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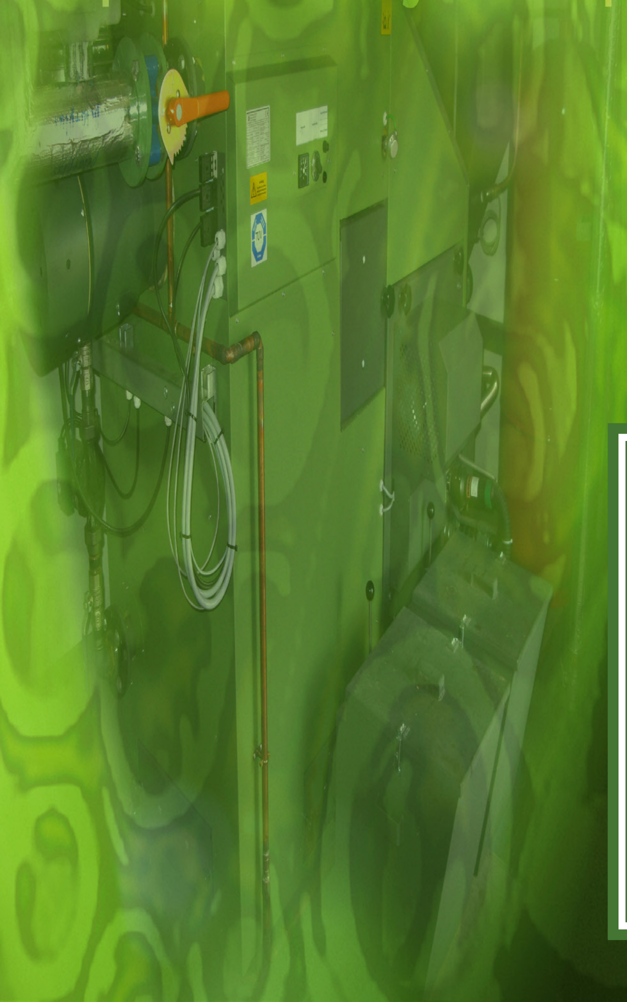
Temperature Heating circuit Support stand Draught stabilizer Pressure switch Chip



Wood Fuel Guide for Biomass Boilers

IN1284

Contents

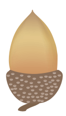
Introduction

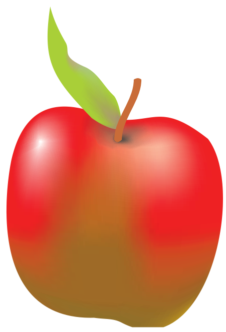
That you are reading this document means that you are probably new to the subject of wood burning and as with all new subjects there will be new information to absorb and possibly some misinformation you previously believed that you will need to discard.

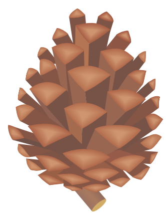
Wood has traditionally been regarded as a simplistic fuel that everyone has an inherent understanding of, but the reality is that it is the most chemically complex fuel that anyone will come into contact with and to compound wood's chemical complexity it does not have even the consistency we take for granted in oils and gasses because it does not receive any refinement. When you add to all the uncertainties of wood's makeup, the problems associated with transporting it and to delivering quantifiable amounts to the point where it is to be burned, then only the fact of it being produced by nature in a relatively short time makes it a desirable fuel to burn without the wide range of engineering skills that have been invested into your Zero Ridge supplied boiler.

Classifying Wood

Wood is neatly and simplistically classified into two categories, hardwood and softwood which would seem to be self-explanatory, but as with so much about wood the truth is a little less obvious. The categories of hardwood and softwood that wood is placed into have nothing to do with the wood's density or material strength, it is categorized by the way the trees reproduces. Hardwood trees produce seeds with a covering such as an apple or shell as with an acorn, whilst softwood trees throw out their seeds with no covering, as in pine trees that have cones which open to allow the seeds to fall directly to the ground. The two extremes that illustrate and indeed emphasise that these categories have nothing to do with the wood being physically hard or soft are balsa, which is the lightest and softest of all woods yet is classified as a hardwood and yew which has an iron like hardness while classified as softwood. (If you want to impress your friends with your knowledge of wood and etemology; softwoods come from trees classified as gymnosperm which is the greek word meaning naked seeds, and hardwoods from trees classified as being angiosperm which is greek for seeds in a receptical.)







Which Wood is Better for Burning

There are several curious old rhymes that give the burning properties of wood and many people who burn wood on a stove will tell you that whatever wood they burn is by far the best. Fortunately whatever the truth in any of the old rhymes and stove users have in their declarations, none of it has any relevance to a biomass boiler user because they have no interest in the aesthetics of wood burning; their only concern is getting the maximum heat for the least expense. The solid scientific fact is that whilst wood's properties vary enormously from species to species and even differs in a single species because of variations in growing environments, the potential heat that can be realised from any given weight of wood burned will vary by no more than approximately 10%. This does not mean that a choice of wood to burn can be regarded as a matter of irrelevance because the density of the wood dictates the volume it will occupy for a given amount of heat, which is certainly of interest if you only have limited storage facilities or a batch loaded boiler in which the amount of heat produced by each loading is dictated by the boiler's combustion chamber volume.

How Much Heat Will Wood Produce

The amount of heat produced by wood when burned is defined by its "calorific value". The term will be at least vaguely familiar even to those with no knowledge of wood burning because the calorific value of the contents is written on the packaging of all packaged foods. The term calorie means the energy to raise one gram of water through one degree Celsius. (If you look at a food package and wonder why so few calories are needed to keep you warm and active you should be aware that the food industry and nutritionists, for reasons best known to themselves, often write calorie when they really mean kilocalorie.) The calorific value of wood is given in Watts or Joules (Joules are one watt of power for one second).

Whilst the definitions of energy are exacting, trees and wood are not exacting and so however diligent and thorough the people who test wood to establish its CV it will vary from one batch to the next so never assume any figure you read is the definitive figure. With that in mind the following figures will be as close as possible to reliable averages. Assuming you could obtain wood that contained no moisture whatsoever then it will give you 19Gj/tonne, or 5.3kWh/kg. If we take wood that has been dried in a typical British climate and contains typical moisture we will find that 14.7Gj/tonne or 4.1kWh/kg are reliable figures.

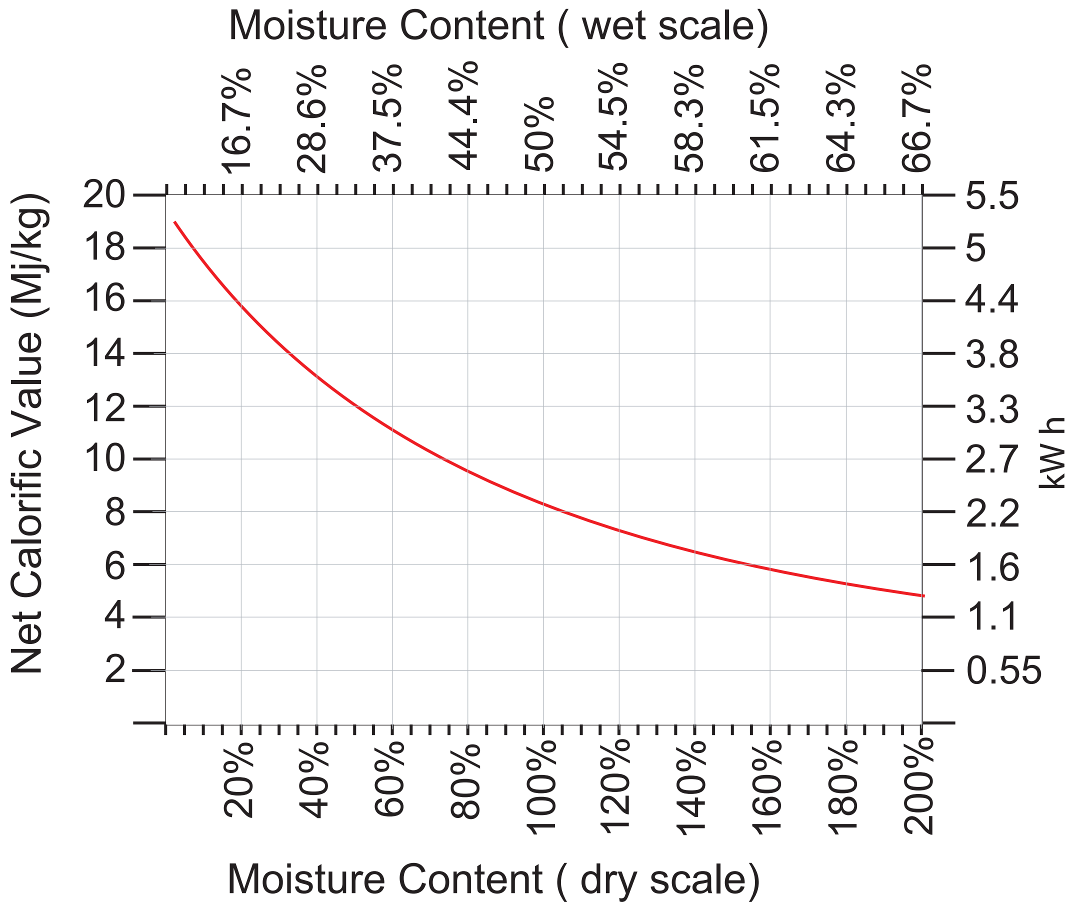
The esoteric units of Gj/tonne are meaningless to most people until they become seasoned wood burners so you can ignore them for now and concentrate on kWh. Perhaps even this might be somewhat forbidding because of the inclusion of the "h", which represents an hour, but it allows for the quantifying of power which will vary during its delivery. Unlike electricity where a 3kW heater will produce a consistent 3kW immediately it is turned on and until it is turned off, a supply of burning wood will slowly ramp up its heat output as the fire size increases and will then start to decrease its heat output until it extinguishes. So by saying 6kWh we know that whatever we are discussing might produce 1kW for six hours, 12kW for 30 minutes or whatever variations in between that add up to this figure. So given that typical wood in Britain will give 4.1kWh/kg or 4100kWh/tonne we can use this to work out how much heat we can expect from a tonne of wood and how long our tonne of wood will last.

The Importance of Moisture Content

Zero Ridge **Moisture Meter AC100**

Whatever the wood's potential CV, wood containing moisture gives out far less heat and serious wood burning people have moisture content permanently uppermost in their minds. Unfortunately the moisture content in wood can be defined in two ways, either as a percentage of the wet wood's total weight which is conveniently known as the wet scale or the weight of water with reference to the weight of wood when completely dry, which is thankfully known un-confusingly as the dry scale.

Traditionally the wet scale was used by forestry personnel and the dry scale was used by people drying wood for use in construction and furniture. With the advent of electronic moisture meters that are almost all calibrated in the dry scale it you should be wary of any reference to moisture content figures not qualified with the scale they refer to. Convert from one to the other with the following chart.



Although the term seasoning is used when talking about wood the reality is that the term "seasoned" is one of those meaningless terms like "farm fresh" or "freshly squeezed". To ensure we can extract as much heat as possible and as economically as possible we need to be exacting about the moisture content of the wood we intend to burn and a reliable way of determining its moisture content. The simplest way of doing this if we are burning logs is to use a simple electronic moisture meter that monitors the current flowing between its two spikes when pushed into the wood to indicate the wood's moisture content.

Unfortunately these meters will only measure the wood's moisture content for the depth to which the spikes can be pushed, which is not usually deeper than a few millimetres, so it becomes necessary to split the log at several points to ensure you have a reasonable representation of the log's cross section and then measure each piece to come up with an average. This might sound a little tedious but several logs from different parts of the log stack can be evaluated in a few minutes.

Another option would be to invest in one of the moisture meters that generates an electromagnetic wave which penetrates the wood. The moisture content is then determined by the strength or amount of the outgoing signal that is reflected back to the meter. These meters claim to read to a far deeper depth than the meters that use spikes and are very popular with people preparing wood for uses other than burning because they leave no mark on the wood. Which ever sort you might investigate, you will notice that as the accuracy claimed for the meter increases so too will the need for specifying the temperature and species of wood being tested and the testing becomes a far more laborious task.

Unless you buy very specialist and expensive equipment, measuring the moisture content of wood chips or pellets cannot be performed by electronic meters. However, if you are the sort who likes to be exacting and you have patience in abundance, a shallow dish, an oven, together with a good set of scales the following method is as exacting as it gets.

Please note that we are talking about a convection oven. Do not be tempted to use a microwave to dry the wood. Within a short time the wood will catch fire which will damage the oven and reduce the evaluation to nonsense.

To reduce the drying time, if testing wood other than chip or pellets, the wood to be tested should be in pieces as small as practicable before placing into the shallow dish. The dish and its contents should be weighed and then placed in an oven set to a temperature no higher than 103°C. If the temperature is too high not only the water but other volatile matter will be driven out, which will give the impression of the wood having been far wetter than it was. The wood should be weighed every four hours or so until no further reduction in weight is recorded and at this point the wood should have no moisture content. The empty dish should be weighed and this weight subtracted from the original and final recorded weights.

The final weighing is the weight of the dry wood. This weight subtracted from the original weighing gives the weight of water that was in the wood and the following formula gives the moisture content on the dry scale.

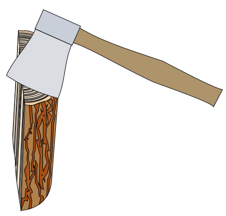
$$MC = \frac{\text{mass of water}}{\text{mass of dry wood}}$$

If our original weight was 250 gms (the wood and water) and our final weight was 216gm (the dry wood) we have the mass of water as being (250-216) 34 gm.

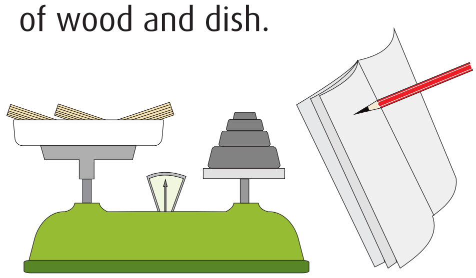
$$MC = \frac{34}{216} \quad \text{or} \quad MC = 0.1574$$

Moving the decimal point over two places (i.e. multiply by 100) to give us a percentage, we have a moisture content of 15.7% on the Dry Scale.

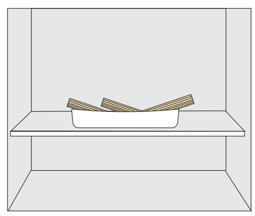
1 Split any logs into smaller, more easily dried pieces.



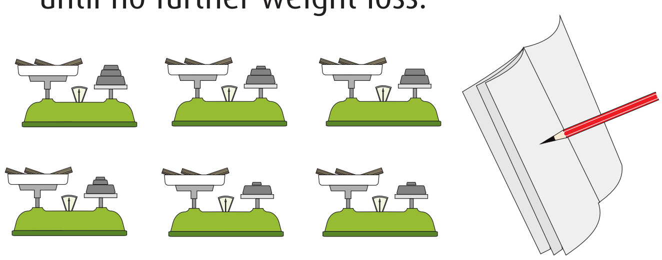
2 Weigh and record weight of wood and dish.



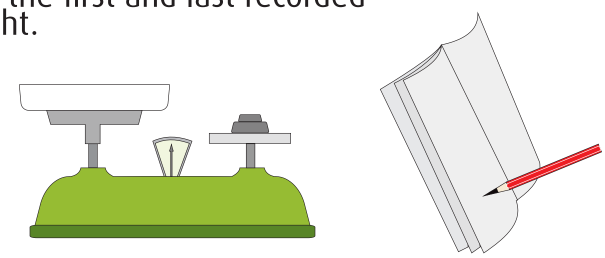
3 Place dish with wood into an oven at 103^{0}C.



4 Repeatedly weigh and record until no further weight loss.

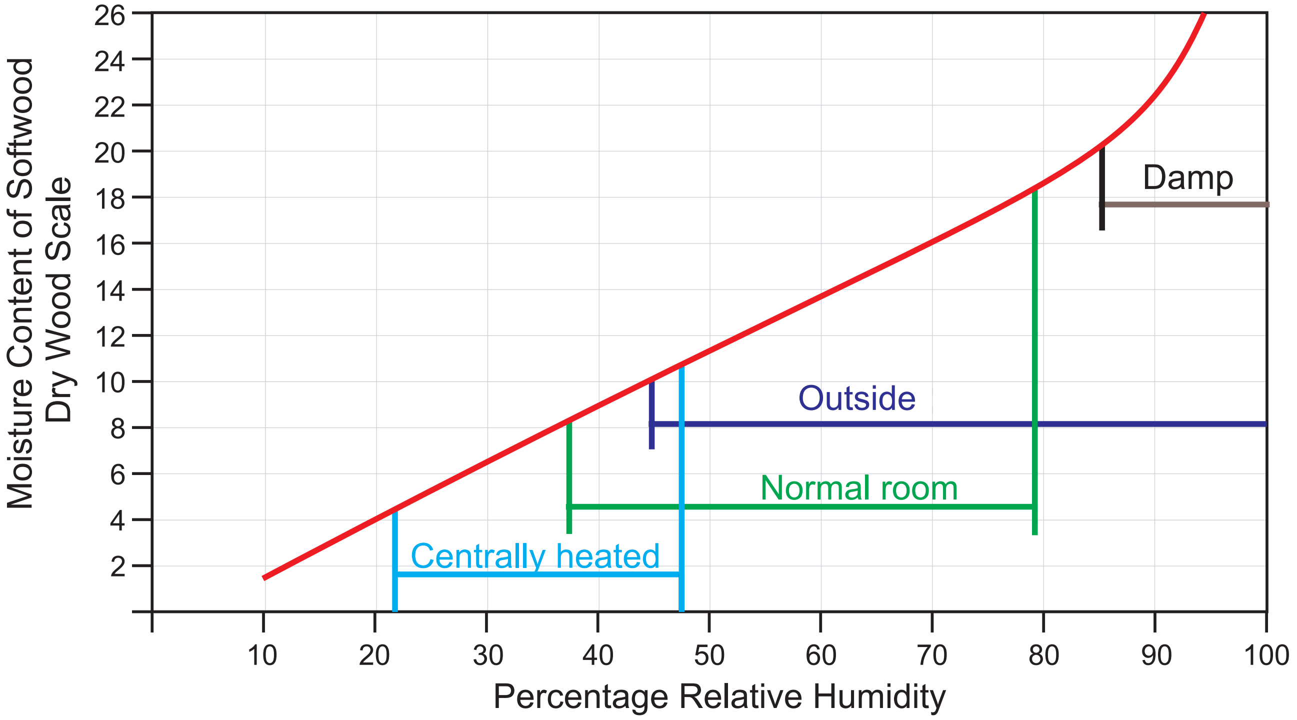


5 Weigh dish and subtract its weight from the first and last recorded weight.



Realistic Moisture Content

Because wood is hygroscopic, if the wood we have just dried completely is placed outside, but sheltered from any rain, you will note that after a few days it will, unless the atmosphere is unusually dry, have absorbed sufficient water from the atmosphere to now be weighing something approaching its original weight. A visit to the BBC weather web site will give you the relative humidity of the atmosphere on a daily basis and noting it over several weeks will enable you do an approximate calculation of what your stored wood's moisture content is likely to be, using the chart below. You will quickly be able to appreciate that Britain is not a country that will ever be very good for drying wood naturally. The term relative humidity is used because the air's ability to carry water is relative to the atmospheric pressure and its temperature.



Wood for Burning Does Not Keep Forever

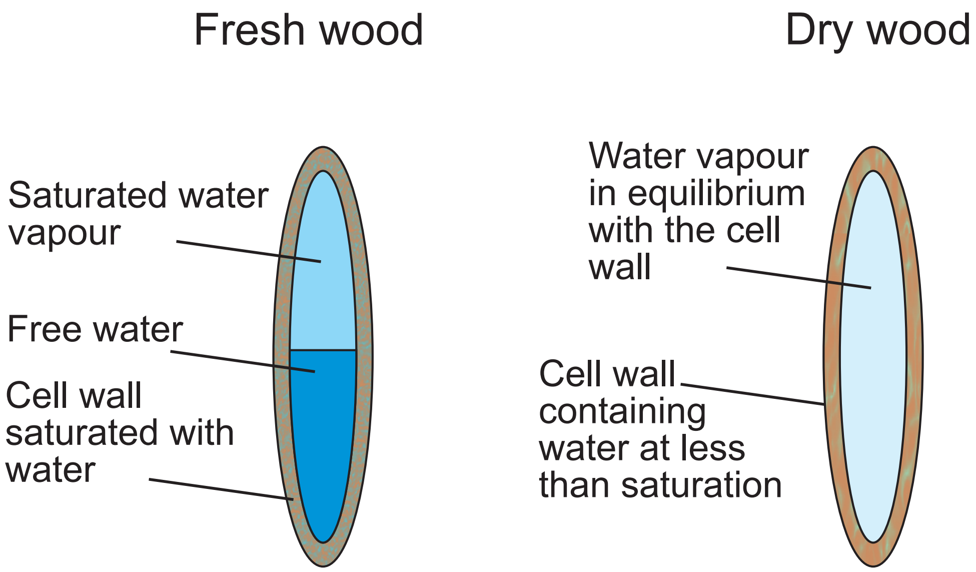
If you have ever watched a house fire in an old house that has an abundance of wood in its structure you will know how fiercely it burns and it would be reasonable to assume that wood stored in a barn for many years would burn with the same intensity. Unfortunately the reality is that the wood in the house has been sitting in a relatively dry and stable temperature atmosphere while wood in a barn will spend its time cycling between losing and absorbing water, which over time effectively washes out the resins and tars that make up the combustible volatile matter within wood; it also causes the wood to disintegrate as the continuous wetting and drying of the cell structures cause them to break apart.

If you are allowing the wood to dry naturally you will be able to watch the wood and gauge the drying progress as the wood reaches a moisture content in balance with the atmosphere. As mentioned earlier the wood will gain or lose water as the atmosphere's relative humidity changes and it is when the water begins to be lost from the cell walls that the wood begins to shrink, with wood in log form developing cracks between shrinking layers.

The time wood takes to dry to an acceptable moisture content will depend firstly on the access the water in the wood has to the atmosphere. A bark covered log that has not been split will only have the ends through which the water can migrate but a split log will have the ends and the split surface and so will dry very much faster. Obviously wood chip has the ability to lose its moisture content extremely quickly, but conversely its moisture content will increase far more rapidly whenever the relative humidity increases.

How Wood Dries

Wood like any other material dries by its water content being absorbed into the atmosphere, but wood is a little more complex than some materials. Because wood's bark is waterproof it needs to be split to maximise the surface area from which it can lose moisture. Wood is made up of various kinds of cells which hold water within their cell cavity, which is described as free water, they also have water bound to the cellulose molecules of the cell wall. The free water has little to do with the wood's structure beyond adding weight and is readily removed, which will reduce the wood's moisture content to about 30%. When this point is reached the water in the cell walls will begin to migrate causing the cell walls to contract and as the cells contract the wood begins to shrink and split.



Kiln drying might be an option to people who only burn a few logs in a stove each evening but it is not a cost effective means of drying wood on a large scale. If you are interested in building constructions and have the room, plans for buildings that look like a cross between a poly tunnel and a shed, that their designers call solar powered wood dryers, can be found on the web.

Buying Wood as Logs

Whilst you can always burn any fallen or felled trees you may have on you own land it will probably be necessary to purchase wood from a supplier at some stage. It is important that you do not burn any wood for which there is even a remote possibility of it having been subjected to chemical preservatives. Do not use wood that may contain nails or screws as these make chopping or splitting a hazardous operation

The British Standard that attempts to standardise logs for use in wood boilers is BS EN 14961-5-2011. This specifies that the species of wood or woods must be given and then gives the range of log diameters and lengths together with the moisture content that your wood supplier should be able to supply wood. Whilst this gives a reasonably well defined product with a degree of repeatability for future purchases it will never be as simple or as defined as buying oil. If you are buying wood by weight the MC of the wood will be important because you will want to know how much of the weight is simply water. If you are buying by volume then you have to establish whether the volume is of neatly stacked logs or a random jumble of logs as the difference will be significant. Whilst you will be able to find a number of tables giving the weight of wood in a cubic metre, both stacked and jumbled, It will not surprise you to discover that few of them confer because of their assuming differing moisture contents, log sizes and stacking ability.

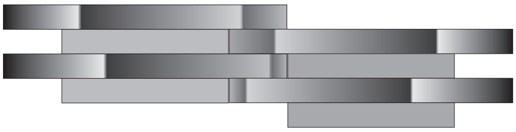
A summary of the codes and their meaning when logs are said to conform to BS EN 14961-5:2011

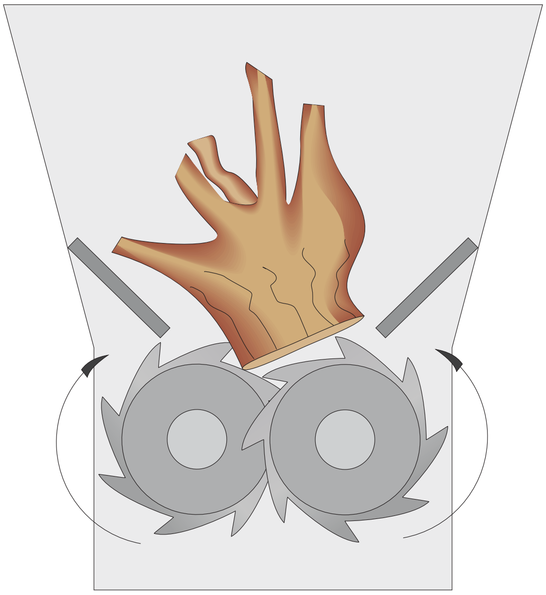
	A1	A2	B
Wood species	The wood species must be given in all categories. Where more than one species is in a batch they should be listed in descending proportions.		
Diameter Specified in cm	D2 which is less than 2cm D5 is between 2cm and 5cm D10 is between 5cm and 10cm D15 is between 10cm and 15cm D15+ means greater than 15cm when the sizes must be given		D15 means less than 15cm D15+ means greater than 15cm when the sizes must be given
Length Specified in cm	L20 not more than 20cm L25 not more than 25cm L33 not more than 33cm L50 not more than 50cm L100 not more than 100cm		L33 not more than 33cm L50 not more than 50cm L100 not more than 100cm
Percentage weight of water Wet basis.	M20 less than 20% M25 less than 25%		M25 less than 25% M35 less than 35%
Percentage weight of water Dry basis.	U25 less than 25% U33 less than 33%		U33 less than 33% U54 less than 54%
Proportion of split logs by volume	More than 90%	More than 50%	No requirements
Decay	No visible decay	Less than 5% in number	If more than 10% in number of the batch it the percentage must be declared

Wood with the Appliance of Technology

Whilst we always tend to think of logs when we think of wood as a fuel, many parts of a tree are unsuitable for making into reasonably consistent sized logs and this wood is turned into wood chips for using as wood chips in large automated boilers or as briquettes and pellets.

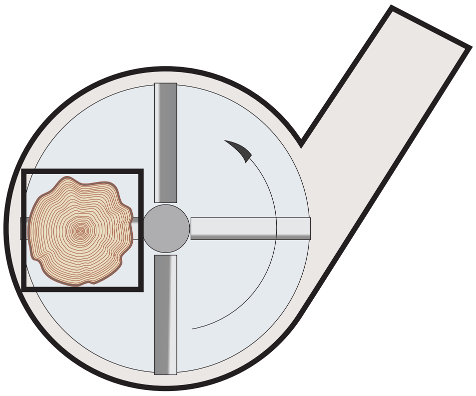
The Shredder

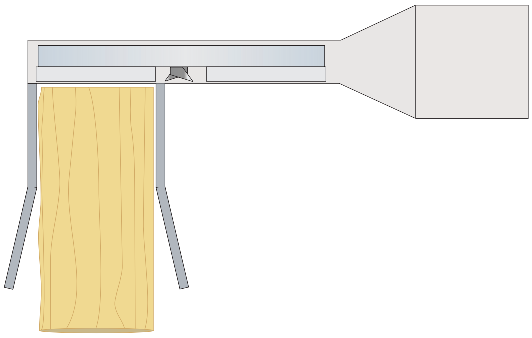




The shredder uses thick closely fitting blades revolving only slowly to rip rather than cut the wood. The design is so successful that these machines are used to shred a wide variety of materials including car bodies and even mattresses. The uncertainty of the chip size uniformity does not make them ideal for chipping wood prior to pellet production but they are used mainly for shredding tree stumps for low grade wood chips.

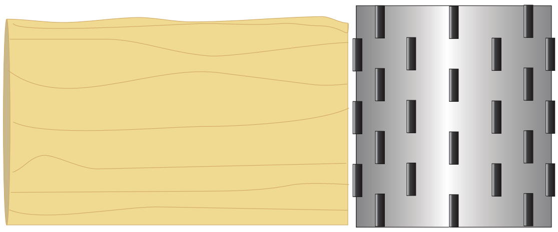
The Chipper

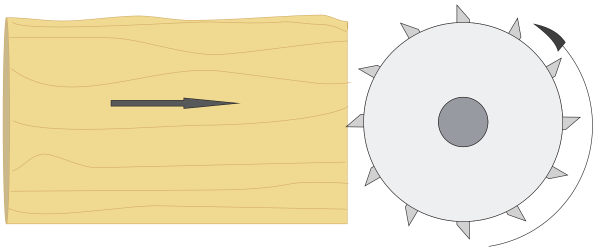




There are many designs of wood chipping machines, with the simplest being a spinning disk fitted with blades, which again are of many varying designs. Its simplicity makes it ideal for smaller trees, but are generally not used for the production of chips for pellet making. Disk chippers are most commonly seen being used by tree surgeons, where the blade's ability to draw in the wood together with the disk's high speed allow the resultant chips to be propelled into a spout to be deposited into a storage container, making it an ideal one man tool.

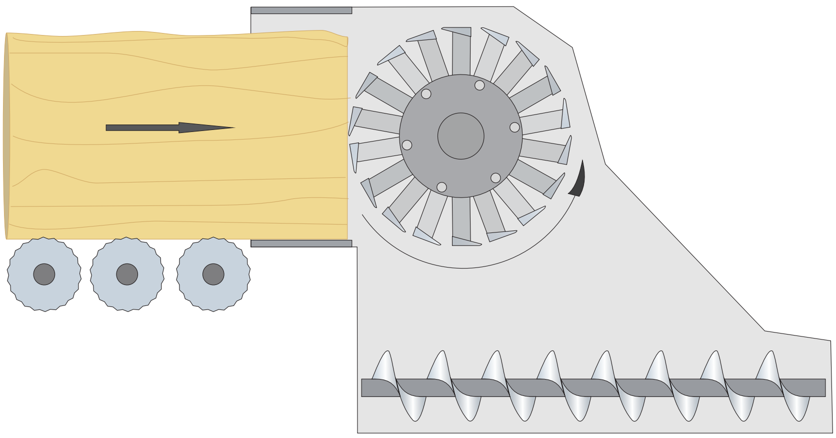
The Drum Chipper

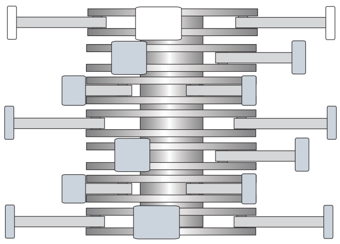




The drum chipper, with whatever blade design it has, produces consistent chip sizes and copes with very large diameter tree trunks and is used by many manufactures of wood chips and pellets. It operates well with straight sided trunks but large and more curvaceous trunks sometimes cause problems when a bulge will split away and stall the drum.

The Flail Chipper





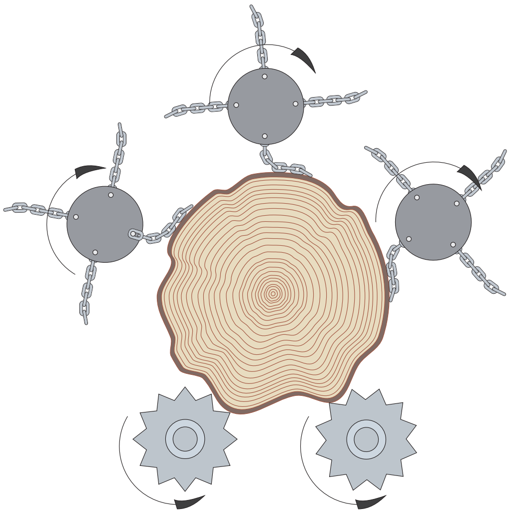
The flail chipper uses blades attached to pivoted arms. These chippers can cope with virtually any size and shape of tree trunk, and because the arms pivot it is almost impossible to stall the cutters. These machines are usually equipped with augers to remove the chips and automatic monitoring controls to ensure the discharge of chips is matched to the supply of wood.

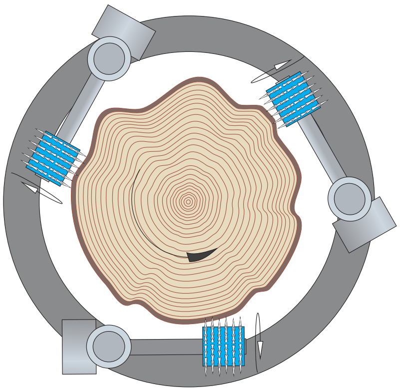
So far we have looked at machines for producing wood chips, from those that produce irregular chips that will be used in larger automated boilers to those that can produce chips of more consistent size making them ideal for preparing wood for further processing into wood pellets for the smaller automatic boilers. Because the tree bark will be contaminated with soil and sand, burning the bark will result in large amounts of noncombustible minerals adding to the ash and so better quality chips and pellets are made from trees that have had their bark removed.

Bark Removal

Similarly to the wood chippers there are many systems and variations to each system that exist for removing bark from the tree and the following are just an indication of their diversity.

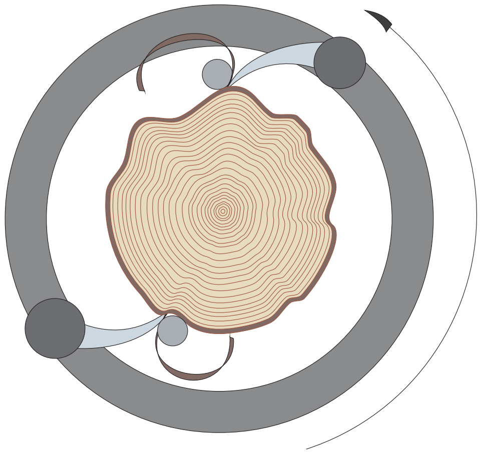
The chain flail literally beats the trunk with chains mounted on spinning disks which are rotating in the opposite direction to the toothed wheels which cause the trunk to rotate. This system will remove the tree limbs as well as the bark.

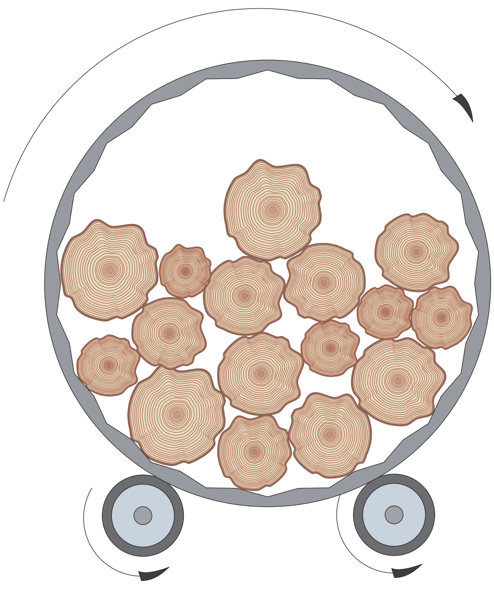




The rosser head de-barker rotates the trunk while it passes a series of pivoting spinning drum cutters.

The ring de-barker uses blades to peel off the bark by tensioning the blades to travel through the cambium layer, which is the thin slippery layer between the wood and bark.

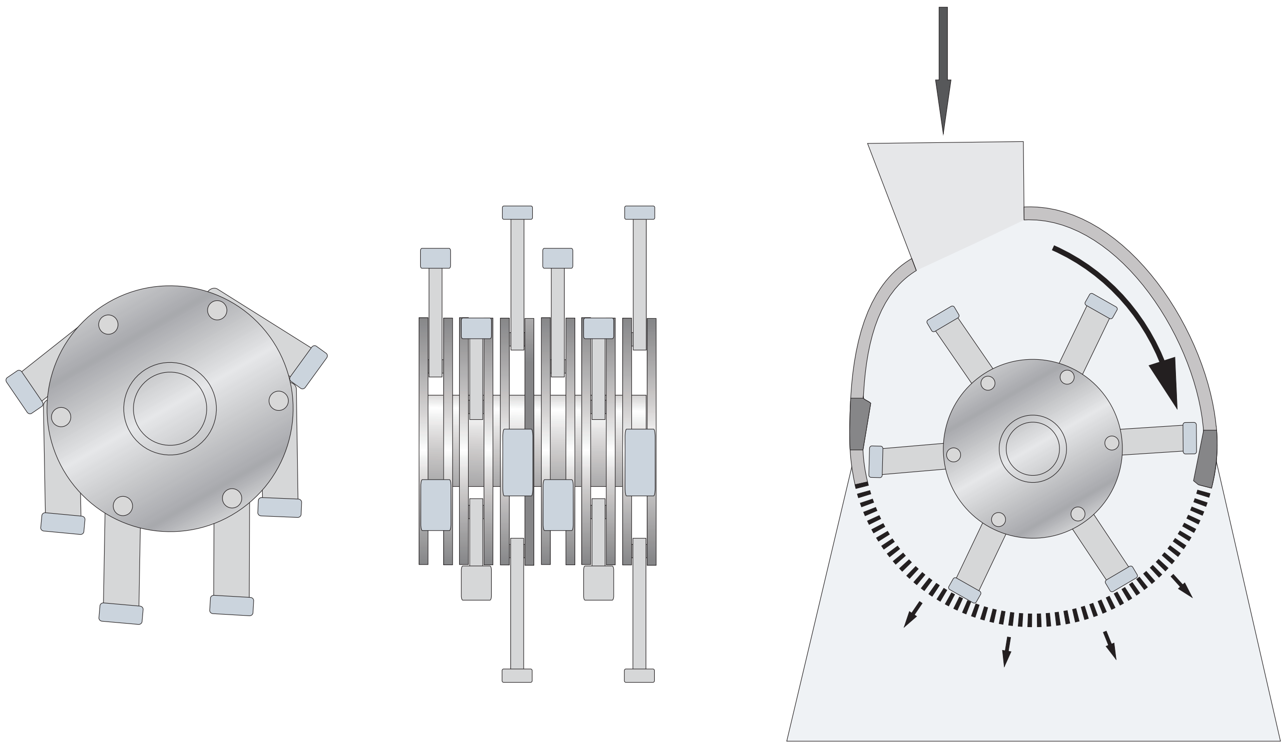




The drum de-barker is a rotating drum that when holding a collection of trunks causes the trunks to abrade against each other and the drum wall to grind off the bark. This system necessitates the logs to be debarked in batches rather than as the continuous flow as with the other systems.

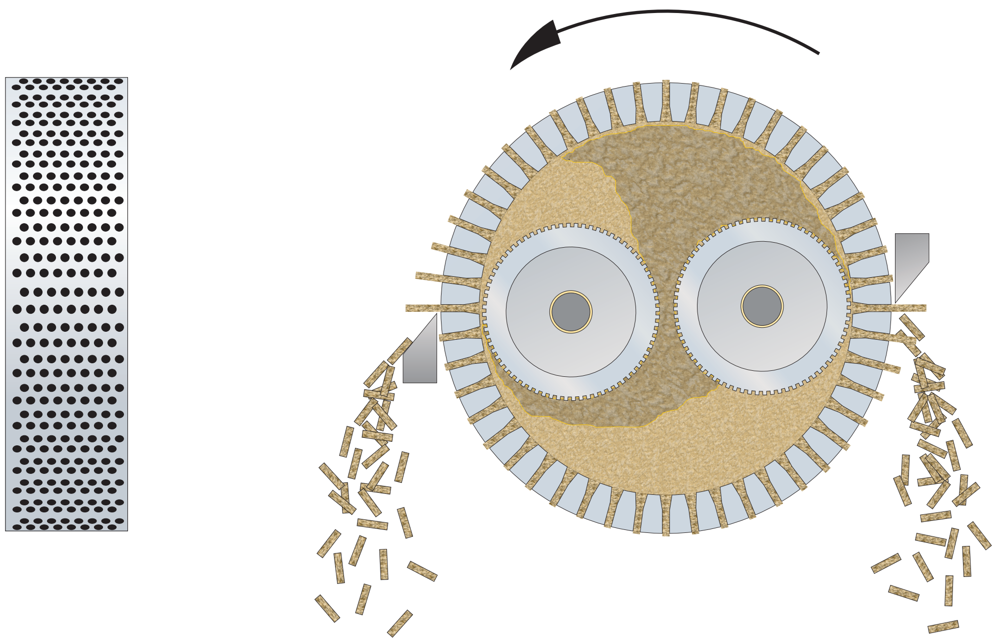
The Hammer Mill

If the wood is to be processed beyond simple chipping the chips will need to be reduced in size and the machine that does this is a hammer mill.



The central hub has a series of hammer headed pivoting arms that fly outwards when the hub is rotating, in a similar way to the blades of the flail chipper. The incoming wood chips are initially hit by these arms which begins to break them apart and as they are sent to the outer casing wall they get crushed between the hammer heads and the striking plates, Constantly being driven passed and ground against the mesh at the bottom of the mill it is the mesh size that governs the fineness of the wood pulp produced.

The wood from the hammer mill will be the smallest particle size when it is needed for wood pellets. As with all wood processing machines there are many variations as to the shape and size of pellet making machines but the basic principle applicable to them all is that the dry wood pulp is delivered into a circular revolving chamber whose wall is an extrusion die on the form of a ring with a series of holes around its circumference.



When the pulp arrives at the extrusion die, wheels with fixed centres squeeze the pulp into the extrusion holes at such a high pressure that the pulp heats and the lignin in the wood plasticices, binding the wood fibre as it passes through the extrusion hole. After being cut to the required length the pellets are quickly cooled, solidifying the lignin, to produce a mechanically resilient pellet.

Briquettes are made in a similar way to pellets in that the wood is compressed to plasticise the lignin which binds the wood, but the wood is usually compressed with a hydraulic ram. There are many different sizes and shape of briquettes produced and produced from differing wood particle sizes and both pellets and briquettes often include wood from woodworking manufacturers off-cuts.

Storing Wood Fuels

To store a given amount of heat, wood that has been processed usually has a smaller volume than logs but it will be a considerably larger volume than oil. To store the energy that would be available from 1,000 litres of oil would occupy 14,000 litres of wood chips or 3.300 litres of wood pellets, which means that providing and maintaining storage facilities is a major element of wood burning. Not only is its size going to be significant but so too will your responsibility for maintaining it in a safe and hygienic state.

Wood and especially wood that has been heated in a manufacturing process gives off an impressive list of volatile compounds, which accounts for the distinctive smell associated with wood. Unfortunately while giving off these smells it is also absorbing oxygen and giving off carbon monoxide and the wood that has been heated in manufacture, which are pellets and briquettes, doing so at the highest rates. This means that without adequate ventilation the store rapidly becomes a serious potential hazard and however well ventilated, you should always treat a wood store with the utmost caution and never enter one without somebody watching and communicating with you from outside the store. Never enter or even put your head into a silo or other sealed store. A carbon monoxide alarm device should be fitted in the store but do not assume if it is not triggered that the store is safe to enter without assistance.

Wood dust is not only a fire risk but it also has the potential to carry fungal spores and other nocuous matter so this should be removed regularly taking the precaution to wear a dust mask while doing so. Do not use a vacuum cleaner as any arcing from its motor might ignite the dust. The rumour that wood stores are prone to spontaneous combustion is unsubstantiated folklore. The few that have caught fire have done so because of pellets being delivered by vacuum without proper suppression of any resultant static electricity, or because electrical fittings were not of an approved design for a wood store.

Wood Pellets

The British standard for wood pellets for non-industrial use BS EN 1461-2:2011 gives three categories for wood pellets. For the user rather than an enquiring chemist the differences are because of their ash content by weight with those categorised as A1 having less that 0.7%, A2 pellets having 1.5% and B2 pellets having 3%, with the differences being caused by the differing woods that are allowed to be used in each category. The ash content not only determines how often you will need to empty it from the boiler but the higher the ash content the greater the problem if it sinters, making more frequent slag/clinker removal necessary.

As mentioned earlier, the pellets are formed by the wood fines being squeezed through a tapering die tunnel where the tremendous pressure causes the temperature of the wood to reach approximately 90°C and causes the lignin in the wood to become soft, when it disperses throughout the pellet and acts as an adhesive to bind the whole pellet together, with the terpene in the wood adding a final gloss. The pellet's composition and the temperature reached when the pellet was formed dictates its ability to withstand mechanical shock and abrasion which in turn determines, how much dust will be caused by the pellets. Because of all the processes the pellet have been through during their production it is not difficult for them to achieve a moisture content of less than 10% on the wet scale as specified in the British Standard and at this moisture content they will weigh approximately 650kg per cubic metre.

The purpose of pellets is not only to make a reasonably consistent fuel and to utilise off-cuts of wood that might have been sent to landfill. By being reasonably uniform, small sized pellets, in bulk they will behave rather like a fluid and the fuel can be moved from a storage area to the boiler's combustion chamber in a constant flow by gravity, air flow or mechanical means rather than in separate hand loaded batches. This means that with relatively uncomplicated system wood can be used to fire a comparatively small boiler and for the boiler to operate automatically while needing only the minimum of attention.

Pellets can be supplied in 15 and 20 kilogram polythene bags to be stacked into a storage as well at 1 tonne tote bags, or as a delivery of loose pellets that can be blown into your store if it has been purpose built and complies with all the requirements. The polythene bags will invariably cost far more money weight for weight that the pellets delivered loose but they can be stored with the minimum of facilities and if your use of them is relatively small and you are prepared to transport them manually they might be the ideal choice. Being able to accept loose pellets in bulk into a purpose built store means you do not have to handle them at all and if you added an automatic conveying systems to feed your boiler directly from your pellet store then you have all the convenience and hands free operation that you would expect from an oil or gas boiler.

The British standard allows the addition of up to 2% of non wood products in the pellets. These may be to aid production by reducing the amount of pressure needed to bind the wood pulp or as an aid to minimise the ash from fusing together. Any additives must be declared by the supplier together with details of the ash's melting details.

If when using a supply of pellets the ash sinters to form troublesome slag/clinker too often, you should not immediately assume you need pellets with ash having a higher melting point but to look to see how much dust/fines are mixed with the pellets. These particles being far smaller than the pellets burn faster than the pellets, causing the flame temperature to increase, which may be hot enough to cause the ash to melt and sinter. Usually if the pellets seem to contain more than 1% of fines it is an indication that the pellets were not compressed enough or that insufficient binding agent was used if the pellets have a low softwood content.

A summary of the codes and their meaning when pellets are said to conform to BS EN 14961-2:2011

	A1	A2	B
Diameter and length specified in mm	D06 a diameter of between 5 and 7 mm and a length between 3.15 and 40mm D08 a diameter of between 7 and 9 mm and a length between 3.15 and 40mm		
Percentage weight of water Wet basis	M10 less than 10%		
Percentage weight of ash when dry	A0.7 is less than 0.7%	A1.5 is less than 1.5%	A3.0 is less than 3.0%
Percentage weight of fines	F1 is less than 1% fines		
Additives	Less than 2% The additives and the amounts must be specified		
Net calorific value in MJ/kg or kWh/kg.	Q 16.5 is not less than 16.5 kWh/kg and not more than 19kWh/kg Q 4.6 is not less than 4.6 kWh/kg and not more than 5.3kWh/kg		
Nitrogen Percentage by weight dry	N 0.3 less than 0.3%	N 0.5 less than 0.5%	N 1.0 less than 1.0%
Chlorine Percentage by weight dry	Cl 0.02 less than 0.02%	Cl 0.02 less than 0.02%	Cl 0.03 less than 0.03%
Sulphur Percentage by weight dry	S 0.03 less than 0.03%	S 0.03 less than 0.03%	S 0.04 less than 0.04%
Ash melting behaviour	Shrinkage starting temperatures, deformation temperatures, hemisphere temperature and flow temperature in oxidising conditions should be given		

In addition to pellets conforming to BS EN 14961-2 The European Pellet Council operate a scheme called EN Plus to certify pellet producers and suppliers who supply pellets meeting with this standard but the council imposes additional requirements. Whereas BS EN 14961-2 simply asks that the ash melting behaviour is stated, pellets supplied as being EN Plus must meet with a minimum tolerance. Pellets supplied as EN Plus-AI must have an ash deformation temperature above 1200°C and pellets supplied as EN Plus-A2 and EN Plus-B must have a deformation temperature above 1100°C.

Pellets are often quite dark on the surface for many reasons but if you snap a pellet in two you should find the interior almost white, indicating that good quality softwood has been used. Dark particles indicate that the pellets contain bark which will increase the ash remaining after combustion. If a handful of the pellets are placed in a glass vessel containing water, the pellets should disintegrate into separated particles within a few minutes. If an excessive amount of binder has been used the pellet will remain whole for perhaps even longer than thirty minutes, although it will eventually fall apart if only the permitted binding agents have been used. Giving the water and wood dust a swirl you will see the heavy and densest particles settling in the middle of the vessel's bottom. Look at this for evidence of dirt or sand that should never be there. If there seems to be an excessive amount of very fine wood particles it indicates that dust from a sanding machine has been added to the wood pulp which will make sintering more likely. If any of these little tests cause doubts as to the quality of the pellets an alternative supply of pellets should be sought.

Wood Chips

By chipping the wood into small pieces it can, like pelleted wood, be stored and conveyed as if almost a fluid. The British standard for wood chips is BS EN 14961-4:2011 The first subject covered is the size of the chips and these are defined as particle size and given as a classification following the initial P. Unfortunately wood cannot be chipped into uniform sizes so the size given is the size of the round hole that the chip would pass through. Obviously smaller pieces will also have fallen through so the standard calls for a percentage to be within a defined range.

If we add to the variables of the sizes of chips in two dimension the addition of a third dimension you will begin to grasp that defining even the size of collection of chips is not easy. However, assuming a batch of chips is defined as P31.5 we are told that more than 75% of the chips by weight will be between 8mm and 31.5mm and that the fines below 3.15mm will be less than 8%. No chip is to be longer than 120mm, and no more than 6% of them to be above 45mm and the cross sectional area of any chip over 31.5mm must not exceed 200mm^2 which means that the 120mm chip would be less than 17mm thick.

The elaborate detail of the chip size specification is to make it easier for the designers of the equipment that will move the fuel into the boiler to design equipment that will efficiently and reliably convey the chips from the wood store to the boiler. By knowing the chip sizes it also allows the combustion engineers to design the boilers combustion chamber and controls to give optimum efficiency with the minimum emissions; unfortunately it will be some time before anyone can produce the perfect cubes of wood they would like. As a further aid to the combustion engineers the chips are categorised with the letter M which gives the moisture content of the chips. These range from M10 which means that with less than 10% moisture the chips will have been dried artificially, through to M25 and M35 and on to whatever MC the supplier specifies. You will by now appreciate that the MC given by the supplier it will be at the moment of delivery and within days the chips will be at the mercy of the atmosphere when the MC will change according to its relative humidity. You will also appreciate that because the cells in the wood have such short access routes to the atmosphere that any changes will happen quickly. The categories of A1,A2 B1 and B2 specify what wood is used and more importantly its ash content. Whilst a large chip boiler is more tolerant to the problem of ash sintering than a pellet boiler it is still an important consideration.

A summary of the codes and their meaning when wood chips are said to conform to BS EN 14961-4:2011

	A1	A2	B1	B2
Percentage weight of water Wet basis	M10 less than 10% M25 less than 25%	M35 less than 35%	As specified	
Percentage weight of ash when dry	A1.0 less than 1%	A1.5 less than 1.5%	A3.0 less than 3.0%	
Net calorific value in MJ/kg or kWh/kg	Q13.0 not less than 13 kWh/kg Q3.6 not less than 3.6kWh/kg	Q11.0 not less than 11 kWh/kg Q3.1 not less than 3.1kWh/kg	As specified	
Nitrogen Percentage by weight dry	Not specified	Not specified	N1.0 less than 1.0%	
Chlorine Percentage by weight dry	Not specified	Not specified	Cl0.05 less than 0.05%	
Sulphur Percentage by weight dry	Not specified	Not specified	S0.1 less than 0.1%	

Wood chip sizes allowed in BS EN 14961-4:2011

Chip size class	75% as a minimum weight in a batch	Fines smaller than 3.15mm by weight as a percentage	Percentage by weight with reference to the chip length and cross sectional area in mm
P16A	Chips that will pass through holes measuring between 3.15mm and 16mm	Less than 12%	Less than 3% above 16mm and all below 31.5mm in length. The cross sectional area of all oversized chips to be less than $10mm^2$
P16B	Chips that will pass through holes measuring between 3.15mm and 16mm	Less than 12%	Less than 3% above 45mm and all below 120mm The cross sectional area of all oversized chips to be less than $20mm^2$
P31.5	Chips that will pass through holes measuring between 8.0mm and 31.5mm	Less than 8%	Less than 6% above 45mm and all below 120mm The cross sectional area of all oversized chips to be less than $20mm^2$
P45	Chips that will pass through holes measuring between 8mm and 45mm	Less than 8%	Less than 6% above 63 mm a maximum of 3.3% above 100mm and all below 120mm The cross sectional area of all oversized chips to be less than $50mm^2$

Producing Your Own Wood Chip

If you are lucky enough to have a woodland to provide you with a supply of wood suitable for chipping you will be pleased to know that you can hire wood chippers, but hiring one that will produce consistent sized chips will be expensive and unless you learn extremely quickly by the time you have cut down the trees and removed their branches the amount of chips you produce per hour will not be very impressive. You might do a little better if you have staff able to chop trees and to man a hired chipping machine the progress would still be relatively slow and the chip of dubious quality. However, you might like to consider instead hiring a contract chipping company who, because they have the experience and machinery to fell and produce chips conforming to the relevant British Standard as an everyday operation they will be worth every penny of their cost. Loading your boiler with the wrong chips might be a very expensive mistake for a multitude of reasons from lost efficiency to mechanical damage.

Chip Storage

Wood chips occupy an enormous volume for a given amount of heat compared with other fuels and so you will need to make the store as big as possible. The transport costs represent a significant proportion of the cost of any delivery of wood chips so you want there to be as few deliveries as possible and even if you are chipping you own wood you need to ensure you have the capacity for accepting the result of a days labour. Because you will be wanting to accept a new delivery long before the store has emptied you should allow for storing 50% more than the delivery vehicle's capacity or a similar amount more than you can chip in one session. This and the reality of running out of fuel during severe weather conditions when no supplies can be obtained should be uppermost in the initial storage planning agenda. Although chips can be delivered in lorries capable of blowing the product into the store the process is both noisy and slow and the distances the chips can be blown are finite and assume 8 metres horizontally and 4 metres vertically to be the absolute maximum and if the delivery vehicle is a tipping lorry then ideally it should tip from a position above the store so either the store is below ground level or, if there is sufficient space, a ramp built to allow the delivery lorry to tip from well above ground height. Other options include the lorry tipping into an auger conveyancing system that will transfer chips put into its collection tray to the store; again this will be a rather slow process.

Briquettes

Briquettes are made from finely chipped wood that is put into a mould and compressed so that,similarly to pellets, the pressure causes the wood to heat and lignin in the wood to plasticise and bind the chips. This allows the wood not only to be compressed but to be formed into consistently uniform shapes. This means that the wood can be densely stacked to occupy far less volume than natural logs giving an equivalent amount of heat and more importantly a log boiler can be loaded with a far greater weight of wood than loading it with natural logs. The British Standard for briquettes is BS EN 14961-3:2011. and unsurprisingly many of the defined limits are, apart from size, very similar to those given for pellets, with the major difference being the ash content, with A1 being less than 0.7%, A2 being less than 1.5% and B being less than 3%. As with pellets the fine wood particles will be capable of drying out quickly before being formed and when the briquettes are formed they become heated so the moisture content is between 12% and 15%.

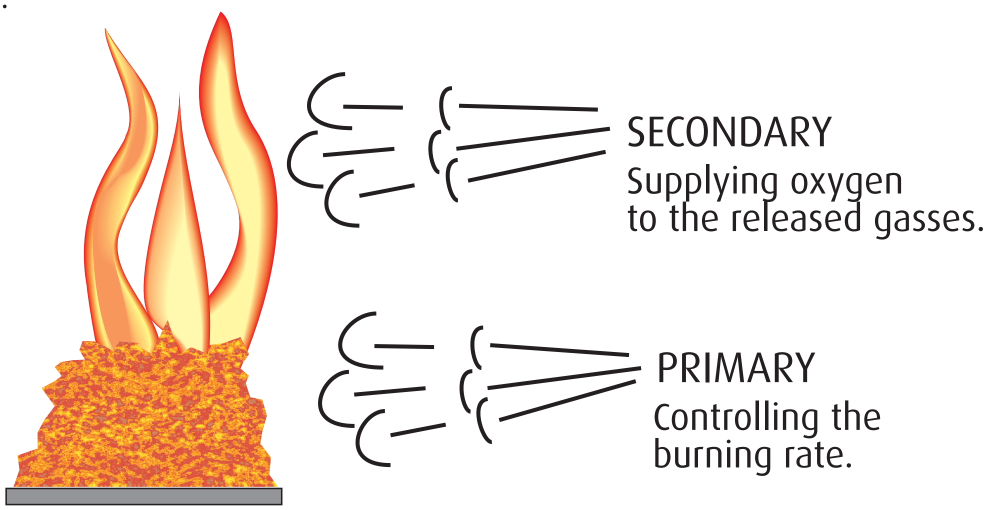
A summary of the codes and their meaning when wood briquettes are said to conform to BS EN 14961-3:2011

	A1	A2	B
Shape and size mm	The three dimensions must be given together with details of the briquettes shape		
Percentage weight of water Wet basis	M12 less than 12%	M15 less than 15%	M15 less than 15%
Percentage weight of ash when dry	A0.7 is less than 0.7%	A1.5 is less than 1.5%	A3.0 is less than 3.0%
Additives	Less than 2%. The additives and the amounts must be specified		
Net calorific value in MJ/kg or kWh/kg	Q 15.5 is not less than 15.5 kWh/kg Q 4.3 is not less than 4.6 kWh/kg	Q 15.3 is not less than 15.3 kWh/kg Q 4.25 is not less than 4.25 kWh/kg	Q 14.9 is not less than 14.9 kWh/kg Q 4.15 is not less than 4.15 kWh/kg
Nitrogen Percentage by weight dry	N0.3 less than 0.3%	N0.5 less than 0.5%	N1.0 less than 1.0%
Chlorine Percentage by weight dry	Cl0.02 less than 0.02%	Cl0.02 less than 0.02%	Cl0.03 less than 0.03%
Sulphur Percentage by weight dry	S0.03 less than 0.03%	S0.03 less than 0.03%	S0.04 less than 0.04%

Wood as a Fuel

Wood is the most complex of the fuels we burn for heating because despite being able to turn it into pellets briquettes and chips, no attempt has been made to separate out the combustible components within it. The compounds in wood that burn are a multitude of chemicals made up of differing combinations of carbon, oxygen and hydrogen. These combinations fall into two categories, with the skeleton of the wood being defined as fixed carbon and the various resins contained within the skeleton being the volatile organic compounds. If you can imagine a sponge into which candle wax has been poured and allowed to cool and solidify you will have a good model of wood when thinking about combustion. If you were to heat up the wood to a temperature only hot enough to cause the volatile elements to vaporise the wood would issue a smoke which would be the volatile elements with the remaining skeleton of the fixed carbon turning black and eventually becoming charcoal. The ignition temperature is the temperature at which the chemicals need to be to start reacting with oxygen and so if when heating the wood the volatile compounds reach their ignition temperatures we will have flames and as with all fuels when the reaction starts it gives off heat and so it becomes a self perpetuating process. The fixed carbon, if heated sufficiently will burn as glowing embers. If the wood and the emitted gasses are kept hot enough with an adequate supply of oxygen, almost all the carbon will be converted to carbon dioxide and in doing so the wood will have produced the maximum heat possible. If either insufficient oxygen is available or the gasses become chilled by impinging against a surface below the ignition temperature of the gasses some of the carbon atoms will only be able to join with a single oxygen atom to become carbon monoxide, which is not only a poison but evidence of poor and inefficient combustion, or the carbon will combine with nothing and will be left as soot.

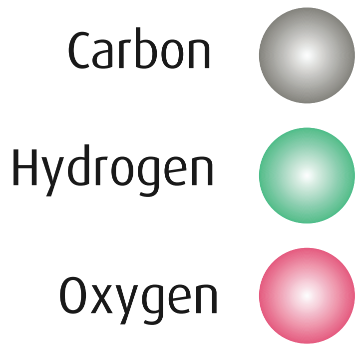
It is normal for a boiler's combustion chamber to be lined with insulating material so that it heats up rapidly to be above the wood's ignition temperature and ensures the flames are never chilled against a cold surface. The chamber will also be sized to ensure it is possible for all the gasses to have burnt within the chamber and so their combustion cannot be interrupted by chilling. This leaves the problem of providing sufficient oxygen at all times, but given that a little over 78% of air is nitrogen we have to arrange to supply enough and no more as all air not taking part in the combustion process only serves to cool the boiler. For smaller boilers this can be achieved by balancing the supply of air with the rate at which the fuel is introduced. For larger boilers the air supply is capable of being constantly adjusted automatically under the control of an oxygen sensor measuring the flue gasses. Because air supply is so critical it is defined and often split into two or more supplies aimed at differing parts of the combustion chamber. If the air supply is aimed at the core of the fire it has the effect of getting the fire to burn faster; imagine blowing on a piece of glowing wood to get it to burst into flame. This air is referred to as the primary air supply and it controls the rate at which the fire burns. Because the combustion chamber design will be positioning this air supply to be fully utilised feeding the core of the fire there would be insufficient air to supply air to the gasses, so we add a secondary air supply. The secondary air supply is positioned to have no influence on the core of the fire and its burning rate but only to supply air to any released gasses.



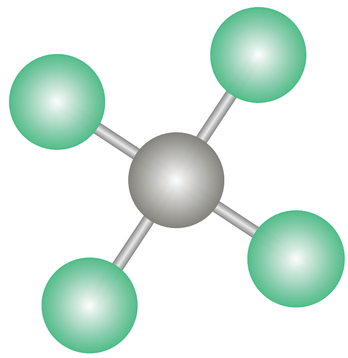
Assuming the wood is bone dry, 10 kilograms of wood will need about 13.5 kilograms of oxygen to burn completely, which means about 64 kilograms of air because oxygen is only 21% of air; more will be needed as the moisture content increases. Because we never want to find we have insufficient oxygen to allow the gasses being produced to burn, which would pose the risk of an explosion, we always add a percentage of spare air.

When our ten kilograms of wood have burned away we will have made about 18 kilograms of carbon dioxide and five kilograms or 5 litres of water from the hydrogen that combined with the oxygen. Although water is produced with all hydrocarbon fuels, wood has an added moisture content and the abundance of water is made more serious because of other chemicals that will be in the products of combustion, which if allowed to mix with water form numerous acids and other corrosive substances. This means that we not only have the wood's moisture content but also the water made during combustion dispose of safely. Fortunately whilst water is being formed and existing water is being released from the wood it will be happening at a temperature high enough to be kept as a vapour, but as the flue gasses lose heat to the boiler and make their way to the flue we need to maintain just enough heat in the flue gasses to keep the water as a vapour and not allow it to condense or there could be some serious corrosion problems.

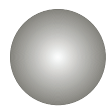
The Science

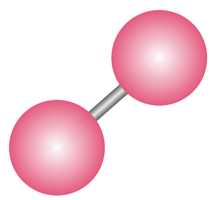


How much heat we can get from our wood relies on having the equipment to optimise splitting all the wood's molecules containing carbon and hydrogen and getting them both to combine instead with oxygen.

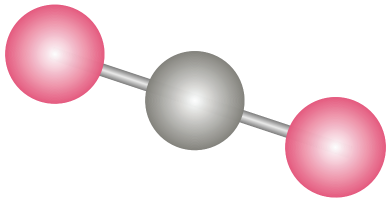


The fixed carbon in our wood exists as atoms of carbon and the volatile matter exists as carbon and hydrogen atoms linked in various combinations, but if we take one of them, methane, or natural gas if you prefer, which is a single atom of carbon linked to four atoms of hydrogen we have a representation of what we will have in our wood. We can, because of our interest in knowing only about the heat we will produce ignore everything but oxygen in the air. Oxygen is a rather sociable atom and exist in pairs if possible. If you have ever wondered what causes the strange smell whenever an electrical spark occurs it is because the spark has caused three oxygen atoms to link and become a gas called ozone which has that peculiar smell, with no resemblance to the smell in the air at the sea side whatsoever.

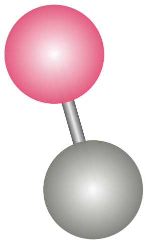




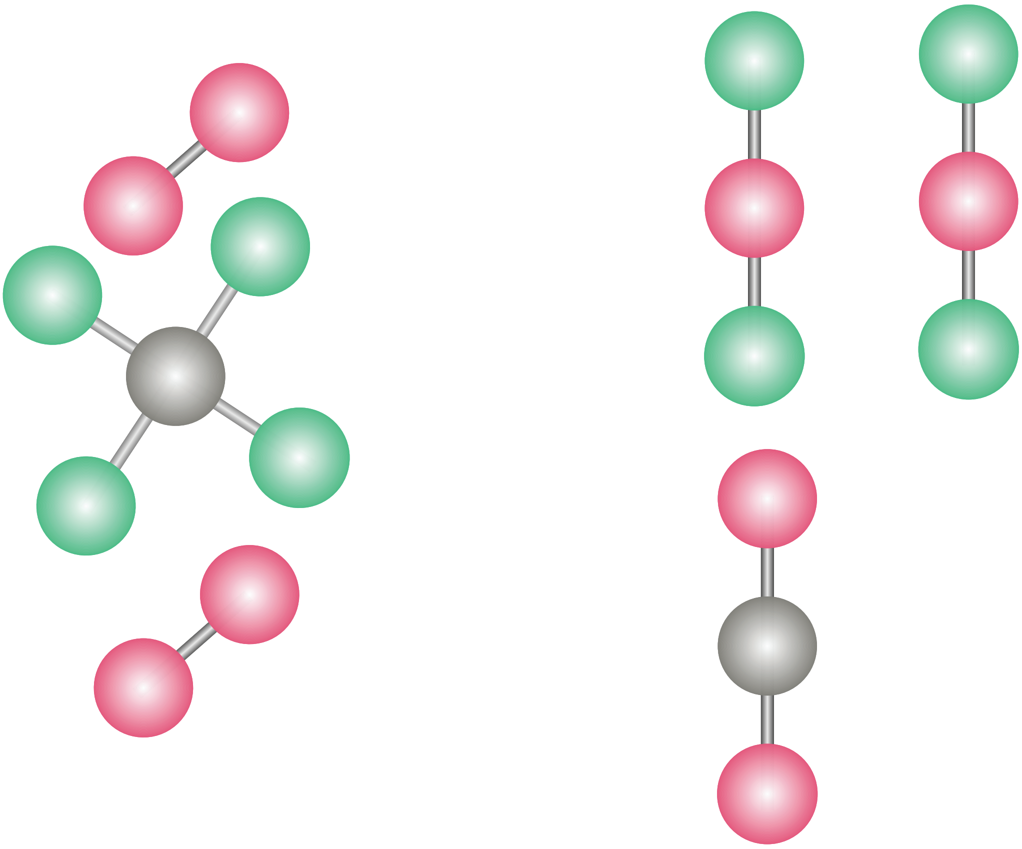
If we take our fixed carbon and add the oxygen we have the carbon linking to two oxygen atoms to give carbon dioxide.



If there is insufficient oxygen or the carbon is cooled we get carbon monoxide which, being a smaller reaction we get a smaller amount of heat and an unpleasant toxic gas..



If we take our methane molecule it should find enough oxygen to make two molecules of dihydrogen oxide, or water, and one molecule of carbon dioxide.



The temperature this chemical reaction reaches will be dependent upon the speed at which the reaction occurs and this in turn is dependent upon how the oxygen is mixed with the gasses being released from the wood. In a natural draught stove where the air supply is gentle it is possible for the flames to reach 1400ºC and in a system where the air supply is fan assisted it is possible for the flames to reach almost 2000ºC. Ordinary cast iron melts at approximately 1200ºC so you appreciate that the use of specialist refractory cement linings in combustion chambers not only maintains the ambient temperature needed for the wood to burn efficiently but it also protects the metal used in the boiler's construction. Whilst these temperatures are achieved within the flames themselves the gasses remaining after the reaction is completed are at a far lower temperature as they lose their heat continually to the surrounding atmosphere.

Ash

Ash is the all-embracing term used to define the inorganic content of a fuel, which is the matter which will not burn. It can be part of the fuel's structure itself, or in the case of wood it can be material it has absorbed from its environment while growing, or any soil that may have inadvertently been collected when harvesting the wood. Ash is usually considered to be of little importance beyond the frequency of having to dispose of it but its composition is very important in determining the efficiency and longevity of any wood fired boiler. Anything that cannot be burned has the potential to coat and partially insulate all boiler surfaces. Certain chemicals can etch the surface of the boiler and the ash can fuse to block airways and pellet burners.

All British Standards have limits for the incombustible elements and give the permissible total percentage content by weight and the standards also include limits to a list of chemicals that the wood might be contaminated with. British Standard pellets will also be supplied with details about the ash melting behaviour. When referring to ash the chemicals within it are split into two categories "Minor Elements" and "Major Elements". The term "Minor Elements" refers to chemicals that will only be present in trace amounts and are usually chemicals regarded as toxic such as arsenic, mercury and cadmium. Most of these chemicals will have little if any effect on any combustion equipment but do have environmental consequences if the wood was to be burned and the ash returned to the soil. "Major elements" are those chemicals that are in ash in relatively large amounts and which although environmentally innocuous have a large influence how the ash behaves and the corrosion it may cause.

The tendency for ash to be deposited onto surfaces are defined with the terms "fouling" and "slagging". Slagging refers to the deposits of molten or half molten ash that sticks to the combustion chamber or burner body where the ash is subjected to high radiant heat temperatures. Fouling describes the deposits that form on the cooler surfaces such as the boiler surfaces. These deposits are the inorganic vapours that have condensed onto the cooler surfaces. These deposits tend to be sticky as they condense and so collect fine fly ash particles. The corrosive effects of herbaceous biomass, for example Miscanthus, pictured below, is because of its high amounts of chlorine and sulphur, however wood has far lower amounts of these chemicals. Both fouling and slagging are proportional to the ash's melting and vaporising temperature and are reduced when the ash has higher melting temperatures. Major elements such as calcium and magnesium increase the ash's melting point while potassium and sodium decrease it and as these elements reflect some of the chemical differences between herbaceous and woody biomass it is why herbaceous biomass has a lower ash melting temperature than woody biomass.

Because the ash in wood burning can be so troublesome various methods of determining its behaviour and effects upon the equipment it is being burned in have been devised and the simplest is to determine the Ash Melting Behaviour. To do this a sample of the fuel is placed in a laboratory furnace and reduced to ash at 550°C in an oxidising atmosphere. The ash is then squeezed into cylindrical shapes and are placed into the furnace, which is set to increase its temperature while the ash samples are observed and the temperatures are recorded at the moment the following definitions are achieved.

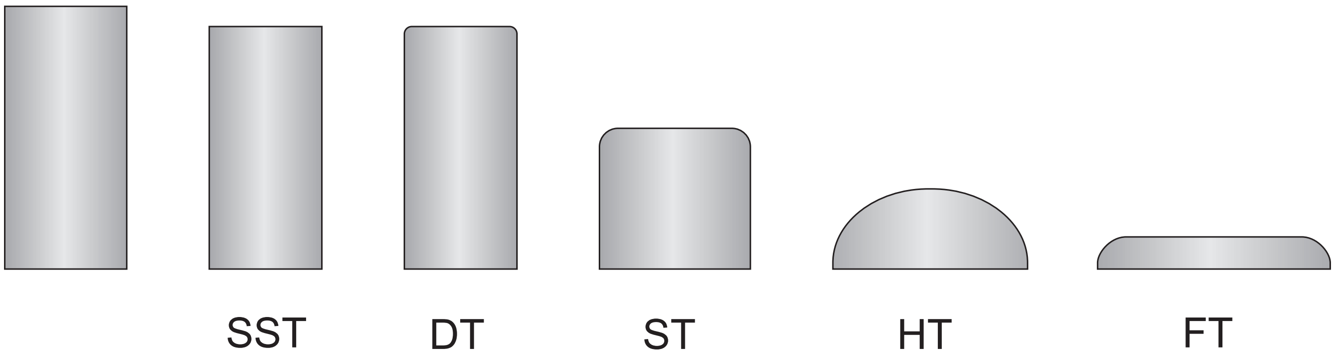
The Shrinkage Starting Point (SST) is the temperature recorded when the sample starts to shrink which may be because the sample is emitting volatile inorganic matter or it is beginning to sinter. If the ash sample was prepared at a higher temperature this stage will not be seen as is will effectively have occurred when the sample was prepared.

The Deformation Temperature (DT) is the temperature at which the tip of the sample loses its sharp edge and begins to round.

The Softening Temperature (ST) is the temperature at which the height of the sample equals that of its width.

The Hemisphere Temperature (HT) is the temperature at which the sample forms a hemisphere.

The Flow Temperature (FT) is the temperature at which the sample has melted to form the shape applicable to a fluid.



Using some of the temperatures recorded during the ash melting behaviour test a Slagging Index can be calculated using this equation:

$$Rs = \frac{4 \times DT + HT}{5}$$

This test gives a reliable indication of the fuel's propensity for slagging without having to undertake complex chemical analysis and an index based on the actual high temperature behaviour is an ideal guide. A slagging index below 1100°C will probably cause significant slagging but it will become less of a problem as the index temperature increases.

Wood ash as a fertiliser from an efficient boiler is sadly not the ideal it would seem because much of the nitrogen will have been removed during combustion and whilst seemingly rich in other nutrients many will have been locked into other compounds that will be unavailable to plants and with the possibility of the ash containing heavy metals and other toxic compounds its use is not recommended.

Examples of Poor Wood Fuels

Logs stored outside exposed to the elements will deteriorate rapidly. Store them correctly, away from rain but with adequate ventilation.

Pellets mishandled will get smashed and turn to dust. Ensure that pellets are treated carefully.

Pellets containing impurities, these have blue plastic amongst other things that should not be in them in them, which can lead to a damaged boiler. Ensure that you only purchase pellets complying to BS EN 1461-2:2011

Examples of What Have Been Found in Boilers

Sintered ash found on the grate of a pellet burning boiler. Only buy good quality pellets and clean out ash from all the combustion areas regularly.

Moulten metal, screws and other metal objects found on the grate of a wood chip boiler. Using pallets to make wood chips is not a good idea.

This spanner was found inside a wood chip boiler after it had been chopped into two by the fuel delivery system. Ensure that only wood is fed into the boiler.

zeroridge