# CHARCOAL PRODUCTION

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## Introduction

Charcoal production offers a possible means of utilizing wood waste. It can be produced from all wood species and, providing suitable heating and processing methods are applied, practically all forms and sizes of forest and mill waste may be utilized as the raw material. At present, the kiln, converted-oven, vertical retort and oven recovery processes are the principal methods used in the United States for the production of charcoal. Kiln charring is conducted in both relatively small, fixed structures and in portable structures by igniting part of the charge for the initial heating, and allowing the remainder to burn in the presence of a limited amount of air. Only charcoal is recovered in this kiln operation. In oven and retort recovery processing the wood is charred in closed, externally heated containers without the admission of air. In addition to charcoal, other important byproduct chemicals are recovered. All of the methods operate chiefly on cull trees and the larger tops remaining after logging operations and on mill waste, such as slabs, blocks, and edgings. Stump sections from old, cut-over pine areas of the South and considerably lesser amounts of the timber and mill waste provide basically the raw material for softwood charcoal operations.

Similarly kiln methods are employed in the production of charcoal from both hardwoods and softwoods. This is true also in oven and horizontal retort operations where no major differences exist in conventional carbonizing technique or equipment. With the exception of a few kilns operating on "fatty" pine wood for the production of pine tar, charcoal is the only product recovered from the kiln. With the oven and horizontal retort methods, associated byproduct chemicals also are recovered commercially. Little attention is given to the selection of wood species for kiln operations whereas for hardwood oven operations considerable effort is made to choose the denser species, such as beech, birch, maple, hickory, ash, and the oaks. Also for operations that are dependent upon the recovery of byproduct chemicals, the highly resinous material from such species as longleaf and Cuban pines is essential.

[1] Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

Upwards of 300,000 tons of charcoal are produced annually in the United States with probably 25 percent of this amount accountable to kilns. There is little if any difference in properties between good kiln charcoal and oven charcoal and both generally have the same market applications. Each kind commands the same market price which, within recent years, has increased from about $40 to $60 per ton. Unlike most other industrial raw materials, charcoal is seldom sold on specifications. The usual market guarantees relate only to the weight per bushel and to the percentage of contained volatile matter. Limiting values for volatile matter and for moisture content are that they be not more than about 14 percent and 2 percent, respectively. The following lists indicate the more common market outlets for charcoal in the form of lumps, screenings, powder and briquets.

| Domestic and Specialized Fuel | Metallurgical | Chemical |
| --- | --- | --- |
| Citrus growers | Aluminum metal | Activated carbon |
| Domestic | Armor plate | Black powder |
| Foundries | Case hardening | Brake linings |
| Incinerators | Cobalt metal | Carbon disulfide |
| Laundries | Copper, brass and bronze | Carbon monoxide |
| Meat and fish curing | Electro manganese | Catalyst reactor |
| Railroad dining cars | Foundry molds | Electrodes |
| Shipyards | Magnesium metal | Fertilizer |
| Tinning and plumbing | Mining | Galvanizing |
| Tobacco curing | Molybdenum | Gas cylinders |
| | Nickel | Glass |
| | Pig iron | Glues |
| | Powdered iron | Graphite |
| | Special alloys | Magnesium |
| | Steel | Molding resins |
| | | Nursery mulch |
| | | Pharmaceuticals |
| | | Plastics |
| | | Poultry and stock feeds |
| | | Potassium cyanide |
| | | Sodium cyanide |

## Kiln Burning

The aim of kiln burning in the production of charcoal is to char the wood without burning it. This is accomplished, after the charge of wood has been ignited, by regulating the amount of air entering the kiln so that only "glowing" and not flaming takes place.

Any of several types of kilns are suitable for charcoal production. For the small operator a kiln provides a means for the production of charcoal that is low in initial investment and simple in operation. Although kilns may vary in size, shape, and detail of construction, the principle of operation is the same in all.

Probably the earliest charcoal production was in the pit or the dirt kiln. When the burning is properly controlled these types of kilns give satisfactory results. Materials for construction of either kind are available at any site and little investment is required other than for labor.

Considerable vapors and uncondensable gases are given off as the wood chars. In the pit as well as in subsequent types of kilns these volatile products escape to the atmosphere through smoke flues. Although a watery condensate may be obtained that contains acetic acid, methanol and other chemical products, it is not considered practical to refine it commercially. This is mainly true because the generally limited capacities of kiln operations would hardly justify the high cost of the refining equipment required.

In the early days, charcoal production from the large pit and brick kilns was often competitive with the production of charcoal from distillation plants and could not always show a profit. Contributing factors to this situation were the lower capacity of the kilns and the high costs of cutting and transportation of the wood to the kiln. In order to overcome these difficulties in part, numerous investigators have conducted studies within comparatively recent years toward the development of inexpensive units that could be easily moved to various sources of wood supply, and that would require a minimum of labor and produce good yields.

One of the earlier domestic units developed for portability is referred to as the Black Rock Forest Kiln. It is circular in cross section, of light, sheet-steel construction and consists of a bottom and top section and shallow lid. The kiln is 7 feet in diameter at the base, sloping to a diameter of about 4 feet at the top and is 5 feet high to the top of the lid. Its gross volume is approximately 100 cubic feet into which may be end stacked about one cord of 4-foot wood. The kiln is equipped with 4 draft ports and 4 smoke flues alternately spaced through the bottom section at ground line. In operation the burning proceeds from the point of ignition at the center of the kiln to the outside and generally against the flow of air entering the draft ports. When the burning is properly conducted, insufficient air is present to destroy the charcoal previously formed. A yield of about 32 bushels of charcoal per kiln charge is normally obtained. The estimated cost for a fully equipped 1-cord kiln at 1947 prices is about $250 and its life about 5 years. Bulletin No. 4, "A Portable Charcoal Kiln," prepared by H. H. Tryon, Black Rock Forest, Cornwall-on-the-Hudson, N. Y., gives a complete description of the construction and operation of this unit.

Further work has been conducted here and abroad by other investigators. An English kiln of brick construction is described at length in "A Charcoal Kiln of Brick Construction," Forest Products Research Laboratory, Princes Risborough, Aylsbury, Bucks, England. Although the feature of portability is sacrificed in this type of construction some advantage is claimed in that there is less heat loss and the cost of materials is lower.

On the other hand, a correspondingly longer cooling period is required with a reduced charcoal capacity per unit of time compared to the steel structures. These kilns are cylindrical in shape and have a capacity of about 1-1/2 cords of wood. Approximately the same yields of charcoal are reported as are obtained from the circular steel kilns of American design.

Probably the most intensive investigations in kiln burning within recent years have been carried on by H. W. Hicock and A. R. Olsen at the Connecticut Agricultural Experiment Station, New Haven, Connecticut. The results of these studies, which included research on both portable and semiportable units, are given in "A Portable Charcoal Kiln (using the chimney principle)" Bull. 448 and "The Connecticut Charcoal Kiln," Bull. 431. In the design of these kilns a departure has been made from the more common cylindrical shape to a rectangular shape. Essentially the chief differences between the two types are in the means employed for the regulated flow of air into the kilns and for the escape of gases through one instead of several chimneys. In a comparison of the two types of kilns it is recognized that some portability is lost by using cement block construction. However, this condition is balanced somewhat by reduced material costs and higher yields for kilns of equal capacity. The steel-panel kiln may be built generally to hold 1, 2, or 5 cords of wood while the cinder-concrete kiln may be constructed to have charges as great as 13 to 15 cords. Both types of kilns are especially adaptable for battery operation if greater production is desired.

Yields of about 40 and 42 bushels of charcoal per cord of seasoned mixed hardwoods are reported for the two kinds of kilns. Unseasoned white pine wood yielded 20 to 30 bushels per cord. A substantially higher yield could be expected if the wood were seasoned.

Reliable figures are not available regarding either an average production cost per bushel of charcoal or an average cost per cord of wood for kiln construction. A current estimate of $75 per cord may be assumed for construction of the concrete block kiln of 1 to 2 cords capacity and $75 to $100 per cord for sheet panel units.

Kiln operations appear most successful in areas having an adequate demand for charcoal and in which hauling distances are relatively short. Because of its extreme bulk, the cost of any long distance transportation of charcoal would be prohibitive.

## Wood Distillation

In kiln burning, the heat necessary to distill or carbonize the wood is furnished by combustion of part of the charge. The standard procedure for accomplishing the same effect in the hardwood and softwood distillation industries is the external heating of a wood charge contained in large, steel retorts or ovens. At the same time facilities for the recovery of valuable products other than charcoal are employed.

### Distillation of Hardwoods

The ovens and converted ovens used are generally rectangular in cross section and have a capacity of 2 to 4 cars, each loaded with 2 to 2-1/2 cords of wood. The ovens are heated by fire-boxes placed at one or both ends depending upon their length. Distillation vapors and gases pass through usually two openings to condensers located at the side of the ovens. Carbonization is completed in about 22 hours and the charcoal is immediately withdrawn to coolers at the same time that another charge of wood is entering the oven. The larger oven plants have a capacity of about 200 cords of wood per day and produce from this amount about 10,000 bushels of charcoal.

The initial products obtained from the condensers are uncondensable gases, crude pyroligneous acid, and tars. The pyroligneous liquor is the most valuable of the three products collected since it contains appreciable amounts of acetic acid and methanol. These byproduct chemicals are recovered by suitable refining methods and together with charcoal comprise the chief marketable products of the industry. An outline of the methods and kinds of equipment required for the recovery of byproduct chemicals is given in Forest Products Laboratory Report No. R738, "Hardwood Distillation Industry."[2]

Charcoal is produced continuously by the Stafford vertical retort process in one domestic operation. In this process hogged wood is fed into the top of a vertical tube retort and the charcoal is discharged from an outlet at the bottom. The heat of reaction of the wood undergoing decomposition is the only heat required for the processing. Details regarding the commercial applications of the Stafford process are contained in the article, "Waste Wood Utilization by the Badger-Stafford Process," appearing in the April 1930 issue of Industrial and Engineering Chemistry and also in Forest Products Laboratory Report No. R738.

The more recently applied carbonization methods of Reichert and Lambiotte in Europe have created considerable interest in the United States. With the exception of the carbonization being carried out batchwise in the

[2] Forest Service Report, "Timber Requirements of the Hardwood Distillation Industry," includes information on distillation technique as well as statistical data on wood requirements and distillation products.

Reichert and continuously in the Lambiotte, the process principles are, in general, similar. The wood is placed in vertical tube-type retorts and is heated by the continuous circulation of hot wood gases that are supplied from wood undergoing decomposition. Wood bolts 12 to 15 inches long and wood scrap provide the raw material commonly used in these operations. The work of T. Reichert in Germany is described in FIAT Report No. 444, "Wood Carbonization Industry in Germany" and in the following United States patents:

No. 2,160,341 (1939) "Process for the Carbonization of Organic Materials of Vegetable Origin."

No. 2,202,231 (1940) "Process for the Carbonization of Wood and Similar Materials."

The results of investigations by A. Lambiotte in Belgium are shown in U. S. Patent No. 2,289,917 (1942) "Process of Continuous Carbonization of Cellulosic Materials."

## Distillation of Softwoods

Carbonization methods similar to those employed in the distillation of hardwoods are also used for softwoods. As a rule, however, the charring vessels are smaller and in some cases the charging and discharging of the retorts is performed with hand labor. The retorts are equipped with vapor outlets and condensers in order that the products of decomposition may be recovered and subsequently refined as marketable materials. In addition to charcoal, these plants usually produce turpentine, pine oil, pine tar and in some cases dipentene from the resinous woods. The average yield of charcoal obtained from highly resinous wood is about 30 bushels per cord. The yields of charcoal and volatile products will, of course, vary somewhat with the amount of resin in the wood. A more complete outline of plant operation and of the methods applied is given in Forest Products Laboratory Report R496 and in the book "Wood Distillation" by L. F. Hawley.

## Cost of Operation

In order to operate economically, recovery plant charcoal production requires essentially a permanent source of wood supply of suitable species and adequate markets for all of the products. Large scale production requires further a heavy initial plant investment. It is commonly understood within the industry that to operate profitably an oven hardwood plant must have a capacity of at least 100 cords per day. No accurate figures on plant cost are available at the present time. It is estimated that a hardwood recovery plant would now cost between $20,000 and $25,000 per cord per day capacity. On the same basis the estimated cost for a resinous wood plant would be between $10,000 and $15,000 per cord per day capacity.

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