IMPROVING

BOILER EFFICIENCY IN HOTELS

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Hotels are energy intensive buildings, typically consuming more than 400kWh/m² and they account for 11% of the energy usage across the Australian commercial buildings sector. It is important for Hotel Engineers to consider improving the efficiency of heating systems, for the following reasons:

- Large hotels in temperate climate zones of Australia typically have gas fired boilers that provide space heating. With gas prices forecasted to rise steeply, with some estimates predicting increases ranging from 200% to 300% over the foreseeable future, the efficiency of the installed boilers, their optimised operation and the application of best practice maintenance is important.
- Reducing energy costs will always help competitiveness. Energy costs can be as high as 10% of operating costs. Energy management offers the means to reduce operating costs without compromising the high levels of service delivery- which is essential to keep guests comfortable and to make the hotel their chosen venue for the next visit.
- Reducing heating energy will reduce CO_2 emissions and improve the environmental credentials of the hotel. Ecological branding is becoming more important for hotels, with corporate clients seeking environmentally friendly venues to hold business conferences and to accommodate their staff.

Where gas fired boilers are installed for space heating, they produce heating hot water which is circulated to air handling units, fan coils or other forms of heat emitter such as radiators which provides heating to the spaces. The gas consumption for space heating can account for 10-20% of the total energy consumption of a hotel. The use of natural gas has often been the obvious choice as the energy source for space heating due to its lower cost, convenience of distribution and lower greenhouse gas emissions which is typically 80% less than the CO_2 emissions from grid connected electricity.

For reducing greenhouse gas emissions, manufacturers of boilers have developed technologies that have seen the thermal efficiency increase from around 65-70% thirty years ago to about 95-97% for a boiler with condensing type technology. As a point of reference the National Construction Code (BCA) 2014 mandates the thermal efficiency for a new boiler to be at least 80% or 83% for boilers >750kW which are both fairly low targets, considering the options readily available.

Condensing type boilers have been successfully used in overseas countries (mainly Europe) for around 30 years. Therefore users and installers in these countries are well aware of their advantages, shortcomings and system design characteristics for optimised operation. Boiler efficiency regulations in many European countries are such that only condensing type boilers are now able to be installed for new buildings and retrofits.

In Australia, condensing type boilers are now being installed, however there are misconceptions about the optimal application of these boilers and this technical fact sheet attempts to address some of these issues. Engineers and contractors often specify and install condensing boilers without fully appreciating the factors that make them condense, thereby denying the owner the potential benefits.

Condensing boilers are more efficient than non-condensing boilers mainly because they have bigger (better) heat exchangers that extract more useful heat from the hot gases produced during combustion. Such boilers also have more sophisticated burners and controls which increase efficiency. Due to higher efficiency these boilers emit less greenhouse gases (CO_2) to the atmosphere and since combustion occurs at lower temperatures the emission of harmful nitrogen oxide gases (NO_x) is also reduced.

Condensing boilers have the potential to reduce gas consumption for space heating by as much as 15-30% (in comparison to an existing inefficient boiler), providing there are carefully selected and controlled properly.

The term 'condensing' is used to describe these boilers because under favourable conditions of operation, these boilers extract heat from the flue gas (exhaust) products to such an extent that the water produced in the flue gases condense into a vapour, thereby giving a visible plume. This effect is somewhat similar to the visible vapour trail of an aircraft at high altitude or the plume of exhaust from a motor vehicle on a cold day when the cool exhaust system acts as a condenser.

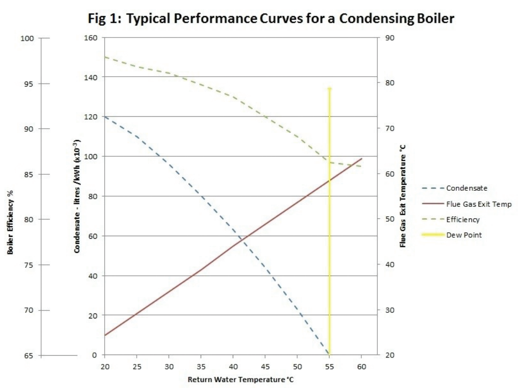

Figure 1 shows how the efficiency of condensing boilers falls fairly steeply with rising return temperature, up to about 55°C (the dew point of flue gases), at which point no condensation occurs and the appliance performs as a high efficiency boiler beyond this.

When compared to conventional boilers, the thermal efficiency of condensing boilers is highly dependent on heating flow and return temperature, especially the return temperature.

Under full load conditions, a condensing boiler typically has a thermal efficiency of around 93-95%, in comparison to a non-condensing boiler which tends to have efficiencies of around 85%. Another advantage is that under part-load conditions, the efficiency of most condensing boilers improves slightly, whereas conventional boilers suffer from decreased efficiency at part load.

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, therefore is approximately 10% higher than the latter which excludes the latent heat of vaporisation. When expressing thermal efficiency, should the latter value be referenced, this results in a somewhat exaggerated value which exceeds 100%. Therefor it is important to check whether the efficiency stated by the boiler manufacturer is referenced to the gross calorific value.

Condensing boilers are designed to positively encourage condensing of the flue gases whereas conventional boilers are corroded by condensation. Therefore, condensing boilers are more efficient than non-condensing boilers under typical operating conditions, and their efficiency significantly improves when the flue gases are cooled below 55°C, which is the dew point. For this to be achieved, it is essential for the return water from the heating circuit to enter the condensing boiler at temperatures below 50-52°C. Such conditions are readily available when these boilers are used for low temperature heating circuits.

Conventional heating systems typically have heating flow and return temperatures of 82-71°C respectively, and under such conditions condensing boilers will not condense, therefore maximum efficiency will not be achieved and the boiler will lose about 10% of heat through the flue gases. Since a condensing boiler typically costs 30-50% more than a non-condensing boiler it is important that designers and installers consider the factors that would optimise the operation of these boilers under condensing conditions.

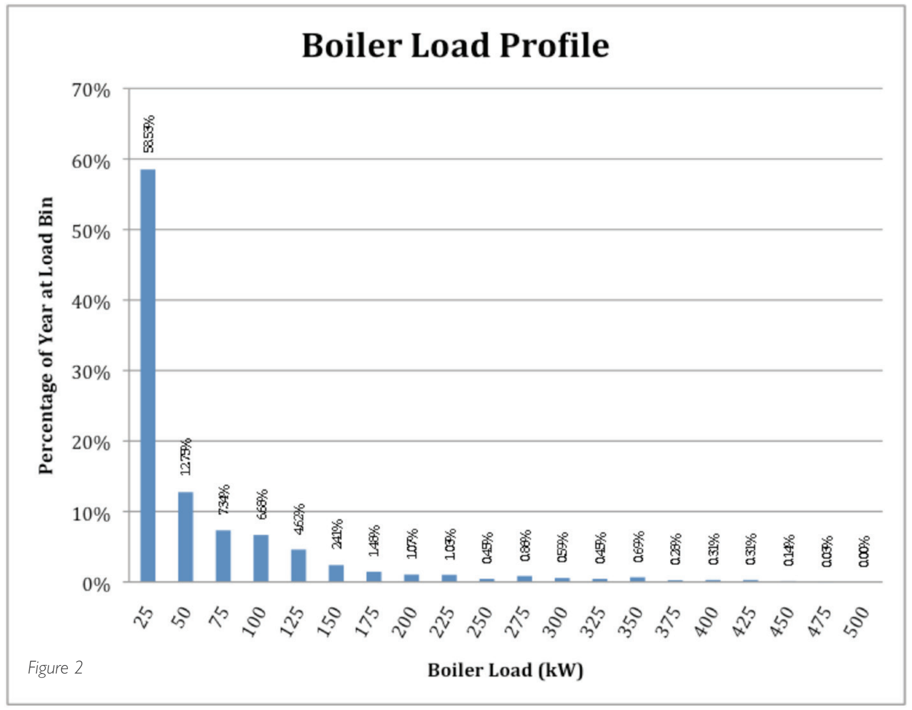

Figure 2

TO CONDENSE OR NOT TO CONDENSE?

For applications that involve low temperature heating circuits, the heat exchangers can be sized that that the return temperature to the boiler is below 50°C, therefore the boiler will always operate in condensing mode, delivering maximum efficiency. Such applications include swimming pools, underfloor hydronic heating, greenhouses, pre-heating domestic hot water and low surface temperature radiator or perimeter skirting type heaters.

For new installations, which have long operating hours (such as hotels in cooler climates) where energy efficiency is paramount for achieving exceptional performance, it may be cost effective to oversize heat exchangers to enable operating the heating circuit at lower temperatures, that provide condensing conditions. Heat exchangers sized for low hot water flow and return temperatures will be physically larger when compared to those sized for conventional temperatures of around 82-71°C, therefore this will lead to extra cost and space requirements for the larger heat exchangers.

However, for most applications in Australia, if the seasonal heating load is established accurately using means such as a building simulation, a result similar to the following will be evident.

Fig 2 shows the annual heating demand profile for an office type building which had boiler plant with total capacity of 500kW, sized for winter design conditions of -2°C. The graph shows that most heating demand is only a small proportion of the maximum boiler capacity of 500kW. Therefore even if the heat exchangers are sized for conventional flow and return water temperatures (82 & 71°C), they can be operated during the low load conditions using a condensing boiler, 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 the flow temperature at around 82°C, other 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.

For most new applications such an approach is likely to give the best return on investment rather than specifying the most expensive option with all boilers being the condensing type. Having all boilers to be of condensing type will no doubt be slightly more efficient but the payback period will be much longer because the additional costs associated with lag boilers being of the condensing type will not deliver significant savings, because the plant will be used for very short periods in the year.

Similarly, when retrofitting condensing boilers to existing heating systems the likelihood is that the existing heat exchangers are somewhat oversized for the required duties due to traditional design safety factors being applied and the heat losses from the building reducing over the years due to upgrades to thermal insulation and the building façade. The impacts of global warming are also likely to have reduced the heating loads slightly. Under such circumstances the best design approach is likely to install a condensing boiler as the low load (lead) boiler and to schedule the heating flow temperature upwards as heating demand increases and then to sequence conventional boilers.

For smaller applications, having heating demands around 300-500kW, it may prove cost effective to use a modular boiler arrangement where all boilers are condensing type. There are manufacturers who offer this arrangement complete with modularised heating pipe headers and flue arrangements and the simplicity of this arrangement could be advantageous.

Based on the author's experience, most hotels will benefit cost effectively through the installation of a (small) condensing boiler as the lead boiler to provide the space heating base load through most of the year with the existing conventional boilers providing back up capacity for the relatively short spells of extreme weather. The BMS must be configured to ensure that the condensing boiler is operated for as long as possible with its return temperature below 50-53°C. When additional heating is required, the heating flow temperature should be sequenced (or re-set) upwards to 82-85° (or as recommended by the manufacturer) before the conventional boilers are fired. For reasons given in the next section, conventional boilers must not be operated for long periods with the return temperature below 55°C.

This temperature re-set can be achieved by the BMS through an algorithm that uses feedback from the positions of the modulating heating control valves or through ambient weather compensation. For existing installations where the positions of the heating control valves are not visible to the BMS, the latter will be a satisfactory solution.

A poor outcome is achieved in terms of return on investment, when condensing boilers are installed without including a controls strategy in the BMS for achieving condensing conditions whenever possible.

IMPORTANT FACTORS TO CONSIDER

Flues:

The condensate from condensing boilers is acidic, as shown in the chemical reaction below:

$CH_4 + 2O_2 => CO_2 + 2H_2O$ (water vapour) $=> H_2CO_3$ (carbonic acid)

Natural gas (mainly methane) when burnt, produces carbon dioxide and water vapour which combine to form carbonic acid which has a pH of around 3.

Therefore it is important that the flues for condensing boilers are made from acid resistant materials such as stainless steel 316 or high temperature plastics (only if approved by the gas regulator). Significant condensation occurs in flues for condensing boilers when compared with conventional boilers, therefore the integrity at flue joints is 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, to avoid water leakage into the plant room. Horizontal runs must be graded upwards at least 5° towards the discharge.

The flue discharge from a condensing boiler has very little residual thermal energy hence low buoyancy. Therefore a plume of water vapour will be visible and this could cause aesthetic or nuisance issues near windows, to neighbouring properties, balconies or semi enclosed courtyards where hotel guests walk hast or congregate. This issue must be considered, especially in hotels. The plume is harmless, apart from being slightly acidic and will have fewer impurities than the flue from a conventional boiler because of the scrubbing effect from the vapour which will be drained. The UK publication Guide to the Condensing Boiler Installation Assessment Procedure for Dwellings, available from the internet provides guidelines for domestic type applications. For commercial applications, similar principles apply and it is important to seek advice from manufacturers.

Condensate Removal:

Condensate from the boiler and flue must not be drained into copper, cast iron or lead pipes, which typically exist in older buildings. In commercial (non- domestic) boiler installations, condensate should be neutralised prior to connection to drainage, which may even be a local authority requirement if trade waste charges are to be avoided. Manufacturers supply acid neutraliser kits which contain consumable neutralising agents (alkalis) which need to be periodically replaced. This must be written into operating and maintenance manuals, if not it could be overlooked and expensive remedial work may be required to copper or cast iron sewer pipes.

System Cleanliness:

When fitting 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 a good water treatment regime to be installed. If the existing system is extensive (long pipe runs) and has steel pipework (rather than copper), it is advisable to install a good quality dirt separator in addition to conventional strainers.

Water Treatment:

When retrofitting condensing boilers to existing systems that have a mixture of metals such as steel, copper and brass, it is especially important to ensure that the heat exchanger of the condensing boiler is made of corrosion resistant metal such as stainless steel 316. There are many reputable condensing boilers available with heat exchangers made of Aluminium/Silicon for reasons of lower cost. However for these to have a good lifespan, the quality of flushing and water treatment in the heating system is paramount. Aluminium corrodes at a high pH, because the passivation layer deteriorates above a pH >8.5, with such conditions being acceptable (or even desirable) for conventional heating systems that have steel components. It is very important to maintain the system pH and other important parameters such as chlorides and total dissolved solids (TDS) as recommended by the boiler manufacturer. For such boilers, it is typically recommended to avoid NaOH and tannin based water treatment and instead to use inhibitors having orthophosphates or molybdite.

Back End Corrosion in Conventional Boilers:

Condensing boilers are designed to encourage condensation to occur within them. They have heat exchangers made out of metals that withstand the condensate which is acidic in nature with a pH value of around 3, the same as tomato juice. If conventional (non-condensing type) 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, which is termed 'boiler back end corrosion'. Therefore it is important when conventional boilers are operated in conjunction with condensing types, the return water temperature to the conventional boilers are always maintained above 58°C or higher as recommended by the manufacturer. For energy efficiency, it is also important to prevent standing losses from off line boilers through the automatic shut- down of water circulation through motorised valves, with slow re-opening on demand, to reduce any thermal shock.

Some engineers and energy auditors recommend the heating flow temperature to be re-set downwards based on prevailing outside temperature, in order to save energy losses from the heating distribution pipework systems. This can lead to severe back end corrosion in conventional boilers, if they are operated for prolonged periods with the return temperature below 55°C. The replacement cost of the boiler will far exceed any energy cost savings.

Best Practice Maintenance and Operation:

It is important to assess the build quality and service provision from the suppliers of the condensing boiler. Some of the condensing boilers appearing in the Australian market are the cheaper end products available overseas. The quality of the secondary heat exchanger is important because it has to withstand corrosion. Other factors to consider are that components such as burners are more complex due to arrangements such as pre-mixing and control of excess air, therefore it is important that these 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 about the equipment- ideally gained through attending training courses accredited by the manufacturer. Unless the owner and the designer give consideration to these factors, it is unlikely that the condensing boiler will deliver a return in investment.

Hotels operate for long hours with highly variable occupancy, with high expectations for user comfort. Therefore the use of optimised controls strategies through BMS is essential for efficient operation. The use of BMS for energy efficiency will be covered in a future article.

For further information on best practice maintenance, refer to the Guide to Best Practice Maintenance and Operation of HVAC Systems for energy efficiency, which is available as a free download at www.industry.gov.au

ABOUT THE AUTHOR:

Lasath is a Chartered Professional Engineer and the director of Engineered Solutions for Building Sustainability (ESBS) – www.esbsconsult.com.au with 30 years' experience on building services design and maintenance management in England, Scotland, New Zealand and Australia. Lasath has a passion for sustainable design and operation of building services, being the lead author of the Guide to Best Practice Maintenance and Operation of HVAC Systems for Energy Efficiency- published by the DCCEE. One of Lasath's recent projects – 4 Mort Street was awarded the 2012 AIRAH Engineering Excellence Award for the Most Sustainable HVAC Retrofit Project, presented by the NSW NABERS Team. Lasath has performed more than 100 energy audits including hotels and this knowledge gives him a unique perspective of the potential causes for inefficient operation in buildings and how to avoid them. If you have any questions regarding this article, please address them to: Lasath@esbsconsult.com.au