Biomass Heating – Common problems and their resolution

The Desk-Based Review of Performance and Installation Practices of Biomass Boilers published by DECC in June 2014 highlights the poor performance of biomass systems and there is also much anecdotal evidence of systems that have fundamental issues. There are numerous causes for biomass systems not working correctly and the reason that a lot of the issues never get satisfactorily resolved is the interaction between various elements of the system, which makes identification of the true cause(s) difficult, particularly when there are several parties with vested interests trying to prove that they are not to blame.

This situation is not unique, I've been involved in resolving poor performing building services and associated control systems/BMS for over thirty years, but resolution of issues becomes significantly more difficult with biomass boilers.

CIBSE AM15 2014 Biomass heating systems provides comprehensive guidance and is an essential reference document for biomass system design. I got involved initially to verify findings on common biomass hydraulic arrangements and then to contribute in other areas, particularly on controls and controllability of systems.

The following are some of the issues that I have found in around twelve years of being involved in biomass projects, this is not a comprehensive guide to all possible issues, but a pointer to some of the more common problems and possible solutions. Design guidance and a lot more is contained in AM15, but trying to resolve poorly functioning systems in a cost effective manner requires a thorough understanding of not only the unique issues of biomass boilers, but overall heating/HWS systems, system controllability and control systems/BMS.

Control systems are frequently blamed for systems not operating correctly, controls for biomass systems are far more complex than most heating systems due to the interaction between the biomass boiler and buffer/thermal store control which responds slowly to changes in load and the control of the rest of the system which responds far more quickly. However, controls are rarely the sole cause of the problems and other issues normally need to be addressed before trying to sort the controls out. Where the overall system is controlled and monitored via a BMS the data logs can be very valuable in clearly identifying performance issues which greatly assists with finding solutions.

A sanity check on system sizing and loads is normally the starting point for any operational analysis, if there are fundamental issues on biomass boiler sizing relative to the thermal store/buffer and the remainder of the system then no matter what you do the system will never perform satisfactorily. I have walked onto a number of sites and without doing any calculations can see that the thermal store is undersized.

Some situations can be overcome with novel solutions, my initial suggestion for an installation I looked at a few years ago where sizing and many other items were questionable was to sell the biomass boiler and revert to oil. The client insisted on an all biomass solution retaining the boiler installed on site. A carefully redesigned hydraulic arrangement with a generously sized thermal store and a semi-storage HWS system together with a comprehensively revised control system has resulted in a very successful installation, albeit at significant cost.

I've witnessed a number of systems where the thermal store is depleted long before the biomass boiler is able to provide heat. Thermal store sizing needs to take into account the reaction time of the biomass boiler, slow initial heat up can be overcome to some extent by starting the biomass boiler in advance of the normal optimum start time and/or preheating the HWS prior to occupancy, but response during normal operation must also be considered.

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Thermal store physical design can be a significant issue, a tall vertical vessel promotes stratification, essential for effective operation. Poorly positioned inlet and outlet pipes can compromise the effective capacity of the vessel.

If thermal stores are undersized additional capacity can be added with additional stores, series connection of multiple thermal stores is preferable in my experience as it effectively makes the thermal storage taller and narrower which promotes stratification. There is another option that I've tried on other thermal stores, although not so far on biomass, which provides a partial solution to some of the issues at lower cost, but is not universally applicable.

Biomass response and utilisation can be assisted where the biomass boiler is started as soon as there is adequate demand, even if the thermal store is nearly fully charged. Unfortunately many biomass boiler manufacturers are not happy with this arrangement as it is not part of their standard control strategy. Some suppliers are more amenable and these systems have performed far more satisfactorily in my experience.

The pump from the thermal store to the system needs to be variable speed suitably controlled to deliver more heat from the thermal store than the biomass boiler can input to make use of the thermal capacity and optimise biomass utilisation, it must revert to a lower speed when the thermal store is depleted. This is often poorly appreciated and settings may need to be adjusted to take account of biomass boiler response and effective thermal store capacity.

System hydraulics, in particular connection of the biomass boiler and thermal store to other heat sources can be very complex and there are many different opinions. Many manufacturer's/biomass specialist's recommended solutions were considered during the development of AM15. Some were fundamentally flawed and others had significant limitations that affected overall system operation under the widely varying load conditions typical of the UK. Some may work satisfactorily in other climatic conditions but care needs to be taken with anything other than the solutions in AM15. Which is not to say alternatives can't be made to work, but overall system operation must be considered not just the biomass boiler.

Most successful hydraulic arrangements require the secondary system to be variable flow. Constant flow secondary circuits need to have constant flow primary circuits to avoid dilution via a common header, which will normally compromises the effective operation and control of the biomass boiler/thermal store/ancillary boilers.

A compensated heating circuit, which is often the greatest load in buildings, will automatically create a variable draw from the primary circuit at part load regardless of the actual circuit flow due to the position and operation of the compensated valve, so is highly recommended, although not normally applicable for community/district heating systems providing HWS.

OK I've now mentioned community/district heating, are they viable particularly in view of the findings in the DECC report? I've lost count of the number of community/district heating schemes I've been involved with, great care needs to be taken in their design, I'm always suspicious of over optimistic feasibility reports and have recommended alternative solutions on a number of occasions. However, I suspect that reported high heat losses may not actually be as bad as they appear in some cases due to poor metering. Flow and heat meters are often poorly located, or poorly selected, this causes meter readings to be inaccurate. If main plant readings are correct and sub meter readings low then heat losses could be exaggerated, although losses could be greater if it is the other way round.

What is often not fully considered are pumping loads in district/community heating systems, these can be significantly reduced with good design and control/PICV selection. There is some good guidance on variable flow and some manufacturer's that is a little biased, although I've not seen any that addresses all factors, but that's for another article.

I've not touched on biomass boiler selection, there is a wealth of information on different types in AM15. However, if the boiler has slow response, or other characteristics that make it unsuitable for the application, performance will always be compromised, although overall system performance and biomass utilisation can often be improved. I have found that some biomass boilers do not operate reliably at their rated maximum temperature and the boiler commissioning engineer turns down the setting to prevent the overheat thermostat being tripped. This not only affects boiler capacity but also the effective capacity of the thermal store which is normally at a higher temperature than the rest of the system.

Flue design is critical to the safe and reliable operation of biomass boilers, I have seen a number of installations where the flues were grossly inadequate. Guidance is contained in AM15, plus see Jim Kinnibrugh's excellent article in the November 2015 CIBSE Journal.

Coming back to controls, I'm often asked to resolve system control problems, but have to sort out all the other issues first to make the system controllable. All systems, not just biomass, should have a controllability review as recommended in AM15, but this rarely happens.

A controls specification that states the biomass boiler should always provide the primary heat source but does not detail the principle of operation is unfit for purpose and the control systems integrator cannot be expected to guess how the system should be controlled.

A common problem is the use of temperature based sequence controls for the fossil fuel boilers working in sequence with the biomass boiler/thermal store control. If the biomass boiler and thermal store are working perfectly under all load conditions and the heat only needs to be topped up by the fossil fuel boilers then a sequence control system based on temperature can work. However, as soon as there is any delay in response the fossil fuel boilers will start to operate and often remains running unnecessarily even when the biomass system has responded.

A temperature based sequence control based on flow temperature often interacts with the individual boiler modulation controls and some boiler manufacturer's sequence controls are fundamentally flawed. This can be overcome via direct modulating control of burners, but care needs to be taken to avoid compromising safety functions. A P&I sequence control loop will inherently try to achieve the temperature setpoint and will always bring on heat sources as required to meet the temperature setpoint. Therefore, supplementary boilers are often enabled when they could have been left off and temperature allowed to drift a little, hence the utilisation of the biomass boiler will be less than expected. P&I flow temperature sequence control can be made to work, but setting up can be lengthy and drift in plant performance over time can compromise operation.

Proportional mode flow temperature sequence control loops will normally either be unstable or allow too much drift in flow temperature. But what about nice stable proportional control from return temperature? Biomass systems (and most other modern systems) are normally variable flow systems, return temperature does not represent system load ($Q=MC\Delta t$). Therefore, return temperature cannot be used for control!

My recommended control strategy for the fossil fuel boilers is heat load based control, this should take account of the variable heat output from the thermal store. This should preferably also be used

to enable the biomass boiler as soon as there is adequate load rather than waiting for the thermal store to be depleted. Biomass boilers must always stop in sufficient time to enable residual heat to be dissipated, this is normally via the lower sensor location and setting in the thermal store.

Heat load control requires an instantaneous heat load in kW. This can be derived from some heat meters (which often are installed for RHI purposes with just kWh outputs), or additional heat meters can be installed. Clamp on ultrasonic flow meters in association with matched temperature sensors can be used to provide a heat load calculation (kW) via a BMS, or local calculation unit, where suitable outputs are not available from heat meters.

Biomass boilers can be connected in series with fossil fuel boilers which enables simpler control strategies. However, care needs to be taken as most modern boilers will not take additional flow without excessive pressure drops, condensing boiler operation will be compromised and an old inefficient boiler used in series with new biomass boilers will often have high thermal losses and poor control.

The above is a brief overview of some of the typical issues with biomass systems and ways to overcome them, there are many other possibilities, for further advice please do not hesitate to contact me - graham.smith@birlingconsulting.co.uk