Residential Pellet Fuel Information

Understanding Pellet Fuel Production, Standards, Performance, and Use

Residential Pellet Fuel

(Excerpt from *"Pellet Hearth Systems Reference Manual Second Addition" December 2008*)

In much of the world, the concept of home is linked directly to the ability to maintain a heated environment in winter months. With the energy crisis of the 1970's came the first notice that the source of that heat and comfort had to be scrutinized. The realization of limitations and eventual shortages for finite, irreplaceable, fossil fuels spurred a new interest in renewable, and therefore sustainable, alternative fuel sources.

Almost simultaneously, the issue of waste surfaced. The habits of our throwaway society not only resulted in costly waste of valuable energy resources, but also in a crisis in disposal space and methods. The development of residential pellet fuel responds to both the call for renewable biomass sources of home heating fuels and waste stream reduction.

NORTH AMERICAN PELLET MILLS

1. PELLET PRODUCTION

As forest products companies produce lumber, plywood, and other goods, they create wood and bark residues that contain energy. In the form of sawdust, bark, and chips, these residues are bulky and vary greatly in moisture content. The process of pelletizing reduces their bulk by compression and increases their combustion manageability by controlling consistency. Originally produced for industrial and institutional use, pellets entered the residential fuel market with the introduction of the first home pellet appliances in the mid-1980's.

1.1 RAW MATERIALS

Although a wide variety of materials, including sawdust and wood scraps from hard and soft woods, shells and nut hulls, agricultural by-products, paper, and cardboard, is pelletized for use as fuel, residential pellets are primarily wood-based residues. Corn, because of its natural similarity to pellets, is used in some specially designed residential appliances. Because corn combustion differs from wood pellet combustion, corn should not be burned alone or mixed with wood pellets unless the appliance is specifically designed for corn combustion.

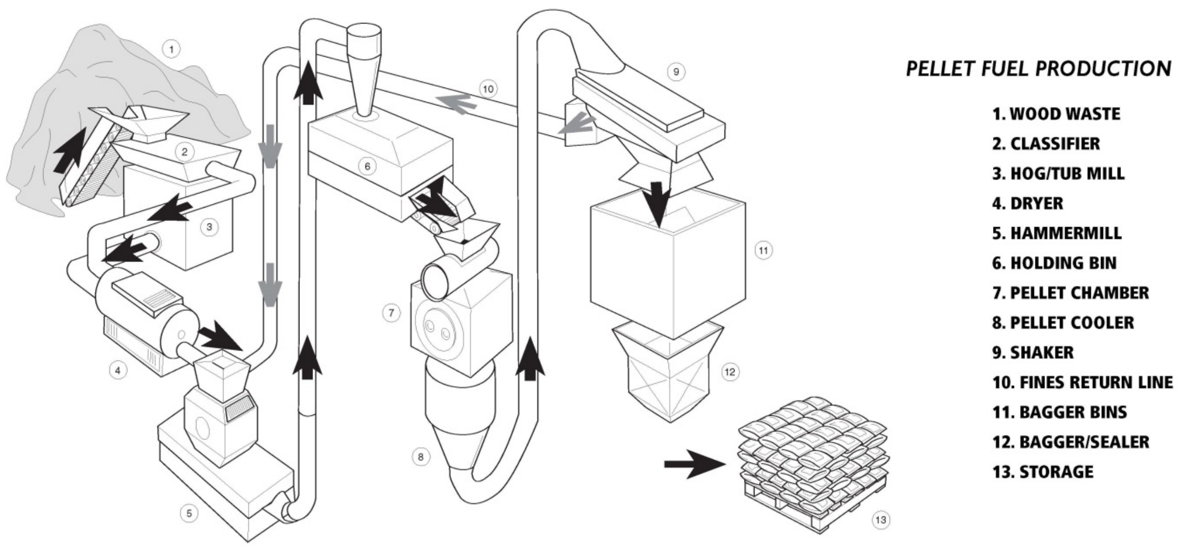
Because ash content and other factors presently limit or prevent the practical use of other agricultural and paper products in most residential appliances. Increasing competition for forest industry by-products and reduction in logging in some areas are a growing concern of pellet manufacturers. Pellet appliance design, however, is responding to fuel manufacturers' predictions of future shortages of premium grade fuel with research and development aimed at greater ash tolerance.

The amount of residues available from processing logs varies depending on factors such as log size, timber species, lumber dimensions, moisture content, and processing machinery. Typically, 5 to 10% of the original material is available for pellet fuel conversion. The raw materials may be received at the pellet processing plant as residues from kiln dried lumber or as residues from freshly processed (green) wood in which the weight of moisture may exceed the dry material weight. Heating, or caloric, value of finished pellets ranges from 7,000 to over 9,000 Btu (British thermal units) per pound (at 5% moisture), with resinous species (such as pines and fir) having slightly higher gross caloric values than non-resinous species (hardwoods) and bark. Average Btu content of pellets as received by the consumer is 8,300 Btu per pound at 5% moisture.

Softwoods, hardwoods, and blends of different species are used as raw materials and known as feed stock. Where hardwoods are generally the preferred species for cordwood appliances because of their higher Btu content and lower emissions, pellets from softwoods generally have slightly higher caloric value and lower ash content than pellets produced from hardwoods, particularly hardwoods containing bark. Resins in softwoods that are more difficult to burn in a cordwood appliance are not a problem in pellet appliances, which regulate the air for combustion and provide precise, gradual fuel feed in small amounts.

Raw material particle size ranges from fine sawdust to large chips that must be ground to uniform size. Careful handling of raw materials before the pelletizing process is important in reducing unwanted foreign materials.

1.2 MANUFACTURING PROCESS



The production of pellet fuel begins with the raw materials, or feed stock. Contaminants must be removed by using magnets to remove iron and classifiers to remove stones and non-magnetic metals. Classifiers, also known as scalpers, are devices which employ air flow to move and separate the lighter wood particles from heavier unwanted materials. Storage facilities and methods for managing feed stock materials are determined by the moisture content of the materials; dry materials must be protected from the elements, and green materials must be processed in timely fashion to prevent microbiological deterioration. After storage, feed stock is pulverized and screened into small uniform pieces by hammer mills and grinders and conveyed to holding bins or silos. A cyclone process of swirling air collects the lighter fines, or dust, for use as dryer fuel.

In the case of green materials, the next step is the drying process. The most commonly used type of dryer is the rotary dryer, a large revolving drum (some more than 10 feet in diameter and 40 feet long) which continually lifts and tumbles the material through a hot gas stream. The drying process is regulated by a variable rate feed screw and by control instruments which measure and match heat input to demand. Uniform moisture is also achieved by the larger, wetter, heavier particles moving more slowly through the drum than finer, drier, lighter particles. Dryers are often fired by using a portion (about 8 to 10%) of the feed stock, mainly the fines, or smallest particles (also known as wood flour). The drying process generally reduces incoming moisture content (wet basis, see following) of 40-45% to 6-10%.

MOISTURE CONTENT

Fuel moisture content has a dramatic effect on efficiency: wood at 50% moisture has a heating value of 4,000 Btu/lb., at 20% the heating value is 6,200 Btu/lb., and oven dry wood delivers up to 8,600 Btu/lb. One of the advantages of pellet fuel is its high Btu content (about 8,000 Btu/lb.) and consistently low moisture content, usually between 6-10%, calculated on the wet basis.

Because there are two methods for determining wood moisture content (M.C.), the wet basis and the dry basis, the concept can be confusing. The pellet fuel industry universally uses the wet basis when describing residential pellet feedstock and fuel. The dry basis is used primarily in labs and technical situations. The following M.C. calculations demonstrate the difference in the two methods.

In the dry basis, the wood is weighed wet, then dried to an oven dried condition. The oven-dried weight is subtracted from the wet wood weight to determine the weight of the lost water. Moisture content is then calculated by dividing the weight of the water by the weight of the oven dry wood. In the wet basis, the weight of the water is divided by the weight of the wet wood.

Example: A quantity of wood weighs 10 pounds. It is dried to oven-dry condition, and then it weighs 8 pounds. What is its wet basis M.C.?

Weight of the wet wood (10 lbs.) - weight of the oven dried wood (8 lbs.) = weight of the water (2 lbs.)

$$\frac{\textit{Weight of water} \quad (2)}{\textit{Weight of wet wood} \quad (10)} = .20 \textit{ M.C. (Wet Basis)}$$

The dry basis used in labs follows the same procedure but divides the weight of the water by the weight of the dried wood.

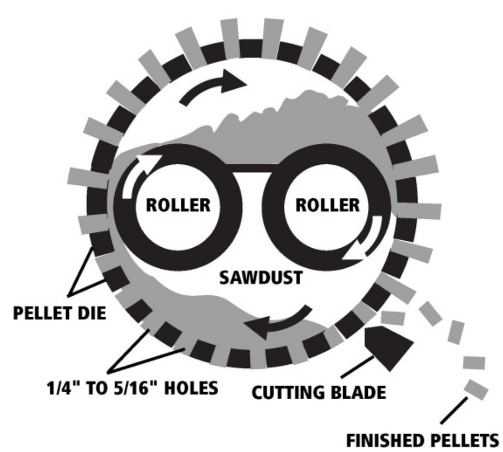
Weight of wet wood minus weight of dried wood = weight of water

10 - 8 = 2 (pounds of water).

$$\frac{\textit{Weight of water} \quad (2)}{\textit{Weight of dried wood} \quad (8)} = .25 \textit{ M.C. (Dry Basis)}$$

The dry basis moisture content is thus 25%, while the wet basis moisture content of this same quantity of wood is 20%. Customers are more likely to understand and relate to wet basis percentages since dry basis figures can exceed 100%. Pellet industry standards use the wet basis.

The dried materials are conveyed to the conditioning chamber where steam may be added to lubricate the materials and to help soften the natural lignens that act as a bonding agent to hold the pellets together. The materials (feedstock) go next to the pelleting chamber where they are extruded, or pressed, through thousands of 1/4 to 5/16" diameter holes in a steel die 1.5 to 3.5 inches thick. This extrusion process heats the newly formed pellets to temperatures approaching 250° F. The hot, still soft pellets are conveyed to a cooler to achieve room temperatures and hardening. Dust and loose fines are shaken off and recycled as the pellets proceed to be bagged.



PELLET CHAMBER

2. FUEL STANDARDS

The importance of consistent fuel and quality controls became apparent in the early years of residential pellet appliances. Fuel characteristics are crucial factors in appliance performance and maintenance. The Fiber Fuels Institute (FFI) and the Association of Pellet Fuel Industries (APFI) adopted national standards recognizing acceptable criteria for these characteristics in 1991. FFI and APFI have now merged into one association, the Pellet Fuel Institute (PFI). Voluntary fuel quality certification is the responsibility of the pellet manufacturer. Not all pellet fuels carry the voluntary PFI guaranteed analysis, even though some packaging may be marked “Premium.” End users may have to rely on experienced retailers in choosing appropriate fuel.

2.1 CRITERIA

PFI standards establish two grades of fuel, Premium and Standard. The following chart indicates that the only difference between the two grades is inorganic ash content. Table 1 outlines the fuel grade standards. However, each of the six criteria is important, because understanding them clarifies appliance performance and maintenance.

TABLE 1. PFI PELLET FUEL STANDARDS

Criteria	*Premium Grade*	*Standard Grade*
1. Bulk density/cu. ft.	*Not less than 40 lbs.*	*Not less than 40 lbs.*
2. Dimensions	*Diameter 1/4-5/16"*	*Diameter 1/4-5/16"*
3. Fines	*Not more than .5% by weight shall pass 1/8" screen*	*Not more than .5% by weight shall pass 1/8" screen*
4. Sodium (salts)	*Less than 300 parts per million*	*Less than 300 parts per million*
5. Inorganic ash	*Less than 1%*	*Less than 3%*
6. Length	*Maximum 1 1/2"*	*Maximum 1 1/2"*

Understanding the rationale for each of the criteria begins the process of understanding appliance performance and maintenance.

2.1.1 DENSITY

The density, or weight per cubic foot, reflects the amount of solid material packed into the pellet and therefore has a relationship to the heat content of the fuel. In the same number of auger turns, higher density fuel delivers more Btu content than a low density fuel. Additionally, lower density fuel burns faster and may affect low burn settings. Wide variations can require appliance adjustment, particularly in the case of excessively low density fuel which could cause the fire to go out. Density is also important as a gauge that adequate pressure and bonding have produced hard pellets that can withstand shipping and handling.

2.1.2 DIMENSIONS

Pellet diameter is another factor that affects stove performance. The 1/4-5/16 inch standard reflects the common die size for residential fuel in the Americas. Industrial pellets can range as large as 1/2" in diameter and are unacceptable in residential appliances. The most common size for residential appliances is 1/4"; in fact, some appliance manufacturers report problems with some varieties of 5/16" pellets. Apparently, unusually hard pellets of this size may not cut easily when caught between parts of the feeding mechanism and may cause feeding jams. It is therefore important to know whether an appliance manufacturer specifies the size of pellets to be used in a specific appliance.

2.1.3 FINES

Fines are the smallest, dust-like particles produced in the pelleting process. They also occur in breakdown during shipping and handling. The production standard is intended to assure hard pellets that withstand handling. Excessive fines represent loss of usable fuel and cause performance and maintenance problems. They are also a source of irritation for appliance owners when the dust escapes into the home during pouring from the bag into the hopper. The fines are less likely to burn because they are easily blown away from the flame by combustion air. Fines cause performance problems, including loss of fuel feeding if they build up on the sides of the hopper and reduce the opening size to the fuel delivery system. Additionally, fines can increase the need for maintenance by filling ash traps prematurely and by jamming augers.

2.1.4 SODIUM

The presence of excessive salt, specifically water soluble inorganic sodium, can cause severe damage from corrosion in appliances and venting systems. The sources of salt contamination include logs that have been floated in salt water, plywood, and particleboard. Manufacturers now test to ASTM E776, standard for sodium extraction. Additionally, the presence of trace amounts of alkaline salts can increase clinkering, due to a reduced ash melting point for silica.

2.1.5 INORGANIC ASH

Ash is the term for the various noncombustible minerals that remain after combustion. Ash content is the basis for determining fuel grade since all other criteria are identical for both premium and standard grade. Later discussion of appliance design and maintenance requirements will indicate clearly how crucial this fuel characteristic is. On one hand, fused ash, or clinkers (see discussion under 3.1.1 Combustion below), can block combustion air inlets and affect performance adversely. On the other, fly ash that is blown from the fire chamber can accumulate on heat exchangers and in the venting system with problematic results. Simply put, ash content is the main factor determining the frequency of appliance maintenance. In some appliances, that frequency can make the use of higher ash fuels impractical. Predictions of premium quality low ash fuel shortages are consequently a growing concern that appliance manufacturers are addressing in appliance design.

Appliance sensitivity to ash content varies with design, venting system design, and recommended maintenance frequency. Even within the allowed 1% ash content of premium grade pellets, there are noticeable performance variations in some appliances. Changing from a .25% ash content fuel to a .75% ash content fuel can cause troublesome performance and maintenance in some appliances. Manufacturer’s fuel recommendations and individual ongoing experience with locally used fuels are important for appliance adjustment and customer satisfaction. Some biomass and corn burning appliances have been introduced to deal with the 1-3% ash produced from these fuels. A fuel stirring/aeration device may be incorporated to mix the ash with the fuel and to increase fuel efficiency.

2.1.6 LENGTH

Excessively long pellets can cause bridging, the condition of pellets getting stuck across the fuel delivery entrance of the hopper. The effect is that of a log jam, with fuel unable to feed past the blockage. Long pellets may also cause auger jams. Finally, long pellets deliver inconsistent amounts of fuel. Dramatic variations in fuel feed rates in turn causes performance problems since combustion air settings deliver a volume of air based on expectations of consistent amounts of fuel. PFI standards call for maximum pellet length of 1 1/2 inches. In spite of this standard, some appliances will bridge with this length pellet and can be difficult to diagnose. The appliance manufacturer should be consulted regarding their recommendations for maximum pellet length.

2.2 LABELING

PFI Fuel Standards recommend that manufacturers identify their product with a guaranteed analysis and parameters included in the label (example below).

GUARANTEED ANALYSIS	
Grade:	*xxx*
Type of Material:	*xxx*
Ash:	*x%*
Fines:	*x%*
Chlorides:	*x ppm*

3. EFFECTS ON PERFORMANCE AND MAINTENANCE

When compared to cordwood on a one to one basis, pellets offer some distinct advantages. Pellets are more consistent and predictable in moisture and BTU content. They are more compact, so they require less storage space. They are cleaner, easier to handle, and they burn cleaner. However, these characteristics have to be put into the perspective of the appliances they burn in to have real meaning. Pellet fuels narrow the wide variables of cordwood fuels, but pellet appliances, as mechanical, electrical based systems, also have a narrower range of fuel tolerance than wood stoves. Understanding the effects of fuel characteristics in pellet appliances is essential for optimum performance, adequate maintenance, and overall customer satisfaction.

3.1 PERFORMANCE

As will be discussed later, different appliance designs have different fuel requirements and tolerances. For now, we can look broadly at some effects of using unsuitable or impure fuel.

3.1.1 COMBUSTION

A direct effect of fuel quality on combustion that is not included in the PFI Standards is silica content. Silica is essentially sand or dirt that is naturally in the bark of the tree or that enters the feed stock in the handling process. In the combustion process, silica is heated to fusion temperatures, melts, and solidifies as it is cooled. The result is clinkers, solid chunks of lava like material. The effect on combustion occurs if the clinkers stay in the grate area and block incoming combustion air.

Analysis of silica content is impractical because of the variations in growing conditions and because of the significant effect on fusion temperatures of small amounts of trace elements. The normal melting point of silica, 2,700° F., is reduced to 1,500° F. in the presence of minute amounts (1/4%) of alkaline salts (sodium chloride or potassium chloride).This reduction in the melting point promotes ash fusion at lower temperatures and increases clinkering. Combustion temperatures in the burn pot/grate area vary widely with appliance design, so fuel with silica may cause clinkering problems in a stove with high combustion chamber temperatures and not in another appliance that operates with lower temperatures.

Ash content has indirect effects on combustion. Excessive ash content, if not maintained properly, can restrict or block burn pot air holes and/or the venting system and result in poor combustion due to inadequate combustion air.

Improper pellet density can also have a direct effect on combustion by causing an abnormal feed rate. Low density pellets may feed too little combustible fuel and may cause the fire to go out, while excessively high density pellets can be difficult to start in automatic ignition appliances or they can overfeed the stove, causing high temperatures or smothering the fire. Most appliances now have simple adjustment mechanisms to overcome these difficulties. Proper adjustment of fuel to air settings for the particular fuel must be made for maximum performance as the appliance owner changes the fuel source to one with different density.

Bridging and blockage or auger jamming caused by unsuitable pellet diameter or length, or by excessive fines, indirectly affects combustion by depriving the combustion chamber of fuel.

3.1.2 HEAT TRANSFER

Fly ash gradually builds up on heat exchanger tubes or fins. The coating of ash acts as an insulator and prevents proper transfer of heat to the convection air passing through the tubes into the home. The frequency of cleaning heat exchangers is determined in large part by the ash content of the fuel.

3.1.3 MECHANICS

High ash and fines content can build up on impellers and affect blower motor durability.
Jamming from excessive fines or improper pellet size can affect auger durability.

3.2 MAINTENANCE

Using a fuel that is not suited for a particular appliance increases the frequency of maintenance. Clinkers from high silica content fuel (or from lowered ash fusion temperatures brought about by the presence of alkaline salts) must be removed before they block combustion air, affect performance, or cause other maintenance needs. High ash and/or fines in fuel necessitate more frequent cleaning of the burn pot/grate, ash storage areas, heat exchangers and venting system. The systems and components of pellet appliances are interdependent and sensitive to proper maintenance. Simple maintenance tasks, left unattended, can become a need for total system maintenance as well as a source of owner frustration. The frequency of component replacement is also increased by the lack of regular, properly performed maintenance.

4. SUMMARY

- Residential pellet fuel is recovered biomass products processed to be of uniform size, density, moisture content, and ash content.
- Feed stock is separated from unwanted contaminants, pulverized into small pieces, dried, compressed, cooled, and bagged in the pellet manufacturing process.
- PFI standards for density, dimensions, fines, sodium and ash are voluntarily complied with by pellet manufacturers. Recommended labeling includes an analysis of these factors.
- Ash content, the primary maintenance factor, is the only difference in composition between standard (up to 3%) and premium (less than 1%) grades of fuel in PFI standards.
- The fuel quality standards include characteristics that affect performance, maintenance, durability, and customer satisfaction. Another factor not included in the standards is silica content, the primary cause of clinkering.