CHARCOAL

The history of the charcoal industry in the United States illustrates how the needs of an emerging nation may combine with various world events, new chemical products, and new processes of chemical synthesis to affect the harvesting and utilization of forest resources. From the colonial period through much of the nineteenth century, the need for iron products required that forests be harvested for charcoal to stoke the blast furnaces. Charcoal was also required for making gunpowder, for some domestic heating and cooking, and for the smelting of other metals, but in the nineteenth century, American charcoal was largely consumed in iron manufacture. The census of 1880 showed that over 94 percent of the 74 million bushels of charcoal consumed in that year went for this use. In the twentieth century, World War I, the airplane, and the automobile created a need for chemicals produced as by-products of charcoal, such as acetone for munitions and acetate for airplane dope and automobile lacquers. Photography and bakelite also created a demand for acetate and formaldehyde from wood. Chemicals were the principal product, and charcoal became a by-product.

Charcoal is a complex mixture of residues resulting from the decomposition of wood or bark heated under conditions that severely restrict the supply of oxygen. Around 280 degrees centigrade, an exothermic reaction occurs. The usual carbonization procedure involves prolonged heating to a final temperature of 400 to 600 degrees centigrade in the absence of air. The carbon content of the resulting charcoal is around 80 percent.

United States charcoal production peaked at around 700,000 tons about 1882. The consumption of wood for charcoal probably has never been surpassed since; the 1970 and 1980 production figures are for charcoal briquets that contain char from sources other than wood, along with starch binder and other ingredients.

The charcoal iron industry in America began with the construction of an iron furnace at Falling Creek, some eighty miles from Jamestown, Virginia, about 1620. The Falling Creek furnace was destroyed in 1622; no written accounts remain of its operations. In 1645, a furnace was constructed near Saugus, Massachusetts, and it operated successfully until 1675. Additional furnaces started up in many localities near iron ore deposits. Charcoal iron works, built like plantations, included entire communities of homes, stores, and churches, along with extensive woodlands. The early furnaces were twenty to thirty feet high with a diameter of four to eight feet. They were constructed on steep hillsides so that raw material could be easily loaded through the top. These furnaces produced one to six tons of iron per day, using about one ton of charcoal for each ton of pig iron. By the end of the nineteenth century, new charcoal iron furnaces averaged sixty feet in height and had the capacity to produce 20,000 tons a year. As furnaces and iron production grew, so did the demand for charcoal. When Franklin B. HOUGH made a survey of the charcoal needs of American iron furnaces in the late 1870s, he found that they needed the harvest of 100 to 1,521 acres of woodland annually to sustain their opera-

TABLE 1. Charcoal Production for Selected Years

Year	*Thousands of Tons*
1850	260
1882	700
1905	266
1910	500
1920	200
1930	450
1940	250
1950	250
1960	320
1970[1]	500
1980[1]	800

1. Charcoal briquet production from all sources including wood, bark, lignite, coal, and agricultural residue.

Brick beehive charcoal kilns, Colorado, 1916. Forest Service Photo.

tions. The twenty-three furnaces reporting expected to cut over their woodlands in cycles ranging from fifteen to fifty years; to assure a permanent supply of charcoal, each furnace needed anywhere from 9,000 to 50,000 acres of woods.

After the Revolutionary War, ironmaking expanded rapidly as the colonists moved westward. The first blast furnace west of the Allegheny Mountains was built in 1790. The great iron and steel center of Pittsburgh started with a furnace constructed in 1796. Until at least 1832, all United States pig iron was made with wood charcoal. In 1850, when pig iron production was 563,000 tons from 377 furnaces, about one-half was still charcoal iron and the rest was made with coal. Charcoal iron production continued to increase until 1880 when about 800,000 tons were produced, or 14 percent of the nation's total pig iron production; about 700,000 tons of charcoal were required to produce that record figure. As larger blast furnaces were built, the use of charcoal in iron manufacture declined, in part because charcoal lacked strength adequate to support the overburden in the higher furnaces and in part be cause once local forests had been harvested for charcoal production, longer hauling distances increased transportation costs. By 1892, charcoal pig iron was down to about 5 percent of total iron production, although the last charcoal blast furnace in the country did not shut down until 1945.

In the colonial period, all charcoal was produced in "earthen kilns'' or "pits" made by stacking wood carefully around a central chimney (kept open with poles and small pieces of wood) and covering the pile with several inches of earth, mud, or leaves and charcoal dust. The iron industry preferred charcoal with a high crushing strength, such as was produced from dense hardwoods like maple, birch, beech, oak, and hickory. The wood was ignited through the open chimney, and the rate of combustion was controlled by using a shovel to open or close vents at the base of the mound. The progress of charcoaling operations in these pits was judged by observing the color and amount of smoke leaving the kiln. Pits ranged widely in size, containing anywhere from ten or fifteen cords up to eighty cords of wood. Those associated with the iron furnace at Hopewell, Pennsylvania, averaged thirty to forty feet in diameter and held twenty-five to fifty cords.

Nineteenth-century charcoal makers also used

TABLE 2. Yield of Various Products per Ton of Dry Wood

Intermediate Products		*Final Products*	
		Charcoal, lb.	600
		Noncondensable gas, cu. ft.	5.000
Total 100 percent spirits, gal.	5	C.P. methanol, gal.	3
		Methyl acetone, gal.	.7
		Allyl alcohol, gal.	.1
		Ketones, gal.	.2
		Methyl acetate, gal.	1.0
		Soluble tar, gal.	22
Settled tar, gal.	11	Pitch, lb.	66
		Creosote oil, gal.	3
Acetic acid (as 100 percent), lb.	101	Ethyl acetate, gal.	14.7
		Ethyl formate, gal.	1.3

brick or stone kilns, which were said to secure a higher yield of charcoal per cord of wood and to require less labor to operate than open pits. Brick kilns were of two types: dome or beehive shaped, holding about forty cords, and rectangular, with a capacity of about eighty cords. Their use never entirely replaced charcoal pits; when Franklin B. Hough made a survey of charcoal iron furnaces in 1876, the great majority reported making all their charcoal in open pits, chiefly because pits could be located anywhere in the woods and because it was moreeconomical to haul charcoal than wood. Charcoal pits remained in use in some areas until after the middle of the twentieth century. According to Nelson Courtlandt Brown (1937), 672,000 bushels of charcoal were made by the open pit method in 1935, a little less than 2 percent of the nation's total production for that year.

Hardwood Distillation

The recovery of the volatile products of hardwood was started about 1812 with the collection and condensation of the gases from a beehive kiln. This process was cumbersome because of the multiple stacks required, and the gases were contaminated with combustion products resulting from air infiltrating into the kilns. The brick kiln, like the pit, was satisfactory only so long as the chief product of wood distillation was charcoal. As Hough could remark as late as 1878, "scarcely a thought has been had as to the saving of the volatile products of carbonization." However, during the course of the following decades, externally heated cast iron or steel retorts began to replace beehive kilns for charcoal production and made it feasible to collect the vapors from the carbonization of wood. Cylinders about nine feet long and holding about five-eighths to one cord of wood were used at first, but about 1895 there came into we the larger oven retort, which could be loaded by running cars directly into the chambers. The capacity of most retort plants was in the range of 22 to 100 cords, but a few could handle up to 225 cords. They operated on a twenty-four-hour cycle, whereas brick kilns had taken fifteen to twenty-five days to complete the carbonization process. Retorts were also more efficient in the conversion of wood into charcoal. Richard Schallenberg has calculated that open pits produced from thirty-five to thirty-eight bushels of charcoal per cord of wood, brick kilns from forty-five to fifty, and iron retorts from sixty to sixty-five bushels per cord. Furthermore, the retorts recovered usable by-products in the form of crude "pyroligneous acid" and noncondensable gases ("wood gas"). The pyroligneous acid was refined to make acetate of lime, methanol (wood alcohol), and tar. The tar was burned to heat the retort, and the wood gas was burned to dry and preheat the wood. Methanol was widely used as a solvent in the production of shellacs and varnishes, in stiffening hats, and in perfumery, aniline dyes, formaldehyde, and the manufacture of explosives, and it was mixed with grain alcohol to produce denatured alcohol; the acetate of lime was used in the manufacture of wood vinegar, acetic acid, many commercial ace-

TABLE 3. Composition of Noncondensable Gas

Constituent	*Volume Percent of Dry Gas*
Hydrogen	2
Methane	17
Hydrocarbons	1
Carbon monoxide	23
Carbon dioxide	38
Oxygen	3
Nitrogen	16

tates, acetic ether, acetone (which in turn supplied iodoform and chloroform), and other products.

Before the rise of petrochemical production in the 1920s, all industrially important organic chemicals were distilled from wood. The recovery of acetone as a by-product of butanol fermentation decreased the importance of acetone from wood, but the biggest blow to the importance of wood chemicals came in 1925 when synthetic methanol arrived from Germany at forty-five cents per gallon, thirty-two cents below the price of pure-grade methanol from wood distillation. Commercial Solvents Corporation began the first commercial synthetic methanol production in the United States in Indiana in 1927 from carbon monoxide and hydrogen collected also as a by-product of butanol production.

In 1930, about fifty hardwooddistillation plants were still in operation, but most closed down during the Depression. In 1950, only five were still operating, and this number was reduced to one by 1960. In 1969, the last plant, located at Marquette, Michigan, closed down.

Softwood Distillation

Softwood species were also distilled, but the products were different from those obtained from hardwood species. The only commercially successful plants used longleaf pine (*Pinus palustris*) lightwood, knots, and stumps. The products were charcoal and pine tars and oils. Turpentine was refined from the oils. The yield of charcoal was 350 to 400 pounds per ton of wood. Turpentine and pine tar yields were 4 to 6 gallons and 20 to 30 gallons, respectively. The softwood distillation industry was never as large or as significant as the hardwood distillation industry. In 1919, L. F. Hawley estimated that twelve or thirteen plants were operating. The last plant, located in Louisiana, operated occasionally during the 1970s.

The construction of the ovens and methods of operation vaned considerably between plants. Some were externally heated ovens, similar to those used for hardwoods, with a capacity of about ten cords. Most, however, were smaller-capacity retorts heated by internal flues. Operation varied from collecting all of the distillate externally, as for hardwoods, to collecting the volatile distillates externally and the remainder from the bottom of the kiln.

The charcoal product was used for fuel. The liquids were refined for various end uses. Turpentine was refined from the oil liquids and the remaining oil was refined for solvent, chemical, and pharmaceutical uses. The tar was used for cordage, rubber, oakum, roofing cements, and pharmaceuticals.

Recent Charcoal Production

After World War 11, charcoal production began to increase to meet a demand for its use for restaurant, home, and recreational cooking fuel, which the U. S. FOREST SERVICE reported to consume over half the charcoal produced in 1956. Since most of the large wooddistillation plants had ceased operations, new sources were needed, and many small kilns were constructed in rural areas to utilize low-grade logs from woodlots and slabs and edgings from sawmills.

In 1961, the Forest Service counted 1,977 charcoal-converting units in the United States. These included 262 brick kilns, 805 concrete and masonry block kilns, 430 sheet steel kilns (mostly portable, for use in the woods), and 480 other units such as retorts and ovens. Ninety-four percent of these producing units (accounting for 98 percent of the charcoal production) were located in the eastern portion of the United States. Thirteen large producers provided 56 percent of the total production.

Traditionally, charcoal was used in lump form, often screened to remove pieces smaller than one-half inch. This practice left behind a large volume of unusable fines. The accumulation of charcoal fines, the desire to produce a uniformly sized product with uniform burning rates, and the need to supply a cleaner product for the new home and recreational markets led to the production of briquetted charcoal. The briquetting process consists of dry grinding the charcoal and mixing it with a starch solution to form a paste. The paste then goes to a double-roll rotary press which delivers the formed briquets to a continuous drier. In about three hours, the moisture content is reduced from 40 percent to less than 1 percent. The briquets may contain charcoal and starch and various amounts of coal, clay, and char from lignite or agricultural residues.

Kilns, most commonly constructed of poured concrete, are used to convert roundwood, sawmill slabs, and edgings into charcoal. They have a capacity of from 40 to 100 cords and operate on about a seven- to twelve-day cycle. Raw material in the form of sawdust, shavings, or milled wood and bark is converted to charcoal in a continuous multiplehearth furnace commonly referred to as a Herreshoff furnace. The capacity is usually at least one ton of charcoal per hour. The yield of charcoal is about 25 percent by weight on a dry basis. The first reference to the use of the Herreshoff furnace for charcoal was reported in 1948; by 1980, there were about sixteen in operation in the United States, supplying over one-half of the wood and bark charcoal. Gases from the kilns and furnaces are burned to alleviate air pollution, sometimes with additional fossil fuel

to recover heat and steam, or in afterburners to nearly eliminate visible pollution and odors.

In 1980, charcoal was nearly all consumed for cooking as charcoal briquets, although some was employed in certain metallurgical and filtration processes and horticultural uses. The market for charcoal briquets showed promise of continued growth, although the use of wood residues for fuel offered increasing competition for raw materials. No longer would unused, low-cost wood residue provide an incentive for constructing charcoal plants, and the cost of charcoal seemed likely to increase at a rate that is higher than the increase in cost of wood fuel.

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ANDREW J. BAKER

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