UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

FOREST TRUCK TRAIL HANDBOOK

PREPARED BY

DIVISION OF ENGINEERING

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SECTION I

POLICY

Purpose of Handbook

100. The purpose is

(a) to prescribe standards for the various classes of minor Forest Highway projects and of both major and minor Forest Development projects;

(b) to outline in sufficient detail the governing factors in the selection of standards so that as far as possible uniform thought and practice may be secured;

(c) to serve as a reference manual on the location, construction and maintenance of minor projects.

101. As a reference manual, the guiding thought has been to show what is wanted and to assist men who are naturally qualified to do this work but who have not had special training or experience in it. Some of the most desirable and successful construction and maintenance methods that have been developed by the Service in past years are outlined.

Selection of Projects

102. See Roads Section of National Forest Manual.

General Policy

103. The Forest Service will build types of roads and truck-trails that will fully serve the purpose. The Forester recognizes that the service demands differ materially and necessitate variations in standards in order that the traffic requirements upon the individual projects may be met. The standards and requirements in this Handbook are based on reasonable adaptation of standards and costs to the requirements of the specific project.

Classification of Projects

104. For the purpose of determining standard specifications and instructions, three service standards are established:

1. Low Service
2. Medium Service
3. High Service

Roads and Truck Trails

105. People generally use the term "road" as practically synonymous with "highway". Also with few exceptions they regard the minor projects constructed by the Forest Service as "trails" permitting utilization by cars and trucks but at low speeds as compared with ordinary public roads. Because of this situation the term "truck trails" has been established.

106. As used in this handbook the term "roads" means (1) major work, i.e., handled by the Bureau of Public Roads; (2) comparable to highways and handled by other Federal organizations; (3) minor work handled by the Forest Service on the Forest Highway system excepting that done under principle 14. (See Roads Section of National Forest Manual). As used in this handbook, the term "truck trail" means all other minor work handled by the Forest Service.

107. The word "road" however is at times used as a general term referring to the truck-trail type as well as to a highway or real road. Also the term "road" occasionally appears where "truck trail" should have been used, this situation being due to oversight. The context will make clear whether reference to "roads" or "truck-trails" or both is intended.

Fundamentals

108. The Forester on January 30, 1935 approved the following fundamentals governing the location and construction of truck trails:

1. The planned system shall fully meet the needs of all Forest activities, rather than just one or two. Preliminary to deciding that a truck-trail is necessary, a careful investigation shall be made of Forest and public needs and the truck-trail included in the System only when it is really necessary.

2. The approved location and standard shall render adequate service to all Forest activities needing transportation service.

3. The construction work shall be finished during the original construction instead of doing the job partially and returning later for completion.

4. The road location and standard shall be such as to render adequate service for future needs rather than those of the immediate present. Compliance with this will make early reconstruction unnecessary and eliminate expenditures now being made.

5. To reduce maintenance expenditures to the practicable minimum, the construction standard shall be such that the annual cost is the least. This annual cost includes maintenance and interest on the construction investment. Carrying this out will mean better original construction and higher construction costs but fully adequate service and lower costs in the following years.

6. The termini and general location shall be determined by the administrative office concerned and the regional truck trail organization. The latter shall determine the detailed location and this shall be followed in construction except that minor variations may be made without regional office approval where these will result in lower annual costs but no reduction in service value.

7. The truck trail organization shall have sufficient overhead and inspection personnel to assure all the work being handled efficiently and in full accord with Service and Regional instructions.

Permanent or Stage Construction

109. A "permanent" road is one which under the present conception of permanent location is so located that changes in location will not have to be later made. Obviously, changes in the amount, character, or requirements of traffic or property may result in changes in the present conception of a permanent location.

110. As used in this Handbook, the term "stage construction" means not only roads which as originally constructed are within the "prism" of the objective road - that is all excavation or fill on the original road will be a part of that required for the later higher standard work - but also roads where some sections may have to be abandoned when the higher standard project is built.

111. Compliance with paragraph 108 practically eliminates stage construction except in those cases where, due to construction into areas previously without transportation service, a possibility exists that the public use for recreation or other Forest utilization may exceed the use estimated at the time of construction.

Care in Classification

112. The amount and character of work or expenditure warranted to accomplish the purpose to be served by the respective classes of roads differs greatly. It is important that painstaking analysis, prior to survey, be made of all facts bearing upon the expected value, uses, and purposes of a given project. Officers responsible for selection of projects and construction of roads should expect to be called upon to defend any classification for which they are accountable.

Organization

113. The duties and functions of Engineering and other Divisions in the development of minor road systems, selection of annual program, classification of projects and similar matters, have been defined as follows:

The development, adoption, and amendment of the minor road and trail system, both as to quantity and quality, is a job for all Divisions, with the assistance of Engineering, subject of course to the Regional Forester's action before it is submitted to the Washington Office for approval.

It then becomes Engineering's job to construct the roads and trails in accordance with an annual program decided upon by the same group mentioned above, except that final decision is reached in the Region.

Engineering also keeps the records and handles the administrative correspondence on road and trail matters, subject of course to concurrence by other Divisions where appropriate.

Where the minor roads, truck trails, or trails are needed for Experiment Stations or experimental areas outside the Forest or Purchase Unit boundaries, Research, after securing the advice of Engineering, will make the decisions on system, program, and service classification.

114. Handling minor work as a Forest Project is decidedly favored and in all ordinary cases should be the approved practice. To the greatest extent consistent with his responsibility for a minor project, the Supervisor should delegate to the Superintendent of Construction or other officer responsible for handling a project, authority and responsibility for selection and use of equipment, construction methods, and organization, and for similar matters of a technical nature. The Supervisor should request the assistance of the Regional Office in matters, technical or otherwise, when in doubt as to the best method to use.

115. After decision on termini and general location is reached, (see par. 108, Part VI), the details of location should be left to the locator but technical decisions beyond his capacity should be referred to the Regional Engineer.

116. The use of Superintendents of Construction is approved as a general practice for :

Relieving Supervisors of detail;
Assurance of improved and uniform handling of jobs;
Reducing time requirements and cost of Regional Office inspection and supervision.

117. Where the number of projects is large, where it is advisable to get special cost data, or where the Supervisor's office should be relieved of administrative work on vouchers, etc., a special clerk for the road jobs will often be advantageous.

118. The Superintendent of Construction will be responsible for all jobs under his supervision, and inspection by the Regional Office inspector of one or two projects will be considered as typical of all projects in the group. Other inspections should ordinarily be necessary only when the inspected projects are not fully satisfactory.

119. The Superintendent of Construction should be competent to make location surveys and to direct the survey activities of surveyors regularly assigned to the Forest. He will also direct the work of surveyors temporarily assigned to the Forest from the Regional Office of Engineering. Surveys made by the Bureau of Public Roads will be directed by that agency.

Determination of Program

120. Priorities should be established for all betterment and construction jobs on the truck trail system, (see Par. 113), in order that location may be completed well in advance of construction. Ample consideration can then be given the location in regard to esthetic values, erosion, fish, and wild life (See Par. 122). Clearing and burning can be done during the year preceding the construction whenever practicable. Arrangements can be made for procurement or transfer of equipment and completion of all organization plans ahead of the construction period.

Coordination of Road Work and Fire Suppression

121. Full correlation of the road and trail work and the fire suppression activities is desired by the Forester. The

following instructions will govern:

1. Size of road or trail crew: -- The size of all such crews should be that which is most efficient from a road or trail construction or maintenance standpoint. Determining the size of crews by fire suppression needs is not approved; the inevitable result of such a practice is confused and inefficient management.

2. Wages of Crew: -- The wage rates of the man on the road or trail crew should be based primarily on his value for the road or trail work involved. But selection should be made with an eye to the efficiency of such individuals and crews whenever needed for fire suppression. If any measurably larger rate has to be paid to secure a road or trail worker who is particularly desirable because of his value for fire fighting, the excess over what would be necessary for road or trail purposes alone, should be paid from S & E funds.

3. Maintenance work: -- Under no circumstances should road or trail funds be used for an excessive amount of road or trail maintenance in order to have fire fighters available. The size of maintenance crews paid from road and trail funds should be dictated solely by the determination of what is most efficient from the standpoint of road and trail maintenance work.

Maintenance work, such as heavy clearing of brush from trails, etc., which can be efficiently handled during the fire period should be done within that period, but the maintenance of roads necessary to fire travel should be performed before travel for fire is necessary. Under other conditions, road maintenance should be done at such times that the greatest value and service can be realized.

4. Selection of construction projects: -- The dominating principle in the determination of the construction program should be the most profitable and efficient use of the road funds in providing a transportation system. But without violating this principle, the objective should be to select from the most urgently needed projects, such projects as will give a satisfactory distribution of crews during the fire season. The following are considered as violating the dominating principle: (1) projects greater in number than can be efficiently handled and supervised; (2) available equipment so distributed that the kind, size, and amount required for most efficient handling of construction is not provided to individual jobs; (3) a construction period of insufficient length to overcome all

expenses due to the beginning and cessation of construction operations such as the establishment and breaking up of camps, moving equipment, etc.

5. Cook, perishable supplies on hand, and similar costs: -- It is desired that cooks employed on road jobs should be capable of going with the road crew to fires and cooking on a fire-fighting job. When necessary to leave someone to guard the camp, equipment, etc., such a person should be paid from road funds.

Unavoidable loss of perishable supplies incident to the use of road crews on fires should be regarded as one of the concessions which road funds must make for the benefit of fire fighting. To the extent practicable, the perishable supplies at the road camp should be taken to the fire camp. When this is done, the road supplies should later be reimbursed or replaced to the extent the supplies were used at the fire camp.

Where necessary and proper to allow a rest period under pay for a road crew which has returned from a fire job, the cost may be paid from fire-fighting funds, but this must be handled with extreme care. Such a practice is easily subject to abuse.

6. Road crews on fire duty: -- The advantages offered by utilizing road crews and road equipment on fires are thoroughly recognized and such use is approved. Every road crew should be selected, trained, equipped, and so instructed that it becomes a vital part of the organized forces available for fire suppression. The men of the crews who are to be used on fires should be given the opportunity to attend the guard training camps at the expense of protection funds. The project foreman is responsible for keeping such equipment as is specified in the plan to be furnished to him for fire use always in shape and in the amount specified.

When experience indicates that a road crew will be used on fire fighting for an appreciable period of the fire season, this fact should be taken account of in planning allotments, construction periods, etc. Management of the interrelated fire and road work should have such flexibility and planned capacity for adjustments to the varying demands of a season that a road crew is as a matter of course, used on the work which at a given time is the most important. The fact that machinery stands idle while a road crew is fighting fire is unimportant compared to the fire fighting values a road crew should render when such a road crew is needed to supplement the fire fighting work of guards and cooperators. On the other hand, a road crew should not be taken to or retained on a fire when the only real reason for such action is inertia and failure to recognize that the total situation would be served best by using other forces at the start or by sending the crew back to its road work with dependence on other men for fire fighting or mop up work.

7. Road equipment used on fire work: -- The road and trail appropriations should be fully reimbursed for the use of road equipment on fire work. The amount of reimbursement will be determined by the amount of use and the rentals approved by the Forester for such equipment.

8. Telephone connections: -- Road construction crews which it is expected may be called upon for fire control work, should be provided with telephone connections or other satisfactory means of communication.

Relation to Aesthetic Values, Erosion, Streams, Fish, and Wild Life

122. Public use of the National Forests for recreational purposes has increased twelve-fold since the first systematic estimates of its volume were initiated in 1917. A further increase in that type of use confidently may be expected. Practically every National Forest visitor makes extensive use of the Forest Highways and Forest Development roads, and the conditions encountered in such use doubtless make lasting impressions as to the effectiveness of National Forest administration.

Wise road construction offers unlimited opportunity not only to preserve but to enhance the natural charm of the National Forests; their scenic beauty and inspirational quality; the appeal of their primitive simplicity; the attractiveness of their lakes and streams; the interest of their abundant wild life. Such opportunity should be realized to the fullest practicable degree. Such realization may entail expenditures in excess of those made in earlier stages of the program, but ample justification exists for such expenditures. The large sums expended by the Federal and State Governments to stock streams and increase the numbers of game birds and fish is proof of the definite public value of such resources. Expenditures elsewhere to control erosion, and to develop esthetic qualities are regarded by all parties in interest to be necessary and desirable and will be equally so in relation to National Forest projects.

The extent to which additional expenditures, above those necessary from a strictly road building standpoint, can be justified, must be determined locally for each individual project. There are wide variations in the recreational values between different forests and between individual projects within a forest. To fix proper standards, the men responsible for preparing plans and specifications should have a comprehensive idea of the use to be made of the area through which the road is being constructed.

Before final location of a road is decided upon, the engineer in charge or other responsible forest officer will obtain all data available on the services to be rendered by any given area where a road is proposed. Final location and construction will be coordinated with the needs and requirements of all services to be rendered, and the consideration and advice of the Regional Recreational Specialist will be secured before the location of the project is finally decided.

In laying out and constructing a forest road system, the relative importance of the following points should be kept clearly in mind:

A. Relation to aesthetic values

1. The road should harmonize with its surroundings. Make the road conform to the topography where this will not result in objectionable curvature. Long sweeping curves in mountainous country will often result in less scar on the landscape than would tangents. The use of such curves is advantageous provided it will not result in uncompensated loss of travel speed or service value.

2. Avoid having roads on both sides of a stream for any great distance, particularly if they are close to the water. Roads should be kept well back from the shores of lakes and streams that may be used for recreational purposes.

3. In blasting operations, flying rocks sometimes result in much damage to timber along the road. If such damage is of real consequence, its amount should be reduced by using more care in placing and loading the holes.

4. A fringe of trees along the bank enhances the beauty of the stream. It is generally thought that the most attractive location is that which at times affords a full view of stream or lake, at other times, a partially disturbed view and again with the water entirely out of view.

5. The roadsides should be left in as natural a condition as possible. In most cases, removing the

underbrush does not improve the aesthetic value. The extent to which logs should be removed from streams should be governed by shade and cover requirements for fish. Large borrow pits should be screened where practicable.

6. Vegetation on cut and fill slopes and shoulders increases the attractiveness of a road. Insofar as possible, local species should be selected.

7. When a road climbs and open mountain slope by means of switch-backs and topography and cover lend themselves to the purpose, it is desirable to screen as much of the road as possible from the valley below. This can often be accomplished by keeping the road back in side canyons instead of bringing it out onto the face of the mountain.

8. On projects of considerable recreational importance, bridges and other structures should be made to harmonize with the surroundings.

9. Preparation of specifications for road projects should be a joint responsibility of the engineering, administrative, and recreation staffs.

B. <u>Relation to Erosion</u>

1. Any road construction operation loosens large amounts of soil, greatly increasing the tendency to erode.

2. From an erosion standpoint, the road should be built with a minimum amount of disturbance of the natural conditions. The most objectionable feature of a road is its fill slope. Fills constitute a large percentage of the exposed area and are in a very unstable condition during the first couple of years after construction.

3. The practice of stage construction other than clearing is detrimental from an erosion standpoint through disturbing the vegetation and compacted shoulders and banks of the earlier stage of the road development.

4. The amount of erosion increases rapidly with increases in gradient. Therefore, on soils that erode easily, consideration should be given to some sacrifice of alignment for grade; i.e., wind around hills on comparatively level grades rather than go over them on straight lines where this can be done by <u>long radius curves</u> which do not interfere with the service value of the road. The truck trail handbook permits no grade

to be used that will result in an excessive amount of erosion. Complete compliance with its provisions is necessary.

5. The water in the side ditches of the road should not be allowed to accumulate in large quantities. The amount of material eroded increases with the volume of water. From an erosion standpoint, therefore, it is desirable to construct culverts at frequent intervals in order to keep the volume of ditch water to a minimum. Close observance of provisions in the truck trail handbook is necessary.

6. The probable damage by drainage water after it leaves the road should be considered. Construction men should provide for handling run-off from culverts in order to reduce damage to a minimum. Water flowing from culverts should be dispersed over the hill side rather than allowed to accumulate in one stream. This can be done by small check dams of logs, brush, or rocks. See also the instructions in the truck trail handbook regarding protection of fills below culverts.

7. Where ditches erode easily, check dams should be placed in them at frequent intervals. In places, it may be necessary to resort to paving with rock.

8. On soil that erodes easily, the roadside cleanup should not be overdone. Litter, small sticks, and down timber act as check dams and help keep the soil in place. Stumps along the right-of-way help hold the soil in place, but if they are pulled, the result will be a spot of loose bare soil which will erode very readily.

9. Where it is necessary to place the road right against a stream, the toe of the fill should be riprapped with rock or timber to reduce the amount of eroded material that will reach the stream. It may even be necessary to construct a check dam in the stream itself to confine the damage to a short section. If the course of the stream is materially changed, the effects of such changes on the opposite bank or perhaps for some distance below should be fully determined and necessary protective measures applied.

10. On roads constructed some distance from the creek, a row of logs or brush below the toe of the fill slope will reduce the amount of soil that will be washed into the stream.

11. All cut banks and fill slopes of soils that erode

easily should be protected by means of vegetation. They should be first sloped so the soil will stay in place and the slopes should be seeded or planted to some form of vegetation that will quickly develop an extensive root system. The Forest Experiment Stations can suggest species and methods to meet particular conditions.

C. Relation to Streams and Fish Life.

1. The value of the stream for fish should be ascertained. This information can be secured through the Bureau of Fisheries. The extent to which the following are applied should be based on the relative value of the stream for fish. If the Bureau of Fisheries is unable to survey the stream, it should be assumed to be a good fish stream unless sufficient evidence to the contrary is found.

2. The road should be kept somewhat back from the stream wherever possible.

3. A fringe of timber and brush should be left along the stream to provide shade. Streams may become too warm in the summer if a large amount of the overhanging brush and trees along the creek are removed.

4. In locating a road along a stream, it may be advisable to put in more bridges, thus keeping the road on flats well back from the stream instead of following one side continously, thereby causing a considerable portion of the road to lie at the edge of the water.

5. The chemical composition of the water, particularly its acidity, may be changed by the addition of large quantities of debris from construction operations. This may be detrimental to fish.

6. A large amount of fish food in streams consists of crustacea and immature stages of aquatic insects, as well as vegetable forms which are found along the bottoms of streams. This growth of food is gradually developed in a stream through a long period of time. A large amount of silt and debris thrown into a stream will cover up and destroy much of this source of food.

7. Large quantities of silt and debris thrown into streams results in filling up the larger pools which the fish use for resting places.

8. The removal of overhanging brush, trees, banks, and

rocks destroys hiding places for fish. This makes them more susceptible to attack from enemies both in and out of the water.

9. Trout, bass, and other game fish require gravel beds in which to construct their nests for spawning. If a stream is filled with silt, these gravel beds become covered and any eggs therein are smothered and prevented from hatching.

10. Changing a stream channel is often very harmful to fish life for a considerable distance down the stream. It usually results in a large amount of debris being thrown into the stream and often creates new problems of erosion control and bank protection. Therefore, channel changes should be carefully considered in regard to their effect upon the entire stream as well as the immediate vicinity.

11. To maintain certain areas of best fishing, it is desirable to build no roads into them. They could be made accessible by trail.

D. Relation to Wild Life.

1. When a road is constructed through a dense stand of timber, the resulting clearing is conducive to more luxuriant growth of palatable plants. This results in the birds, deer, and other forms of wild life being attracted to the roadside.

2. Where the underbrush is cleared out for a considerable distance back from the road, the hazards to wild life are increased. A dense fringe of underbrush along the road is, therefore,desirable as cover.

3. When banks are planted to stabilize the soil, the plants selected should be those that have a food value for wild life, particularly for birds. This applies only where there is a shortage of game food and the plants selected have adequate soil stabilizing qualities.

4. On forest areas which are open to hunting or which are game preserves, the number of entrances to the Forest has a definite relation to the ease of protecting the game and checking on hunters. Where this is an important consideration, it is desirable to have as few entrances to the Forest as possible. The roads should branch out within the Forest boundaries rather than outside.

To be effective, consideration must be given these relations of truck trails to the values of esthetics, erosion, streams, fish, and wild life during reconnaissance, location survey, and in the review of the location before its approval. The necessity of establishing priorities for betterment and construction jobs and early completion of location on high priority projects is again emphasized.

SECTION II

STANDARDS

GENERAL

Application of Prescribed Standards

200. The standards in this section apply to and will be followed for (a) all major and minor projects on the Forest Development System, (b) minor roads on the Forest Highway System.

The standards and specifications to be followed on each construction and betterment project will be prescribed on the Service standard form MR-1. The MR-1 will be prepared by the Supervisor for the approval of the Regional Engineer. Additional copies should be supplied to the construction superintendent and foreman in charge.

STANDARDS

201. A transportation facility has two standards - (a) a service standard, (b) a construction standard. A clear understanding of each and the relationship of each to the other is essential to avoiding confusion in administrative action and for clarity in expression.

There is no definite, direct and fixed cost relationship between a service standard and any construction standard. Whether the service requirement be expressed in terms of speed attainable, size of vehicle to be accommodated, or any other way, the expenditure required in different cases varies greatly. For instance, where the simple-turnpike cross-section can be used and the construction difficulties and costs are little, the speed may average 25 miles per hour and the construction cost per mile expressed in mile-per-hour of speed may be $20, and the corresponding annual cost less than $2. As against this, in heavy side hill work, with much rock and with broken topography, it may be impossible to get the same speed at any reasonable construction cost, or, if secured, the construction cost per mile expressed in mile-per-hour speed may be $400 and the corresponding annual cost $9. In other words to get the same service, the construction and annual cost for the second road is many times that for the first.

Service Standard

202. A transportation facility is provided in order to render service to (2) traffic, (b) real property. The requirements of each vary greatly; accordingly the service standard varies in similar manner. The term "duty" is frequently used instead of "service".

The service required or rendered can be measured in several ways, for instance, (1) speed of travel or elapsed time; (2) total cost per mile including both road and vehicle cost and the value of the road user's time; etc.

203. Except for certain classes of utilization roads, particularly those for hauling timber or other Forest products, the service standard used in this Handbook, is based on the distance that can be traveled in an hour.

Construction Standard

204. The construction standard is a combination of all the specified elements that determine its ability to carry traffic. The combination desired is that which will render a specified duty or service at the least annual cost - i. e. maintenance plus 2% of the expenditure for construction.

205. Theelements of construction standard are grade, alignment, width, structures, surface condition and the shape of the surface. One element frequently has a greater effect on the traffic than any or all other elements. Each element should be given its proper weight and all elements coordinated so that no element is over emphasized to the extent that extra expenditure would result. It is entirely permissible to secure surplus width, lesser gradient, improved alignment, etc., provided no increase in annual cost results.

206. In this Handbook, certain limits are set up for width, gradient, etc., in connection with each of the three service standards. Each such specification is tied in with the service standard but not as a part of any fixed combination of the elements of construction standard. No definite rules are established as to the extent to which the various limiting elements of construction standard will be used. Instead the Regional Forester is made responsible for determining and using that combination which under the topographic and other conditions existing on the project or section thereof, will provide a road rendering the required service at the least annual cost.

207. Placing a road in any class or standard is dictated by the requirements of the activity or activities served by that road. The service classification fixes limits as to elements of standard for which funds may be expended to attain. But if faster speeds result from work done to proper limit of grade, width, etc., the service standard or class is unchanged.

208. The service standards are Low Service or 3rd Class; Medium Service or 2nd Class; and High Service or 1st Class.

The speeds or elapsed times referred to apply to those attainable from a 1932 Model B Ford $\frac{1}{2}$ ton pick-up truck, or equal.

Selection of Service Standard

209. The Transportation Plan where made and approved will be the basis for classification. This plan is designed to cover the needs (1) for fire detection and suppression, (2) for Forest administration, development and utilization in all phases, (3) for public use of the Forests, (4) for public travel within or across the Forests, (5) for the development or utilization of resources upon which the communitites within or adjacent to the Forest are dependent.

Elapsed time is the basis for designing the protection portion of the plan. The decision on lengths, location and standard is based on providing the system which at the least annual cost per unit of area will make possible reaching a designated area within the specified allowable travel time. Accordingly the speed planned for a road or truck-trail indicates directly the appropriate service standard. For instance, if a road as planned is to make possible traveling 17 miles within an hour, it belongs in the Medium Service class.

In preparing the plan, elapsed time or speed of travel is also used in the decision on certain roads or truck-trails not required for protection against fire and others where the standard required for some other purpose is higher than that required for protection.

However, on a large portion of the system -- particularly roads of primary importance to public travel, for the hauling of timber products, etc., -- it is probable that a measure of service value other than speed or elapsed time will be deemed preferable. If so, a determination of the economic value may be made in accordance with the method approved by the Forester,*and the instructions issued by him. In the determination for the individual project, the speed of travel is one of the factors used; accordingly the appropriate service standard is made evident. However, in the selection and extent of use of various elements of construction standard, the use to be made of the road or truck trail should govern.

*This is in files of Regional Office. Also in Journal of Forestry. Vol. XXX No. 8, Dec. 1932.

Where the transportation plan has been partially or entirely made but not approved, the planned standard of any road or truck trail will be considered the approved service standard unless the Regional Forester decides to apply some correction factor to the recommended plan.

Where the transportation plan has not been started, the following action is suggested as good practice: - (1) For protection and other projects where speed or elapsed time is a satisfactory measure of value: - make a rough or approximate transportation plan for the area to be served by the road or truck trail. (2) For other cases: - make an economic study following the approved outline completely or to the extent necessary to show what the service standard should be.

Definitions

210. In the following definitions, attention is directed to the requirement of negotiating a distance within the range of speeds indicated for the various class truck trails, when the length of project requires one hour or more of travel time. On short projects where the travel time is less than one hour, the rate of travel in m. p. h. will be within the range of speeds indicated for that class project.

Low Service - 3rd Class

211. A truck trail shall be classified as Low Service when the speed requirements of the activities it will serve are met by negotiating 15 miles or less within an hour.

Examples:

(1) Where the primary usage is for protection including stub roads to lookouts and guard stations.

(2) Where public and recreational travel is very light or negligible.

(3) Where slow speed will meet all needs.

Medium Service - 2nd Class

212. A truck trail shall be classified as medium service when the speed requirements of the activities it will serve are met by negotiating within an hour a distance of 16 to 25 miles inclusive.

Examples:

(1) Protection projects which because of length of travel, highfire risk or tonnage of supplies, equipment and man power to be moved, require higher than the low-service standard.

(2) Of importance from the standpoint of Forest administration in facilitating travel from forest headquarters to ranger stations and to other points of similar importance and for connecting such stations and points.

(3) Of considerable length and an integral part of the transportation system, although not necessarily a main trunk road.

(4) Where a moderate speed of travel is needed and obviously the low-service standard is inadequate.

(5) For hauling of timber, livestock and other Forest products, where the amount of hauling and the weight of individual loads is moderate.

(6) Public economic use such as intercommunity business, power plant or irrigation operations, hauling of mineral products and operation of mines.

(7) To serve important recreation and special use areas, or otherwise subject to considerable public travel.

High Service - 1st Class

213. A truck trail shall be classified as High Service when the speed requirements of the activities it will serve can only be met by negotiating more than 25 miles within an hour.

Examples:

(1) Of the highest importance to the protection system - first line, support or second line - from the standpoint of speed of travel although not necessarily so important from standpoint of hauling supplies, equipment, etc.

(2) Where a moderate speed of travel will not satisfactorily meet the requirements.

(3) For tourist or through travel.

(4) The backbone or a part of the primary trunk portion of the Forest road and trail system.

Variations in Speed

214. The specifications for distance traveled in an hour do not mean that the speed on all portions of that distance will necessarily be the same as the average. The speed may be uniform. On the other hand there may be decided variations from the average speed. The amount of acceptable variations will depend largely on the character of use. For instance, more variations would be expected on a primarily protection truck-trail than on one utilized primarily for timber hauling or public travel.

Examples of Different Standards

215. The illustrations clearly show that the description is not definite but instead is rather general and broad. However, they should be of value especially in those cases where the transportation plan has not been made or where time is not a satisfactory method of expressing the service value.

Single-Track, Double-Track, or Two One-Way Single-Track Truck Trails

216. In paragraphs 211-213 no mention is made of single-track or double-track widths. On single-track roads, the character and amount of travel will have an important bearing on the number, location, and design of turnouts. Double-tracking or two one-way single-track truck trails are made necessary by the volume of travel exceeding that which can be handled by a single-track road with turn-outs.

The easiest way of deciding what should be done when a two-way, single-track truck trail with turnouts will not adequately meet the traffic needs is to approve the construction of a two-way, double-track truck trail. However, the easiest way may not be the best way in all cases. Decision to double-track should not be made until complete investigation and study has been made of the possibility, practicability, and advisability of providing two-one-way, single track truck trails instead of one two-way double-track road.

The advantages offered by on-way truck trails are many and diverse. (1) One-way travel is safer--this is generally recognized by safety organizations and highway engineers. (2) The capacity of two one-way single-track truck trails materially exceeds that of onetwo-way, double-track truck trail. (3) The safe speed of travel is materially greater. (4) The danger of serious erosion is much less because the area of exposed surface on cut and fill banks is materially reduced. (5) Aesthetically, single-track truck trails are advantageous because of smaller scars, less clearing width, a closer view of the country adjacent to the truck trail, and affording a view in retaining a larger portion of the area adjacent to the road instead of being restricted largely to the road surface itself. (6) Opportunity is offered to provide a higher standard for the truck trail upon which timber, mining, or other products will be hauled and to utilize for the return trip a truck trail of a lower standard on a location of greater value for suppression, detection, and often scenery. (7) Particularly on side-hills--the usual condition in the National Forests--the construction cost is less for yardage, bank protection, and similar items. (8) The maintenance cost may be higher or lower depending on such matters as bank sloughing, surfacing, soil, and amount of traffic. (9) One-way truck trails, where the return route departs considerably from the incoming route, are advantageous from the standpoints of Forest administration, detection, and suppression through opening up and making more country accessible.

The disadvantages of one-way truck trails include (1) traffic may not observe restrictions and hence danger of collision exists; (2) when connections with the return route are far apart, excessive distance must be traveled by those desiring to travel only part way and then return; (3) topographic and similar conditions may be unfavorable or unsuited to one-way truck trails because of excessive expense or other reasons; (4) costs for clearing and drainage will usually be higher for two one-way single-track truck trails than for one two-way double-track truck trail.

In considering whether the two one-way single-track truck trails are preferable to one two-way double-track truck trail, a comparison of the advantages and disadvantages of service and cost should be made. For instance, will the natural points of intersection sufficiently meet the needs? If not, and intermediary connections by means of truck trails should be provided, will the values gained by and the advantages of the two one-way truck trails plus the values of and additional service rendered by the intermediary connections exceed or be less than from one two-way double-track truck trail?

The roads or truck trails in the Low Service Class will be single-track in width; those in the High-Service largely but far from wholly, of double-track width; those in the Medium Service will ordinarily be single-track but there will be some of double-track width. The single-track width with turnouts should be provided unless clearly evident that it will not adequately meet the requirements, or that the added width will not increase the annual cost.

Regional Forester's Responsibility

217. The Regional Forester will be responsible for the selection of service standard. Also for the route and the elements of construction standard that will provide the required service at the least annual cost. For instance, if the approved service standard of a truck trail is 12 miles within an hour, the Regional Forester will seek such location and such use of the elements of construction standard as will result in making possible traveling any 12 mile section within an hour and at less annual cost than would result from any other selection of location or elements.

Inspection by Forester

218. The regional work will be inspected from the following standpoints:

(a) Selection of service standard.
(b) Selection of location and elements of construction. Standard satisfying the service requirements at the least annual cost
(c) Selection and use of equipment, organization and methods on the basis on minimum cost per mile of survey, construction and maintenance.
(d) Efficiency of handling survey, construction and maintenance work.

Low Standard Protection Truck Trails

219. The technique developed by the Forest Service for low standard protection roads giving a maximum of service at minimum expenditure departs from standard highway engineering practice in many ways. These include: - (a) Many changes in grade, including reverse grade, when necessary to attain the primary objectives, as against the use of long unbroken or sustained grades; (b) Introducing additional climb (within the limits of accepted maximum grades) if neccessary to attain primary objectives; (c) accepting high maximum grades for short stretches where this will avoid more costly construction and where the contemplated needs of transportation service will not be affected.

Sound location of low standard projects requires balance in the use of money saving expediencies. As an example, a locator should avoid excessive and unnecessary use of uniform sustained and low grades and at the same time guard against an excessive and unwarranted use of the broken and high grades. The low cost standard, though offering great elasticity in location, must and does have maximum limits of grade and curvature and minimum standards of surface, just as any other type of road. It does not allow free and indiscriminate choice of excessive grades or curves by everyone concerned with the road building. The character of traffic must constantly be kept in mind. For instance, the standards of alignment and gradient for timber utilization truck trails will usually be higher than those for primarily protection truck trails.

The basic principle of flexibility in location, which is an essential of the low standard, finds a place even in long sustained climbs, and in sidhill construction.

WIDTH

Standards

220. The following table shows the standard widths in feet for different sections. Width is given shoulder to shoulder after settlement. The letters refer to the sections shown on Figure 201.

Standard Widths After Settlement

	A	B	C	D	E
Single Track ---------	11	10	12	10	12
Double Track ---------	18	17	19	17	19
Single Track Surfaced-	14	13	15	13	15
Double Track Surfaced-	21	20	22	20	22

Above widths are exclusive of drainage ditches which should be installed only where needed. Such ditches should be of reasonable cross-section, of minimum depth to meet drainage needs.

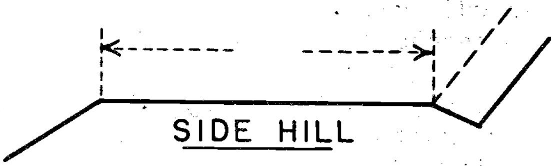
During construction allowance will be made for settlement. The allowance will be one foot of width for each fill slope unless actual experience for the material involved and prevailing precipitation and other conditions have clearly demonstrated a greater or less width is needed. In such cases variation from the one foot standard should be made.

FIG. 201

TYPICAL GRADING SECTIONS

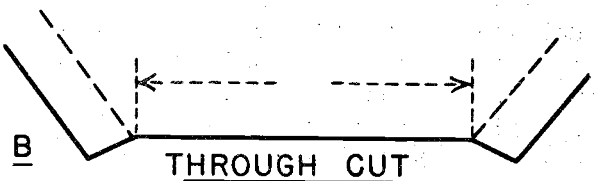
Truck Trails

A



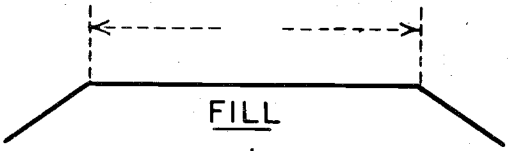
SIDE HILL

B



THROUGH CUT

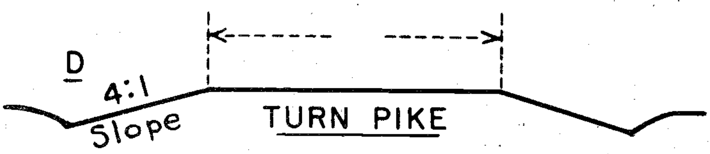
C



FILL

Fills over 6' in height add 2' to width shown in table.

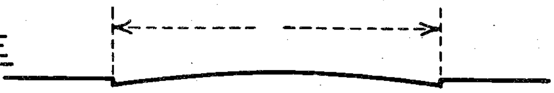
D



TURN PIKE

Level with surrounding ground unless additional height is needed for drainage

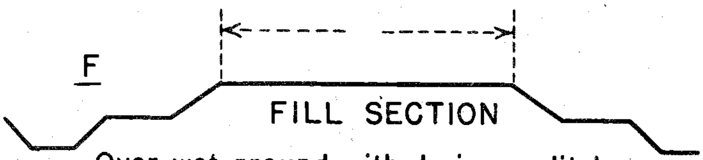
E



FLAT SECTION

Use where ditches are not needed

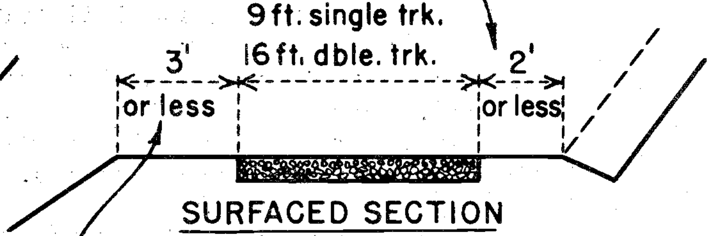
F



FILL SECTION

Over wet ground with drainage ditches

Shoulder on all cut sections 2' maximum width. Cut side on side hill, both sides on through cut and turnpike.



SURFACED SECTION

Shoulder on all fill sections 3' maximum width. Fill side on side hills, both sides on through fills.

Note: Shoulder width on both cut and fill sections must be sufficient to hold surfacing material in place. Total width of road must not be less than that required for the corresponding cross section unsurfaced

STANDARD WIDTHS

	A	B*	C	D	E	F
Single Track	11	10	12	10	10 TO 16	12
Double track	18	17	19	17	20	19

* Add 2 ft. where ditches are not used.

Widths shown are net after settlement and exclusive of ditches. On unsurfaced truck trails ditch to be built only and to the extent needed. Ditches to be constructed on all surfaced truck trails. Increase width on curves as instructed.

Widths for surfaced sections may be used only where there is an absolute certainty that surfacing will be completed within two years after construction.

Variations in standard widths. Variations in the standard widths are permitted as follows:

1. The use of the usual truck trail construction method will result in unavoidable variations in width. A tolerance of one foot and inspecial cases additional as allowed in paragraphs 4 and 5 below, will be permissible when checking the construction with the approved specifications. This is not to be interpreted as authority to build intentionally to more or less than the standard.

2. The continous use of one foot variation in standard width is allowed in the following cases which apply only to single track, unsurfaced truck trails.

One Foot Greater Than Standard Width

(a) High service single track truck trails
(b) Where wide-gauge trucks are commonly used for utilization and protection.
(c) To serve important recreation and special use areas or otherwise subject to a large amount of public travel.

One Foot Less Than Standard Width

(a) Low service truck trails
(b) Medium service truck trails primarily for protection.

3. Increased width on curves is required as follows:

(a) Two feet on curves of 40 to 60 ft. radius
(b) One foot on curves of 61 to 100 ft. radius

4. Extra width should be provided where made necessary by some peculiar feature of location, such as sliding earth or a special drainage problem. Extra width will often result from cutting sharp points to secure desired alignment and such is fully justified provided the standard of alignment sought is proper. Frequently the extra width provided at curves can be utilized to advantage in providing a turnout.

5. Excess width can also be frequently justified on curves where the excavated material is used in adjacent fills. Clearly this is advisable practice whenever the cost is not greater than from borrow alongside of the fill.

221. If the width secured exceeds that necessary to render the required service and the cost exceeds that for the required width, the increase in expenditure must be justified.

ALIGNMENT

222. General Standard. It is not possible to lay down clear-cut and definite rules governing alignment. Unlike width and grade, it can not be exactly expressed in mathematical terms except that the minimum radius of curvature may be prescribed. The standard must vary, first, with the service required of the road, and second, with the difficulties and cost of construction. Where topographic and other conditions are very uniform and easy, the standard of alignment may have little influence on the cost. Selection of the stage construction plan will of course affect the alignment standard. On Forest roads the alignment standard is usually one of the most important elements affecting the cost.

223. Where the truck trail or road will serve protection needs but the greater portion of the travel is for some other purpose, the alignment standard should be decidedly higher than when protection is the major or sole use. Also in deciding on the standard and particularly the radius and frequency of curves, the amount of travel must be carefully kept in mind. Each time cars going in opposite directions pass, time is lost even though they pass on a turnout. On each blind curve, the speed is held down to less than would be had if certain of no possibility of a car traveling in the opposite direction.

224. As a means of increasing speed of travel and decreasing the possibility of accidents, long tangents and easy curves are desirable on medium and high service truck-trails. However, if long tangents will make travel monotonous slight changes in alignment and gradient may be introduced provided the annual cost is not increased.

225. A contour line should not be followed if this will seriously impair the serviceability of the road. But on the other hand heavy cuts and fills should be avoided as much as practicable on low and medium service truck trails. On uneven slopes cutting and filling will be necessary to give a standard of alignment commensurate with the purpose for which the road is built.

226. Whenever it is believed that a higher standard will be needed in the future, the location should be planned with this in mind, even though it will not always be practicable to make the present location such that all portions can later be used.

227. Horizontal versus vertical curvature. The use of vertical instead of horizontal curvature is often decidedly preferable. In other words, the straighter alignment with variable grades even up to the maximum permissible will provide the desired speed with less annual cost and with greater safety to travel than a more uniform and lesser grade with a large proportion of the distance in horizontal curves. Speaking generally, horizontal curvature with short radii lessens the speed of travel much more than undulating grades. Gradient has less effect on the speed of modern cars and trucks than in the past; its effect of horizontal curvature remains practically the same. The use of truck trails for timber hauling will decidedly limit the use of steep grades.

The changing of a short radius curve to the longer radius necessary to make possible the higher required speed frequently requires an excessive expenditure. It is extremely difficult to convert from single-track with sharp curvature into a road permitting two-way travel at the desired speed of travel and with safety to traffic. It is far better during the original construction to keep in mind the future requirements and locate on this basis. This frequently will result in selecting the route with the straighter alignment and grades.

At times the cost of providing and maintaining drainage structures and other work necessary to prevent wash, destruction, etc., will control the decision and require the selection of (1) horizontal curvature instead of vertical, (2) vertical curvature instead of horizontal, or (3) the use of less maximum grades than would otherwise be approved.

227-A. Alignment at Bridge Locations. Existing locations of bridges and their approach roads are conclusive proof that alignment in many cases has not been given proper consideration. The bridge should fit the adjacent truck trail location. The construction of skew bridges is approved practice where necessary to obtain reasonable alignment and in other cases to improve alignment where cost will not be appreciably greater. Short radius curves at the approaches are to be used only as a last resort after careful consideration has been given to all possible locations of the structure and approaches.

228. Minimum Radius. The minimum radius of curvature for the several service standards and widths are as follows: -

For low-service ....40 feet
For medium-service ....50 feet
For high-service ....80 feet

The preceding apply to both open and blind curves. 60 feet radius may be used as a minimum on high service where it will not constitute a danger point and where the 80 foot radius would be unreasonably high in cost.

229. For shortspur low service truck trails, the use of an absolute minimum of 25 feet is permitted in specific cases when approved by the Regional Forester. Care should be exercised in giving such approval since curves of this radius can not be negotiated by vehicles larger than those in the $1\frac{1}{2}$ ton Ford or Chevrolet truck class. Accordingly the use of this radius should be limited to cases where there is no probability of larger sized vehicles being used and to other cases where the advantages arising through reduction in construction cost outweigh the disadvantages arising through loss of time and inconvenience in backing and filling to get the vehicles around the curve.

230. Extent of use of Minimum Radius. The decision will be based on the individual case and on meeting the service requirements for such case. This applies to projects as a whole as well as individual portions of each project.

Minimum radius should never be used when longer radius curves can be obtained at practically the same cost.

Avoid sharp curves at end of long tangents.

GRADE (OR GRADIENT)

231. Definitions. "Grade" and "gradient" as used in this handbook are synonymous. Either term means the number of feet rise or fall for each 100 feet in horizontal plane. Grade is expressed in percent. For instance plus 5% grade means an increase in elevation at the rate of 5 feet vertically in 100 feet horizontally.

"Sustained grade" means uniform grade, i. e. a straight line in a vertical plane. In other words, on a length of sustained grade, there is no variation up or down from a certain percent of grade.

232. Permissible maximum grades.

The maximum grades which may be used are dependent on traction and on the resistance of the materials withstanding erosion. The maximum grade approved and used should in no case be that which will result in unreasonable erosion or which will not provide traction fully adequate for the weight, size and speed of vehicles that will use the truck trail.

Subject to being satisfactory from both the traction and erosion standpoints, the permissible maximum grades are as follows:

Maximum Grades

	3,000	6,000	9,000 or over
Low Service	15	13	11
Medium Service	11	10	9
High Service	8	7	6

Pitch grades, exceptions to maximum grades. The gradient shown in the above table may be increased as follows for distances of not more than 500 feet, where approved by the Regional Forester:

1. Primarily protection; low and medium service may be increased by 5%.

2. Primarily public travel; medium and high service may be increased by 2%.

Pitch grades must be separated by at least 500 feet of grade not in excess of maximum sustained grade. While variable in amount, the velocity of approach to a steep pitch has a decided effect on ability to pull a steep pitch; this should not be overlooked in deciding wheather or not to use a steep pitch and the grade to be used. Pitch grades should not be used on curves of less than 100 ft. radius.

Elevation has a decided effect on the power of a motor. A loss of 3½% is encountered for each 1,000 feet rise in altitude. Account of this was taken in establishing the standards.

233. Effect of Grade on Travel Speed. See Table 202. That grade affects travel-speed is obvious. The effect is comparatively little for the lower gradients; for the higher gradients, the effect increases faster than the increase in gradient.

The effect of any one grade, however, is not always the same. This is partly due to the use of different styles, weights and makes of vehicles, but more to the driver himself. The variation is much greater on down grades than on up grades. On the latter, especially the steep grades, the power of the motor is usually the determining factor. In the case of "medium service," travel by the general public and cars driven by those inexperienced in mountain driving must be planned for.

Uniformity of Grades

234. The use of adverse or undulating grades within reasonable limits is not only approved but is specifically advocated to assist natural drainage and to reduce cost especially on Low or Medium Service projects. Care, however, should be taken that the expenditures necessary to providing and maintaining proper drainage do not exceed the benefits derived from reduction in the amount of excavation.

235. The practice of cutting off the tops of long broad knolls and filling in well-rounded hollows in constructing roads across rolling dry flats and on the face of broad inclines is not approved. The grade, however, should be well enough sustained to avoid having holes that will collect water.

Grade versus Level

236. Where practical avoid level location. To obtain satisfactory drainage, use grades of not less than 2 per cent with good soil conditions and not less than 3 per cent for heavy clay soils.

237. Grade versus alignment. The relative cost (including drainage provisions and maintenance) and the effect on travel-time of following sharply winding contours on the lighter slopes in comparison with cutting them must be weighed in deciding on the location. By cutting across points and filling depressions, a connected series of short curves can be avoided. The desired speed can frequently be secured at less present cost and with a less future expenditure where a higher standard road will be required, through the use of vertical rather than horizontal curvature.

Changes in Grade

238. Avoid sharp breaks in the grade. Changes in gradient, especially if over 5 percent and on ordinary or heavy duty roads, should always be as gradual as practicable.

Where a plus gradient of a road on which travel will be heavy meets a minus grade at the top of a hill, the top should be well rounded off by means of a vertical curve to provide for the best practicable line of sight for opposing traffic.

Grade at Bridges

239. Observance of the general principle expressed in paragraph 238 is particularly important for the grade line of bridges and approaches. A bridge particularly a one-lane structure is a hazard and visibility of opposing traffic is of great importance. The grade of the road should, where practicable, be maintained across bridges without any break and otherwise with only slight changes in grade that do not restrict visibility unreasonably. A driver approaching a bridge should be able to see a vehicle that is within 100 feet of the other end of the structure.

Compensation of Gradient on Curves

240. When the grade exceeds 4 per cent it is highly desirable to reduce the grade on sharp curves to compensate for the extra power required to carry the vehicle around the curve. Where the amount of traffic is very light and the weight of vehicles comparatively small, compensation is desirable but the amount indicated by the table may be reduced.

Where soil or other conditions require a grade compensation on curves having radii of over 80 feet, a gradient to meet these special conditions should be used.

Grades on Curves

Grade of road approaching the curve	Curves with central angle of 50° to 120°: Radii 40' to 60'	Curves with central angle of 50° to 120°: Radii 60' to 80'	Curves with central angle exceeding 120°: Radii 40' to 60'	Curves with central angle exceeding 120°: Radii 60' to 80'
5%	4%	5%	3%	4%
6	4	5	3	4
7	5	6	4	5
8	5	6	4	5
9	6	7	5	6
10	6	7	5	6

Care should be taken to distribute the grade uniformly throughout the entire length of the curve. Otherwise much of the advantage of compensated grades is lost.

SURFACE

Effect of Surface on Speed of Travel

241. Speaking generally, surface condition has a greater effect on travel speed than any other element of construction standard. Unquestionably sharp curvature causes a decided reduction in the approach speed. Also on a steep gradient, the speed is much less than on lower grades. Surface condition however influences all high and moderate speeds and sometimes even lowers the speed made necessary by very low standards of other elements. A slight roughness in surface conditions is immediately reflected by the speedometer. Shallow ruts have a greater effect. On two sections with identical conditions except surface condition, the speed on the section with fairly deep corrugations and ruts may be much less than that on the section with a good surface condition.

242. Perfect smoothness is desirable but frequently can not be secured with the available materials even if the expenditure for smoothing is not limited in any way. But even though physically possible, the cost of securing perfect smoothness will often be unreasonably great. Weight the costs and benefits. Possibly the desired service and lower annual cost will be secured in some other way.

243. It is difficult to prepare a satisfactory definition. It is believed that what is wanted will be evident by considering together the following separate statements, no one of which alone is a complete or accurate description.

1. A surface equal to that resulting from scarifying, shaping loosened material with grader, settlement and compaction by Nature and by traffic.

2. Hard and well compacted. An even mixture of the different constituents of the road material.

3. Reasonably smooth. Without well-defined ruts. Where ruts are unavoidable because of cost of removing or the nature of the road material, they should be shallow and wide.

4. No holes, protruding rocks, or other irregularities. Or if unavoidable on account of cost or other reasons, not sufficient in amount to cause the driver to reduce the speed which would otherwise be possible.

5. A uniform shaping of surface along a stretch of road. Where a change of shape is made because of drainage, alignment, etc., make the transition easy and not abrupt.

Shaping of Surface

244. The shape given during construction and maintenance is of decided importance from the standpoints of safety, travel-speed, ease or comfort in driving and cost of maintenance. As a general rule, the best shaping is that which will result in a minimum of surface wash and with no ruts; or if ruts are unavoidable, shallow and of even depth. Care should be taken (1) to bank the curves in the right amount and direction; (2) to avoid excessive inslope or outslope; (3) against using the wrong crown, i. e. inslope instead of two way, outslope instead of inslope, etc.

BANKING ON CURVES

Definition of Banking

245. Banking is the amount that the outside edge of curves is raised. Frequently the term "superelevation" is used.

Standard

246. All curves should be banked except when a wet or soft surface condition will cause a tendency for the vehicle to slide sideways and constitute a danger to traffic. Also the speed of traffic must be considered; on a truck trail to be used by both cars and heavy trucks, a banking based on facilitating car speed and operation may be decidedly objectionable from the standpoint of the truck.

247. The amount of banking should properly be based on the radius, speed and other conditions existing at each individual curve. See Table 201, page 218. As general standards the following is established:

Banking of Curves and Limiting Radii

Road Standard	Amount of Bank in inches per foot		
	1½" : 1'	1" : 1'	1/2" : 1'
	Radius of curve in feet		
Low Service	25	30-35	40 - 80
Medium Service	50 - 70	75-95	100 - 160
High Service	80 - 110	115-160	Over 160

Table 201

Maximum Safe Speeds on Open and Blind Curves

Miles Per Hour	12	14	16	18	20	22	24	26	28	30
				10 ft. Road						
				Open Curves						
				Radius of Curve in Feet						
Level	30	45	65	95	130	150	175	205	240	275
1/2" to 1 ft. bank	25	35	55	80	110	130	155	180	210	240
1" to 1 ft. bank	25	30	45	65	95	110	135	155	180	205
1-1/2" to 1 ft. bank	25	25	40	55	75	95	115	135	155	175
				Blind Curves						
Vertical Back Slope	25	45	80	125	200	300	400	510	650	850
1/2 to 1 " "	25	35	55	85	130	180	240	310	400	550
1 to 1 " "	25	30	40	65	95	135	175	240	320	470
				12 Ft. Road						
				Open Curves						
Level	30	40	50	70	110	130	155	180	210	240
1/2" to 1 ft. bank	25	35	45	60	90	110	135	155	180	205
1" to 1 ft. bank	25	30	40	55	75	95	115	135	155	175
1-1/2" to 1 ft. bank	25	25	35	45	60	95	100	115	135	155
				Blind Curves						
Vertical Back Slope	25	35	60	100	145	205	275	370	470	620
1/2 to 1 " "	25	30	45	70	105	150	200	255	325	430
1 to 1 " "	25	25	35	55	80	115	145	200	265	360

It is realized, however, that compliance with the table will at times be very difficult since it will result in different bankings for adjacent curves and the required quick adjustment of blade is beyond the ability of the average graderman. Where this is the case, a standard of 1":1' should be established for all curves on the specified project, or if the curves are frequent and very sharp, a greater banking may be advisable. The danger of side-slip may require the use of a 1/2:1 banking or even a flat road. A good rule is to provide the banking that will make "driving the curve" the easiest and at the same time result in the least damage by surface wash, and in a minimum of rutting. Ruts on one side of the road that are deeper than the ruts on the other side indicate improper banking.

248. Securing banking requires effort, planning and skill. The added cost, however, is little or nothing. As shown in Table 208 banking has a decided effect on the speed of travel, a banked curve affording the same speed as a curve of decidedly greater radius but with less or no banking. The effect on cost through the use of banking is obvious.

249. Curves should be banked as a part of the construction operation. The banking then provided should be continued during maintenance or another banking provided if traffic or other conditions have shown the original to be undesirable.

<u>EROSION CONTROL</u> (See also paragraph 122-B)

249-a. This is not a new subject as far as truck trail construction is concerned, for all of the normal provisions for drainage are at least attempts to control erosion. The need for road maintenance is primarily because of erosion, either from travel or natural forces. The damage from erosion is often serious to property and to values other than the road itself, but even if this were not so, it is still a serious problem because of damage to the road itself. Therefore, the prevention of erosion, slides, washing, etc., will pay dividends in decreased maintenance expense.

Adequate drainage practice in all cases and the planting of cut and fill slopes wherever soil and runoff conditions are such that exposed soil is unstable are the objectives. The matter is discussed here to call attention to the problem. Specific treatment of individual projects calls for detailed study on the job with the advice of the nearest Forest Service Experimental Station. Much of the following discussion has been taken from U.S.D.A. Circular No. 380 by Charles J. Kraebel and other data prepared by the Forest and Range Experiment Stations.

No sooner is a new road constructed than the forces of nature are at work to destroy it and of these natural forces the most powerful by far is water. The destructive action of water is especially rapid on mountain roads, where the area of erosible fill slopes is not only large but is often needlessly exposed to the concentrated runoff from the road surface. Many times, truck trails are blocked by slides from cut slopes, and gullies are carved into fill slopes by the escape or road-surface water over the shoulder.

The damage below a storm gullied road is often much greater than to the road itself and is frequently of such a nature that probably it will never be repaired. In many cases a part of the displaced material finds its way into stream channels, reservoirs, water spreading grounds and irrigation works. Recreational values are injured by the extermination of fish in pools filled by the eroded silt and sand, in the destruction of campgrounds, in the despoliation of streamside beauty by mud and boulder flows, and in damage to other roads and bridges. Agricultural lands are encroached upon and sometimes ruined.

U.S.D.A. Circular No. 380, "Erosion Control on Mountain Roads" gives methods of erosion control while the control methods and species of vegetation listed are primarily adapted to conditions found in California, many of them have a wide application for all mountain roads. Copies of Circular No. 380 should be available in each Regional and Supervisor's office.

Preventative and Corrective Measures

(1) Location and Alignment. From the erosion viewpoint the ideal mountain road is one that will require a minimum of excavation. The road should have in some degree the appearance of having been fitted with the landscape rather than chopped and blasted from it. Long tangents should not be used where reasonable curvatures will better fit topography and reduce excavation.

(2) Greater Use of Retaining Walls and Cribbing will reduce the excavation, particularly on steep slopes, and will leave much less fill area exposed to erosion.

(3) Improved Drainage Practice is vital to the whole problem of road maintenance and erosion prevention. Inadequate drainage is responsible for most of the serious erosion of mountain roads. For example:

(A) Culverts emptying on the middle or down one edge of highly erosible fill slope. Emptying culverts on adjacent brush covered slopes is especially destructive where the soil is susceptible to deep erosion from the concentrated runoff. Where the natural channel cannot be reached directly the culverts should extend to solid rock ledges from which the flow will be over rock all the way to the natural channel or the fill protected by heavy rip-rap. An alternate method is to flume the culvert discharge down the slope to a point that is firm enough to resist erosion.

(B) Surface drainage inadequately controlled resulting in erosion of side ditches and escape of water over shoulders or to fill slopes or other unstable area. The low point on inside curves is one often in need of protection. Careful inspection following heavy rains on a new road will indicate the points requiring attention. It is most important that culverts be of adequate size to accommodate heavy storm runoff.

Cutslope construction should not be used in areas where the unavoidable accumulation of water in wheel ruts will erode the surface of the fill. Such water accumulates and runs down the road to some slight obstruction or depression where it pours out over the side often causing a troublesome gully.

EROSION CONTROL IN ROADSIDE DITCHES

249-b. Erosion in roadside ditches can be controlled by: (a) selecting locations having low gradients and very shallow cuts and fills, (b) shallow and wide ditches rather than deep and narrow, (c) providing sufficient culverts and outlet ditches, (d) avoiding construction practices which encourage the formation of new drainage channels in native soil, (e) reducing roadside ditch grades and checking flow in the ditches, (f) planting and seeding slopes. (a), (b), and (c) are matters of intelligent location and design; (d) requires that no cuts be made or any ground stripped of vegetation where avoidable; (e) is accomplished through the use of check dams; and (f) is discussed herein under paragraph 249-c.

Checks or baffles should be installed where necessary to prevent erosion resulting from rapidly flowing water. They protect the roadbed by establishing a permanent ditch having a low rate of gradient and thus reduce the velocity of flowing water. Checks should be constructed in accordance with designs approved by the Regional Engineer.

TREATMENT OF CUT AND FILL SLOPES

249-c. Road bank control must be considered only as a supplement to good road construction. It does not take the place of adequate berm and drain construction, and other standard practices for controlling road water. Road bank control and planting serve three major purposes:

1. Reduction of road maintenance costs.
2. Improvement of roadside appearance.
3. Reduction of the amount of eroded soil carried into ditches and streams.

Slope control is effected by inducing the growth of a vegetative cover on the slopes. In sections where natural reproduction of grasses and shrubs takes place, no special treatment is necessary other than to slope the banks to the required angle and to round the tops of cut slopes where soil and vegetative conditions warrant this treatment. This method is not applicable where the tops of slopes are covered with trees. In such situations the method should be modified to fit conditions. Some soils stand better and with less erosion on a vertical cut than when sloped back. Where question exists as to advantages of rounding off tops of cut banks the advice of Research should be secured.

SELECTION OF SPECIES

The selection of plant species for road planting must be governed by the following rules:

1. Vegetation must not create a fire hazard.
2. It must be easy to establish and maintain with the amount of moisture available from normal precipitation.
3. It must be rapid and vigorous growing, without becoming a nuisance on adjoining lands.
4. It must be easily available in large amounts or easily propagated.
5. It should be reasonably attractive for landscaping, preferably an evergreen.

The advice and assistance of the nearest Forest Service Experiment Station should be secured in selecting species and determining proper methods for planting. Circular E 1787 transmitted a list of desirable species suggested by Research for trial in various sections of the country.

Seeding and Planting - In sections where vegetation does not reproduce naturally it will be necessary to give the slopes special treatment designed to induce plant growth. The simplest, cheapest and one of the most successful methods of treatment is to cover the slopes with seed bearing forest litter or debris when such material is available along-side the roadway. In this method the litter is raked down over the slopes and held in place by light brush or poles. The use of this treatment most generally results in vegetation establishing itself from seed contained in the litter. This method is impracticable on slopes steeper than 3/4: 1.

When seed bearing forest litter is not available, it will be necessary to either seed, sod, or plant the slopes.

Sod strips of common sod-forming grasses may be set in shallow furrows dug along the contour. Although spring is the most favorable season, transplanting may be done any time except during very dry seasons.

Root clumps of honeysuckle or other plant material may be set either in furrows dug along the contour or preferably in holes dug into the bank and filled with top soil. Furrows may cause additional sloughing of the banks.

Grass seed may be sown in the spring or early summer. It should be carefully raked in. When necessary an approved fertilizer may be used. The grass species used should be the important sod grasses of the locality. On long fill slopes of particularly loose soil, stake and brush wattles may be used for holding the soil until vegetation has become established. On dry, sterile slopes, brush and litter may be staked on the slopes to conserve moisture and favor the establishment of vegetation. South facing banks of dry, sterile sub-soil cannot be seeded with any degree of success without first improving moisture and shade conditions of the soil.

Figures 201-A and 201-B illustrate successful methods of road bank control. These methods must be adapted to specific local problems at hand, and all of them call for independent judgment on the part of the man in charge. In general, heavy mechanical structures should be kept to a minimum. This applies particularly to stake and brush wattle construction. Woods litter and debris from the forest floor raked on to a bank and held by simple mechanical devices is one of the very best methods by which soil washing may be presented and vegetation established.

FILL SLOPES AND CUT SLOPES

Fill Slopes

250. General standard: - In earth 1-1/2:1; in rock 1:1. See paragraphs 325 and 327.

Cut Slope

251. General standard: - In earth 3/4:1; in certain stable soils 1/2:1; in solid rock 1/4:1 or even 1/6:1.

The selection of the cut slope requires the exercise of good judgment and should be based on the conditions existing on the ground. In selecting a cut slope, first consider the type of soil. The slope must be flat enough to prevent erosion.and favor an early recovery of the vegetative cover.

A slope flatter than that on which the material will stand may be provided when necessary for adequate clearance of truck body and load and where cheaper to secure a flatter backslope - by backsloper, high lift grader or otherwise - than to increase the width of the truck trail. Also where the material is such that an undue amount of sloughing will occur, it will be necessary to provide a slope with a ratio of 1:1 and in exceptional cases an even flatter slope. Exceptions to the standard practice will also be justified in cases where construction work has loosened the earth on the uphill side and the bank will not hold on what would ordinarily be the selected slope.

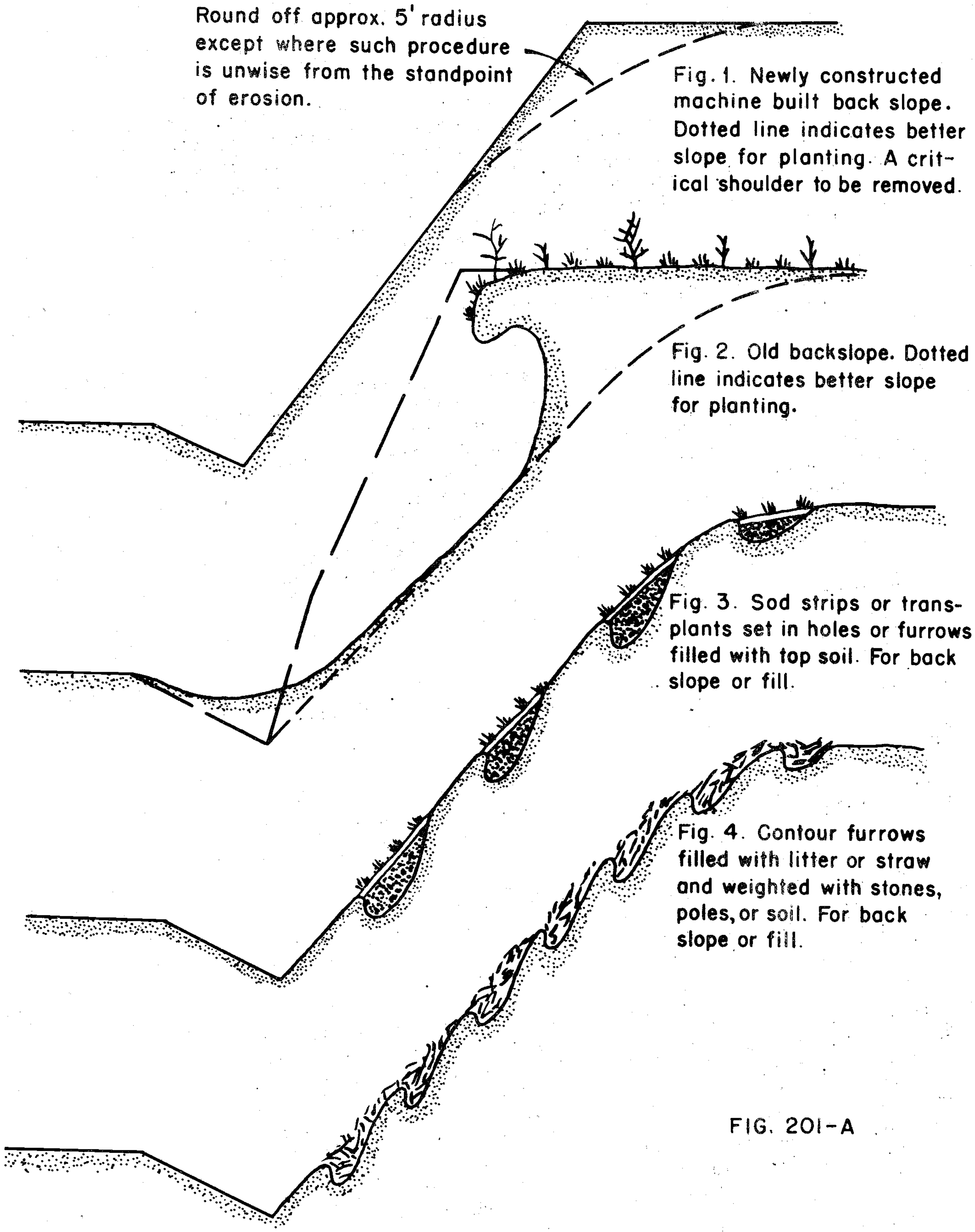

Round off approx. 5' radius except where such procedure is unwise from the standpoint of erosion.
Fig. 1. Newly constructed machine built back slope. Dotted line indicates better slope for planting. A critical shoulder to be removed.
Fig. 2. Old backslope. Dotted line indicates better slope for planting.
Fig. 3. Sod strips or transplants set in holes or furrows filled with top soil. For back slope or fill.
Fig. 4. Contour furrows filled with litter or straw and weighted with stones, poles, or soil. For back slope or fill.

FIG. 201-A

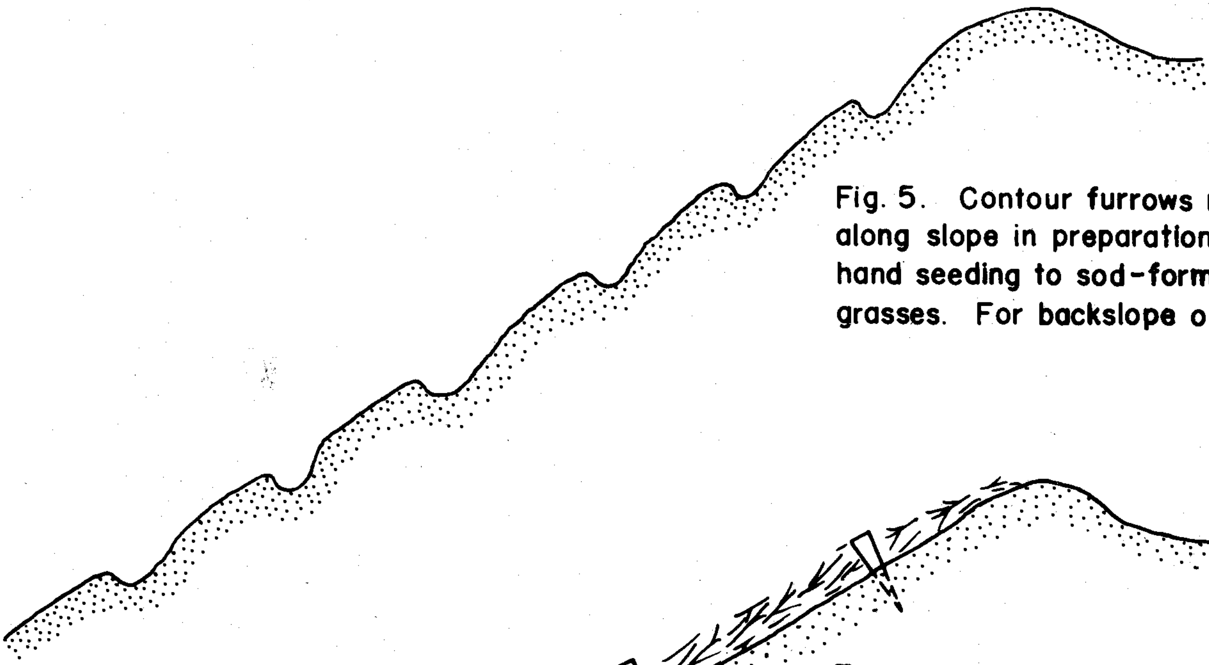


Fig. 5. Contour furrows made along slope in preparation for hand seeding to sod-forming grasses. For backslope or fill.

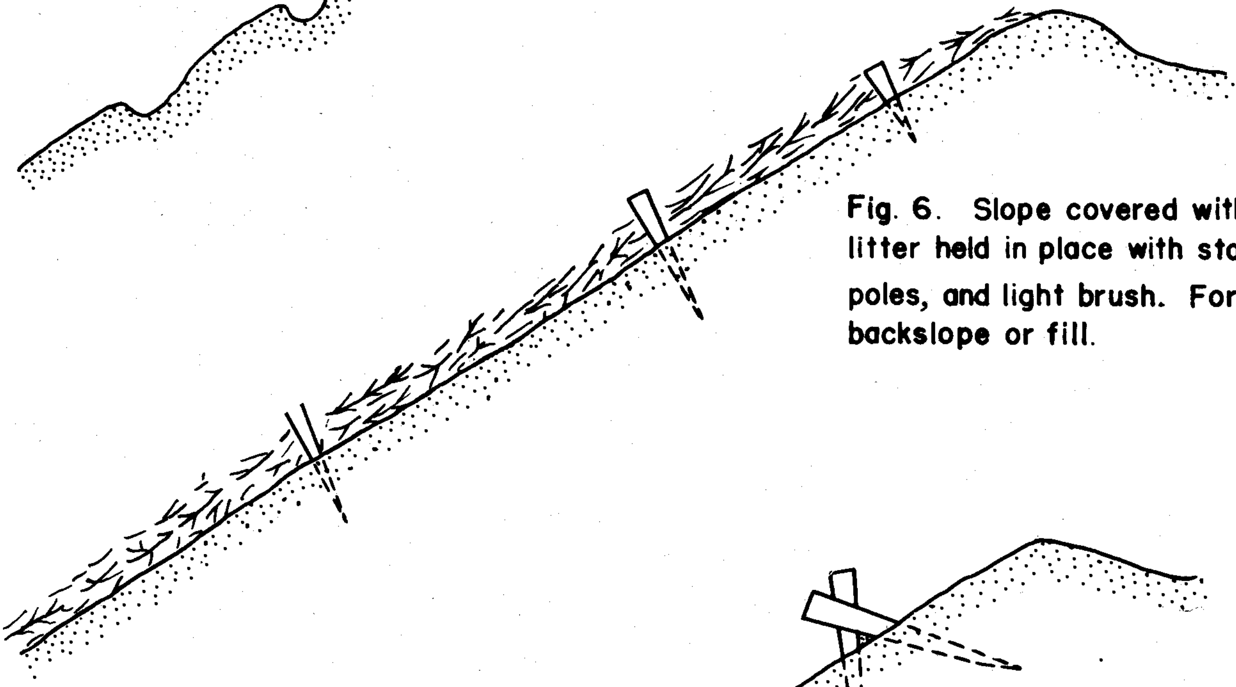


Fig. 6. Slope covered with litter held in place with stakes, poles, and light brush. For backslope or fill.

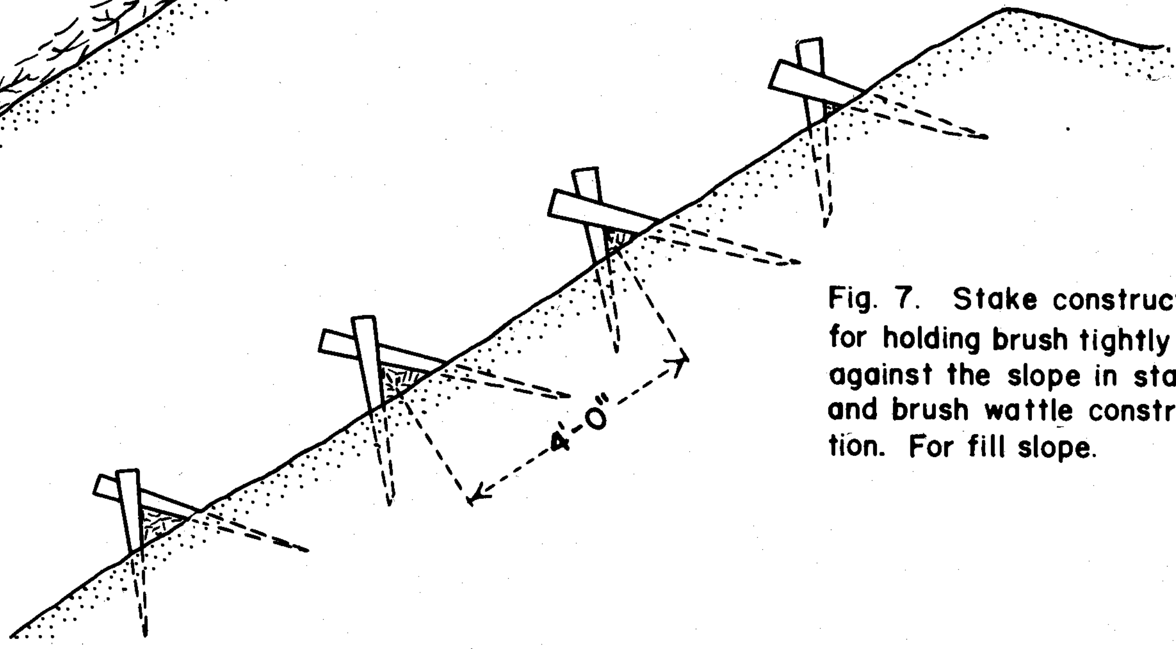


Fig. 7. Stake construction for holding brush tightly against the slope in stake and brush wattle construction. For fill slope.

FIGURE 201-B

DESIGN OF TURNOUTS

SINGLE TRACK TRUCK TRAILS • SHOWING METHOD OF MEASURING LENGTH AND WIDTH OF TURNOUTS ON CURVES AND TANGENTS

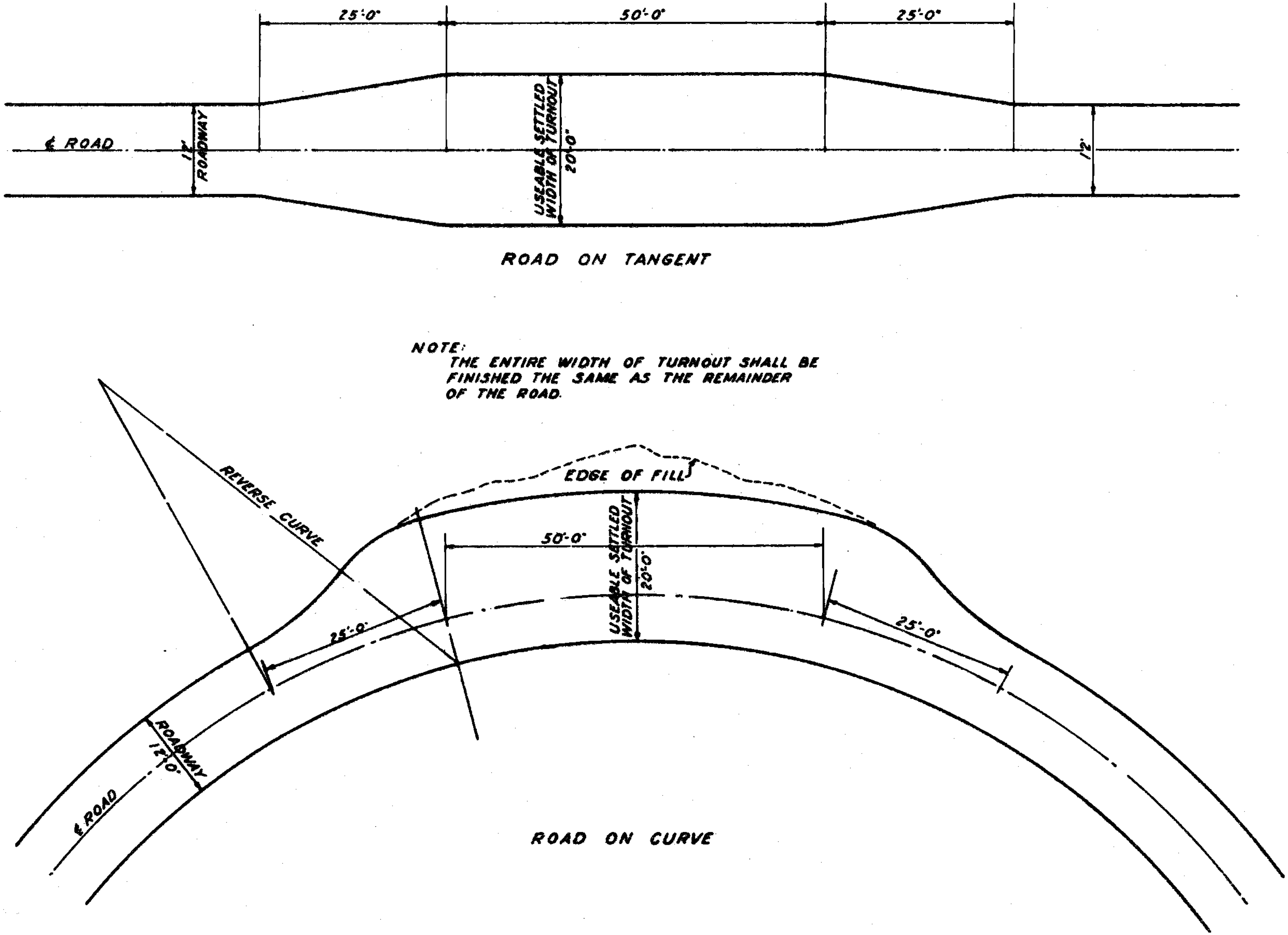


FIGURE 202
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Some soils will stand upright better than where sloped if backsloping is done on such soils the topsoil should, where practicable, be returned to the slope to assist in an early vegetative cover to help prevent excessive erosion.

TURNOUTS

252. Importance. Turnouts adequate as to size, number and location are essential for safe travel on both one-way and single track roads. Turnouts rank equally with grade, width, alignment, etc., in determining the service that a road will safely render.

Do not fail to provide sufficient turnouts but guard against extremes in the other direction.

The cost of providing a road of high value and primarily needed for protection, with turnouts adequate in number and size for a fire emergency, may be very great. In such cases consideration should be given to establishing a control of travel, i.e., one-way travel. This may be cheaper and more satisfactory in other respects.

Standard or Normal Practice

253. See Fig. 202 for dimension, shape, etc., of turnouts. This represents standard or normal practice. The number, location and spacing of turnouts should be adequate to meet the maximum needs. They should always be intervisible.

When necessary for road maintenance, for wide, long, or heavy vehicles or for fire suppression travel, the width, length, etc., may be increased.

Location

254. Do not construct turnouts in flat sections or in other places where the natural topography makes passing safe and comparatively easy. But where rock, stumps, trees, rough surface or other factors present obstacles, turnouts should be made.

As a general practice, constructed turnouts should be located on blind curves, especially dangerous curves, and the summits of sharp vertical curves. Exceptions should be made where the cost would be excessive and unwarranted under existing conditions.

255. Attention should be given to providing turnouts
(1) at watering places on roads where water is scarce, and
(2) on turns from which particularly scenic views are afforded.

256. The alignment of a road may frequently be materially improved by exercising care in the location of turnouts. Where practicable, locate turnouts so that they will serve both as an opportunity for passing and also to increase the service value of the road.

257. Construction. Turnouts should be built during construction. Be certain to constuct turnouts to necessary width and length. Do not build in excess of either of the specified dimensions unless the excess is really needed. Give inslope to all outside turnouts and along slopes. The entire width specified for the turnout should be solid usable width, safe for actual use. Care should be exercised in getting the outside edge true to shape. Avoid irregularities.

Turnarounds

258. Turnarounds should be provided as occasion demands, choosing locations requiring the minimum of excavation and cost.

Signing

259. Where turnouts are not frequent and side slopes are precipitous, their location should be marked with a distinctive and conspicuous sign visible from both directions. Service-wide instructions for posting signs on roads should be followed in case of conflict with this paragraph.

Table 202

Approximate speed standards where grade and curvature do not control

On simple low turnpike sections - 32 m.p.h.
On steep side hill, 12 foot width - 28 m.p.h.
On steep side hill, 9 foot width - 25 m.p.h.

Table 203

Maximum Maintained Speeds on Grades

Miles per hour	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
% Grade (El. 3000')		21%	21%	21%	21%	20%	18%	15%	12%	12%	11%	10%	9%	8%	4%
% " (El. 6000')		19	19	19	18	17	15	13	10	10	9	9	8	7	3
% " (El. 9000')		16	16	16	15	14	13	11	9	8	8	7	6	5	2
Down Grade %		20	19	18	17	16	15	14	13	11	10	9	7	0	4
				1-1½ and 2 ton trucks with capacity load											
% Grade (El. 3000')			24	14	11	7	7	7	6	3½	3½	3	3	3	2½
% " (El. 6000')	25%	24	21	12	10	6	6	6	5	3	2½	2½	2½	2½	2
% " (El. 9000')	21	20	18	10	8	5	5	5	4	2	2	2	1½	1½	1
Down Grade %	18	16	15	14	12	11	9	8	7	5	4	2	1	1	1
				Average 3 ton truck with capacity load											
% Grade (El. 3000')	21	20	19	11	10	5	5	5	5	5	4	2	2	2	2
% " (El. 6000')	18	18	16	10	9	5	5	4	4	4	3	2	2	1	1
% " (El. 9000')	16	16	14	8	7	4	4	3	3	3	3	1	1	1	1
Down Grade %	18	16	15	14	12	11	9	8	7	5	4	2	1	1	1

Note: Speeds shown are for Single Track forest roads with hard smooth dirt surface; alignment not controlling.

Table 204

Distance to Gear Shift on Up Grades
1/2 ton Pickups and light cars with capacity load

High Gear

Speed of approach miles per hour	% Grade - Elevation 3000'						
	8%	10%	12%	14%	16%	18%	20%
20	400 ft.	200 ft.	140 ft.	110 ft.	80 ft.	70 ft.	50 ft.
25	670	370	260	200	150	130	100
30	950	550	390	300	240	200	160
35	1250	730	530	410	330	280	230
40	1550	900	680	540	440	380	320

For 6,000 ft. elevation reduce grades 1%
For 9,000 ft. elevation reduce grades 2%

Second Gear

Speed of approach miles per hour	% Grade - Elevation 3000'				
	14%	16%	18%	20%	22%
15	300 ft.	180 ft.	110 ft.	90 ft.	70 ft.
20	490	200	200	150	120
25	660	280	280	220	180

For 6,000 ft. elevation reduce grades 2%
For 9,000 ft. elevation reduce grades 4%

Note:-To reduce grades by 2% means to use for 12% grade the distances in the 14% columns, etc.

Table 204 continued

Distance to Gear Shift on Up Grades
Average 1½ and 2 ton trucks with rated load

High Gear

Speed of approach miles per hour	% Grade - Elevation 4000'					
	6%	8%	10%	12%	14%	16%
15	130 ft.	70 ft.	50 ft.			
20	320	200	130	100 ft.	80 ft.	60 ft.
25	580	340	240	180	150	130
30	840	500	370	280	230	200
35	1100	700	500	390	320	270

For 8,000 ft. elevation reduce grades 1%

Second Gear

Speed of approach miles per hour	% Grade - Elevation 4500'			
	10%	12%	14%	16%
10	100 ft.	50 ft.	35 ft.	25 ft.
15	290	150	100	75
20	490	260	180	140

For greater elevation reduce grades 2%

Note: - To reduce grade 2% means to use for 12% the distances in the 14% column, etc.

DESIGNING FOR A GIVEN SPEED

A Road Provides Service

260. A road is provided to meet a specific need of traffic or real property for transportation facilities.

Nearly always service to both property and traffic is rendered but the relative amount varies greatly in individual cases.

The value of traffic depends largely on the character and amount of traffic. A main trunk highway is a good example of a road whose main service is to traffic. Such a road increases the value of abutting or near-by land and is used by the landowners in connection with the land use. However, the main value lies in what it saves or gives to the road users.

The value to property while affected by the character and amount of traffic is based largely on other considerations. A good example of such roads is the truck trail used exclusively for protection purposes. The primary value and justification is in having a transportation facility available for use if the necessity arises. The amount of use may be little or even nothing without lessening the value to the property. Such a facility increases the value of the property itself. When the road is actually traveled, value to traffic is also rendered.

Measurement of Value.

261. To the extent that a road serves traffic, the best measure of its value is the cost per car-mile or ton-mile. This includes not only the cost of operating the vehicle itself but maintenance of the road, interest on and retirement of investment in construction and the value of the time of travel while using the road. While difficult to estimate the volume and character of future traffic, the value to traffic can be determined with adequate accuracy in most instances.

But determination of the value to real property is much more difficult. However, a method of determining the economic value for real property as well as traffic has been developed.* This method shows that the value of the time of the road users and the value derived by them during the period of traveling constitute a very large portion of the total road value. Elapsed time in traveling over the road is of so predominant value in connection with fire protection, that such matters as vehicle cost are relatively inconsequential.

* See official files. Also Journal of Forestry Vol. XXX No. 8, December 1932.

Determination of Construction Standard

262. Obviously the construction standard should make possible the road rendering the service required of it.

The customary method of stating the specifications to be followed designing a road is in terms of the various elements of construction standard. This method has largely worked out satisfactorily where the primary need for the road is to serve traffic over the road.

But where this method was applied to Forest roads, the results were not satisfactory. Instead of the new road rendering the service expected, it would give more or less. Or two men utilizing the same specifications would produce roads of entirely different service value or cost. The real explanation is simply that the major value of the Forest Development roads and truck trails is to serve the Forest property rather than to serve traffic.

The service value of the Forest Development roads and truck trails to the Forest property can be expressed with sufficient accuracy in terms of travel time except as regards timber-hauling or similar uses. There are also other cases of hauling supplies, etc., to a fire crew where the travel-time is important but not the controlling consideration.

A very large proportion of both mileage and expenditure on the Forest Development system is for fire protection. The time required for travel to a fire is obviously of very great importance. It is therefore clear (1) that the best measure of service value for the Forest Development system as a whole is elapsed time (2) that the relatively small number of cases where some other measure is clearly better should be treated as exceptions, and (3) all Forest Service activities such as utilization, recreation, logging, etc., which the project may serve should be considered in the selection of the standard.

Determination of Speed

263. The elements of construction standard determine the speed at any section of a road. Under some conditions one element, for instance width, may determine the maximum possible safe speed. In other cases, it may be some other element. Ascending a steep hill, grade may control; coming down the same stretch it may be width or alignment or both. With all conditions except elevation identical, the controlling element may be different. Surface condition and shape have a very decided effect on speed.

As a result of much field and office work, a determination has been made of the effect of gradient (up and down) curvature (open, blind and various bankings) and width. The effect of various surface conditions has not been determined because the very great loss in speed due to poor surface condition and the relatively little cost of providing and maintaining a surface of adequate smoothness make very evident that it would be better to use money in securing a relatively smooth suffface than by raising the standard of some other element of construction standard.

From the field and office determinations the summations appearing in Tables 201, 202, 203, and 204 have been prepared.

Use of Data

264. As evident from Pars. 209, to 213, the roads and turck trails are to be designed and constructed to render a certain prescribed service. Except for special cases this service is specified in terms of the distance to be traveled within an hour. In such special cases, the data on effect of elements of standard on speed will have only partial application.

While the method of expressing service value in terms of time and of designing roads for a specified travel-time is now several years old, is an essential part of the Transportation Plan and has received many commendations, especially in its application to conditions like the National Forests, nevertheless the method does constitute a decided change from the usual method of prescribing specifications. Accordingly doubt may be felt of its practicability and value. Such doubt is unnecessary if the way of using the method is understood.

Certain explanations are appropriate.

1. The tavel speed need not be uniform throughout the entire distance to be traveled within an hour.

2. The extent of permitted variations from a uniform speed should be based on the character of road use. Variations greater in number and speed are permissible in the case of preliminary protection truck trails than in those primarily for public travel and in the case of low service as against high service roads.

3. The speed on adjoining sections should be coordinated. Changes in speed should not be abrupt or require sharp braking; where such is unavoidable warning signs should be erected. Between 20 and about 35 miles an hour, a reduction of 20% in the speed can be accomplished within a short distance without sharp braking. Below 20 miles per hour the percentage reduction is higher; for higher speeds, a less percentage.

4. On single track roads, the amount of travel in the opposite direction affects the time required to travel a specified distance, even though what are believed adequate turnouts are provided. The travel time estimated from the tabulations should therefore be increased, on the basis of the estimated amount of opposing travel.

5. In selection of the general route, that route will be favored which will provide the required service at the least annual cost. In the case of primarily protection roads, this frequently means the use of a ridge top or some route other than that which otherwise would be selected.

6. What is sought at any section - long or short - is that use of the elements of standards as will give the speed desired at that section, at the least annual cost. Use of a higher standard of one or more elements is objectionable except when clear that the annual cost is not increased thereby.

Warnings

265. 1. The data in tabulations 201 to 204 are not expressed as accurately as were determined from the field and office studies for the reason that value were "rounded off" and adjusted to fit classes of vehicles. Speeds and grades tabulated are conservative and based on the average skilled and safe driver. They will be exceeded by the reckless driver or by the better than average car.

2. Avoid going to extremes in utilizing the speed data and in applying the method of designing for a specified travel time. Use common sense. Consider and investigate carefully the various alternatives offered in general or detailed location but avoid going into great refinements.

3. It is not expected that when the road has been completed, the actual travel time will be exactly as estimated during location. This is due to variations between drivers and vehicles but particularly to the impossibility of exactly determining the effect of opposing traffic.

4. Intelligent use of the data and method will give results of adequate accuracy and of higher accuracy and less road cost than through using other methods. On the other hand, waste of time and money will result from going to extremes in using the speed data for planning. Also the value of the data and of the method be lessened.

Determination of General Location

266. Illustration of Application of Method

Specifications - Travel from A to B or B to A in one hour; design to be based on using standard 1/2 ton pickup or light carewith capacity load. Elevation 3,000 feet.

Three possible routes, each of which is satisfactory from the standpoint of protection or other purpose to be served.

(1) Total length 18 miles, all side-hill, rather uniform slope, average grade about 5% for half the distance, about 8% for quarter, and 10% for quarter.

(2) Total length 21 miles; simple turnpike 1/3 of distance, 3% grade; sidhill for balance, with grade averaging $7\frac{1}{2}$%.

(3) Contour road; 24 miles sidehill; 1/2 tangent or no control of speed by curvature; 1/4 - curves 50' radius; 1/8 curves 70' radius; 1/8 curves 100' radius; grade average $5\frac{1}{2}$%. Curves open and blind in about equal distances.

Speeds

Width control

Simple turnpike	32 mph
Sidehill	25 mph

Curvature control

50'	radius	16	mph	open 15	blind
70'	"	18	"	" 17	"
100'	"	20	"	" 18	"

Grade control

	Up	Down
3%	30	30
5%	29	29
5½%	29	28
7½%	28	25
8%	28	25
10%	24	22

Elapsed time

Control		Speed	Travel Time in Minutes
Route 1			
Side hill, 5% grade	Width	25	22
" " 8% "	"	25	11
" " 10% "	Grade (Down)	22	12
Opposing travel - 6 vehicles - lost time			12
Total time required			57
Route 2			
Simple turnpike 3% grade	Grade	30	14
Sidehill 7% grade	Grade (down)	25	34
Opposing travel - 6 vehicles - lost time			12
Total time required			60
Route 3			
"Straight" sidehill	Width	25	29
Sidehill-50' radius	Alignment	15½	23
" 70' "	"	17½	11½
" 100' "	"	19	10
Opposing travel - 6 vehicles - lost time			12
Total time required			85

With either location 1 or 2, the elapsed time is withing the required 60 minutes. Location 3 does not comply with the specifications and will not be considered herin. If consideration were to be given it would be noted that widening the road would cut down the travel time appreciably but the biggest opportunity lies in reducing the length of road through increasing the grade.

Estimated Annual Costs

Route 1:

Const. cost per mile

9 miles on	5%	grade	- 1500
4½ " "	8%	"	- 2000
4½ " "	10%	"	- 2500

Total construction cost - $33,750
Maintenance cost per mi.- 25
Total annual cost = 33750 x .02 + 18 x 25 = $1125

Route 2:

Const. cost per mile

7 miles of simple turnpike	- 1500
14 " " sidehill 7½% grade	- 2200

Total construction cost $41,300
Maintenance cost per mile 20
Total annual cost = 41300 x .02 + 21 x 20 = $1246

Conclusion as to general route: - Route #1 - with less distance but steeper gradients - is the best.

267. Detailed Location.

The description used in deciding upon the general location is very broad. Many opportunities are found to exist in connection with the detailed location (1) to cut the construction and annual cost of sections through changing elements of standard but without affecting travel time; (2) to reduce the travel time or to increase the safety or comfort without increasing the cost.

268. Example 1.

The general description is that for half the road lengths, the road is on sidehill and the grade averages 5%. In the detailed location, opportunities are found as follows:

	Dist.	Grade	Speed	Elapsed Time
(1)	9 Miles	5%	29	19
(2)	4 "	8%	28	9
	5 "	2½%	32	9
				18
(3)	1 "	9%	26	2
	2 "	7%	28	5
	4 "	4%	30	8
	2 "	3%	32	4
				19

Assuming that grade controls the speed, it is evident that any one of these three opportunities would meet the requirements of travel time. The selected combination would be that which costs the least.
But with the sidehill section, width and not grade controls in this instance. Accordingly the maximum speed for these three opportunities would be 25 mph for a 10' road width and 28 mph for a 12' road width. The data would then be

	10' Width		12' Width	
	Speed	Time	Speed	Time
(1)	25	22	28	20
(2)	25	10	28	9
	25	12	28	12
		22		21
(3)	25	2	26	2
	25	5	28	4
	25	10	28	9
	25	5	28	4
		22		19

The decision on general location was based on the travel time for this 9 mile section being 22 minutes. Therefore, any one of the above 6 combinations would meet the requirement. The time to be gained by using the 12' width would be very slight and this width would not be approved unless (1) due to equipment used, construction method adopted or for some other reason, the annual cost with the 12' width will not exceed that with the 10' or (2) the total road cost would be less through providing the 12' width at this section and then utilizing the gained travel-time at some other place.

269. Example 2.

Within the 4-1/2 mile section with an average grade of 8%, some short draws are involved. The general grade through this short section is 7%, and the back slope is 1/2:1. The question arises whether (1) to use horizontal curves, (2) to cut across with sustained grade or (3) to cut across but with up and down grades.

(1) If horizontal curves are utilized, the radius will not exceed 60 feet. Table 201 shows that for such radii the speed on blind and open curves with 1/2" to 1' banking, can well be assumed as the same. The following combination would seem best.

Alignment	No.	Length
50' radius curves	6	600
60' " "	1	200
Tangent so far as speed is concerned	4	800
		1600

Some time is lost in reducing speed on approaching the curves and in accelerating after leaving the curves. With so many curves and such short tangent sections within such a short overall distance, the 1600' sections is a "Slow section" and it can well be assumed that the 25 m.p.h. speed ordinarily possible on sidehill sections of this width will be reduced to an average of 20 m.p.h. The travel time for the 600' distance will therefore be 1/2 minute.

On the 50' radius curves, the speed on the curves will be 15 m.p.h. and the travel time will be 1/2 minute.

The speed on the 60' radius curve will be 16 m.p.h.; the travel time is too short to be worthy of inclusion.

The total travel time will then be about 1 minute, assuming that alignment rather than gradient controls the speed. Table 203 shows this to be true.

(2) With a sustained 7% grade and alignment not controlling speed, the total length is 800', the travel speed 26 m.p.h., and the travel time 1/3 minute.

(3) With one dip in sustained grade, the overall length is practically 800'. The up pitch is 12% and 200' long. If this grade was sustained, the speed on the grade would be 20m.p.h. However, Table 204 shows that with an approach speed of 25 m.p.h. - this probably will be exceeded - the up pitch can be negotiated without shift of gear. While the average speed will be less than the approach speed and also less than the normal speed on 7% grade, the up pitch is so short that the travel time for the 800' length can well be taken as the same as for the 7% sustained.

The overall distance in this example is so short and the possible savings in travel time so little that the use of the horizontal curves would be acceptable provided

(a) Such would not constitute a danger spot on the road - this arises frequently when the general speed standard along the entire road is decidedly above that on a short section.

(b) The annual cost including drainage is less than on the straighter alignment.

If the cost is the same or less, the location with the straighter alignment is decidedly preferable. As between (2) and (3), (2) is undoubtedly the highest standard of practice and would be approved whenever the annual cost of (2) is the same or less than (3). If more, (3) would ordinarily be favored. However, even if (2) cost more, it might be approved if clear that (3) would constitute a danger point to traffic through its effect on travel speed. In this particular case, this would not be so as the reduction of from some 30 m.p.h. to about 20 m.p.h. even in such a short distance would not be particularly objectionable.

But while the possible savings in travel time are very small in this short stretch of less than 1/2 mile, there may be many of such cases rather concentrated in location. Where this occurs the individual time losses due to "contour road" location frequently add up to large amounts and justify the substitution of the better alignment.

270. Example 3: Sidehill construction; some rather sharp curves running from 50' radius down to 40; grade not controlling 1/2:1 backslope.

Table 201 shows the speed on open and blind curves, with various bankings and for different radii.

Assuming that the speed on approach to the curve does not exceed 22 m.p.h., that traffic and other conditions permit the use of 2":1 banking and that an 18 m.p.h. speed curve is acceptable from the standpoint of designing for travel time, the following of the available alternatives seem most worthy of further consideration:

Radius	Width	Banking
45	10	2":1'
50	10	2":1'
40	12	2":1'
45	12	2":1'

Assuming that no other considerations prevent decision being based solely on coast, the 45-10 would appear the best. However the 40-12 may be better.

On the blind curves, Table 201 shows that the bank slope appreciably affects the speed. Assuming that a speed of 16 mph on the curve is acceptable, the following alternatives are available and worthy of further consideration:

Radius	Width	Bank-slope
45	10	1":1'
50	10	3/4":1'
40	12	1":1'
45	12	3/4":1'
50	12	1/2":1'

The steepness of ground slope will largely determine whichis the most favorable combination.

271. Example 4. Steep sidehill construction. Speed on curve - 12' wide - is 16 mph. Speed on approach to curve is controlled by width only.

Table 202 shows that a 9' width will give speed of 25 mph and a 12' width, 28 mph. Assuming that a 20% reduction in approach speed is the maximum permissible on account of safety, nothing is gained by providing more than a 10' width on the approach section.

272. Example 5. The description of "general route" shows that for $4\frac{1}{2}$ miles the grades average 8% and that sidehill location is proposed. More careful study shows that in one stretch of about 2 miles, it is possible to depart from this location, climb to a ridge top and join the other location in about 3 miles.

Two questions are involved (1) will the ridge top location be satisfactory from the travel-time standpoint: (2) what is the relative cost of the two locations:

	Relation of annual cost ridge top section to side-hill location	Relation of travel time on ridge top section to that on sidehill	Tentative conclusion
1	same	same	Either route satisfactory
2	same	more	Take sidehill location unless loss in time can be made up with less total cost through providing at some other section, a fester road than would otherwise be provided.
3	same	less	Take ridge top location. Also see if cost of other sections cannot be reduced by utilizing the time savings on the ridge-top section.
4	same	same	Take sidehill location
5	more	more	" " "
6	more	less	Take sidehill location unless evident that through lowering the speed standard of some other section of the road savings in cost exceed the increase in cost through using the ridge top location.
7	less	same	Take ridge top location.
8	less	less	Same as (3)
9	less	more	Same as (2)

The above shows that logical first action is to estimate approximately the cost of each route. The relative cost will show whether further consideration of either route should be given. If so, the estimated travel time will be needed.

In long sections like this and where there will be many different combinations of the elements of construction standard, care must be exercised to avoid going into too great detail. To a very large extent, satisfactory results can be secured through (1) noting the number of different combinations and the length of each (2) a record and computation as on the next page.

Notes on tabulation

S. T. means simple turnpike or comparable section. S. H. means sidhill.

The speed used for steep pitches is somewhat greater than in tables due to short length of pitch and to effect of approach speed.

Where grade is controlling, use speed on down grades since usually somewhat less than on up grades.

Where average length of section of case is short or the number of short radius curves is many, use somewhat lower than speed given in tables.

Assume short radius curves are banked 1":1'.

Underline the element that controls the speed, i.e., where the resulting speed is the least. Use N.C. where evident that the element is not controlling and it is therefore unnecessary to consider in determining the speed or travel time.

Amount of opposing travel will normally be the same. An estimate of time lost will usually be unnecessary in comparing the two locations. If made the loss will probably be greater on the essentially sidehill contour location.

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In this particular instance, the computed travel time is greater on the ridge top location. This is due primarily to (1) the increased total length, (2) the amount of horizontal curvature and (3) the assumed distance and grade to get up to and back down from the ridge top. This illustration of application of method should not be considered as evidencing that sidehill location is always the better. Very frequently the contrary is true.

Width	Section	Alignment	Grade	Total	Number of cases	Length per cases	Speed in mph	Estimated travel time
			Ridge Top Location					
12-16	S.T.	N.C.	N.C.	7000	10	700	30	2.6
12-16	S.T.	40' rad.	N.C.	200	2	100	16	.1
12-16	S.T.	45-60' rad.	N.C.	500	4	125	17	.3
12-16	S.T.	60-100	N.C.	1000	5	200	20	.6
12-16	S.T.	N.C.	18	2000	4	500	15	1.5
10	S.H.	N.C.	12	3000	6	500	21	1.6
12	S.H.	40' rad.	8	200	2	100	15	.2
12	S.H.	40-60' rad.	8	500	4	125	16	.4
12	S.H.	60-100 "	10	500	2	250	19	.3
Total	-	-	-	14900	-	-	-	7.6
			Sidehill Location					
10	S.H.	N.C.	8	8000	20	400	25	3.8
12	S.H.	40' rad.	5	400	4	100	15	.3
12	S.H.	45-60' rad.	6	800	6	133	16	.6
12	S.H.	60-100' "	7	1400	4	350	19	.8
Total	-	-	-	10600	-	-	-	5.3

273. The preceding discussions have been based on the use of the standard vehicle, i.e., 1/2 ton pickup with capacity load. They are equally applicable to light cars. However, for $1\frac{1}{2}$ ton and heavier trucks, the speed may be appreciably less than with the standard vehicle.

The effect of curvature is largely the same for cars and trucks of varying weights.

Width tends to bring down the speed somewhat below that of the light vehicles but the travel time is not materially affected except on roads where the major part is of simple turnpike or widehill with width controlling the speed.

Grade however has a very decided effect and as shown by Table 203 the heavy-truck speed is less than that for light trucks and cars for all gradients and for both plus and minus. For the steeper gradients the reduction is large. For instance, with an elevation of 9000', and a plus grade of 15%, the light car and $\frac{1}{2}$ ton truck speed is 10 mph, the $1\frac{1}{2}$ and 2 ton truck speed is about 7 mph, and the 3 ton speed 5 mph. On the down grade, the corresponding speeds are - 14, 6 and 6 mph.

274. In the selection and decision on the elements of standard, careful investigation must be made of the effect of gradient if trucks heavier than the standard vehicle are to be used. The effect on speed of inferior traction may necessitate the use of lesser gradients than would be satisfactory for the standard vehicle. The data in the tabulations are based on average good traction and unloaded vehicles. With somewhat inferior traction, it will may be possible for a car or light truck to negotiate a steep grade at less than the speed given in the tables. The heavier truck however may be unable to pull the grade at all.

SECTION III

SURVEYS

Introduction and Scope of Section

300. The service that a road will render depends primarily upon the location and the standards adopted. The route, alignment, grade, width, surface, drainage structures, and degree of permanence anticipated for the location have a direct bearing upon the service rendered and the unit transportation cost. Therefore, each of these related subjects must be considered in locating and designing the truck trail.

ANALYSIS OF LOCATION

301. The location survey problem is divided into the following subjects:

(a) Selection of standard
(b) Reconnaissance and selection of route
(c) Location survey, including preliminary lines
(d) Staking for construction.

SELECTION OF STANDARD

302. A truck trail of simple location and standard may serve the present and future requirements adequately. The other extreme is where for both present and future travel the location of the satisfactory road is a technical highway engineer's problem. Each case should be considered separately. However, as specified in Regulation 6, Section 1, of the Regulations for the Forest Highway and Forest Development funds, the Bureau of Public Roads should be requested to make a reconnaissance survey of a road that may ultimately constitute a part of an important public highway. In interpreting this regulation, special consideration should be given to the roads where the amount of future public travel will be heavy for Forest roads and where a high speed is required for adequate service.

303. The reconnaissance survey made by the Bureau of Public Roads will be in sufficient detail to define the general location of the future road and to establish the important control points. If decided to handle by the stage construction method the location made by the Forest Service should follow that indicated by the Bureau of Public Roads survey, making such departures in width, alignment, grade, and in location of sections as appear advisable.

RECONNAISSANCE AND SELECTION OF ROUTE

304. The importance of through reconnaissance cannot be overempha sized. The soundness of the location depends largely on the ability and the initiative of the locator. His assignment is of major importance. Poor location may greatly increase construction and maintenance costs as well as decrease the service value of the project.

Of primary importance is a thorough investigation of all feasible routes before deciding on the final location. To select the proper route it is necessary that the locator have a clear understanding of all construction and drainage problems encountered on the various prospective locations.

The selected route should be that which provides the required service at the least annual expense.

LOCATION SURVEY

305. The most important factors influencing location are:

1. Purpose of truck trail
2. Aesthetics of location
3. Standards
   (a) Grade
   (b) Alignment
   (c) Width
4. Physical conditions
   (a) Type of soil
   (b) Clearing
   (c) Excavation
5. Drainage
6. Location and data of bridge sites
7. Ownership of land.

Purpose of Truck Trail

306. The purpose for which a project is built should be kept constantly in mind. For example, if a truck trail is to serve timber utilization, all feasible timber sales should be accessible to the truck trail; or if the project is for recreationists, items of special recreational value should be accessible.

Aesthetics of Location

307. The locator should try to fit the road into its surroundings and conserve the recreational and aesthetic value. Good location, design and finish give a road the stamp of quality for which we should strive. (See Construction Section for treatment or roadside strips).

The ability of a locator is not determined by his comprehension of the individual factors but by his success in incorporating the several factors into the location.

Standards

308. Since modern vehicles can negotiate heavy grades, gradient is the locator's most effective means of reducing costs except for such as timber utilization truck trails. By ascending and descending, the locator is afforded an opportunity:

1. To avoid rock, heavy clearing or other heavy or expensive work
2. To improve alignment or to eliminate curves
3. To place the location on desirable soil
4. To shorten the distance between control points by an amount that more than compensates for the decrease in speed occasioned by the heavy grade
5. To improve the natural drainage.

All Forest Service locators should be acutely grade conscious. Instead of adhering to a continous or arbitrary grade, the location should utilize the possibilities offered by changes in grade.

309. The locator is expected to secure the best location possible with a reasonable cost of construction. Minimum standards of curvature are set up as a guide. But wherever the expenditure is justified and the service to be rendered requires, he should use the minimum number of curves, and the longest radius curves permitted by the topography and consistent with construction cost.

Vertical curves should be used to insure an adequate "slight distance" in going over tops of hils and to ease out sudden changes in grade.

Width of road must also be considered in selecting a location. On steep slopes the yardage increases as the square of the width.

Physical Conditions

310. The locator should be guided by the following principles in dealing with soil, clearing and excavation problems:

1. Southern exposure should be given preference.

2. Sites where snow drifts last late in the season should always be avoided if practicable.

3. If practicable the location should be kept away from spongy or boggy ground. Frequently land satisfactory for summer conditions is not at all appropriate during the wet season. This always must be kept in mind when working along creek beds and adjacent to meadows and parks. Creeping ground is an unsuitable location.

4. Sidehill location slightly above the toe of the slope on moderate slopes in common material is decidedly preferable to location on adjacent bench or flats. However, such locations should not be used to the extent of making the alignment unduly sinous. Sidehill locations may some times eliminate the necessity of gravel surfacing and usually provide better natural drainage.

5. Where gradient permits utilizing the tops of ridges the following conditions will determine whether it will be preferable to keep on top:

(a) Steep rocky or broken sideslope may make it necessary to follow the ridge top

(b) To secure proper alignment or for fire break and patrol purposes it will usually be desirable to shift the location from side to side of the ridge.

(c) Where the top is wide, flat and difficult to drain, the location should be to one side near the break in slope

(d) Where the ridge consists of good mineral soil and is easily drained, the most economical location will usually be on top.

6. Very steep slopes and hard rock should be avoided. The use of undulating grade usually makes this possible.

7. If a route parallels a stream, the grade line should be well above high water level, and the fill section protected against wash.

8. Where it does not interfere unduly with the service value of the truck trail, large trees, clumps of trees and other heavy clearing should be avoided. This can often be done by shifting the center line slightly to one side, a change in gradient, or by locating long radius curves.

Trees standing in the position marked "y" in Fig. 401 should be constantly in the locator's mental vision when working through timber.

9. Expensive fills should be avoided if practicable to follow contours or to negotiate the depression with a vertical curve. No definite rule can be established. The extent to which alignment and speed can be sacrificed to follow contours must be termined by the required service of the truck trail.

The locator must be relied upon to get the best practicable location after first consideration to the cost and purpose of the road.

10. With the exception of rock, excavated material when placed in a fill shrinks during settlement. No definite amount of shrinkage can be prescribed. For a general figure, 10 percent may be used. Shrinkage has been considered in compiling the slope tables.

11. Rock expands from 40 to 60 per cent depending upon the size of fragments. A working average of 50 per cent is a safe figure to use. However, if the fill is a mixture of rock and earth, the percentage of expansion is diminished.

Drainage

311. Drainage is one of the most important problems in connection with location, design and construction. To obtain economic and efficient drainage, the locator must take every opportunity to provide built-in drainage such as dips, grade breaks and outslopes. Without adequate drainage no road can furnish the required service. To the extent a road fails to render the required service the original investment is wasted.

The locator should constantly bear in mind that the main objective of his location is to secure the required road service at the least "annual cost," that is, the sum of the annual charge for maintenance and the annual charge for depreciation. The locator must be familiar with paragraphs on drainage in the Construction Section of the Handbook. These paragraphs cover the subject from both the survey and the construction viewpoint.

Location and Data of Bridge Sites

312. The most important considerations of the locator are as follows:

1. To provide good approaches to the bridge, i.e., tangents or long radius curves. On shallow streams a channel change may be more economical than providing approaches for the existing channel.

2. To examine the footing conditions at the bridge site before final adoption of the site. Poor footing conditions may result in increased cost.

3. Tof fit the structure and its approaches to the stream. This consideration incorporates locating the structure to afford it maximum protection from channel currents, ice flows and drift.

The locator should bear in mind that bridges are expensive and their cost will often permit doing considerable heavy work to avoid a crossing. A bridge is a perpetual maintenance liability and should be resorted to only after thorough consideration of the possibilities of eliminating the crossing.

313. On the more important projects where the bridge abutments are to be designed or an appropriate type selected from standard plans, a survey of the bridge site should be made. This should include the following:

1. The maximum high and low water elevation obtained from the best information possible.

2. Plan and profile of the road for a distance of about 500 feet on each side of bridge site.

3. Topographic survey of the bridge site with 2 foot contours including a sufficient distance each side of the center line to give the necessary design data.

4. Complete data on foundation conditions should be secured. If necessary, test pits should be dug to a sufficient depth to determine the bearing capacity of the foundation material. Ordinarily driving a bar into the stream bed will be sufficient to determine the distance to a good foundation.

A topographic map should be prepared for each bridge site showing the center line of the road and the contours at the bridge site. The map scale should show the bridge site in adequate detail, probably 10 ft. to the inch.

Ownership of Land

314. Whenever possible, all questions in regard to the desired location of the road across private property should be settled on the ground and signatures obtained to a proper deed granting the rights-of-way during the execution of the survey. All right-of-way questions should be settled before any construction work is started.

Ordinarily rights-of-way will be provided by the local authority without cost to the Federal Government and only in exceptional cases will forest road funds be used for this purpose. To avoid the delays incident to a title examination by the Attorney General, title will ordinarily be vested in the local county or State Government.

After the location has been determined on the ground, a careful traverse of such portion of the final line as involves right-of-way matters should be made. All ties and other information should be secured which are necessary for the accurate plotting of the located line in relation to the property lines.

STAKING FOR CONSTRUCTION

Extent of Design on Forest Service Work

315. Usually the quantities involved are small and the problem of design so simple that it is accomplished from a mental picture as the location progresses. Design when required is usually in an elementary form requiring only a plan and profile. Such readily compiled plan-profiles afford an opportunity for materially improving alignment and taking maximum advantage of grade.

Map Records

316. The road and trail funds may be expended only for such surveys and maps as are required to tie the located road to land corners or other land markers, in order that it may be accurately located on the Forest map. However, the locator should secure data incident to the location that will contribute to the general map correction program on the Forest.

Notekeeping

317. See Engineering Field Tables for sample pages of survey and cross-section notes.

Truck Trail Survey Methods

318. The importance of adequate surveys and careful planning for construction cannot be overemphasized. The simplest methods giving the desired results are the ones to use, but this in no wise affects the importance of adequate survey and planning.

Methods of relatively high technical nature will rarely be necessary.

The two survey methods, recognized by the Forest Service, are classified by the instruments used.

A. The Abney, compass and tape.

B. Transit, level and stadia (or tape) or transit and tape (or stadia) using transit as level. This method is not described in this handbook.

Method A is decidedly more practicable and better adapted for truck-trail surveys. These instruments are capable of giving sufficiently accurate data and can be handled much faster by the average locator. Method B is justified only in exceptional cases.

Description of Method A

319. On side hill locations:- On side hill locations, grade rather than alignment ordinarily is the governing factor in locating. Decision should be made on the ruling grade between the point at the lower elevation and that at the higher elevation. For example, assume that a ridge top is to be connected with a valley with a grade of 8%.

Situation 1. On class of road and with topographic conditions that will give acceptable alignment from a contour location:

Locate grade line with Abney level from the ridge top to floor of valley. Use 8% except where sharp curves occur, where lesser amount should be used to compensate for curvature. (See Par. 240).

Stake the curves.

Situation 2. Topography so irregular that a grade contour line would not give the required alignment. Assume a ruling grade of 8%.

Run a preliminary grade contour line from the ridge top as in Situation 1, using less than ruling grade to give some leeway in grade changes. Assume that the locator uses 7%. Measure side slope of ground at each stake.

Run a compass and tape traverse between located grade points, locating features such as heavy rock work, springs, marshes, heavy clearing, etc., near enough to the line to affect the final location. On particularly difficult sections it may be necessary to locate contours.

Plot a map of the line showing:

(a) Location of each grade stake
(b) Side slope at each grade stake
(c) Location of heavy rock work, springs, marshes, heavy clearing, etc.
(d) Contours if necessary.

Draw a proposed location line approximately along the grade line.

The amount of cut or fill at any point on the location line can be determined from the side slope and the scaled distance between the preliminary grade line and the location line. Some cutting and filling can be avoided by using undulating grades.

Locate the curves on the map. Show the radii, central angle, and external distance to aid in running in curves on the ground.

After staking the final center line on the ground it may need some adjustment. If the paper plan is carried into the field, shifts in location can be plotted and the effect of such changes on the alignment will be readily seen. Final decision on the location can then be made with confidence.

Staking Curves

For definitions of common terms applied to curves see appendix.

General Principles

320. In truck-trail location the curve selected and used should be that which fits the topography with a minimum of excavation and provides the service required of the road. Longer radius curves will be required for trucks and trailers than for ordinary traffic. The curves should be designed for the normal traffic speed expected on the truck trail.

The Standards Section gives the permissible radius for each "service class." These radii should be used only when necessary to avoid unjustifiable expenditures.

A road or truck trail may be said to consist of a series of straight lines, called tangents, connected by curves. In highway practice, the simple circular curve is the one ordinarily used.

As a general rule long tangents should be joined by long radius curves. Sharp changes from tangents to shor-radius curves or from a curve of long radius to one of short radius are undesirable. Wherever practicable reverse curves should be joined together by a common tangent of not less than 50 foot length. Elimination of the tangent is undesirable.

In mountainous regions the cost of construction will increase very rapidly with increases in the radii and the curves will necessarily have to be made as sharp as the Service requirements will permit, taking into consideration the costs of construction.

The location and direction of all tangents should be critically examined to determine if a change would improve the alignment. Often the direction can be changed or it can be offset to allow a much longer radius curve at the end, with no increase in construction cost. A common error in location is to hold to a tangent as long as possible and then introduce a sharp curve when it would have cost no more to have gone back on the tangent and made a long radius curve.

Methods

321. The five methods explained herein do not contemplate the use of a transit. The tables and diagrams included are for purposes of illustration only and are not as complete as similar tables to be found in the Engineering Field Tables.

1. From Center of Curve. Curves of less than 100' radii can readily be laid out by simply locating the center of the curve and describing an arc with a tape or string. (See Fig. 301). This method may not be satisfactory where the topography is exceedingly rough.

2. Methods of Externals. On Fig. 305, page 318, assume that AB represents the extension of a straight section of the line. At PI the line makes a turn to the right in the direction of C. The angle is measured with a compass or transit. In the first example, it is 32° and in the second, 102°. This angle is equal to the central angle formed by the radii drawn perpendicular to the tangents from both ends of the curve, i.e., from PC and PT to the center O.

To connect the two tangents with a curve, proceed as follows:

Stand at PI and estimate the distance to where the road should be; say it is 15 feet for the 32° angle. This is the external distance, shown as PI-G on Fig. 305.

From Fig. 302, page 315, the radius for a 32° central angle and 16 feet external distance is found to be 400 feet. (16 feet is close enough to 15 feet so that the even 400 ft. radius can be used without throwing the position of the road too far off).

Find tangent distance from Fig. 303, page 316. In this case, tangent distance is 115 feet.

Measure 115 feet from PI toward A and set PC.

Measure 115 feet from Pi toward C and set PT.

Measure 16 feet from PI toward G and set stake at G. Three points on the curve are now located, the beginning, middle and end.

For the example with a 102° central angle (Fig. 305) the proper external distance is estimated to be 60 feet. The above method determines that a curve of 100 foot radius, 59 foot external distance and 123.5 foot tangent distance, fits the case.

When a curve is too long to construct from the three points PC, G and PT, intermediate points such as I and J (Fig. 305) should be staked. These can be found by using the diagram for "Middle Ordinates" (Figs. 304 and 306). The chord PC-G is measured. In the second example this is 86 feet.

In Fig. 304 the length of the middle ordinate for a 100-foot radius curve and a chord length of 86 feet is 9.8 feet. The middle point F on the chord PC-G is found by measuring one-half of the chord length, or 43 feet from either PC or G. Then I is 9.8 feet from F at right angles to the chord. The point J is located in a similar manner.

This fixes five points on the curve, and ordinarily these will be enough for construction purposes. In cases of an extremely long curve, points between I and G, etc., can be obtained by measuring the chord distance IG and finding the middle ordinate for this distance.

3. <u>Method of Middle Ordinates</u>. This method is suitable for use by an inexperienced engineer or a man with no technical engineering training. The only instruments needed are a tape (preferably 100 feet long) and a "good eye."

The problem is to select the proper radium of curve to connect two tangents. In some cases the selection may be limited to the minimum radius for the project. If so, the curve must be fitted to the ground so the excavation will be the least possible. Usually, however, the curve radius best fitting the ground must be estimated.

Assume a 60 foot radius is selected for the first trial. Stakes will be set every 25 feet. Fifty feet is the chord length.

Refer to Table 301, page 319, and Fig. 306, page 320.

Find the middle ordinate distance for a 60 foot radius, 50 foot chord, from Table 301 or from the graph, Fig. 304. Middle ordinate is found to be 5.4 feet.

Extend tangent AB (See Fig. 306) 1/2 the chord length (25 ft.) to Y.
From Y measure 5.4 feet to locate C. Set stake at C.
Locate K, 5.4 feet from C and 25 feet from B.
From B stretch tape through K to D.
Measure 5.4 feet from D to locat L, which is 25 feet from C.
From C stretch tape through L to E. Set stake at E.
Proceed as above until the entire curve is laid out.

If this first trial results in a curve which does not intersect the line JZ approximately at a tangent, another trial should be made by shifting the beginning of the curve toward A or Y or by changing the radius. It is not essential that the end of the curve be made absolutely tangent to the straight road whidh it intersects as at J, for instance. An approximate tangency can be remedied by moving the point J sufficiently to make a smooth curve. If the error is more than a few feet the curve should be re-run.

When the mid-ordinate is 6 feet or less, measuring the middle ordinate distance separately at each curve point can be eliminated by cutting a stick to the length of the middle ordinate. Hold one end at the curve point and stretch the chord across the opposite end.

4. Method of Tangent Offsets. This method also lends itself to use by non-technical men; a tape is the only instrument needed.

In Fig. 307, page 321, a curve is represented by BFGJNPQ. The comments on the selection of the proper radius of curve in using the middle ordinate method apply to this method also.

Assume that the locator decides to try a curve with a 90 foot radius, setting stakes every 20 feet on the curve. Table 302, page 322, shows that for "Radius of Curve" 90 and "Curve Length in Feet" 20, the tangent length is 19.8 feet, and the tangent offset 2.2 feet. The tangent AB is extended 19.8 feet to C and 2.2 feet measured at right angles to line AC to F. Table 302 shows that for a 40 foot curve length, 38.7 is tangent length and 8.8 feet the offset. The locator measures 38.7 feet from B to D and at right angles 8.8 feet to G. In similar manner further points on the curve are determined.

The offset for N with a 90 foot radius would be 33.3 feet. If difficult to make such a long offset measurement it is desirable to start again. If this starting point be J it is first necessary to establish a tangent; this is done by measuring 2.2 feet from G to H from G. The line HJ is tangent to the curve at J. This tangent extended to K, L and M, from which are established N, P, and Q, may be established in the manner described for F, G, and J.

5. Parabolic Method. This method is very simple, requiring no tables or equipment other than a tape, hammer and stakes. For central angles of about 45^o and less the resulting curve almost coincides with the true arc of a circle. With this method it is not necessary to measure any angles. (See Fig. 308, page 323, for illustration of procedure).

322. Switchbacks and Curves with Large Central Angle

(a) Location.

Switchbacks are undesirable, their use should be avoided wherever practicable and the increase in cost by some other location is not excessive. Switchbacks involve the moving of large quantities of material. They are required, however, in cases where the physical characteristics limit the location rather definitely and where the difference in elevation between two points is such that the maximum allowable grade is not sufficient to meet the required rise in the distance obtainable.

In general, to find the points between which the switchbacks should be constructed, a grade line on the maximum grade should be run down hill from the higher control point to a point where the topography of the country lends itself to the construction of a switchback. Favorable topography for a switchback is any section of light side slope or where the two legs of the switchback can be placed on ground of approximately the same elevation. The locator then reverses his direction and continues on the down grade. Usually he can sight through his Abney, set on the maximum allowable grade, and determine whether he can get down without additional switchbacks.

(b) Method of Staking.

On smooth uniform slopes, switchbacks can be satisfactorily located and staked by the average slope method. Fig. 309, page 324, illustrates this method and gives the working data for various radius curves on 4% grades. The tables on Fig. 309 will give approximately 10% more cut than fill to allow for shrinkage and to make the fill section about two feet wider than the cut. The field procedure to be followed in conjunction with the switchback diagram and tables is as follows:

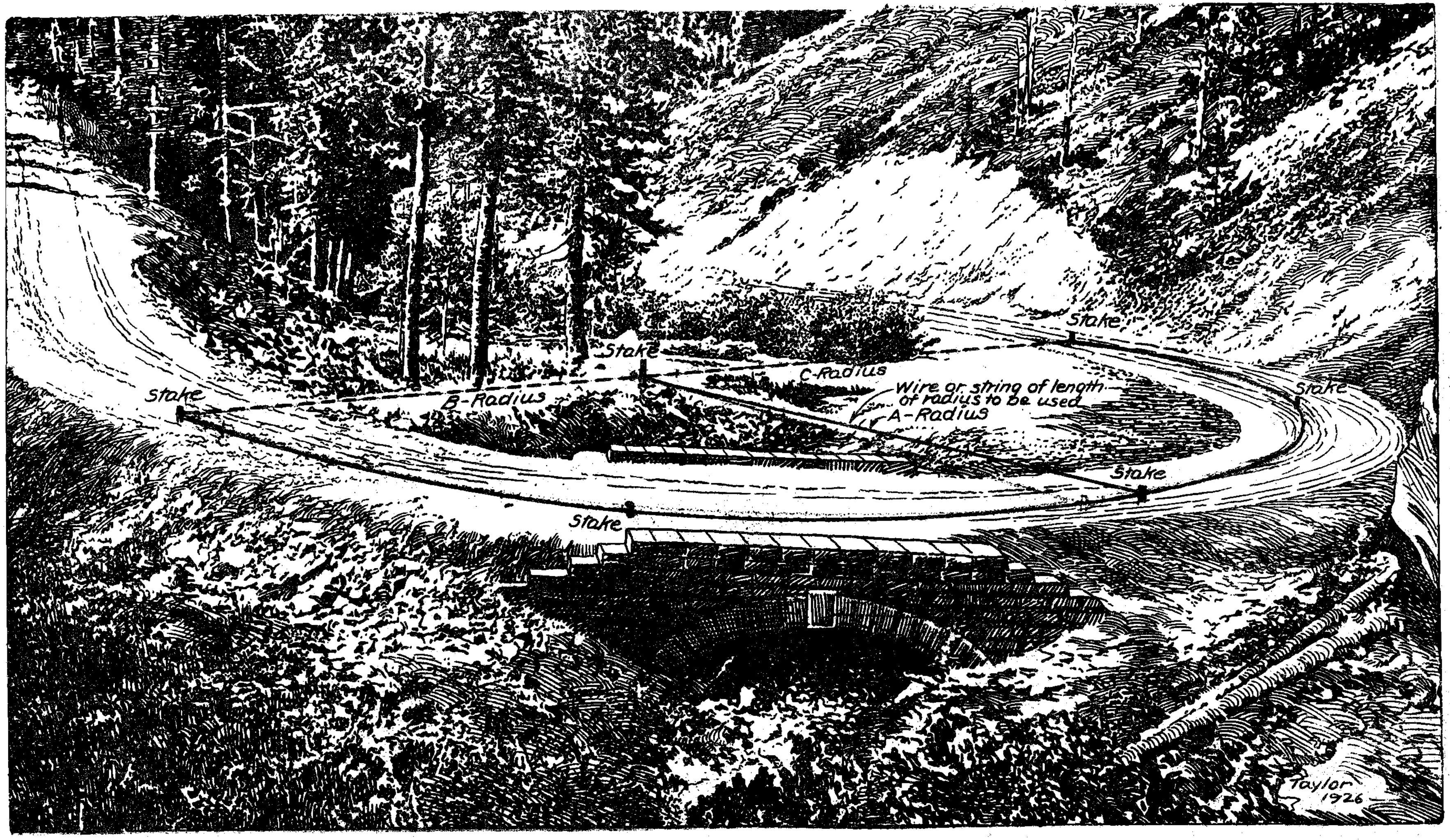
The 6% grade lines which intersect at the PI form base lines from which the switchback is laid out. Regardless of the approach grade at either end of the switchback, enough 6% grade line must be run in above and below "PI" to form this base.

Procedure:- Determine the average slope of the ground by several Abney readings taken over the area covered by the proposed switchback. Select one of the four switchbacks and from the table find the distances A and B opposite the average ground slope. Measure A along the hillside on a line which bisects the intersecting grade lines. (See Par. 331 for method of bisecting an angle). Then measure B up hill and at right angles to bisecting lines (measure horizontally, not along the slope of the ground) to "O", the center of the curve. (See Par. 332 for method of laying right angle with a tape).

Having located "O" the center of the curve, the right angle line should be produced up and down the hill to locate the "PC" and "PT". Describe a half circle setting stakes at the "PC" and "PT" of the curve and at intervals of about 25 feet around the curve. From the "PC" and "PT" of the curve lay off the distance C to intersect the grade lines at the beginning and end of the switchbacks, points S1 and S2. Note that the distance between S1 and S2 is twice the curve radius.

(c) Plotting Profile of Switchback

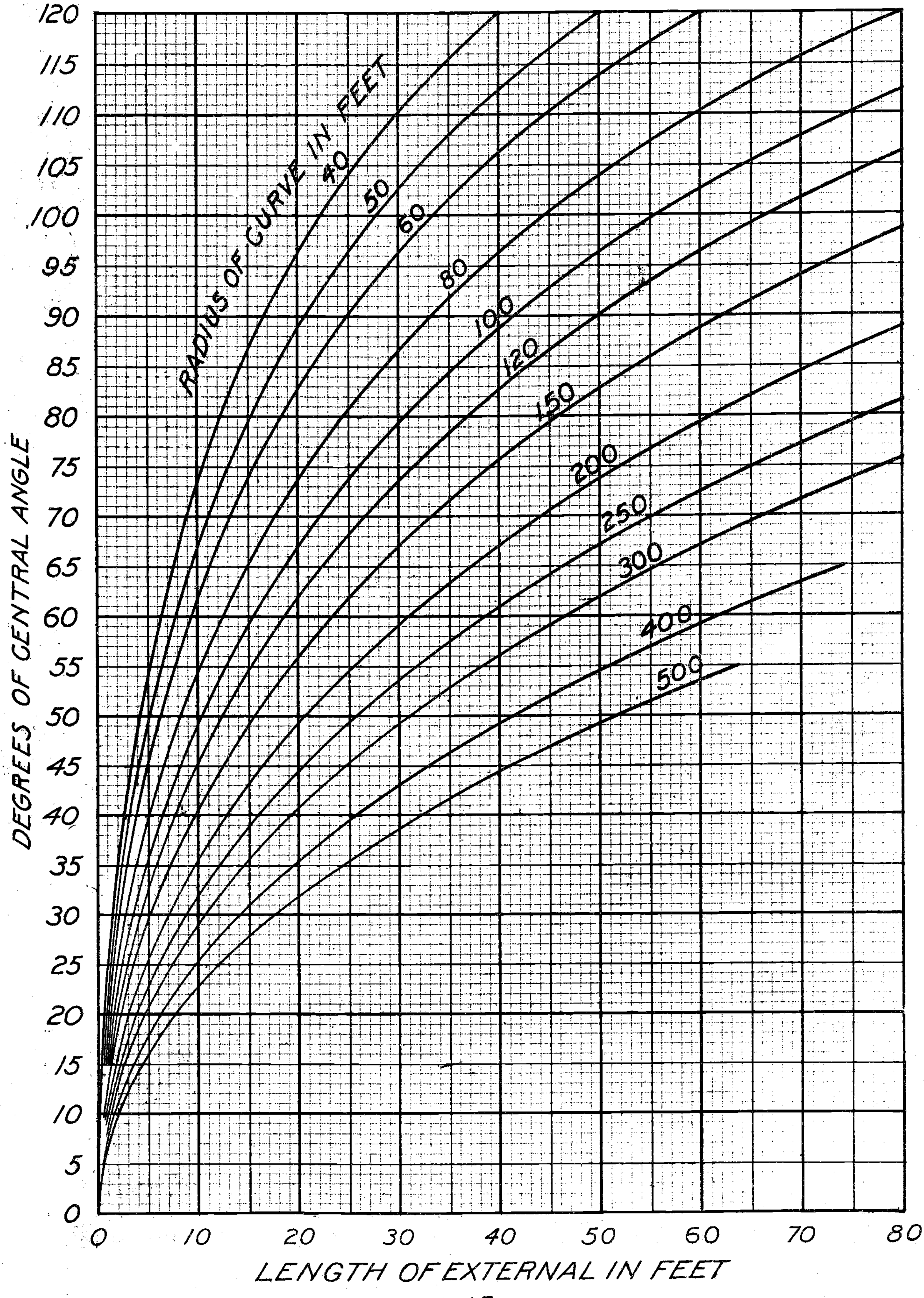
Having determined the proposed location of the switchback on the ground, a line of levels may then be initiated at S1 and the elevation of each stake secured. The center cut or fill can then be determined by plotting on profile paper or by computation. The side cut and fill stakes can be located by the use of slope tables or by the method of Par. 326. From these data any necessary shifting of the initial line, to balance cut and fill or otherwise effect economies, will be apparent.



METHOD OF LAYING OUT A CURVE WITH A TAPE OR STRING

FIG. 301

FIG. 302



RADIUS OF CURVE IN FEET
40
50
60
80
100
120
150
200
250
300
400
500
DEGREES OF CENTRAL ANGLE
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
110
115
120
0
10
20
30
40
50
60
70
80
LENGTH OF EXTERNAL IN FEET

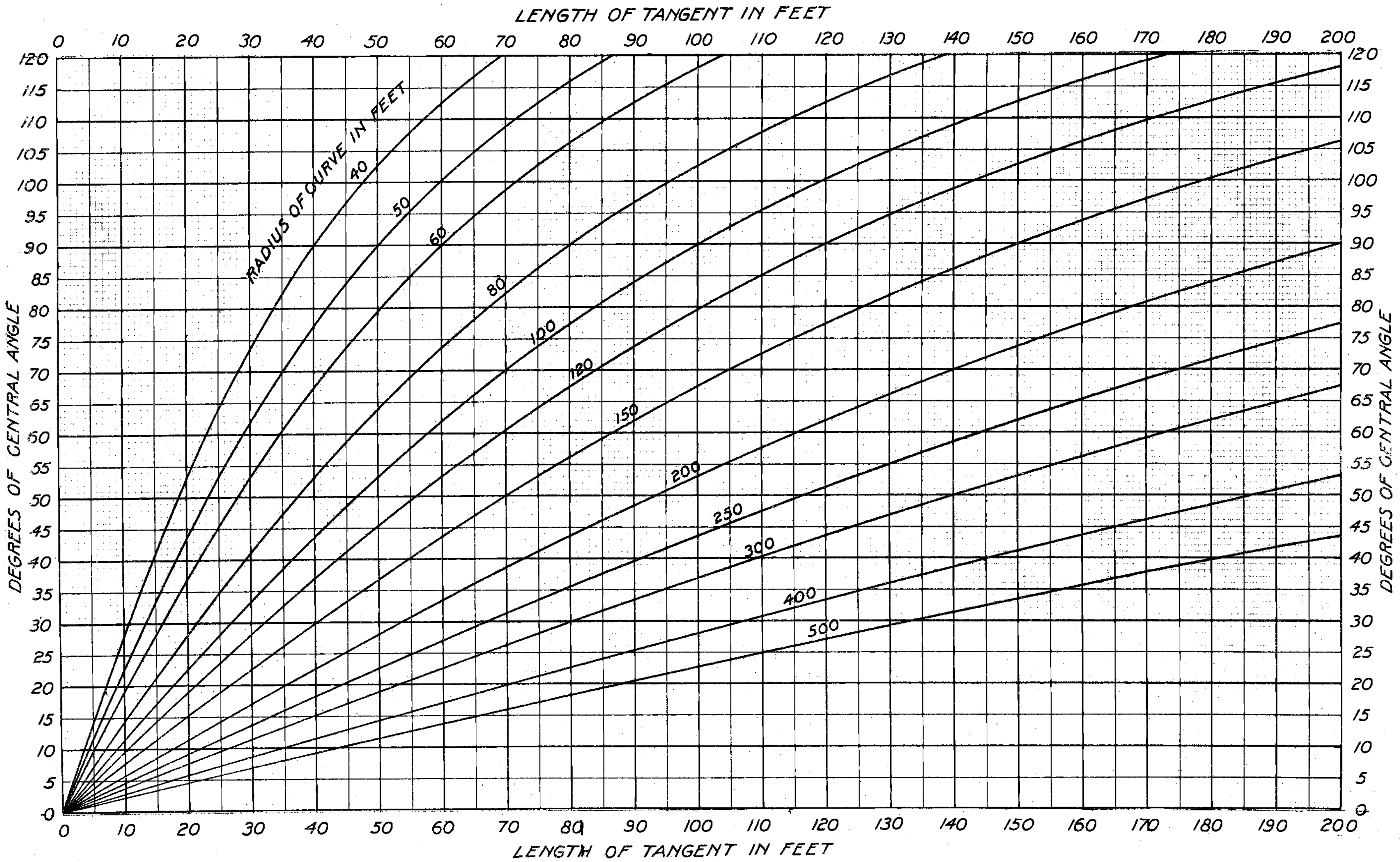

LENGTH OF TANGENT IN FEET
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200
DEGREES OF CENTRAL ANGLE
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105 110 115 120
RADIUS OF CURVE IN FEET
40
50
60
80
100
120
150
200
250
300
400
500

FIG 303

MIDDLE ORDINATES

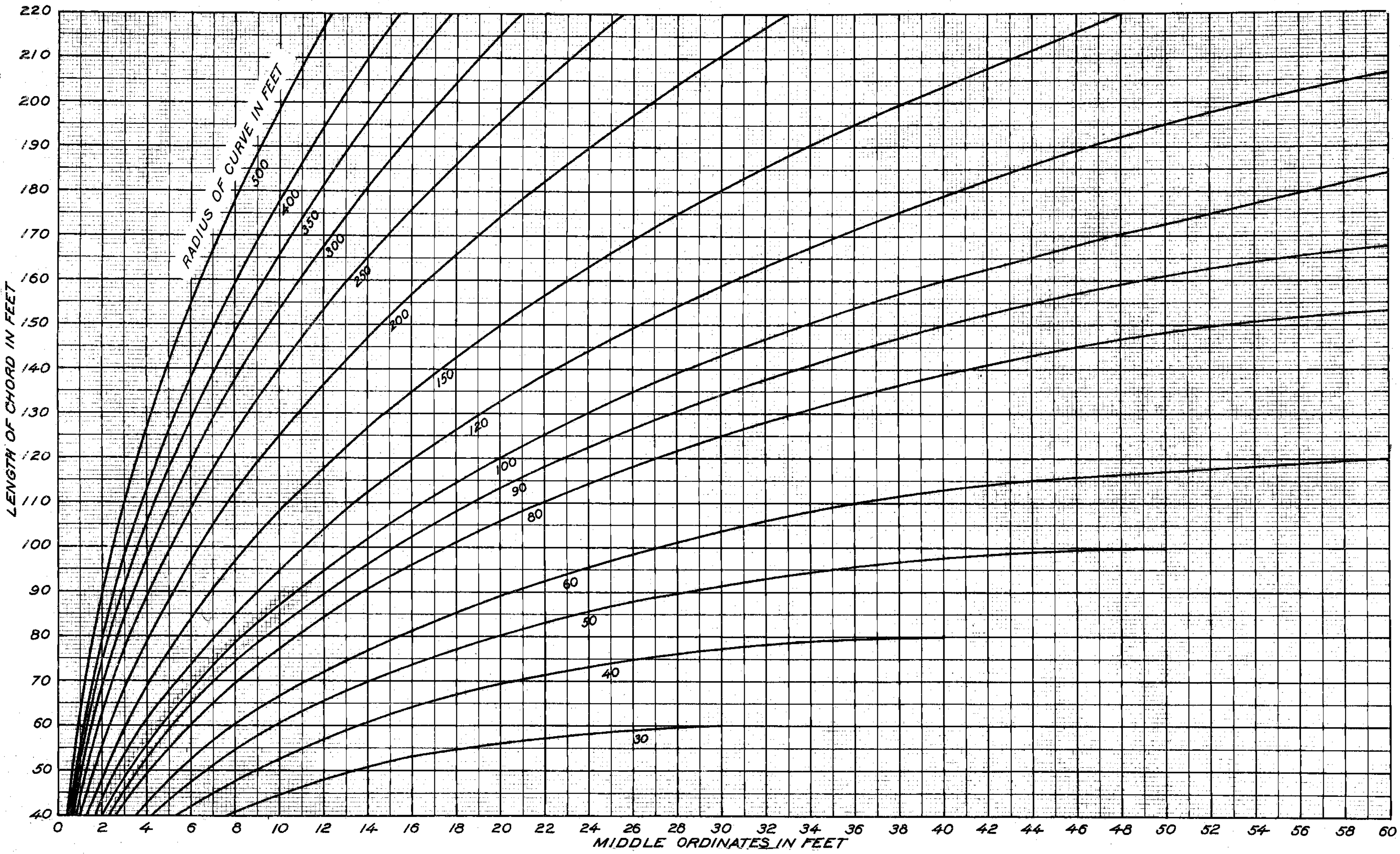
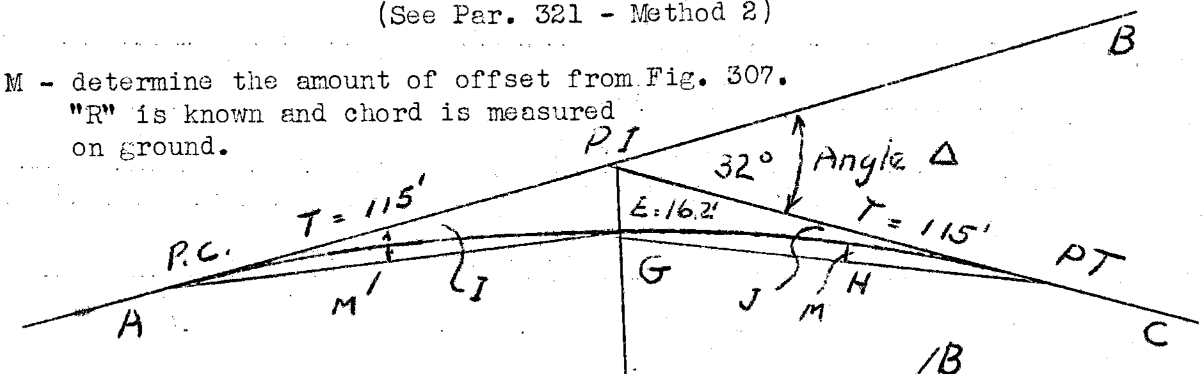


FIG 304

FIGURE 305

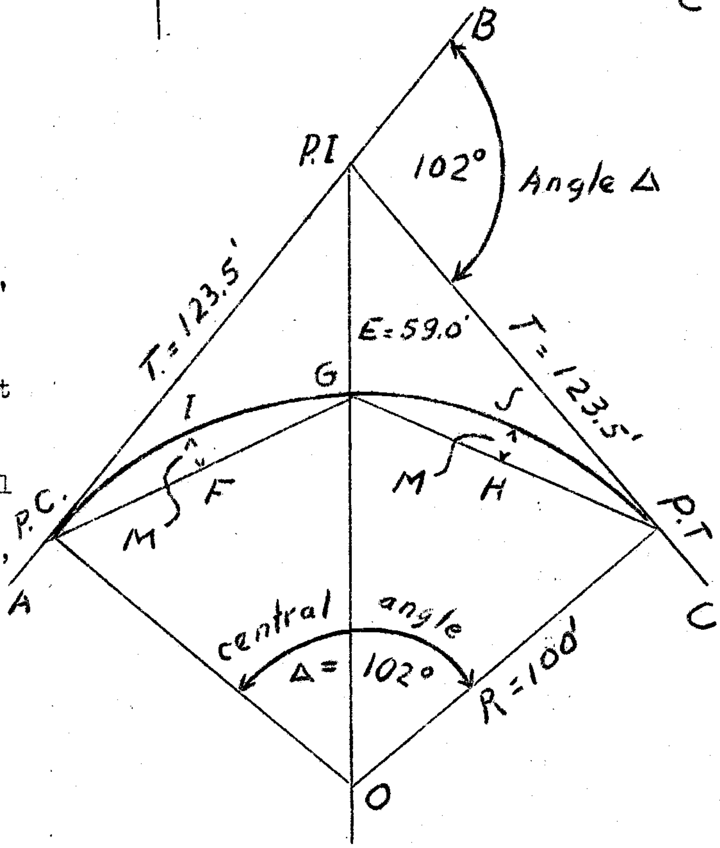
DIAGRAM FOR STAKING CURVES BY METHOD OF EXTERNALS
(See Par. 321 - Method 2)

M - determine the amount of offset from Fig. 307. "R" is known and chord is measured on ground.



Method of staking:
Produce tangents to P.I.

(1) Measure angle and decide on radius of curve.
(2) Find "tangent distance" from Fig. 303, page 316.
(3) Find "length of external" from Fig. 302, page 315.
(4) From PI measure along each tangent the "tangent distance" setting points PC and PT.
(5) From PI, lay off external distance (E) midway between the two tangents, setting point G.



This gives three points on the curve; A, G and C. If additional points are required:- Measure the chord length from PC to G and find from Fig. 304, page 317, the "middle ordinate" for that chord length and "radius."

From mid point of chord and at right angles to it lay off middle ordinate (M), which gives points I and J on curve. This gives five points on curve.

If further points are necessary chord lengths from PC to I, I to G, G to J and J to PT can be measured and M for each chord found from Fig. 304.

TABLE 301

Table of Middle Ordinates

Radius of curve in feet	Chord Length in Feet: 10	15	20	25	30	40	50	60	70	80	90	100
	Middle Ordinate in Feet											
40	0.3	0.7	1.3	2.0	2.9	5.3	8.9	15.5	20.6	40.0		
50	0.3	0.6	1.0	1.6	2.3	4.2	6.7	10.0	14.2	20.0	28.2	50.0
60	0.2	0.5	0.8	1.3	1.9	3.5	5.4	8.0	11.2	15.3	20.5	26.8
70		0.4	0.7	1.1	1.6	2.9	4.6	6.8	9.4	12.6	16.4	21.0
80			0.6	1.0	1.4	2.6	4.0	5.8	8.1	10.7	13.8	17.6
90			0.6	0.9	1.3	2.3	3.5	5.1	7.1	9.4	12.1	15.2
100				0.8	1.1	2.0	3.2	4.6	6.4	8.3	10.8	13.4
120				0.6	1.0	1.7	2.6	3.8	5.4	6.9	9.0	10.9
150					0.8	1.3	2.2	3.0	4.1	5.4	6.9	8.6
200					0.6	1.0	1.6	2.3	3.1	4.0	5.2	6.4
250					0.5	0.8	1.3	1.8	2.5	3.2	4.1	5.1
300					0.4	0.7	1.1	1.5	2.1	2.7	3.4	4.2
350						0.6	0.9	1.3	1.8	2.3	3.0	3.6
400						0.5	0.8	1.1	1.5	2.0	2.5	3.1
500							0.7	0.9	1.2	1.6	2.0	2.5

FIGURE 306

MIDDLE ORDINATE DIAGRAM

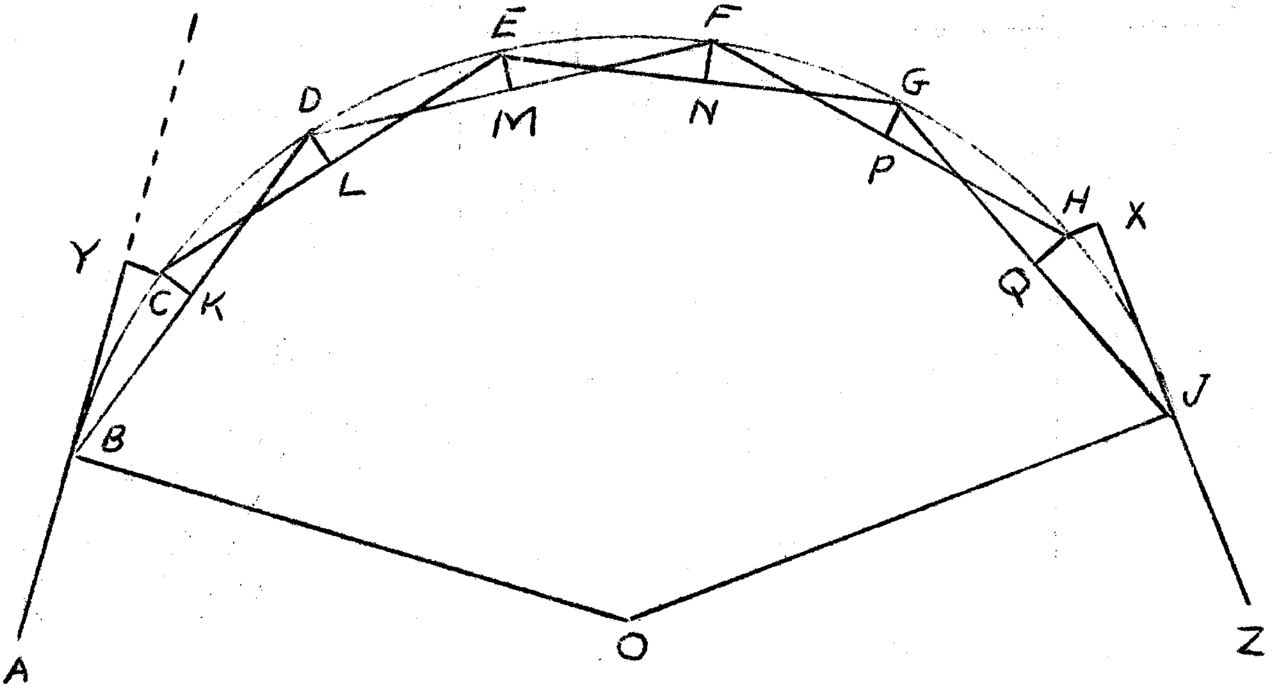


FIGURE 307
TANGENT OFFSET DIAGRAM

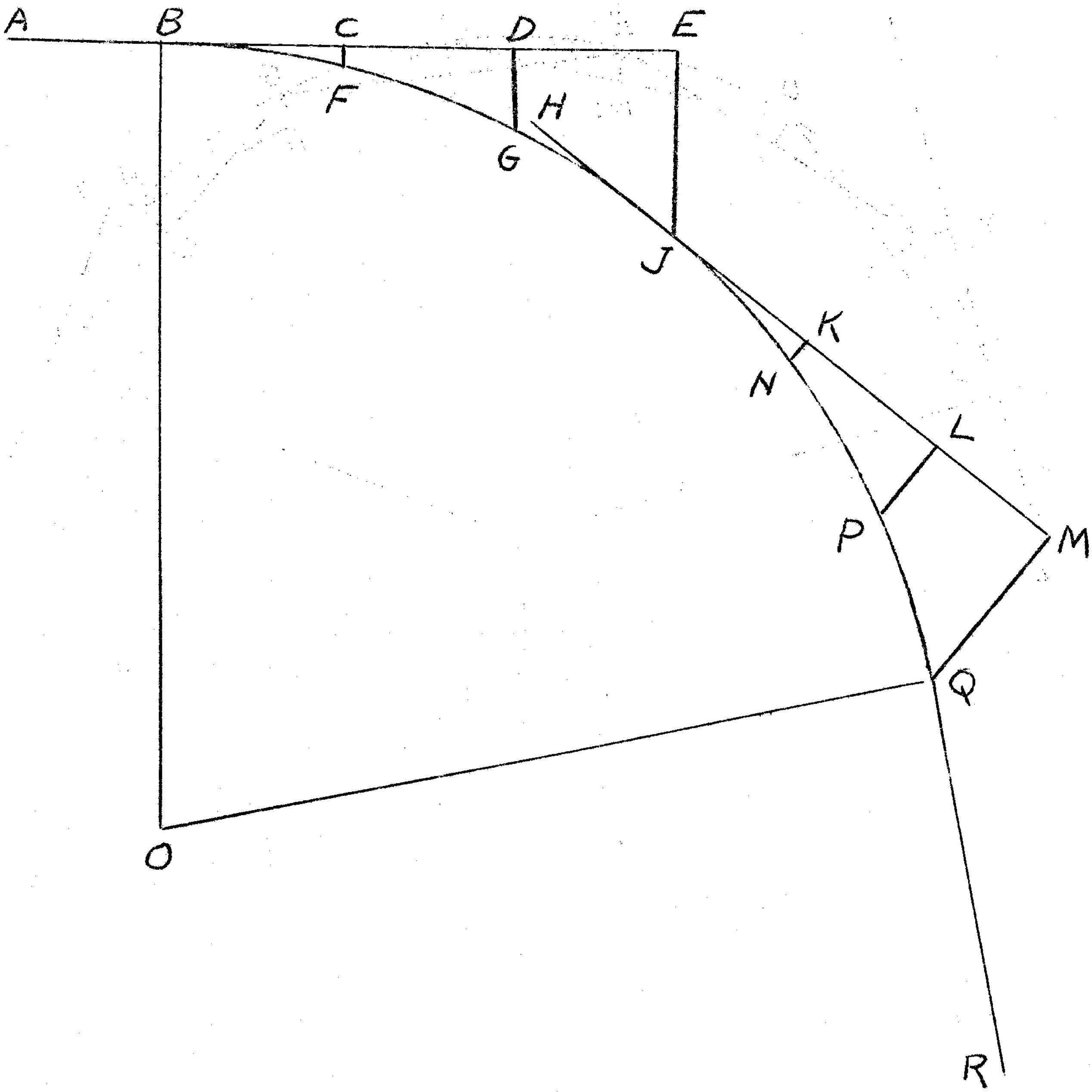
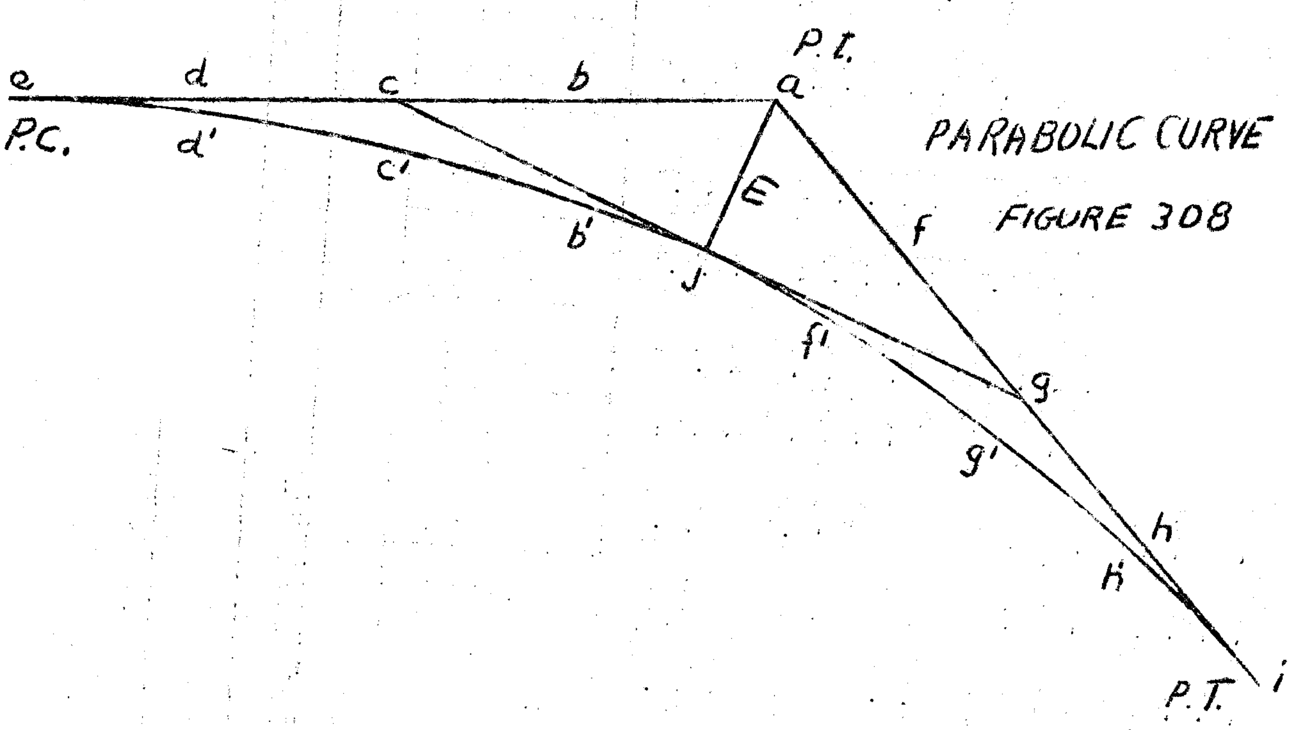


TABLE 302

TABLE OF TANGENT LENGTHS AND TANGENT OFFSETS

Radius of Curve	CHORD LENGTH IN FEET: 10		20		25		30		40		50		60		70		80		100		Radius of Curve
	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	Length	Offset	
30:	9.8	1.6	18.6	6.4	22.0	-	25.2	13.8	29.2	22.9	29.9	32.8									30
40	9.9	1.2	19.2	4.9	23.4	7.6	23.7	10.7	33.7	18.4	38.0	27.4	39.9	37.1							40
50	10.0	1.0	19.5	3.9	24.0	6.2	28.3	8.7	35.8	15.2	42.0	23.0	46.6	31.9	49.3	41.5					50
60	10.0	0.8	19.6	3.3	24.3	5.2	28.8	7.3	37.1	12.8	44.4	19.6	50.5	27.6	55.2	36.4	58.3	45.9	59.7	65.7	60
70	10.0	0.7	19.7	2.8	24.5	4.5	29.0	6.4	37.9	11.0	45.8	17.3	52.8	24.0	58.7	32.0	63.7	40.8	69.3	60.0	70
80	10.0	0.6	19.8	2.5	24.6	3.9	29.2	5.6	38.4	9.8	46.8	15.1	54.5	21.5	61.3	28.7	67.3	36.8	75.9	54.8	80
90	10.0	0.6	19.8	2.2	24.7	3.5	29.4	5.0	38.7	8.8	47.5	13.7	55.7	19.3	63.0	26.0	69.8	33.3	80.6	50.3	90
100	10.0	0.5	19.9	2.0	24.8	3.2	29.6	4.5	38.9	7.9	48.0	12.2	56.5	17.5	64.4	23.5	71.8	30.3	84.2	46.0	100
120	10.0	0.4	19.9	1.7	24.8	2.5	29.7	3.7	39.2	6.6	48.5	10.3	57.6	14.7	66.1	19.8	74.2	25.7	88.8	39.3	120
150			20.0	1.3	24.8	2.2	29.9	3.0	39.5	5.3	49.1	8.3	58.4	11.8	16.0	76.2	20.8	92.8	32.1	32.1	150
200			20.0	1.0	25.0	1.5	29.9	2.2	39.8	4.0	49.5	6.2	59.0	8.9	68.6	12.1	77.9	15.6	95.9	24.5	200
250			20.0	0.9	25.0	1.2	29.9	1.8	39.9	3.2	49.7	5.0	59.4	7.2	69.1	9.7	78.7	12.7	97.3	19.7	250
300							30.0	1.5	39.9	2.7	49.8	4.2	59.6	6.0	69.3	8.1	79.1	10.6	98.1	16.5	300
350							30.0	1.3	40.0	2.3	49.8	3.6	59.7	5.2	69.6	7.0	79.3	9.1	98.6	14.3	350
400							30.0	1.1	40.0	2.0	49.9	3.1	59.8	4.5	69.7	6.1	79.5	8.0	99.0	12.4	400
500							30.0	0.9	40.0	1.6	49.9	2.5	59.9	3.6	69.7	4.9	79.6	6.4	99.4	10.0	500



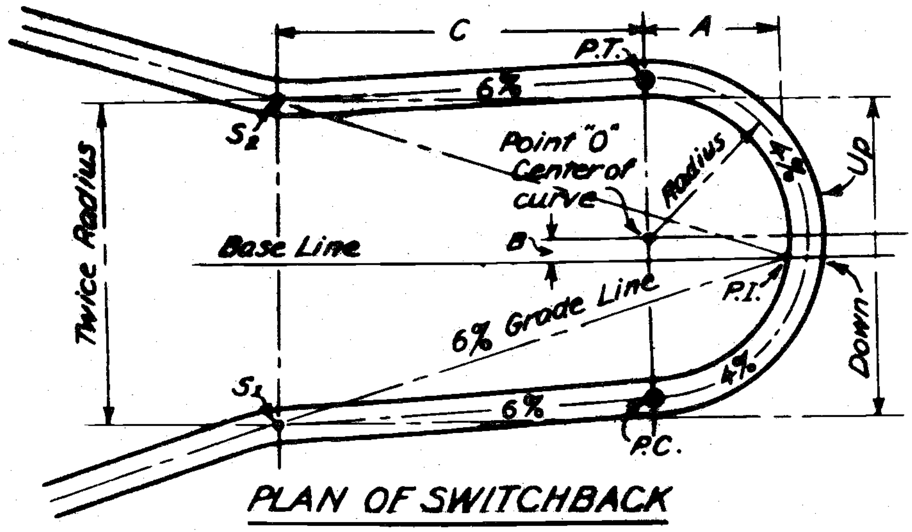
(For curves of less than 45° central angle results are sufficiently close to a circular curve).

1. Establish P.I.
2. Set stakes at a, b, c, d, e, f, g, h, and i in order named. The distances between these stakes to be equal.
3. Sight between c and g to establish j which should be approximately equidistant between C and G. Point J is now the midpoint of the curve.
4. Measure the external aj--E
5. Offset stakes d, c, b, f, g, and h to d', c', b', f', g', and h', respectively. The amount of offset will be as follows:

dd' & hh'	1/16 E
cc' & gg'	1/4 E
bb' & Ff'	9/16 E

When the tangent distance PC to P.I. is less than 200 feet points d, b, f, & h may be omitted if desired, leacing only c & g midway between PC-PI and PI and PT, respectively. Points c & g should then be offset a distance of 1/4 E to c' & g', respectively.

FIG. 309



PLAN OF SWITCHBACK

Tangent 6% and Curve 4% Grades

40 FOOT RADIUS CURVE

Ground Slope	A	B	C
10%	28.4	2.0	25.0
15%	33.1	3.0	58.3
20%	35.4	4.3	91.6
25%	37.0	5.5	125.0
30%	37.7	6.7	158.3
35%	38.0	7.8	191.6
40%	38.4	8.8	225.0

50 FOOT RADIUS CURVE

Ground Slope	A	B	C
10%	35.5	2.7	31.3
15%	41.4	4.3	72.9
20%	44.3	5.7	114.5
25%	46.3	7.0	156.3
30%	47.1	8.2	197.9
35%	47.5	9.4	239.5
40%	48.0	10.4	281.3

60 FOOT RADIUS CURVE

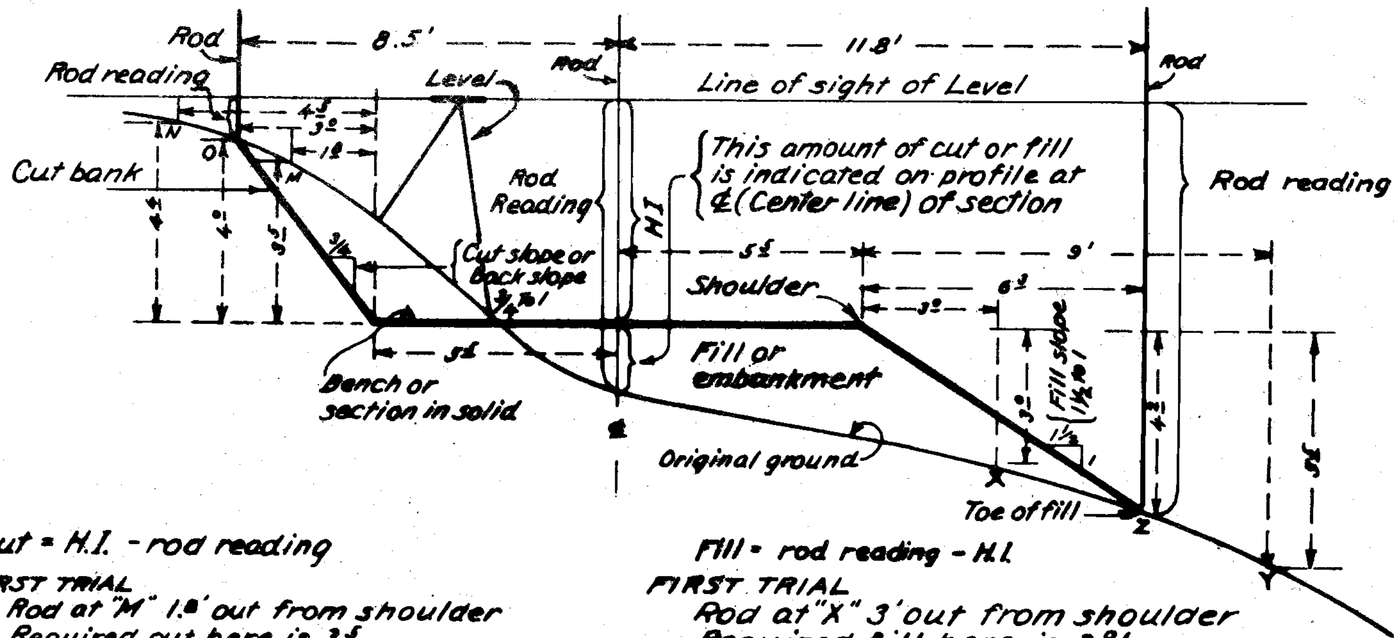
Ground Slope	A	B	C
10%	42.6	3.5	37.5
15%	49.7	5.5	87.5
20%	53.1	7.1	137.4
25%	55.5	8.5	187.5
30%	56.5	9.0	237.5

80 FOOT RADIUS CURVE

Ground Slope	A	B	C
10%	56.8	5.0	50.0
15%	66.2	8.0	116.7
20%	70.8	10.0	183.3
25%	74.0	11.7	250.0
30%	75.4	13.0	316.7

METHOD AND TABLES FOR STAKING OUT SWITCHBACKS WITH 10% MORE CUT THAN FILL

Cut Banks 3/4 : 1 Fill Slope 1½ : 1



Cut = H.I. - rod reading

FIRST TRIAL
Rod at "M" 1.8' out from shoulder
Required cut here is 3.5
Necessary distance would be $\frac{3}{4} \times 3.5 = 2.6$
Rod must be moved farther out

SECOND TRIAL
Rod at "N" 4.5 out from shoulder
Required cut here is 4.4
Necessary distance would be $4.4 \times \frac{3}{4} = 3.3$
Rod must be moved in

THIRD TRIAL
Rod at "O" 3' out from shoulder
Required cut here is 4.0
Necessary distance would be $\frac{3}{4} \times 4.0 = 3.0$
"O" is correct point for cut stake

Distance: ℄ to cutstake =
½ road width + (cut × cut slope)

Fill = rod reading - H.I.

FIRST TRIAL
Rod at "X" 3' out from shoulder
Required fill here is 3.0'
Necessary distance would be $3' \times 1\frac{1}{2} = 4.5$
Rod must be moved farther out

SECOND TRIAL
Rod at "Y" 9' out from shoulder
Required fill here is 5.5
Necessary distance would be $5.5 \times 1\frac{1}{2} = 8.2$
Rod must be moved in

THIRD TRIAL
Rod at "Z" 6.3' out from shoulder
Required fill here is 4.2
Necessary distance would be $4.2 \times 1\frac{1}{2} = 6.3$
"Z" is correct point for fill stake

Distance: ℄ to fillstake =
½ Road width + (fill × fill slope)

METHOD OF SETTING SLOPE STAKES WITH ABNEY LEVEL
AND NOMENCLATURE OF A TYPICAL ROAD SECTION

FIG. 310

Slope Staking

323. Purpose. Slope stakes are required for three main purposes:

1. To indicate how far into the bank it is necessary to excavate in order to get the desired width.

2. To guide the construction men in making the initial cut, in drilling holes for blasting, in determining the limits of clearing, etc.

3. To mark the toes and to indicate the height of through fills.

Where Required

Grade and cut stakes should be set on sidehill "contour" surveys on slopes exceeding 20%. On flatter slopes, grade stakes only should be set. All through cut and fill sections should have center line and two cut or fill stakes. Ordinarily stakes should be on 100 ft. intervals. Stakes may be set closer than 100 ft. on sharp curves, over broken rough topography, etc., if needed. The extent to which slope stakes should be used in low standard construction depends upon their value to the job. Slope stakes are usually unnecessary where the standard is low and trailbuilders are in use.

Procedure of Setting

324. When required, center line or grade line stakes and slope stakes should be well marked and firmly set since a year or more may elapse between the location survey and construction. (See Fig. 311 for approved method of marking stakes). Slope stakes should be set directly opposite the grade or center line stakes and at right angles to the line. Stakes should be set on both sides for turnpike or through fill sections and on uphill side for sidehill location to give good alignment.

The slope tables in the Forest Service Engineering Field Tables indicate how to stake sidehills to secure on given slopes enough dirt from the cut section to make the fill with an allowance for shrinkage. A slope table is easy to use and has excellent possibilities for rapid work in staking on sidehills where excavated material is cast over.

From the "slope stake and area tables" the slope distance corresponding to the slope angle is found in column S. The slope stakes are set at that distance from the grade stakes measuring along the slope of the ground. This distance is designated on the figure at the lower corners of the slope stake and area tables. The stakes should be marked with the depth of cut shown in column C opposite the per cent slope under consideration. The stake may also be marked with the slope distance, if to the advantage of the construction men.

Application of Slope Stake Tables

325. The errors resulting from use of slope stake tables are largely due to the irregularities of terrain, since the tables assume uniform slopes.

The slope stake tables for through cuts should be used where there is a cut at center line.

The use of slope stake tables for side hill sections is limited to the following:

1. Sections on which a point at the grade of the finished truck trail is available, and a balanced section is desired.

2. Sections where the slopes are reasonably uniform.

3. Sections in material that shrinks, "sticks" on side slopes and otherwise conforms to the theoretical shrinkage, etc., considered in compiling the tables.

As a general rule the excavated earth will not "stick" on sidehill of over 35 degree (70%) slope. Excavated solid rock will "stick" on slopes up to 40 degrees (84%) if handled carefully. use of rock walls to retain excavated material causes adjustments to be made in widths of cut section to fit the particular case. Variations in shrinkage of material will in some cases require the use of tables for wider or narrower sections to secure a settled roadway of the proper width.

The slope stake tables contained in the "Forest Service Engineering Field Tables" must be followed. If better tables are found by any Region they should be brought to the attention of the Chief Engineer in order that they may be considered and if decided better than the standard tables be substitituted in the "Field Tables."

Cross sectioning and slope staking may also be done with an Abney level, rod and tape, without reference to slope stake tables. This method is described in par. 326. It is particularly applicable when staking from actual center line instead of grade line.

Setting cut and fill slope stakes by Abney level, rod and tape.

326. The following procedure is graphically explained in Fig. 310, page 325:

1. From profile notes, the cut or fill at center-line stake is determined.

2. Abney, with level reading 0, is set up at a point where the Abney level or height of instrument (H.I.) is at higher elevation than the highest point in the cross section but near enough to read the rod easily with the naked eye.

3. Rodman holds the rod on ground surface at center-line.

4. With a proposed cut at center line, H.I. is rod-reading plus the amount of cut; with a proposed fill, H.I. is rod-reading minus the amount of fill.

5. Determine on the ground, at right angles to center line on tangents and radially on curves, the intersections of the cut and fill banks with the ground surface. This is done as follows:

(a) Intersection of cut bank with ground surface.

Top of cut slope is the point where the distance from center line is equal to half the width of road plus the depth of cut multiplied by the cut slope.

(b) Intersection of fill slope with ground surface.

The toe of the fill is the point where the distance from center line is equal to half the width of road plus the depth of fill multiplied by the fill slope.

Staking Turnouts

327. Turnouts should be measured and staked in order to provide the proper width and length of turnout and to avoid unnecessary excavating and expense. Slope stakes should be placed opposite each end of the maximum width section and each end of the turnout. Full

advantage of natural features must be taken in placing turnouts. These may occur at draws, section of light side slope, etc.

Staking Turnarounds

328. Turnarounds should be provided at maximum intervals as specified for the several service standards. Turnarounds will ordinarily be provided in saddles, on flats or other topographic features where they can be provided by simply clearing and smoothing up.

In those cases where turnarounds must be provided on a sidehill section they should be staked by laying out two circular curves which form a Y, the main stem of the Y being approximately at right angles to the road. The curves should have a radius of about 40 feet. Economical design will usually involve using in fill the material, excavated from the stem, to provide the curves.

Methods of Measuring Side Slopes

329. Where required side slopes to the right and left of the center line should be measured in per cent and recorded in the notebook. The side slope is taken by one of three methods, the instrument man being at the grade stake in each case:

1. The rodman on the hill directly above holds the rod upright on the approximate point for the slope stake. The instrument man sights the level on the rod at eye height and reads and records the percentage of slope.

2. The instrument man estimates the eye height of some object on the hill above. He measures the percentage of slope by sighting the level at the object and records the reading.

3. The instrument man places the rod edge down on the ground parallel to the slope and gets the slope by laying upon it an Abney level and adjusting the arc of the Abney until the bubble shows level. He then reads and records the percentage of the slope.

Marking Stakes

330. See Fig. 311, page 331, for acceptable method for marking grade, center line, slope and other stakes.

Method of Bisecting an Angle

331. This method is primarily used in determining the direction of the "base line" when laying out switch backs. It is, however, equally applicable to any intersecting lines.

Figure 312, page 332, illustrates and describes the method.

Method of Laying out a Right Angle

332. Fig. 313, page 332, illustrates a field method of determining a right angle with a tape.

Perpetuation of Public Land Corners

333. The wilful destruction of the corners of the public land surveys is prohibited by Section 57 of the Penal Code of the United States (35 Stat., 1088) and whoever shall wilfully destroy, deface, change, or remove to another place any section corner, quarter-section corner, or meander post, or any government line of survey, or shall wilfully cut down any witness tree or any tree blazed to mark the line of a government survey, or shall wilfully deface, change or remove any monument or bench mark of any government survey, shall be fined not more than $250 or imprisoned not more than six months, or both.

In the construction of roads it often becomes necessary either to bury or remove a corner from its original position, and insuch cases the General Land Office has delegated authority and issued instructions to different Federal and State Highway organizations to execute this work in a manner that will perpetuate the original position of a corner, and will also be in accord with its adopted methods.

Under date of March 1, 1919, the Commissioner of the General Land Office gave his approval to the following method:

"Corners to be witnessed by 4 monuments so that original point can be located by intersection alone.

"Monuments to be of iron pipe of 1 inch or more in diameter and at least 30 inches long driven, so that top is about 3 inches above ground surface. Guard stakes with description of corner on one side and distance and angle on the other side to be driven at witness monuments.

"The following disposition is to be made of the original corner:

"When the corner is in fill, cover corner and record in notes depth of fill at that point.

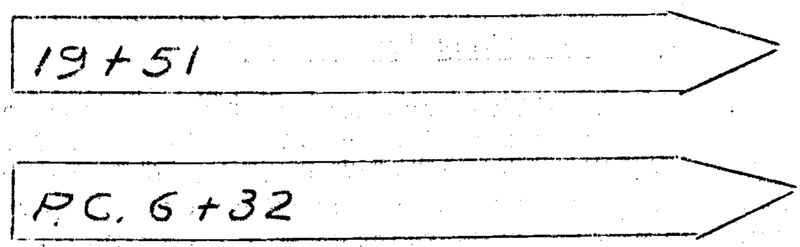
"When corner is in cut, reset corner from witness monuments, placing some at least 12 inches below road surface, and record depth in notes.

"Notes, accompanied by sketch, are to be filed in the office of the County Clerk and Recorder and a copy of same to be sent to the office of the Public Land Survey."

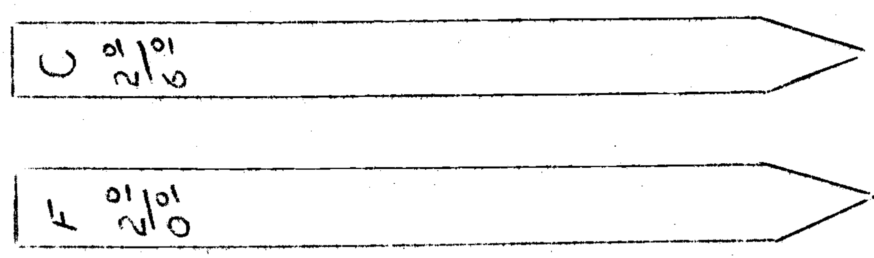
The location surveyor should preferably secure the approval of the District Cadastral Engineer of the General Land Office before moving or destroying the position of a corner.

FIGURE 311

MARKING STAKES

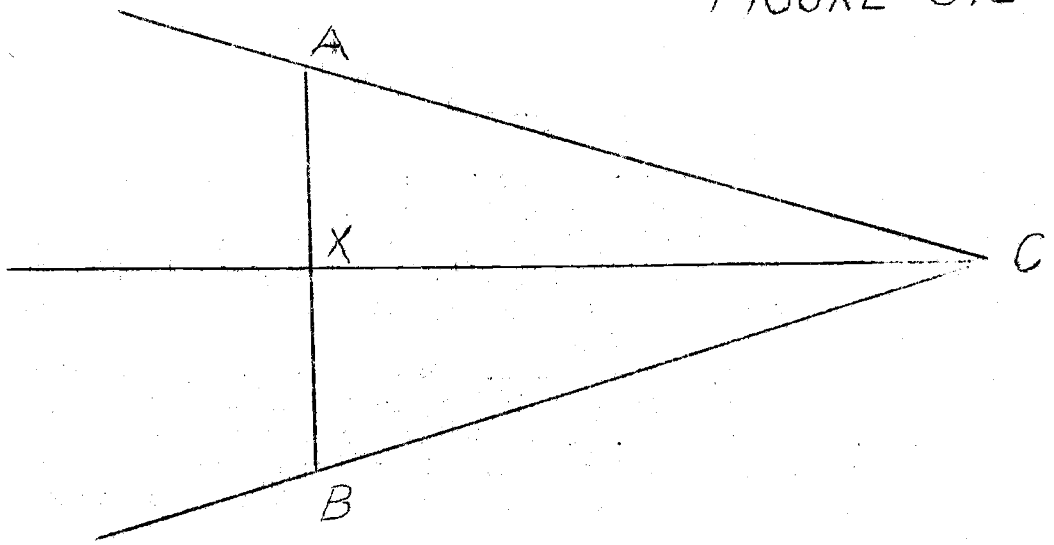


Station of center line stakes should read toward the pointed end as shown. The numbered side should face the beginning of the line, i.e., the zero end.



Slope stakes or cut and fill stakes should be marked F for fill, C for cut. The top number is the amount of cut or fill and the bottom number is the distance out from the center line. They should be driven in with the marked side facing the center line.

FIGURE 312



To bisect an angle measure CA equal to CB and place stake at X, half way between A and B. CX is the bisecting line.

FIGURE 313

Length of sides to form right angle with sides a or b.

a	b	c
3'	4'	5'
9	12	15
15	20	25
21	28	35
27	36	45
33	44	45
39	52	65

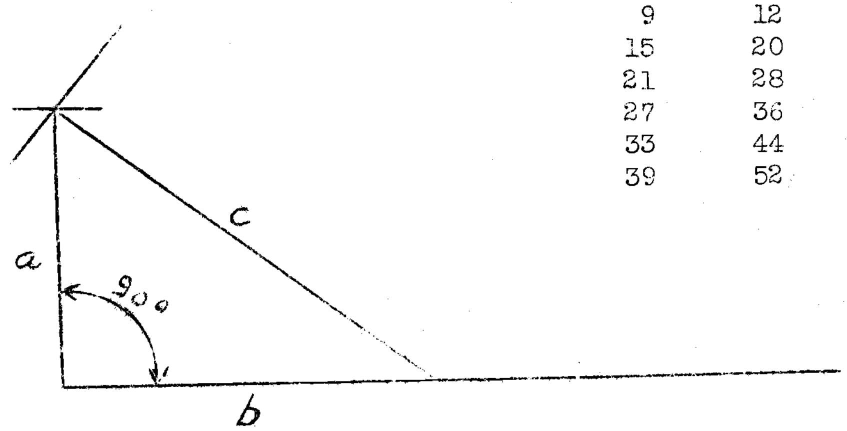


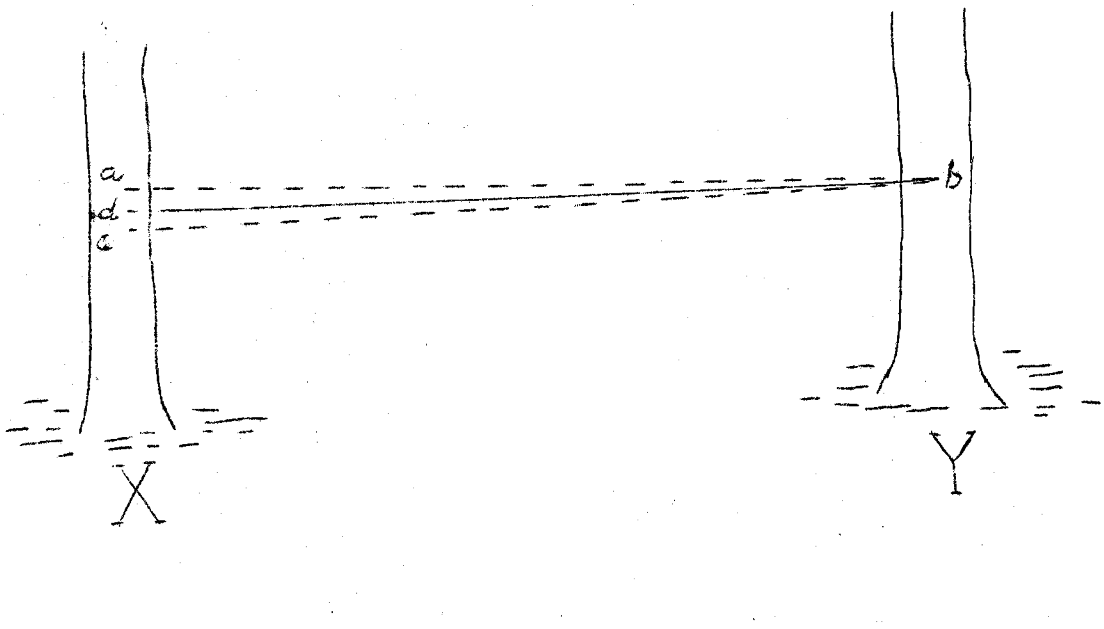
FIGURE 314

ABNEY LEVEL - BUBBLE ADJUSTMENT

Select two trees or other objects about 100 feet apart on nearly level ground, as X and Y in figure. Set a mark a at X; then move to Y. Set the index arm of the Abney to 0 and sight a from Y; move the Abney up and down at Y until some point b is found which apparently is on a level line through a. Mark point b.

Now move to X and sight b. Move the Abney up and down at X until some point c is found which apparently is on a level line through b. Mark point c. Set a point d midway between a and c. Line db is level. Adjust the level bubble until (with the index arm reading zero) the buble will show lwvel when the instrument is sighted from d to b.

As a final test, read up and down between two definite objects on a steep slope (30 to 45 percent). If both readings are identical, the instrument is in good adjustment.



SECTION IV

CONSTRUCTION

JOB MANAGEMENT

400. The most important function of the man directly in charge of a construction job is the planning of his work. Successful planning is facilitated by breaking the job down into activities. An average job consists of the following activities:

(1) Clearing, brush disposal, and clean-up.
(2) Excavation; (common and rock).
(3) Drainage.
(4) Finishing.

Such division of the job should be made by each construction man. He should then select from the equipment available, the best suited to handle the several activities. The foreman can then determine the most economic size of his crew.

Men in charge of construction projects should plan the work two weeks ahead. Successful planning requires close study of the location. The construction superintendent must keep himself currently informed of the location ahead.

Construction men should save survey stakes where practicable for future reference. No standard practice is set up but experience dictates that backslope stakes should be offset at least 3 to 5 feet, measured along the slope of the ground.

CLEARING

Forestry in Road Construction

401. The point of view of the forester as well as that of the construction man will govern clearing of timber from the right-of-way. Clearing, from the forester's point of view, means to protect and develop the forestry and aesthetic values of the location as far as compatible with the mechanical requirements of construction. Such requirements must always be kept in proper place. This will naturally follow, if it is borne in mind that truck trails are built for sane rates of travel in fire control, administrative, and utilization activities, and for use by recreationists. With this principle always governing, a forest project can be made to fit in as a part of its surroundings instead of violating them.

Where to Clear

402. Limit clearing of trees to those which are an obstacle to construction or maintenance and to those which become severely damaged during construction or the burning of debris. Where the earth is loose, trees which stand nearer than 3 feet to the upper line of the back slope should be cut; this is especially applicable to trees which, having several main roots cut, may slide into the road. (See Fig. 401). Dead or otherwise weakened trees that may fall across the road, should be removed during construction.

The trees to be removed should be carefully determined and clearly marked by some one competent to judge whether removal is necessary. This is particularly important on a sidehill section.

Cut all stumps low, consistent with forestry practice. Stumps with tops nearer than one foot to the completed grade line should be blasted or pulled.

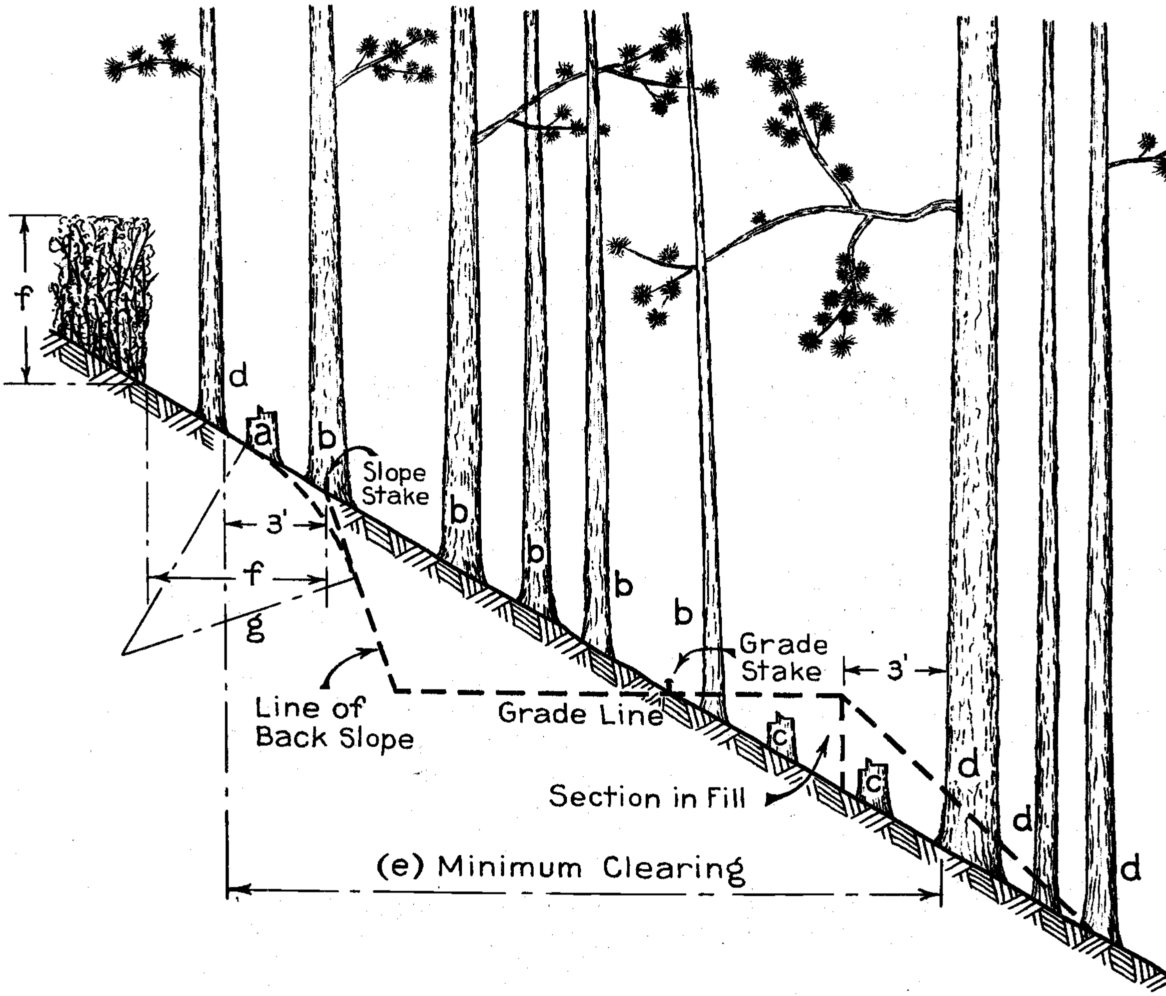
Clearing for Sunlight

403. A wider clearing may sometimes be necessary in order that the sunlight may keep the tread dry or hasten the melting of snow banks. The need must be clear. The extra width should be only on the sunny side. In very tall timber, it will be impracticable to make a clearing wide enough to get anything like full mid-day sunlight on a truck trail running east and west. If doubtful, the decision should be postponed until the truck trail has been in use over winter.

The cost of clearing for sunlight, and the value of timber wasted, should always be weighed against the cost of surfacing or additional drainage. Frequently, surfacing or draining, or a combination of both, is cheaper. If clearing fails to accomplish the desired results, the truck trail must be surfaced later.

Clearing for Visibility

404. Adequate thinning to provide a safe degree of visibility on curves is very important on all truck trails. Where practicable, secure visibility for 200 feet on the inside of curves on medium or high service projects. Wholesale clearing of mature timber to improve visibility on curves, is never necessary. Selective thinnings, trimming off lower limbs, and cutting brush are all that is required. Visibility secured by thinning may be cheaper than constructing numerous turnouts.



(a) Cut and fell tree. Leave stumps of trees so located.

(b) Remove both tree and stump.

(c) Cut and fell trees so stumps will be 12" or more below grade line. Do not pull or remove stumps so located.

(d) Leave trees found in this position to demonstrate the forester's point of view in road construction. Standing trees must be at least 3 feet from edge of fill shoulder or cut-slope stake.

(e) Circular E-1527, dated October 28, 1935. - "The width of right-of-way can be selected within the range of 66 feet, the same as given in Lands Regulations for Class 3 roads. The minimum allowable clearing to be the distance shown above "Minimum Clearing".

(f) All brush that will fall over into road from snow, rain, etc., should be cut back of slope-stake a distance equal to height of brush.

(g) Where considered advisable by the Regional Forester, particularly from the standpoints of erosion, appearance or stability, the top of cut slope bank may be rounded off on approximately a 5 foot radius curve.

Note: Distance necessary to be cleared above the grade line on slopes where cut is $3\frac{1}{2}$ feet or more, will range about two times wider than the clearing necessary below the grade line. This difference becomes gradually less as percentage of slopes decreases.

FIG. 401

Time for Clearing

405. The clearing of a right-of-way must be coordinated with fire conditions. If required that the brush be piled and burned, it may be necessary to do the clearing during the season preceding the beginning of construction; however, such division of the job usually results in higher costs and should be resorted to only when clearly necessary.

Under average conditions, the best time from the road cost standpoint is in connection with the other activities of the construction job.

Methods of Clearing

406. Those responsible for clearing operations must carefully weigh the relative merits of the various methods. No definite rules can be prescribed. The size, type, and density of timber; the roadside-strip policy; and fire conditions in any locality may supersede economic considerations in the selection of a method. At all times, study the clearing methods as applied to the individual job, and avoid allowing the impressive features of mechanical set-ups to obscure the actual unit costs of such operations.

The following have been found to be economical under various topographical and cover conditions:

1. Pushing over all small or medium trees with front bumper (Diamond Box or R-1 type).

2. Drawbar pull with tag line choker or chains for individual scattered trees that are either inaccessible or too large to be pushed over.

3. Single drum attached to tractor. The cable can reach trees or stumps that cannot be reached by drawbar pull and can exert a pull two to three times greater than the drawbar. This method is good for large individual trees and stumps.

4. Double drums attached to tractor. This method should be used in thick heavy stands of larger sized timber and stumps that cannot be avoided. The quick return of rigging, chokers, etc., by the haulback drum is the feature of this method. Do not let the power of the rig obscure the high costs of each set-up.

In pulling over large trees by any of the above methods, the leverage is secured by placing the choker as high up in the tree as practicable.

5. Tractor and trailbuilder method. On side cuts, stumps up to 20 inches, and even larger can be undermined and disposed of at less cost than blasting.

The trailbuilder can be used, in conjunction with other methods, on most all other types of clearing and is particularly valuable in butting and pushing down-timber into piles for burning. An occasional saw cut in a large down log will expedite the progress of the trailbuilder in clearing work.

In clearing a right-of-way covered with down-timber, send one or two saw or chopping gangs ahead of the trailbuilder to cut off all logs so that the trailbuilder can swing them around easily, chopping all those which are axe-sized and leaving the larger ones for the saw gang. Do not attempt to break them off with the trailbuilder for they will bunch up and impede the progress of the work. Saw or chop the trees into sections of such length that the trailbuilder operator can easily move them to suitable places for disposal. Sections over 16 feet long are awkward to handle and often cause expensive delays.

6. Explosives are profitably used in three ways on clearing operations: (See Section V).

(a) Trees or stumps that cannot be pulled with the equipment on hand. If the trees are not felled, take advantage of the "lean" of the tree when placing the load. When trees are very large, use two or three separate loads under the base and fire them simultaneously with a blasting machine. Trees with a large tap root and a strongly developed root system, such as western pine, are so difficult to throw that it is usually cheaper to fell the tree, split the stumps with a shot than pull the pieces out with machinery. Conversely, trees with moderate tap roots or a spreading root system, such as overmature hemlock and white fir, can usually be blasted out cheaper than the tree can be felled and the stump blasted later. In dense stands of timber it is usually impracticable to blast standing trees. They should always be felled, and the stump blasted.

(b) Trees or stumps that are more economically handled by machinery after splitting or loosening them with explosives. The exact size of trees and the growing conditions that justify blasting before removal with machinery, is a matter for determination on the individual job. The following procedure will apply to average conditions:

On side slopes too steep for easy maneuvering of tractors and in dense stands, cut all trees over 6 inches in diameter.

Cut all trees close to the ground where stumps will be one foot or more below grade. This will save blasting a large number of stumps. Shoot the remaining stumps hard enough to split them.

Do not shoot them out clean; such action wastes powder as the split stump is easily taken out by the trailbuilder at the time grading is done.

(c) Cutting or breaking "down snags" with a "fast" dynamite. Where the road traverses old burns or other extensive down snag areas it will sometimes be economical to cut snags with dynamite rather than to saw them. Type A - Class 3, or Type B, Class 1a, 1b or 1c, 40 to 60% explosives from the Forest Service Acceptable List are usually most effective for the log cutting. The tractor trailbuilder will push most down snags out; cutting by explosives can be deferred until the machine is actually stuck.

Brush and Timber Disposal

407. The minimum amount of roadside treatment shall be as follows: (The term "clearing limits" as used herein means the edges of the cleared strip as shown in Figure 401.)

(a) ON ALL PROJECTS EXCEPT THOSE CLASSIFIED UNDER (B) AND (C), the following seven rules will govern brush and timber disposal and roadside cleanup.

1. All stumps should be cut low to conform to good forestry practice.

2. Small, low vines or plants that tend to protect the soil from erosion should not be cut or removed.

3. All slash, logs, and debris resulting from clearing and construction operations must be burned or systematically removed to outside the clearing limits. Slash, logs and other organic debris must not be covered into any portion of the road fill.

4. Snags outside the clearing limits which may fall across the road and obstruct travel should be felled and disposed of as provided in Rules 3 and 5.

5. Unless exceptions are approved by the Regional Forester, all unsightly snags, logs, slash and debris outside the clearing limits, but within the immediate field of vision of the driver of an automobile, shall be burned, scattered, removed or otherwise treated so as to render them inconspicuous and unobjectionable.

6. Trees, logs, slash and debris shall not be thrown into live streams.

7. Borrow pits shall be left in such condition as to minimize erosion and promote revegetation. Borrow pits will be

located out of sight of the road if practicable without wholly unreasonable cost. If exceptions are permitted, the borrow pit must be left in a satisfactory condition from the standpoint of appearance.

(b) ON PROJECTS WHERE PUBLIC TRAVEL IS PRIMARILY LOCAL IN CHARACTER AND RECREATIONAL USE IS RELATIVELY LIMITED, the above rules will govern with modifications as indicated below:

Rule 1 - Applies

Rule 2 - Applies

Rule 3 - All slash, logs, and debris resulting from clearing and construction operations must be burned or systematically removed to outside the clearing limits. Logs too large to be thus disposed of may be neatly piled or placed as inconspicuously as practicable along the clearing limits. Slash, logs and other organic debris must not be covered into any portion of the road fill.

Rule 4 - Snags outside the clearing limits which may fall across the road and obstruct travel should be felled, and any portion coming within the clearing limits disposed of as provided in Rule 3.

Rule 5 - Does not apply.

Rule 6 - Applies

Rule 7 - Borrow pits shall be left in such condition as to minimize erosion and promote revegation, and as sightly as practicable.

(c) PROJECTS PRIMARILY FOR FIRE CONTROL WHERE LITTLE OR NO PUBLIC TRAVEL WILL OCCUR. The rules given under (a) will govern with modifications as indicated below:

Rule 1 - Applies

Rule 2 - Applies

Rule 3 - Slash, logs and other organic debris must not be covered into any portion of the road fill. Disposal of slash, logs and debris shall be made as directed by the Regional Forester and in keeping with the benefits to be derived.

Rule 4 - Snags outside the clearing limits which may fall across the road and obstruct travel should be felled and disposed of as provided in Rule 3.

Rule 5 - Does not apply.

Rule 6 - Applies

Rule 7 - Borrow pits shall be left in such condition as to minimize erosion.

408a. The requirements of wildlife for shelter and cover should not be ignored. The above instructions do not contemplate removal of small timber reproduction or other cover to the extent that all shelter for game will be eliminated along the edges of the right-of-way. Consideration in specific cases may lead to the conclusion that small patches of brush which might otherwise be removed should be left for protection of birds or animals.

ROCK EXCAVATION

Sizing up the Job

409. In all cases where an appreciable quantity of rock is to be moved the plans for each section should be definitely determined:

1. Determine the possibilities of "seam shooting" handling the rock with a trailbuilder, tractor, ripper or other method.

2. Determine the amount of "break" obtainable back of the holes. Then drill a line of holes, a distance equal to the assured break, away from the backslope stakes. The depth of these holes will depend on the total depth of cut at the backslope. If total depth of cut is within the economic depth of drilling, it is usually desirable to put these holes down to approximately 6 inches below grade. If cut is over the depth capacity of the drill, the backslope will have to be "benched" off.

3. If the material will "stick" on the side slope and it is economical to hold it, shoot so as to break it up without "kicking" it too far over.

4. Do not "peck away" at rock work; find out how much powder is required to loosen the material well down to grade, then put down enough holes to accomodate the powder. When this is done return trips for the compressor outfit will usually be unnecessary.

5. Coordinate the drilling and shooting with the equipment and method to be used in handling the material.

Stripping Rock.

410. If overburden is heavy, weigh the relative economy of cleaning for individual holes and cleaning the entire upper half of the cross section of the road. The individual hole method is usually much more economical.

Dig a foot trail along the grade line. To uncover the rock for toe holes, dig trenches about 18 inches wide along the grade line at right angles to the center line. To reach the rock for back holes, start the trench high enough up the slopes, 3 to 6 feet or more depending on the slope of the ground, to uncover the rock. Run the trench in level to the rock at the point where the down hole is to be. Dig the trench only wide enough for a man to stand in to operate a jackhammer.

On jobs where drilling must be done by hand, it will be necessary in most cases to strip off all the dirt. This will expose crevices and low spots in which to start the drilling. Also hand drilling requires more space for each driller.

Stripping overburden on winter jobs may require shooting. In this case a slow propulsive powder is best, similar to Type A - Class 7; Type H - Class 2, 20 and 30%; Type B - Class 1^a, 1^b, 1^d of the Forest Service Acceptable List of Explosives. Sink the holes vertically through the frost or better yet, use slab shots run in against the under side of the crust.

Drilling Operations

411. Drilling demands close study by the official in charge. He should check the operation against the following check list and against supplemental lists of his own:

1. Is the rock work holding up progress on the job?

2. Would the work be speeded up if the air and drilling set-up were changed?

3. If topography is such as to make difficult keeping the compressors close enough to the drilling, would it not pay to have a pipe line and probably an auxiliary receiver, or a compressor mounted on a crawler tractor?

4. Is there adequate air, volume and pressure at the tools?

5. Are the bits giving maximum footage or would smaller gage-changes, better tempering, use of detachable bits or an air sharpener give more economical footage?

6. Is the air hammer of proper weight for the rock being drilled? Ordinarily a light fast-hitting hammer is best for soft rock such as sandstones and a heavy-hitting hammer for hard rock.

7. Is the "blowing" or cleaning of drill holes being properly done? Do not cushion the hammer blows by leaving loose material in the bottom of the hole.

8. Is time being lost by freezing of the air in the line or at the tools? Would it pay to equip with "Tanner gas" or anti-freeze?

9. Is there adequate lubrication for the hammer?

<u>Location and Depth of Holes</u>

412. Improper location, spacing or depth of drill holes are the most frequent causes of poorly broken material. Too often spacing of holes is determined by the existence of a good place to drill rather than by relative distance to adjoining holes.

Economical shooting and thorough breakage can only be obtained through correct depth and placement of drill holes which have been properly loaded with the correct amount of suitable explosives and fired. Even heavy shooting sometimes fails to break up a hard or tough material properly unless the charges have been both placed and spaced correctly.

(a) Down holes and lifters:- In drilling rock sections on slopes over 50%, use down holes and lifters alternately. Put in down holes about 2 feet below grade and space them from one-half to three-fourths of their depth apart. If rock shatters freely, space the holes farther apart and if the rock is hard or touch, space them closer together. The kind of material will govern the spacing.

Lifters are put in half-way between down holes to break out the toes and centers. Start them at grade and slope them down so that the back end of the drill hole will be about 2 feet below grade and even with the row of down holes.

In shallow rock cuts it is sometimes cheaper to drill deeper below grade than is advisable in the deeper cuts. This will permit a wider spacing and so reduce the drilling cost. The tendency is too close spacing of the holes.

In deeper cuts of tough, blocky or non-uniform rock, through breakage cannot readily be accomplished if the holes are spaced too far apart. In such material, a spacing of over 10 to 12 feet will usually require the drilling of secondary holes to about one-half the depth of the cut staggered between the main holes. These secondary holes, as well as any supplementary charges in the stem of the main holes, are then fired simultaneously with the main charges.

(b) General rules for spacing. The spacing of drill holes both from the face and from each other should be proportioned to the depth of cut at that point, except that only in the most exceptional cases where it is impracticable to drill the holes at least 4 feet deep, need the spacing of rows ever be less than 3 feet. For most rock the spacing between holes need never be less than 4 feet provided the total depth of the hole is not less than 4 feet and penetrates at least a foot and a half below the level to which the material must be removed.

No definite rules or formulas will fit all drilling conditions. The spacing between the holes in a row along the back slope should average about three-fourths of the total depth. Where adjacent improvements prevent heavy shooting, closer spacing is of course necessary.

Compressors

413. Volumetric efficiency is approximately 65% to 75% for Single Stage Compressors at sea level; i.e., the Single Stage "240" Compressor delivers 160 cu. ft. of actual air per minute.

The two stage compressor delivery is practically constant regardless of elevation, the drop being about 2% for 5,000 feet above sea level.

The single and two stage compressors of today, (1935), are rated at actual delivery of free air per minute at sea level. At 100# gauge pressure the delivery of free air for various size compressors at various elevations is as shown in Table 401.

TABLE 401

FREE AIR DELIVERY OF COMPRESSORS

Cubic feet per minute at various elevations

Sea Level	3,000'	6,000'	9,000'	12,000'
		Two stage compressors		
105	104.2	103.5	102.6	101.7
160	158.3	156.7	155.0	153.3
210	207.8	205.6	203.5	201.3
315	311.8	308.7	305.6	302.2
		Single stage compressors		
105	99.5	94.1	88.6	83.2
160	151.4	142.8	134.2	120.6
210	201.5	193.3	184.6	176.2
315	302.5	290.	277.4	264.8

The air consumption of jackhammers varies as to make, model and wear. When necessary consult the manufacturer of your particular hammer for the required air consumption. Their catalogues usually give the air required for the most efficient working speed.

Table 402 gives the pressure drop in pounds for each 100 foot length of various size pipe at either 80 or 100 lbs. pressure. Knowing the pressure required at tools, Table 402 can be used in computing the pressure required at receiver to give the desired pressure at tools. This provides the receiver pressure against which the compressor will have to work. The next step is to determine the size of compressor required. In selecting the size (piston displacement) required, keep in mind that displacement is a theoretical volume of air and that this volume is <u>never</u> actually delivered. Types of valves, pressure that machine works against, lubrication, piston rings, etc., used on machines of different manufacturers influence the percentage relation between displacement and free air delivered.

TABLE 402

COMPRESSED AIR TRANSMISSION

Pressure Drop in Pounds per 100 feet for Various Size Pipes

Delivery of free air per minute cu. ft.	Diameter of Pipe Inches					
	1"	1¼"	1½"	2"	2½"	3"
	At 80 lbs. Gauge Pressure					
70	1.7	.4	.2	.05		
80	2.2	.5	.2	.06		
90		.6	.3	.07		
100		.8	.4	.09		
150		1.8	.8	.2	.08	
200			1.4	.4	.1	
250				.6	.2	.07
300				.8	.3	.1
350				1.1	.4	.1
	At 100 lbs. Gauge Pressure					
70	1.4	.3	.1			
80	1.8	.4	.2	.05		
90		.5	.2	.06		
100		.6	.3	.07		
150		1.5	.6	.2	.06	
200			1.1	.3	.1	
250				.5	.2	.06
300				.7	.3	.08
350				.9	.4	.11

The pressure drop in long lengths is directly proportional to the above, i.e., 500 feet of pipe would be five times the above, etc.

Globe valves, tees and elbows reduce the pressure along air lines. Their use should be confined to the minimum.

Air Delivery Lines

414. Before starting his shift, the driller should make certain that the compressed air line is in condition to function properly. The points to watch are:

(a) That the valve from the air line to the drill is fully open.

(b) That there are no undersize connections in the line to restrict the flow of air to the drill. See Table 402.

(c) That the air line to the drill is blown out to eliminate any moisture that may have collected in it. Do not connect the hose to the botton of a tree manifold where moisture may collect.

(d) That all pipe lines and hose connections are kept in good repair. A vast amount of compressed air is wasted through leaks which are so small individually that they are likely to be considered unimportant. Pipe lines, hose and valves should be inspected regularly for leakage. Large leaks can be detected by the sound of escaping air or by the rush of air against the hand. Smaller leaks can be found with the aid of a lighted candle, or by coating the joints with soapy water. Each thread in the pipe line should be painted with graphite and oil before hooking it up. This not only stops leaks but makes it easier to connect and disconnect the pipe.

(e) That the compressor is kept as close to the drills as possible. Long pipe lines should be avoided. At 80 pounds gauge the loss in pressure due to friction in 1,000 feet of 2 inch diameter pipe line carrying 300 cu. ft. free air per minute is about 8 pounds. (See Table 402).

(f) That if drills show a tendency to freeze up in cold weather, a coil is put in the pipe line and a fire built under it. This coil is made with two 2-inch return bends, one union and two pieces of 2-inch pipe 2 feet long. When several hammers are operated on one line, a Tanner gas outfit can be installed to prevent freezing.

415. Lubrication of Air Drills.

(a) The drill should be well oiled. The importance of lubrication cannot be overemphasized. Due to running at such high speeds, the surfaces of rubbing parts will soon burn if used dry.

(b) Line oilers should be furnished and used with all compressor outfits. They should be placed in the air hose line not more than 12 feet away from the hammer and filled with oil every half day. This oil is picked up with the air and carried under pressure to all parts of the drill that require lubrication. If special oil is not available, use SAE 30 truck oil. SAE 20 may be used during cold weather.

(c) The line oiler must be kept in adjustment; if a drill is receiving sufficient lubrication, oil will appear on the drill steel shanks. If too much, an excessive amount of oil will show on the hammer chucks and run down the sides of the steel.

(d) When a line oiler is not used, the oil plug in the side of the hammer should be filled every two hours of operation.

416. Cleaning and Tightening Air Drills

(a) Drills should be thoroughly cleaned after every 40 to 48 hours of operation. To do this, they should be dismantled, the parts cleaned with gasoline and then oiled and all connections tightened as they are reassembled.

(b) The drill parts must be <u>cleaned thoroughly when reassembled</u>. Do not try to assemble the drill along a dusty road where wind or working equipment may cause dust to settle on the cleaned parts.

417. Efficiency in Drilling.

(a) Do not crowd the drill. A little experience will serve to determine the amount of pressure to put upon the drill to obtain maximum efficiency. Too much pressure slows the drill speed as much as insufficient pressure.

(b) Best results can be obtained by applying pressure through the handles and by using both hands. Do not throw one leg over the handle, or use a metal bar or piece of wood to obtain leverage in applying pressures, as they lead to varying the pressure on the drill and have a tendency to hold the drill off line with the drill steel. The drill will do its best work if the contact between the piston face and the drill steel shank face is as large as possible. This will result only when the drill is kept in line with the drill steel so that direct blows will be struck.

(c) Keep the drill steady. If it is allowed to jump around it will ruin the hammer and the drill steel.

(d) Be sure that the hole in the drill steel is open. As air is directed through the hole from time to time to remove cuttings, obstructions in the steel interfere with the blowing capacity.

(e) Blow the holes frequently to remove the cuttings and thereby prevent binding of the bit. There is an attachment on the drill which permits passing the entire flow of air through the drill steel for this purpose. In ground that is slightly moist, there is a tendency for the drill cuttings to accumulate just above the bit and to become packed against the sides of the hole through the action of the rotating steel. To avoid sticking in such ground, remove the steel frequently while rotating.

Drill Steel

418. Before a drill operator starts work, he should have close at hand an adequate supply of drill steels of proper lengths with well-sharpened bits of the correct sizes. Time will be saved by sorting the steels and segregating them into groups. If the drill operator becomes systematic in arranging the steels he can select the correct length and gage change without confusion or delay.

Irregular bits and shanks must be avoided. The repeated use of a dull bit and the resulting accumulation of shocks to the piston lead to premature failure of the drill. Dull bits are a leading cause of drill steel breakage.

It is known that the practice of using each steel until its full depth has been reached is far more common than that of changing the steel when it has become dulled to such extent that the rate of penetration is materially reduced. Changing drills consumes about 7 to 12 per cent of the lost time. However, some operators consume twice as much time in changing steel as others, and in certain kinds of rock the unskilled operator often consumes excessive time in extracting stuck steel. Other lost time factors that can be avoided are:

(a) Low air pressure at drills
(b) Too soft or too hard steel
(c) Poorly sharpened or gauged steel
(d) Requiring the operator to bring up his own steel.

419. Reconditioning:- The principal purpose of properly forged steel is to insure effective cutting action, and in preventing undue wear within the drill itself. The experienced blacksmith watches every step in his work and learns to modify details of the treatment according to the performance of the steel.

It requires two heats for forging and tempering, and the two operations should never be performed with one heat. After it is forged, the steel should be laid aside on dry ground and allowed to cool before being reheated for tempering. For forging steels, used in average rock, a heat of about 1,900 degrees F. is satisfactory. This produces a light yellow color. Drill steel is tool steel and, for forging, should be heated slowly and uniformly. As the color will vary to the eye according to whether the day is bright or dull, it is best to judge all colors in a dark corner of the shop where the light will be fairly uniform at all times. Heating below 1,600 degrees or above 2,100 is to be avoided.

420. Tempering:- Bits must have sufficient hardness to give them maximum cutting ability but must not be so hard as to become brittle and subject to easy fracture. For general use, they should be filed hard. For tempering, bits should be heated to about 1,450 degrees F. or to a cherry red. The bit should be hardened by placing it in water and allowing it to remain there until cool. The water should be as pure as possible and in regions where the normal water supply is alkaline, rain water should be used. Care must be taken to see that no hardening cracks develop.

Shanks are not required to be so hard as bits, and it is of vital importance that at no time they be hard enough to damage the drill piston. All shanks should be tempered in oil. A shank tempered in water will be too hard and, upon being struck by the piston, will spall off at the edges. With subsequent use, it will in turn damage the piston and eventually cause its failure. Shanks should be heated for a distance of from 7 to 9 inches from the end to a temperature of about 1,500 degrees F. and should then be quenched in oil. Oil used should have no objectionable odors, and should not thicken materially or decompose with use. If shanks are too hard, look for water which collects in the bottom of the tank and drain the water off. Before being sent out of the shop, all shank ends should be ground true. Small pedestal type grinders or hand wheels may be used for these purposes.

421. Detachable bits and steel. Detachable bits should be furnished on small rock jobs or in isolated locations. These bits are screwed on to drill shafts of suitable length. The use of these will often mean considerable saving; (1) by eliminating costs of steel transportation to and from the job, (2) by eliminating the need for a drill sharpener on small jobs where they could not be used to maximum efficiency, (3) by eliminating the need for extra compressor capacity to run a sharpener and forge. Hence, practicability of detachable drill bit use depends on the volume of drilling to be done at any location.

Bits when new have one-eighth inch changes in gauge. When reground the change will be one-sixteenth inch. The bits can be furnished in containers which can be used on the work, and, as shipping boxes, in returning them to a central regrinding plant where regrinding is not done on the job.

Blasting of Rock

422. See Section V and the Forest Service Acceptable List for information on explosives. That Section gives methods of use to reduce the hazard to a minimum. All construction men will be held responsible for the application of its methods.

Due to the individual characteristics of blasting jobs, no definite procedure can be stated. The following are of importance:

1. From the Forest Service Acceptable List determine the explosive characteristics that will work the particular rock most economically.

The most important original characteristic to consider is the type of action necessary. High explosives, such as 60%, Type A, Class 6 or Type B, Class 1a, 1b, 1c, give the best shattering effect. Low explosives such as 20% or 30%, Type A, Class 2 or Type B, Class 1a, 1b, give the best loosening or propulsive effect. Other characteristics to consider are moisture and freezing resistance, sensitiveness propogation, and density required. Factors influencing selection as to moisture or freezing resistance are apparent. Density is important because of its direct influence on the size and shape of drill holesrequired.

2. Determine the quantity of explosives necessary to accomplish a given purpose; i.e., the sticks or pounds necessary per cubic yard or other unit of rock or dirt.

3. Fire all charges with a blasting machine. The use of a blasting machine minimizes misfires, gives greater efficiency from the explosive and is safer.

Safety rules and precautions. Definitely arrange for safety measures whenever and wherever explosives are used. See Section V for Safety rules.

Handling rock after blasting

423. This activity also requires individual consideration. The following have general application:

1. Break up boulders that cannot be moved by the construction equipment. Such breaking up with explosives is accomplished either (a) by "Blockholing", that is, drilling supplemental holes in the individual boulders and loading them with a small charge of powder or (b) by "mudcapping", that is, laying a "fast" explosive on the surface of the boulder and covering it with mud, clay, or some other soil.

Men in charge of a rock job should carefully consider the relative economy of blockholing and mudcapping. Table 503 in the Explosive Section shows the quantity of 40% straight nitro-glycerin dynamite required to satisfactorily break up boulders of various sizes.

If it is at all feasible to get power drilling equipment to the boulder, it will be more economical in most every case, to blockhole boulders of 5 ft. diameter and over.

2. In all trucktrail rock excavation the best practice is to save the finer material for the roadbed base or surface if the material is fine enough. The best equipment developed to date for this type of construction is the "Rock-picker." A trailbuilder removes both the coarse and fine material from the rock cuts which often necessitates the costly hauling-in of material to build a suitable wearing surface.

The "Rock-picker" picks out, side casts, or moves the larger rock in the same manner as an ordinary trailbuilder, leaving the finer material for a base course or a wearing surface on the roadbed. This implement reduces to a minimum the costly hauling in of surfacing material. It was developed in Regions One and Six.

The "Rock-picker" can be installed on a tractor trailbuilder by replacing the mouldboard of the trailbuilder with the rock-picker. The change can be made in a few minutes. The cost of a rock-picker is approximately $200.00 and should be a standard piece of equipment on all rock excavating projects.

3. Placing with tractor and hoist. This equipment has its utility in getting large boulders from and into normally inaccessible places. The tractor equipped with hoists can often be maneuvered into a position where a straight line pull from the hoist will enable the operator to deposit the rocks at the desired location. Or, if this is not feasible, a snatch block or a snatch block and flying block will permit placing of boulders under almost any operating conditions. The construction man, however, should bear in mind that arranging for haulback of the line, and hitching to individual boulders requires considerable man-power and time for setup. The trailbuilder method should always be considered before deciding to use the tractor and drums.

4. Placing of boulders with tractor using a chain or cable from the drawbar. This method has its application on locations where maneuvering of the tractor is possible. The tractor may be used to move the boulders by means of a direct drawbar hitch or the line may be takennthrough a snatch block.

5. Placing with drag line bucket. This method requires either a tractor equipped with drums or a drum and engine mounted on a separate skid or trailer platform. It will seldom be an economical method unless the quantities to be moved at each setup are large.

6. Placing with power shovel. Where quantities are large the power shovel is an efficient means of side casting rock. If the material must be endhauled, the shovel can be used to load material on tractor wagons, trucks, or other transporting vehicles.

Removal of rock below grade line

424. The purpose is to leave a uniform wearing surface that can be maintained by machinery.

The economical time for removing rock below grade line is during construction. Time and money are lost by bringing equipment back to do the work at a later date.

EARTH EXCAVATION AND GRADING

Job Management

425. It is difficult to overstate the importance of the construction man thoroughly sizing up his job and assigning the available equipment to the various activities in such a manner as to prosecute the entire job with the least delay.

Sidehill Excavation

426. On side slopes of 30 percent, or less, the tractor grader should be put on as the initial construction unit. In making initial cuts around a side hill with the tractor grader, the moldboard should be set at an angle of approximately 15 to 30 degrees with the center line of the grader, keep the material rolling sideways. Then set the front end of the moldboard well below the rear or "heel end", which will give the moldboard a distinct turner plow action.

After one or two trips are made with the tractor grader on a light slope, the bench is of sufficient width to permit effective use of the ripper. The grade should be thoroughly ripped before supplemental trips with the grader are made. In some cases, it is desirable to remove two of the standards from the ripper when ripping a grade during the process of construction. Using three standards materially lessens the amount of debris that the ripper picks up and reduces the number of dumping operations for the ripper. In practically all materials, three teeth ripping to a depth of approximately 8 inches gives thorough breakage of the excavated material between the teeth.

Construction men should keep in mind that time taken out for ripping is many times saved by the increased effectiveness of each tractor grader trip.

427. The trailbuilder should be used only on sections where its services are required. When it has opened up a section to a sufficient width to permit satisfactory operation of the tractor-ripper and grader, these units are more efficient side casters than the trailbuilder.

Do not be deceived by the relative rapidity of motion of the tractor trailbuilder as compared to the slow but constant operation of tractor graders in side casting material on steep side hill sections. Repeated tests have verified the conclusion that after a trailbuilder has opened up a side hill section to a width sufficient to permit effective operation with a tractor, ripper and grader, the latter combination as a side casting unit far excels a tractor trailbuilder.

Use of the tractor grader should be carefully synchronized with the progress of the trailbuilder. Do not attempt to keep the grading work too close to the tractor trailbuilder. This results in unnecessary turning of the tractor grader.

The trailbuilder is generally the most economic tool for providing extra widths on turnouts and curves.

During construction there are usually some extra widths to be found at the mouth of small draws or along low side hill sections. A relatively small amount of extra work by the tractor trailbuilder at these places provides an adequate turnout.

Where the locations of turnouts are marked in advance of construction the extra width can be provided as the excavation progresses along the right-of-way.

When the turnouts have not been definitely located, it is usually found more economical to defer the construction of turnouts until the tractor grader outfit has practically completed the road to the required width.

The trailbuilder is a very efficient tool for making fills or other endhaul up to a distance of approximately 100 feet. However the construction man should consider at all times the relative value to the project of having the trailbuilder engage on endhaul or using it in opening up additional steep sidehill sections.

428. Power shovels are economical tools for side casting provided there is a considerable mileage of heavy work in the same locality. Even then, the use of the trailbuilder should be considered.

<u>End Haul</u>

429. The type of required service to be rendered by the truck trail determines whether the endhauling of material to through fills or to grade equalizing points is justified. Endhauling should produce a saving in drainage, eliminate objectionable curvature, prevent decided changes in travel speed, or provide a wearing surface over rock sections, corduroy, swampy soils, etc.

When fills are included in the road design, it is advisable for the construction man or the locator to mark the limits of the fill on the ground and to indicate definitely the point or points from which the borrow will be made. Borrow should usually be made along the roadway where the operation will improve the alignment or visibility. Borrow pits should be made as inconspicuous as possible.

With the improved methods of endhaul now available, the locator or construction man should always weigh the relative costs of fills against trestles or small structures. A well constructed fill is a permanent improvement, while the maintenance of trestles or small structures is a perpetual burden.

430. The tractor-scraper is a most efficient endhaul tool. Since tractors are necessary on many other construction activities, the only direct investment for endhauling is that for scrapers. However, most tractor-scraper outfits are more efficient if supplemented by a ripper for loosening the material.

431 The tractor-trailbuilder for short hauls, up to approximately 100 feet, is often the most economical tool for building small fills. It maneuvers easily in restricted places and is capable of excavating as well as transporting material.

432. The drag line bucket or scraper requires power from either a tractor equipped with hoist or an engine and hoist mounted on skids or a trailer. It is economical where large quantities are to be moved from a single set-up.

Turnpike

433. The construction of turnpike sections is the simplest and cheapest class of grading. In turnpiking, the material for the roadbed is taken from both sides. There are three reasons for turnpiking.

1. To provide drainage where water is likely to collect and saturate the subgrade.

2. To secure a satisfactory surface over rock, or other surface irregularities that require a cushion.

3. To turn up mineral soil, which retards the growth of vegetation and affords a more stable wearing surface.

If none of these purposes are served, turnpiking is a waste of money and should not be done. On some soils flat truck trails are entirely satisfactory. In such cases nothing is gained and frequently the good natural tread is spoiled by throwing up a turnpike.

Where drainage is not important, there is no point in building up a high roadbed with deep ditches on both sides. The grading up should be restricted to that necessary to obtain a good smooth surface that can be satisfactorily maintained. On a simple turnpike with a low crown, travel can and will use the entire width from ditch to ditch. Do not build a deep ditch with a steep, pronounced shoulder that will prevent the use of the entire roadway.

Finishing

434. From the standpoint of reduced travel time the money spent in providing a wearing surface is usually the most productive road expenditure.

Ripping is an essential part of the finishing operation and should never be omitted.

Rocks, roots, stumps, etc., should be removed to a sufficient depth below grade to provide a wearing surface of reasonably uniform consistency that can be maintained with power machinery. Thorough ripping will generally cause the finished section to compact evenly and produce a surface free from holes.

If the material being worked is rocky or if a great many roots are in the roadbed, put all standards in the ripper and rip to a depth of a few inches before making the finishing rounds with the grader. This procedure results in more uniform compaction, smoother wearing surface, and a decrease in maintenance cost.

The outside of curves should be elevated in the process of ripping and grading. The service that a road will render may be raised appreciably at no added cost by well directed ripping and grading around curves during the finishing and shaping process.

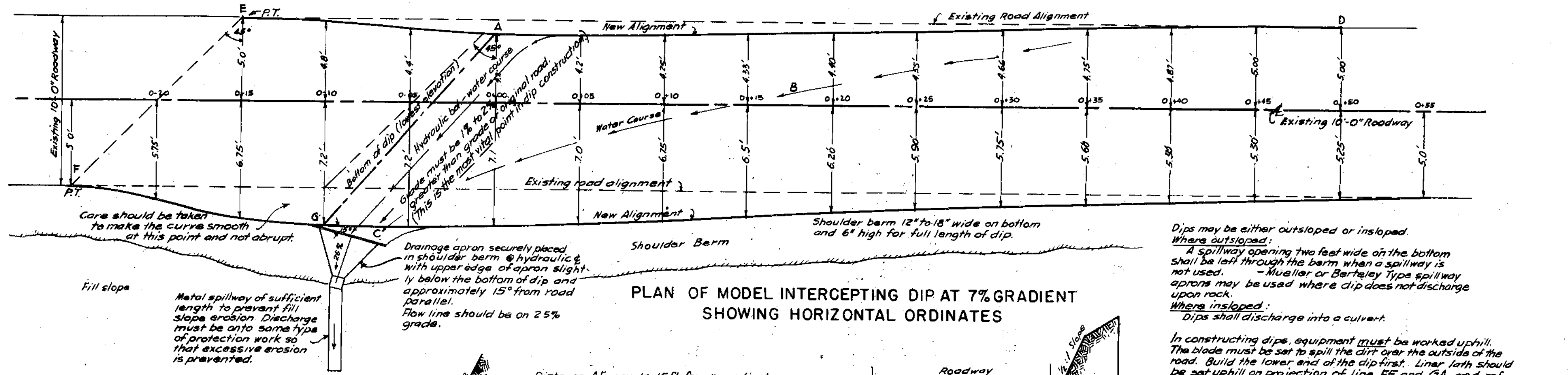
In the finishing of cut slopes, where soil conditions are favorable, the rounding off of the top of the cut slope to prevent the loose top soil from sloughing into the roadbed is recommended.

To assist the early revegetation of cut slopes on certain soils and avoid excessive erosion on others, the recommendations of the Forest Experiment Station as when to or not to round off the top of the cut slopes should be followed.

DRAINAGE

Importance

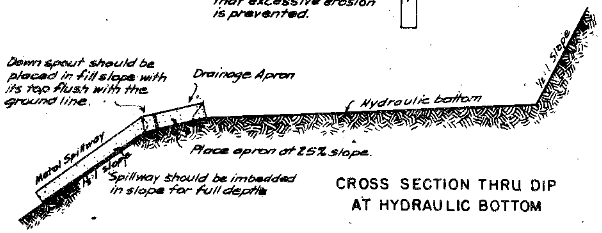
435. Of first importance is realization that the annual cost of any improvement is composed of maintenance charges plus a percentage of the construction investment. For comparison in planning



PLAN OF MODEL INTERCEPTING DIP AT 7% GRADIENT SHOWING HORIZONTAL ORDINATES

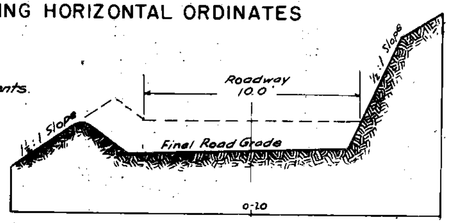
Dips may be either outsloped or insloped.
Where outsloped:
A spillway opening two feet wide on the bottom shall be left through the berm when a spillway is not used. — Mueller or Berteley Type spillway aprons may be used where dip does not discharge upon rock.
Where insloped:
Dips shall discharge into a culvert.

In constructing dips, equipment *must* be worked uphill. The blade must be set to spill the dirt over the outside of the road. Build the lower end of the dip first. Liner lath should be set uphill on projection of line FE and GA, and reference hubs set for points A and G. Point D should be located. Further staking is unnecessary for operators skilled in dip construction. Increase in outslope should be gradual from D to C so that water from D follows course B.
Both ends and the trough of the dip must be rounded to make easy riding.

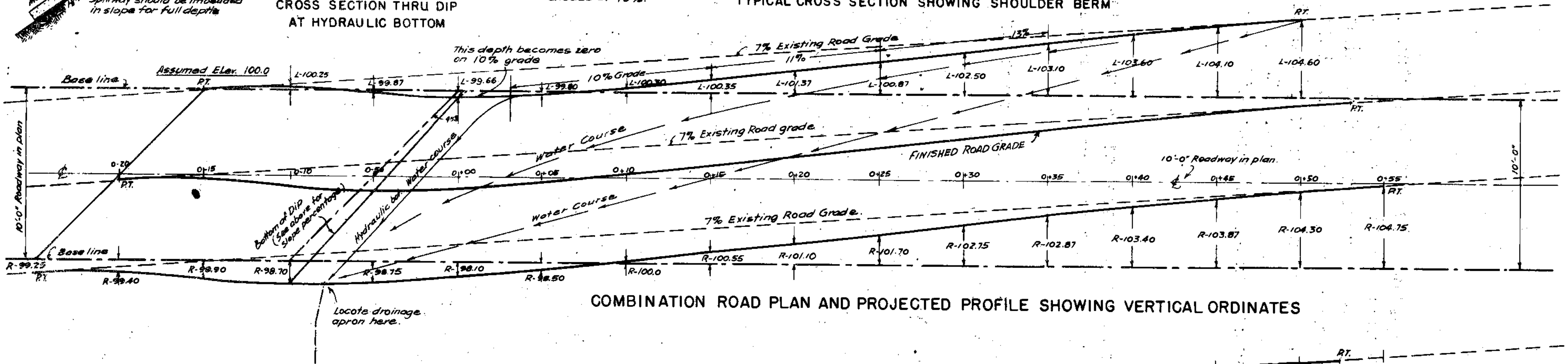


CROSS SECTION THRU DIP AT HYDRAULIC BOTTOM

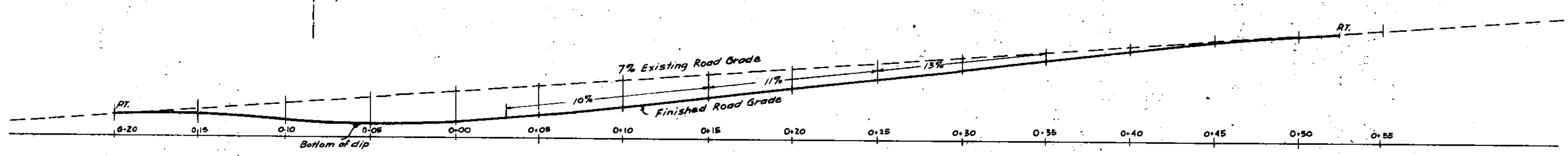
Distance AE equals 15 ft. for all gradients.
Distance AD as follows:
Grades to 7% : 50'
Grades over 7% add 5 ft. for each % of grade in excess of 5%.
Intercepting dips not recommended on grades in excess of 10%.



TYPICAL CROSS SECTION SHOWING SHOULDER BERM



COMBINATION ROAD PLAN AND PROJECTED PROFILE SHOWING VERTICAL ORDINATES

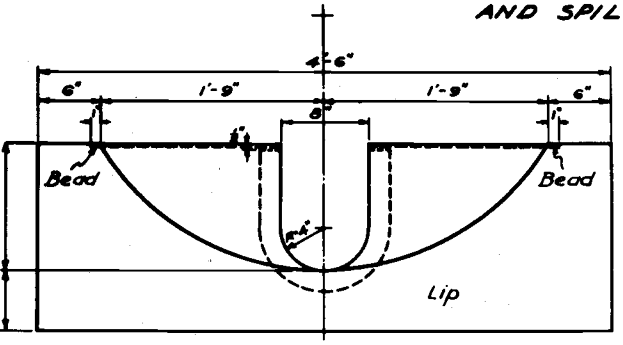


PROFILE OF INTERCEPTING DIP

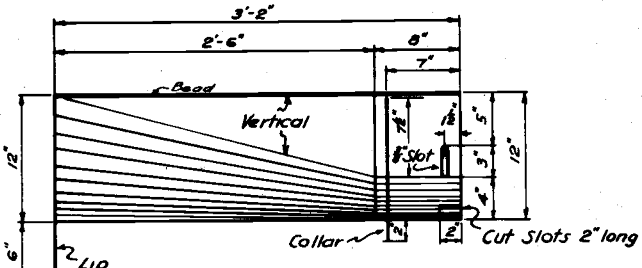
U. S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
REGION 5

MODEL INTERCEPTING DIP FOR 10'-0 TRUCK TRAILS @ 7% GRADE

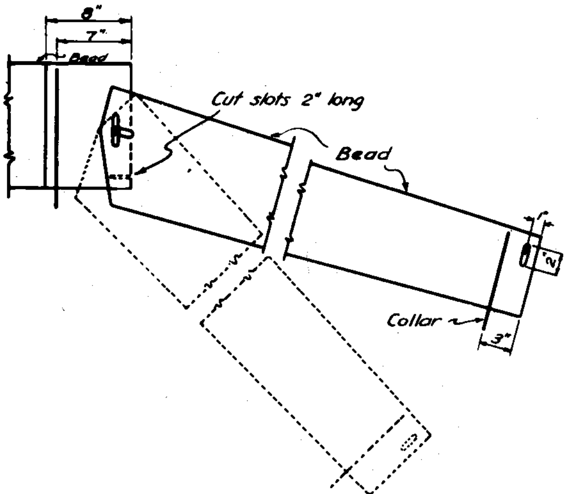
MUELLER DIP DRAINAGE APRON AND SPILLWAY



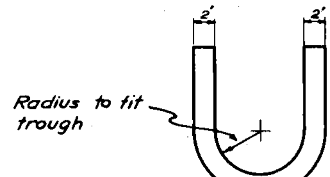
ELEVATION



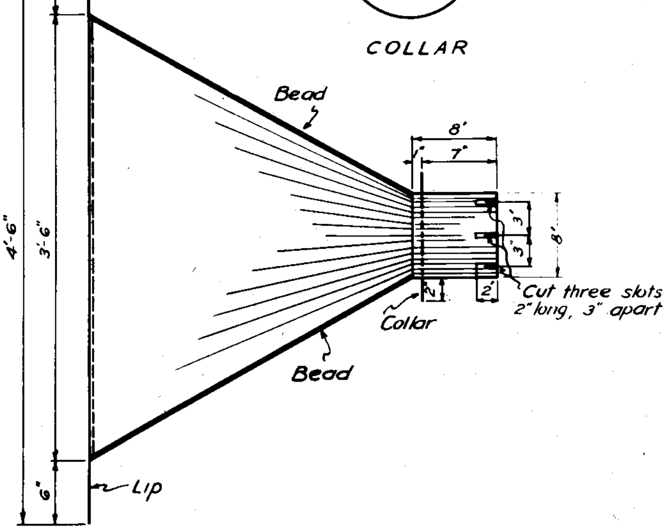
SIDE ELEVATION



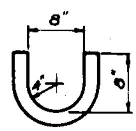
DETAIL : Showing Assembly of Apron and Trough Extension Nº 1



COLLAR

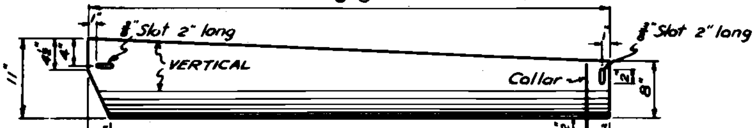


PLAN

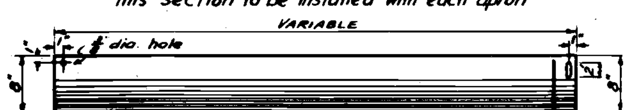


COLLAR

NOTE :
2 - ¼"×1" Full threaded bolts, and 4 Washers for each section.
To be made of #16 gauge metal

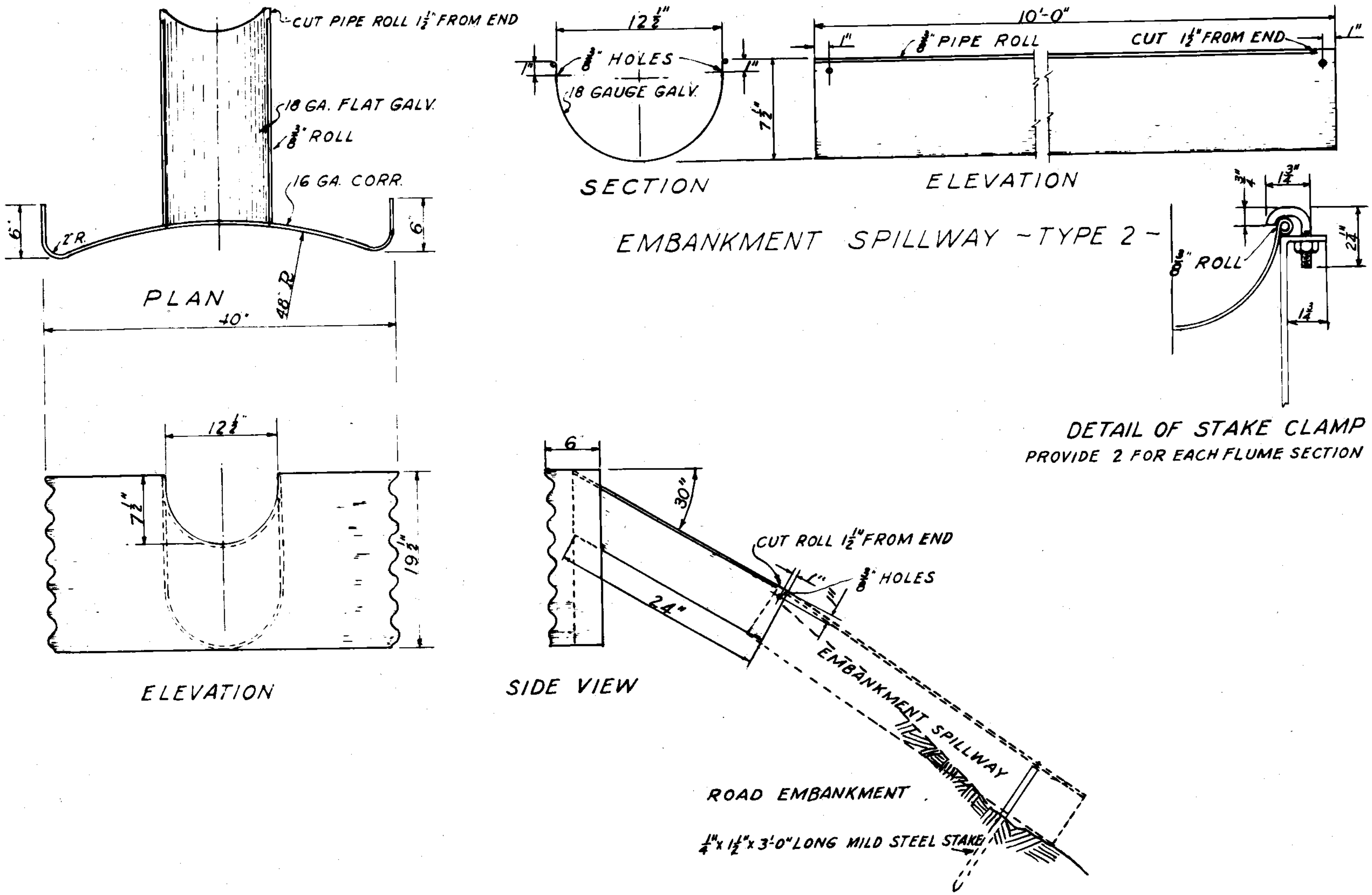


EXTENSION TROUGH Nº 1
This section to be installed with each apron



SIDE ELEVATION EXTENSION TROUGH Nº 2
To be furnished in lengths of 6', 8', 10' or 12'

INTERCEPTING DIP-SPILLWAY
BERKELEY TYPE



the project, a low initial cost must be thoroughly investigated as to length of life and frequency of replacement. The additional first cost of the drainage provided should be balanced against resulting reductions in future maintenance charges.

In addition to reducing future maintenance, proper drainage increases the service rendered by the road.

The common drainage problems may be divided into three types:

1. Surface drainage
2. Cross drainage
3. Subsurface drainage

SURFACE DRAINAGE

436. Inadequate provision for the disposition of water coming onto the surface of a truck trail is the cause of great damage such as wheel rut wash, and a general washing away of side-hill fills, through-fills, and of the finer materials in the roadbed.

Wheel rut wash is the most serious single cause of damage to mountain roads. In some kinds of soil it is impracticable to maintain such a perfectly shaped roadbed that water will be deflected promptly from the surface to the side or off the road. Even if well shaped and all ruts eliminated before a period of storms, travel while the road surface is wet will form ruts for the water to follow unless the surface is hard and firm. The primary concern is to prevent scouring and deepening of ruts by water following them for long distances.

Methods of handling surface drainage are suggested:

1. Outslope. Where soils are not easily eroded the most practicable means of diverting surface drainage from the road has been found to be outsloping of the roadbed. It is believed that a more general use of outsloping on low service truck trails, where the material is other than clay, should now be used than has been the practice in the past.

Crown roads are one-half outslope. Outsloping settled roadbeds from the outside wheeltrack and removing obstacles that will cause the surface water to collect is good practice in soils where erosive action is not serious.

Outsloping is a hindrance to travel, cuts down safe travel speed, and is particularly objectionable if the road surface is liable to become slippery during period of use. On high service truck trails and other places where the disadvantages of outslope outweigh its advantages it should not be used.

2. Grade Breaks. The grade line may be broken into short sections of level grades or even adverse grades. The frequency of such breaks should be based on the volume of drainage water and the ability of the soil to resist erosion. Such flattened sections should be placed at points that permit outsloping. The outsloped sections act as intercepting barriers to surface water and as spillways.

3. Dips. (See Figure 402). The road surface may be provided with dips having an overall length of not less than 50 feet. Where needed the dip should be installed so that it will have a slope of approximately 8%. To prevent erosion of the fill slope water from the discharge end should be handled over a rock fill or riprap. If dips are built with machine equipment the length may be greater than fifty feet. The added length eases the suddenness of the vertical curvature.

4. Inslope and cross drains. Insloping may be used to prevent erosion or as a safety precaution on slippery soils. Culverts or other suitable and underground cross drainage also must be provided. An insloped road necessitates the installation of some type of culvert. Since these structures constitute an added investment in the construction of the road and materially increase the annual maintenance charge, insloping should be used only when soil or other conditions will not permit the use of a natural or "built in" type of drainage. Proper attention to banking curves will assist in disposal of surface water.

5. Open top culverts are necessary on roads subject to heavy damage from wheel rut wash. The spacing will depend on soil formation and grade of the road. The rut water should be diverted before it accumulates in appreciable quantities. Where open top culverts are used on heavy grades a culvert should be placed immediately above each through fill. Install such culverts at grade on firm sections of road. This usually necessitates installing culverts after the grade has settled. Where the culvert discharges upon other than rockfill, wash must be prevented by protecting the fill bank. See Figures 403, 404, and 405 for typical open top culvert types and method of installation.

6. Intercepting ditches above the road should be used where the run-off would carry large quantities of eroded material. It is good drainage practice to keep large quantities of water from accumulating in the roadside ditch. Intercepting ditches can often be constructed to lead the accumulated run-off from the hillside directly to the nearest natural water course or culvert. This will result in much less erosion of cut banks and less maintenance of ditches.

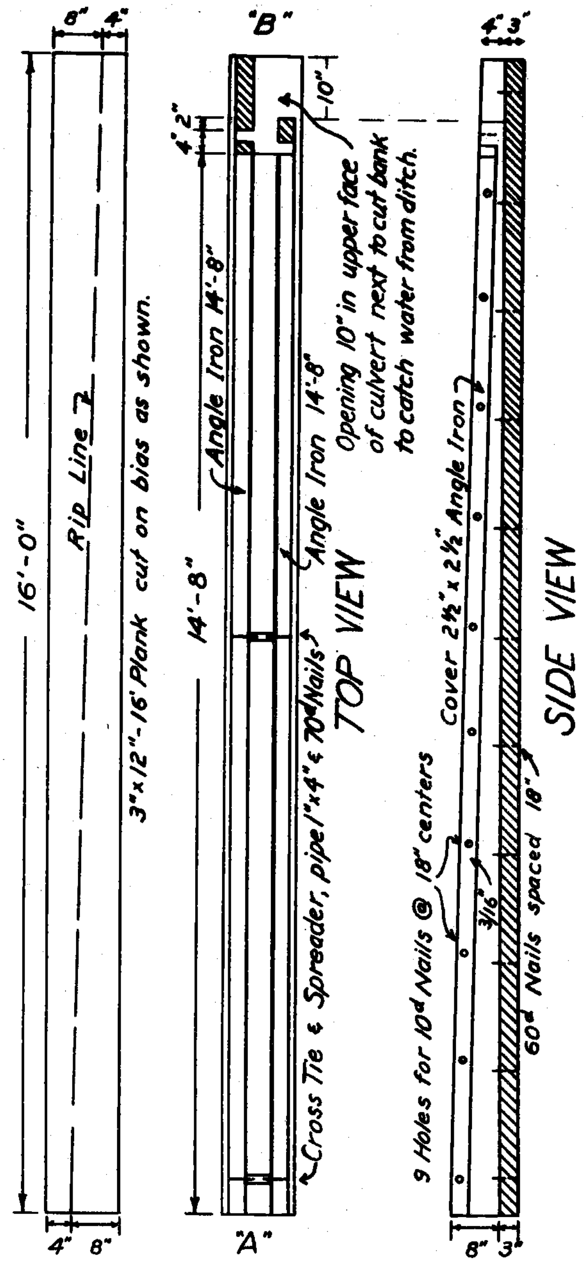
7. Water bars. Earth, or pole, water bars may be installed on lightly used projects only in exceptional cases and on heavier

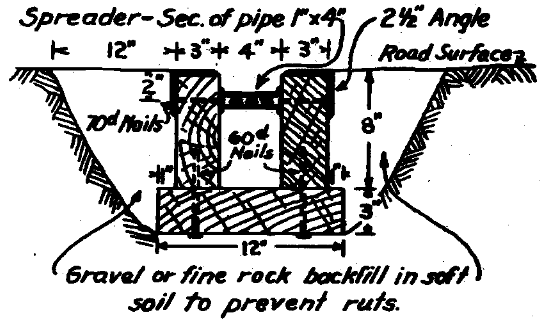
used projects only in the event of an exceptionally difficult run-off problem at certain seasons of the year. Always in the latter case, and usually in any case water bars are permitted only as a temporary expedient to protect the project during an emergency.

CROSS DRAINAGE

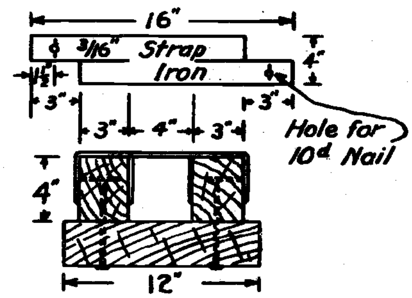
437. Adequate provision must be made to care for water which may flow across the truck trail either from live streams or from the ditch alongside.

OPEN TOP BOX CULVERT
WITH ANGLE IRON COVERING





END VIEW "A"



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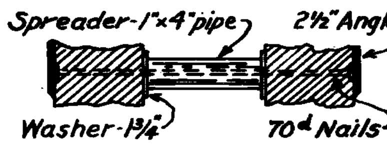
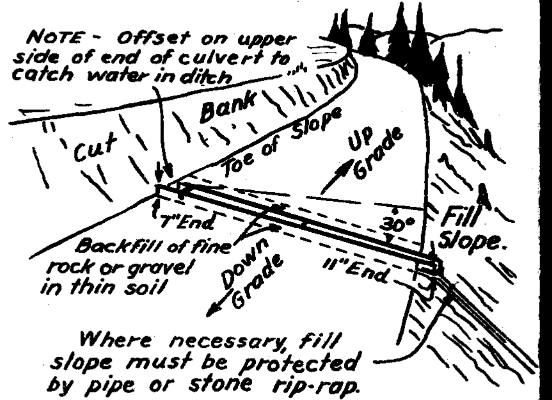


CROSS TIE & SPREADER



METHOD OF INSTALLATION

BILL OF MATERIALS

HARDWARE

Spreader - 2 pcs. 1"x4" sec. of water pipe
Nails - 1 lb. 70d cross ties
Nails - 2 lbs. 60d 18 - 10d
Washers - 4 - 1¾"
Angle Iron - 2 pc. 2½" x 2½" x 14'-8" long
Strap Iron - 1 pc 3/16" x 4" x 16" long

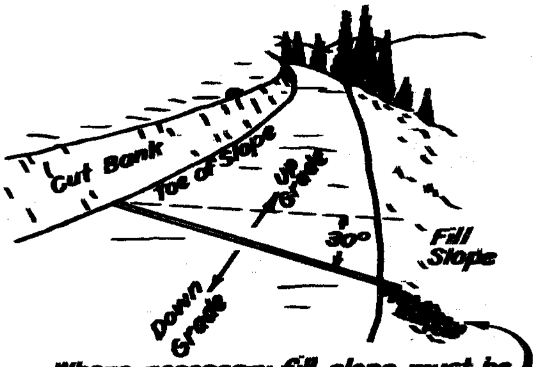
LUMBER

Bottom Plank	1 pc. 3"x12"-16'	48 F.B.M
Side Planks	1 pc. 3"x12"-16'	48 F.B.M
	Total	96 F.B.M

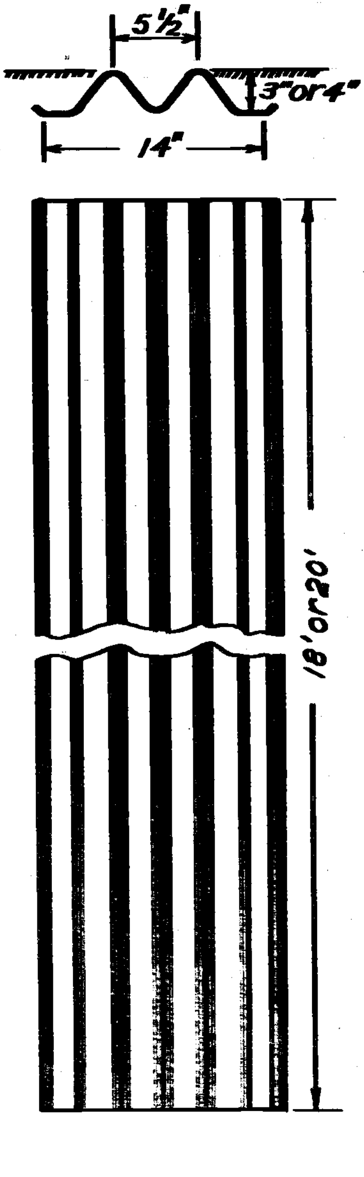
FIGURE 403

OPEN TOP CULVERT

CORRUGATED METAL GROOVE TYPE — #12 GAUGE HIGH CARBON STEEL



Where necessary, fill slope must be protected to prevent excessive erosion.



METHOD OF INSTALLATION

Culvert shall be placed by trenching.

If native material is unsuitable for foundation, the deficiency in sand or clay, as the case may be, shall be corrected by introducing the material needed for the purpose of obtaining a firm foundation and backfill. This shall be free from large stones, sticks, etc.

After the foundation is thoroughly tamped, the culvert should be laid to proper line and grade and well tamped with same material over its aprons and outslopes until flush with road surface.

Culvert to be installed below out-curves and above in-curves and out-sloped sections of road and elsewhere when needed.

Grade of culvert to be not less than 3%. Culvert to be placed at an angle of 30° with road.

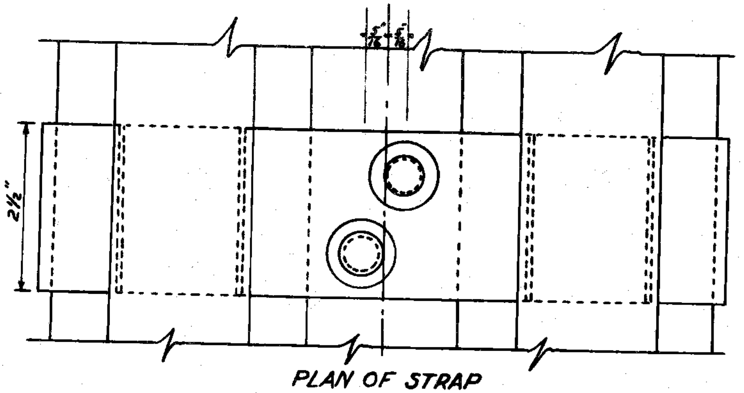
Upper end of culvert to extend into cut bank with earth dam at upper end, where necessary, to deflect water into it. The inverted grooves are to be securely plugged at inlet end, to prevent water passing under culvert.

Water from discharge end should be handled down fill slopes, where not flowing over rock, by some satisfactory method to prevent excessive erosion.

Tests upon this culvert have shown that a base plate or timber is unnecessary. It should be installed as received.

FIGURE 404

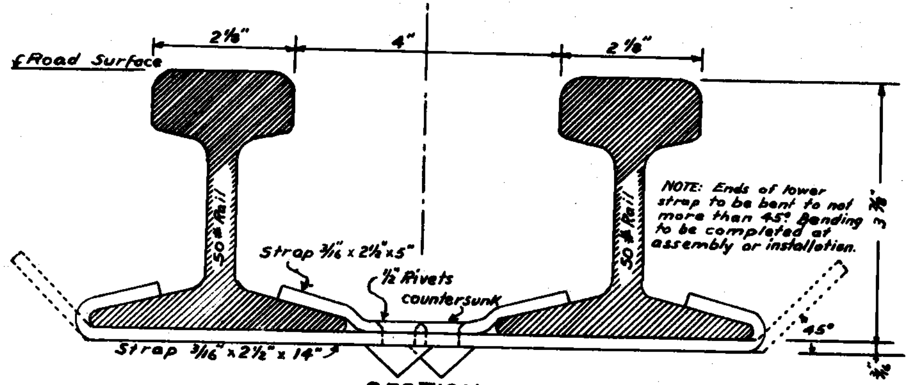
OPEN TOP CULVERT
RAIL TYPE



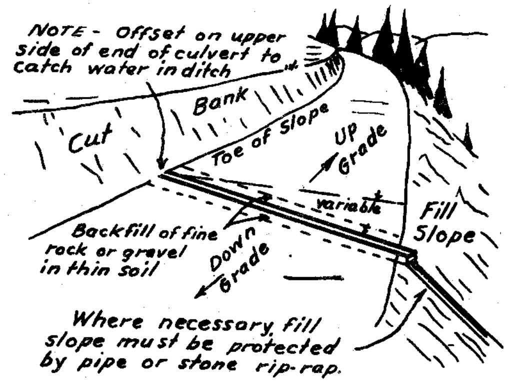
PLAN OF STRAP

INSTALLATION

Excavate a trench sufficiently large so that a layer of large rock may be placed under the culvert for foundation. Backfilling should be well tamped and of sandy material.



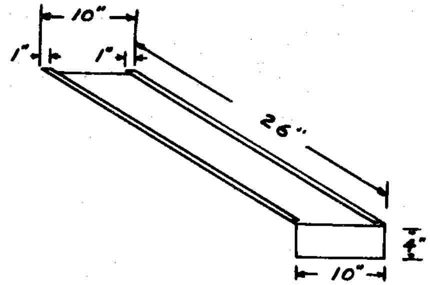
SECTION



METHOD OF INSTALLATION

BILL OF MATERIALS

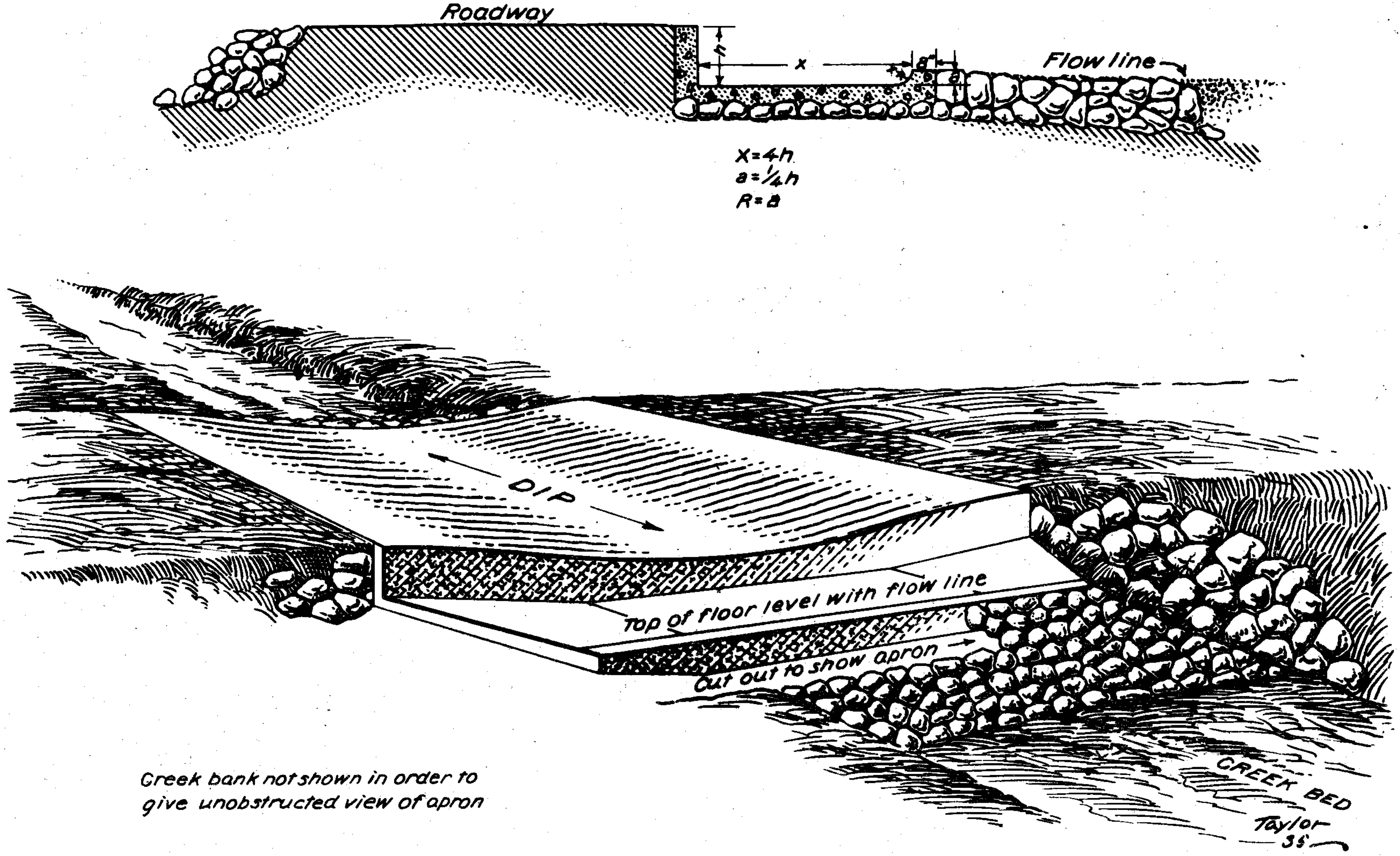
1- 50# Rail 33' long, cut to 16'0" & 17'0".
3- 3/16" x 2½" x 14" Iron straps, bent as shown.
3- 3/16" x 2½" x 5" Iron straps, bent as shown.
6- ½" Rivets - 2" long.
1- 12" x 30" - No. 26 gauge Galv. Iron Plate, bent as shown.



GALVANIZED IRON PLATE

To be used at outer end of culvert to deflect water from edge of fill and prevent undercutting.

FIG. 405



WALL AND APRON FOR ROAD DIPS

FIG. 406

The following types of structure are ordinarily used for cross drainage:

1. Bridges
2. Fords or dips
3. Culverts
    a. Galvanized iron corrugated metal pipe
    b. Paved invert corrugated metal pipe
    c. Galvanized iron multi-plate types
    d. Multi-plate arch on stone or concrete footings
    e. Standard corrugated arch types on stone or concrete footings
    f. Precast concrete pipe
    g. Cast iron pipe

SIZE OF DRAINAGE STRUCTURES

438. The three available methods of estimating the required size of drainage structures are:

(a) Measurement of channel, and observation of high water marks.
(b) Use of runoff tables. (This involves a measurement of the drainage area).
(c) Adequacy of other openings over some comparable stream.

Run-off tables when desired, should be obtained from the Regional Engineer.

When cloudbursts are common, the drainage should be adequate to take care of the run-off. If such occur only at long intervals, it will not be practicable in all cases to provide adequate drainage. Instead, it will probably be more economical to provide only for the maximum ordinary precipitation and to repair the damage resulting from occasional floods. When this practice is followed, the parties responsible for the location and design of the road should make adequate provision for accommodating excess run-off with the minimum damage to the road.

Cross Drainage Dips

439. The most important factor in the successful installation of dips in established water courses is to place a cut-off wall deep enough to insure stopping the flow under the dip. The dip finds a wide application in sections subject to cloudburst run-off, melting snow, or other periodic heavy run-off. This type of dip crossing meets a drainage problem that may not be successfully met with trestles and all sizes of pipe. A low place in the wall should be left to carry the flow. See Fig. 406.

The practice of placing one or more pipes in the dip to carry the ordinary stream flow has given satisfactory results. Under severe run-off conditions, a concrete slab may be necessary. This should be the full width of the road and of sufficient length to protect the sidewalls.

Culvert Materials

440. Timber, round or sawed. The use of wood having a life underground of less than 10 years is seldom justified. The cost of replacement in a few years must be weighed against the greater initial cost of metal culverts. In all cases, only the most durable timber available should be used. Where round or split timbers are used, do not skimp on size; use "big sticks."

441. Stone. In localities where good-sized durable flat rocks can be obtained readily for cover rock to span between walls, stone culverts are economical. Rock that will disintegrate rapidly should not be used. Where suitable cover rocks are not availalbe, walls may be laid up from local native stone and concrete, metal or even durable wood covers used. Metal culverts are usually more economical where good stone is not available.

442. Metal. Galvanized corrugated iron pipe is widely used. Such culverts properly installed have a long life and are preferable to other types in that metal culverts can be lengthened easily if the roadbed is widened. To facilitate handling extra long lengths, pipes can be secured in two sections and spliced together on the job. In placing an order, it is often advisable to include some short sections (2', 4', 6' lengths) and necessary connecting bands for use in lengthening culverts. Federal Specification QQ-C-806 should be used for the purchase of metal culverts.

442-A Bituminous Coated Culverts. Metal culverts with lower half coated, also called paved invert culverts, should be considered for use for carrying small, live streams where the grade of the culvert is over 8%. Specifications are enclosed in "Specifications for Road Equipment and Supplies", which is on file in each Regional Office.

443. Cast Iron and Concrete. Where cast iron and precast concrete culverts can be installed at approximately the same cost as other types, they should receive consideration. If carefully installed to prevent breakage, their life is indefinite.

Installing Culverts other than Open Tops

444. The selected site should be the best available from the following standpoints:

1. Economy of excavating for installation.

2. Utilization of natural watercourse to improve efficiency of inlet and outlet.

3. Stability of material at both inlet and outlet. Poor material at the inlet results in added maintenance and in decreased efficiency of the culvert. At the outlet it results in erosion.

4. No deviation from the natural water course, except for urgent reasons, and if used should not permit the formation of new erosion channels. If necessary, a paved channel should be provided.

5. No discharge on a fill section; if necessary to direct water from a natural channel, the discharge should be on native rock or on a prepared rock or other type of spillway so that new channels in native soil will not develop.

6. Installation on sharp curves except where natural stream beds are crossed should be avoided.

Relation to Grade of Road

445. Pipe culverts shall have a cover of at least one-half the diameter and not less than one foot at any one point.

Reinforced concrete and timber culverts may be placed in such relation to grade as economy of design and installation dictate. Direct impact loads from wheels increase the required strength of culvert tops; safety and possibly saving of material may be secured by placing the culvert well below grade.

Corrugated culverts should be installed with the same gradients as the streams, if possible. Gradients less than 3% will promote filling in the culvert, and gradients over 8% may cause excessive scouring. Where gradients exceeding 8% cannot be avoided in "live streams" only, the abrasive resistant type is preferable. Decided breaks in gradient of stream adjacent to the culvert, either above or below it, always causes deposition of suspended matter and should be avoided.

Inlets and Inlet Ditches

446. See Figure 407.

1. Each end of a culvert should be not less than $1\frac{1}{2}$ feet beyond the shoulder of the road. This is a minimum requirement; greater projection may increase the safety of travel and prolong the life of the culvert through protection against damage by vehicles.

2. The inlet of culvert should be connected to the road ditch by a lead-in ditch not less than 10 feet in length and with a uniform grade of not less than 3%. The ditch should be regular in shape, free from abrupt changes in direction and paved where necessary.

3. If inlets must be located in unstable material suitable catch basins, walls or rip-rapped banks should be provided.

4. Outlets must discharge clear of the fill section. Spill troughs or extra length culverts will be necessary on some locations.

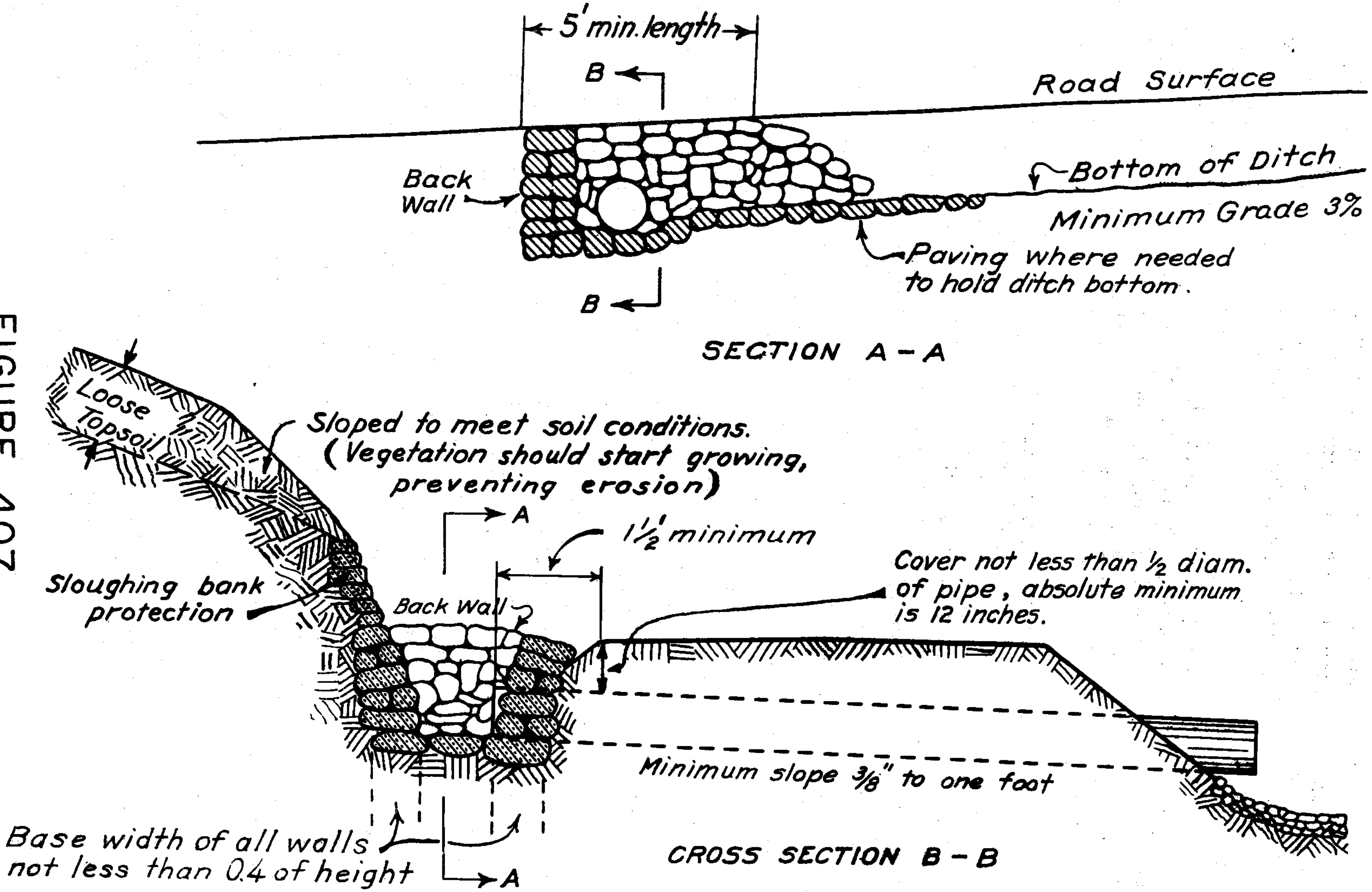
SUB-SURFACE DRAINAGE

447. The sub-surface drainage problem is to overcome the condition caused by marshes, seepage, rising water table of the surrounding ground, saturated hillsides, or capillarity acting through finely divided soil particles. It is poor practice to attempt to make a satisfactory roadbed on wet ground by surfacing alone; good drainage always comes first.

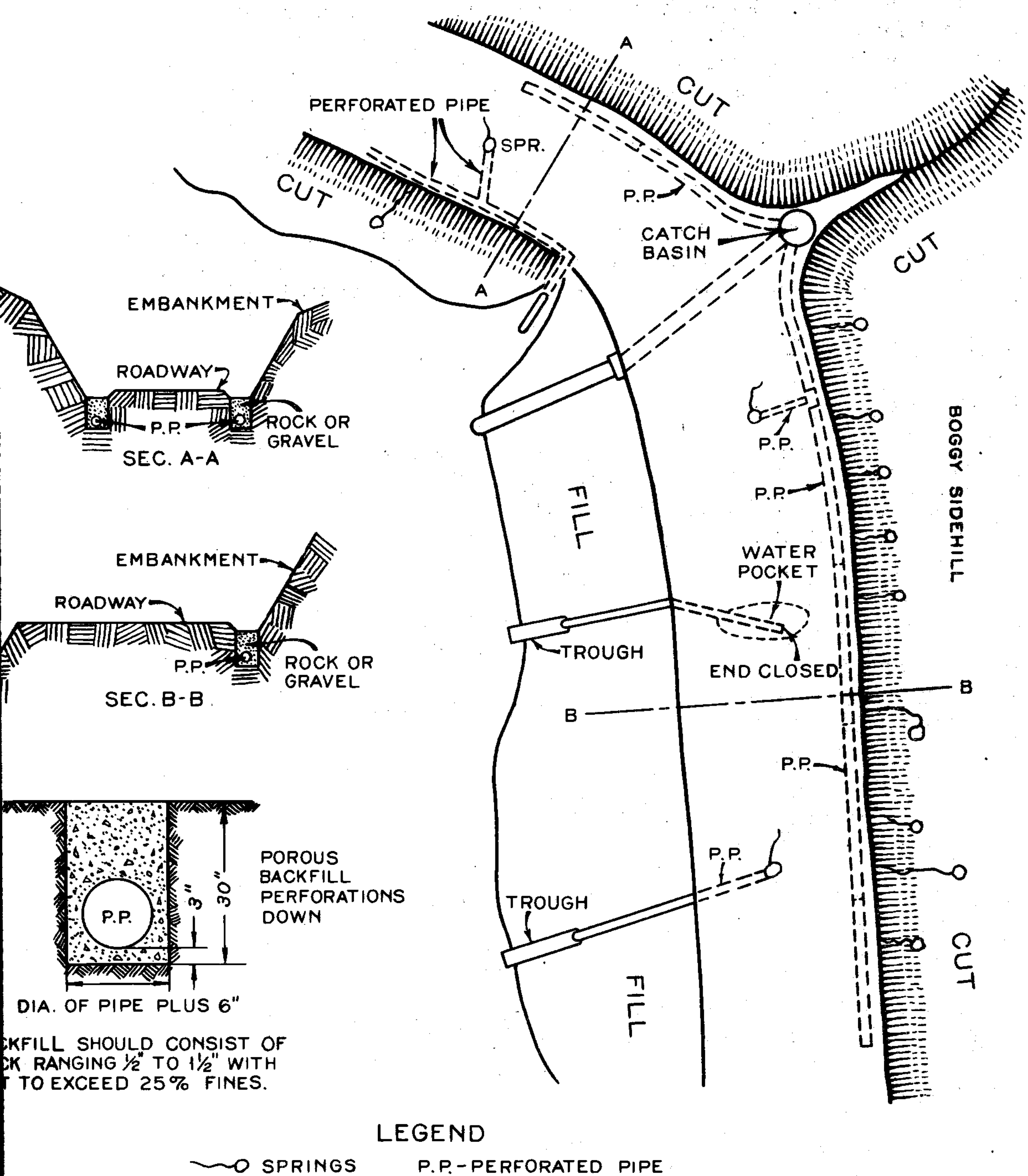
First cut off the source of the water. Deep intercepting ditches should be dug between it and the road. Frequently an intercepting ditch at some distance from the road will entirely cut off the water. Bank seepage on sidehill sections may necessitate a deep ditch on the inside of the road. In loose soil, rock walls should be used to protect the ditch from sloughing or caving. Sometimes it is advisable to construct a blind drain by covering the ditch with slabs of rock.

On flat marshy ground, care must be taken to give the ditches adequate depth and fall to carry the water away as rapidly as necessary. In soft ground it is sometimes advisable to leave a berm or unexcavated strip of ground from 3 to 5 feet wide between the fill and the drain ditch. This berm keeps the ditch water farther away from the truck trail and prevents the fill from sliding into the ditch. Use the material excavated from the ditch to build the fill if suited to that use; if not, waste it and borrow or haul in better material, rock or gravel.

FIGURE 407
PAGE 432



CULVERT INSTALLATION



SHOWING PERFORATED PIPE SYSTEM FOR SUBSURFACE DRAINAGE, ILLUSTRATING DIFFERENT METHODS; IT IS NOT EXPECTED THAT ALL DRAINAGE SHOWN WILL BE INSTALLED AT ONE SITE.

FIGURE 408

PAGE 433

In some cases good drainage cannot be obtained without prohibitive cost. When these occur a practicable solution is the use of buried corduroy. Good corduroy - the only kind it ever pays to build - is expensive and its cost should be weighed against the cost of adequate drainage with rock or gravel fill. If corduroy is used, it should be completely buried. Another method which may prove satisfactory where the soil is always wet is a brush mattress of good depth and well interwoven.

Perforated iron pipe make excellent subdrains and its use should be considered if an appreciable amount of subdrainage is to be undertaken. (See Fig. 408 for typical installation).

WALLS AND CRIBBING

RETAINING WALLS

448. General:- The force that a retaining wall must resist is "the horizontal thrust." This force will depend on the weight, angle or repose and kind of material retained. The weight of any equipment or structure resting on the fill must also be considered. (See Fig. 409 for typical retaining wall sections).

The pressure to which the retaining wall is subjected is directly proportional to the height of the retained material. Live loads imposed on a back fill section or material filled higher than the wall are designated as surcharge.

449. Types of Retaining Walls

1. Dry masonry
2. Wet masonry
3. Mass concrete in which little, if any, reinforcing steel is used and in which it is permissible to drop large boulders.
4. Reinforced concrete.

Dry masonry and mass concrete walls may be treated safely under the 50% base rule. Reinforced concrete walls should generally be designed by the Regional Engineer or his designated representative.

450. Safe Dimensions of Walls

For practical purposes in all average conditions, a safe retaining wall is obtained by incorporating the structural features listed below and in providing a base width equal to 50% of the height. This rule provides for normal live loads, up to 15 tons, and gives a safe wall for actual surcharges up to 6 ft. above the height of the wall. (See Fig. 409 for dimensions of a standard wall).

Be sure that:

1. At least one-fourth of the front and rear face of the wall is composed of headers of a length not less than two and a half times the thickness.

2. All headers are laid with their greatest dimensions extending into and never parallel to the wall except at corners in which case alternating headers should cross.

3. The front and rear face are well tied together with good, big header stones. Under no conditions should a face course be laid up of any kind of rock and the space behind it filled with small rocks and dirt as the wall goes up.

4. Projecting points that prevent stability of the wall are removed from the top and bottom of main rocks.

5. A minimum thickness of 12 inches at the top of wall is provided.

6. The outer face of wall has a batter, or a slope inward, of at least 3 inches to each foot of height. The inner wall can be vertical if necessary. The width of base, width at top and batter of front face determines the batter of rear face.

7. Joints in walls are broken, or staggered at least 6 inches. In other words, a joint should be 6 inches or more horizontally from the adjacent joint in the next course.

8. Drainage for the back-fill is provided by porous material, or a pipe through the wall.

Hand Laid Fills

451. Where rock is plentiful, it is occasionally desirable to secure the necessary width of roadbed by laying up a rock fill on the outer side of the embankment. If good-sized angular rocks are available, a fill can be laid up on a 1:1 slope in much less time than required to build a rock wall. It is only necessary to slide the rock roughly into place, being careful to allow plenty of slope. If the face is steeper than 3/4:1 with anything but very large angular rocks, it is probable that a standard rock wall should be used.

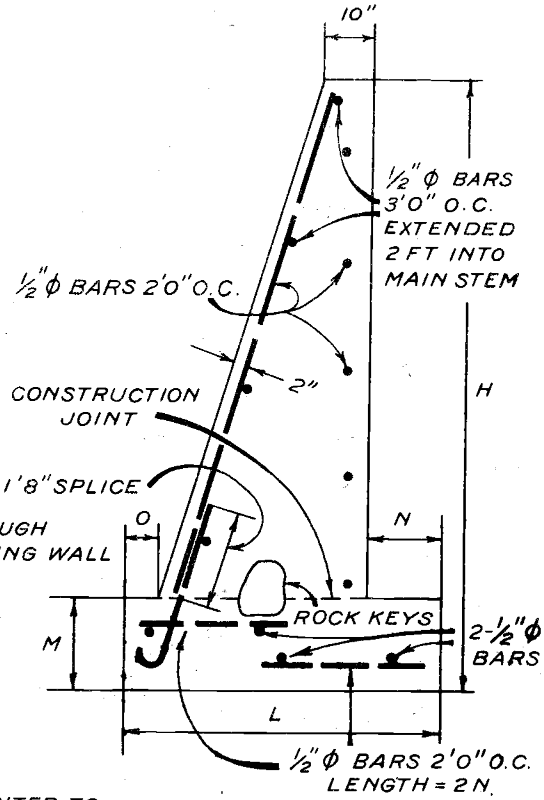
CRIBBING

452. Types of Cribbing

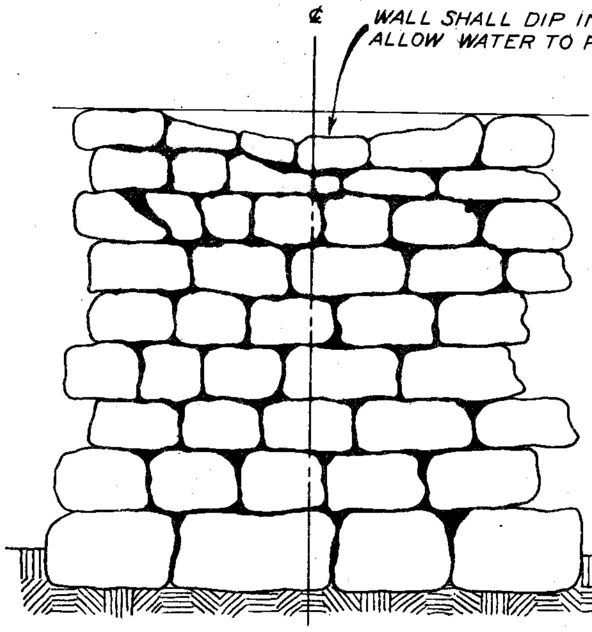
The most common type of cribbing in use by the Forest Service is timber. However, on many jobs it would be economical to use precast concrete, galvanized metal, or creosoted timber.

CONCRETE RETAINING WALL

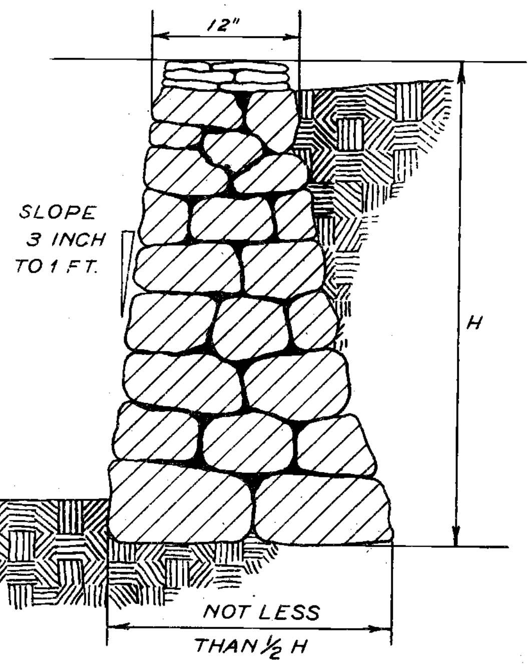
TOTAL HEIGHT H	BASE				CU. YDS. LIN. FT.
	WIDTH L	THICKNESS M	TOE N	HEEL O	
4'	2'-0"	1'-0"	6"	6"	.15
5'	2'-6"	1'-0"	6"	6"	.27
7'	3'-6"	1'-0"	9"	6"	.48
9'	4'-8"	1'-4"	1'0"	6"	.80
11'	5-9"	1'-8"	1'-3"	8"	1.13
13'	6'-10"	2'-0"	1'-6"	10"	1.59



SECTION THROUGH CONCRETE RETAINING WALL

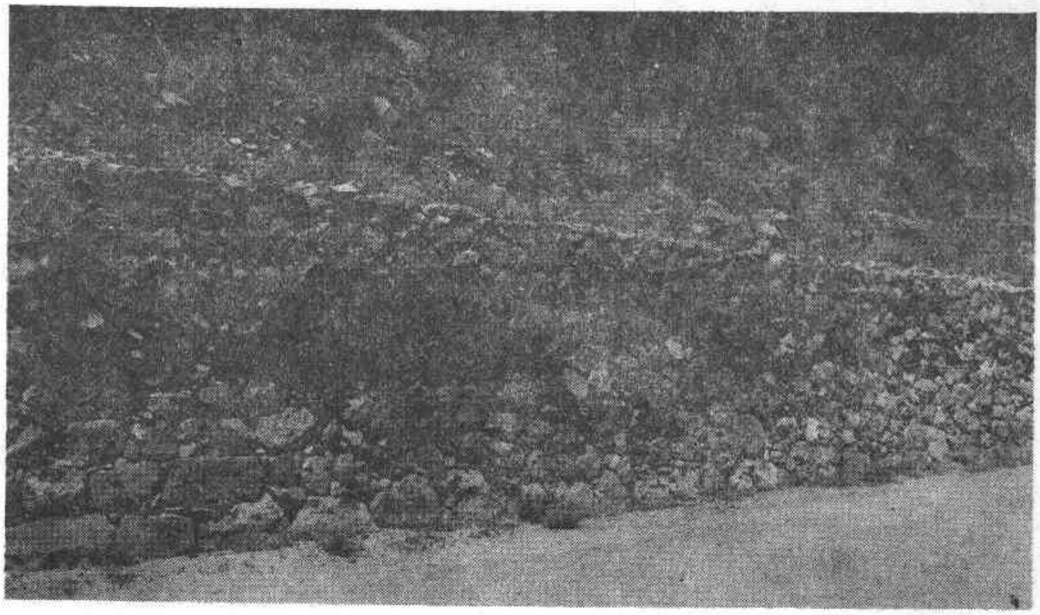


SIDE VIEW

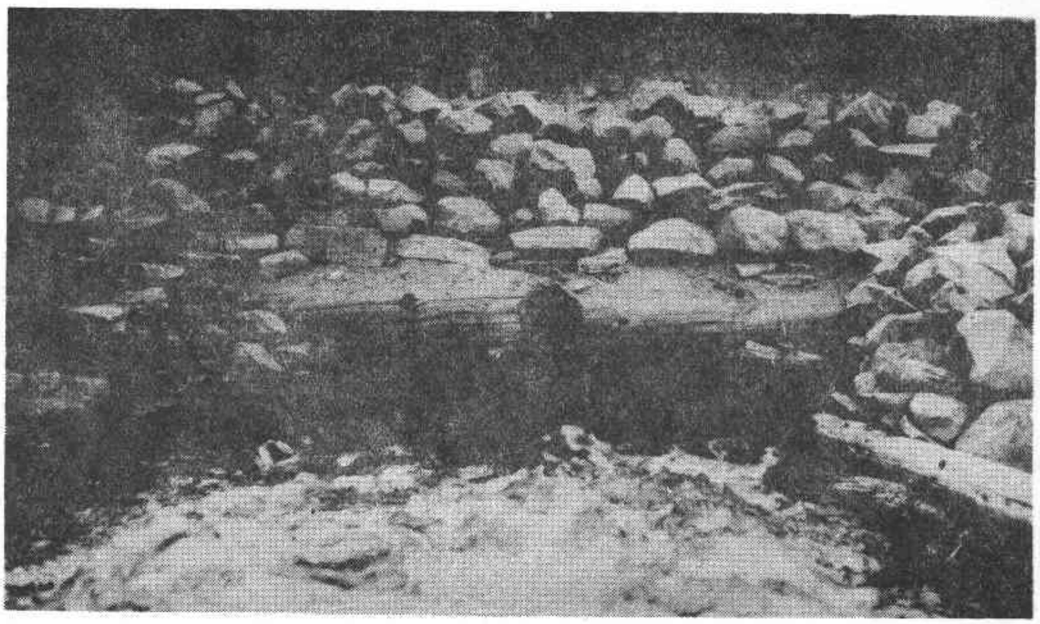


SECTION THROUGH ROCK RETAINING WALL
FOR RETAINING WET MATERIAL
USE CONCRETE WALL

FIGURE 409



Illustrating a well constructed wall. Note large stones in the bottom courses, the way the rocks overlap to effect a bond between courses, and adequate headers placed with longest dimension perpendicular to wall.



A poorly laid rock wall. Note poor arrangement of rocks and use of logs in construction. Absence of bond is very apparent.

FIGURE 410

Timber Cribbing

453. Use only the most durable timber available even though necessary to go a considerable distance. It is very doubtful if placing second-growth pine or fir in such structures is ever justified. All logs must be peeled. See Fig. 411.

The following is essential in good cribbing:

1. The ends of the base log of the cribbing must have a good bearing upon a stable foundation for at least 2 feet. Preferably the base log should have such a foundation throughout its entire length.

2. All tie logs should be well notched over the face logs and inner course logs.

3. All tie logs on sidehill work should have a pitch toward the hill of three inches per foot and should be extended well into the bank and be joined in the rear with cross logs in order to develop the greatest possible stability.

4. In soft ground the space between logs should be chinked with rocks or pieces of wood.

5. Batter with the ratio of three inches per foot of vertical height should be provided.

SURFACING

454. Importance

Not only have certain projects failed to give continuous satisfactory service because of poor surface conditions but there are many other miles which would give satisfactory service if surfaced in spots or for sections of considerable length.

The length of the period in each year that a truck trail is rendered unserviceable because of poor surface should be weighed against the relative importance of keeping it in good condition for travel.

455. Materials for surfacing

For surfacing truck trails, lava, cinders, gravel, disintegrated grante or other natural surfacing material can be used. Schist, sandstone, and ordinary slate are poorly adapted for wearing surfaces because of their softness. Their use at times may be necessary and the expenditure justified. The harder rocks, such as trap rock, limestone, granite, andesite, etc., are more satisfactory surfacing materials.

The practicability of improving sandy soils by adding clay or of bettering clay soils by adding sand should be fully determined.

A method commonly used is to spread over the roadbed a course of sand or clay, as the case may be, then scarify or harrow it to a suitable depth. Traffic is depended upon to compact the mixture. Frequent dragging or working with a grader in the meantime is necessary. If the first rains show the mixture to be not right, sand or clay should be added until the right condition is developed.

When any doubt exists as to the suitability of the available material for surfacing, it should be examined by a competent engineer and tested if necessary. The Bureau of Public Roads and most State Highway Departments have testing laboratories for such purposes.

Surfacing gravel is usually classified as follows:

1. Pit run or run of the bank. This is material taken out of the pit and placed on the road without screening or sorting other than the selection of portion of bank used. Aggregates larger than #3 stone should be raked to the side of the truck trail.

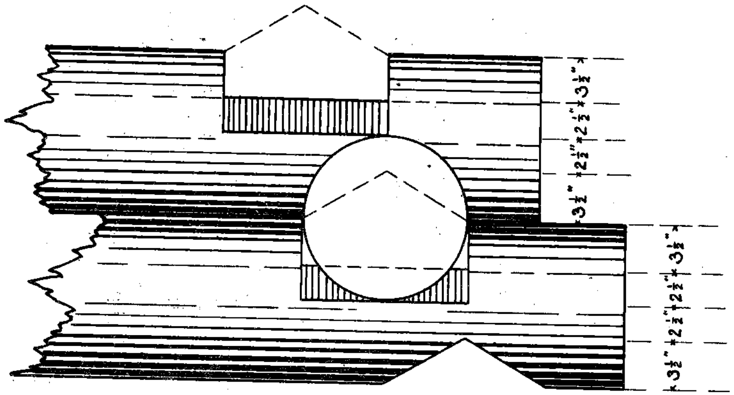
2. Screened gravel.

3. Crushed rock or crushed gravel.

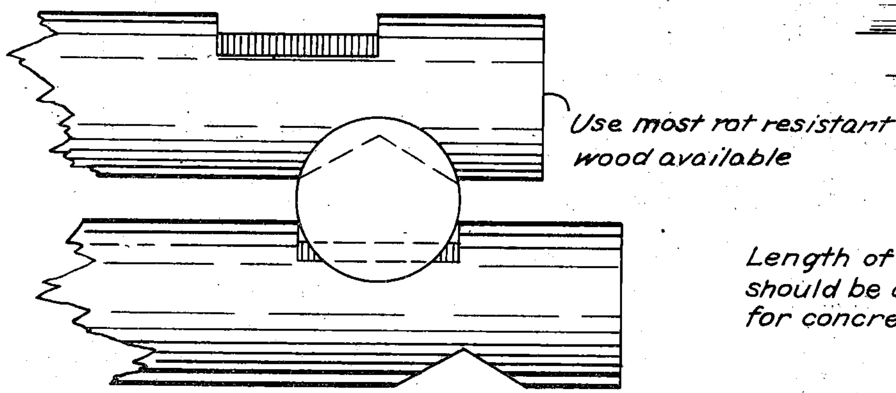
To make a good surface, the material should have not only adequate wearing qualities but should contain enough binder to compact under travel. If the surfacing material does not contain enough binder, binding material should be added. Do not add more than is needed; an excess will spoil the surface. The best natural binder is clay.

456. <u>Crushed Rock Surfacing</u>

Crushed rock surfacing should be in accordance with one of the following classes which are designated as Class A, Class B, and Class C. The class of surfacing to be used will depend on the importance and classification of the project in the Forest Road System and the volume and kind of traffic to be carried. Class A surfacing should be used only on Class 3 Forest Highways and the more important development projects which may carry a considerable volume of traffic or heavily loaded vehicles, and which serve as trunk line roads in the Forest Road System.

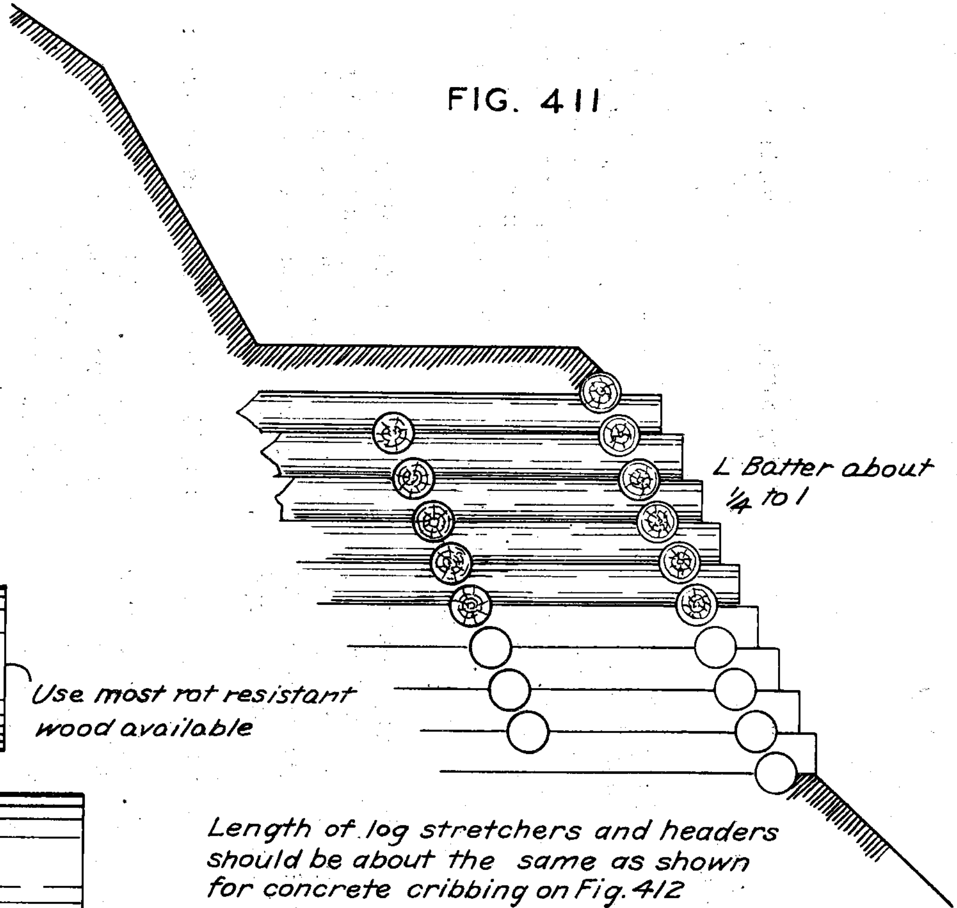


Detail of Dap for Earth Fill

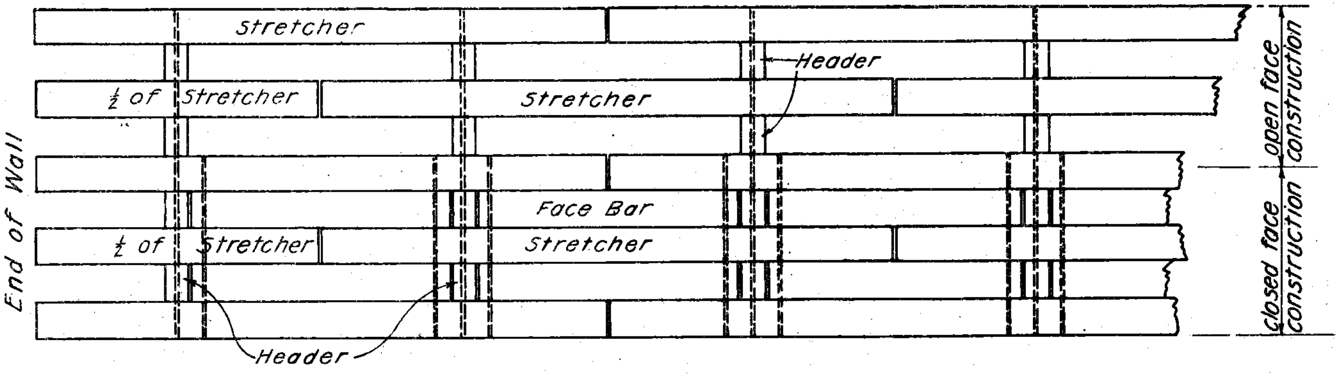


Detail of Dap for Rock Fill

FIG. 411



LOG CRIBBING



Elevation

NOTES

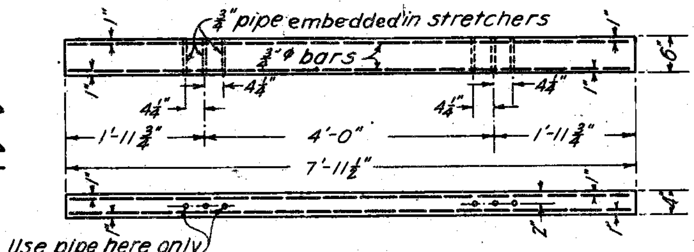
Galvanize pipe and dowels after cutting.

When a closed face is desired cast 3 pieces of pipe at each connection in each stretcher and fill the spaces between stretchers with headers for face bars.

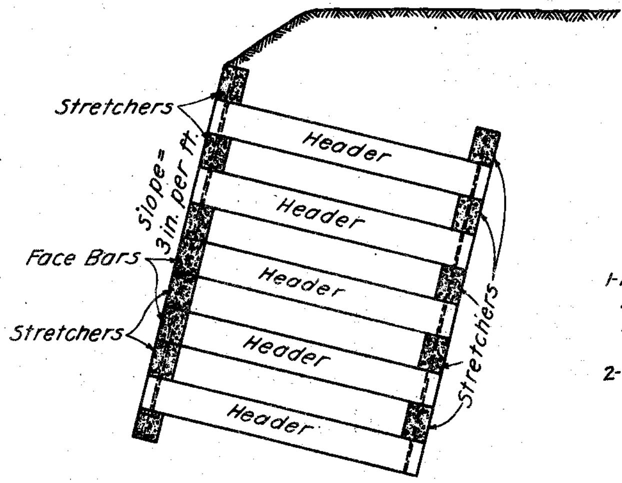
Excavate to firm material for foundation.

ESTIMATED QUANTITIES PER SQ. YD. OF WALL

Stretchers = 2¼ Bars
Headers = 2¼ Bars
If closed face is desired add 2¼ headers per sq. yd. of wall for face bars.



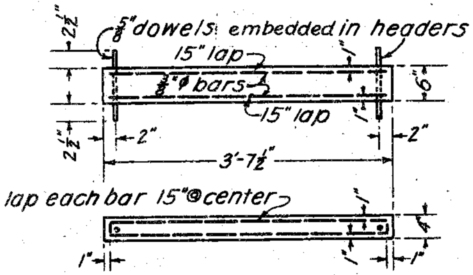
Detail of Stretcher



Section

SPECIFICATIONS

1-Reinforcing Bars - F.S.B. 350a, Type B, Grade I, Deformed structural Class (a) or (b) open hearth steel.
2-Concrete - Class A-½"



Detail of Header

NOTE.
For end finish of wall cast ½ of stretcher by cutting off bars and set stop block in the middle of the form.
For curved walls change the length of the stretchers in the rear face to suit the curvature.

REGION-7
PRECAST CONCRETE CRIBBING
FOR RETAINING WALLS
HEIGHTS TO 10 FT.

HEC

FIG. 412

457. Subgrading

The subgrade should be "trenched" to conform to the cross-sections for the different widths and types of surfacing. The depth of the trench shall be that required for the thickness of surfacing to be placed, due allowance being made for settlement and thorough compaction of the shoulders.

The subgrade shall be in such condition that it will drain rapidly. Trench drains should be constructed through the shoulders as may be needed to drain the trench. The subgrade shall be prepared in final condition for receiving surfacing material in advance of the placing of the crushed rock, a distance equal to that required for not less than two days' operation. Judgment should dictate the amount of finished subgrade at all times.

458. Classes of Surfacing

Class A.

(1) For double track truck trails (graded width 20 to 22 feet). - Class A surfacing shall be placed in a trench 16 feet wide and in three courses of stone consisting of base course 3 inches thick of #3 stone, middle course 3 inches thick of #2 stone, and top course 2" thick of #1 stone, or a total uniform thickness of 8 inches, loose measurement.

(2) For single track truck trails (graded width 13 to 15 feet). - Class A surfacing shall be placed in a trench 9 feet wide and in three courses. The total thickness shall be 8" at the outer edge and 4" at center, loose measurement. The base course shall be of #3 stone of varying thickness with a maximum of 3" at outer edge, the middle course, shall be #2 stone of varying thickness with a maximum of 2" loose at center and 3" loose at outer edge and the top course shall be #1 stone 2" loose uniform thickness,

Class B

Class B surfacing shall be placed in two courses consisting of a base course 2 to 3 inches thick of #2 stone and a top course 2 inches thick of #1 stone, or a total thickness of 4 to 5 inches, loose measurement.

Class C

Class C surfacing shall consist of a single course of approximately 2 inches uniform depth by 8 ft. wide of crusher run stone, the maximum size to be not greater than that which will pass 1" circular openings in a revolving screen.

The thickness of the surfacing material may be increased or the section modified when, in the judgment of the Regional Engineer, subgrade conditions require such changes.

After the shoulders have settled or been compacted they should be brought to grade and 1 inch (loose) of #1 stone spread over them evenly.

459. Size of Stone

#1 Stone

#1 stone shall consist of all material (including stone dust) which will pass 3/4" circular openings in a revolving screen.

#2 Stone

#2 stone shall be retained on 3/4" diameter openings and pass 1-1/2" diameter openings in a revolving screen.

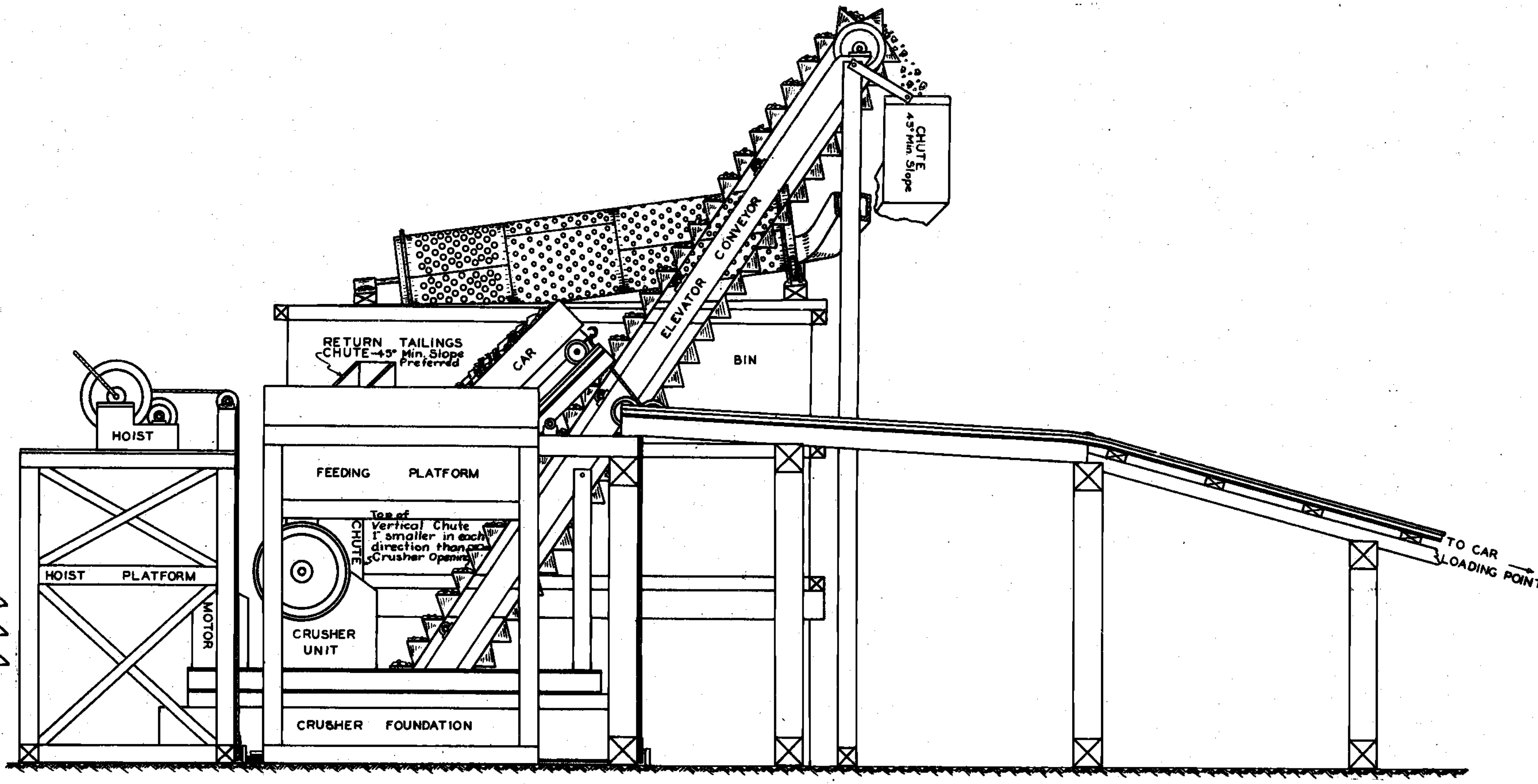
#3 Stone

#3 stone shall be retained on 1-1/2" diameter openings and pass 3" diameter openings in a revolving screen.

460. Placing the Material

Crushed stone should be evenly spread on the subgrade to such a depth that it will have a thickness (loose measurement) as specified above and as shown on the typical sections. Stone should be spread to the required thickness for each course directly from the dumping devices. Shovels and rakes should be used to spread each course evenly and bring it to the proper cross-section. Each load of stone should be spread over a pre-determined distance as computed by the construction superintendent to provide the desired thickness.

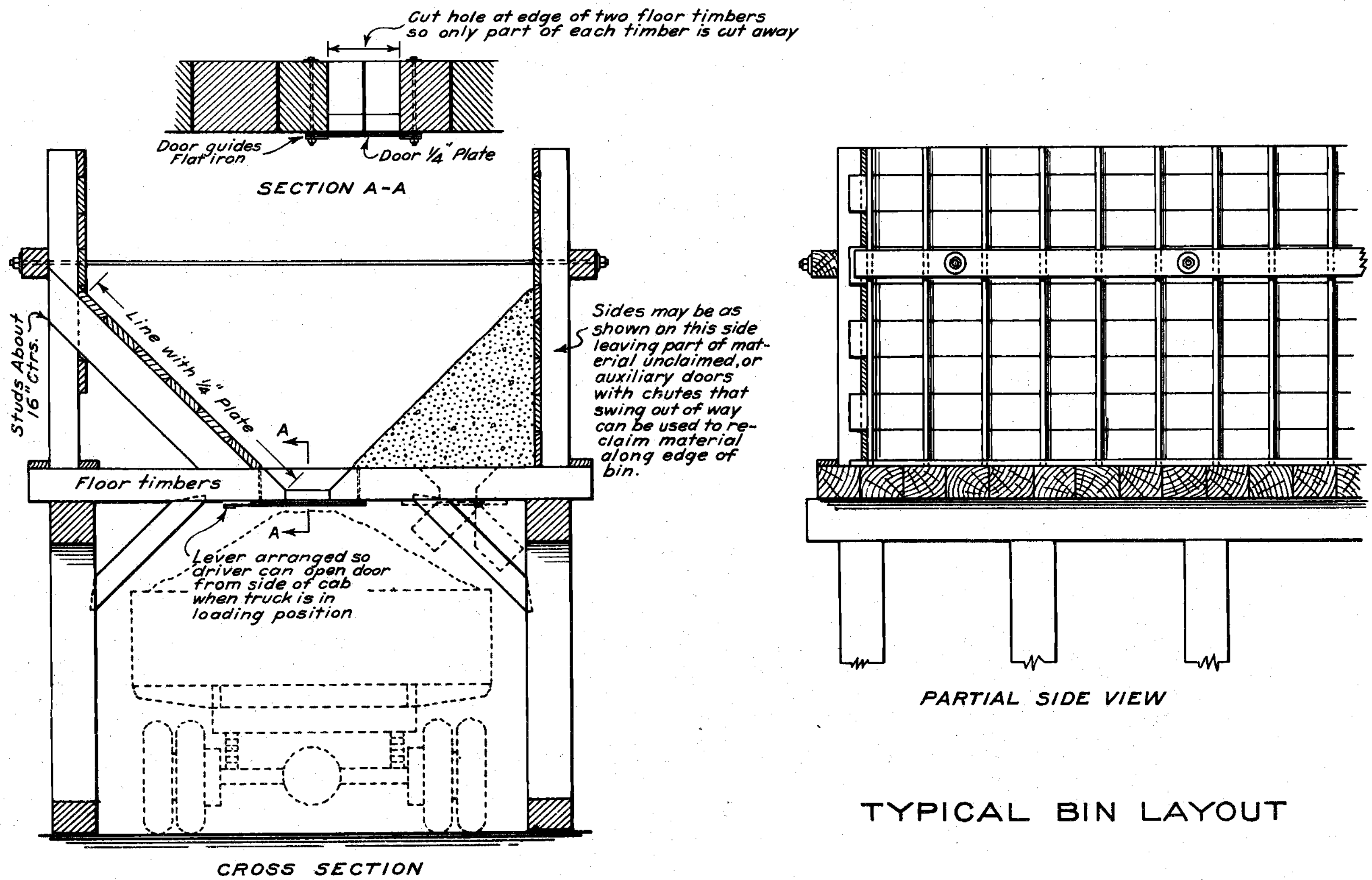
Beginning the day after it is laid and continuing each day for three successive days thereafter, the newly laid surface should be reshaped with a road machine weighing not less than 6000 pounds. Additional reshaping of the surface should be done after settlement and at such times as the road superintendent deems such operation necessary.



SIDE ELEVATION

TYPICAL REGION 7
CRUSHER SETUP FOR
GRAVITY RETURN
OF TAILINGS

FIG. 413



TYPICAL BIN LAYOUT

FIG. 414

There should be an interval of time between laying the courses sufficient for the lower courses to be compacted with some of the soil in the subgrade working up to fill the voids and stabilizing the stone. The subgrade will have some weak places that will develop under traffic and the depressions will be filled as the stone is bladed back and forth. This plan may require stockpiling of #1 and possibly #2 stone to allow the lower courses to get ahead, but the fine material in stockpiles can be utilized later for construction or possibly for maintenance.

When the subgrade is soft or muddy and it is necessary to proceed with the surfacing without waiting for it to dry out; the subgrade may be stabilized with a thin layer of #1 stone.

Quarrying

461. In working a cliff of rock for quarry purposes carefully analyze the most effective spacing and location of holes and powder charge to get the maximum shattering effect on the cliff. Seamy or laminated deposits of rock may break up or shatter better by using "coyote hole" method. Monolithic deposits usually work better by drilling staggered holes with air hammers. In working monolithic deposits it usually develops that after a quarry site is opened up, the most economical stones are had by working the quarry floor down rather than continuing to work back on the cliff. This gives greater shattering effect from the powder and usually the stone in such deposits shatters better at the lower strata than at the surface strata.

Crushing

462. Do not attempt to handle stone from quarry to crusher in wheel barrows. An important consideration is to reduce the loading height of the stone in the quarry. The crusher and bins should be so located as to facilitate the loading and movement of trucks. See Figure 413 for typical crusher set-up.

Tram cars should usually be of the end dump type to get low loading height. The dump of such cars can be accomplished by a tipping rail platform at the crusher deck or by spread rails.

Drag line buckets are an effective transporting medium from quarry to crusher when blasting produces rock of a size that can be taken by the crusher with little or no additional breaking. If necessary to "pop shoot", "blockhole" or otherwise reduce in size an appreciable quantity of boulders in the quarry, drag line bucket installations are of questionable value.

463. Bins. The important consideration in the layout of bins is to obtain ready discharge of material from bins and to have the bins accessible to the transporting vehicles. Discharge of material is usually best accomplished by a bottom gate dump type bin. In handling damp or wet materials it may be necessary to provide a bottom in the bin that slopes to the discharge gate. Usually such bottoms are more economically provided by constructing a conventional flat bottom bin without decking and then put in a false bottom on approximately a 100% slope. The slope of the bottom will depend on the material worked. (See Fig. 414 for typical bin layout).

464. Unless considerable surfacing is anticipated in a Region or locality, the cost of surfacing equipment and set up can seldom be justified on a single job. It may be more economical to contract the surfacing job or to rent surfacing equipment. Hence, before undertaking a surfacing job, carefully consider the initial cost of quarrying and crushing equipment and the high installation and operation costs of such heavy machinery.

465. Tables showing the theoretical quantities of material required per station or mile for various depths and widths of surfacing are in Field Tables. Such tables must be based on some assumed average degree of compaction. This factor fluctuates to such an extent that equally reliable results may be obtained by theoretical computation of the volume of stone per station or mile and applying to these results a coefficient obtained by experience or test with the specific materials used.

SECTION V

EXPLOSIVES

GENERAL DESCRIPTION OF EXPLOSIVES

Action of Explosives

500. Commercial explosives are solids or liquids that can be instantaneously converted by friction, heat, shock, sparks, or other means into large volumes of gas. While the conversion of explosives into gas is much quicker than converting water into steam it is essentially similar. When fired or exploded, they simply change into another form, largely gaseous, having many times greater volume. This increased volume exerts both a blow and a pressure on the confining material. It is this action that is effective in blasts.

The pressure acts equally in all directions, but the gas tends to escape through the path of least resistance, or the easiest way out. All explosives, in this respect, act in exactly the same manner, and therefore, no matter what explosive is used, loading and tamping must be done very carefully in order to confine the gas so that it will be forced to work upon the material to be blasted.

For performing this work, the blaster must consider the choice of explosives, supplies for firing the explosives used, methods of preparing bore holes, and methods of loading and firing.

Only explosives on the U. S. Forest Service Acceptable List of Explosives may be selected.

High Explosives

501. High explosives include all of the dynamites --- nitro-starch, ammonia, nitroglycerin and gelatin types. All of these are detonating explosives. That is, they are fired by shock from an intermediate agent called a detonator or blasting cap.

In selecting high explosives, many factors must be taken into consideration. Some of the principal characteristics are strength, velocity or shattering effect, water resistance, sensitivity, temperature of freezing, ignitability, and fire-setting ability. (Explosive engineers call fire-setting ability, "Incendivity").

Strength

502. By this term is meant the power or force developed by the explosive. The straight, or nitroglycerin, dynamites are rated on the percentage, by weight, of nitroglycerin which they contain. Thus a 40% straight dynamite contains 40% of nitroglycerin. The strength developed by this type serves as a basis for the grading of all other dynamites. Thus the percent strength grading of any other kind of dynamite means that it will release as much force as an equivalent grade of the straight dynamite weight for weight.

The relative energy contained in the different strengths of dynamite is greatly misunderstood by many users. The prevalent opinion is that the actual energy developed by the different strengths is in direct proportion to the percent markings. This is not true. For instance, 40% dynamite is less than twice as strong as 20%, and 60% is less than three times as strong as the 20%. The simple ratio does not hold because the ingredients other than nitroglycerin and ammonium nitrate, which enter into the composition of dynamite, have some explosive strength of their own when mixed with nitroglycerin.

Careful laboratory tests have been made which show the energy in each particular strength of dynamite. The results of these tests show that 30% is 1.16 times as strong as 20%, that 40% is 1.31 times as strong as 20% and that 60% is 1.50 times as strong as 20%.

Velocity

503. The rate of exploding or detonating is spoken of as velocity, or sometimes as quickness. Some high explosives detonate more quickly than others, and their shattering effect is accordingly greater. For this reason the lower percent grades are used for stump blasting and loose rock formations and the higher percent grades for hard rock, springing and mudcapping.

Water Resistance

504. High explosives differ greatly in their power to resist water. In dry work this is of no importance, but when much water is encountered, a water-resistant explosive is necessary. If the blasts are fired soon after loading, the use of an explosive intermediate as to water resistance is found satisfactory. Thus ammonia dynamite can be used satisfactorily where water stands in the holes, if the blast is fired immediately after the holes are loaded; whereas if the explosive is to be left under water any length of time, a gelatin or semi-gelatin dynamite must be used.

Propagation Sensitiveness

505. Propagation sensitiveness is the property which causes an explosive to detonate when subject to shock. The test for propagation sensitiveness is made by placing the two halves of a $1\frac{1}{4}$" x 8" stick in a roll or type of paper. The two halves are separated a few inches so that the roll will be $1\frac{1}{4}$" in diameter but will be longer than 8". The lining paper in dynamite cases, or its equivalent, should be used. One half of the cartridge is detonated with a #6 cap. The spacing between the two halves is varied to determine the maximum distance at which the primed half will explode the other half. This distance in inches is known as the propagation sensitiveness of the powder tested. In general, high velocity explosives are more sensitive than low velocity explosives. Explosives low in velocity and in sensitiveness are not desirable for use where fire hazard exists.

Temperature of Freezing

506. Practically all commercial explosives are now low freezing. They will not freeze under ordinary exposure to such atmospheric temperatures as occur in this country. These may or may not be marked "L.F.", but in general, it may be said that explosives from reputable manufacturers are non-freezing.

Ignitibility Index

507. Ignitibility index is the term used to indicate the property of explosives which causes them to ignite, or burn, when exposed to heat. Standard tests of ignitibility are conducted by the Bureau of Mines, The explosive is exposed to a standard flame. The index is the mean of the maximum time for three non-ignitions and the minimum time for three ignitions divided into 100. Explosives with an ignitibility index greater than 250 should not be used where fire hazard exists. Different types, or strengths within the same type, may have a widely varying index and therefore an explosive cannot be judged by tests of some other brand of the same general type or by tests of anything except the particular brand, type and strength in question.

Incendivity (Fire-setting Ability)

508. An explosive having the least flash or fire-setting ability is peculiarly adapted to Forest Service use during extreme dry periods when the humidity is low. Tests are now being made by the Bureau of Mines' explosive engineers to determine the explosives best suited to Forest Service work during the high fire hazard periods. Inflammable litter should not be used for stemming of any explosive. Until the selection of the "special fire season explosives" is available, extreme caution should be used in firing shots during the hazardous fire periods.

Acceptable List

509. The explosives used on Forest Service work must be on the Forest Service List of Acceptable Explosives. (See Table 501 for recommended types of explosives).

This list of explosives has been prepared by the Bureau of Mines for Forest Service use. The explosives are enumerated are peculiarly adapted to our work. As other explosives are tested and found suitable, or the explosive manufacturers develop new explosives, or as existing brands are changed or their manufacture discontinued, the lists will be changed. It is mandatory that these explosives be used for Forest Service work.

TABLE 501

Approved Types of Explosives

The Type A, Class 7; and Type B, Class 2^b are free flowing bag explosives.
The types are selected from the Forest Service Acceptable List and are offered as a guide.

Use	First Choice			Second Choice			Third Choice		
	Type	Class	Grade	Type	Class	Grade	Type	Class	Grade
Quarry or solid rock drill holes, etc.	A	4	40%	A	2	40%	A	2 or 7	60%
	A	7	40%	B	1^b	40%	B	$1^a\ 2^b$	60%
	B	$1^a1^c2^b$	40%						
Wet holes	A	4	40%	A	1	50%			
	A	6	60%						
Mudcapping or bulldozing	A	2,4	60%	A	2,4	40%			
	B	1^a1^b	60%	B	1^a1^b	40%			
Hardpan, Cement Gravel	A	2	20%	A	2				
	A	7	20-30%	B	2^b	40%			
	B	2^b	20%			30%			
Stump Shooting Ordinary clay soils, etc.	A	2	20%	A	4	30%			
	B	$1^a1^b2^b$	20%	B	$1^a1^b2^b$	30%			
Stump Shooting Loose, sandy or Volcanic soils	A	4	40%	A	4	30%			
	B	1^a1^c	40%	B	1^d	30%			
Soil Erosion Control Gully Bank Blasting	A	7	20%	A	2	20%	A	4	30%
	B	2^b	20%	B	1	20%	B	1^a	30%

Do not use Gelatin for mudcapping, because when shot without proper confinement, its action is relatively slow.

TRANSPORTING EXPLOSIVES

Regulations

510. Any person having occasion to handle or use explosives should familiarize himself with all Federal, State and local laws and regulations and comply with them.

The Federal Act of March 4, 1909, revised March 9, 1921, provides in Sections 232, 233, 234, 235 and 236 that it is a criminal act:

(a) To carry or cause to be carried any explosives (other than exceptions named) in a train, boat, trolley or other vehicle carrying passengers for hire; or

(b) To deliver or cause to be delivered to a common carrier for transportation any explosives under false or deceptive marking or description on the package, invoive or shipping order; or

(c) To violate or cause to be violated any regulations of the Interstate Commerce Commission relating to the marking, shipping or handling of explosives.

(d) A violation of any of the provisions of this law is punishable by fine of not more than $2,000 or by imprisonment of not more than eighteen (18) months or both; or if injury or death results from such violation by fine of not more than $10,000, or by imprisonment for not more than ten (10) years or both.

Unloading Cars

511. In the case of a carload shipment, an inspection should be made on the arrival of the car to ascertain whether its contents are in the proper condition. Occasionally, rough handling in transit may telescope cases or break them open so that there will be loose explosive between cases or on the floor. If inspection reveals such a condition in a car of high explosives, the workmen who are to unload the car should be warned to avoid every chance of friction against the loose explosive that might cause an explosion in the car. As soon as a sufficient number of cases has been removed from the car to make it feasible, the loose explosive should be carefully swept up, spread on the ground at a considerable distance from the cases of explosives, and burned, taking care to light the explosive in such a way as not to be burned by the flame.

Cases containing explosives should always be lifted and set down carefully, never slid over one another nor dropped from one level to another.

Vehicle for Transporting

512. The vehicle provided to transport explosives from the railroad to the magazine should be strong and substantial and in good working order. A closed body is best. If an open bodied vehicle is used, the ends and sides should be high enough to prevent packages of explosives from falling off, and the load should be covered with a fire-resistant tarpaulin. The floor should be of wood, and any metal in the body likely to come in contact with the cases should be covered with wood.

A truck should never be overloaded with explosives, nor should packages of explosives be placed in such a position that they may fall off.

Neither blasting caps nor electric blasting caps should be transported in the same bed or body of the vehicle with explosives, nor should metal tools, carbide, oil, matches, fire-arms, electric storage batteries, inflammable substances, acids or oxidizing or corrosive compounds. Explosions have occurred on vehicles transporting explosives with some of these commodities.

Bale hooks or other metal tools should never be used for loading or unloading explosives.

Rule for Driver of Truck

513. The truck for transporting explosives should be driven by and in charge of a driver who is careful, capable, reliable, able to read and write the English language, and not addicted to the use of intoxicants or narcotics. He should never smoke while on or near the truck, nor carry matches, fire-arms or loaded cartridges. He should be familiar with road rules and also with the state laws and the local ordinances and regulations governing explosives in the cities or other municipalities in and through which it is necessary to travel or pass, and should comply with them. He should have the truck always under complete control and should never allow it to coast down hill. He should, of course, be familiar with the proper manner of handling explosives.

All trucks transporting explosives must be equipped with an adequate fire extinguisher. The extinguisher should be accessible at all times and tested frequently.

Unauthorized persons should never be permitted to ride on trucks transporting explosives.

When transporting explosives, the truck should come to a full stop before crossing any railroad track and should not attempt to cross the track until it is known that the way is clear and that a train or engine is not approaching.

The truck engine should always be stopped when gasoline is being put into the gasoline tank.

A truck containing explosives should never be left without first stopping the motor and securely setting the brakes. When transporting explosives over the highways, it is advisable to avoid unnecessary stops. Stops for meals should be made at some wayside restaurant and the truck should be left well away from traffic and parked vehicles. A truck containing explosives should never be taken into a garage or repair shop.

Explosives should never be left anywhere unless they are placed in a magazine and the magazine is locked, or are delivered to some one authorized to receive them. In unloading, packages of explosives should never be piled immediately back of the exhaust, as a spark may start a fire and cause an explosion.

It is safer to transport explosives in daylight. If lights other than the truck lights are necessary, only an electric flashlight or an electric lantern should be used.

STORING OF EXPLOSIVES

Importance of Proper Storage

514. The storage of explosives has a much deeper relation to safety in their use than is commonly realized. Improper storage of explosives and detonators leads directly to:

(a) Misfires
(b) Incomplete detonation which leaves unexploded dynamite in the bore hole or thrown out among the blasted material
(c) Burning of charges in the bore holes.

Even a small leak in a magazine roof may allow a few cartridges of explosives to become wet, and the use of these cartridges may result in either misfire or incomplete detonation. A dilapidated magazine, or a magazine with floors close to wet ground, or any condition of storage which would expose ammonium nitrate explosives, or blasting caps, to moisture is almost sure to result in one or both of the above troubles.

515. Inadequate ventilation of magazines may also lead to misfires or incomplete detonation. Unless air circulates freely through a magazine the atmosphere may become hot and humid. Long exposure to such atmosphere has much the same ultimate effect as dampness upon ammonia explosives and blasting caps. With nitroglycerin explosives, it tends to cause a separation of the nitroglycerin from the other ingredients, or a leakiness, that makes the explosives much more sensitive and hence dangerous to handle.

516. The handling of misfires and the existence of undiscovered misfires or of unexploded dynamite in the bottoms of the holes or in the broken material, constitute some of the chief sources of accident from explosives. For all of these reasons it is imperative to prevent deterioration of explosives and detonators in storage. Dry, well ventilated and reasonably cool magazines are essential to safety in the use of explosives.

Storage Magazines

517. Permanent magazines for storage of explosives in quantity should be constructed from approved plans which can be obtained from explosive manufacturers. Also see the "Structures" section of the Truck Trail Handbook. Where no State laws exist, it is recommended that the location of storage buildings be in accordance with the American Table of Distances. Some excerpts from this table follow:

Quantity of Explosives	Inhabited Buildings Barricaded* (Feet)	Public Railways Barricaded* (Feet)	Public Highways Barricaded* (Feet)
From 100 to 200 lbs.	180	110	55
" 500 " 600 "	400	240	120
" 1000 " 1500 "	530	320	160
" 1500 " 2000 "	600	300	180
" 5000 " 6000 "	780	470	235
" 10000 " 15000 "	890	535	265
" 20000 " 25000 "	1055	635	315
" 40000 " 45000 "	1340	805	400

*Barricaded, as here used, signifies that the building containing explosives is screened from other buildings, railways, or from public highways by either natural or artificial barriers. When barriers do not exist, the distance should be doubled.

518. Electric caps or detonators should be stored in a separate magazine not less than 100 feet from the powder magazine.

The wires of all electric caps should have their exposed ends twisted together to prevent any possible electric current, static or otherwise, from causing a premature explosion. These twisted ends should not be untwisted until everything is ready for the final wiring, a short time before firing the round.

519. In storing powder on going projects, dependence should be placed on such natural barricades as heavy timber, ravines, etc. The area surrounding such caches should be adequately posted with "Explosives" signs. For small quantities, a portable magazine may be constructed of two-inch plank or of shiplap covered with heavy flat iron and mounted on skids or wheels. The word "EXPLOSIVES" should be painted on all four sides and the top of the structure.

A wooden box, with heavy double board hinged lid, built with hollow sides, the center to hold from one to five boxes of explosives, has been found useful on the job. The hollow space of the walls should be approximately 4 to 6 inches in width. For safety and uniform temperature, fill the space with sand or dry soil. For convenience when moving, the soil may be dumped out and the walls re-filled at the new location. During cold or freezing weather, replace the soil with sawdust. This will keep the explosive in a good handling condition. Do not bury small boxes or other magazines in the damp soil as moisture is detrimental to most explosives.

HANDLING EXPLOSIVES

Safety First

520. Care should always be exercised in handling explosives. Do not let familiarity breed contempt. Explosives are safe to handle when treated with due regard for their properties, but they are dangerous when abused. Carelessness and rough handling are apt to cause explosions and accidents.

Persons working on E.C.W. projects will be held responsible for strict compliance with "Rules for Handling Explosives," as laid down by the Director of Emergency Conservation Work.

Opening Cases of Explosives

521. The opening of dynamite boxes is an operation that should be performed with due care. Dropping dynamite cases to burst them open is both inefficient and dangerous. Whether one case or a thousand cases are to be opened, safety demands the use of wooden tools without any metal whatsoever about them. Any kind of a metal tool - hammer, sledge, chisel, pick or drill steel may strike a spark from the nails and thereby cause the dynamite to explode. While many dynamite cases are opened every year by means of metal tools without accident, the hazard is always present, and any workman who uses a metal tool for this purpose is exposing himself to possible injury or death. Wooden tools do away with this hazard and are just as effective. It takes a little forethought perhaps, to have them at hand when needed, but the prevention of accidents is worth some effort. Any wooden wedge and mallet will serve.

FREEZING AND THAWING

522. Because most dynamites are today manufactured on a low freezing formula, the hazard of thawing them is largely avoided. However, if in cold weather the dynamite becomes hard, it must be thawed. Otherwise, in handling, it may explode prematurely. It must be borne in mind that the thawing of dynamite is a hazardous undertaking. Always use a two-compartment thawer, which can be procured from any manufacturer of explosives. A thawer consists of a water-tight compartment for holding the dynamite, and a receptable for hot water, which surrounds the dynamite compartment. Under no circumstances should the water be heated in the thawer, as there is danger of firing nitroglycerin left in or on the walls of the thawer from the warming of a previous quantity of dynamite which,

when warm, exudes nitroglycerin readily. The water should be heated in something other than the thawer, and should be tested by immersing one's hand in it. The temperature will probably not be above 126° F. if the immersed hand is not uncomfortable. However, if the water is hot enough to burn the hand, do not put the dynamite into the thawer. The dynamite compartment must be kept dry and clean, and care should be exercised to prevent the explosive coming in contact with water. Should any of the ingredients of dynamite leak out into the thawer, it should be thoroughly cleaned with a solution of sal soda. The thawer should be kept away from stoves and fires at all times.

Making Primers

523. Punch a hole from the center of the end of the cartridge in a slanting direction so that it will come out at the side two or three inches from the end. Insert the ends of the double-over wires of the electric blasting cap and loop these around the cartridge. Then punch another hole in the top a little to one side of the first, and straight down. Insert the capsule in this last hole as far as possible and take up the slack on the wires. You now have a primer where the wires do not cross each other at any point. The capsule or detonator is lying nearly along the center line of the cartridge and the primer hangs vertically, so that it is possible to load it in a vertical bore hole without its lodging against the sides.

A second method preferred by most explosive foremen is:- Punch a hole in the end of the cartridge approximately one-half inch deeper than the length of the blasting cap. About 3 inches from the end make a hole through the cartridge. Pass the cap through this hole and imbed in the hole in the end of the cartridge. Then pull the wires taut. This method is quick and will not chafe or bend the wiring.

The wires of electric blasting caps should never be fastened around high explosive cartridges by half-hitching them, as a strong pull is apt to break the wires or to cut the insulation. See Figure 502.

524. All of the recommended methods of priming are based upon two principles:- First, placing the detonator so that its greatest force will be exerted upon the charge of explosive, not upon the stemming or the walls of the bore hole; and, second, protecting the cap from accidental detonation and the wires from injury. Painstaking application of these principles will aid in reducing premature shots, delayed shots, and misfires, and in securing maximum execution from the explosive.

Loading

525. Loading is the placing of a charge of explosives in a bore hole or tunnel, or placing a mud-cap charge, and adding the stemming material.

As used in this Handbook the word "tamping" means the act or work of closing a bore hole or covering up a shot and the word "stemming" means the material used.

526. In order to insure complete detonation of the explosive, it is important that it be carefully loaded and confined in a clean bore hole. The blaster should avoid smearing the walls of the bore hole with loose explosives. Contamination of the explosive with rock dust, earth or other foreign matter tends to lower its propagation sensitiveness.

A careful examination of a sprung hole should be made before loading, to be sure that it is open, and especially to see that it has cooled off from the heat of the springing shot. If this latter precaution is neglected, hot rock in contact with the charge may cause a premature explosion resulting in serious accidents. Particular care should be taken in sprung holes to secure compact loading and to eliminate air spaces.

First, try the hole with the tamping stick to see that it is open and sufficiently deep and large. The required number of cartridges should be slipped in, one at a time, and pressed into place with the tamping stick. The primer should be placed last or next to last.

Do not exert too much pressure in loading the explosive charge or attempt to ram the cartridges into place. This may result in a premature explosion. Utmost care should be used in loading the primer cartridge. Care should be taken to avoid leaving air spaces around the charge.

Explosive wrappers shouldnot be taken off the car cartridge as the wrapper ingredients actually help in the explosion. In loading, the cartridge wrappers should be slit so that the cartridge will expand, filling the space prepared for the load and not allow large air pockets to occur. If, for any reason, cartridge shells, bags, liners or packing material cannot be mixed with the explosive, they should be carefully collected and burned in a suitable location where no fire hazard exists. These wrappers are poisonous and stock will lick them for the "salty taste." Under no conditions should these wrappers be left where stock can get at them.

The first few inches of stemming should be pressed only lightly to avoid jarring the cap. The rest of the stemming should be packed in firmly, using the wooden tamping stick. Take care to avoid losing the end of the electric blasting cap wires in the hole.

527. Good confinement is often difficult in loose, or shattered soil and rock, under which conditions fire-setting is possible. Some of the charge, if mixed with soil particles or on becoming separated from the main charge along cracks, may burn instead of detonating, and set fire to surrounding carbonaceous material.

Where it is impossible to make a clean bore hole and firmly pack the explosive, special precautions should be taken to remove combustible matter from the danger zone before making the blast.

528. Stemming, except for gopher holes and tunnels, should be free from stone and grit. For large holes where the weight of the stemming gives the confinement, dry, free-running sand is good. For other work, a moist, easily packed sand, clay or loam is best. Stemming is probably the most dangerous single feature connected with the use of explosives in setting fires. Be sure the stemming is non-combustible.

When a large amount of water covers a charge of high explosives in a vertical or downward pointing hole, further stemming is sometimes omitted, as the water gives fairly good confinement.

Good tamping is one of the prime essentials of successful blasting.

No. 6 electric blasting cap. Wires of different lengths to suit different depths of bore holes.

Electric blasting cap (Section)

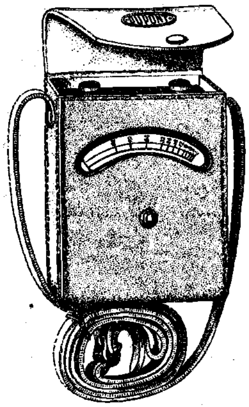
A $1\frac{1}{4}$ in. x 8 in. dynamite cartridge is used as a standard in this handbook

Connecting Wire

Roll of leading wire

Single leading wire

Duplex leading wire



Circuit Tester with carrying case and strap

Push-down blasting machine

Pocket blasting machine

FIG. 501

WIRING, TESTING AND FIRING ELECTRIC BLASTING CIRCUITS

Electric Blasting Equipment

529 See Figure 501.

(a) Detonators

Electric blasting caps, or detonators, are fired or exploded by an electric current produced by a blasting machine or other source. The electric current passes through a fine resistance wire in the cap, heating it to a high temperature which sets off the sensitive explosive compound. Detonators are designated as No. 6 or No. 8.

(b) Connecting Wire

This wire is No. 20 gauge and is furnished for use in splicing electric blasting caps when they are too short to reach between holes.

(c) Leading Wire

Leading wire is used to carry the current from the blasting machine or power circuit to the electric blasting cap wires in the bore holes and return. No. 14 gauge wire is recommended and ordinarily used for this purpose.

(d) Blasting Machines

Blasting machines are used to generate current for firing blasts by electricity. Two general types of blasting machines are largely used. One, a wooden case, containing a small generator or dynamo, is operated by a downward thrust of the rack bar. The second type is known as a pocket blasting machine and is operated by a twist of the hand, using a special key. With either machine, success of the shot often depends upon holding the rack bar or twist action handle down until the dynamo quits turning.

(e) Galvanometer or Circuit Tester

This is an instrument used by blasters to test individual electric blasting caps; to determine whether or not a blasting circuit is closed and in the proper condition for the blast; to indicate the existence of leaks or short circuits and the approximate resistance of a circuit.

(f) Rheostat

This instrument is used for testing the efficiency of blasting machines. It will tell the number of detonators the current generated in the blasting machine will fire.

The internal construction of the rheostat is an arrangement of coils of high-resistance wire of a certain length with the binding posts at both ends attached to its ends, and the intervening binding posts attached to it at intermediate points. The entire length of the resistance wire in the rheostat has a resistance sufficient to represent a test of one hundred 30-foot electric caps, with a factor of safety to allow for the leading wire, connecting wire and all connections in the blasting circuit. The resistance wire between binding posts is so arranged that blasting machine tests can be made in multiples of five.

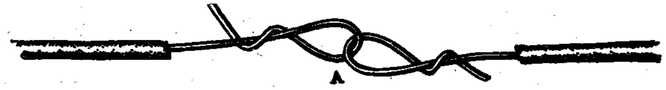
Connecting Wires between Detonators

530. Connections between detonator wires, or between detonator wires and connecting wires, must all be carefully made. First, scrape the bare ends of the wires with a knife blade, and then join them with a long twist, (generally known as the Western Union twist).

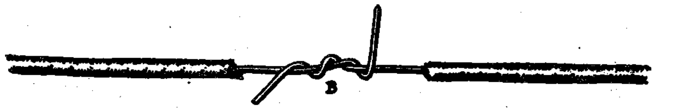
Such a twist should be made tightly to keep the resistance in the joint down to a minimum. A quick method of connecting detonator wires consists of placing them side by side, bending the ends to form a short crank and winding them together by turning this crank. This gives a quick, tight connection which becomes tighter if pulled. This connection extends at right angles to the wire but if necessary to tape the joint, this can be along side one of the insulated wires and the whole taped the same as any other joint. If there is no bare end to the connecting wire, skin off about two inches of the insulation. Never, under any circumstances, loop wires together.

Series Connections

When using a blasting machine, all rounds must be wired in series. This is done by connecting one wire from each hole to a wire from the adjoining hole, and so on to the end, when the two free wires are connected to the leading wire. See Figure 502.

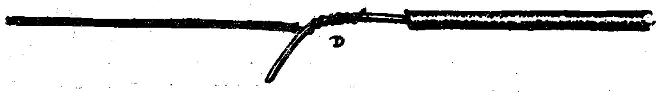


Loop connection. Do not use this splice

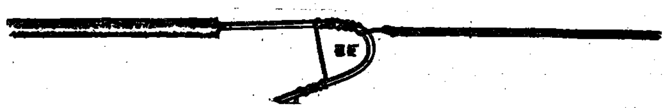


Another type of poor connection

"Western Union" connection. Always use this splice with wires of the same size



A poor connection with wires of different sizes



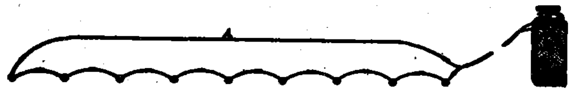
A good splice with wires of different size

Splice A is sure to give trouble and with presence of a little dirt on the wires may become practically equivalent to a break in the circuit.

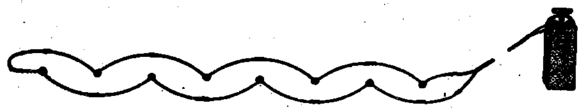
Splice B, while better than A, is poor and is sure to add materially to the resistance of the circuit.

Splice C, known as the Western Union splice, is ideal and should be used where and whenever possible.

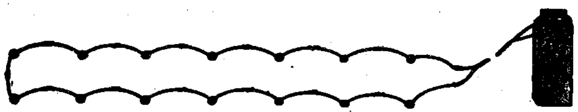
Western Union splices are difficult to make with two wires of unequal size. Twisting the wires as in D will make a splice easily pulled apart. A good splice for wires of different size is shown in E.



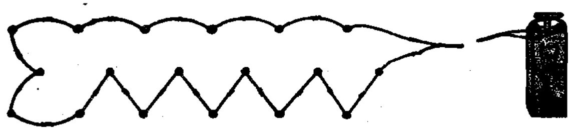
Series connection. "Lead-back" method



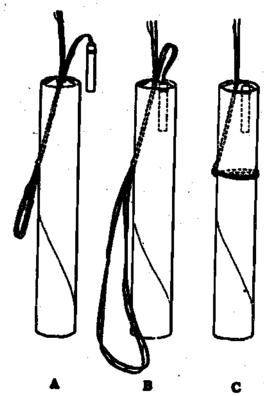
Series connection. "Loop-over" method



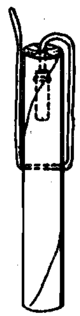
Series connection. Two lines of holes



Series connection. Three lines of holes



A method of priming with electric blasting cap for cartridges



Make primers with electric blasting caps so that the wires do not cross. This method preferred.

FIG. 502

Connecting Detonator Wires to Leading Wires

531. In making this connection the ends of the wires must be cleaned. Wrap the detonator or connecting wires tightly around the end of the leading wire, about one inch from the end. Then bend the end of the leading wire back sharply and take a turn or two of the detonator wire around the loop. This last loop is simply to make a stronger connection to withstand any accidental pull on the leading wire that might tear the connection loose. (Figure 502).

Connecting Leading Wires to Blasting Machine

532. The connection of the leading wires to the older type of blasting machine is made by loosening the nuts on the two binding posts, inserting the ends of the leading wires into the two small holes in the binding posts and tightening the nuts down on the wires. With some of the newer types of pocket blasting machines which have spring posts, all that is necessary is to slip the wires between the two sections of the posts.

When using a duplex lead wire the line should be tested frequently as the wire sometimes breaks within the insulation. Breaks in the single lead wire are easily found.

Protection of Bare Joints in Wiring

533. The naked joints in the wires of a blasting circuit must always be protected against short circuiting, especially through water. This is done in several ways. When connections lie on moist ground, they may be held up by supporting them on stones, blocks or sticks, so that only the insulated parts of the wires touch the ground and supports. The joints may be insulated with tape. While not generally needed where the joints can be held off the ground, the taping of the joints is strongly recommended where the joints are covered by tamping, where they cannot be held out of the water on props, and where blasting must be done during a rain storm.

Care of Leading Wires

534. The proper care of leading wire is simple. After being used it should be coiled and hung up out of the way; under no circumstances should it be dragged over the ground. Leading wire reels are very convenient and their use greatly prolongs the life of the wire. There are two ways to coil and uncoil a length of wire. If two or three coils are separated when dropped on the ground and the wire pulled, it may spiral out straight. More often it will kink.

To pay out a wire properly make one end fast; take the coil in an upright position with the wire leading from the bottom of the coil and pay out by rotating the coil away from the point at which the end is made fast. It will be more convenient to handle the coil if the operator can walk backward, paying the wire out as he goes.

To recoil a length of wire, it is important that the first turn be tied, otherwise it is almost impossible and very inconvenient to make a coil that will not afterwards be difficult to unwind.

Frequent inspections of the leading wire should be made for the purpose of locating breaks in the insulation. If breaks in the insulation are discovered they should be taped immediately, thus prolonging the life of the wire and preventing possible misfires.

Testing a Blasting Circuit

535. After the round has been wired, the circuit should be tested with a galvanometer to be sure there are no breaks in the line. A very accurate way is to test the wires from each loaded shot or, by using a small back line, test each shot wired to the main round to be sure none of the detonator wires were broken during the loading.

Care of Blasting Machines

536. Do not allow the blasting machine to remain uncovered over night or to remain out in wet or damp weather. Care in handling is demanded if good results from firing the round are to be expected.

The bearings and gears should be lightly oiled occasionally. Use a little graphite on the commutator, which is the small copper-covered wheel on the end of the armature shaft. See that the two slots cut in the copper part of the commutator are clean, and with no particle of metal or anything else in them which might cause a short circuit. Keep the copper brushes clean and see that they bear firmly on the commutator. Keep the circuit-breaking contacts clean and bright.

A blasting machine should be kept in a tight clean box and removed only when it is to be used. When a blasting machine is not in use, store it in a dry and comparatively cool place; not in a leaky tool box or in the open. Test the machine occasionally with a rheostat.

Firing

537. <u>Do not fire until you are sure</u> that all charges are properly loaded and stemmed and that all persons, animals and machinery are at a safe distance from the shots. Helpers should be stationed on each side of shots to warn anyone who may be approaching. As a safety precaution, instruct the crew as to the meaning of the shouted "Fire" warning, and the number of times the word will be shouted before firing. Stump fragments and rock are sometimes thrown a considerable distance. <u>One man only</u> should be allowed to fire a round of explosives. This man should always be the last to leave the danger zone.

Blasting machines with 50 shot capacity should be used where shots are numerous. Smaller machines can be used to good advantage for springing and where from one to ten shots are to be fired in a round.

538. After the line has been tested, work the rack bar up and down vigorously 4 or 5 times to warm up the magneto. Then hook the blasting machine on to the line and plunge the bar to the bottom of the machine to make the contact. Hold the rack bar down until the magneto stops turning.

If the blaster cannot get under safe cover he should always face the blast with his back to the sun, as this gives him the best chance to watch and avoid any flying matter.

After a blast is fired, the blaster, before returning to look over the result, should wait a sufficient length of time to allow the falling material to drop, and for the smoke, fumes and dust to be partially dissipated or blown away.

Make sure no fires have been started.

Handling Misfires

539. While there is no perfectly safe method for handling a charge which has missed fire, it is usually entirely possible to prevent a misfire, when using electric blasting caps, by testing each electric blasting cap with a circuit tester before loading, before tamping, and after tamping.

All misfires should be placed under the direction of a careful and experienced workman, who should make his examination in a slow, methodical manner before begin ning the work of repriming.

540. Handling a misfire is by far the most hazardous duty any blaster is called upon to perform, and he should proceed with every precaution for his own safety and that of other men on the job. Misfires are much easier to prevent than to cure. Careful priming and loading will reduce the chances of shots failing to fire. When a misfire does occur the blaster should be governed by conditions, and carefully investigate.

(a) When electric blasting caps are used and one or all of the holes fail, disconnect the wires from the blasting machine before going back to investigate the trouble.

(b) Try your Galvanometer to see if the circuit is complete; if not, search for broken wires and faulty connections. Many so-called failures are the result of connections in contact with wet ground or other conductive material.

(c) If poor connections are found, make the proper repairs, re-connect the leading wires and operate the blasting machine.

(d) If the missed hole is tamped with water, make up another primer, place it on top of the charge, and fire.

(e) If the hole is tamped with solid material, load and fire another charge far enough away for drilling in safety, but close enough to cause detonation by concussion or sensitivity.

When a second hole is drilled, place it so that the two holes lie in a plane parallel to the face, or so that the second hole is in front of the missed hole. Many accidents have occurred from striking unexploded dynamite in the debris from the blast.

With holes that have been sprung, it is not practicable nor safe to drill another hole alongside of them to blast out the charge.

541. There are many ways to remove stemming from a bore hole. The safest and most practicable method is that of blowing the stemming out with compressed air. There is danger, however, of striking the explosive with the metal pipe, and exploding the charge. The danger is somewhat decreased, but not eliminated, by having the blow pipe tipped with copper or brass. A safer method of using compressed air is to attach to the air line a stiff rubber hose with a valve for regulating the flow of air and push this hose into the bore hole.

BLASTING SOLID ROCK

Amount of Explosive Required

542. Because of the different types of rock to be blasted and conditions encountered, it is impossible to give a set rule as to quantities of explosives necessary to remove a given quantity of rock. The charge will vary from 3/4 lb. to $1\frac{1}{2}$ lbs. of dynamite for each cubic yard of solid rock to be moved.

For most shales, hard-pans and partly disintegrated rocks, a low-strength, slow explosive is usually the most economical to use. Type A, Class 7 and Type B, Class 2b, U. S. Forest Service acceptable list are recommended. These explosives should be primed with a high strength primer.

For the first trial, only enough holes should be drilled and fired to make a fair test of what this spacing and loading will do in the given material. From this evidence, either the spacing or the loading, or both, should be modified to conform to the results of the trial.

Table 502 shows spacing of drill holes and amounts of explosives for the first trial shots in unfamiliar materials where hard shooting is permissible. Also see paragraph 412 for spacing of holes.

TABLE 502

	Spacing of drill holes	Lbs. of explosive per cu. yd. of burden (Exclusive of Springing)	U. S. Forest Service Acceptable List of Explosives		
			Type	Class	Grade
Any rock difficult to shatter Tree cutting	$\frac{1}{2}$ to 3/4 their depth apart	1 to $1\frac{1}{4}$	A B	2-4-6 & 7 $1^a1^b\&2^b$	60% 60%
All medium hard weathered or partly disintegrated rock Tree cutting.	" "	1 to $1\frac{1}{2}$	A B	2-4-7 $1^a\&\ 2^b$	40% 40%
Ordinary shales hard pan, etc.	" "	7/8 to 1	A B	4-7 $1^a1^b2^b$	30% 30%
Soft rock	$\frac{1}{2}$ to 3/4 depth apart	2/8 to 1	A B	2-7 $1^a1^b2^b$	20% 20%
In wet holes or damp holes that will not be fired within several hours use Gelatin Dynamite or Ammonia Semi-Gelatin.			A B	2-4-7 $1^a1^b2^b$	(60% (or (40%
			A A A	3 1 6	40% 50% 60%

See Figure 503 for illustrations of blasting solid rock.

Springing

543. In very tough hard material, the holes should always be sprung so as to form a cavity, or chamber, of sufficient size to accommodate most of the charge at the bottom of the drill hole. The same is also true of deep holes in the softer rocks, except when the danger of losing the hole by springing is too great. To form the cavity in hard rock may require the firing in each hole of several successive charges. A fast, high strength explosive should be used for springing. Always allow the hole to cool after springing. This may be hastened by blowing the hole with compressed air.

Seam Shooting

544. By taking advantage of seams or crevices in all outcropping rock formations, it is possible to cut down the drilling, and in some cases to eliminate it entirely. A Free Flowing Explosive (Grade A and B, Class 7 and 2b) is best for seam shooting as it runs into the small crevices easily, and does very effective work when confined with good stemming. However, do not use a free flowing explosive for wet work, as it takes up moisture readily.

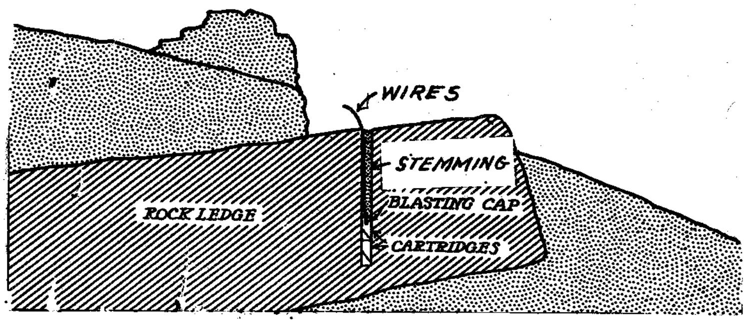
If compressed air is available, and the seams can be cleaned with a blowpipe, a loading pipe will be found very efficient for loading free flowing explosives. The air should be turned on with sufficient force to blow the explosive back into the small recesses, and without such force as may have a tendency to blow the explosive out of the hole.

BLASTING BOULDERS

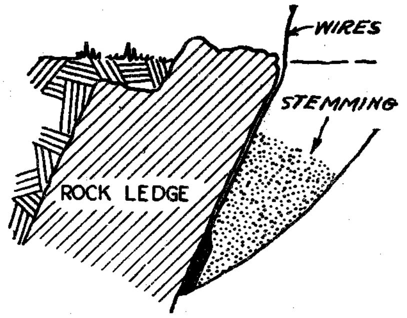
Amount of Explosive Required

545. The amount of explosive required for blasting boulders varies with the method used. Block holing requires the least, and mudcapping requires the most, of the three common methods.

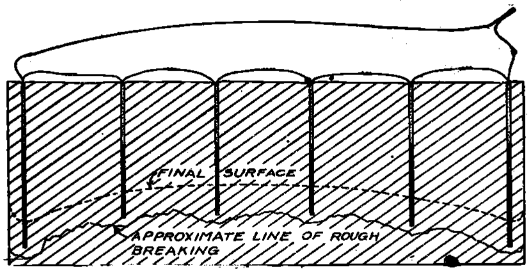
See Table 503 for suggested charges for boulder blasting.



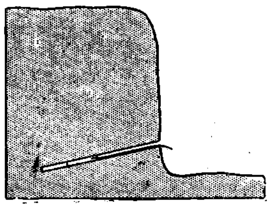
Blockhole method for ledge blasting

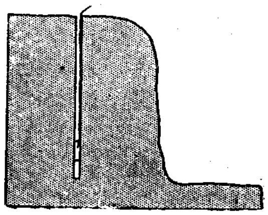


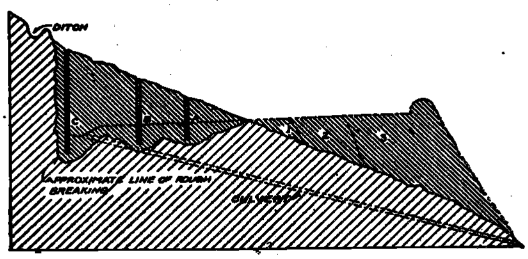
Snakehole method
for ledge blasting



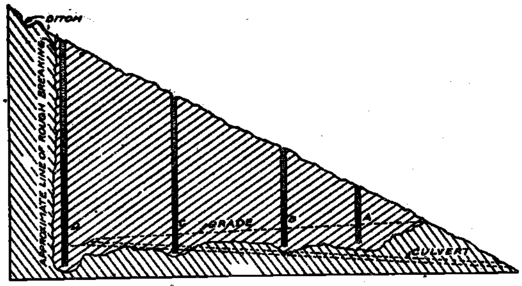
Elevation of approximate loading for cut work on highways. To give the proper crown and sufficient depth for the side ditches, the holes away from the center are drilled deeper.


Location of a flat or horizontal bore hole in a road cut

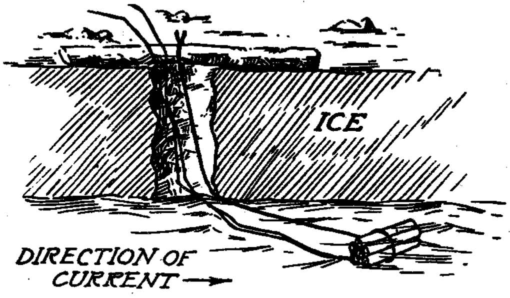

Location of a deep, vertical bore hole in a road cut



Approximate method of loading for side hill cut and fill. In earth or clay the side of the cut should be sloping to prevent caving. Another short-hole in the top of the bank will aid in making this slope



Approximate method of loading for side hill cut where excavated material is to be wasted or hauled elsewhere. In earth, the side of the cut should be left sloping instead of vertical, to prevent caving



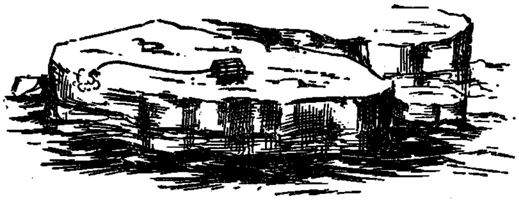
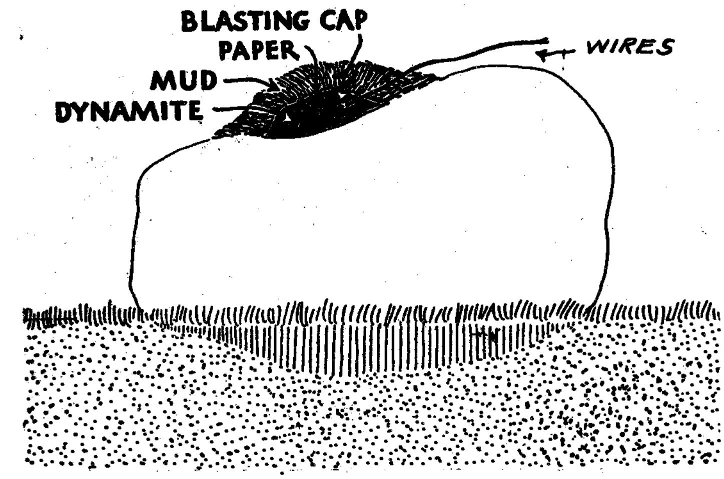
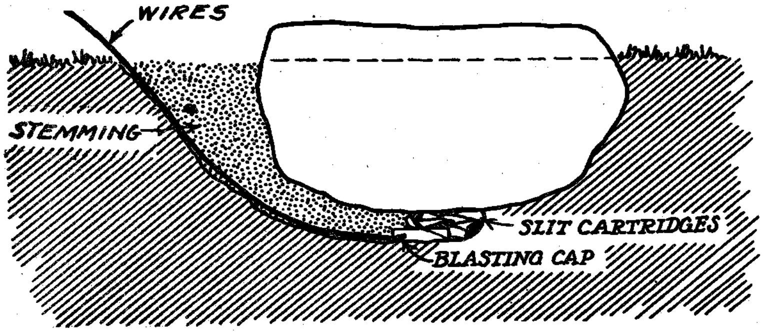


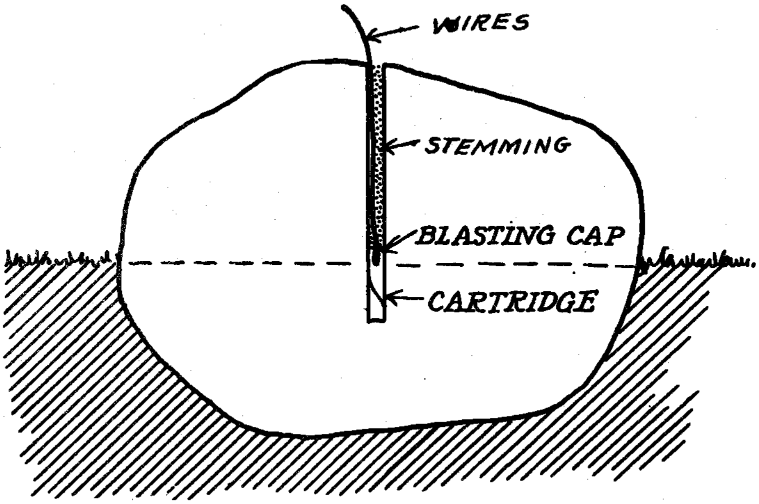
FIG. 503



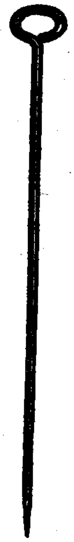
Cross-Section of a mudcapped load



Locating a snakehole charge



Locating a blockhole charge



Sounding rod for examining the size of buried boulders

FIG. 504

TABLE 503

Suggested Charges for Boulder Blasting

Thickness of boulder apposite charge	Cartridges of 1-1/4" x 8" Grade 40%		
	Mudcap Method	Snakehole Method	Blockhole Method
1½ feet	1-2	1	¼
2 "	2-3	1½-2	¼
3 "	4-5	3 -4	½
4 "	6-8	5 -7	1

The above figures are based on 40% L.F. straight nitroglycerin dynamite.

See Figures 503 and 504 for illustrations of blockholing, snakeholing and mudcapping.

Blockholing

546. Blockholing consists of drilling a hole into the boulder and charging it with a small amount of dynamite. It is the best method for breaking very hard or very large boulders, especially those of the "nigger-head" type that are difficult to break by other methods. The hole should usually be drilled about half-way through the boulder, and may be an inch or larger in diameter.

The explosive is sometimes removed from the shell and packed firmly into the bottom of the hole. Tamping the hole helps the explosive to give the best breakage.

As the confinement is perfect in the proper loading, any of the lower grade dynamites will give good results.

Blockholing is very effective in blasting out-cropping ledges that are too large to remove entirely.

Snakeholing

547. Snakeholing consists of digging a hole under but immediately against the bottom of a boulder, and placing the charge of explosives in as compact a shape as the size of the hole will permit. The explosive, being confined on the underside by the earth, can exert a powerful blow on the boulder and will roll it out. If a sufficient charge is used, the boulder will be broken into fragments. This is one of the easiest andmost successful methods of boulder blasting.

Mudcapping

548. Mudcapping is known by a variety of names, such as "bulldosing," "blistering," "poulticing," "plastering," and "dobying." It is made possible by the fast, shattering action of the higher strength explosives. One method of mudcapping consists of removing the explosive from the shell and packing it in a compact conical heap on the boulder, and, after inserting a primer, covering it with the wrappers and several inches of thick, heavy mud. Where there is a great deal of this work to be done, the explosive is not removed from the wrapper, but whole or half cartridges, sometimes slit, are arranged as compactly as possible at a given point on the boulder. The cap is inserted in the end of one of the cartridges, and the whole charge covered with mud.

The explosive should be placed on the boulder at the place where the rock would be struck with a hammer, were it possible to break it in that way. This may be on the top or on the side. If the boulder is embedded in the ground, a snakehole shot to roll it out on the surface should first be made, because the confining dirt makes it much harder to break with a mudcap shot. The mud covering should be as thick as is convenient to make it, but not less than 5 or 6 inches, and free from stones. The blast will throw stones as though they were bullets. Never lay a stone on top of the mud, for the same reason.

BLASTING STUMPS

Organizing the Work

549. (a) Keep the clearing ahead of the stumping, and the stumping far enough ahead of the grading, so that neither the clearing nor grading will be held up waiting for stumps to be shot out.

(b) If possible, distribute the explosive along the right-of-way ahead of the stumping gang. The stumping crew follows the clearing crew, digging holes under the stumps to be shot. While the digging is going on, the powderman with one helper should make up a supply of primers for the loading of the round. Do not make more primers than needed at the time, as a primer is always dangerous. The powder man will then, with his helper, load the stumps until noon or a known time, and when all is ready, fire the round as soon as the crews go off the job. Check for misfires and reshoot before the crew returns for the next shift. Follow the same procedure in the afternoon.

(c) During dry weather, leave a patrolman on the job after shooting during the noon hour, and in the evening, to spot and control any fires that might be started by shooting operations.

The proper Forest officer should keep all explosive crews informed during high fire hazard weather. Only such shots as are necessary to avoid costly delays of equipments, etc., should be fired.

At the time the stumps are shot, any surface boulders should also be removed by shooting, if necessary. See paragraph 545.

In some cases, it is possible to shoot out the entire tree without cutting, but this is usually advisable only on slopes under 25% where trees are large and scattering. To shoot the tree out and pull it in the clear with the tractor, is an economical method of clearing when properly done. However, conditions must be right to do a good job. On steep slopes the tree can be thrown clear of the right-of-way.

Amount of Explosive Required

550. The amount of explosive necessary will, of course, vary with the types of soil and timber. Some species require more explosive than others. In gravelly or loose soils, more explosive is required than in moist compact soil. A slow propulsive explosive is recommended for stump shooting in most soils. However, in loose soils a fast explosive with cutting action is preferable.

More explosives are required in dry soil than in wet soil. When five or more sticks are used, springing is usually necessary. Large green stumps are more easily shot with distributed charges.

Guard against waste of explosives. Do not shoot the stump so hard that a deep hole is left, and most of the roadbed material blown away with it. No stump should be shot harder than just sufficient to shatter it so as to enable the trailbuilder to push or pull it out. Stumps up to 6 inches in diameter can usually be pushed out by the trailbuilder without shooting.

See Tables 504 and 505.

TABLE 504

Amount and Kind of Explosive for Stump Blasting

Diameter stump (1 ft. above ground)	No. of $1\frac{1}{2}$" x 8" cartridges	Kind of Explosive U. S. F. S. Acceptable List		
		Type	Class	Grade
6"	3-4)			
8"	4-5)	(A	2 - 7	20%
10"	5-6)	(B	$1^a 1^b 2^b$	20%
12"	6-8)	(A	7	20-30 Free Flow
14"	8-10)	(B	2^b	20-30 Free Flow
16"	9-12)			
18"	10-14)			
20"	12-16)			For Cutting
24"	14-18)	(A	2.4.7	40% - 60%
30"	17-21)	(B	$1^a 1^b 2^b$	40% - 60%
36"	20-25)			Stick or Free Flowing

Use Types A & B Class 7 and 2^b (Free Flowing Bag Powders) where loading is very difficult. The charge should be placed by air through a pipe constructed for the purpose.

So many factors enter into stump shooting that any precise table can be used only as a guide for the first few test shots. The table simply offers a starting point and the explosive foreman must use his own judgment after a few trial shots.

The table was made for a medium loam soil. Heavier moist soils will take less and light dry soils will take more explosive. If the stumps are green, more explosive will be needed. If they are partly rotted, less explosive will usually blast them out. See Stump Figure 505.

TABLE 505

Amount of Explosive for Stump Blasting

Tap-rooted Pine Stumps - Charge Loaded in Tap Root

Diameter 1 foot above ground	No. of $1\frac{1}{2}$" x 8" Cartridges of Explosives	
	Green stump	Dead stump
6"	2	1
12"	3	$1\frac{1}{2}$
18"	5	2
24"	7	3
30"	11	$3\frac{1}{2}$
36"	14	5

Hard Wood Stumps - Moist Firm Soil

Diameter 1 foot above ground	No. of $1\frac{1}{2}$" x 8" Cartridges of Explosives	
	Green stump	Dead stump
6"	2	1
12"	4	2
18"	5-7	3
24"	7-10	4
30"	10-13	5
36"	13 up	6 up

Old but Solid White Pine Stumps - Moist Soil

Diameter 1 foot above ground	No. of $1\frac{1}{4}$" x 8" Cartridges of Explosives	
	Heavy	Light
18"	2 - 3	3 - 4
24"	3 - 4	4 - 6
30"	5 - 6	6 - 10
36"	7 - 8	10 - 15
42"	10 - 12	15 up

Placing the Charge

551. Different classes of stumps have very different roots. Some have heavy tap roots, others only lateral, spreading roots, while some have both kinds. The loading must suit the nature of the roots, and be placed to break their hold in the soil. See F igures 505 and 506.

(a) If the stump has a tap root, the charge must be placed well under the center of the stump and against the tap root.

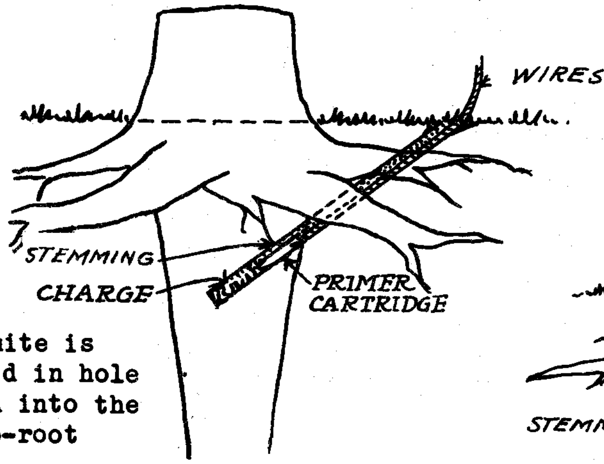
(b) If the stump is on level ground, place the charge under the strongest part of the root structure.

(c) If the stump is on a sidehill, always place the shot under the upper side of the stump so that the impact of the hillside will give more impetus to the shot.

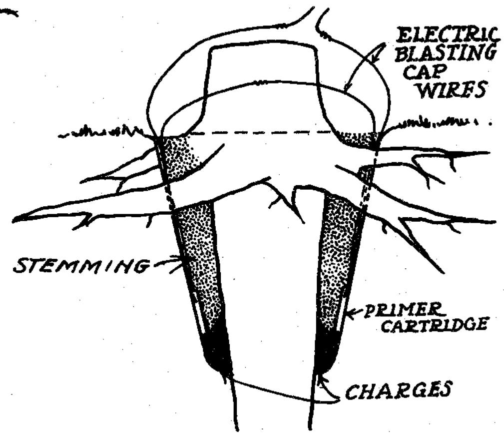
(d) To shoot large stumps, over 30 inches in diameter, it pays to put in 2 or 3 light charges rather than to put in one big charge that is costly to place, and which may be much less effective.

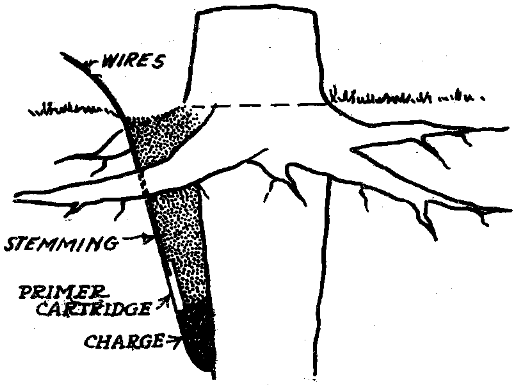
(e) Do not spring the hole unless there is no other possible chance to get a hole down under a stump. Springing loosens the ground under the stump, and much of the effectiveness of the charge will be lost. Too heavy springing may shoot all the dirt away and leave the stump high and dry, but still tightly imbedded by the roots.

(f) Stem the hole with mineral soil to be sure the charge does not blow out. Use a wooden stick or a pick handle for tamping.



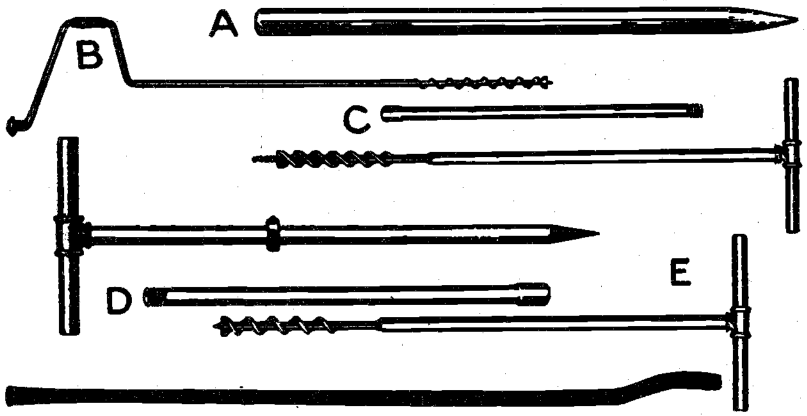
Dynamite is placed in hole bored into the tap-root





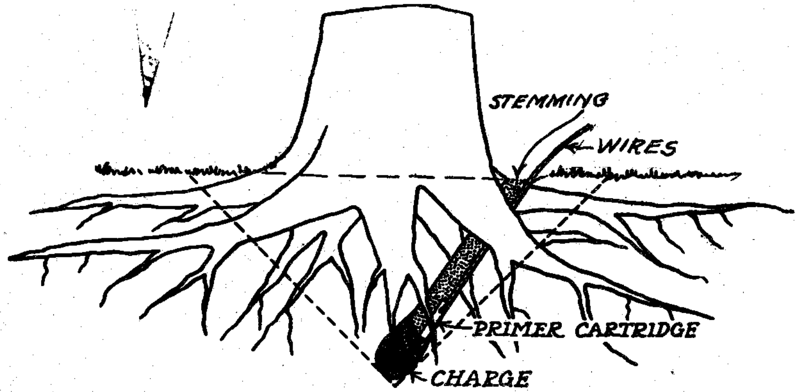
Locations of Charges
Above: Two charges are placed as shown. Electric blasting caps are needed and a blasting machine to explode dynamite.
Left: Single charge placed on one side of tap-root.

Tools Required When Blasting Stumps

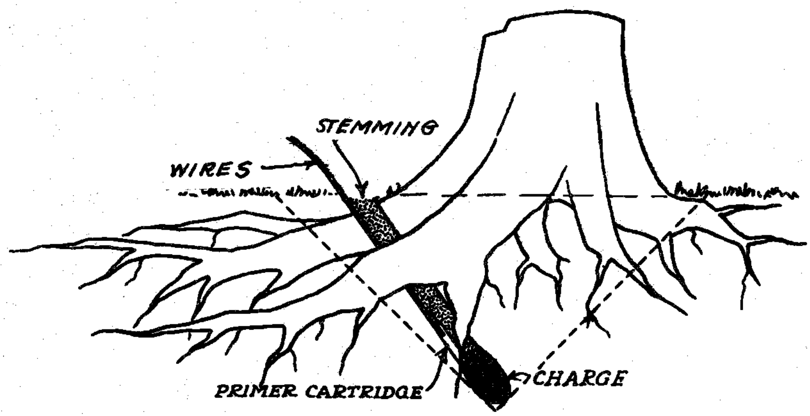


A. Steel bar 2 inches in diameter, 5 feet long, either round or octagon and pointed. B. Red Top wood auger with ball-bearing crank handle. C. Red Top wood auger 5 feet long, and extension section, with bit $1\frac{3}{4}$ or 2 inches in diameter. D. T-punch bar 3 or 4 feet long, $1\frac{1}{2}$ inches in diameter with 20-inch handle. E. Soil auger 5 or 6 feet long, bit $1\frac{3}{4}$ or 2 inches in diameter. Tamping stick to pack explosives in place.

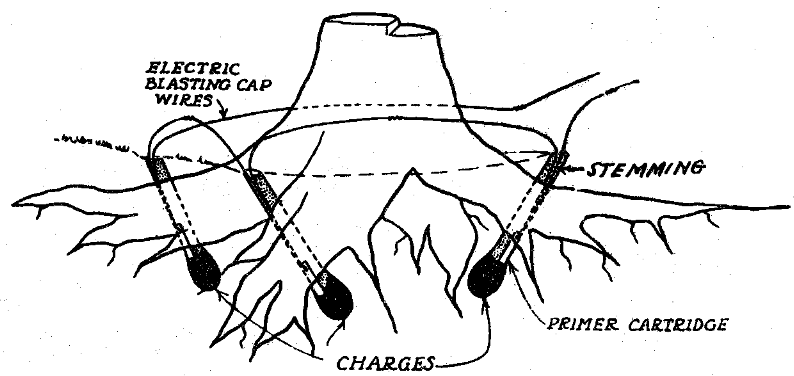
FIG. 505



A charge of explosive blows out nearly a right angled cone, as marked by the dotted line. If the stump is evenly rooted, the charge should be placed under its center and at such a depth that this cone will just include the body of the stump and the largest roots, as above.



If the stump has much larger roots on one side than on the other, place the charge under the stronger side.



Place the charges under the strongest roots. Whenever two or more charges are used, they must be fired with electric blasting caps.

FIG. 506

552. Safety Rules for Handling, Storing, and Using Explosives

(1) Explosives should be kept in a clean, cool, dry, and well ventilated place.

(2) All storage of explosives must be in accordance with American Table of Distances.

(3) Always store cases of stick explosives with the bottom side down. Do not allow the cartridges to stand on end.

(4) A complete record of explosives should be kept. This includes the amounts issued and to whom.

(5) Always inspect a car in which a shipment of explosives arrives, to ascertain whether its contents are in good condition. If cases are found broken, remove sufficient good cases and sweep up the broken cases, remove to a safe distance and destroy them by burning.

(6) Do not smoke while handling or transporting explosives. Do not handle explosives or make primers where there are open fires, flames, lights, or any danger of sparks.

(7) Electric blasting caps of different manufacture should not be used in the same round.

(8) Only handle explosives and make primers during daylight hours, if at all possible. If necessary to use artificial light, use only electricity.

(9) Do not handle packages of explosives roughly as by rolling or sliding them in a rough manner or dropping a case to open it.

(10) Do not leave explosives or blasting caps uncovered, exposed to the direct rays of the sun or where children, unauthorized persons, or animals have access to them.

(11) Do not make primers in a magazine where explosives are stored.

(12) Do not carry blasting caps in your clothing. Make a separate damp proof container with padding to prevent sudden shocks.

(13) Metal tools must never be used to open cases of explosives, because of the ever present danger of striking a spark from the nails in the cases. Always use wooden wedges and mallets.

(14) Never use explosives that are frozen. They must be thawed out to prevent a premature explosion.

(15) Do not force a cartridge of high explosive, especially a primer into a bore hole.

(16) Always use a wooden tamping stick with no exposed metal parts.

(17) Loose packing paper from explosives must be collected and destroyed for the aesthetic roadside values and to prevent stock from consuming it for its salty taste.

(18) Be sure that the leading and connecting wires are not short circuited through exposed wires. Avoid kinking the wires.

(19) Do not tap or otherwise investigate electric blasting caps or attempt to withdraw the wires.

(20) Do not load or connect up shots for electric firing during the approach or progress of a thunder storm. If charges are already loaded and connected, all persons should be kept at a safe distance from them while the storm is in progress. If necessary to leave over night, twist the ends of the lead wire together, coil, and cover with dirt.

(21) Be sure when springing to allow time for the sprung chamber to cool before placing the next springing charge or loading. After each springing shot, the chamber should be blown out clean. The blowing out of the chamber will help to cool the cavity.

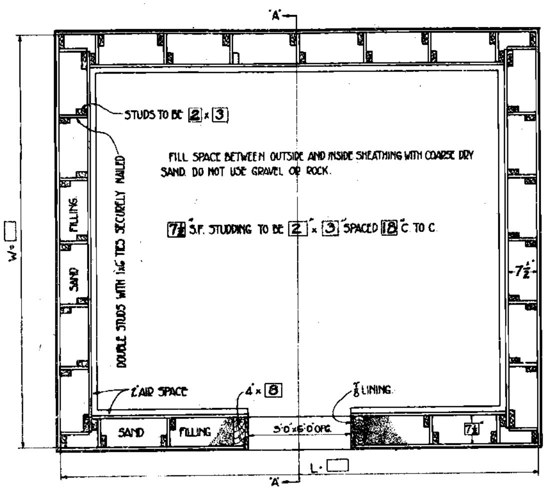
(22) Use every precaution known to insure a safe shot. Be sure that all persons are at a safe distance or under prepared or natural cover.

(23) Do not use explosives having different rates of detonation in the same shot or series of shots unless used only as a primer.

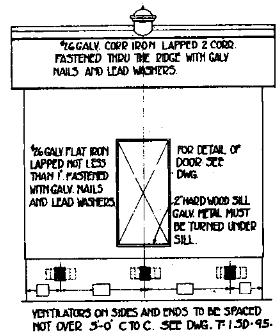
(24) Destroy loose or old explosives by burning. Care must be exercised to prevent burns by sudden flares and be sure to retire to a safe distance to minimize the chances of injury by flying debris in the case of an explosion. Do not burn more than 100 lbs. at one time.

(25) All vehicles used for transporting explosives should be in first-class condition and have a warning sign, "EXPLOSIVES - KEEP OFF", pasted conspicuously front and rear. A closed

body is best. If the body is metal or has metal strips, etc., a false lining of wood should be made. Explosive packages should not be piled higher than the false body and each vehicle must be equipped with an adequate, easily accessible, fire extinguisher.



PLAN



SIDE ELEVATION

SIZE AND SPACING OF DIMENSION LUMBER FOR VARIOUS WIDTHS.							
DIMENSION W WIDTH OF MAGAZINE	GIRDER	FLOOR JOISTS		CEILING JOISTS		RAFTERS 2'0" ℄	COLLAR BEAMS
		12" ℄	15" ℄	12" ℄	15" ℄		
10	6" x 8"		2" x 8"		2" x 6"	2" x 4"	2" x 4"
12	6" x 8"		2" x 10"		2" x 6"	2" x 4"	2" x 4"
14	6" x 8"		2" x 12"		2" x 8"	2" x 4"	2" x 4"
16	WALL	2" x 12"	3" x 12"	2" x 8"		2" x 6"	2" x 4"
18	"		3" x 12"		2" x 10"	2" x 6"	2" x 6"
20	"	3" x 12"		2" x 10"		2" x 6"	2" x 6"

ALL LUMBER TO BE FREE FROM LOOSE KNOTS, WIND SHAKES, BARK EDGES, OR DECAY

ALL MATERIAL AND WORKMANSHIP TO BE FIRST CLASS.

ALL METAL TO BE SECURED TO BUILDING WITH GALV. NAILS AND LEAD WASHERS.

NUMBER AND DIAMETER OF VENTILATORS WILL BE DETERMINED BY CLIMATIC CONDITION AND LENGTH OF BUILDING.

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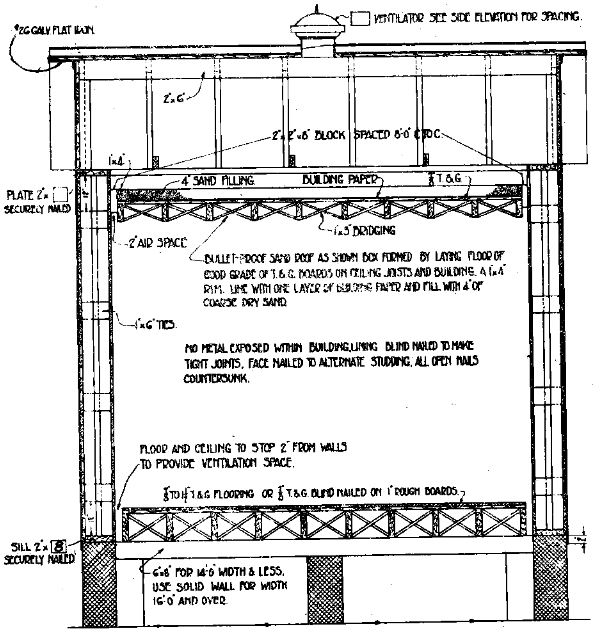
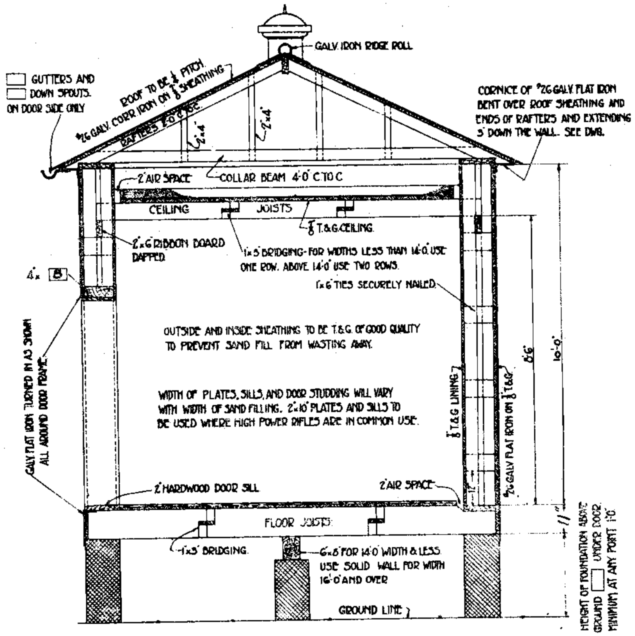
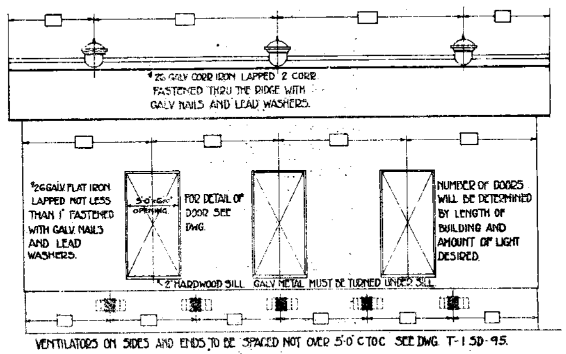


LONGITUDINAL SECTION.



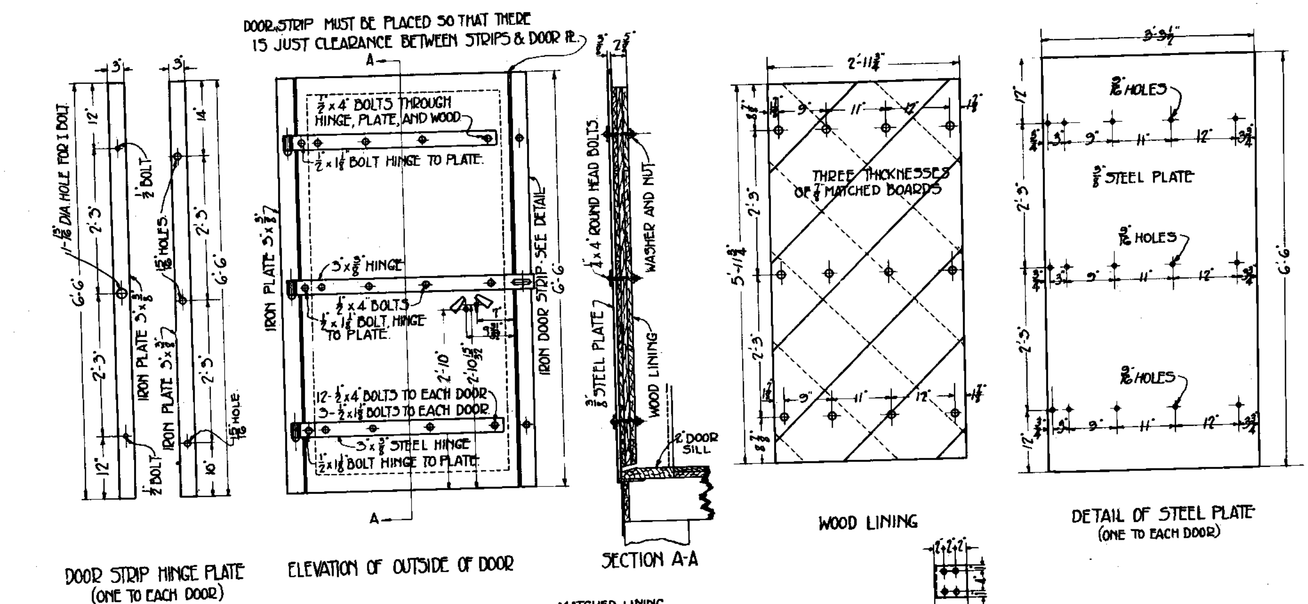
CROSS SECTION 'A-A'.

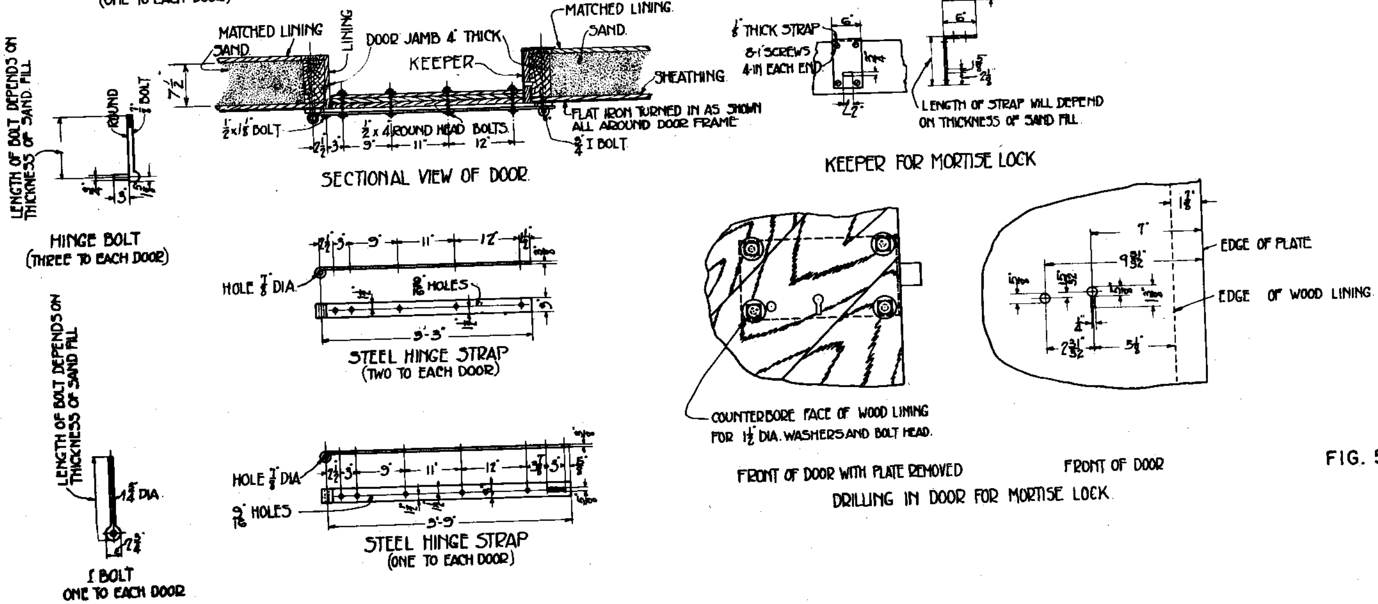


SIDE ELEVATION SHOWING SPACING OF DOORS AND VENTILATORS.

MAGAZINE DESIGNED FOR HIGH EXPLOSIVES. ALSO SUITABLE FOR BLASTING AND SPORTING POWDERS AND BLASTING SUPPLIES.

FIG. 507- STANDARD SAND-FILLED MAGAZINE





SPECIFICATIONS.

DOOR TO BE BUILT OF THREE THICKNESSES OF 7/8" TONGUE AND GROOVE HARDWOOD BOARDS LAID DIAGONALLY.

PLATE AND PARTS OF 3/8" WROUGHT IRON OR STEEL.

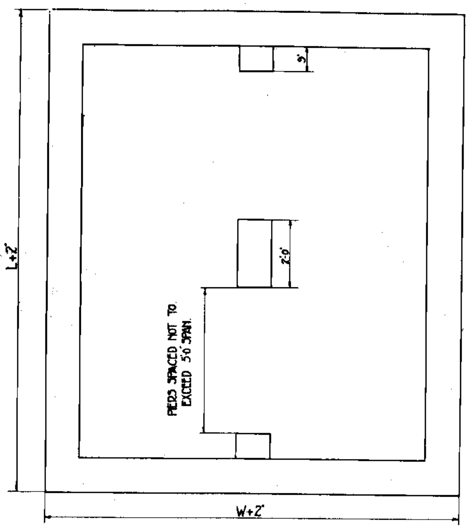
EITHER PAD LOCK OR MORTISE LOCK MAY BE USED, OR BOTH IF DESIRED. IF MORTISE LOCK ONLY IS USED, MAKE ALL HINGE STRAPS OF THE SHORTER LENGTH, AND REPLACE I BOLT WITH 1/2" DIA. CARRIAGE BOLT. IF PAD LOCK ONLY IS USED, OMIT KEEPER FOR LOCK BOLT AND DRILLING IN PLATE SHOWN IN DETAIL OF MORTISE LOCK. USE ONE LONG HINGE STRAP FOR HASP AND I BOLT FOR STAPLE.

MORTISE LOCK MUST BE PUT ON WITH BOLTS AS SHOWN IN DETAIL, NOT WITH SCREWS.
BOLTS TO EXTEND ENTIRELY THROUGH THE WOOD BACKING, BUT NOT THROUGH THE METAL PLATE.

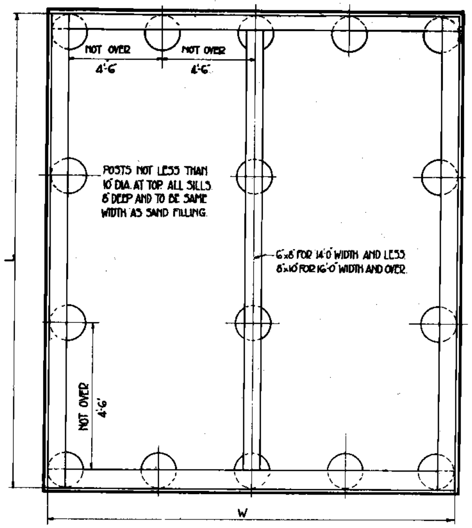
PAINT DOOR PLATE AND STRIPS TWO COATS BLACK METAL PAINT.

DU PONT
ESTABLISHED 1802

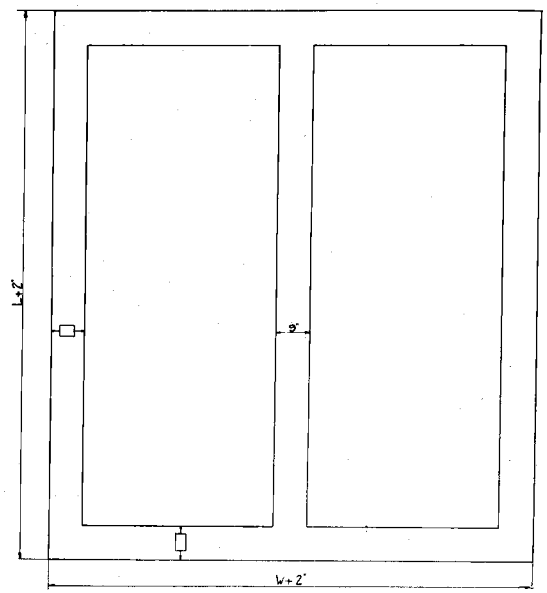
FIG. 508- STANDARD BULLET PROOF DOOR
SAND FILLED MAGAZINE



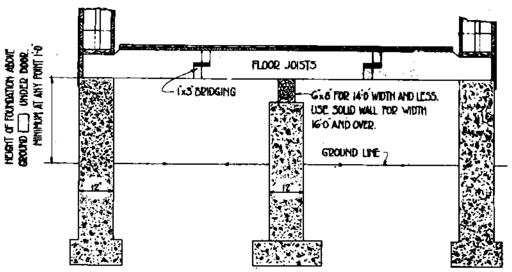
PLAN OF FOUNDATION FOR 14'0" WIDTH AND LESS.



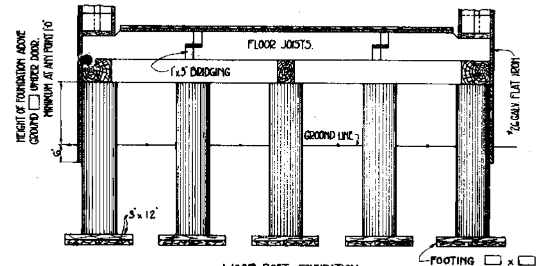
PLAN OF POST FOUNDATION.



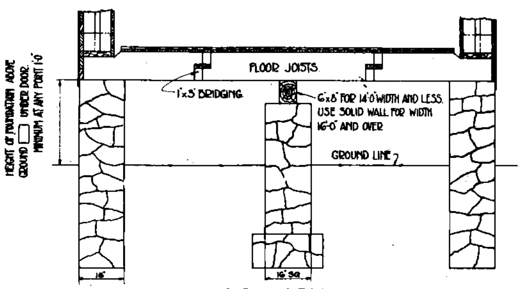
PLAN OF FOUNDATION FOR 16'0" WIDTH AND OVER.



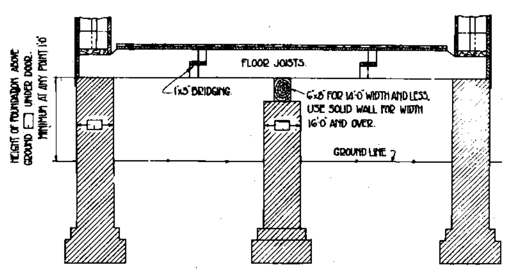
CONCRETE FOUNDATION



WOOD POST FOUNDATION



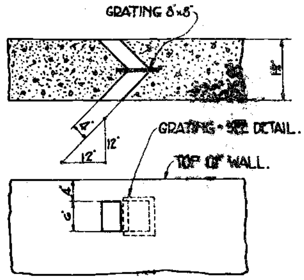
STONE FOUNDATION



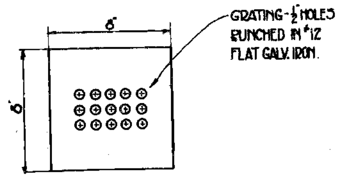
BRICK FOUNDATION

FOUNDATIONS MAY BE CONCRETE, BRICK, STONE, OR POSTS. TO EXTEND INTO GROUND TO BELOW FROST LINE & UNTIL GOOD BEARING MATERIAL IS REACHED. FOOTING NOT LESS THAN 16" WIDE BY 9" DEEP AND AS MUCH MORE AS LOCAL CONDITIONS REQUIRE.

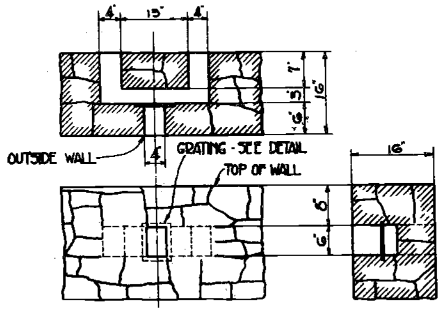
FIG. 509 - STANDARD SAND-FILLED MAGAZINE FOUNDATIONS



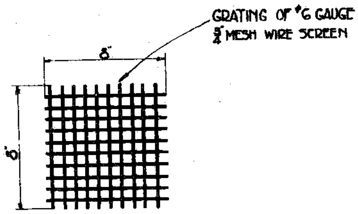
DETAIL 'A'
VENTILATOR IN CONCRETE FOUNDATIONS.



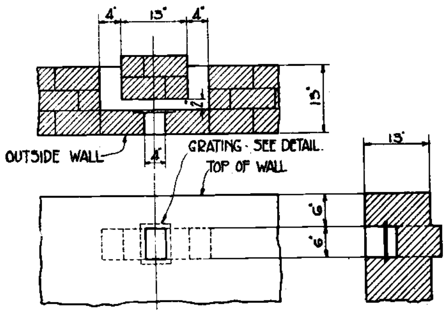
DETAIL 'E'
DETAIL OF GRATINGS IN FOUNDATION.



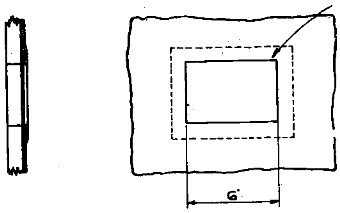
DETAIL 'B'
VENTILATOR IN STONE FOUNDATIONS.



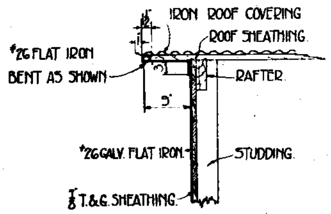
DETAIL 'F'
DETAIL OF GRATINGS IN FOUNDATIONS.



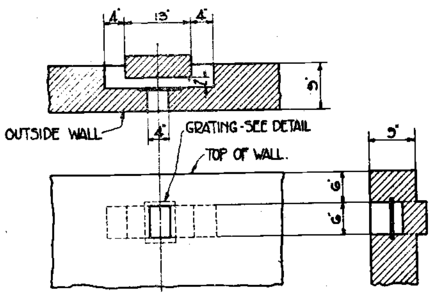
DETAIL 'C'
VENTILATOR IN 13" BRICK FOUNDATION WALL



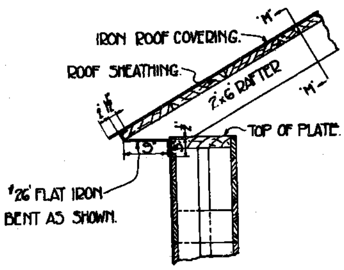
DETAIL 'G'
VENTILATOR IN POST FOUNDATIONS.



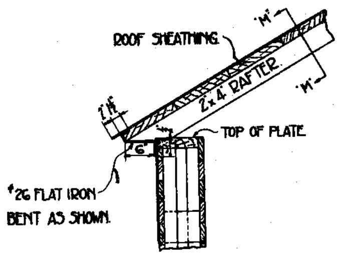
SECTION 'M-M'
DETAIL OF ROOF FLASHING AT END OF BUILDING.



DETAIL 'D'
VENTILATOR IN 9" BRICK FOUNDATION WALL.



DETAIL 'H'
DETAIL OF CORNICE 2"x6" RAFTERS.



DETAIL 'J'
DETAIL OF CORNICE 2"x4" RAFTERS.

FIG. 510

SECTION VI

MAINTENANCE

Definition

600. Maintenance consists of all activities and work necessary to keep a road up to the last standard attained by construction or betterment work.

Policy (See Roads Section of Administrative Manual)

601. All existing mileage upon the Truck Trail and Trail System should be maintained. Adequate action must be taken to insure proper maintenance of projects where the maintenance is financed from Government funds. Maintenance of Forest roads by other agencies should be closely inspected and watched to assure protection of the Forest Service investment in construction. To obtain the least annual cost in maintenance, the truck trails must be finished to full standard at the time of construction. Incompleted projects are more expensive to maintain.

Complete construction includes the following:

(a) Clearing completed to a width which will not interfere with the work of the maintenance equipment. (See figure 401.)

(b) Grading completed, including super-elevation of curves, and finished cut banks and fills.

(c) Drainage finished including completion of the roadbed or surface drainage or built-in drainage.

(d) Erosion control measures such as planting of cut banks and fill slopes must be completed.

(e) Curves, in-slopes and out-slopes finished.

The National Forest Manual defines the projects where the financial burden properly may be borne by Forest road funds and those on which the cost should be paid by the users. Many projects originally falling in the first class will gradually be transferred to the second class.

If desired by the local authority, the Forest Service may handle and supervise the actual maintenance work although such work is financed in whole or in part by the former.

Maintenance may be delegated to a local authority if it is equipped for such work and will handle it efficiently. The work should be thoroughly inspected, preferably while in progress, so that if found unsatisfactory, it can be brought to the immediate attention of the local authority concerned.

In many cases the limited annual allotment will necessitate maintenance of long mileage with limited funds. Ordinarily the funds are insufficient to permit patrol maintenance and it will require careful management to secure essential results with periodic maintenance.

Maintenance Plan

602. A careful study of all needed maintenance work should be made in detail. The study should include all existing Forest roads and truck trails and determination be made of the projects that require maintenance during the current year. After arranging for the maintenance of such roads as will be maintained by other agencies, a careful plan should be made covering the amount and character of work which should be done by the Forest Service; its approximate cost, time required, and the period during which maintenance can be done most efficiently and economically. Arrangements should then be made for financing; overhead; crew organization; equipment; priority; and time schedule. Complete instructions covering all phases of necessary work should be given to those to be in charge of and responsible for the maintenance operation.

Selection of Maintenance District

The selection of a district should be governed by:

1. Natural boundaries.
2. Time of the year when the maintenance should be done. (Execution at the wrong time frequently is worse than no work at all.)
3. Frequency of maintenance work.
4. Soil conditions existing in the district.

Crew Organization and Equipment

A maintenance crew should be selected for its ability to make repairs where needed and to avoid doing maintenance work where it is not required. A competent, experienced foreman or crew leader should be in charge of each maintenance crew. The number of laborers in each crew should be determined by a careful study of the maintenance work necessary in the district and the equipment which will do the work most efficiently.

The type and character of the most effective equipment varies with different conditions. Available information and cost data are as yet insufficient to determine the most suitable arrangement for each condition. However, from the studies made in the field of truck trail maintenance work, the motor patrol grader outfits have shown a cost of 25% to 50% less than that with a tractor trailbuilder and grader outfit.

A combination rolling kitchen and sleeping quarters should be provided for each outfit where it will be too far for the maintenance crew to travel from established camps, towns or homes to the work. The rolling kitchen should, for convenience, be moved each day with the advance of the maintenance work. Designs of suitable portable sleeping and mess outfits to accommodate from two to five men are available at the Washington Office.

It may be found necessary to increase the number of the maintenance crew where the amount of work of cleaning culverts, cutting out brush, removing fallen trees, and repairing walls is greater than the ordinary crew can handle. This work, however, can be done by a separate crew either in advance of or after the grading operation. The following set-ups of maintenance equipment for various types of work have proved to be very efficient.

Two-man outfit:

One motor patrol grader
One rolling kitchen and sleeping quarters
One dump truck

This outfit has been found to be most economical on truck trails where the slopes measured at right angles to the road are less than 30%; on truck trails having side slopes greater than 30%, this outfit will prove very efficient, provided slides are not too large or numerous. The truck is used to tow the rolling kitchen and sleeping quarters as well as to do the necessary hauling of supplies and such hauling of materials as will be necessary in the maintenance work along the truck trail.

Three-man outfit:

Where regular construction equipment must be used to do the maintenance work, the following listed outfit is recommended, the trailbuilder to be used to remove slides, fill washouts, etc.:

One tractor and trailbuilder
One rolling kitchen and sleeping quarters
One grader
One dump truck

Five-man outfit:

Where it is necessary to accomplish the maintenance work over a large district in a very short time, and where motor patrols are not available, it will be found advantageous to use a five-man crew and:

One tractor and trailbuilder with grader
One tractor and grader
One dump truck
One rolling kitchen and sleeping quarters

On maintenance districts where the road slough and slides are large and numerous, and special equipment is not provided a tractor and trailbuilder is the best implement for the removal of the larger slides. Very often this type of work can be accomplished by the three-man crew, provided that the hand work necessary to clean out the culverts, repair walls and remove brush and trees is not too great, or a follow-up crew, for this work, has been arranged. Equipment for use where slough and slides are encountered should consist of:

One tractor and trailbuilder
One motor patrol grader
One dump truck
One rolling kitchen and sleeping quarters.

Where the majority of the truck trails are surfaced, the outfit listed below is recommended for general use. In addition to this equipment, a tractor operated crusher and extra dump trucks should be added as needed to haul, crush and provide necessary aggregate for re-surfacing and stock piling.

One motor patrol grader
One tractor and grader
One dump truck
One multiple blade drag

A truck shovel is more mobile than a tractor and trailbuilder or a motor patrol grader and is very useful in a maintenance district having numerous slides and washouts. The truck-shovel can travel rapidly from place to place removing the larger slides and replacing washed out fills. The truck trail can then be shaped with the less costly two-man motor patrol outfit.

A truckshovel will do the work of making fills, removing slides far in advance of other maintenance equipment. For this reason the shovel should be used as a separate unit. It can with careful planning do the slide and fill work of several maintenance districts or where the work is not too heavy, and time allows, the work on several Forests. This unit is also useful throughout the year for loading trucks, betterment work and the lighter excavating jobs.

A truck for supplies and where the work is remote from camps, etc., a portable kitchen and sleeping quarters should accompany the shovel outfit.

The Dump Truck with an underbody scraper attachment has been found to be a very useful piece of maintenance equipment for certain work. Sufficient data as to the best uses of this equipment have not been obtained by the Washington Office and cannot, therefore, be recommended as a general piece of equipment for all kinds of maintenance work.

Maintenance Instructions

603. The instructions should include such portions of the following as are applicable to the work to be done:

1. Open up all blocked or partially blocked culverts, clear inlet and outlet ditches of all debris, repair headwalls, check spill troughs of culverts in fill sections to see that they are properly functioning and protecting the fill slope.

2. Remove culverts that are not working because of poor installation or location and reset them properly where needed.

3. Note where additional drainage is required and mark location by stakes or otherwise. A culvert should not be replaced by one of higher standard with maintenance funds; construction funds should be used. Additional culverts should be financed from construction funds.

4. Eliminate ruts, build up shoulders, repair damage to fill slopes; in general, reshape the road to conform to the cross section to which originally constructed.

5. Remove slides and slide rock.

6. Fill holes or pockets in the roadbed which catch and hold water forming and holes. Add material where needed to compensate for losses due to wear, erosion, or wind.

7. Drag roads to maintain a smooth surface after storms and whenever rutting condition requires smoothing of the surface.

8. Remove brush and fallen trees that interfere with traffic.

9. Repair walls and cribbing.

10. Install open top culverts diagonally across sustained grades where rapid run-off might cause damage.

11. All bridge structures should be examined at least once a year. Minor repairs should be taken care of by maintenance. A record of bridge inspections made annually should serve as a basis for estimating maintenance allotments and for instructions to the foreman.

12. Repair and replace signs where necessary.

13. Repair surfacing where holes and ravelling edges have occurred.

14. Repaint structures as needed in accordance with the Regional standard color scheme.

15. Stake work to be done on jobs and reference it to mile posts, points shown in road logs or other prominent marks.

16. Turnouts should be graded to standard width.

SECTION VII

COST KEEPING AND CONCRETE

700. Accurate cost data should be obtained on a comparable number of Forest Service projects to show the efficiency of various similar jobs and to serve as a basis for estimating new work. Cost records on sections having various types of soil, weather, etc., are valuable in determining the equipment best suited to truck trails, or maintenance work. Detailed cost data are not warranted on small low cost projects.

Expenditures on all construction and/or betterment projects will be kept on Accounts Form 19-h.

Expenditures for minor road maintenance need not be kept separately by projects but can be lumped together by funds. A plan found quite satisfactory to get project maintenance cost with a minimum of bookkeeping is to use Accounts Form 21-I. The certificate number and amount of each voucher are entered in the second and third columns, the other columns to the right being used for individual projects. This saves any necessity for transfers among maintenance sub-allotments.

The elements of cost will be those listed in the Forest Service timebook (Revised summer, 1932). These elements have been designed to break down the cost of grading, surfacing, or bridge jobs into the principal classes of work, each element being subdivided into labor, equipment rental, and materials.

The elements of cost have been expanded to cover details of surfacing and bridge work, otherwise they are nearly the same as the first part of Form 880, "Standard Timebook." Clearing and grubbing have been combined, but brush disposal has been left separate in order to differentiate between the cost of removing brush and trees from the roadbed excavation and the cost of cleaning up the right-of-way for fire protection purposes and/or to protect the inherent scenic values. Data on the cost of "fills" is desired separately from "excavation" to show just how much is being spent on endhaul work and whether or not the cost of making fills as compared to side-hill location or other design is justified.

In order to have the cost data in the most usable form, it is divided into labor, equipment and materials. The cost of equipment might be the actual cost of operation, repairs and depreciation, but to have all cost reports for all regions in comparable form, it is better to use a common rate for the use of large equipment. This rate will cover operating expense, repairs and depreciation. The equipment rental rates to be used in getting engineering costs used during any one fiscal year will be the ones issued by the Forester's office annually prior to July 1.

Forms 69 and 69a have been designed to give an analysis of the various elements of cost on grading, surfacing and bridge jobs. These report forms may be used for final project reports and may also be used for progress or cumulative reports for any period of time desired by the Region.

It is not difficult to work up the reports in the form shown on Forms 69 and 69a provided the base data are accurately kept and the routing carefully followed by the time-keeper. All base data, i.e., labor, use of equipment and materials used on the job, should be kept in the Forest Service timebook. Work sheets (Forms 68, 68a and 68b) have been prepared to facilitate assembling the data on Forms 69 and 69a. First the cost of the labor for each man during the report period should be listed on the appropriate "Work Sheet" and the totals posted on Forms 69 and 69a in the labor column; next, the equipment rental for each piece of "large" equipment would be posted on a Work Sheet and totals entered in the column for equipment rental on Forms 69 or 69a. If the cost of materials used on the job is known to him, the time-keeper can fill in the "Materials" column on 69 or 69a and then get the totals. He can also fill in the column for "work done units" and get the "unit cost."

The time-keeper, who may be the foreman or some qualified member of the road crew, knows the time for the men and the hours used of all the equipment and can easily complete the two columns "labor" and "equipment rental" on 69 or 69a. It is often difficult to get the cost of materials on the job and it is not always necessary to include the materials cost on progress reports. A complete financial report is not needed from the road foremen since the Supervisors' offices will generally be responsible for allotment control. The annual progress report and/or final report will ordinarily be made up in the Supervisor's office and should include the cost of materials used on the job.

The engineering cost report form has been designed to tie in with the accounting Form 19-h Expenditure Record for Roads - see sample enclosed with Circular E-958 of April 25, 1932. The total labor cost on 69 and 69a, including the cost of labor for "Equipment Repairs" paid for from project suballotment, can be checked against "Salaries and Temporary Labor" on form 19-h, making such allowance as necessary for salaries of monthly employees. The only entry opposite Equipment Repairs will be for Labor. "Equipment Rental" on Forms 69 and 69a will include the rentals based on depreciation plus operation and plus all repairs of equipment (large). Also the 858's (small) on Form 19-h will be included on the report 69 and 69a under the caption "Equipment Rental" and against the appropriate classifications. The total for the column Equipment Rental cannot be checked against any column totals on 19-h; comparable data are given in "Equipment Repairs and Operating Expense," and "Equipment Depreciation" (large) and (small). "Materials" on Forms 69 and 69a should equal the sum of columns 2, 3, 4 and 8.

SYMBOLS FOR CLASSIFICATION OF ACCOUNTS ON ROAD CONSTRUCTION PROJECTS

GRADING JOBS

O - OVERHEAD and general items not strictly chargeable to other classifications. This is a general item with no unit of measurement and will be charged as a lump sum.

C - CLEARING, brush disposal, grubbing, shooting or pulling stumps, cleaning up adjacent to the roadway. The unit of measurement will be acres cleared.

E - EXCAVATION, Common - cast over or sidehill work, includes loose rock. The unit of measurement will be miles completed. (Use cubic yards when quantity estimates are available).

E - EXCAVATION, Solid Rock - includes all rock excavation requiring use of explosives, except material for "FILLS." The unit of meausrement will be miles completed. (Use cubic yards when quantity estimates are available).

F - FILLS, from cut or borrow, includes cost of loosening material, loading and tr nsporting fill material, i.e., all endhaul work. The unit of measurement will be the lump sum except as required by the responsible Forest Officer.

V - CULVERTS, and drainage structures under ten (10) foot span - includes all intercepting or drain ditches. The unit of measurement will be the lump sum, except as required by the responsible Forest Officer.

G - GRADING, on sideslopes under 16%, turnpike sections, ditching and finishing roadbed. The unit of measurement will be miles completed.

On surfacing jobs improvement of grade or roadway (width, grade and alignment) estimated cost not over $250.00 per mile, but not cutting the subgrade. Use "GRADING" classification for improvement or betterment of road costing over $250.00 per mile.

S - SURFACING, with selected material incidental to a grading job but not an extensive surfacing job ordinarily undertaken separately; for latter use special classification. The unit of measurement will be the lump sum except as required by the responsible Forest Officer.

W - RETAINING WALLS. The unit of measurement will be lump sum except as required by the responsible Forest Officer.

Z - GUARDRAILS. The unit of measurement will be linear "feet."

B - BRIDGES, structures of ten (10) foot span or over, incidental to a grading job; ordinarily of local timber, estimated cost less than $500.00 For all steel and concrete bridges and timber bridges estimated to cost over $500.00, use special classification. The unit of measurement will be lump sum except as required by the responsible Forest Officer.

Y - CAMPS - GENERAL, buildings, tents - erection, maintenance, tearing down and moving. A general item and will be charged as a lump sum.

M - Meals, food supplies and cooks wages. Unit of measurement will be number of meals.

SURFACING JOBS

A - CRUSHING PLANT - Moving, setting up and dismantling complete plant - also maintenance of plant exclusive of equipment. This is a general item and will be charged as a lump sum.

J - STRIPPING - Removing all overburden or other undesirable material. This is general item and will be charged as a lump sum.

D - DRILLING AND BLASTING. The unit of measurement will be "cubic yards."

K - CRUSHING - includes breaking stone, transportation to crusher, crushing and loading into bins. The unit of measurement will be "cubic yards".

H - HAULING. The unit of measurement will be "cubic yards." Give average length of haul in progress and final report under "Remarks."

P - SUBGRADING, SPREADING AND FINISHING. The unit of measurement will be miles completed.

BRIDGE JOBS - for steel and concrete bridges and timber bridges estimated to cost over $500.00

N - EXCAVATION - Includes cofferdams. A general item and will be charged as a lump sum.

Q - BACKFILL and cleaning up job. Charge as a lump sum.

T - PIERS AND ABUTMENTS, includes forms and hauling. The unit of measurement will be "cubic yards."

U - SUPERSTRUCTURE, includes hauling, erection of steel trusses, girders, beams and/or stringers, and painting, but not timber decking or concrete floor. The unit of measurement will be "linear feet."

X - FLOOR, includes wheel guard and handrail except when latter is furnished by the steel contractor. For timber decking the unit of measurement will be "linear feet" of bridge, while for a concrete floor it will be "cubic yards."

EQUIPMENT

ER - Equipment repair, includes labor and materials for all maintenance, repair and overhauling. Charge as a lump sum.

Where unit of measurement is "miles" give distance to the nearest one-hundredth. (See table to convert feet into tenths and hundredths of a mile).

701. 1. The foreman should keep a record of the powder, and caps used on rock excavation or for clearing, so that they may be taken into account in arriving at unit cost figures. Also a record must be kept of the size and number of culverts installed. These can be recorded in the timebook as shown on the sample pages.

2. At the end of the job, inventory should be made of all subsistence supplies and construction materials, such as blacksmith coal, powder, iron, etc.

3. A progress report may be required by the Regional Forester to be submitted periodically as designated by him.

4. Work done on grading and surfacing projects will ordinarily be measured in miles and fraction of miles, although where measured quantities are available such as cubic yards for excavation, it will be better to use these than miles. On bridge jobs the cost of piers and abutments should ordinarily be in cubic yards, steel superstructure in cost per pound and the cost of floor in cubic yards for concrete. The forms lend themselves to special cost studies where it is desired to make an accurate cost analysis of any job or part of a job.

702. Where desirable to classify excavated material either in securing cost data or in estimating proposed work, it is preferable to use the method of classification that is followed in highway work in the locality. The method will be one of the following three:

(a) Unclassified - All yardage is lumped together whether earth, loose rock or solid rock and regardless of the character of the material.

(b) Two-way classification consisting of

1. Common excavation, which includes everything not solid.

2. Solid, which ordinarily includes all rock found in ledges or in masses over 1/2 cu. yd. in volume, to remove which blasting is necessary.

(c) Three-way classification consisting of

1. Common, including all excavations that can be done with ordinary earth-moving machinery. This is frequently specified as including everything not classed as loose or solid.

2. Loose rock, including material that cannot be moved with ordinary earth-moving machinery but does not require blasting. Usually it has to be moved by hand. Frequently the size of rock in this class is specified as from 1 to 10 cu. ft. or up to 1/2 cu. yd. in volume.

3. Solid rock. Usually specified as rock found in ledges or in masses over 1/2 cu. yd. in volume, to remove which blasting is necessary.

703. Equipment operating and cost records should be kept on major equipment such as trucks, tractors, trailbuilders, graders, rippers, compressors and other units, in accordance with the latest instructions, by circular letter from the Forester's office. Any additional information for Regional use may be kept as desired.

The equipment rental column of the road construction report Forms 69 and 69a, includes the rental of major equipment that is used on the job, and the cost of equipment (small) that may be worn out or abandoned on the job as shown on the 858's. This detail should be handled promptly in the interest of good records and so as not to allow an accumulation of useless equipment.

CLASSIFICATION OF SOILS

704. For determining the suitability of soils for subgrade, surface, and concrete structures, it is sometimes necessary to make soil classifications. This is a specialized field of knowledge and it is not expected that many men in the Service will master more than the fundamental principles. It is, however, an important subject and should be given serious thought and attention. Engineers responsible for truck trail work should know enough about soil mechanics and classifications to recognize problems when they are met in the field. Most of such problems they should be able to solve. Others must be referred to experts.

705. The following paragraphs are intended merely to outline some of the more important phases.

706. Soils are classified according to the degree of fineness, as follows:

Coarse Material - Any particles that are retained on a 10-mesh sieve (10 meshes to the linear inch).

Sand - Particles that pass through a 10-mesh sieve but are retained on a 200-mesh sieve and subside through a height of 8 centimeters of ammoniated water (concentration 1:500) in 8 minutes.

Silt - Particles that pass through a 200-mesh sieve and subside as above.

707. Silt is very fine rock dust in which the particles when wet behave like sand. It differs from clay, which when wet has a semi-chemical or colloidal action with the water causing it to become plastic or sticky.

708. Clay, because it is composed of very finely divided particles, resists for a time the penetration of water but when saturated holds water for a long time. A high percentage of clay therefore renders a soil unsuitable for either subgrade or surface of a road.

709. Soil containing less than 20 per cent clay makes a good subgrade, 20%-30% a fair subgrade and over 30% a poor subgrade. Capillary action and undue retention of moisture will result from the presence of more than 30% of clay in the subgrade. Whether or not this same percentage will seriously affect the value of a soil forming the surface of a road, will depend upon the degree of coarseness of the material with which it is mixed.

710. A considerable amount of clay is sometimes needed in surfacing to bind together the coarse particles.

711. The ability of sand to stand up under traffic depends upon:

(1) Size of the grains. Large particles have greater interlocking strength than small particles. To make good road material, 40% of the sand should be retained on a 60-mesh sieve.

(2) Shape of the grains. Sharp, rough, angular sand has greater interlocking strength than round, smooth grains.

(3) Absence of mica. The fine flat scales of mica prevent interlocking of particles and furnish easy access to water. The presence of 3% or more of mica is considered by some authorities to affect seriously the ability of sand to stand up under travel.

CONCRETE

CEMENT

712. Cement is furnished in bags of 94 lbs. each. Cement should preferably be purchased in paper bags. Bags which are broken when received at destination or which contain lumpy cement should be rejected. Cement should be stored under shelter and protected from dampness and no lumpy cement used in concrete.

SAND

713. Clean sand is probably the most important requirement for good concrete. It is a simple matter to determine if the coarse aggregate is clean, but more difficult to be sure that the fine aggregate is free from silt and organic matter. If purchased on bid use Federal Specification #SS-F-351.

714. Organic impurities - If local bank run sand or gravel are used for concrete aggregates, they should be tested both for organic impurities and also for silt, even for Class C concrete. Sand containing organic material should not be used which gives a color darker than the standard color when tested in accordance with the following method.

1. Obtain a representative test sample of sand weighing about one pound by quartering or by use of a sampler.

2. (a) Fill a 12-oz. graduated clear glass bottle to the $4\frac{1}{2}$ oz. mark with the sand to be tested.
(b) Add a 3 percent solution of sodium hydroxide in water until the volume of the sand and liquid indicated after shaking is 7 liquid ounces.
(c) Stop the bottle, shake vigorously and then allow to stand for 24 hours.

3. After standing 24 hours the color of the clear liquid above the sand may be compared with an appropriate color plate. Color plates may be procured from the Portland Cement Association.

715. Silt test - The following method may be used for determining the approximate quantity of clay and silt in the sand:

A 32-ounce, graduated prescription bottle is filled to the 14-ounce mark with sand and clear water added to the 28-ounce mark. This mixture is then shaken vigorously and the contents allowed to settle for one hour. If more than 1 ounce of sediment then appears above the aggregate, the sand should be rejected. The sand may be subjected to washing and samples again tested and the sand approved for use if the test requirements are fulfilled.

COARSE AGGREGATE

716. Coarse aggregate should consist of clean gravel or crushed stone (but not slag). If purchased on bid, use Federal Specification SSC 571. The proposal should state the maximum and minimum size as $1\frac{1}{2}$" to #4 screen or $2\frac{1}{2}$" to #4 screen (the minimum size in all cases is #4 screen). If $2\frac{1}{2}$" maximum size is used the proposal should state that "in addition to section E-7A (of F.S. SS-C-571) the following size designated as $2\frac{1}{2}$" to #4 screen should be added":

	Percentage of material retained on laboratory sieves (Square openings in inches)			
	$2\frac{1}{2}$"	2"	1"	No. 4
$2\frac{1}{2}$" to No. 4	0	15-30	25-60	95-100

BANK RUN AGGREGATE

717. If bank run aggregate is to be used for Class A or Class B concrete, it should be screened and the sand and gravel remixed in the proper proportions.

WATER

718. All water used should be reasonably free from oil, acid or alkali and vegetable substance, and should not be brackish or salty.

CLASSES OF CONCRETE

719. The following classes of concrete are designated for variations in conditions of exposure and type of structure. The proper mixture should be selected under each class to suit the conditions of extreme, severe or moderate exposure. In addition to withstanding stresses of live and dead loads concrete must resist the action of climatic changes and the elements and this requires a sound dense concrete, the density increasing with the severity of the exposure.

Class A Concrete:- To be used in all reenforced concrete structures.

Maximum size of aggregate 3/4" to $1\frac{1}{2}$". Approximate slump 3" to 4". (See par. 720).

Exposure	Gallons of water per bag of cement	Mix (By volume)
Extreme	$5\frac{1}{2}$	1:1 3/4:2 3/4
Severe	6	1:2 :$3\frac{1}{4}$
Moderate	$6\frac{1}{2}$	1:$2\frac{1}{4}$:$3\frac{1}{2}$

Class B Concrete:- To be used in light non-reenforced concrete structures such as walls 12" or less in thickness.

Maximum size of course aggregate $2\frac{1}{2}$". Approximate slump 2" to 3". (See par. 720).

Exposure	Gallons of water per bag of cement	Mix (By volume)
Extreme	6	1:2:3 3/4
Severe	$6\frac{1}{2}$	1:$2\frac{1}{4}$:4
Moderate	7	1:$2\frac{1}{4}$:$4\frac{1}{2}$

Class C Concrete:- To be used in foundations, heavy walls, piers and other massive structures.

Maximum size of course aggregate $2\frac{1}{2}$". Approximate slump 1" to 2" (See Par. 720). Use as many one man stones, "plums" as possible without displacing reenforcing. "Plums" must be clean and placed not closer than 3" to the form or to each other. Do not use "plums" in any wall less than 12" thick.

Exposure	Gallons of water per bag of cement	Mix (By volume)
Extreme	6	1:$2\frac{1}{4}$:4
Severe	$6\frac{1}{2}$	1:$2\frac{1}{2}$:$4\frac{1}{2}$
Moderate	7	1:2 3/4:$4\frac{1}{2}$

720. Consistency is measured by the slump test. The procedure is to fill with concrete and open ended section of a metal cone 12 inches high, 8 diameter at bottom and 4 diameter at the top. Place upright on a flat surface and measure the height of the mass of concrete after the metal form is withdrawn. The slump is the difference between the measured height and 12 inches.

EXPOSURE CONDITIONS

721. Extreme

(a) In severe climates like in northern U.S. exposure to alternate wetting and drying, freezing and thawing, as at the water line in hydraulic structures.

(b) Exposure to sea and strong sulphate waters in both severe and moderate climates.

Severe

(a) In severe climates like in northern U.S., exposure to rain and snow, and freezing and thawing, but not continously in contact with water.

(b) In moderate climates like in southern U. S., exposure to alternate wetting and drying, as at water line in hydraulic structures.

Moderate

(a) In climates like southern U.S., exposure to ordinary weather, but not continously in contact with water.

PROPORTIONING CONCRETE AGGREGATES

722. In proportioning concrete aggregates the number of gallons of water per bag of cement, i.e., the water cement ratio, is the most important factor in producing a concrete of the required strength and density, and the amount of aggregate is selected to produce a plastic workable mix of the proper consistency (taking into consideration the use for which intended). The materials should be accurately measured. Sand and coarse aggregate (broken stone or gravel) should be measured in boxes, struck measure.

BULKING OF SAND

723. Coarse aggregates are not materially affected by moisture but sand increases materially in volume with small addition of water, the increase running as high as 20 to 30 per cent with as little as 6 per cent of water (approx. 3/4 gallon per cubic foot). Therefore when moist or wet sand is used it is necessary to take this bulking into consideration, since one cubic foot of bulked sand when measured dry would be less than a cubic foot, depending on the amount of bulking.

When bulked sand is inundated or flooded with water it occupies very nearly the same volume as when dry, and this makes possible a handy method of determining the amount of bulking. First fill the measure (use a measure with vertical sides) with the moist or wet sand, then completely flood the measure with water (being careful not to wash away any of the sand) and measure the distance from the top of the measure to the top of the sand. This divided by the height of the inundated sand will give the approximate amount of bulking. For example, let's assume that a cubic foot measure is filled (struck measure) with moderately wet sand and after being inundated the sand has settled to a level 2 1/4" below the top of the measure. Since the measure is 12" high the height of the inundated sand is 9 3/4". The amount of bulking is therefore 2.25/9.75 = 0.23 or 23%. In this case the quantity of sand to be used must be increased 23%, and if a 1:2:3 mix is indicated it will be necessary to use 2.46 cubic feet of the moderate wet sand for each bag of cement instead of 2 cubic feet.

WATER CONTENT OF AGGREGATES

724. As noted above, the water cement ratio is important and since the aggregates may contain some moisture this must be taken into account in measuring the water. The following approximate table may be used as a guide in estimating the water content of the aggregates:

Very wet sand	-3/4 to 1	gallon	per	cubic	foot	
Moderately wet sand	-1/2	" "	"	"	"	"
Moist sand	-1/4	" "	"	"	"	"
Moist gravel or crushed rock	-1/4	" "	"	"	"	"

Taking the above example of a 1:2:3 3/4 mix with 6 gallons of water per bag of cement, and assuming that the moderately wet sand contains $\frac{1}{2}$ gallon of water per cubic foot, the 2.46 cu. ft. of sand will contain approximately $1\frac{1}{4}$ gallons of water. Assuming again that the coarse aggregate is moist, the 3-3/4 cu. ft. (the dry measure is used because the bulking of the coarse aggregate is negligible) of coarse aggregate will contain approximately 1 gallon of water, making the total moisture content of the aggregates used for each bag of cement equal $2\frac{1}{4}$ gallons of water. This must be subtracted from the 6 gallons specified, leaving 3 3/4 gallons of water to be used for each bag of cement.

On high standard work it is desirable to determine the percentage of moisture in the sand and coarse aggregate by weighing a sample before and after drying it.

ADJUSTING AGGREGATES FOR A GIVEN MIX

725. The "mixes" or proportions of fine and coarse aggregate, i.e., sand and stone, vary more or less because of the variations or graduation in the sizes of the sand grains and the stone. The mixes given under "Class of Concrete" are for average conditions but in order to obtain high grade and dense concrete it may be necessary to increase or decrease the amount of sand or coarse aggregate to produce the proper mix. The ideal concrete mixture is one where the cement-sand mortar just fills the voids between the gravel or crushed stone. This can be determined by running a few trial batches.

A concrete mixture in which there is not sufficient cement-sand mortar to fill spaces between pebbles will be hard to work and will result in rough honey-combed surfaces.

A mixture with an excess of cement-sand mortar is plastic and workable and will produce smooth surfaces but the yield of concrete will be low and the concrete is likely to be porous.

A concrete mixture which contains the correct amount of cement-sand mortar makes a good workable mixture and will give maximum yield of concrete with a given amount of cement. With such a mixture, light troweling will fill with mortar all spaces between pebbles.

The mixes specified under "Class of Concrete" are for a medium stiff mix. For thin sections with a large amount of reenforcing it may be necessary to use a slightly smaller "total amount" of aggregate.

FORMS

726. Forms should be so designed and constructed that they can be removed without injury to the concrete. In designing forms the concrete shall be treated as a liquid weighing 150 lbs. per cubic foot for vertical loads and 85 lbs. per cubic foot for horizontal pressure (in a wall 10 feet high the concrete will exert a horizontal pressure of 850 lbs. per square foot on the sides of the form at the bottom and it is important that special attention be paid to ties and bracing).

The interior surface of the forms should be oiled, greased or soaped to prevent adhesion of the mortar.

MIXING CONCRETE

727. Concrete should be thoroughly mixed in a batch mixer for a period of not less than $1\frac{1}{2}$ minutes after all materials, including water, are in the drum.

The entire contents of the mixer should be removed before adding any of the materials for the next batch. Upon the cessation of mixing for any extended period the mixer should be thoroughly cleaned.

No mixer should be overloaded above its rated capacity as such overloads prevent thorough mixing.

Hand mixing should be avoided if possible. When necessary it should be done only on water-tight platforms. The sand and cement should be thoroughly mixed while dry by means of shovels until the mixture is of a uniform color, then formed into a "crater" and enough of the specified water added to produce a plastic mortar and the entire mass turned and sliced until of uniform consistency. The coarse aggregate should then be added and wetted with the remainder of the specified water, and the entire mass turned and returned at least six times and until all of the stone particles are thoroughly covered with mortar and the mixture is of uniform color and appearance.

PLACING CONCRETE

728. No element of the entire cycle of concrete production requires more care than the final operation of placing concrete at the ultimate point of deposit. Before placing concrete all debris, water and ice should be removed from the forms.

Before placing concrete in foundation or other parts under water the water should be pumped out of the cofferdam. Pumping during placing of concrete or for a period of 24 hours thereafter should be done from a suitable pump separated from the concrete by a water tight wall, or in some other manner which will preclude the possibility of any portion of the concrete materials being carried away. Water should not be allowed to flood the concrete until 24 hours after it has been placed.

Concrete should be placed in forms immediately after mixing. In no case should concrete be used which does not reach final position in the forms within 30 minutes after water is added to the mix. Special care shall be taken to fill each part of the forms by depositing the concrete directly as near final position as possible. If chutes are used they should extend as nearly as possible to the point of deposit.

Concrete should be placed in each section of the work in a continous operation. Concrete should be compacted by continous working and each layer compacted in a manner that will break up and tendency to form a plane of separation between the layers. The concrete should be thoroughly spaded especially along the sides of the forms.

In placing concrete in deep layers a gradual increase of water content of the upper portion will result from increased pressure on the lower portions. The excess water should be worked to a low point, without actually causing a flow, and removed. Excess water in the upper layer is just as objectionable as excess water in the mixing.

If it is necessary, by reason of emergency, to stop placing concrete before any section is completed, bulkheads should be used to avoid leaving a feather edge layer or a layer less than 6 inches thick. In no case will stoppage of pouring be permitted in reenforced slabs or girders. In order to bond successive courses suitable keys should be formed at the top of the layer by insertion and subsequent removal of beveled wood strips which were saturated with water before insertion. Rough stone or dowel pins may be used instead of keys.

In joining fresh concrete to concrete that has already set, the forms should be drawn tight against the face of the set concrete and all gage strips and key forms removed. The surface of the set concrete to be contacted shall then be cut over with suitable tools to remove laitance and foreign material, washed and scrubbed with wire brooms, drenched with water until saturated, and kept saturated until the new concrete is placed. Immediately prior to placing new concrete, the old surface should be thoroughly coated with neat cement mortar.

In placing concrete in reenforced structures it should be so placed as to avoid coating the reenforcing with cement before its final embedment. Care must be exercised to work the concrete completely under and around the reenforcement bars without displacing them.

In placing concrete slabs it shall preferably be deposited by beginning at the center of the span and working from the center toward both ends. Concrete in girders shall be deposited uniformly for the full length and brought up evenly in horizontal layers and as a continous operation.

Freezing Weather. When necessary to place concrete at or near freezing temperature; the concrete should have a temperature of at least 50 degrees F. but not more than 120 degrees F. This may be accomplished by heating the water and/or aggregates, but neither the water nor aggregates shall be heated to a temperature of more than 150 degrees F. In no case will dependence be placed on salt or other chemicals for prevention of freezing, and no frozen materials shall be used.

FINISHING CONCRETE

729. All concrete surfaces exposed in the completed work, except floors, curbs and surfaces hereinafter designated to have rubber finish, shall be left with ordinary finish, i.e., the surface left by the removal of the forms with all holes left by form ties filled and all defects repaired. The surface shall be true and even, free from stone pockets, depressions or projections beyond the surface.

CURING CONCRETE

730. Concrete hardens because of chemical reactions between Portland cement and water, called hydration, and the process continues indefinitely so long as the temperatures are favorable and moisture is present to complete the hydration. Thorough curing is also of great importance in producing a water-tight concrete, and the necessity of proper curing of retaining walls, tanks and other concrete subject to hydrostatic pressure or severe weather condition cannot be over estimated.

The problem of curing is essentially to prevent the evaporation of water contained in the concrete, and this requires adding a protective covering, such as wet burlap, straw, or dirt, to exposed surfaces. The covering should be added as soon as possible without marring the surface of the concrete, and the entire structure kept wet for a period of at least 7 days. Floor slabs should be covered as soon as possible and kept wet for a period of at least 10 days. These periods apply to temperatures in excess of 70 degrees F., and should be increased for lower temperatures.

Concrete should be kept at a temperature of at least 50 degrees F. for at least 72 hours during cold weather. This may be done by using oil heaters, salamanders or other suitable means, being careful to avoid overheating any part of the structure.

Loads should not be applied to mass structures such as gravity type abutments and walls prior to 7 days after pouring.

REMOVAL OF FORMS

731. In order to facilitate finishing, forms for railings, parapets and posts shall be removed in not less than 12 or more than 48 hours, depending on weather conditions. Forms and falsework under slabs or girders shall not be removed prior to 21 days at temperatures of 70 degrees F., and increasingly greater periods for lower temperatures. Forms for mass structures should not be removed prior to 14 days, except that after 7 days the forms may be removed from the back of walls and abutments if backfilling immediately follows the removal of the forms. In case the form lumber has no salvage value forms may be left on surfaces not exposed in the finished structure.

PLACING OF REENFORCING

732. When placed, reenforcement should be free from dirt, oil, paint, grease, mill scale and loose or thick rust.

All reenforcement should be placed in the exact position shown on the plans, and should be so securely held in position by wiring and blocking from the forms and by wiring together at intersections that it will not be displaced during the depositing and compacting of the concrete.

Blocks for holding reenforcement from contact with the forms should be precast mortar blocks short enough to permit the ends to be covered with concrete. The use of pebbles, pieces of broken stone or brick, metal pipe and wooden blocks should not be permitted.

SPLICING BARS

733. Whenever it is necessary to splice reenforcement, the splice should be made by lapping the bars a distance at least 40 times the diameter or least dimension of the bar, and the two pieces securely wired together. Splices should be avoided at points of maximum stress. When sheets of metal mesh or expanded metal are used they should overlap each other sufficiently to maintain a uniform strength and they should be securely fastened at the edges and ends.

SECTION VIII

BRIDGES

DEFINITION

800. The term "bridge" includes any structure with span of 10 feet or greater.

LOCATION

General Considerations

801. The first consideration is to determine whether or not a stream crossing is necessary. A crossing is obviously required where the objective is to reach the opposite bank of the stream, but where the proposed location crosses the stream more than once in order to avoid heavy construction and where it is immaterial from the transportation standpoint which side of the stream is followed, a careful reconnaissance and an estimate of cost should be made of the two routes, i.e., the one with the stream crossings and the route eliminating the crossings. If immediate construction is planned on standards lower than ultimately required, the comparison of the cost of the two locations should be based on the ultimate standards. Unless a decided saving is indicated in favor of the route with stream crossings, the route eliminating the crossings should be selected because of greater permanency and lower maintenance costs. The relative damage from erosion induced by the road and bridges should also be considered together with other factors as outlined in paragraph 122.

Short span bridges should be avoided if culverts adequate to carry the run-off can be constructed at the same or slightly greater cost. This provides a smooth continous road surface and simplifies maintenance. No bridge at all should be constructed when, as is sometimes true, a ford will satisfactorily serve the use to which the road will be put.

Selection of Site.

802. Alignment of Stream. Insofar as practicable bridges should be located where streams are straight and the flow unobstructed. The nature of the stream bed should be carefully considered and locations subject to channel erosion or shifting should be avoided.

803. Clearance. The site selected should be such that ample clearance above maximum high water can be provided for free passage of drift logs and uprooted trees. This clearance should rarely be less than 5 feet, and greater whenever practicable.

804. There are conditions such as flat country which is overflowed only in extreme high water where it is a good plan to establish the grade of the bridge at a safe elevation and to construct the approach roads only slightly above the natural level and with releatively steep connections to the bridge. The approach roads may be washed out by extreme floods but if this occurs, the cost of road repairs will be nominal.

805. Foundation. All standard abutment and pier designs are suitable for foundations of well compacted clay, gravel, or other material which will not settle under the weight of the structure and where the footing is below the point subject to scouring. The important point here is to select a site where channel changes or scouring will not be encountered. If scouring is a possibility, proper clearance should be given so as to avoid damming up with logs or debris which might result in scouring of the stream bed and undermining of the abutments or piers. Rock ledges or cliffs are desirable in order to reduce the cost of the abutments, provided the existance of the rock does not increase the cost of the approaches more than to offset the savings in the cost of the bridge. Shelving ledges are deceptive and should be investigated to make sure that they are not undercut.

806. Skew Bridges. When the center line of the road is not at right angles to the stream it will often be desirable to construct the bridge without any skew. In other words the abutments will be square with the road. This may occasionally require a longer span than for a skewed structure. The introduction of a skew angle in the abutments will increase the cost of the superstructure due to the special fabrication and the cost of the abutments and piers will be increased due to the additional length. If a skew crossing is found necessary and a pier in the stream bed is required, the pier should be skewed and set approximately in the direction of the stream in order to avoid disturbances of the stream and resultant scouring of the banks.

807. Length of Bridge. Other things being equal, the site making possible the least overall length should be selected, provided adequate opening to carry the maximum ordinary run-off is secured. When more than one span is indicated at a bridge site it is desirable to have a relatively large channel span to reduce the hazard of drift catching on piers.

808. Alignment of Crossing. Bridges should preferably be located on tangents. If curved approaches are necessary, they should be of such radii as are consistent with the alignment obtained elsewhere on the road. When satisfactory alignment of approaches cannot be secured by excavation or filling, consider improving the alignment by erecting multiple spans on a curve. Where the bridge will be of comparatively low cost no special effort should be made to locate a "bridge site". Place the bridge so as to secure the best alignment of the truck trail.

809. Grade. Avoid abrupt changes of grade at ends of bridges. If a change in grade is necessary, make the change far enough away from the abutment to allow for smooth vertical curves. Ordinarily the bridge floor should be level. However, under some conditions, it may be advisable to place the bridge floor, especially stringer or concrete slab spans, on the grade of the approaches. Where practicable, bridges should coincide with the grade line of the road.

810. Road Standards. In the selection of the site and consideration of the standard of approaches, the service standard of the road should be kept in mind and the cost of the bridge and approaches kept in balance with the service to be rendered.

Location Survey (Also see paragraphs 312 and 313)

811. When it is not feasible to determine by a field inspection the most economical structure for a bridge site, a topographic survey should be made and estimates compared for the different designs meeting the conditions. Topographic surveys should be referred to the Regional Engineer for recommendations and special designs.

In addition to data listed in paragraph 313, notes should be made of the availability of material, the haul distance, and a notation of the clear height and opening of other existing structures on the stream, with the location of each structure given so that the drainage area can be determined.

SUPERSTRUCTURE

Standards

812. Standard plans should be used as far as practicable. If standard plans do not cover the needs of some particular case, the Regional Forester should be asked to design a suitable structure.

The book of Acceptable Bridge Plans should be consulted for suggestions in selecting or designing a bridge for any given site. If a suitable plan is found in the book of Acceptable Plans it can be secured directly from the region in which it originates.

Bridges on all Forest Highways and high standard truck trails should be designed for H-15 loading. On the more important projects bridges should be double track or single track designed for ultimate widening for two-way traffic.

Bridges on low or medium service truck trails should be single or double track bridges for H-10 or H-15 loading, depending upon the anticipated traffic.

Selection of Type

813. Materials. Untreated timber if locally available may be used for short stringer spans, for bridges on temporary locations, or for temporary structures with an anticipated life of 5 to 10 years when it is desirable to keep the first cost down or to postpone the erection of a long life structure to give time for further consideration of site or of type of structure or materials.

A steel bridge with concrete piers and abutments, single track H-10 loading, will generally cost from $25 to $40 per foot of bridge, depending upon clearance, the availability of materials and the length of haul. On the other hand untreated timber bridges will ordinarily cost $10 per foot and upwards, with timber crib piers and abutments. The following factors should be considered in deciding which type and kind of bridge will be the most economical in the long run; depreciation 10 years for untreated timber, 20 years for pressure treated creosoted timber and 50 years for steel and concrete, interested on investment, maintenance and permancy of location.

Special consideration should be given to aesthetics and architectural treatment in the selection of type of bridge. This is particularly important in highly used recreational areas.

814. Permanancy of Location. In selecting the type of superstructure, the permanency of the location should be considered, and if it is anticipated that the location will be abandoned or that the type of structure erected will not be adequate for the future need within the economic life of the structure, temporary material or a structure having high salvage value should be used.

815. Low Water Bridges. At some locations a low water bridge can be used at a very material saving in cost over high water bridge. The purpose of the low water bridge is to give a smooth crossing of the stream except during flood stages. The bridges are anchored to bed rock or stable abutments and piers. In the ordinary installation the downstream edge is raise higher than the upstream edge (about 8 inches in 12 feet) so that the resultant pressure when covered with flood water will be downward. The bridges should be located at approximately right angles to the direction of flood in order to prevent a piling up of debris or an increase in the erosive effect of the current at one end of the bridge. The bridge is set just above mean low water and is covered by a rise of 1 to 2 feet in the stream. All floating drift is carried over the bridge. The piers and abutments on these bridges do not extend to bed rock, although they extend down into the gravel stream bed about 4 or 5 feet. It is important to get the foundations below any scouring action of the stream. Concrete slab bridges without handrails make excellent low water

SUBSTRUCTURE

Standard Plans.

816. Standard plans should be used when available. If the standard plans do not cover the particular needs, the Regional Office should be asked to design a suitable structure. See also Book of Acceptable Bridge Plans.

Selection of Types of Substructure.

817. The selection will depend largely upon the availability and cost of materials. If satisfactory concrete aggregates are readily available, mass concrete abutments will probably be cheaper for heights up to 10 feet. For greater heights or for locations where aggregates must be hauled longer distances, reinforced concrete will probably prove more economical. Reinforced concrete bents and open type abutments offer economical design for use where the nature of the stream bed and flow permit. Steel bents may be used on concrete footings if the top of the footing is above mean high water. The type of abutment pier selected should be in harmony with the architectural treatment of the superstructure.

Clearance.

818. It is important to construct abutments and piers high enough to place the superstructure above danger of high water and floating drift. As a general minimum the lowest point of the superstructure of large bridges, should be at least five feet above maximum high water.

Timber. (see Wood Hanbook - published by the Forest Products Laboratory, September 1935.)

819. Untreated timber specifications (except for temporary structures) should call for the proper grade and should provide that each piece show at least 80% heartwood on any girt for stringers, floor beams and flooring and at least 75% heartwood on each of the four sides, measured across the side, for caps, sills and posts.

820. The Preservative Treatment of "Treated Timber" should conform to federal specifications listed in Table 50, Pages 275 and 276 of the Wood Handbook. If untreated and treated timbers are called for in the same proposal, the specifications should clearly state which timbers are to be treated according to the recommendations for one of the above groups, and if the bidder is given option of furnishing one of two or more species the specification should require that he use the penetration and treatment recommended for the species he proposes to furnish.

The simplest and usually least effective treatment is to apply the preservative to the wood with a brush or a spray nozzle. Creosote and similar oils, preferably hot, are used in this treatment. Heating is sometimes inconvenient, however, and the oil is often applied cold. In such event creosote oil that is thoroughly liquid when cold should be selected. The oil should be flooded over the wood, rather than merely painted upon it, and care should be taken to see that every check and depression in the wood is thoroughly filled with the preservative, since any untreated wood left exposed provides ready access for fungi. At least two coats should be applied, the second one after the first has dried. This may require as much as 10 gallons of oil to 1,000 square feet of surface on rough lumber, although considerably less on surfaced lumber. The penetrations obtained will usually be less than one-sixteenth of an inch.

Brush treatment should only be used on seasoned wood. Applying surface treatments of preservative oils to green or wet wood is practically useless, because preservative so applied cannot penetrate wood that is already full of water.

Brush treatment with water-soluble preservatives is not worth while for wood that is exposed to the weather or to water; and is less likely than creosote brush treatment to be effective in protected situations.

Insofar as possible, all cutting and boring of timbers should be done prior to treatment where the pressure method is employed.

Handling and Protection of Treated Timber.

Treated timber should be carefully handled without dropping, breaking of outer fibers, bruising or penetrating the surface with tools. All cuts, bolt holes, etc., in treated piles and timbers, and all abrasions after having been carefully trimmed, should be coated with at least three applications of hot creosote oil and covered with hot roofing pitch.

Piles.

821. Piles should have a minimum diameter of 8" at the tip and 12" at the butt and a maximum diameter of 20" at the butt. A straight line from the center of tip to the center of the butt should be wholly within the pile.

Holes for Bolts, Dowels, and Rods.

822. Holes for bolts, dowels, and rods should be bored with a bit of the diameter as follows:

Type of bolt or rod	Diameter of bit
Round dowels or driftbolts	1/16" less than rod
Square dowels or driftbolts	Equal to least dimension of rod
Machine bolts	Same as bolt
Rods	1/16" greater than rod.

Cast iron washers having a thickness equal to the diameter of the bolt and a diameter of four times the thickness, or malleable or plate washers having a thickness equal to half the diameter of the bolt and a diameter or side size equal to four times the diameter of the bolt, should be used under all bolts heads or nuts which would otherwise come in contact with the wood. A small hand pump should be used to force creosote into bolt holes bored after treatment.

Joints.

823. All joints should be cut to fit so that they have uniform bearing over the entire contact surface; no shimming or blocking will be permitted. All surfaces of sawed untreated timber which come in contact in the finished structure, unless otherwise protected, and all sawed ends should be given two brush coats of hot creosote oil before assembling. The back surfaces of untreated timber bulkheads and all other untreated surfaces coming in contact with earth should be similarly treated.

The brush application of hot creosote oil may be omitted from dense durable materials, such as locust or pitch pine used in sills and posts.

Floors.

824. Plank floors should be laid heart side down, with 3/4" openings between plank for seasoned material and ½" openings for unseasoned material. Each plank should be securely spiked to each joist. The planks should be graded as to thickness and so laid that no two adjacent planks will vary in thickness by more than 1/16" for transverse decking and ¼" for longitudinal decking.

The ends of plank of longitudinal flooring and run strips should be securely fastened.

Where plank run strips are used, a plank, the top of which is flush with the top of the run strip, should be placed across each end of the bridge to keep the road material off the bridge and permit bringing the road grade flush with the top of the run strip.

Joints should be staggered at least 3 feet.

825. Laminated floors should be made up of nominal 2 inch material preferably of full length to avoid splicing. Planks should be laid surfaced edge down, and each piece should be toe-nailed to each alternate stringer with 20-penny nails. In addition each piece should be nailed horizontally to adjacent pieces with 40-penny nails at 18 inches center to center, and staggered horizontally and vertically with nails in adjacent pieces. All floors should be cut to straight lines along the sides of the roadway.

Laminated floors being of a more permanent and costly type of construction should have the decking protected with a bituminous cover and plank or metal run-strips to take the wear of traffic.

The run-strips can be replaced at less expense than the laminated flooring.

After the ends of the laminated floor has been cut to a straight line with the roadway, the cut ends should be treated with hot creosote or similar oils to prevent decay.

Pile Driving.

826. In determining the number of piles required in a bent, an allowable load of 600 lbs. per square inch of average cross sectional area may be used. As an example; you expect to drive piling with an average diameter (d) of 10 inches. Areas = 785d2= .785 x 100 = 78.5 square inches; then allowable load = 600 x 78.5= 47,100 lbs. Allowance of such loads is contingent upon proper setting of the piling. A general rule for setting piling is to drive to a penetration of 8 feet or 1/3 of the length. However, in view of widely varying soil conditions the usual way of arriving at the carrying capacity of a pile is by computation, from data on action of the piling while being driven. Formula (1) gives the supporting capacity of a pile for various rates of penetration while formula (2) gives the average penetration that should result for any required supporting capacity.

These formulae are based on (a) using a gravity drop hammer with free fall, (b) firm head on piling, i.e., pile head is not broomed or crushed (c) penetration is reasonably quick and uniform (d) no appreciable bounce of the hammer or bending, kicking or staggering of the pile.

p-safe load per pile in tons
w-weight of hammer in tons
h-free fall of hammer in feet
s-average penetration in inches of pile during last 5 blows

(1) $p = \frac{2\,w.h}{s + 1}$ (2) $s = \frac{2\,w.h}{p} = 1$

Mote: If steam hammer is used:

$$p = \frac{2\,w.h}{s + 1/10} \quad \text{and} \quad s = \frac{2\,w.h}{p} = 10$$

Example "A": What is the supporting capacity of a pile driven with a hammer weighing 2000 lbs., having a free fall of 10 feet, giving an average penetration of $\frac{1}{2}$ inch. Substituting in formula (1) we have:

$$p = \frac{2 \times 1 \times 10}{.5 + 1} = \frac{20}{1.5} = 13.3 \text{ tons}$$

Example "B": With the same driving equipment, as that used in Example "A", what penetration should be had to give 10 ton supporting capacity per pile? Substitute in formula (2):

$$s = \frac{2 \times 1 \times 10}{10} = 1 = 2\text{-}1 = 1 \text{ inch}$$

Structural Steel.

827. Structural steel should conform to Federal Specification QQQS-711, "Steel, Structural, for Bridges", Class A, non-copper.

Handling Steel.

828. Steel should be handled in such a manner as not to bend or distort any members. Hammering, which will injure or distort the members should not be done. Any straightening of plates and angles or other shapes should be carefully done and inspected for fracture. If fracture is indicated the piece should be discarded. In no cases will welding be permitted. If the member is heated in order to straighten it, the heating should not be to a higher temperature than that producing a dark cherry-red color. After heating, the metal should be cooled as slowly as possible.

Material to be stored should be placed on skids and kept clean and properly drained. Girders and beams should be placed on edge and shored. Long members should be supported on skids set close enough together to prevent injury by deflection.

Bearing Plates.

829. Masonry plates should be set level in exact position with a full and even bearing upon the bridge seat. When indicated on the plans the plates should be set on red lead and canvas as follows:

After the truss or girder is erected it should be jacked off the masonry bearing plate. The bearing area under the masonry bearing plate should then be swabbed with red lead paint and covered with three layers of 12 to 14 oz. duck, each layer being swabbed in turn with red lead. The masonry bearing plate and superstructure shoes or end bearings should then be let down in position while the red lead is still plastic.

Anchor bolts should be accurately placed and the nuts on anchor bolts at expansion end adjusted to permit free expansion and contraction.

Rivets.

830. Pneumatic hammers should be used for field riveting. Cup-faced dollies, fitting the head closely to insure good bearing, should be used. Connections should be accurately and securely fitted before the rivets are driven. Splices and field connections should have one-half of the holes filled with bolts and cylindrical erection pins (half bolts and half pins) before riveting. Drifting should be only such as to draw the parts into position and not sufficient to enlarge the holes or distort the metal. Unfair holes should be reamed or drilled. Rivets should be heated uniformly to a light cherry-red color and should be driven while hot. They should not be overheated or burned. Rivet heads should be full and symmetrical, concentric with the shank, and have full bearing all around. They should not be smaller than the heads of the shop rivets. Rivets should be tight and should grip the connected parts securely together. In removing rivets, the surrounding metal should not be injured.

PAINTING.

831. Steel structures will be painted with three coats of paint as follows:

1. Shop coat - red lead paint.
2. First field coat - red lead paint with tint of lamp black.
3. Second field coat - aluminum paint. This paint will be used only over the first field coat of red lead.

Red lead paint should consist of red lead and linseed oil with drier mixed in the following proportions:

Dry red lead	20 pounds
Raw linseed oil.	5 pints
Turpentine	½ pint
Liquid drier	½ pint

The resulting paint when brushed on a smooth steel surface should dry hard and elastic without running, streaking or sagging.

The aluminum paint shall have the following composition:

Aluminum powder .... 2.0 pounds
Varnish vehicle .... 1.0 gallon

Mix the powder with the varnish in sufficient quantities only for each day's use. Any paint remaining after one day's use may be mixed with freshly prepared paint provided it does not exceed 10% of the newly-mixed paint. For spraying purpose thinner may be added as required but not to exceed 10% of the total volume of paint. The paint must be thoroughly mixed by vigorous stirring and afterwards frequently stirred to retain the proper consistency. Ready mixed aluminum paint will not be used.

Aluminum powder for Aluminum paint. The powder should be made by the best commercial methods from metallic aluminum having a minimum aluminum content of 99%. On analysis, a sample should show not more than 1% by weight of iron, silicon, and copper after deducting the acetone soluble portion. The powder shall conform to the following composition limits:

Acetone extract (2 hours) maximum ...... 3.0 percent
Lead and Zinc maximum .... 0.0 percent
Copper maximum .... 0.2 percent

The aluminum should be powder in the form of flakes, polished and possess the property of "leafing" when suspended in varnish. The fineness should be such that it will pass through a standard 100 mesh screen (determined by wetting a sample with alcohol and passing through the screen). The powder aluminum should contain no powdered mica or other adulterants.

Vehicle. The vehicle should consist of long oil spar varnish. Purchases on bids should be made in accordance with Federal Specifications TT-V-81, and if there is any question as to whether or not the material proposed meets the specifications, the Regional Office will have a sample analyzed. The varnish when thoroughly mixed with the aluminum powder in the proportion of 2 pounds per gallon of vehicle, should show satisfactory spreading qualities and not run or sag when applied to a smooth vertical surface. The paint should set to touch in not less than 2 hours or more than six hours and dry hard and tough in not more than 24 hours.

Mixing - It is recommended that the red lead paint be mixed on the job. Aluminum paint will be mixed on the job and only enough for one day's use shall be mixed at one time. The paint mixed in the proportion of 2 pounds of aluminum powder per gallon of vehicle, results in a paint containing approximately 21% pigment and 79% vehicle. The weight amount of powder should be placed in a suitable container and the measured volume of vehicle then poured over it, and the paint thoroughly mixed by stirring with a paddle. The paint should be occasionally stirred during use.

For painting weather exposed steel structures, the steel surface shall be thoroughly clean and dry. All rust, mill scale, loose paint, dirt and other foreign matter must be removed. Oil and grease should be removed with a mineral spirit. Painting should not be done in wet weather or when there is frost or moisture condensation on the steel, nor when the temperature is below 40° F. On all steel structures and the barespots of old painted structures, a rust inhibitive priming coat shall be applied and allowed to dry for not less than 48 hours before applying the aluminum paint. In the application of aluminum paint by brushing, the finish strokes should generally be made in the same direction.

Before repainting, the entire structure should be well brushed with a wire brush (or well cleaned with a sand blast). All scale or blister spots hand scraped. Give all bare places one priming coat of red lead paint. If the surface is in good condition except for spots, spot priming will be sufficient. If the surface is in poor condition, a priming coat should be applied to the entire surface.

Allow each coat to dry thoroughly before applying the succeeding coat. As the aluminum paint provides an air-tight seal, it is important that the red lead primer be thoroughly dry before applying the aluminum paint. The red lead paint dries slowly and about one week is recommended for allowing the priming coat to dry before applying the aluminum paint.

Apply the priming coat with round or oval brushes and brush well on the metal surfaces. The aluminum paint may be applied with a paint spray or brush.

Storing Aluminum Paste and Powder.

(a) Keep both paste and powder in a warm dry room at temperature between 60° and 80° F.
(b) Keep containers at least three feet away from radiators or steam pipes.
(c) Containers opened for use should be resealed as soon as possible.
(d) Keep absolutely dry.
(e) Do not store in same room with lacquers, varnishes or other combustible material such as oily rags, etc., and avoid accumulation of dust on floors, walls or beams.
(f) No smoking; keep open lights and fire away.
(g) Avoid all friction of metal against metal.
(h) Use an aluminum or other non-sparking metal to scoop out needed material.

In Case of Fire:

(a) Never use water. It reacts with hot aluminum dust to form hydrogen and tends to spread the fire.

(b) Have buckets of clean sand available. Sprinkle gently on the smoldering aluminum until it is completely covered. Avoid spreading the sand in quantities to disturb the burning material.
(c) Do not use liquids of any kind.

Guard Rails.

832. Guard rails are a safety device intended to warn the traveler of a dangerous turn, embankment, etc., and shall conform to the safety requirements as established by the State laws where in the guard rails are located. Guard rails should be painted a conspicuous color. Aluminum, white, striped white and black, and in many states where dense fogs occur, yellow, are the most common colors used. These colors may not harmonize with the surrounding color scheme but safety should be the rule.

Bridges, and particularly the narrow single track bridges should have a conspicuous wing guard rail painted so as to avoid any possibility of an accident caused by poor visibility.

Regulations and Cost Limits on Bridges.

833. Care should be taken that work is not undertaken as minor which under the regulations should be handled as major by the Bureau of Public Roads. The $5,000 per mile limitation on minor work does not apply to bridges. Because a mile of project including a bridge is estimated to cost less than $5,000 does not of itself justify approval as minor. The governing cosideration is the difficulty of design and construction.

Major and Minor Projects.

834. In the following, "major" refers to B.P.R. projects and "minor" to Forest Service projects.

A bridge project will come under one of three classes - (1) major for both design and construction, (2) minor for both design and construction, (3) major for design and minor for construction.

Class (1) will include all bridges:

a. Handled by contract.

b. Costing in excess of $5,000 for the erection of mainspan and abutments or piers but excluding the cost of materials, transportation and approach spans, unless the permission of the Forester to handle specific bridges as class 2 or 3 is secured.

c. Costing in excess of $10,000 total, including erection, materials, transportation, approach spans and all other costs, unless the permission of the Forester to handle specific bridges as class 2 or 3 is secured.

For bridge construction costing not to exceed the $5,000 and $10,000 limits described in the preceding paragraph, the decision on whether the construction shall be handled by contract or by day labor will be made by the Regional Forester. Unless he finds the circumstances exceptional, all day labor work should be handled as minor. Decision to handle as minor will be based on such matters as size or difficulty of the job, its location, relationship to or coordination with going minor road or trail work in the vicinity or coordination with protection needs of fire suppression activities.

The design of class 3 bridges may be made by the Forest Service with review by the B.P.R. or may be made by the B.P.R. If the B.P.R. makes the design, it should also handle the construction unless the Regional Forester decides on handling as minor.

If the bridge falls in class 3, the B.P.R. should be requested to have an inspector make sufficient visits during construction to assure the bridge being constructed in accordance with the design and specifications satisfactory to the B.P.R.

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