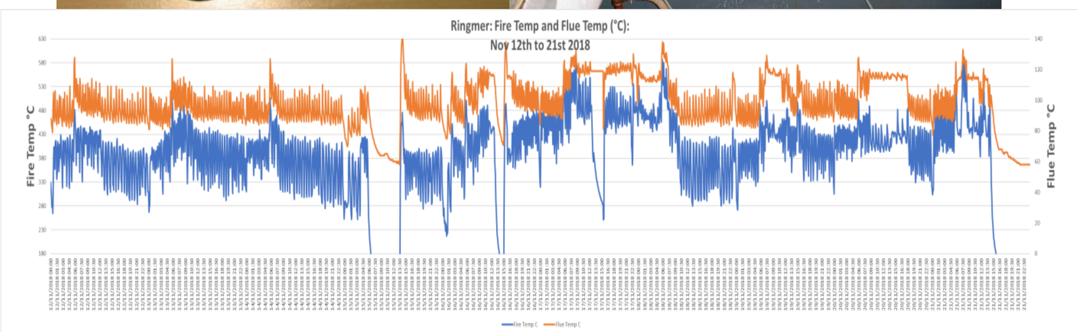
OPTIWOOD PROGRAMME

GUIDANCE MANUAL FOR BIOMASS BOILER OPERATORS



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Contents

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1. Introduction

There are around 30,000 biomass boilers currently operating in the UK[1]. These range from small domestic scale pellet boilers, through farm based log boilers to a wide range of wood chip and pellet commercial boilers. Of these, there are many varying designs, heating systems and maintenance and servicing regimes. Each manufacturer provides both clients and the service engineers with Operational Manuals to maintain and service the systems, and keep them in optimum condition. In the Appendices and other Optiwood sources soon to be available on-line, examples of specific service and maintenance regimes are provided. These are targeted at Operators.

Notwithstanding these variations, there are a wide range of generic issues that run true for all or most biomass systems. This short manual is aimed at increasing the understanding of these so that Operators are empowered to intervene in a range of areas where simple adjustments or responses can ensure that the boilers keep working optimally, or that service engineers are called out early for more serious issues or where signs of clear deterioration in the biomass system is occurring.

This Manual is not intended to replace the specific Boiler Operations or Maintenance Manuals but to support it through greater understanding of the basics of biomass (wood) heating boiler systems, the key issues that lead to poor performance, and remedies for these.

1.1 Fossil-fuelled boilers

Before describing automatically fed biomass boilers, it is useful to look briefly at fossil fuelled boilers as an aid to understanding the differences. Most boilers commonly in use throughout the UK burn fossil fuels, such as gas or oil. Ignition is almost instantaneous, as is heat production, and on cessation of a heat demand the burner shuts off instantaneously.

Complete combustion requires sufficient oxygen to ensure that all the fuel is burned, and all boilers require some excess air at the burner for this reason. However, excess air results in disproportionate heat loss via the flue and can lead to increased formation of oxides of nitrogen (NO and NO_2 often collectively referred to as NO_x) and nitrous oxide (N_2O) at elevated temperatures. Carbon monoxide (CO) is also an issue where boilers are not maintained correctly or air vents are blocked.

Typical Modular Gas Boilers

The natural (or LPG) gas and heating oil

[1] Includes both non-domestic and domestic biomass boilers, and factors in both RHI accredited boilers plus those operating prior to November 2011 when the RHI programme began

are usually very consistent fuels, adhering to strict quality standards. This allows a much tighter design for the boilers. Biomass fuels by contrast have a much wider variation in quality – including moisture content (though pellet fuel is quite consistent), plus fuel grade and chip size.

1.2 Biomass boilers

Biomass or modern wood heating boilers have been developed since the 1900s. In the past 40 years newer design features have allowed the efficiencies of the boilers to improve dramatically, for pollution levels to drop significantly, and for combustion controls to improve (see Figure 1 below showing the dramatic improvements in efficiency and reductions in pollution as recorded in Austria-Germany). Most biomass boilers now offer automatic ignition, auto-cleaning, controlled start and shut-down, as well as a wide range of safety features.

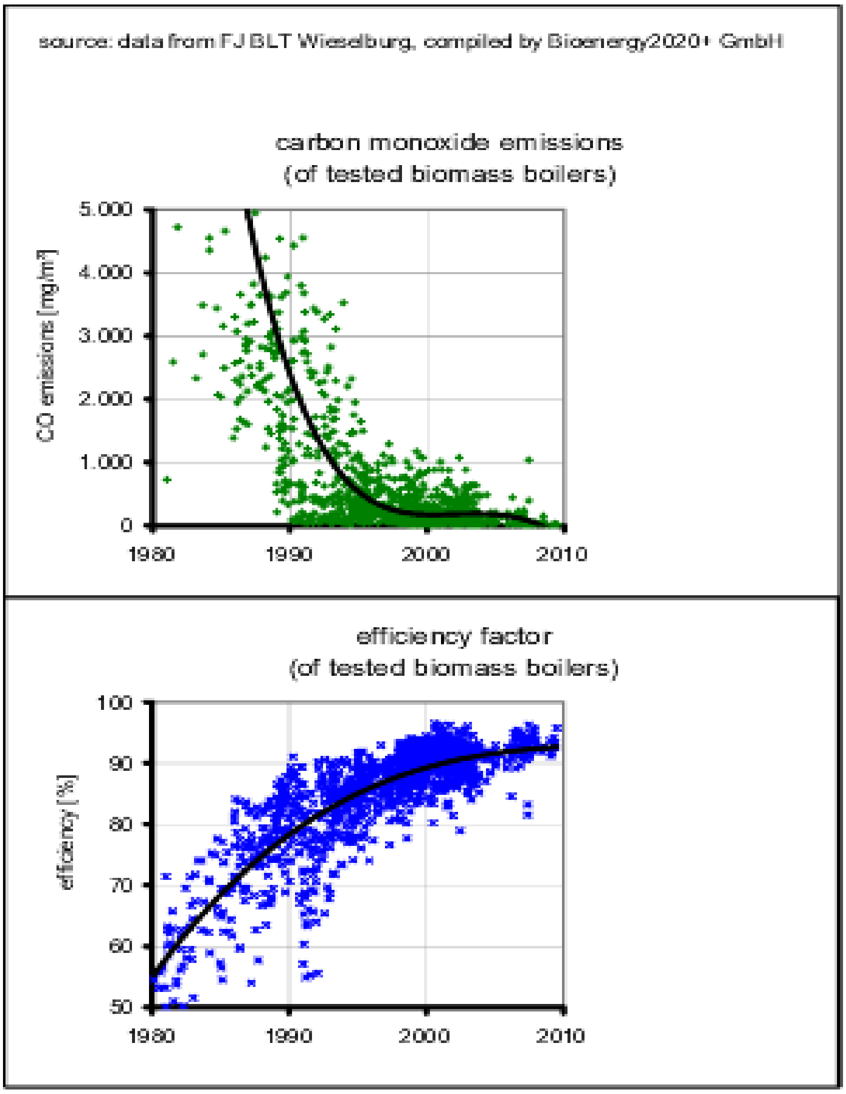


Figure 1: CO Emissions and Efficiency levels of small-scale wood boilers in Austria - trends over 30 years (Source: BE2020+)[2]

[2] 'Determination of annual efficiency and emission factors of small-scale biomass boilers', 2011, Dr. Markus Schwarz, BIO-ENERGY 2020+ GmbH

While higher temperature and power generating biomass boilers are also common across Europe, we are focusing here on low temperature hot water biomass boilers. These are defined as those operating at up to 95°C. They can be classified by various methods based on fuel type or on the physical characteristics of the boilers. The classification that follows is based on fuel type.

1.2.1 Wood Pellet Boilers

Pellet boilers range in size from a few kilowatts (kW), for houses or small commercial buildings, to megawatt (MW) size units for district heating systems. The big advantages of wood pellet fuel are that it is a consistent moisture content (normally 8-10% MC) and size, generally 6mm diameter for commercial boilers or 8mm for larger systems. The pellets flow easily hence not requiring additional fuel stirrers or moving equipment as used for wood chip. Most commercial wood pellet suppliers in the UK adhere to the ENPLUS quality standard.

Pellet systems will usually have an automatic hopper-fed fuel system. The hopper can be either built-in, in the case of some smaller systems, or a detached separate unit. Some of these can accommodate 20-100 tonnes of fuel.

Cross section of a pellet boiler – Boiler being hand fed with pellets (most pellet boilers have larger pellet stores and automatic feeding of the fuel)

Pellet systems are generally the most responsive of the biomass boilers, have the simplest controls and are the closest to fossil fuelled boilers in terms of maintenance and operation, although there can be large variations between systems from different manufacturers in terms of sophistication and features.

1.2.2 Wood chip boilers

Wood chip boilers are fuelled by an automatic feed of chipped wood, which can be supplied with moisture contents from 10% to 50%. They use a stoker burner or an underfed stoker for burning fuels with between 15% and 35% moisture content, or moving or stepped grate systems for burning fuels with higher moisture contents. Boiler sizes range from small domestic systems of 10–20 kW to medium sized of 50 kW and above, to power-station sized boilers of 100 MW and more. Boiler responsiveness is determined partly by the fuel moisture content which the boiler is designed to accept; in general the wetter the fuel, the less responsive the boiler.


Wood Chip – good quality consistent grade chip fuel in contrast with large shards removed by screening

Delivery of G50 grade chip fuel to a client

Moisture Content of Wood Fuel

1) All moisture contents of wood fuels are quoted on a 'wet basis', that is:-

Weight of water in a given sample
-- X 100 = MC% (wet basis)
Total weight of the sample

1.3 Biomass combustion

While several different types of biomass boilers are described below, the principle of operation is the same. In many respects the technology used to burn wood is similar to that used in coal boilers which are still in use in some parts of the UK. Fuel is fed to the grate mechanically where it undergoes combustion to produce energy.

Combustion stage 1	**Stage 2**	**Stage 3**	**Stage 4**
Warming and drying < 150ºC	Pyrolysis 150-500ºC	Gasification 500-800ºC	Combustion of gas 800-1600ºC

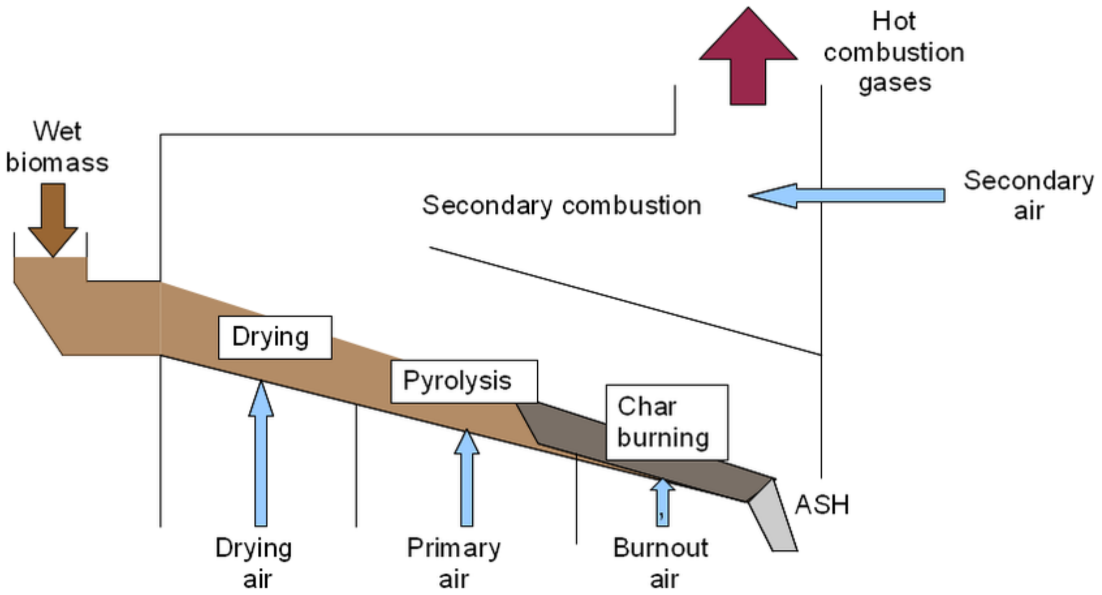


Figure 2: Combustion Stages in a Biomass Boiler

Key points to note:

- A number of automatic ignition systems are used on modern biomass boilers, most notably hot air which dries the first load of fuel on the combustion grate and then heats it to above the spontaneous ignition temperature of 400°C.
- Stage 1 requires the combustion chamber to be hot above and around where the fuel enters the grate. Most biomass boilers contain some refractory material for this reason. Boilers designed to burn wet wood chips have substantial refractory linings in large combustion chambers. The greater the quantity of refractory lining, the less responsive the boiler to changes in heat demand, the longer the time taken to reach ignition temperature and the greater the residual heat that will need to be dissipated when the boiler is switched off.
- Most of the energy is produced at stage 4 when the combustible gases, which are mainly a mixture of carbon monoxide (CO) and hydrogen (H_2), are burned some distance away from the grate at a high temperature, while maintaining the

temperature range on the grate required at stages 1 and 2 to convert the solid material to energy. These features are essential to prevent the formation of slag on the grate.

- Separate control of primary air (from beneath the grate, approximately 1/3) and secondary air (into the gas oxidation zone, approximately 2/3) is required to maintain the lower grate temperature for stage 2 while ensuring that a sufficiently high temperature, velocity and turbulence exist to oxidise the wood gases completely at stage 4.
- Careful control of the excess (flue gas oxygen) O_2 content (often monitored by a 'lambda' sensor) and gas oxidation zone combustion temperature at stage 4 is required to reduce the formation of soot, CO and NO_x and maintain maximum thermal efficiency.
- If wet fuel is not dried sufficiently by the boiler (because the fuel moisture content is outside the fuel tolerance range of the boiler) incomplete gasification and oxidation will occur and black smoke will be produced. In addition, the tars released at stage 2 will gradually coat the heat exchanger surfaces resulting in reduced heat exchange efficiency and the eventual failure of the boiler. Tar accumulation is also one reason why many manufacturers recommend minimum daily running periods for their boilers to ensure that combustion chambers and heat exchangers reach full working temperature to drive off the heavy volatiles deposited during the heat-up phase. Regular short running or 'cycling' often causes extra pollution and tarring up of boilers, as well as lower efficiencies.

An example of tarring and sooting in heat exchangers due to poor quality fuel and inadequate cleaning

- If the fuel is too dry for the boiler, grate (stage 2) and oxidation zone (stage 4) temperatures can be too high, resulting in the formation of slag (melted ash sometimes called clinker) and a higher concentration of NO_2. This latter issue can be addressed by installing flue gas recirculation to the primary air. This allows dry fuel to be used in a boiler designed to burn wet fuel by maintaining the primary gas flow rate while reducing its O_2 content, thus reducing the gasification rates (stage 3) on the grate.

When there is no longer a demand for heat from a biomass boiler, the boiler continues to produce heat for some time (unlike a liquid or gas fuelled boiler which ceases producing heat almost immediately). Fuel on the grate will need to be burned off and, depending on the type of boiler, the fuel in the feed system may need to be emptied onto the grate and burned as well. The refractory lining of the boiler will also need to release heat to prevent steam being generated in the boiler.

The time taken for a boiler to stop producing hot water will vary between 15 minutes for a small domestic pellet boiler and several hours for larger boilers, and the heat produced during this period must be absorbed or dissipated. The usual practice is to store the heat in a large water-filled buffer or accumulator vessel, sized to the specific boiler output and thermal mass. The buffer vessel acts as a store to absorb part of the boiler output when the system load is below the minimum operating output of the boiler. This stored heat is then used at the start of the next heating period when the buffer will discharge in a controlled manner to satisfy part or all of the initial peak heat demand while the biomass boiler heats up.

1.3.1 Slag and ash

Slag formation (sometimes call clinkering) occurs when naturally occurring silica (sand), or unwanted silica in the fuel, converts to glass. While pure silica melts at about 1700°C, chlorides present in the fuel can reduce this to as low as 773°C. Therefore, it is important to keep the temperature on the grate below 750°C. Some boilers are fitted with water-cooled grates and/or flue gas recirculation to ensure that this takes place.

Ash is a by-product of wood combustion, the quantity produced varying from 0.5% to 2% or more of the dry weight of wood chip or wood pellet burned, the exact proportion being dependent on the chemical composition of the fuel. Around 98% of this is bottom ash is from the grate and the remaining 2% is fly ash, which is usually captured by a flue gas clean-up system or by a fly ash drop-out chamber within the boiler.

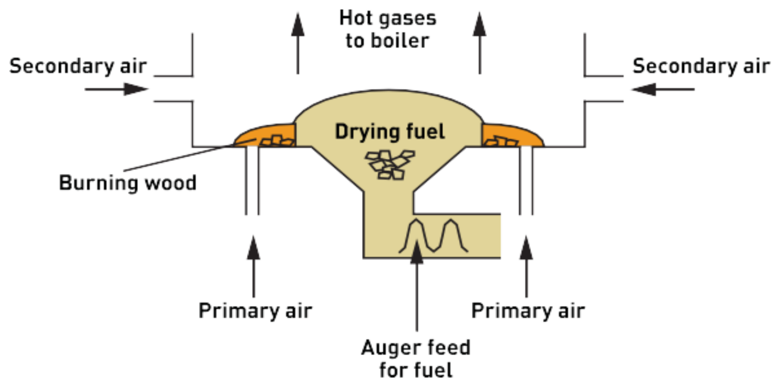
1.4 Types of Biomass Boilers

1.4.1 Underfed stoker boilers

In an underfed stoker boiler the fuel is pushed up through an inverted cone to form a dome of fuel on which combustion takes place. The auger enters beneath the combustion chamber and, because combustion occurs upwards, may not need to be emptied at boiler shut down.

Underfed stoker boilers can burn wood pellets and wood chips up to 35% MC. Some may be designed specifically for use only with pellets, in which case very little refractory lining may be installed. For wood chips up to 35% MC a moderate level of refractory lining will be installed, and the boiler is usually limited in the size of wood chip it can accept. Again, they are designed for a reasonably fast response to heating load demands. Underfed stoker boilers are almost always auger fed. Most underfed stoker boilers have separate primary and secondary air fans to provide an independent combustion control on the grate and in the final gas combustion zone.


Underfed Hearth – Chip Fed in from side via fuel augers



Typical layout for an underfed combustion system

Figure 3: Diagram of Boiler Underfed Hearth Combustion Design

1.4.2 Moving grate boilers

Moving grate boilers - also known as stepped grate or inclined grate boilers - allow the greatest flexibility in boiler design but usually have the slowest response because of the much greater levels of refractory lining installed to enable them to be used with wood chip of up to 50% MC. Moving grate boilers are designed to burn wood chip with a MC of between 30% and 50%. The boiler can be either auger or ram stoker fed. Moving grate boilers are also suitable for burning dry wood chip and some will also burn pellets, but this usually requires the addition of flue gas recirculation to limit the combustion temperature above the grate. A side entry moving grate boiler will also take the larger sizes of wood chip.

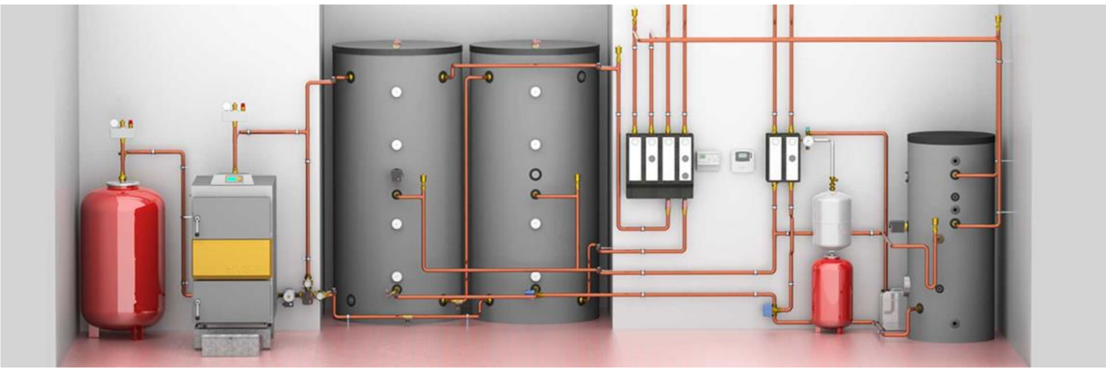
A high level of refractory lining will be used together with a combustion chamber that is physically larger than those found in other boiler types. This is needed to deal with the higher moisture levels in the fuel that need to be driven off before combustion takes place. As with underfed stoker boilers, moving grate boilers have separate primary and secondary combustion fans, and on the largest boilers additional tertiary fans to ensure the complete combustion of all wood gases.

Mechanically Driven Step Grate combustion chamber with wetter wood chip moved along the combustion chamber as it dries

1.4.3 Buffer vessel operation

A buffer or accumulator vessel is more than just a hot water cylinder. In a typical domestic hot water cylinder, or commercial hot water calorifier, the intention is to produce hot water by creating convection currents within the cylinder. When drawing hot water the mixing action continues such that the water temperature gradually reduces as the cylinder is discharged.

However, this situation is of no use in a buffer vessel, where a constant hot water temperature is required from the top of the store as it discharges. Buffer vessels are commonly fitted with 'sparge' pipes on their return inlets which introduce the cooler return water at low velocity to minimise mixing and allow stratification. When charging, the hot interface moves down the buffer vessel, while discharging causes the cold interface to move up the vessel.

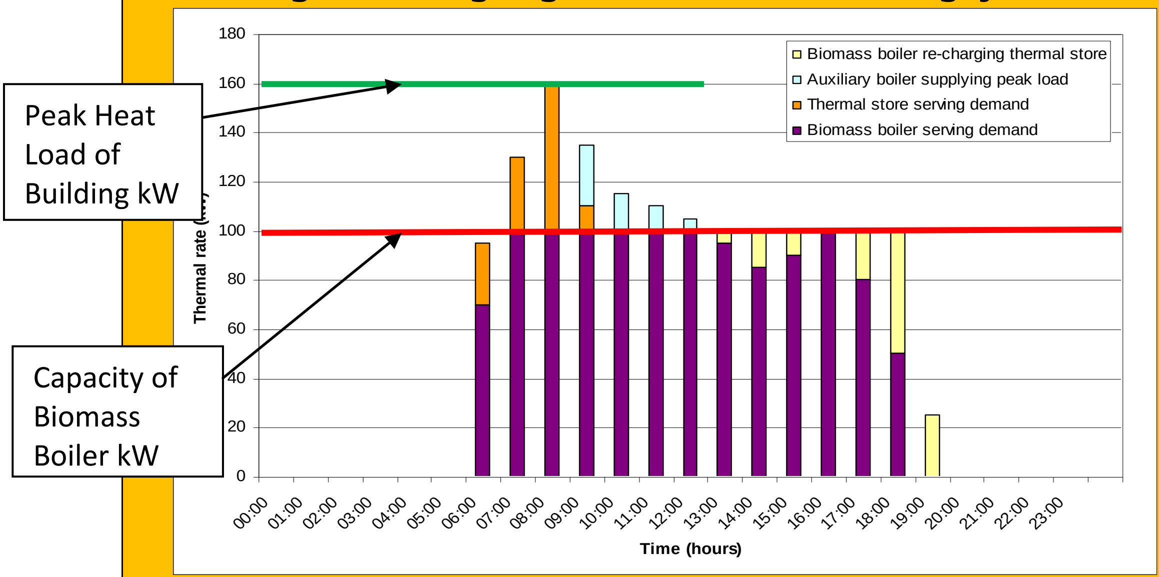


Twin Buffer Tanks taking hot water from both a biomass boiler and solar heating

1.4.3 Why are buffer vessels important?

A biomass boiler is not an instant 'off-on' system like gas or oil boilers buffer so an accumulator vessel offers many benefits. It allows a body of hot water to be charged up in advance of the actual heat demand in a building so that it is available 'instantly'. This is particularly important for end-uses like schools, residential care homes and offices. The buffer tanks also allow the boiler to be switched off before the end of a heating day leaving reserve heat for the remaining demand in the building(s).

Figure 4: Designing an efficient wood heating system



This Figure shows how a building peak heat load of 160kW is met by a 100kW wood chip boiler, a thermal store of 4,000 litres and occasional gas boiler usage[3]

As biomass systems cannot modulate quickly in response to varying heat demand, the buffer tank allows flexible heat to be supplied instantly without constant 'cycling' of the boiler which will reduce both efficiencies and the longevity of the boiler. The final advantage of the buffer vessel is that when sizing the boiler for the actual heat load, it means that the boiler can be sized at below the winter peak load level. For a heat load that has a high and peaky daily and seasonal load, the buffer tank allows such variations to be smoothed out and the boiler to run for longer and then shut off. The graph above (Figure 4) shows how a 100kW biomass boiler plus accumulator tank can meet the bulk of the heating load for a building with a 160kW peak load.

The heat storage of the vessel means a higher peak load can be met for a period of time – say 30 minutes to as much as 5-6 hours. This means the boiler can be run more efficiently and cost savings are made by choosing a smaller and cheaper boiler. The three diagrams below show the phased role of the boiler with buffer and how this manages the heat delivered to the building or end-use itself.

[3] Graph via Sustainable Energy Ltd, 2012

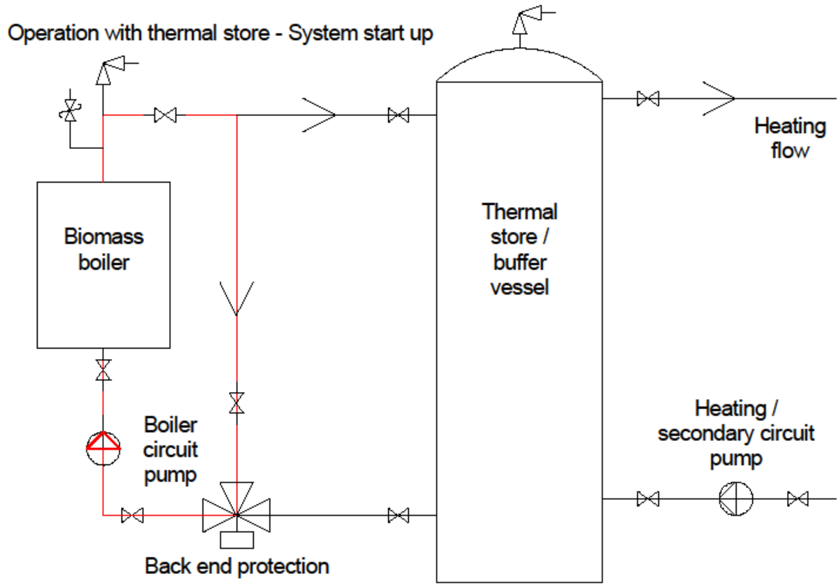


Figure 5 - Phase 1 – the biomass boiler heats up itself and its surrounding water jacket to a useful level that can be sent to the buffer tank and then the end-user

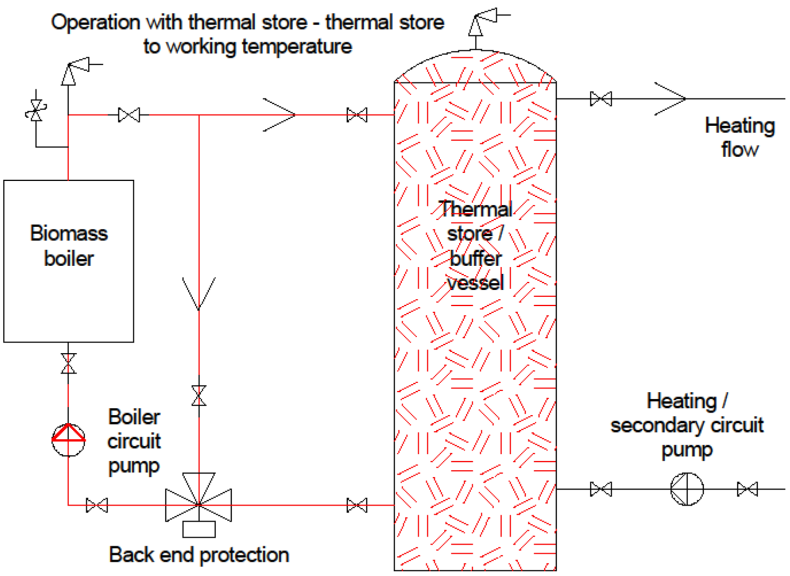


Figure 6 - Phase 2 – warmed up boiler now sends useful hot water to charge up the buffer tank. Hot water not yet being supplied to end-user

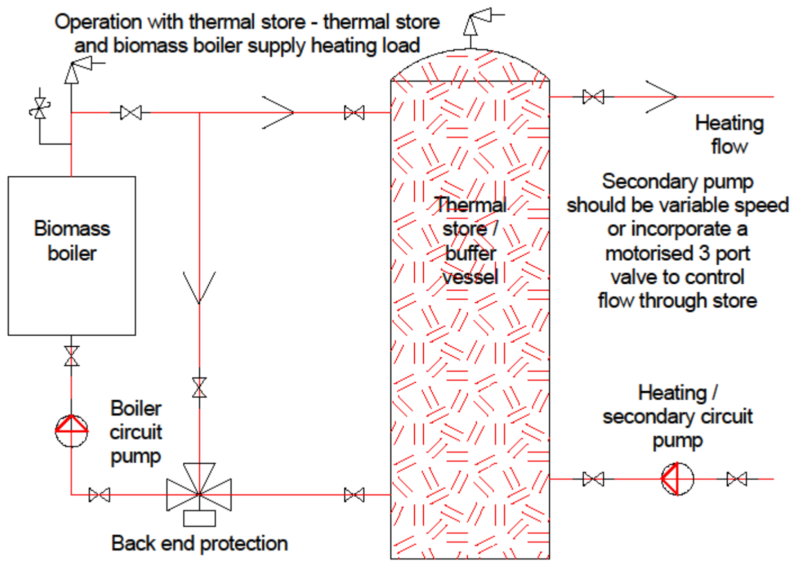


Figure 7 - Phase 3 – the charged up buffer vessel can now send out useful heat to the building-end-user

Some boiler manufacturers claim that they have designed their boilers such that a buffer vessel is not essential for the protection of the boiler. However, this does not mean that a buffer vessel is not beneficial to the end user. As well as offering protection to the boiler, a buffer vessel is likely to improve the overall efficiency of the boiler system, reduce emissions and also enable a biomass boiler to meet a greater proportion of the annual heat energy required than would otherwise be the case. Issues such as constant 'cycling' and over-use of back-up fossil fuel boilers can often be due to the lack of a buffer tank or a buffer tank that is too small for the size of the boiler. The data monitoring provided under the Optiwood project can readily pick up this type of problem (see below).

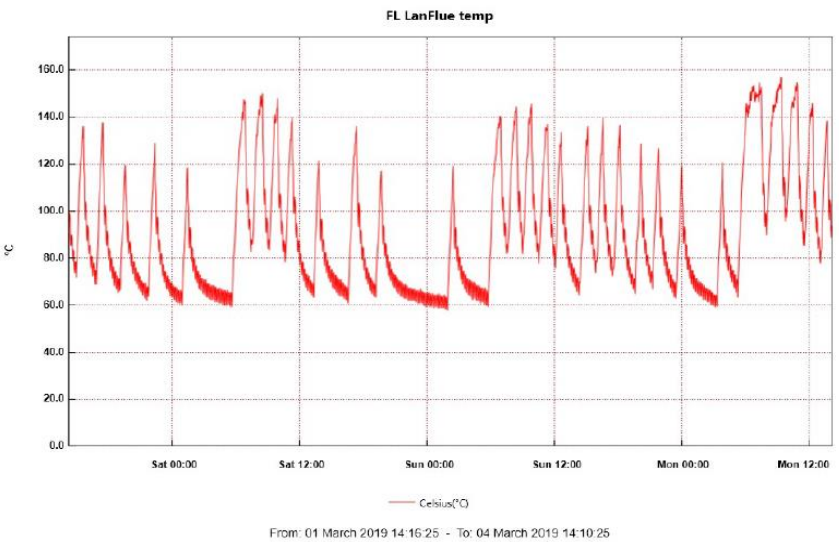


Figure 8: Evidence of regular boiler 'cycling' due to lack of a large stratified buffer tank and an over-sized boiler

2. Boiler maintenance

Biomass boilers have greater maintenance requirements than fossil fuelled boilers. The boiler manufacturer's representative or boiler installer will usually carry out an annual maintenance (and a likely interim service) which will include a full internal and external inspection of the boiler, the replacement of worn components (particularly grate components on moving grate boilers), lubrication, cleaning, control / safety system parameter checks and combustion testing.

An example of the priority maintenance interventions required by the user are daily visual inspections, regular emptying of the ash bin, greasing of bearings, manual brushing of the boiler heat exchanger tubes according to manufacturers recommendations and clearing any build up of ash (normally under fed stoker boilers) from the combustion chamber. If automatic heat exchanger cleaning is installed a significant reduction in boiler down-time and maintenance time is possible, reducing manual heat exchanger cleaning from a weekly / monthly to a 6-monthly exercise. The cleaning system comprises a series of compressed air jets or nozzles, installed on the ends of the boiler tubes, which are pulsed in succession at regular intervals to blow soot from the boiler. This happens automatically while the boiler is in operation. The system requires a small compressed air supply in the boiler house. For smaller boilers a physical set of metal 'turbulators' can be used to shake any soot loose.

2.1 Producing the boiler maintenance plan

To ensure maintenance is carried out regularly and any issues are raised early-on, it is strongly recommended that you have a maintenance plan for your boiler. If you do not already have one, you should discuss the maintenance schedule with your installer or servicing company. They may have a template you can use. Even if they provide you with a template, be aware this should be *your* document. You should make changes to it on an ongoing basis (for example, by adding extra tasks if it becomes apparent that this helps the boiler operate smoothly).

As there a large number of biomass boiler manufacturers, suppliers and installers it is not always easy to get the information specific to your boiler but it is important to persevere until the correct operation and maintenance manual is provided for your site biomass boiler model. This, along with 'as installed' drawings from the installation contractors, will give the best chance to maintain the boiler to provide long periods of trouble free running. The boiler manufacturer's maintenance recommendations should be supplemented by the maintenance requirements of the fuel and ash handling systems, and those of the heat distribution system.

If it is not possible for the owner or operator to monitor the boiler on a day to day basis, then (potentially untrained or partially trained) staff who work near the boiler could be asked to keep a log of any obvious issues or observations.

Keeping a log of the quantity of fuel burnt per kWh heat metered in a spreadsheet will give a useful indication of how efficiently the boiler is burning. Although this not as accurate as a standardised efficiency measurement, a sudden increase in fuel consumption for the same heat output could indicate a problem with the boiler. Fuel delivery records can be consulted to determine fuel usage.

The boiler control panel may contain additional information that may help the user to solve problems these include:

- Operating parameters changed from the figures obtained after commissioning, e.g. fire temperature, flue temperature, flue oxygen content (lambda) and combustion fans speed.
- Boiler water flow and return temperature and buffer vessel high / low water temperatures.
- Monitor the number and description of faults per week.

One of the factors which affects the performance of biomass boilers is the knowledge of the operator and owner about maintenance. If the operator has good knowledge about their boiler and proactively looks after it, there are normally fewer maintenance issues.

In the UK and France, the situation with an operator with poor knowledge and only reactive maintenance is quite common. The person who is most knowledgeable about the boiler is often the Service Engineer, but he-she is not the person who spends most of their time with the boiler. The manufacturer knows most about the boiler, but often they are only involved during commissioning or if there is a serious problem with the boiler.

Tipping chip into a fuel store

Movable Hook bin fuel silo

2.2 Health and safety in fuel storage and boiler operation

Apart from the well-understood issues of working in confined spaces and in silos containing materials which flow, there are specific and separate issues relating to the delivery and storage of wood chips and wood pellets.

2.2.1 Wood chips

Unless wood chips are reasonably dry, typically less than 30% moisture content, they may degrade in storage. Microbial activity can lead to piles of wood chips generating heat as they decompose.

The loss of calorific value via decomposition has been measured at 1% per month. Under the right conditions, fungal spores will develop in the chip pile and these spores will be released when the wood pile is disturbed. If inhaled they can cause an incurable disease commonly known as 'farmers lung'. To avoid the formation of spores, moist or wet wood chip should be stored for as short a period as possible, and should be used within 1 month of being chipped.

In very large piles of wood chips it is possible for the heat released from microbial action to lead to an increase in temperature in the heart of the pile, sufficient to give rise to spontaneous ignition, causing a fire. The potential for this to occur will depend on a number of factors, including the moisture content of the chips, ambient conditions and the store design. Advice on the maximum safe size for piles of chips varies between countries and sources, with figures quoted from 8 m to 15 m high. In any case, chips in long-term storage should be turned regularly to prevent microbial activity and aid drying.

2.2.2 Wood pellets

The safety risk with wood pellets relates to the dust produced during delivery by pneumatic conveying. When pellets are blown into a silo a proportion break up and produce the sawdust from which they were manufactured. If the dust concentration is not controlled it is possible for an explosive mixture of dust in air to be created which could explode if an ignition source is present. Minimising dust build-up and ensuring no ignition sources are present will prevent this, and can be done by the combination of design, maintenance and operation. Buying quality pellets with a low dust content and good mechanical durability is also important. The 'ENPlus' standard for wood pellets across Europe sets tight quality standards.

Abrasion and impact during delivery of pellets can generate fine dust. This can be prevented by using smooth metal delivery pipes, with any bends of large radius, and a yielding impact baffle (often thick rubber mat) opposite the point of exit from the delivery tube to ensure that pellets are not shattered on impact with the opposite wall of the store. It is also important that, during delivery, tanker drivers avoid excessive pressure and there is some mechanism for dust collection. This will vary between different pellet store designs and size. The store should be regularly checked for build up of dust and periodically cleaned out.

To ensure that no possible ignition source is present there should be no electrical fittings within the store, or if they are required, that they meet the appropriate Explosives Atmospheres (ATEX) specification. Delivery pipes must also be securely bonded to earth to avoid build up of static charge.

Another risk is from the potential for wood pellets to create CO in storage. This gas is both toxic and flammable. In particular nobody should enter an enclosed pellet store until it has been thoroughly ventilated, and only under the supervision of another person, outside the store.

Other safety mechanisms include zoning to classify potentially hazardous areas, ensuring dust is effectively contained within the store and cannot escape into other areas (such as the boiler room), a fireproof partition between the fuel store and boiler room, and in extreme cases inclusion of an explosion relief panel.

2.2.3 Combustion chamber flash-back

Great care should always be taken when opening combustion chamber doors as partly burnt gases very occasionally flare out into the boiler room. While this risk is low, boiler operators must be aware of the risk of flash-back from the combustion chamber. These gases expand when burning and can cause the boiler door to open violently. If your boiler has an oxygen (O_2) reading on the display panel of less than 3 to 5% on start up, you risk causing a flash-back. If looking in a boiler sight glass it is important to acknowledge that this may be dark either through soot build up or simply that a small fire out of sight is still running. **Always run the induced fan first before opening any combustion chamber doors.**

2.3Maintenance and the Role of the Operator

2.3.1 Getting the Basics Right

The maintenance required by a biomass boiler is greater and more involved than that of an equivalent gas or oil boiler. By 'maintenance' we mean:

- Frequent cleaning of the boiler and removal of ash
- Regular lubrication of mechanical parts and checking of wear
- Checking the boiler is operating correctly and checking for damage
- Periodic servicing of the boiler

Failure to maintain biomass boilers may lead to unexpected downtimes, expensive repairs, use of backup systems, and loss of RHI revenue. Whereas for a gas or oil boiler an annual service and the occasional inspection of the boiler may be sufficient, a biomass boiler system generally requires greater intervention. The above maintenance activities should be performed at different time intervals and each require a different skill level, so training of personnel may be required. Details of this are described below.

2.3.2 What is good maintenance?

To ensure maintenance is carried out regularly and any issues are raised quickly, it is strongly recommended that you have a **maintenance plan** for your boiler. If you do not already have one, you should discuss the maintenance schedule with your installer or service company. They may have a template you can use. Even if they provide you with a template, be aware this should be your document. You should make changes to it on an ongoing basis (for example, by adding extra tasks if it becomes apparent that this helps the boiler operate smoothly).

A high-level maintenance plan is shown below in Table 1. This gives an idea of activities that should be performed, their frequency and the skill level required. An example of a more detailed maintenance schedule is also provided in Appendix 1. Be aware this is purely a generic schedule and your boiler may need a different set of activities.

2.3.3 Problems which can arise due to poor maintenance

If a maintenance schedule is not followed or is not comprehensive enough, many problems may potentially occur. Small problems picked up during maintenance may be an indication of more important underlying issues. For example, a noisy boiler ash removal system may be caused by damage to the ash removal system which may be caused by clinker in the ash. Ash fusion caused by the wrong air to fuel ratio in the boiler could indicate a problem with the lambda probe.

A regular maintenance schedule should pick up the initial stages of a problem, before it can develop and have further impact on the boiler. This guide identifies 5 maintenance areas of particular importance in biomass operation.

Table 1: Example of a high-level maintenance schedule

Frequency of Activity	Description of Activity	Skill-level required
Weekly	Cleaning of the boiler and removal of ash	Basic training in cleaning operation
Monthly	Regular lubrication of mechanical parts and checking for wear	Experience with mechanical parts and safe operation
Monthly	Checking the boiler is operating correctly and checking for damage	Knowledge of how to identify issue with: • Boiler operation • Boiler safety issues
Yearly	Periodic servicing of the boiler	Service provider

2.3.4 Ineffective cleaning

If a boiler is not cleaned thoroughly or often enough, dust can build up inside the boiler and inside the flue gas pathways. This can then become entrained in the flue gas and result in higher than normal emissions. This problem will be exacerbated if cyclones and filters are not cleaned regularly and they cease to remove particulate matter effectively. Dust entering the boiler through the fuel feed can also cause maintenance issues.

Identify problems caused by ineffective cleaning servicing

A visual inspection of the boiler is the best way to identify problems with cleaning or servicing. If the boiler has automatic cleaning mechanisms, running them manually through the control panel is an effective way of checking their performance. Listen for unusual noises or vibrations when the boiler performs any mechanical operation such as running augers.

Plant rooms should be clear and free of clutter, particularly in the area surrounding the boiler. If there is fuel dust around the feed system, it could indicate a problem with the fuel delivery system or the fuel itself. Dust in fuel stores should be removed before it builds up to levels where it can enter the boiler.

Periodic inspection of the ash removed from the boiler during normal operation may also reveal the presence of unburned fuel or clinker, which may indicate poor cleaning or poor air distribution. If you find clinker in the ash you should do a thorough check of the inside of the boiler for build up material on refractory surfaces or combustion chamber walls. Also check air inlets within the boiler for blockages.

A visual inspection of the flue gases leaving the boiler can be used to help identify problems. Visible smoke, or a 'characteristic wood smoke smell', particularly during steady burning, may indicate that the boiler internals require cleaning or that cyclones or filters have become blocked. Higher than normal flue gas temperatures are also an indication that boiler tubes may have a build-up of deposits which reduce heat transfer.

Unburned material and pieces of clinker that are not removed from the combustion chamber and surrounding walls can interfere with the air distribution, leading to a reduction in efficiency and increase in emissions. It can also lead to 'hot spots' in the combustion chamber and rapid wear. This problem will be compounded if air inlets become blocked through a build-up of debris.

If pieces of unburnt fuel and clinker find their way into the ash removal system this could cause mechanical problems, particularly with augers as part of automated systems. Similarly, a failure to correctly lubricate and check for wear could lead to otherwise preventable damage to augers and fuel delivery systems.

2.3.5 Unrepaired or unnoticed damage to biomass boilers

It is important to check all parts of the boiler thoroughly for sign of wear and tear or damage because if left untreated this may worsen over time and lead to a major failure which is likely to be expensive to rectify.

Damage to the grate and refractory material surrounding the combustion chamber could be an indication of other problems (for example clinker formation). Damage caused by normal wear and tear should be routinely repaired as it may lead to overheating or sudden failure of the refractory material.

Leaking water should be treated very seriously and the location of the leak identified as soon as possible. Leaks from inside the boiler heat exchanger or from the flow and return pipework could lead to overheating, which can cause major damage to biomass boilers.

Damage to flue pipes and components within a flue (draught diverters, fans, inspection hatches etc.) may lead to escape of flue gases with the risk of carbon monoxide leaks into the plant room. Wet flue gas can corrode boilers which will be very expensive to repair, so the back ends of boilers should be checked for any excessive build-up of moisture in the flue.

How to identify problems of unrepaired damage

Ideally the operator will notice damage to the boiler components before the problem leads to a larger failure. This should also be picked up in the maintenance process. Grate and refractory materials inside the boiler should be checked for damage regularly.

For evidence of water leakage, the operator should check the floor area around the boiler for wet patches or corrosion on pipework around the boiler. Water on the floor may also be an indication of pressure relief valves activating due to the boiler overheating.

For evidence of gas leaks, the operator should examine the boiler for damage caused by hot flue gases coming in to contact with areas of the boiler that should not be exposed to hot gases. This might be revealed by areas of damaged or discoloured paint or metal.

The emission of more smoke than usual may be evidence of ignition problems, The boiler should not be used until any ignition problem is investigated and rectified as the boiler is unsafe for use if it is unable to ignite correctly.

Pump or valve failures are usually noticed quickly, as the boiler will not be able to operate due to overheating etc. Other system components that have failed may go unnoticed for long periods if the heat demand is still satisfied, however these failed components may cause drops in performance and should therefore the boiler system should be checked regularly.

Should pumps or valves fail due to a lack of maintenance the heat distribution system may not be able to remove the heat quickly enough from the boiler, which may lead to overheating or boiling. This will have a negative impact on performance emissions. If valves become stuck, it may mean that a boiler system cannot meet a space heating or hot water demand, or possibly is unable to switch between the two.

2.3.6 Failure of safety features

Biomass boilers have a range of safety features to ensure that unsafe situations do not arise. Should these features fail due to a lack of maintenance, there may potentially be very serious consequences. Maintenance of safety features should therefore be a priority.

Fuel delivery systems are usually designed to ensure that there is never an uninterrupted passage between the fuel on the fire bed in the combustion chamber and the fuel store, to prevent the spread of fire back to the store. If this cannot be achieved then the boiler may feature a sprinkler system to douse the fire should a high temperature be detected in the fuel delivery mechanism upstream from the boiler. If these systems fail there is a risk of fire spreading from the combustion chamber to the fuel store, a phenomenon known as 'burn back'.

How to identify failures of safety features

Ensure that the burn back protection is serviced at regular intervals and that if it uses water, the water works independently of the boiler. There should be housekeeping procedures for the boiler house to ensure it is kept tidy and free of flammable material.

The carbon monoxide alarm, if fitted in your boiler house, should immediately alert you to the presence of unsafe levels caused by a leaking or non-functioning flue. Additionally, the carbon monoxide alarm may have a 'history' function that can reveal any historic instances of high carbon monoxide levels that occur during unattended periods.

Ensure that the water high temperature thermostat is connected and is serviced at regular intervals to ensure it will operate correctly when required.

Biomass boilers are designed to stop firing when the water flow temperature exceeds a certain limit often called the 'limit stat'. Should the boiler exceed this temperature it will shut down to protect itself. The boiler may require maintenance work to reset it after the boiler exceeds this temperature. If this safety feature fails there is a risk of damage to the internal boiler components, firstly with the material surrounding the combustion chamber and potentially with the boiler casing, heat exchangers and flue gas passage ways as well.

In all cases the high temperature limit thermostat should be of the 'hand reset' type. The boiler water temperature will need to be reduced before the 'hand reset' can be activated.

2.3.7 Lack of operator training

It is important that boiler operators have clear instructions on what activities they must carry out and what controls they should and shouldn't alter (see maintenance schedule). Full training should be provided so that they are confident in changing the controls they are supposed to and do not adjust ones they shouldn't. Incomplete or incorrectly completed maintenance schedules may indicate that an operator requires more training.

2.3.8 Incorrect air supply/fuel ratios

Good maintenance of biomass boilers will maximise their operational lifetime, however components will begin to deteriorate over time and need a phased replacement. Such items include fuel augers, lambda probes, primary and secondary fans, and refractory linings. This is not usually a problem as they can normally be repaired and replaced under a planned maintenance and servicing regime.

Over time, the air to fuel ratio in the boiler can drift due to fans not being as effective, or oxygen and temperature sensors becoming less accurate. This causes problems with control of air and fuel rates. This could either result in too much oxygen being supplied to the boiler which has the result of lowering efficiency, or too little oxygen supplied to the boiler which can lead to incomplete combustion. High levels of CO and tar due to incomplete combustion can lead to damage of the boiler internals, or to an increase of particulate emissions and damages to flues.

Identification of air supply/fuel ratios

Visible smoke and/or strange smells in the flue gases can be an indication of a problem with boiler controls as already mentioned. High flue gas temperatures may also indicate high air ratios.

For a boiler working well during steady operation, oxygen should be around 10% (range of 8-11% during normal operation). If the oxygen level is much above or below this over a sustained period (i.e. not just for a few minutes) boiler control adjustments maybe necessary. For monitoring oxygen levels, it may be worthwhile purchasing a handheld flue gas measurement device which will give you an indication of oxygen and flue temperature.

2.3.9 How to solve problems caused by poor maintenance

As already mentioned, a maintenance plan and schedule are essential as is operator training. If you own a biomass boiler it is your responsibility to ensure the operator is trained on how to operate and maintain the boiler. Be proactive about repairs and fix problems as they arise and not allow them to deteriorate.

Performing maintenance on a boiler often requires the boiler to be switched off. Remember that service engineers do not witness the boiler running at temperature and problems that occur after a period of steady operation may be not be visible when starting from cold so record issues in the on-site maintenance log for the boiler that occur when running, in order to report to the Service Engineer.

Keep regular data records of the heat meter for a biomass boiler

2.3.10 Knowledge and Time

One of the key factors which affects the performance of biomass boilers is the knowledge of the operator and owner about maintenance. If the operator has good knowledge about their boiler and proactively looks after it, they normally have fewer maintenance issues and the system often runs more efficiently.

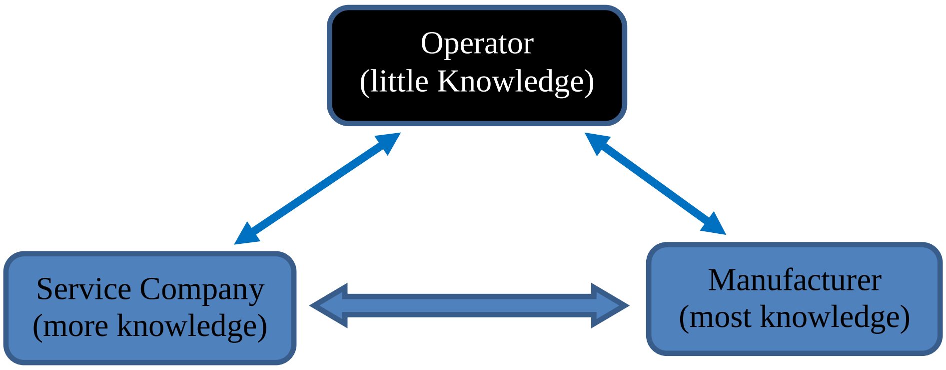


Figure 9: The Levels of Knowledge of Operators, Service Engineers and Boiler Manufacturers. Time spent with boiler is often the complete reverse of the above

While the servicing engineer can be knowledgeable about the boiler, and may not know the detailed history or issues relating to it, he-she is not the person who spends most of their time with the boiler. The converse is often true for the Operator.

In the UK, the situation with an operator with poor knowledge and only reactive maintenance leading to a poorly performing boiler is much more common than in many other European countries such as Austria and Germany, where systematic training and qualifications for Operators occurs. The manufacturer knows most about the boiler, but often they are only involved during the commissioning or if there is a serious problem with the boiler when replacement parts are needed.

Best practice maintenance is having operators trained to ensure that boiler maintenance is carried according to the manufacturer's recommendations, and that issues (especially which may relate to safety) are recognised and corrective action is taken quickly. The boiler manufacturer's maintenance recommendations should be supplemented by the maintenance requirements of the fuel and ash handling systems, and those of the heat distribution system (where appropriate).

Boiler maintenance duties should be carried out according to the schedule, if necessary by different staff. Do not assume that an annual or interim service will cover all required maintenance activities.

See Appendix 1 for a typical Maintenance Schedule.

Appendix 1: Typical maintenance schedule

This appendix is provided as an example of a typical biomass boiler system maintenance schedule. Its intention is to highlight the maintenance activities which should be undertaken by the Operator and others so that deficiencies can be identified and fixed.

This generic maintenance schedule **MUST NOT** be used as a substitute for **the specific maintenance schedule produced by the biomass boiler manufacturer and service engineer.** Activities listed below may be added to maintenance schedules if applicable.

Frequency of activity	Description of activity	Description of task
Weekly	Frequent cleaning of the boiler and removal of ash	Remove ash Clean smoke tubes Clean cyclone bag-filters Check fuel record parameters from Control Panel Record heat meter readings Check Fuel delivery records and details
Monthly	Regular lubrication of mechanical parts and checking of wear	Check/clean fuel delivery system Lubricate motors - bearings
Monthly	Checking the boiler is operating correctly and checking for damage	Check ash for clinker and unburnt fuel Check for leaks on water pipes Check boiler grate and refractory lining for damage Check ignitor guns Check that de-ashing system works Check pneumatic cleaning system works Check burn-back protection Check fans, pumps and mixing valves Check sight-glass Check flue soundness Check draught-diverter Check boiler control system and BMS for faults/alarm codes Check pipe and flue temperature sensors Check for condensation in /corrosion of heat exchanger Check seals on combustion chamber are air-tight Check Lambda sensor Check for unusual noises/vibrations Check area around boiler is tidy Check CO alarm is working and for previous activations Check pressure relief valves not activated Check light-barriers / levels-switches
Yearly	Intermittent servicing of boiler	Check boiler flue O_2/CO_2 and CO levels Clean fuel hopper Check boiler control system and BMS for software updates Clean exhaust flue