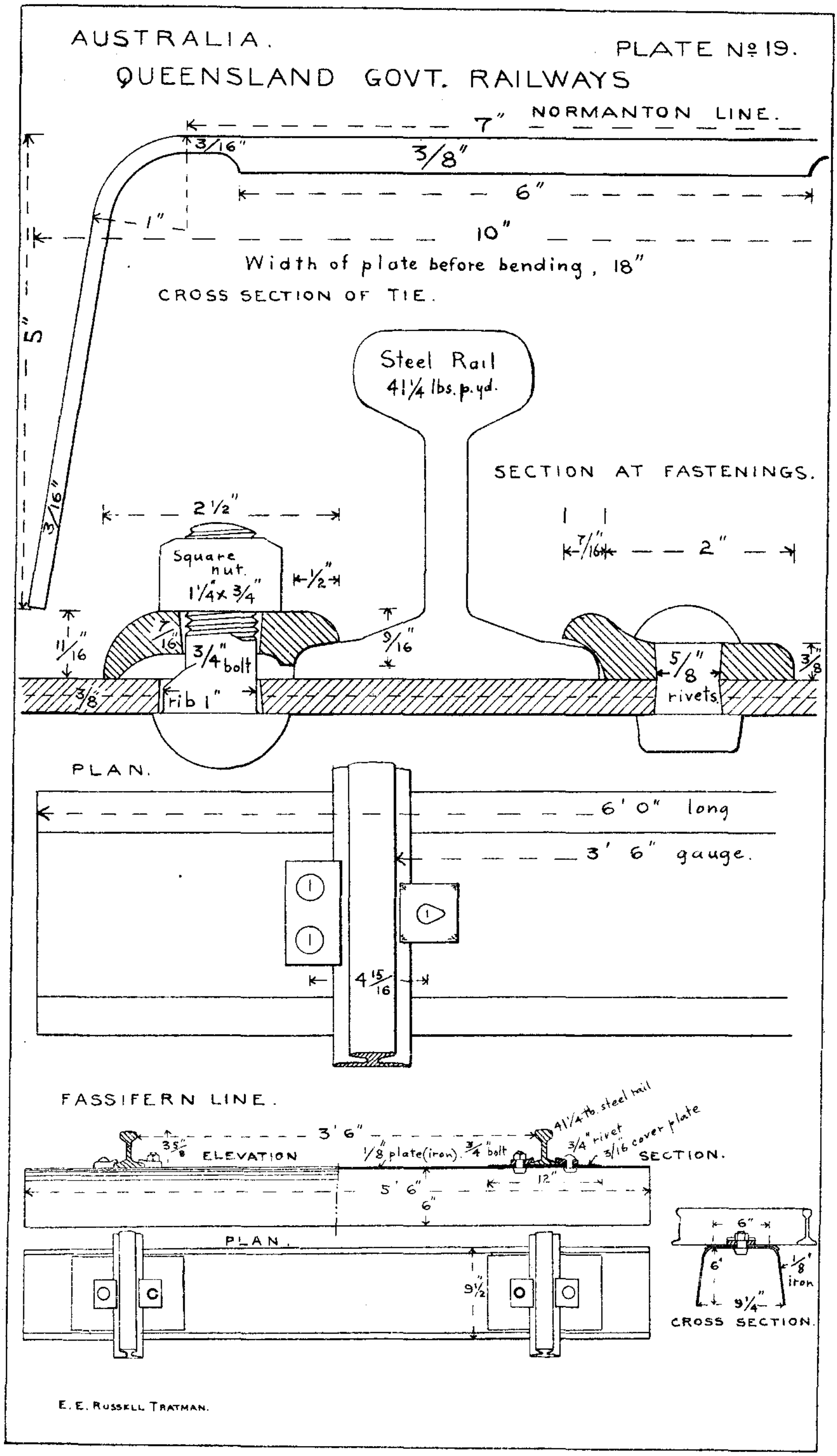


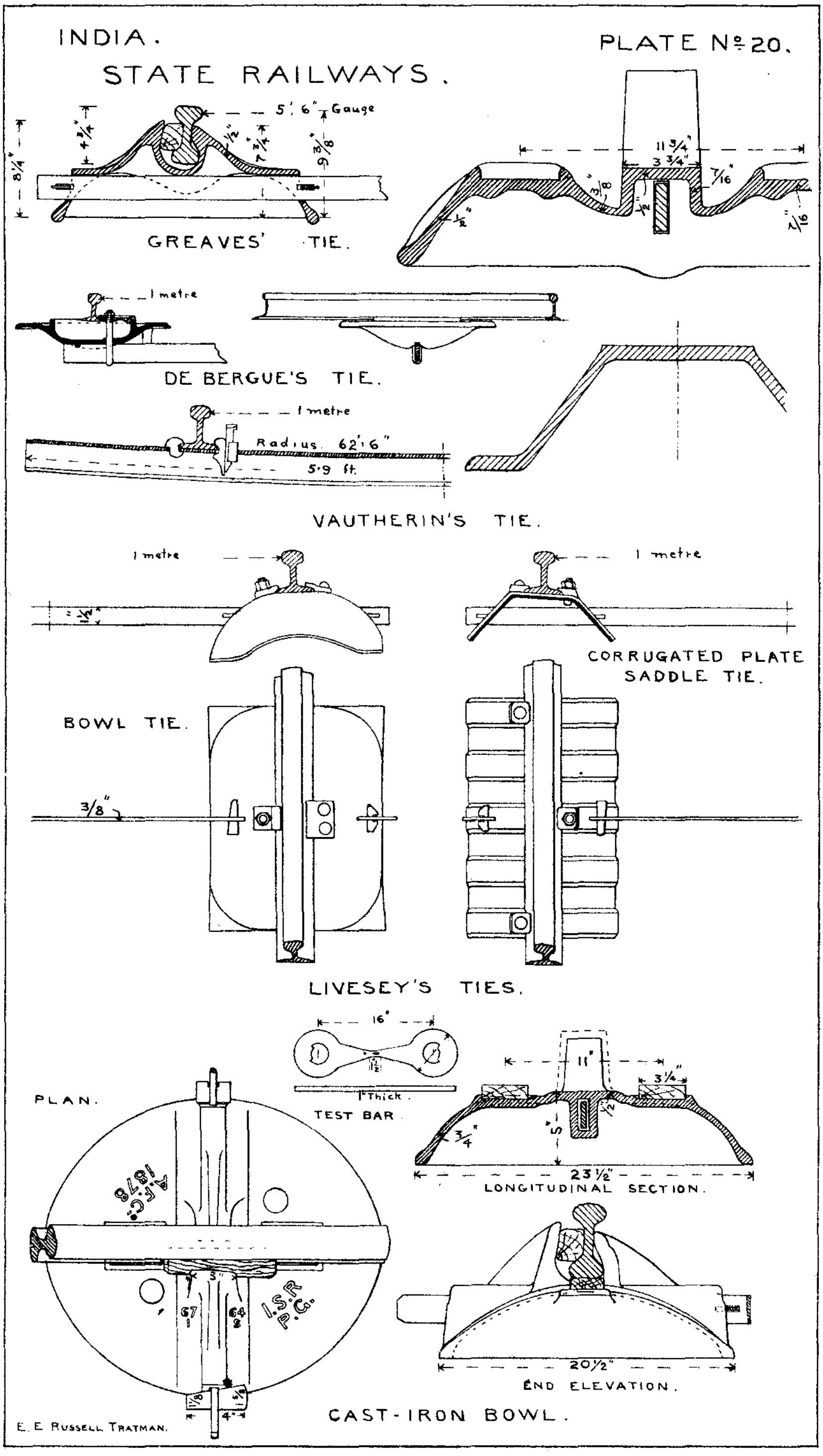


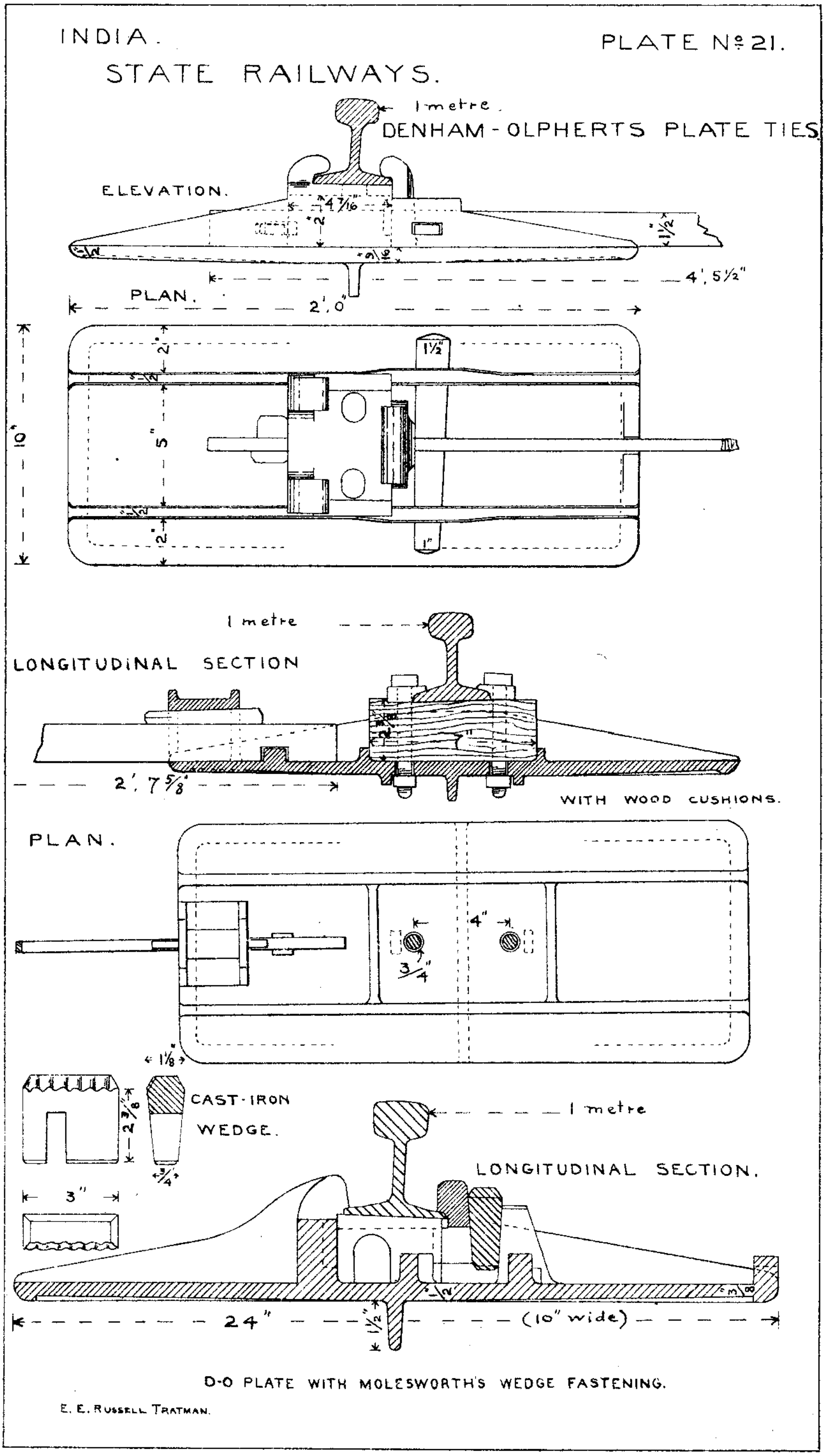
AFRICA.
PLATE No 17.
DELAGOA BAY & EAST AFRICAN RY.
SECTION AT RAIL SEAT.
7/16"
4"
CROSS SECTION AT RAIL SEAT.
1/4"
9½"
HALF CROSS SECTION AT MIDDLE.
11/64"
8¼"
P. L. & M. RY. CO. (FRANCE). - ALGERIAN RAILWAYS.
4' 8½"
10"
12"
7' 6"
LONGITUDINAL SECTION.
5·6"
1·4"
0·28"
0·32"
0·52"
1·44"
2·4"
1"
1·4"
CROSS SECTION OF TIE.
0·20"
8·4"
1' 2"
1' 2"
3' 1/3"
EGYPTIAN
AGRICULTURAL RAILWAYS.
PLAN OF TRACK.
4' 8½"
Tie Bar, 3/8" x 1 7/8", 6 ft. long.
CROSS SECTION

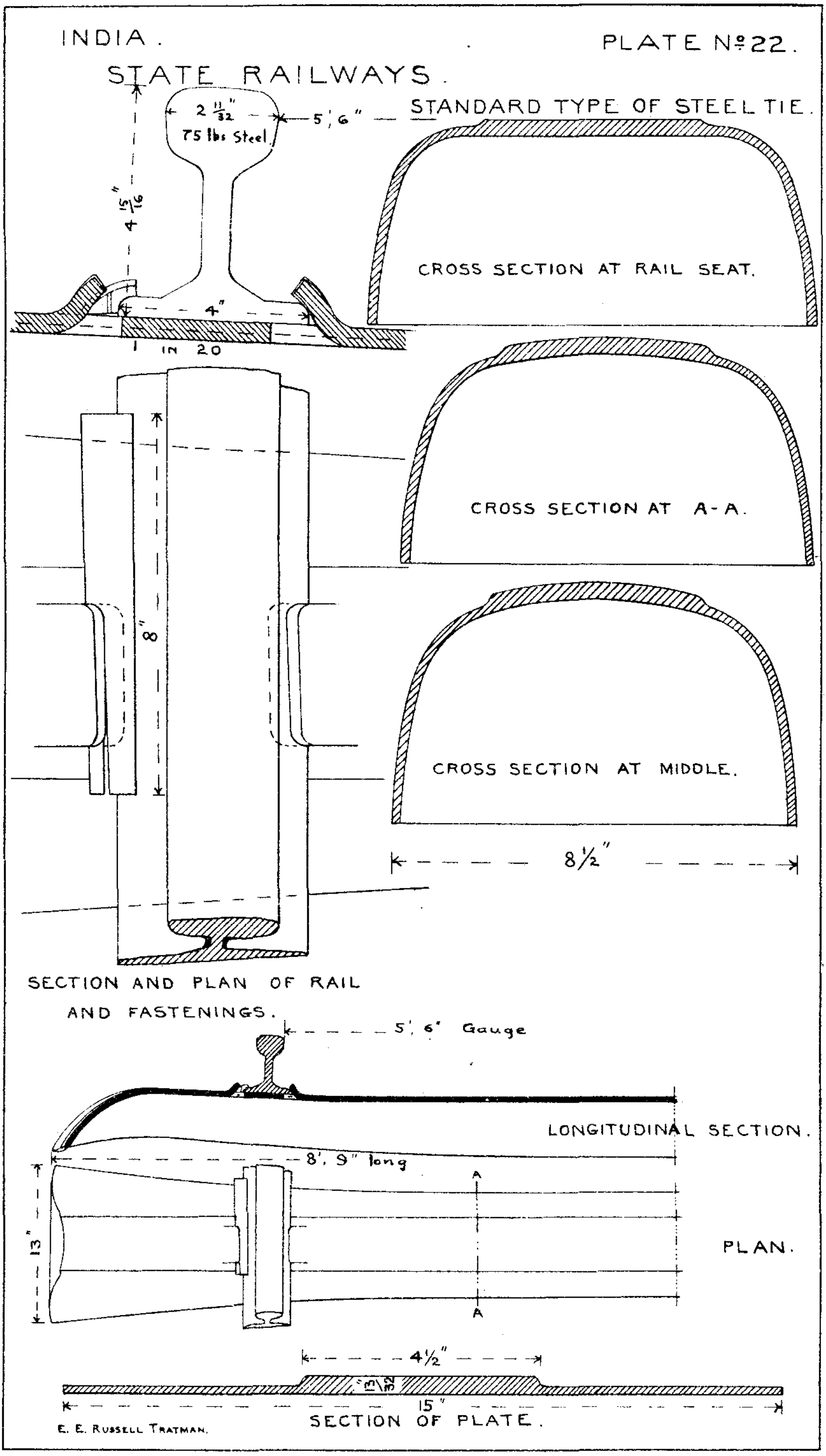


AUSTRALIA:
SOUTH AUSTRALIAN GOVT. RAILWAYS.
PALMERSTON & PINE CREEK LINE.
PLATE No 18.
E. E. RUSSELL TRATMAN.
PLAN.
14"
12"
Weight, 55 lbs.
Thickness, 3/16.
3' 6" Gauge
6' 3" long.
A-A
B-B
C-C
CROSS SECTIONS.
PART ELEVATION.
3 9/32"
10' 6"
RAIL 21 ft. 2 ins. long
2' 4"
1' 11"
2' 4"
2' 11"
2' 11"
Sub Grade
CROSS AND LONGITUDINAL SECTIONS OF TRACK.
6 ins. rad.
1 7/8"
3/8
1/4
3 1/2"
SECTION OF
RAIL, RAIL SEAT,
AND FASTENINGS.
1 1/4"
1 1/4"
1 1/2"
5/8"
13/16"
3/4"
41 lbs. Steel.
3 1/4"
1 in 26
4 13/16"
5/8


AUSTRALIA.
PLATE No. 19.
QUEENSLAND GOVT. RAILWAYS
NORMANTON LINE.
7"
3/16"
3/8"
6"
1"
10"
5"
3/16"
Width of plate before bending, 18"
CROSS SECTION OF TIE.
Steel Rail
41 1/4 lbs. p. yd.
SECTION AT FASTENINGS.
2 1/2"
Square nut.
1 1/4" x 3/4"
1/2"
11/16"
7/16"
3/4" bolt
9/16"
3/8"
rib 1"
7/16"
2"
5/8" rivets.
3/8"
PLAN.
6' 0" long
3' 6" gauge.
4 15/16
FASSIFERN LINE.
3' 6"
ELEVATION
1/8" plate (iron).
3/4" bolt
41 1/4 lb. steel rail
3/4" rivet
3/16 cover plate
SECTION.
5' 6"
12"
6"
PLAN.
9 1/2"
6"
6'
1/8" iron
9 1/4"
CROSS SECTION.
E. E. RUSSELL TRATMAN.


INDIA.
STATE RAILWAYS.
PLATE No 20.
5' 6" Gauge
8¼"
4¾"
½"
7¾"
9⅜"
GREAVES' TIE.
11¾"
3¾"
7/16"
3/8"
½"
1 metre
DE BERGUE'S TIE.
1 metre
Radius 62' 6"
5·9 ft.
VAUTHERIN'S TIE.
1 metre
1 metre
CORRUGATED PLATE SADDLE TIE.
BOWL TIE.
3/8"
LIVESEY'S TIES.
16"
1½
1" Thick
TEST BAR
PLAN.
11"
3¼"
5"
¾"
23½"
LONGITUDINAL SECTION.
A.F.C. 1878
I.S.R. P.G.
3"
67
64
4"
20½"
END ELEVATION.
CAST-IRON BOWL.
E. E. RUSSELL TRATMAN.

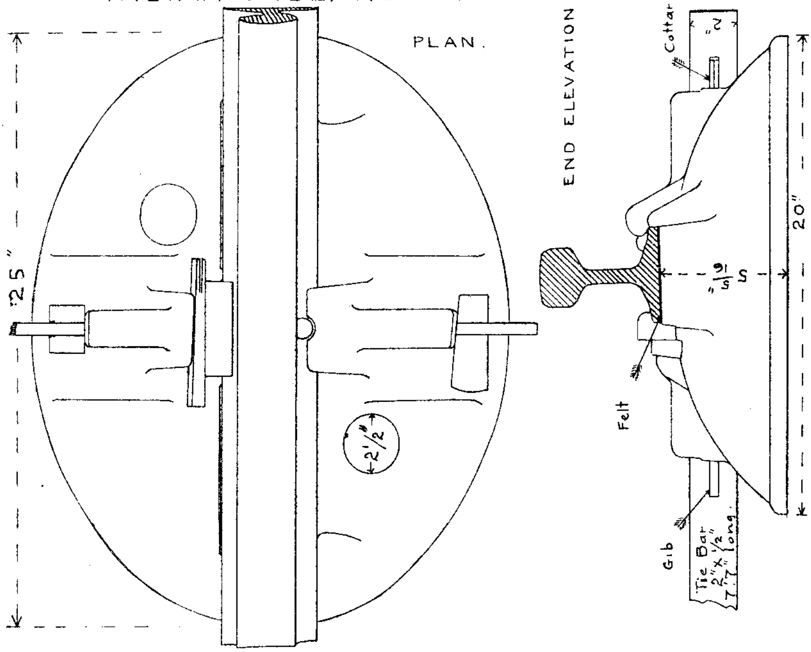

INDIA.
STATE RAILWAYS.
PLATE No. 21.
DENHAM-OLPHERTS PLATE TIES.
1 metre.
ELEVATION.
4 7/16"
2"
1 1/2"
1/2"
9/16"
4', 5 1/2"
PLAN.
2', 0"
1 1/2"
10"
2"
1/2"
5"
1/2"
2"
1"
1 metre
LONGITUDINAL SECTION
2', 7 5/8"
WITH WOOD CUSHIONS.
PLAN.
4"
3/4"
1 1/8"
2 3/8"
CAST-IRON WEDGE.
3/4"
3"
1 metre
LONGITUDINAL SECTION.
24"
1 1/2"
(10" wide)
3/8"
D-O PLATE WITH MOLESWORTH'S WEDGE FASTENING.
E. E. Russell Tratman.


INDIA.
PLATE No 22.
STATE RAILWAYS.
STANDARD TYPE OF STEEL TIE.
2 11/32"
75 lbs Steel
5' 6"
4 15/16"
4"
1 IN 20
CROSS SECTION AT RAIL SEAT.
CROSS SECTION AT A-A.
CROSS SECTION AT MIDDLE.
8"
8½"
SECTION AND PLAN OF RAIL AND FASTENINGS.
5' 6' Gauge
LONGITUDINAL SECTION.
8' 9" long
A
A
13"
PLAN.
4½"
13/32
15"
SECTION OF PLATE.
E. E. Russell Tratman.

INDIA.

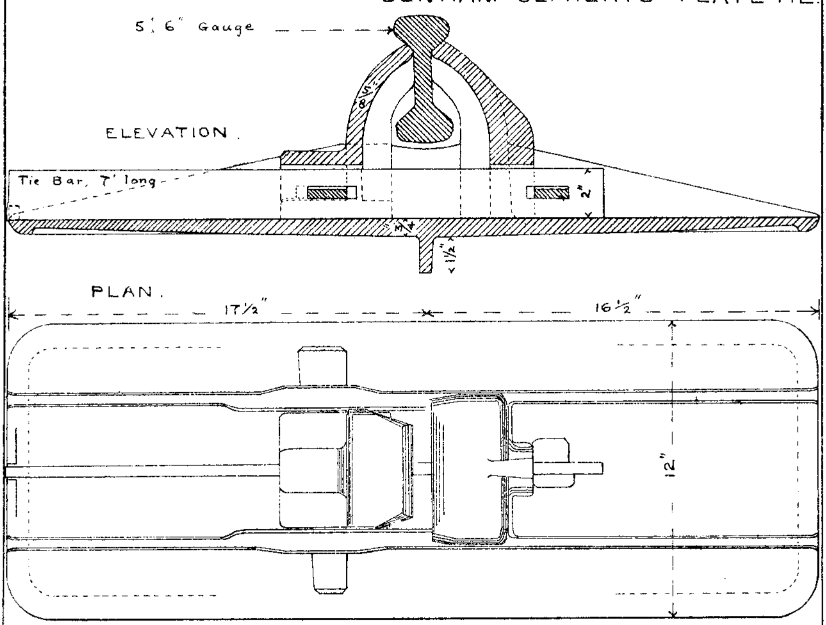
PLATE No. 23.

## INDIAN MIDLAND RY.

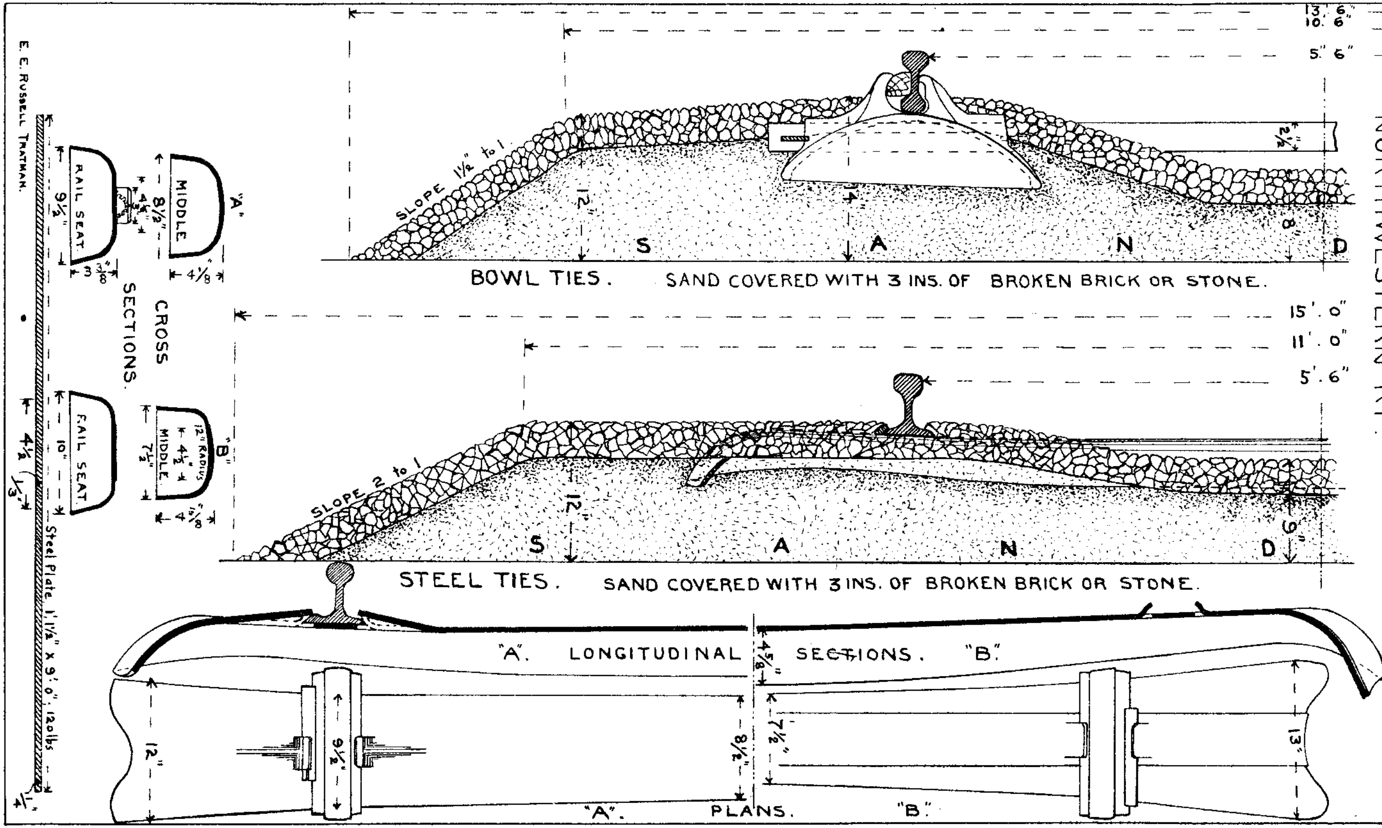



## EAST INDIAN RY.

## DENHAM-OLPHERTS PLATE TIE.

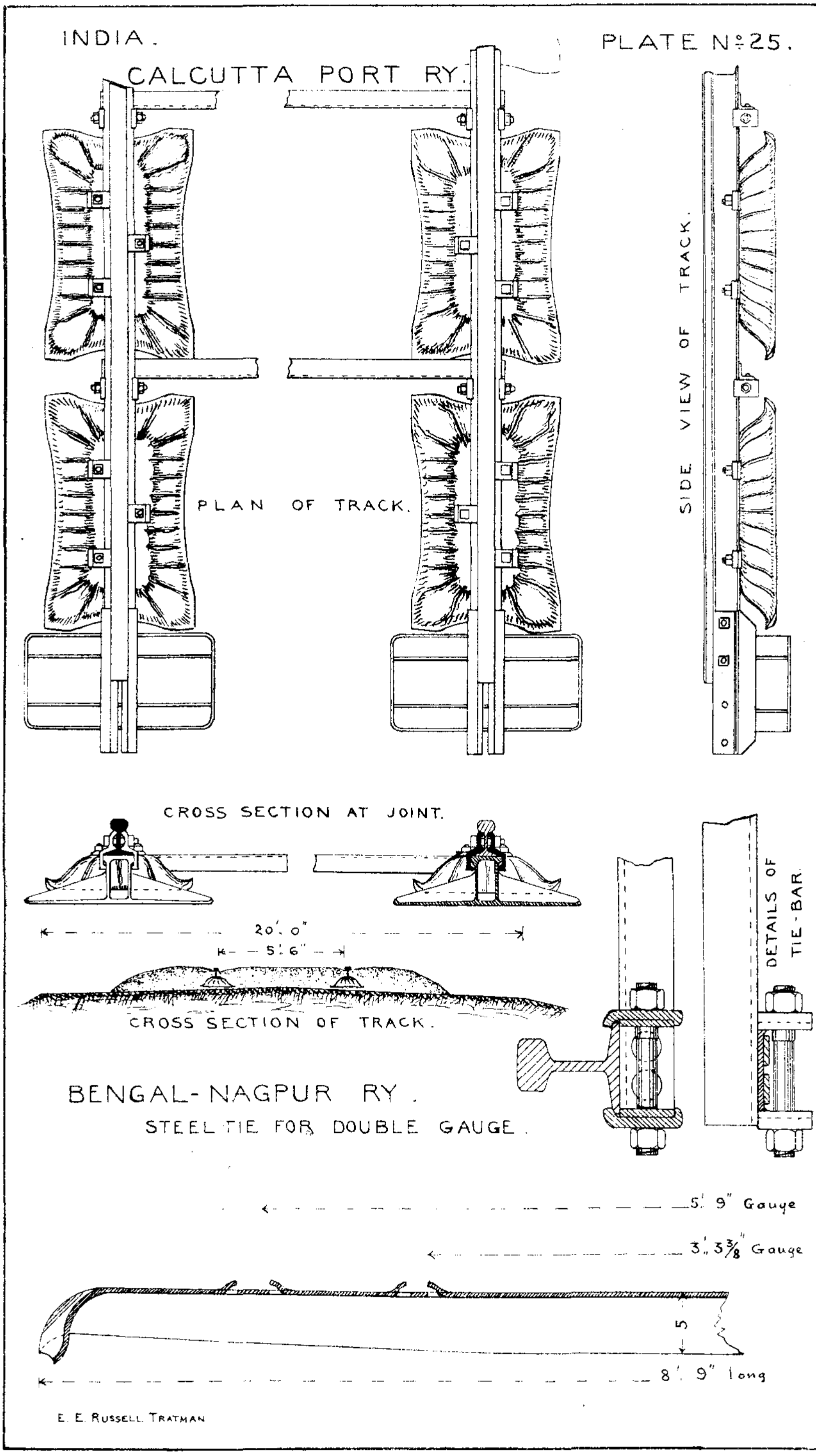



E. E. Russell Tratman.



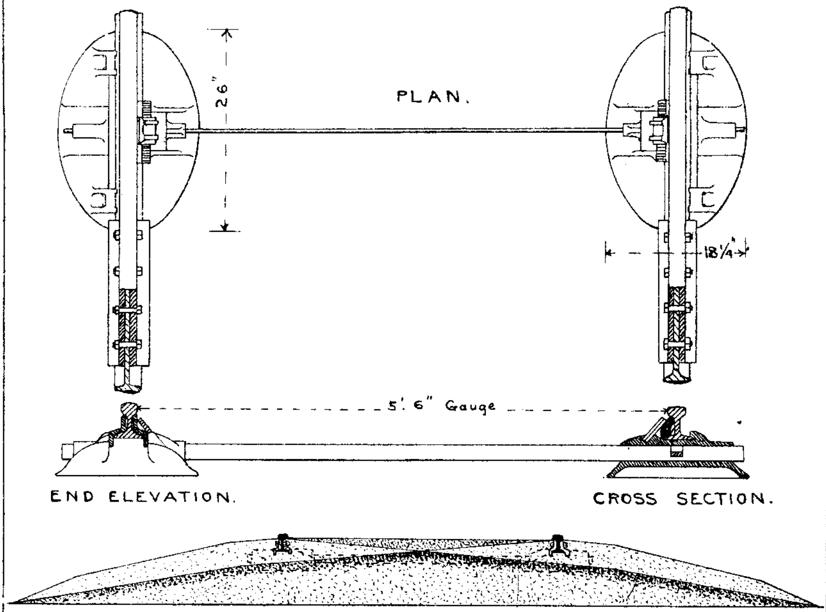

INDIA. NORTHWESTERN RY.

PLATE No. 24.


INDIA.
PLATE No. 25.
CALCUTTA PORT RY.
PLAN OF TRACK.
SIDE VIEW OF TRACK.
CROSS SECTION AT JOINT.
20' 0"
5' 6"
CROSS SECTION OF TRACK.
DETAILS OF TIE-BAR.
BENGAL-NAGPUR RY.
STEEL TIE FOR DOUBLE GAUGE.
5' 9" Gauge
3' 3 3/8" Gauge
5
8' 9" long
E. E. RUSSELL TRATMAN

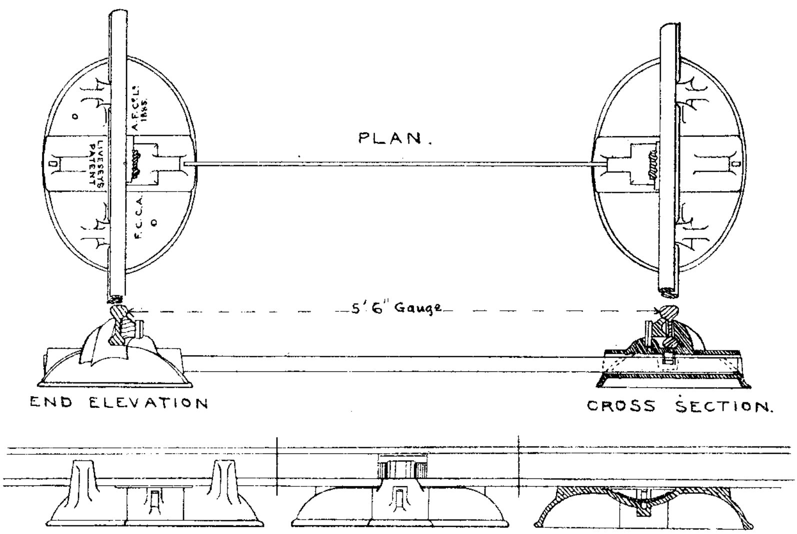
ARGENTINE REPUBLIC. PLATE No. 26.

## BUENOS AYRES GREAT SOUTHERN RY.




CROSS SECTION OF TRACK.

## CENTRAL ARGENTINE RY.

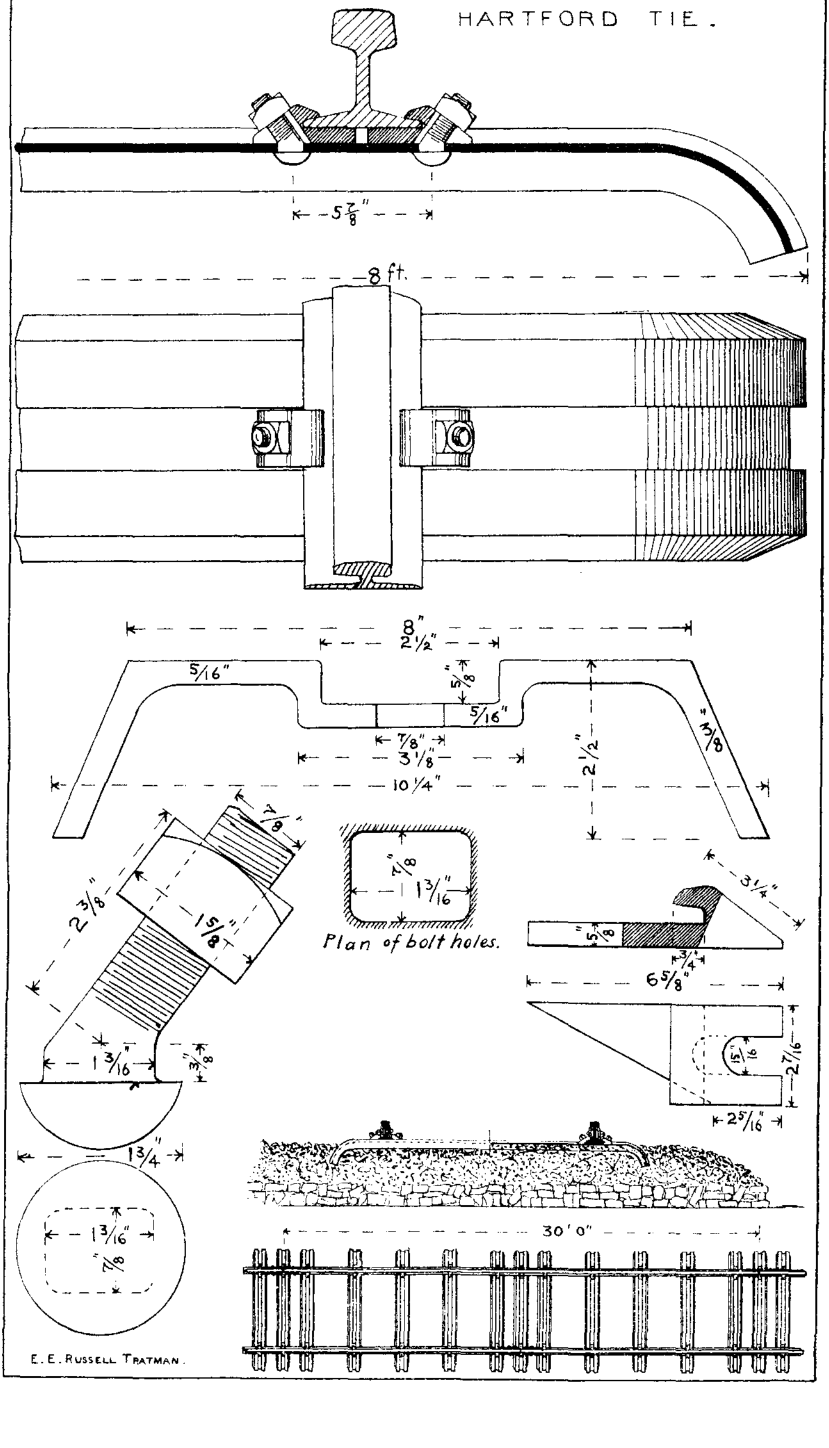



E. E. Russell Tratman.

UNITED STATES — PLATE No. 27.

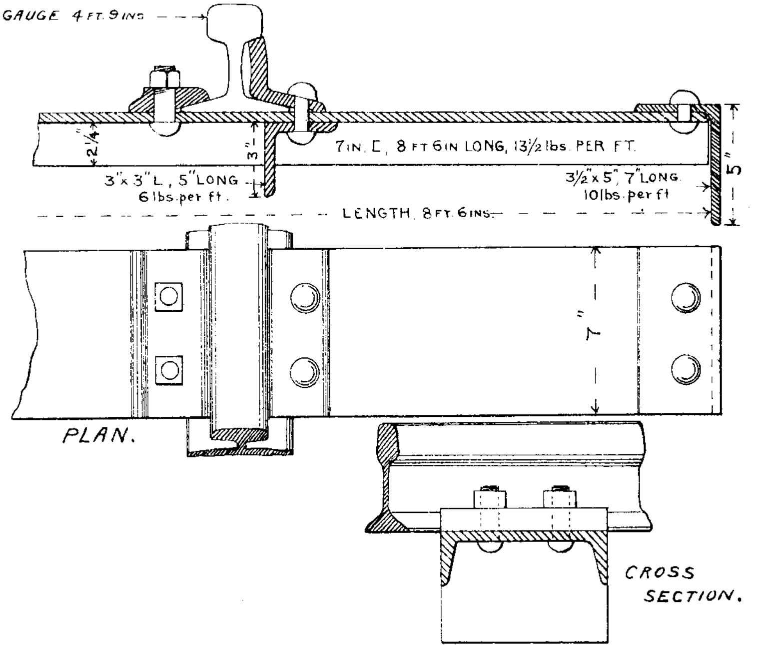
NEW YORK CENTRAL & HUDSON RIVER RAILWAY.

HARTFORD TIE.

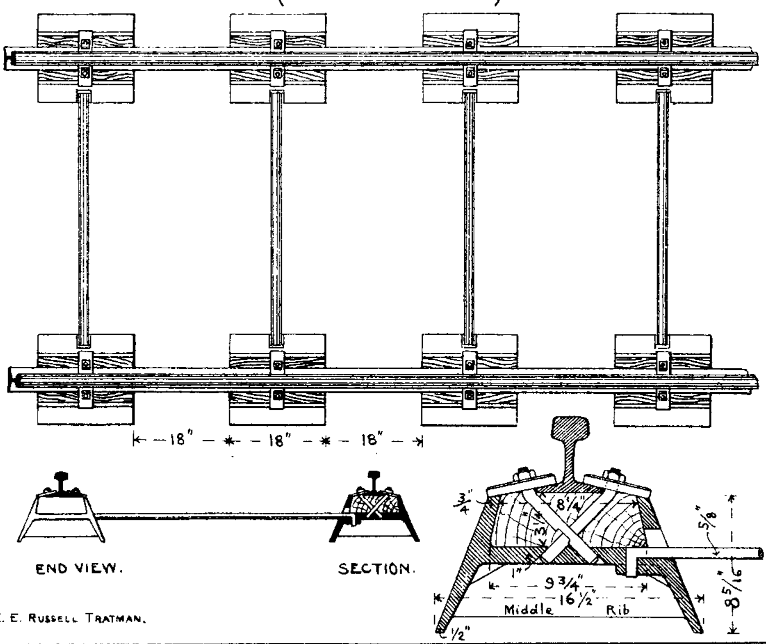


UNITED STATES. PLATE No. 29.

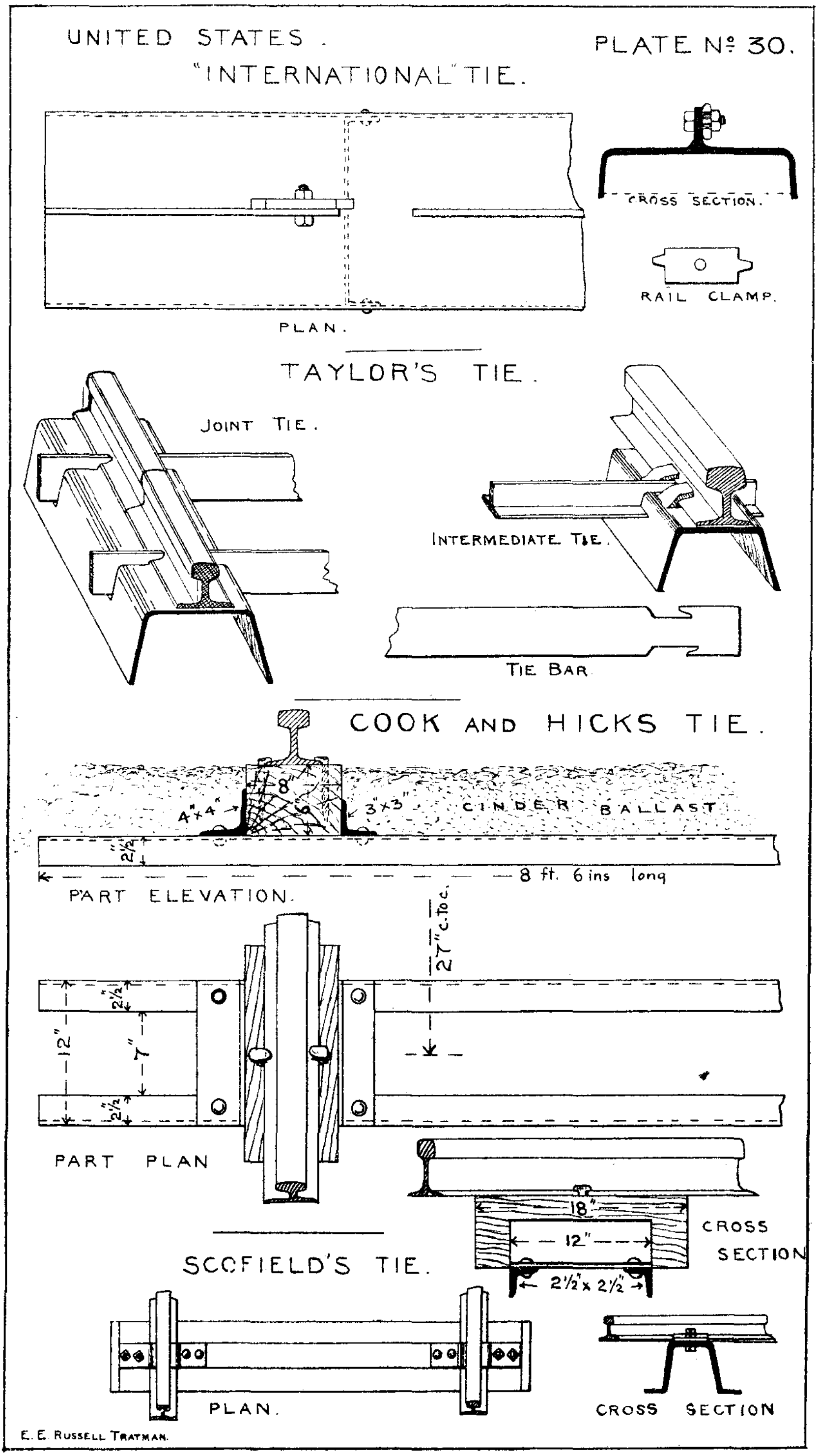
## PENNSYLVANIA RAILWAY.




## NEW YORK CENTRAL & HUDSON RIVER RAILWAY.
(TOUCEY'S TIE.)




E. E. Russell Tratman.


UNITED STATES.
PLATE No. 30.
"INTERNATIONAL" TIE.
CROSS SECTION.
RAIL CLAMP.
PLAN.
TAYLOR'S TIE.
JOINT TIE.
INTERMEDIATE TIE.
TIE BAR.
COOK AND HICKS TIE.
8"
4"x4"
3"x3"
6
CINDER BALLAST
2½"
8 ft. 6 ins long
PART ELEVATION.
27" c. to c.
2½"
12"
7"
2½"
PART PLAN
18"
12"
2½"x 2½"
CROSS SECTION
SCOFIELD'S TIE.
PLAN.
CROSS SECTION
E. E. RUSSELL TRATMAN.

# INDEX.

[All references in regard to Metal Track and Wooden Ties are found under these two captions. For references to Countries see Railways, under Metal Track.]

The letter (*d*) denotes that description is found on the page which it follows.

# LIST OF PATENTEES OF METAL TRACK IN THE UNITED STATES.

[Figures refer to the number of the patent as issued.]

**A.**

Adams, H. P ... 348877, 361199
Ames, A. H ... 391999
Ammon, J. S ... 328632
Anderson, J. J ... 357301
Anthony, J ... 38274
Armstrong, A ... 277000, 289806

**B.**

Baldwin, G. E ... 329429
Bagby, William H ... 419101
Bailey, John M ... 423586
Bañolas, Ramon ... 164793
Barhydt, F ... 382855
Barnes, Lewis ... 423852
Barnett, C. C ... 373656
Barrows, F. L ... 378280
Becket, J. R ... 142668
Beers, S. A ... 18494
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Blaisdell, George D ... 146376, 176213
Bloodgood, George W ... 293302
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Boone, John L ... 127553, 130010
Bousfield, E. T ... 333015, 335523
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Brown, Isaac ... 420674
Brown, William ... 231755
Bryant, George B ... 320231
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Bucknall, Hamilton L ... 211697
Buckner, James, jr ... 212127

**C.**

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Calkins, James ... 134418
Campany, M. E ... 313260
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