Properties and Uses of Bark as an Energy Source

Stanley E. Corder

Research Paper 31
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INTRODUCTION

Energy is extremely important to all societies—but especially important to industrial societies. A characteristic of an industrial society is its enormous consumption of energy. Only in the past few years has there been a broad general concern about energy cost and supply. When petroleum prices increased by a factor of 3 to 4 in just a few months, we all became aware of the importance of, and our dependence on energy supplied by other countries; and we became aware that many energy resources are nonrenewable—once used, they are gone forever.

This paper concerns one resource that is renewable, one constantly replaced by energy from the sun. It is a resource in which there is virtually no international trade, one nearly always used in the country in which it is produced. That energy source is bark.

By far the most important single use for bark (as well as for wood) is for energy. In 1972, nearly half the wood cut for man's use was for fuel (18), and associated with that wood was bark. Worldwide, more people are warmed by wood and bark than by any other fuel.

QUANTITY

Statistics on the quantity of bark produced and used are difficult to obtain. The reason for the paucity of statistics is probably that bark usually has been considered a waste to be disposed of at lowest possible cost. There are, however, production statistics available on roundwood and its uses. As bark is associated with roundwood, information can be obtained indirectly on bark production. Table 1 shows total roundwood production and roundwood used for fuel in 1972 for the world and selected countries with greatest production, as reported by the Food and Agriculture Organization of the United Nations (18). Also in Table 1 is an estimate of total bark production for the same countries that was obtained by multiplying total roundwood production by a factor of 0.13. The factor of 0.13 is the ratio of cubic meters of solid bark to cubic meters of solid wood that has been used for logs harvested in Oregon (12). The factor also nearly agrees with information reported by Millikin (29) for eastern Canadian tree species and by Virtanen (42) for Finnish species. Though it may not be exact, it represents a reasonable estimate for bark production.

Inspection of Table 1 shows that 46 percent of the total world production of roundwood was used for fuel in 1972. As one would expect, the percentage is lower for industrialized than for developing countries.

Information is not available for the percentage of total bark production that was used for fuel. We do know, however, that the percentage was greater than the percentage of roundwood so used. We can assume that all bark associated with roundwood fuel was used for the same purpose. In addition, much of the bark on roundwood used for pulp and lumber was removed from the log in processing and subsequently was used for fuel.

Although data were not obtained for other countries, information was obtained on the amount of bark used for energy in the United States, and in the state of Oregon. The U.S. Forest Service (41) estimated that about 30 percent of total bark produced in the United States was used for fuel in 1970. In Oregon, a recent survey (38) indicated a total production of 49 million cubic meters of roundwood in 1972—slightly greater than in Finland. Oregon produced 6.9 million cubic meters (solid) of bark, and 62 percent—4.3 million cubic meters (solid)—was used for energy in 1972. This information indicates that industrialized countries

Table 1. Total Production of Roundwood and Bark, and Volume and Percentage of Roundwood Used for Fuel[1], in Millions of Cubic Meters for Selected Countries in 1972 (18).

Country	Roundwood			Bark[2]
		Used for fuel		
	Volume	Volume	Percent	
USSR	383	85	22	50
USA	356	13	4	46
China	179	134	75	23
Brazil	164	140	85	21
Indonesia	120	104	87	16
Canada	120	4	3	16
India	117	106	91	15
Nigeria	60	57	95	8
Sweden	58	3	5	8
Japan	46	2	4	6
Finland	43	7	17	6
World total	2,454	1,140	46	319

[1] Includes roundwood used for charcoal.

[2] Total bark estimated by multiplying total roundwood production by a factor of 0.13 cubic meters of solid bark per cubic meter of solid roundwood.

use a higher proportion of bark than roundwood for fuel. Indeed, by far the greatest use of bark is for energy.

Total world production of bark was estimated at 319 million cubic meters (solid) in 1972 (Table 1). A visualization of this can be obtained by calculating the length of a train of rail cars required to hold annual bark production, a train about 70 thousand kilometers long extending 1.8 times around the earth. A train containing bark used for energy certainly would extend farther than once around the earth. Such a visualization shows that bark is an important source of energy.

FUEL PROPERTIES AND ANALYSES

Various properties and analyses are important to a material used as fuel. Among them are heating value, ultimate analysis, proximate analysis, moisture content, and density.

Heating Value

The higher heating value, or gross calorific value, of a fuel is the amount of heat released when a given amount of fuel is burned completely, and when the water formed in burning is condensed. In a practical burning system, water normally is not condensed. The resulting heat loss, as well as others, is considered when thermal efficiencies are calculated.

A summary of some published higher heating values for bark from coniferous species is given in Table 2, and similar values for nonconiferous species are shown in Table 3. The average heating value of bark from the coniferous species listed (5,030 Kcal per kg) is about 7 percent higher than the average from the nonconiferous species (4,700 Kcal per kg).

Factors influencing heating value are moisture, ash, and extractive contents. Moisture content, of course, greatly influences the energy obtainable from a fuel, and it will be discussed later. Heating values based on dry weight (Tables 2 and 3) are affected principally by

Table 2. A Summary of Some Published Heating Values and Ash Contents for Bark of Coniferous Species.

Species	Reference number[1]	Higher heating value[2] (Gross calorific value[2])		Ash content[2]
		Kcal/kg	Btu/lb	%
Douglas-fir (*Pseudotsuga*	15	5,611	10,100	--
menziesii [Mirb.] Franco)				
Fir, balsam	9	5,265	9,477	2.3
(*Abies balsamea* [L.] Mill)	29	5,056	9,100	2.3
Hemlock, eastern	9	5,213	9,383	1.6
(*Tsuga canadensis* [L.] Carr.)	29	4,939	8,890	2.5
Hemlock, western	15	5,444	9,800	--
(*Tsuga heterophylla* [Raf.] Sarg.)				
Larch, western	9	4,885	8,793	1.6
(*Larix occidentalis* Nutt.)				
Pine, jack	9	5,211	9,380	1.7
(*Pinus banksiana* Lamb.)	29	4,961	8,930	2.0
Pine, lodgepole	9	5,997	10,794	2.0
(*Pinus contorta* Dougl.)				
Pine, Scots	42	4,775	8,595	1.7
(*Pinus silvestris* L.)				
Pine, slash	9	5,343	9,618	0.6
(*Pinus elliottii* Engelm.)				
Pine, southern	23	4,909	8,837	--
(Mixed species)				
Pine, spruce	23	4,787	8,617	--
(*Pinus glabra* Walt.)				
Pine, Virginia	28	4,680	8,424	--
(*Pinus virginiana* Mill.)				
Redcedar, western	15	4,833	8,700	--
(*Thuja plicata* Donn)				
Spruce, black	9	4,899	8,819	2.0
(*Picea mariana* [Mill.] B.S.P.)	29	4,783	8,610	2.4
	15	5,000	9,000	--
Spruce, Engelmann	9	4,914	8,846	2.5
(*Picea engelmanii* Parry)				
Spruce, Norway	42	4,760	8,568	2.8
(*Picea abies* [L.] Karst.)				
Spruce, red	29	4,794	8,630	3.1
(*Picea rubens* Sarg.)				
Spruce, white	29	4,739	8,530	3.0
(*Picea glauca* [Moench] Voss)				
Tamarack	29	5,006	9,010	4.2
(*Larix laracina* [Du Roi] K. Koch)				

[1] See Literature Cited.
[2] Based on ovendried weight.

ash and benzene-soluble extractive contents (9). High ash content tends to lower heating values, and a large amount of benzene extractives tends to increase heating values. For example, of the 20 bark species listed by Chang (9), lodgepole pine bark had the highest

Table 3. A Summary of Some Published Heating Values and Ash Contents for Bark of Nonconiferous Species.

Species	Reference number[1]	Higher heating value[2] (Gross calorific value[2])		Ash content[2]
		Kcal/kg	Btu/lb	%
Alder, red	9	4,687	8,436	3.1
(*Alnus rubra* Bong.)				
Aspen, quaking	9	4,958	8,924	2.8
(*Populus tremuloides* Michx.)				
Beech, American	29	4,244	7,640	7.9
(*Fagus grandifolia* Ehrh.)				
Birch, European white	42	5,790	10,422	1.6
(*Betula verrucosa* Ehrh.)				
Birch, paper	9	5,506	9,910	1.5
(*Betula papyrifera* Marsh.)	29	5,728	10,310	1.8
Birch, yellow	9	5,319	9,574	1.7
(*Betula alleghaniensis* Britton)	29	5,111	9,200	2.3
Blacktupelo	9	4,412	7,942	7.2
(*Nyssa sylvatica* Marsh.)				
Cottonwood, black (*Populus trichocarpa* Torr. & Gray)	15	5,000	9,000	--
Elm, American	9	4,121	7,418	9.5
(*Ulmus american* L.)	29	4,222	7,600	8.1
Maple, red	29	4,500	8,100	3.0
(*Acer rubrum* L.)				
Maple, sugar	9	4,315	7,767	6.3
(*Acer saccharum* Marsh.)	29	4,572	8,230	4.1
Oak, northern red	9	4,667	8,400	5.4
(*Quercus rubra* L.)				
Oak, white	9	4,156	7,481	10.7
(*Quercus alba* L.)				
Sweetgum	9	4,412	7,942	5.7
(*Liquidambar styraciflua* L.)	11	4,237	7,627	--
Sycamore, American	9	4,237	7,909	5.8
(*Platanus occidentalis* L.)				
Willow, black	9	4,268	7,683	6.0
(*Salix nigra* Marsh.)				

[1] See Literature Cited.
[2] Based on ovendried weight.

heating value. It also had the largest amount of benzene extractives (28.7 percent) and only a moderate amount of ash (2.0 percent). On the other hand, American elm bark had the smallest amount of benzene extractives (0.5 percent) and the second highest ash content (9.5 percent), which resulted in the lowest heating value for species that Chang investigated. In comparison with wood, bark contains large amounts of ash and extractives (9).

Howard (23) found that bark near the ground line of Southern pine trees had about 3 percent greater heating value than bark near the top of trees (4-inch top). Virtanen (42) reported that outer bark of European white birch had a heating value about 50 percent greater than that of inner bark.

Table 4. A Summary of Some Published Ultimate Analyses of Bark.

Species	Reference number[1]	Dry weight of constituents			
		Carbon	Hydrogen	Oxygen, Nitrogen	Ash
Coniferous		%	%	%	%
Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco)	13	53.0	6.2	39.3	1.5
Fir, balsam (*Abies balsamea* [L.] Mill)	29	52.8	6.1	38.8	2.3
Hemlock, eastern (*Tsuga canadensis* [L.] Carr.)	29	53.6	5.8	40.1	2.5
Hemlock, western (*Tsuga heterophylla* [Raf.] Sarg.)	13	51.2	5.8	39.3	3.7
Pine, jack (*Pinus banksiana* Lamb.)	29	53.4	5.9	38.7	2.0
Pine, Scots (*Pinus silvestris* L.)	42	54.4	5.9	38.0	1.7
Spruce, black (*Picea mariana* [Mill.] B.S.P.)	29	52.0	5.8	39.8	2.4
Spruce, Norway (*Picea abies* [L.] Karst.)	42	50.6	5.9	40.7	2.8
Spruce, red (*Picea rubens* Sarg.)	29	52.1	5.7	39.1	3.1
Spruce, white (*Picea glauca* [Moench] Voss)	29	52.4	6.4	38.2	3.0
Tamarack (*Larix laracina* [Du Roi] K. Koch)	29	55.2	5.9	34.7	4.2
Nonconiferous					
Beech, American (*Fagus grandifolia* Ehrh.)	29	47.5	5.5	39.1	7.9
Birch, European white (*Betula verrucosa* Ehrh.)	42	56.6	6.8	35.0	1.6
Birch, paper (*Betula papyrifera* Marsh.)	29	57.4	6.7	34.1	1.8
Birch, yellow (*Betula alleghaniensis* Britton)	29	54.5	6.4	36.8	2.3
Elm, American (*Ulmus americana* L.)	29	46.9	5.3	39.7	8.1
Maple, red (*Acer rubrum* L.)	29	50.1	5.9	41.0	3.0
Maple, sugar (*Acer saccharum* Marsh.)	29	50.4	5.9	39.6	4.1

[1] See Literature Cited.

Ultimate Analysis

A summary of some published values for ultimate analyses of different species of bark is presented in Table 4. There is considerable uniformity among the different species—particularly among conifers. The average rounded values of carbon, hydrogen, oxygen plus nitrogen, and ash are 53, 6, 39, and 2 percent for the coniferous species listed. Ultimate analysis for bark is not greatly different than for wood. Bark tends to have slightly more carbon and a little less oxygen than wood (4).

In contrast to most coals and many heavy fuel oils, bark has negligible sulfur. The presence of sulfur in fuel is undesirable because of problems with corrosion and air pollutant emissions.

Ash, the inert component of a fuel, is also undesirable. As ash is not combustible, it is either retained in the furnace or entrained with the stack gases leaving the furnace. When it accumulates in the furnace, it tends to interfere with the combustion process, and when it is entrained with furnace gases, it tends to cause erosion of heat-exchange surfaces and ducting. Ash, as well as unburned combustibles entrained in stack gases,also results in particulate air emissions, which makes necessary equipment for separating particulate material from gases (5, 16, 22).

The ash content of bark is usually higher than that of wood (30, 42),and bark from nonconiferous species generally has more ash than bark from coniferous species. Although ash content of wood is usually less than 1 percent (30), average ash content of bark from coniferous species (Table 2) is about 2 percent, and from nonconiferous species (Table 3) is about 5 percent. To the ash present in the bark of standing trees, harvesting and handling of logs frequently adds dirt or sand–thus increasing the total ash of bark fuels. The ash content of bark is lower than that of most coals, which have a range of about 5 to 25 percent ash.

Information on composition and on fusion temperatures of ash from bark is given by Milliken (29) and Virtanen (42). Calcium oxide or lime is the major component of bark ash, and usually accounts for over half of the composition of ash.

Proximate Analysis

Proximate analysis is a standard test for determining the relative proportions of volatile matter, fixed carbon, and ash in a solid fuel. Table 5 is a summary of some published values of proximate analysis for barks. The listed barks average a rounded volatile component of 74 percent and a fixed carbon content of 23 percent. Barks, in general, have more fixed carbon and less volatile matter than woods. Mingle and Boubel (30) found that fixed carbon was about 10 percentage points greater for bark than for wood; consequently, the volatile matter was about 10 percentage points less for bark than for wood.

Bark has more volatile matter than coal, in which the volatile component is usually less than 40 percent. The proportion of volatile components and fixed carbon influences the burning characteristics of a fuel, because the volatile components are driven off when heated and burn rapidly in the gaseous phase, and fixed carbon burns slowly in the solid phase–like charcoal.

Moisture

An important property of a fuel–especially of bark–is moisture content. Moisture influences the combustion process and affects the amount of usable energy that can be obtained. The single attribute of bark that causes most problems in burning is high moisture.

Moisture content can be expressed as percent, based either on total weight or on dry weight of a sample. Because the former is used customarily for fuels, moisture contents in this paper will be expressed as percent of total weight, or wet basis.

Moisture content of bark fuels varies widely; it depends on such factors as species, log handling (wet or dry), season of year, bark-removal process, and exposure to rain or snow in storage. During summer, Douglas-fir and western hemlock bark from sawmills often have moisture contents of about 40 percent (7, 13). But bark can contain 60 or even 65 percent moisture under certain conditions (6, 27, 42). Bark with 60 percent moisture contains 1.5 pounds of water for every pound of dry substance in the mixture.

Table 5. A Summary of Some Published Values of Proximate Analyses for Bark.

Species	Reference number[1]	Dry weight of constituents		
		Volatile matter	Fixed carbon	Ash
		%	%	%
Coniferous				
Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco)	30	70.6	27.2	2.2
Fir, balsam (*Abies balsamea* [L.] Mill.)	29	77.4	20.0	2.6
Fir, grand (*Abies grandis* [L.] Mill.)	30	74.9	22.6	2.5
Hemlock, eastern (*Abies canadensis* [L.] Carr.)	29	72.0	25.5	2.5
Hemlock, western (*Abies heterophylla* [Raf.] Sarg.)	30	74.3	24.0	1.7
Pine, jack (*Pinus banksiana* Lamb.)	29	74.3	23.6	2.1
Pine, ponderosa (*Pinus ponderosa* Laws)	30	73.4	25.9	0.7
Redwood (*Sequoia sempervirens* [D. Don] Endl.)	30	71.3	27.9	0.8
Spruce, black (*Picea mariana* [Mill.] B.S.P.)	29	74.7	22.5	2.8
Spruce, red (*Picea rubens* (Sarg.)	29	72.9	23.7	3.3
Spruce, white (*Picea glauca* [Moench] Voss)	29	72.5	24.0	3.5
Tamarack (*Larix laracina* [Du Roi] K. Koch)	29	69.5	26.3	4.2
Nonconiferous				
Alder, red (*Alnus rubra* Bong.)	30	74.3	23.3	2.4
Beech, American (*Fagus grandifolia* Ehrh.)	29	75.2	16.9	7.9
Birch, paper (*Betula papyrifera* Marsh.)	29	80.3	18.0	1.7
Birch, yellow (*Betula alleghaniensis* Britton)	29	76.5	21.0	2.5
Elm, American (*Ulmus americana* L.)	29	73.1	18.8	8.1
Maple, red (*Acer rubrum* L.)	29	78.1	18.9	3.0
Maple, sugar (*Acer saccharum* Marsh.)	29	75.1	19.9	5.0

[1] See Literature Cited.

Most bark-burning furnaces cannot support stable combustion without auxiliary fuel when fuel moisture approaches 60 percent (7, 42). Bark presses can be used to reduce fuel

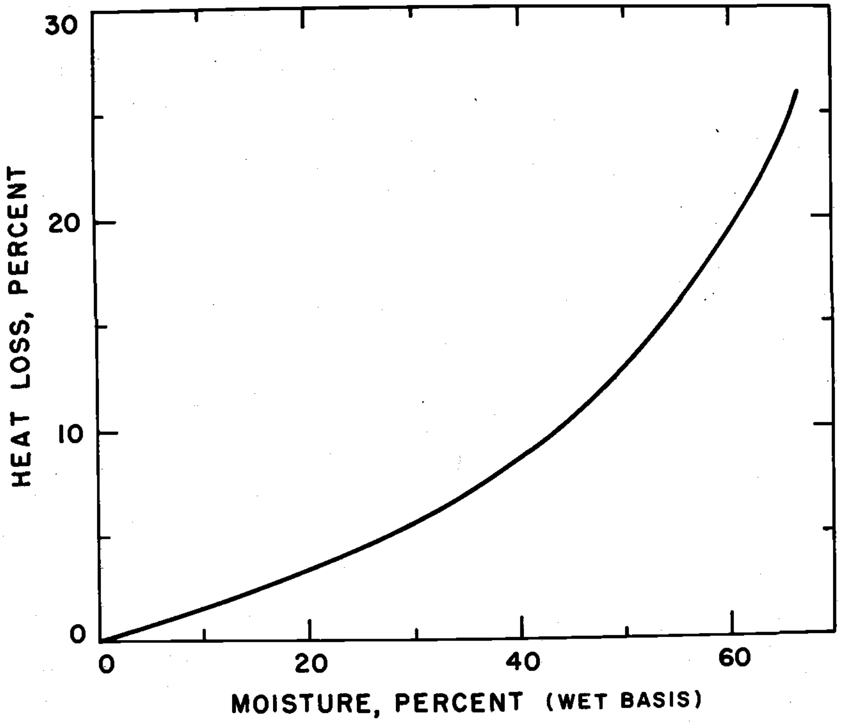

Figure 1. Heat loss caused by fuel moisture shown as a percentage of dry-weight heating value. Stack gas temperature 204 C and bark with a higher heating value of 5,222 Kcalories per dry kilogram.

moisture to a value of 55 to 60 percent (6, 40, 42), and further reduction of moisture is possible with drying systems (6, 25, 40).

When bark fuel is burned in a steam plant, the two major effects of increasing fuel moisture are decreased thermal efficiency and decreased steam capacity. Figure 1 shows the proportion of total heating value of a bark fuel that is required for evaporating moisture from the fuel. For example, about 13 percent of the total heating value of the fuel is required to evaporate water when its moisture content is 50 percent. About 24 percent of the heating value of the fuel is needed to evaporate water when it contains 65 percent moisture.

The effect of fuel moisture on steam production at a Longview, Washington plant that burns wood and bark was published by Johnson (25) and is shown in Figure 2. As fuel moisture increased from 50 to 67 percent, the steam-generating capacity of the plant was decreased about 28 percent. The figure also indicates that a stable fire could not be maintained when the fuel had about 68 percent moisture. Virtanen (42) presented similar curves showing the effect of fuel moisture on steam production. He showed that at one steam plant, where maximum load tests were made, maximum steam production was reduced about 24 percent when moisture content of wood and bark fuels increased from 50 to 60 percent. If at least part of the fuel drying process is removed from the boiler furnace by an auxiliary fuel dryer, output of a steam plant can be increased substantially.

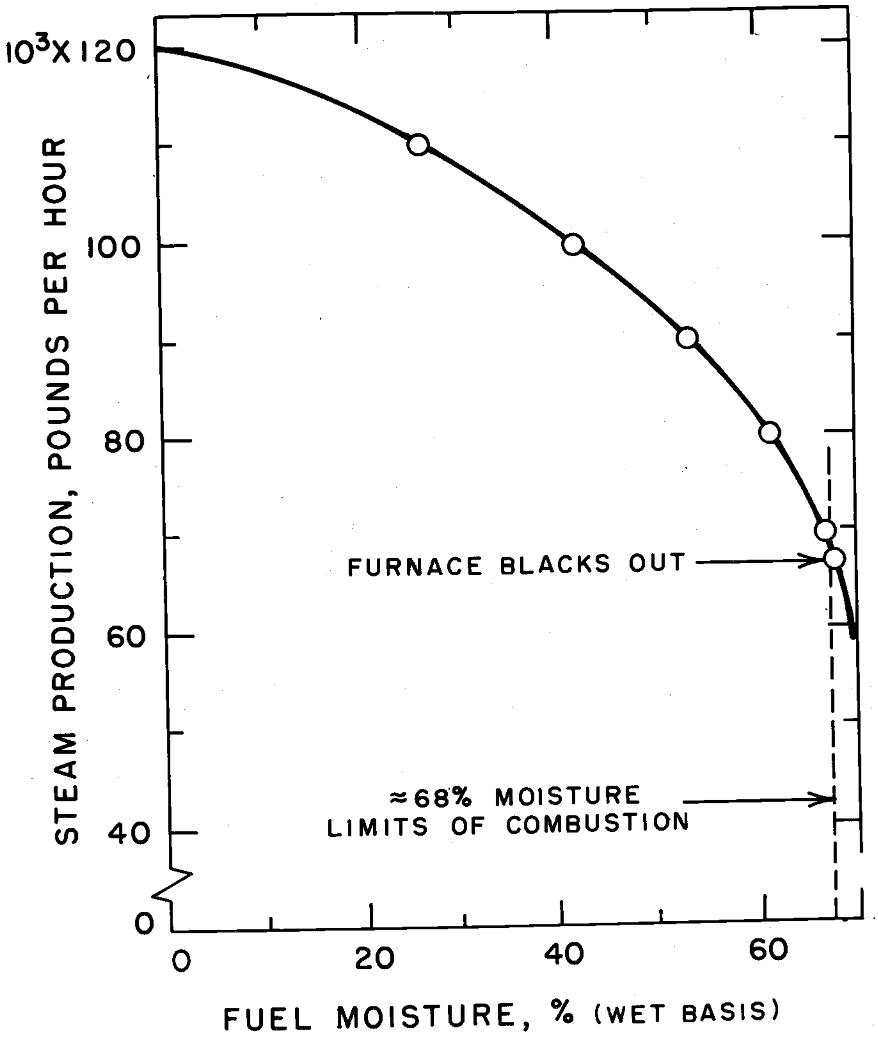

Figure 2. The effect of fuel moisture on steam production as reported by Johnson (25).

Bulk Density

Bark fuel frequently is measured and marketed by bulk volume. Some information on densities of solid bark is given by Hale (19) and Millikin (29). Virtanen (42) reported bulk densities of 105–135 kilograms of dry substance per bulk cubic meter for unprocessed bark from Scots pine and Norway spruce (6.6 to 8.4 dry pounds per bulk cubic foot). For use as fuel, bark frequently is processed through a size-reduction machine called a hog and then is called hogged fuel. The bulk density of hogged fuel, mostly Douglas-fir bark, was reported by Brown (7) to be 173 kilograms of dry substance per bulk cubic meter (10.8 dry pounds per bulk cubic foot), and Corder *et al.* (13) found a bulk density of 214 dry kilograms per bulk cubic meter (13.4 pounds per cubic foot) for similar material. Bulk density of hogged fuel that was mainly western hemlock bark (13) was 179 kilograms (dry) per bulk cubic meter (11.2 dry pounds per bulk cubic foot). The weight of moisture would, of course, have to be added to dry weights to obtain wet-weight bulk densities.

Comparison with Oil

For a given usable energy content, bark fuels are heavier and bulkier than oil. For example, under the following assumptions, about 5.5 kilograms of wet bark are required to obtain the same energy as from 1 kilogram of oil.

Oil
Higher heating value: 10,416 Kcal per kg (18,750 Btu per lb)
Density: 958 gm per l (8 lb per gal)
Thermal efficiency: 80 percent
Bark
Higher heating value: 5,000 Kcal per dry kg (9,000 Btu per dry lb)
Moisture content: 50 percent
Bulk density: 173 dry kg per cu m (10.8 dry lb per cu ft)
Thermal efficiency: 60 percent

A volume comparison indicates about 15 cubic meters of bark are required to supply the same energy as obtained from one cubic meter of oil. Transportation costs are therefore higher, and much larger storage volumes are required for bark fuels than for oil.

PRESENT ENERGY UTILIZATION METHODS

Bark fuels (usually associated with wood) are burned in stoves, furnaces, and fireplaces for home heating. Sometimes bark fuels also are burned to provide heat directly for industrial drying processes. But by far the biggest industrial use of bark fuels is for burning in boiler furnaces to produce steam for heating, processing, power, or generation of electricity. Steam plants that burn bark range in size from small plants producing less than 5 metric tons (11 thousand pounds) of steam per hour to plants at large paper mills producing more than 250 metric tons (550 thousand pounds) of steam per hour.

Burning Methods for Steam Plants

Information about common burning methods now followed at bark-fired steam plants is given in references 3, 8, 12, 32, 33, 36, 39, and 43. A review of some of these methods follows.[1]

Pile burning. A common way of burning bark (and wood) fuel is with a two-stage furnace consisting of a Dutch oven, in which moisture is evaporated and the fuel is gasified, and a secondary furnace, in which combustion is completed (Figure 3). The fuel is fed by gravity through an opening in the Dutch oven and forms a conical fuel pile. Although the Dutch oven furnace has been used widely in the past, most recent installations use other burning methods.

Another pile-burning system with a two-stage furnace is shown in Figure 4. The fuel drops from above onto water-cooled grates in the primary furnaces, and the gases pass into a secondary furnace where combustion is completed. Many boilers of this type have been installed at lumber plants in the western United States where steam is used for drying lumber (34). The steam plants are automated so little labor is required for their operation. They

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[1] Discussion of specific processes in this paper or mention of specific products does not imply endorsement.

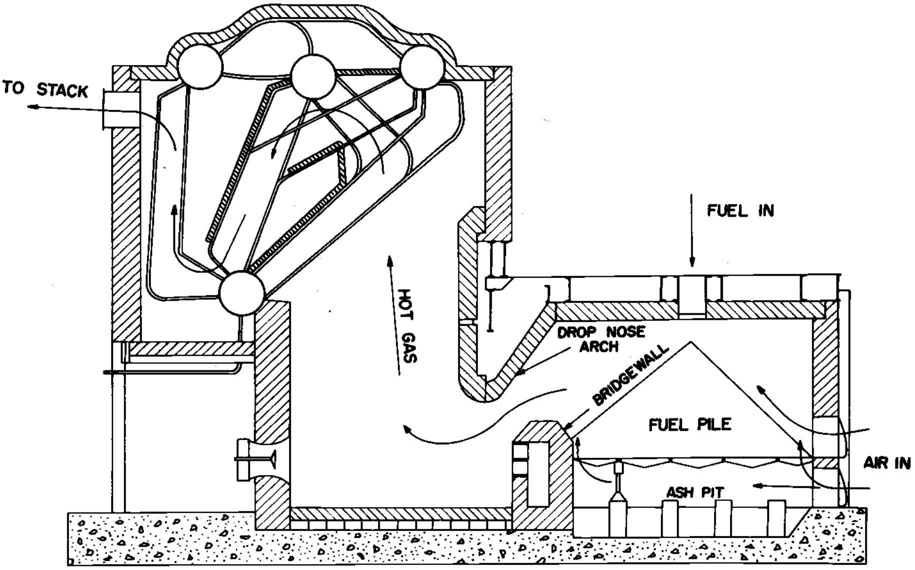

Figure 3. Boiler with a pile-burning, Dutch-oven furnace.

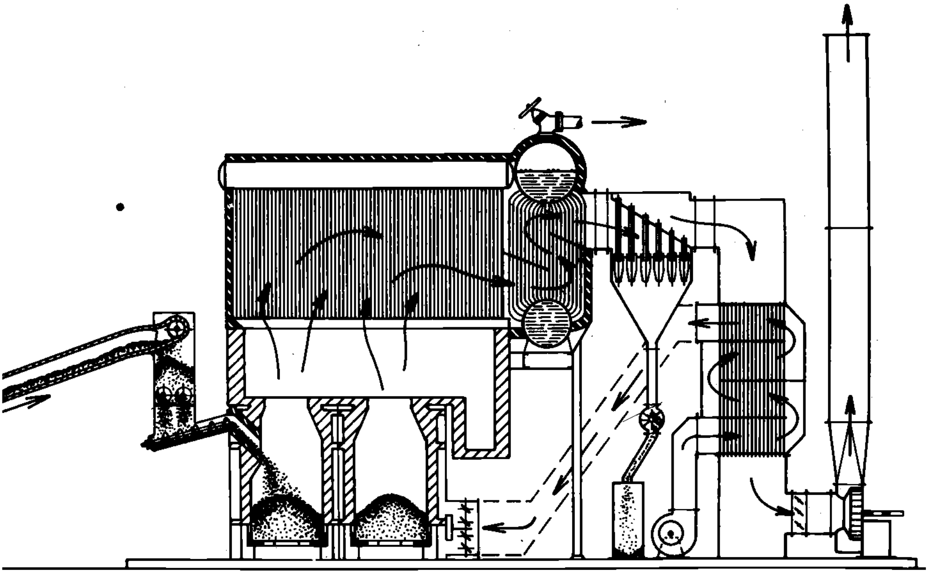

Figure 4. Automatically controlled, pile-burning steam plant that uses wood and bark fuel. (Drawing courtesy of Wellons, Inc.)

usually operate at low steam pressure (below 3 atmospheres) with capacities commonly ranging between 5.4 and 13.6 metric tons (12 thousand and 30 thousand pounds) of steam per hour.

Spreader stoker. Many recently installed bark-fired steam plants have spreader-stoker firing. With the spreader stoker, fuel is introduced above the grates into the furnace by either pneumatic or mechanical spreaders. Part of the fuel is burned in suspension and the remainder drops to the grates where burning is completed. The general arrangement of a spreader-stoker installation with a fixed grate is shown in Figure 5, and Figure 6 shows an installation with traveling grates. Spreader stokers have been used at plants with steam capacities ranging from 10 to over 225 metric tons (22 thousand to 500 thousand pounds) of steam per hour.

Inclined grate. A sketch of an inclined-grate furnace is shown in Figure 7. Fuel enters the furnace at the top part of the grate in a continuous ribbon, passes over the upper drying section where moisture is removed, and then descends into the lower burning section. Ash is removed at the lowest part of the grate.

Suspension firing. One of the newer methods of bark burning is suspension firing (36). The method is similar to that used for pulverized coal. Bark fuel is hogged to a small size, blown into the furnace, and burned in suspension along with oil or natural gas. Roberson (36) noted that suspension-fired units installed before 1968 had a maximum heat input, with bark firing, of 30 to 50 percent of the total heat input to the furnace, with the remainder supplied by oil or natural gas.

Cyclone furnaces. There are two main types of cyclone furnace used for bark firing. (Although the Energex system also uses a cyclone furnace, it will be discussed separately.) In one system, the axis of the cyclone is horizontal, and in the other it is vertical. The horizontal cyclone furnace was developed initially by the Babcock and Wilcox Company primarily for burning coal. Even when bark is burned in the Babcock and Wilcox horizontal furnace, coal is

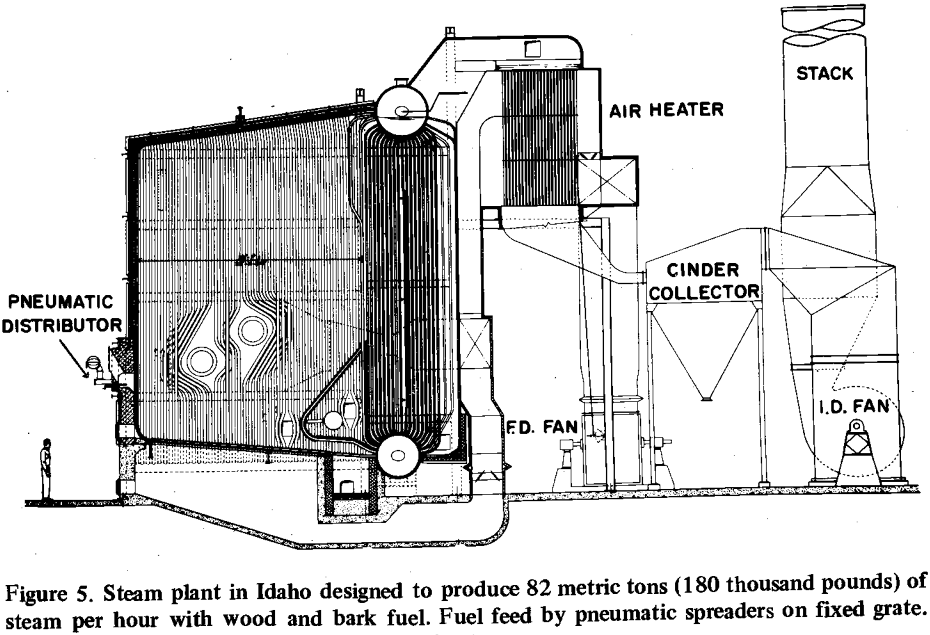

Figure 5. Steam plant in Idaho designed to produce 82 metric tons (180 thousand pounds) of steam per hour with wood and bark fuel. Fuel feed by pneumatic spreaders on fixed grate. (Drawing courtesy of Riley Stoker Corporation.)

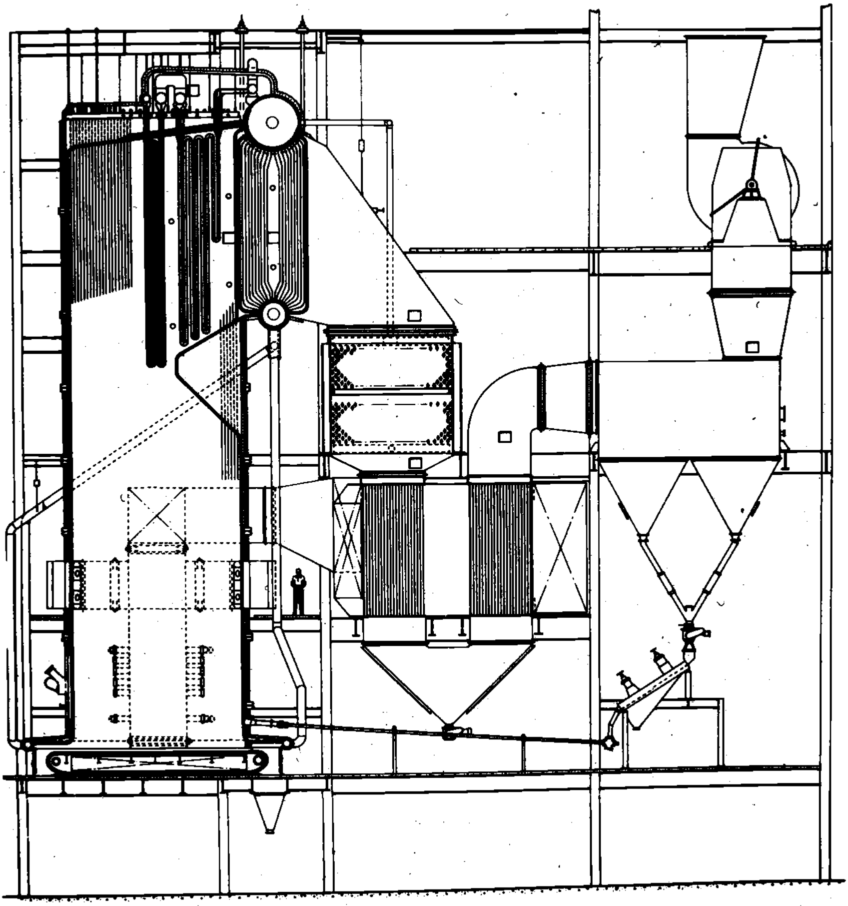

Figure 6. Steam boiler, at a Louisiana paper company, designed to burn hogged bark with a spreader stoker and traveling grates. Capacity of the plant is 204 metric tons (450 thousand pounds) of steam per hour. (Drawing courtesy of Combustion Engineering, Inc.)

required as the primary fuel. Coal ash provides a slag coating around the cyclone that insures proper burning of bark. The bark input to the Babcock and Wilcox horizontal cyclone furnace is limited to a maximum of 30 percent of the total heat input, and the bark must be finely hogged so it can pass a screen of 19-millimeter (¾-inch) mesh (8, 36).

The other type of cyclone furnace has a vertical axis and has been developed recently (since 1962) and applied, especially for bark burning, in the Scandinavian countries (3, 33, 44). The vertical cyclone furnace, which is cylindrical, is refractory lined and has an underfeed stoker pushing the fuel up through the bottom grate to form a conical fuel pile (Figure 8). High-pressure air is admitted tangentially to provide a cyclonic action within the furnace. The cyclone usually is located underneath the boiler furnace, and hot gases from the cyclone enter the main furnace from below.

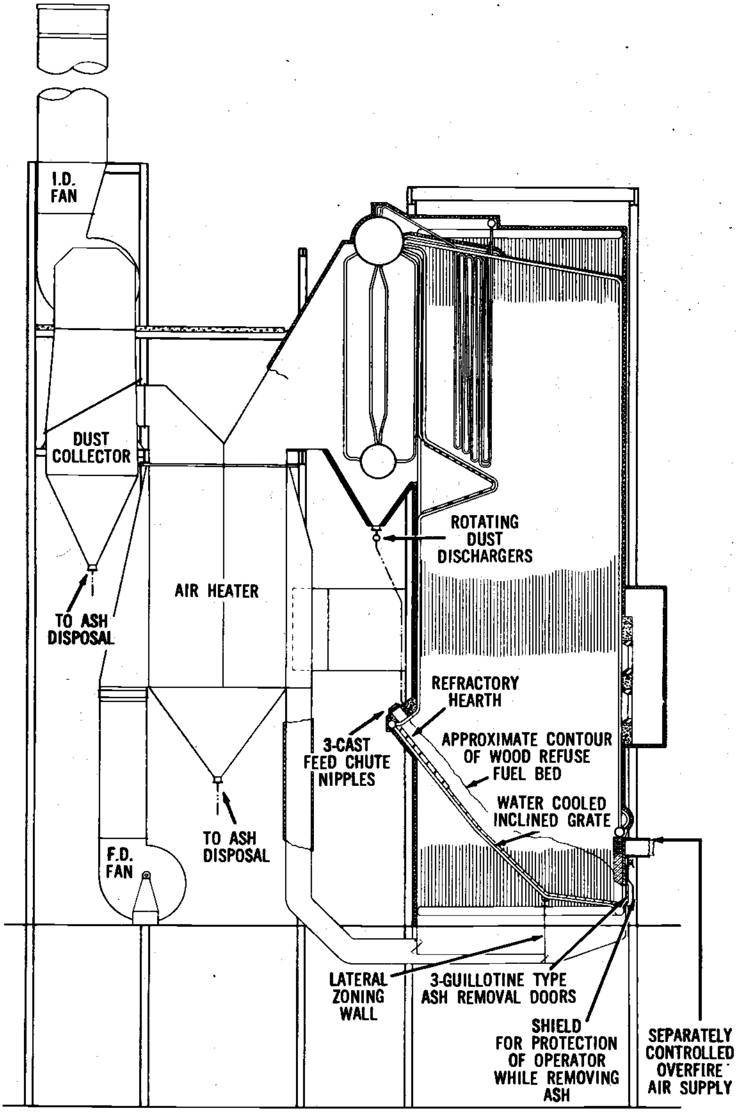

Figure 7. Steam plant, at a pulp and paper mill in British Columbia, with inclined water-cooled grate, designed to produce 113 metric tons (250 thousand pounds) of steam per hour. The fuel is hogged bark and wood combined with oil or natural gas. (Drawing courtesy of Foster Wheeler Limited.)

Direct-Firing Applications

Within the past 5 years, installations have been made in the United States in which hot gases from burning bark and wood have been used directly for heating. Direct firing of wood

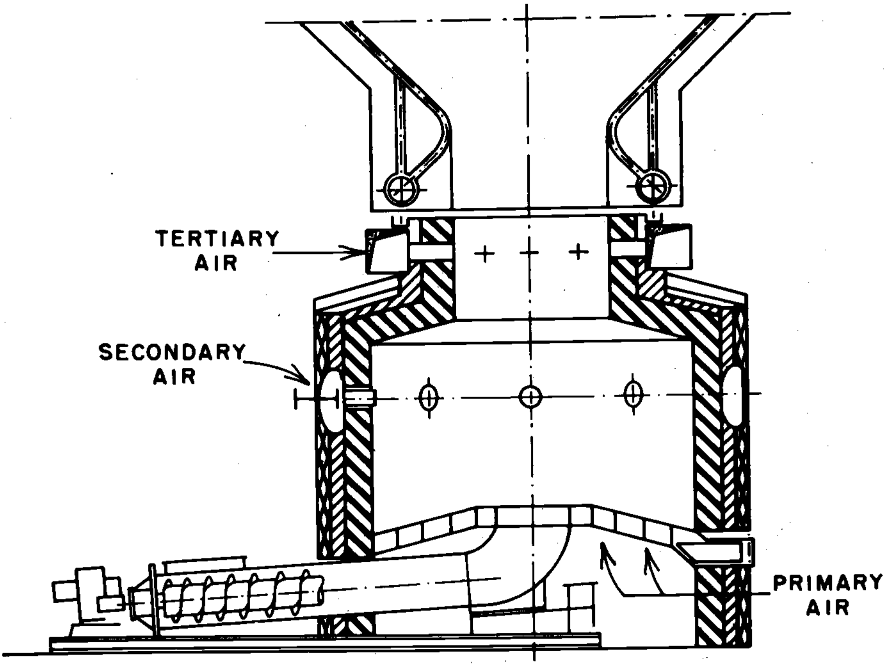

Figure 8. Sketch of a bark-fired cyclone furnace.

and bark has supplied high-temperature gases to veneer dryers, lumber dry kilns, and dryers for wood and bark particles.

The Energex system burns dried, finely divided wood or bark fuel in a cyclonic burner, illustrated in Figure 9 (10, 31). These burners have been used for all the purposes mentioned above.

An interesting application is the use of hot gases from the Energex burner in a rotary-drum dryer for hogged fuel (primarily bark). The fuel for the burner is the fines fraction of the fuel dried. Such installations, which use hogged fuel for steam-boiler firing, have been made in Washington and British Columbia (6, 25, 31). Brenton (6) described the installation in Washington and indicated a potential saving of $1.7 million if supplemental oil fuel used in the hogged-fuel-fired boiler could be eliminated by drying the hogged fuel. Johnson (25) discussed the dryer application and showed increased rates of steam production obtained from hogged fuel with lower moisture content.

Deardorff (14) described a pile-burning furnace fired with hogged fuel that supplied heat directly to a veneer dryer. Jasper and Koch (24) reported on a suspension-burning system in which undried bark was pulverized and burned in a cylindrical, annular combustion chamber. The system had been tested in the laboratory, and they were proposing to construct a production model to be used with a lumber dry kiln.

FUTURE ENERGY UTILIZATION

Newer concepts of using bark for energy will be discussed in this section and projections made of changes likely to occur in more conventional utilization processes. Robison (37) discussed some of these factors in his challenge to the forest products industry concerning energy use.

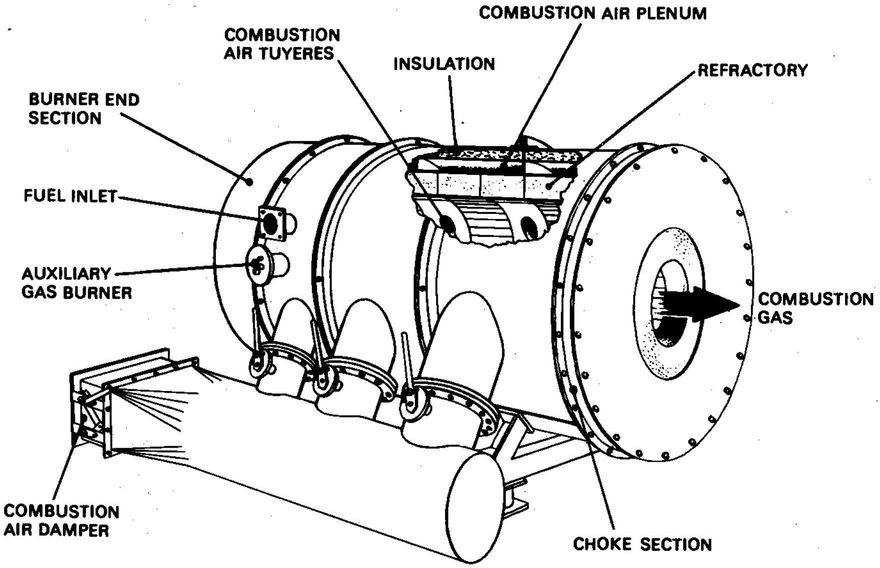

Figure 9. The Energex cyclonic burner.

Conversion to Liquid Fuel

The possibility exists for converting bark and other organic materials into liquid fuel. The U.S. Bureau of Mines has developed a method for producing oil from organic wastes in laboratory-scale equipment (2). They are now constructing a pilot plant at Albany, Oregon that will produce about 2.7 metric tons of oil daily from cellulosic materials. Hill (21) stated that cost of producing oil by their process had been estimated at about $8 per barrel when the feed material was free. One major disadvantage of producing a liquid or gaseous fuel from a solid material is loss of energy in the conversion process. Hill indicated a net energy-conversion efficiency of about 50 percent for the Bureau of Mines process. An advantage of converting a solid to a liquid or gaseous fuel is that equipment and operational costs for a steam boiler, for example, are lower for liquid and gaseous fuels than for solid fuel. An overall economic evaluation needs to consider these factors.

Another form of liquid fuel that could be produced from bark, as well as from other materials, is methanol (methyl alcohol). Reed and Lerner (35) discussed producing and using methyl alcohol as a fuel, especially for automobiles. Although methanol could be produced from bark, much work remains to be done before such conversion can be justified economically.

Conversion to Gaseous Fuel

Bark could be converted to a gaseous fuel. Hammond *et al.* (20) described a method that produced a gas of low heating value from wood waste with laboratory-size equipment. For a plant processing about 200 bone-dry metric tons of wood waste (45 percent moisture content) per day, they estimated an operating cost of $6.60 to $9.90 per bone-dry metric ton and an energy-conversion efficiency of 80 percent.

The Purox system of gasification uses oxygen in a partial oxidation process to obtain fuel gas. Fisher *et al.* (17) described a demonstration plant operating with municipal refuse, as illustrated in Figure 10. They reported a net energy efficiency of about 65 percent.

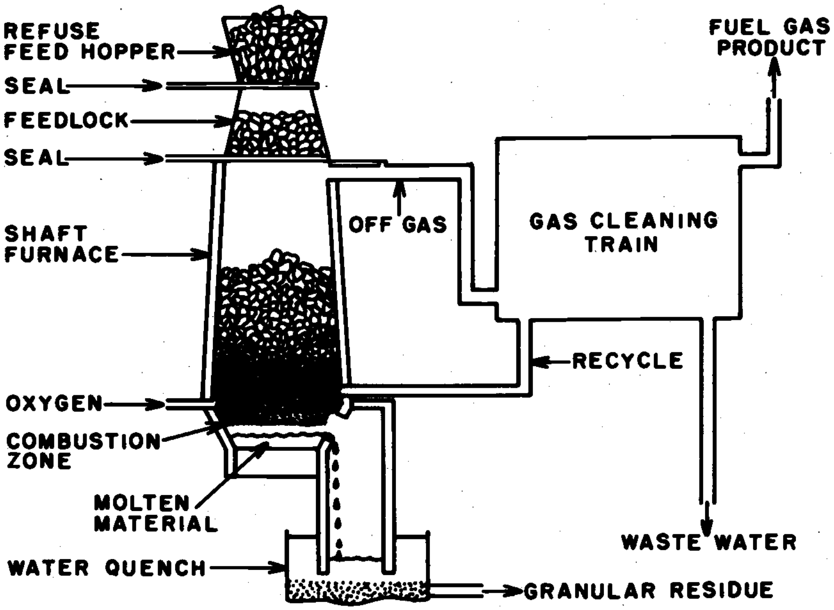

Figure 10. A schematic drawing of the Purox method for producing a fuel gas from refuse material (17).

Fluidized-Bed Combustion

A fluidized bed is a mass of solid particles, like sand, contained in a vessel through which air passes upward at velocities high enough to keep the particles in constant agitation. When a solid fuel like bark is introduced into such a bed, there is a vigorous turbulence or mixing action that produces favorable conditions for combustion. Such combustion systems have been applied to bark. Keller (26) indicated that Energy Products of Idaho expected to have 10 fluidized-bed units in operation with wood waste (including bark) by September 1975.

A fluidized-bed combustion system was installed by Great Lakes Paper Company Limited in Canada to dispose of clarifier sludge and bark (1). Hot water generated in the process was used in a woodroom deicing system.

Experimentation and tests have been conducted by the Combustion Power Company at Menlo Park, California (F. H. Walton, personal communication, Dec. 17, 1975) in which wood waste was burned in a fluidized-bed combustor and hot gases produced to operate a turbine connected to an electric generator. These tests were experimental and further work would be required to evaluate the problem of controlling particulate matter and erosion of turbine blading.

Trends in Steam Plants

In future years, steam plants undoubtedly will continue to be the major industrial users of bark for energy. Fossil fuels will continue to become more scarce and more costly, thus enhancing the value of bark for energy. New burning methods, as well as improvements in existing methods, are likely to be developed for steam plants.

In design and operation of future steam plants, more emphasis will be placed on high efficiency of energy conversion. In the past, Scandinavian mills have had higher cost for energy than mills in North America, so that Scandinavians have become more oriented toward high energy efficiency. North American mills also will become more concerned with energy conservation and increased efficiency of energy conversion. Such concern will mean more heat-recovery equipment on steam boilers—more air preheaters, feedwater economizers, and fuel-drying systems. In addition to increased thermal efficiency, fuel-drying systems offer a major advantage of increased steam production. Increased application of systems for drying bark fuel seems assured.

Trends in Direct Firing

As previously mentioned, only within the past 5 years has there been significant use of wood and bark fuels for direct firing of veneer dryers, lumber dry kilns, and wood particle dryers. Direct-fired systems offer more potential for increased energy efficiency than steam-heated systems. With steam-heated drying systems, there is heat loss from the boiler stack and also heat loss from the stack of the dryer. But direct-fired systems have only a single stack loss. Because of greater emphasis on efficient use of energy, direct-fired burning systems are expected to increase. Bark fuel for direct firing probably will require more preparation of the fuel by size reduction and drying.

CONCLUSIONS

The principle use of bark is for energy. In many developing countries, bark, with wood, is used for home heating and cooking, but the industrialized countries use bark mainly as a source of energy where it is generated—at forest industry plants. For such plants, it is a significant source of energy. Bark has negligible sulfur, is low in ash when compared to coal, and is one of few energy sources that is renewable. Because bark fuels are heavy and bulky, transportation costs are high. Bark normally is used, therefore, at or near its place of production, and widespread marketing of bark fuel is not likely. Because the major problem in burning bark is its high moisture content, there probably will be increased application of bark-drying systems. Well-developed systems for utilizing bark for energy exist, but new systems are being—and will continue to be—developed. Although bark can be converted to gaseous or liquid fuel, energy losses in processing, as well as added processing costs, will tend to inhibit such conversion. In the future, maximum energy efficiency from bark fuels will be emphasized, which will result in more extensive use of heat-recovery equipment. Bark only recently has been used in direct-fired drying systems. There is potential for development and wider application of such systems. As fossil fuels increase in price and become less available, bark will become more important as an energy source.

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