WOOD FUEL AND WOOD STOVES

June 1942

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison, Wisconsin
In Cooperation with the University of Wisconsin

WOOD FUEL AND WOOD STOVES

The big increase in the demand for coal required by industry and the heavy load that the transportation systems are bearing because of the war program have turned more attention to wood for fuel. This trend is reflected by the increase in the number of inquiries received at the Forest Products Laboratory on wood fuel and on the burning of wood.

As a fuel, wood has certain distinct advantages, particularly in regions where plentiful supplies are locally grown. It is cheap. It is easily handled. It burns well, with little smoke, provided certain simple rules are observed. It has a high heat producing potential. The accompanying table indicates the comparative heat values for wood and good coal; for example, a cord (120 cubic feet) of white oak has slightly more heat value than a ton of good coal. And, finally, a standard cord of hardwood burns down to only 60 pounds of ashes, while a ton of hard coal leaves from 200 to 300 pounds.

Heat Value of Wood

In burning wood it is essential to have the wood as dry as possible in order to produce more heat per pound of fuel, to obtain a higher efficiency, and also to lessen the creosote trouble. Oven-dried wood has a calorific value of 8,600 B.t.u., and will yield about 7,250 B.t.u. per pound of fuel when burned under rather ideal conditions, whereas air-dried wood containing about 20 percent moisture will yield about 5,800 B.t.u., and green wood containing about 60 percent moisture will yield only about 4,100 B.t.u.

The table gives the approximate weights, heating value per cord, and the equivalent in heat value to tons of coal for different species of wood. Generally speaking, the heat value of thoroughly dry wood is in direct proportion to its weight per cubic foot. One pound of oven-dried wood substance of any wood has a calorific value of 8,600 B.t.u. The presence of other substances, such as oils, tannins, resin, and the like, somewhat changes the actual calorific value of the different woods. Resinous woods, such as pine, have a higher calorific value than nonresinous wood. In the table all hardwoods were assumed to have a calorific value of 8,600 B.t.u. per pound when oven dry and 5,800 B.t.u. available heat when containing 20 percent moisture. Similar heat values for white pine are 9,150 B.t.u. and 6,400 B.t.u.

Burning of Wood

In the combustion of wood there are three principal phases. In the first phase the moisture is evaporated and driven off; in the second phase the volatile matter is distilled off. When heated to temperatures of approximately 1,100° F. or greater, this volatile matter bursts into flames and burns if mixed with sufficient air. In the third or final phase the fixed carbon burns. All three phases of burning may, of course, go on at the same time, but the first two stages are largely carried on when the fire is started or when new fuel is added.

In the first two phases of burning, heat is consumed. The evaporation of 1 pound of water requires about 1,000 B.t.u., and 1 pound of volatile matter absorbs about 200 B.t.u. when driven off. Since the volatile matter comprises about 60 percent of the weight of bone-dry wood, the amount of heat absorbed may be sufficient to cool the furnace when a fresh charge of fuel is added. Volatile gas is not then maintained at approximately 1,100° F. and will not burn. Incomplete combustion of the volatile matter can, therefore, constitute a big loss in efficiency. It is, moreover, troublesome because the gases that are not burned contain creosote, tarry substances, and acetic acid, which eat away the stove pipe, leak out of the joints, and stain material with which they come in contact.

Due to its high percentage of volatile matter, wood has a long flame and therefore the combustion space above the fuel level must be greater than that for coal. When the air supplied through the grates passes through approximately 2 inches of glowing wood embers about all the oxygen in it is consumed or combined with the carbon to form carbon dioxide. This carbon dioxide is reduced to carbon monoxide as it passes through more glowing carbon. For this reason, according to some authorities, 80 percent of the air needed should be supplied over and around the fuel.

To summarize the points that lead to complete combustion of wood: Sufficient air must be supplied to the fire and a large portion of this air should be supplied over or around the fuel. This air must be mixed with the gases given off from the wood, and the temperature of these gases should be kept above 1,100° F. so that they will burn. Theoretically, it takes 6 pounds of air to burn 1 pound of bone-dry wood, but in actual practice more air is required because the air and the gases are not thoroughly mixed.

Avoidance of Creosote

In severe cold weather there is generally less creosote trouble, for with a hot fire the gases are kept hotter than 1,100° F. and, when supplied with sufficient air, will burn. Also, with a hot fire, the flue gas temperatures are higher and acetic acid and creosote that are present because of incomplete combustion may be carried out of the chimney in the form of a vapor. In order to prevent undue creosote trouble, it is best to burn dry wood in a hot small fire instead of a large smoldering fire. Refueling the stove at more frequent intervals with smaller amounts of fuel also helps. When a small amount of new wood is added less gas will be formed, the fire will not cool down so much, and the gas will therefore burn more completely. Short stove pipes and insulated stove pipes will further help to keep the creosote and acetic acid from condensing.

Hogged Fuel Burners

In the Pacific Northwest, many sawdust or hogged fuel burners have been installed. This development has been largely limited to the Northwest, for here hogged fuel is plentiful and cheap; also, green Douglas-fir has a relatively low moisture content -- about 35 percent on an oven-dry basis. Other green native woods usually contain about twice as much moisture. In large installations some type of automatic stoking is usually used. For home heating with furnaces, the sawdust units are usually installed by removing the ash pit door and the grates, and the unit is aligned with this opening. The burners consist of a hopper from which the fuel flows by gravity on an inclined grate placed in front of a refractory-lined combustion chamber which is usually large enough so that all the burning takes place in the combustion chamber. In all these units secondary air is introduced above or around the layer of fuel. The heat that is radiated back from the refractory lining is an aid in driving off the moisture and volatile gas, and in maintaining the temperature in the chamber above 1,100° F. so that the volatile gas can be burned more completely.

Wood Briquettes

Briquettes made of wood waste make an excellent, clean, and convenient fuel. Since they are made of wood waste many sawmills, planing mills, and woodworking plants desire information on the advisability of converting their wood waste into briquettes. Unless they have a large and constant supply of wood waste, are located in a region where coal is particularly high in price, and are in a position to pay royalties on machinery, briquetting does not rate as a highly attractive proposition.

Wood briquettes are made of dried and ground-up sawmill or planing mill wastes. This material is fed into an automatic briquetting machine where the material is fed into a mold and then subjected to a pressure exceeding 10,000 pounds per square inch. The pressure and the heat developed are sufficient to plasticize the material partly and it forms a briquette that will stand handling. If a binder were used, lower pressures could be employed. Few suitable binders are cheap enough for this purpose, and the manufacturers of briquettes using no binders have been the most successful.

Burning Wood with Coal

In many rural sections wood is burned in the furnace in mild weather when a constant fire is not required or when the rate of burning can be held down and still give off sufficient heat. In severe cold the farmer either burns coal or a mixture of chunk wood and coal. The best way to handle the combined fuel is to partly fill the furnace with chunk wood, then throw coal on top of the wood filling the spaces between the wood and the firepot and between the pieces of wood, besides covering the wood. A bed of coal and wood will hold fire overnight.

European Slow-Combustion Stoves

In the United States within the last few years considerable publicity has been given to the European slow-combustion stove. These stoves are of the hopper type with the grate at the bottom of the hopper. A damper in the ash pit controls both the primary and the secondary air supply. The primary air passes up through the grate, and supports combustion in a limited area above the grate. The secondary air is introduced in the flame area at the bottom of the combustion chamber, which is in front of the hopper. This combustion chamber is lined with fire brick, and provides for a long flame travel so that the gases formed can be more completely burned. The refractory lining is also an aid in promoting cleaner burning and in eliminating much of the creosote trouble. Very high efficiencies have been claimed for these stoves. At the present time European slow-combustion stoves are not available in this country.

Test of Slow-Combustion Stove

Tests have been run at one of the universities on one of these slow-combustion European stoves and on one American stove of similar design. At a low rate of burning with a flue gas temperature of 158° F., the European stove showed an efficiency of 79 percent based on the actual heat value of the wood. In an installation in a home such conditions would be impractical, for the low flue temperature would produce such a small draft and low rate of burning that the stove would produce too little heat. At higher flue gas temperatures with higher rates of burning, the efficiency of the stove would range from 59 to 76 percent. The American stove of similar design had a range of efficiency of from 61 to 72 percent for different rates of burning.

American Wood-Burning Stoves

In the last few years several new wood-burning stoves have been introduced in the United States. Some of these stoves have incorporated the features of the European slow-combustion stove. These stoves of the hopper type have a combustion chamber either in front or behind the hopper where the secondary air is introduced into the flame area. The majority of the new stoves are equipped with thermostats that automatically regulate the rate of burning by controlling the inlet air, and in this way hold the room temperature more constant. All the new stoves claim high efficiency and less maintenance attention. Some of the stoves are also more attractive in appearance. The following are some of the American companies producing new and improved wood burning stoves:

H. B. Smith Company, Westfield, Mass.
Riteway Products Company, Harrisonburg, Va.
Ashley Automatic Wood Stove Company, Columbia, S. C.
Shapleigh Hardware Company, 900 Spruce St., St. Louis, Mo.

Many of the installations of the old type of wood stove with a long stove pipe have as high an efficiency as the more recent stoves. In many cases the long stove pipe gave off almost as much heat as the stove itself. A long stove pipe is, however, objectionable because it generally leads to creosote trouble. In the new type of stove a short pipe can be used and still have good efficiency. Many of the old stoves were designed to burn coal, which has a shorter flame than wood. If the height above the fuel bed is too small, the flames will shoot out into the stove pipe and much of the heat will go out the chimney. In the old airtight and barrel stoves, unless long stove pipes were used to radiate much of the heat, the efficiency would be around 50 percent.

Research in Wood Fuel

Due to the increased interest in wood fuel, several agencies in the Federal Government are carrying on studies designed to lower the cost of wood fuel by developing labor-saving methods and by developing improved wood burning units. Experiments are being carried on with a portable hog to reduce the handling costs and also to put the wood in a form that lends itself to automatic firing. The handling of fuel wood in crates or in wired bundles is also being tried. The Forest Products Laboratory at present is experimenting with a gang saw combined with an automatic splitter to produce cubes of wood. Wood in the form of small cubes about the size of a fist can be more readily handled with belt conveyors, shovels, and spouts than chunk wood. The Laboratory is also working on stoves designed for this type of wood fuel with hopper feed to make firing easier and more convenient.

Approximate weights and heating value per cord of wood containing 80 cubic feet of solid wood with 20 percent moisture[1] and with green wood

Variety of wood	Weight per cord containing 80 cubic feet of solid wood in pounds: Green	Weight per cord: 20 percent moisture	Available[2] heat units per cord million B.t.u.: Green	Available heat units: 20 percent moisture	Equivalent in heat value to tons of coal[3]: Green	Equivalent: 20 percent moisture
Ash	3,840	3,440	16.5	20.0	0.75	0.91
Aspen	3,440	2,160	10.3	12.5	.47	.57
Beech	4,320	3,760	17.3	21.8	.79	.99
Birch, yellow	4,560	3,680	17.3	21.3	.79	.97
Elm, American	4,320	2,960	14.3	17.2	.65	.78
Hickory, shagbark	5,040	4,240	20.7	24.6	.94	1.12
Maple, red	4,000	3,200	15.0	18.6	.68	.85
Maple, sugar	4,480	3,680	18.4	21.3	.84	.97
Oak, red	5,120	3,680	17.9	21.3	.81	.97
Oak, white	5,040	3,920	19.2	22.7	.87	1.04
Pine, white	2,880	2,080	12.1	13.3	.55	.60

[1] Percent moisture given in terms of oven-dry weight.

[2] Available heat equals calorific value, minus loss due to moisture, minus loss due to water vapor formed, minus loss due to heat carried away in dry chimney gas. Flue temperature taken as 450 degrees. No excess air.

[3] Heat value of coal under similar conditions taken as 11,000 B.t.u. This would require a good coal with a total heat value of about 14,000 B.t.u. per pound of dry coal.