HVAC HESS

PEOPLE

PRACTICES

SYSTEMS

Factsheet

Boiler Efficiency

The HVAC and common area lighting systems of a 45 year old 5,400m² commercial office building in Canberra (Figure 1) were upgraded in 2010, resulting in a NABERS Energy Rating improvement from 2 to 4.5 stars. This resulted in a reduction in annual energy usage saving $120,000, a 70% reduction in annual greenhouse gas emissions, and an increase in occupant comfort. One facet of the retrofit included an upgrade of the boilers; other components of the retrofit are detailed in companion factsheets.

Figure 1: Street view of 4 Mort Street, Canberra

Boilers

HVAC systems are made up of various items of equipment including boilers for heating, chillers for cooling, air handling systems for air-conditioning and a range of ancillary components such as pumps and fans. Commercial buildings in colder climates are typically heated by boilers. Boilers produce heat by burning fuel (typically gas), the thermal energy from which is used to heat water through a heat exchange process. The hot water is circulated to air handling units, fan coils or radiators which supply heat to the occupied spaces. Depending on the climatic region, heating makes up 15-25% of a building's total energy requirements. Natural gas is an obvious fuel choice given its lower cost, convenience of distribution and lower greenhouse gas emissions, which are as little as 20% of the CO_2 emissions associated with grid connected electricity. Various technologies have been developed that have seen the thermal efficiency of boilers increase from a maximum of 70% thirty years ago to 97% today for a modern condensing type boiler[1].

Condensing Type Boilers

Condensing boilers have the potential to reduce gas consumption for space heating by as much as 15%, providing they are carefully selected, monitored, controlled and maintained. A typical condensing boiler has a thermal efficiency of 92-95%, in comparison to non-condensing boilers which typically have efficiencies of around 85%. These higher efficiencies are achieved by using the waste heat in the flue gases to preheat the water entering the boiler. Additional heat is extracted by condensing the water vapour in the waste gases to liquid and recovering its latent heat[2]. Condensing boilers also have high efficiency burners and sophisticated controls which assist to reduce the emission of greenhouse gases (CO_2) and harmful nitrogen oxide (NO_x) gases.

Condensing boilers have been successfully used overseas (mainly in Europe[3]) for the last 25 years. In Australia, however, condensing boilers are only just beginning to be used more widely. Design engineers and contractors may specify and install condensing boilers without fully appreciating the factors that make them condense, thereby not realising the full potential benefits. This is a well understood issue in Europe, with a recent Chartered Institute of Building Services Engineers (CIBSE) conference in London dedicated to the topic. Given the fact that a condensing boiler typically costs 30-50% more than a non-condensing boiler it is important that designers and installers understand the factors that optimise the operation of these boilers.

The thermal efficiency of a condensing boiler is dependent on its heating flow and return temperatures. Condensing boilers are designed to positively encourage condensing of the flue gasses and in order for this to occur, the return water entering the condensing boiler from the heating circuit has to be below the dew point of flue gases (55°C), ideally below 52°C[4].

[1] As a point of reference the National Construction Code 2012 (formerly the Building Code of Australia) mandates the thermal efficiency for a new boiler to be at least 80%.

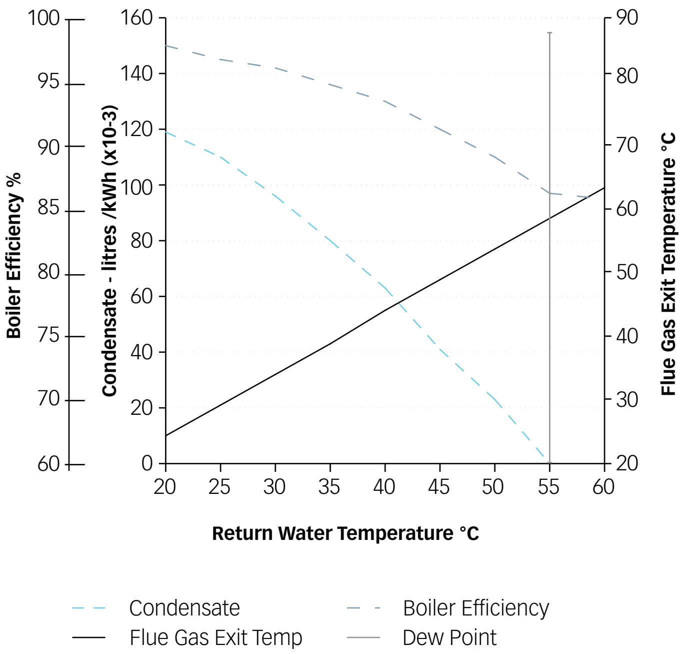
[2] When comparing thermal efficiencies of boilers, the convention is to use the gross calorific value of the fuel, rather than the net calorific value. The former includes the latent heat of vaporisation of the water vapour produced, the latter does not.

[3] Boiler efficiency regulations in many European countries are such that non-condensing type boilers are now disallowed in new buildings and retrofits.

[4] As a point for reference, conventional boilers typically have heating flow and return temperatures of 82-71°C.

Figure 2 shows typical performance curves of a condensing boiler and how the efficiency of a condensing boiler falls fairly steeply with rising return temperature, up to about 55°C, at which point no condensation occurs and the boiler only performs marginally better than a conventional boiler beyond this return temperature.

Figure 2: Typical performance curves for a condensing boiler[5]



Boiler Sequencing

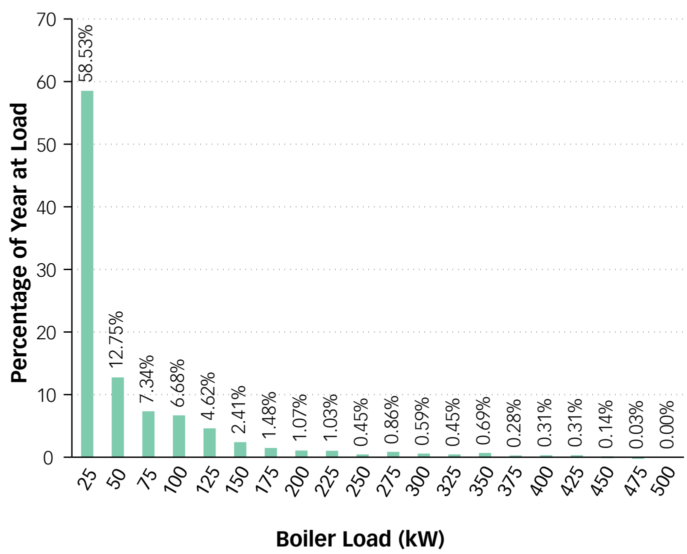
Typical office buildings will have a seasonal heating demand profile similar to the one in Figure 3 where a large majority of heating demand only uses a small proportion of the maximum boiler capacity. Therefore, correct boiler sequencing is necessary to operate the boilers efficiently.

Boiler sequencing involves the correct staging of a number of boilers working in combination to deliver optimal performance. The lead unit would generally be a condensing type boiler which will operate in condensing mode for the majority of the year. If the heat exchangers are sized for conventional flow (82°C) and return (71°C) water temperatures at maximum capacity, they can be operated during low load conditions with the flow and return temperatures reduced, to enable condensing conditions at the boiler. As the heating load increases (during colder weather and/or early morning warm up), the boiler flow temperature can be automatically increased by the building management system (BMS) and if the heating demand is such that the condensing boiler has reached its full capacity with flow temperature at around 82°C, other condensing or non-condensing type boilers can be sequenced. Such an arrangement is referred to as lead-lag operation and the condensing boiler will always operate as the lead unit with the others providing reserve capacity.

Although having all boilers of the condensing type will be more efficient, the return on investment may not be sufficient as the condensing type lag boilers are unlikely to deliver the energy savings required to offset the extra capital expense given that they are operational for such short periods of the year.

When retrofitting condensing boilers to existing heating systems it is likely that the existing heat exchangers will be somewhat oversized for the required duties, given traditional oversizing of systems and improvement to the thermal performance of the systems and the building façade over time. Under such circumstances the best design option is often to install a condensing boiler as the lead boiler, to schedule the heating flow temperature upwards as demand increases and then to sequence the conventional boilers.

Figure 3: Boiler load profile for 4 Mort Street Canberra



For small applications (where heating demand does not exceed around 600kW), it may prove cost effective to use a modular boiler arrangement with all condensing type boilers. Some manufacturers offer these types of products including modularised heating pipe headers and flues. The simplicity along with improved space and energy efficiencies of such units can make them more cost effective than the alternative options required for a mixed arrangement. As shown in Figure 4, a modular triple condensing boiler arrangement was installed at 4 Mort Street, Canberra.

The building's BMS and its correct programming are integral to the proper functioning of condensing boilers. Poor outcomes result when engineers specify condensing boilers without including an appropriate controls strategy in the BMS for achieving condensing conditions whenever possible.

[5] Source: Building Research Establishment, Department of the Environment, UK.

Figure 4: Modular condensing boiler arrangement installed at 4 Mort Street, Canberra

Other Factors to Consider

Flues

Condensate from condensing boilers contains carbonic acid (H_2CO_3) which has a pH of 3. Significant condensation occurs in condensing boiler flues when operating under optimal conditions, therefore it is important that the flues are made from acid resistant materials such as stainless steel or high temperature plastics.

The integrity of flue joints is also important. Where spigot/socket type joints are used, the sockets must face upwards. Horizontal flue joints must either be flanged/gasketed or have generous overlapping spigots/sockets with a high temperature silicone sealant applied where appropriate.

The flue discharge from a condensing boiler has very little residual thermal energy and appears as a plume of vapour. The plume, although harmless, will be visible and may cause aesthetic issues to occupants of the building, neighbouring properties, or passersby.

Condensate Removal

Copper, cast iron and lead drainage piping are commonly found in old buildings. Acidic condensate from a boiler and flue must not be drained through these types of piping as it will corrode the materials over time. In commercial boiler installations, condensate should be neutralised prior to connection to drainage[6]. Manufacturer supplied acid neutraliser kits need to be replaced periodically. These ongoing maintenance requirements need to be included in operating and maintenance manuals, as expensive remedial work may be required to copper or cast iron sewer pipes if replacement is overlooked.

System Cleanliness

When retrofitting condensing boilers (or any modern boiler with compact heat exchange passages) to an existing heating system, it is essential for the system to be thoroughly flushed and water treatment chemicals added. If the existing system is extensive like in a hospital or a campus type establishment, it is advisable to install a good quality dirt separator in addition to conventional strainers in order to effectively remove high quantities of finely dispersed debris typically found in these systems. Such debris, if not removed, can block the fine heat transfer passages in modern boilers.

Back End Corrosion in Non Condensing Boilers

Condensing boilers have heat exchangers made out of materials that withstand acidic condensate. If conventional boilers are used with return water temperatures below 55°C for prolonged periods, they will eventually suffer from corrosion and premature failure due to acidic condensate attacking the heat exchangers. This is termed 'boiler back end corrosion'. The replacement cost of the boiler will far exceed any energy cost savings associated with running the conventional boiler in condensing conditions. When conventional boilers are operated in conjunction with condensing boilers, it is important the return water temperature to the conventional boilers is always maintained above 58°C, or in accordance with manufacturer's instructions.

Quality of Boiler and Boiler Maintenance

It is important to assess the build quality and service provision of the condensing boiler. The quality of the secondary heat exchanger is important because it has to withstand corrosion. It is important that units are installed and commissioned strictly in accordance with the manufacturer's instructions and maintained as recommended by competent contractors with the necessary specialist knowledge. Unless the owner and the designer give consideration to these factors, it is unlikely that the condensing boiler will deliver a good return on investment.

4 Mort St Retrofit

The heating plant installed at 4 Mort Street consists of three 150 kW condensing boilers. The boilers were supplied by the manufacturer as a modular unit ready for site assembly, complete with primary circulators, header pipework and acid neutraliser kits.

Since the heat output requirement was relatively small (450 kW) it was decided to have all boilers of the condensing type rather than to have a condensing boiler as the lead unit supplemented with conventional boilers. The arrangement used was more compact and cost effective for the relatively small duty required.

[6] This may be a local authority requirement in order to avoid trade waste charges.

Since the air handling units were sized with heating coils suitable for low hot water flow temperatures (65°C rather than 82°C), the boilers operate under fully condensing conditions when there is a heating demand. Also, the heating demand is minimised by the use of CO_2 sensors for controlling the amount of outside air drawn into the air handling units and the absence of re-heating systems in the building.

HVAC HESS

The Heating, Ventilation and Air-Conditioning High Efficiency Systems Strategy (HVAC HESS) is a ten year strategy under the National Strategy on Energy Efficiency that aims to drive long term improvements in energy efficiency of HVAC systems Australia wide. Under the Energy Efficiency Working Group (E2WG), the Commercial Buildings Committee (CBC) manages the implementation of the HVAC Strategy. The CBC is comprised of representatives from Australian, State and Territory Governments.

The Strategy takes a whole of life perspective in targeting HVAC efficiency improvement, encompassing the design, manufacture, installation, commissioning, operation and maintenance stages of the HVAC lifecycle. The Strategy consists of a number of complementary measures that fall under the three broad initiatives - People, Practices and Systems. This BMS factsheet specifically relates to Systems. It is one of a suite of factsheets developed to provide a quick overview and reference to inform, educate, and encourage energy efficiency in the HVAC industry.

Acknowledgements

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This and other HVAC HESS factsheets can be found on the Department of Climate Change and Energy Efficiency website at:

www.climatechange.gov.au/government/initiatives/hvac-hess