Application Notes for
Calorific Value & Boiler Efficiencies

Calorific Value

Calorific value is the amount of heat developed by the combustion of different fuels. The calorific value of any substance is a measure of the heat that can be obtained by burning it, and may be defined as **"The heat made available when unit weight is burned completely and the products of combustion cooled down to the standard temperature of 15°C."**

Because most fuels contain hydrogen, the products of combustion include water vapour and which condenses out at low temperatures may be included in the calorific value. This is particularly important for natural gas and LPG fuels where the hydrogen content is high, compared with diesel oil, which has about 6% hydrogen.

In practice there are two calorific values, which may be quoted for a fuel:

1) "**Gross Calorific Value**" includes the specific heat and the latent heat given up by the condensation of any water present in the products of combustion by cooling to 15°C.

2) "**Net Calorific Value**" includes the specific heat only and excludes the latent heat given up by the condensation and cooling of any water present in the products of combustion (including water previously present as moisture in the fuel). It is obtained by deducting the latent heat from the gross calorific value,

The net calorific value is a truer measure of the heat available, and is the commonly used figure in Europe. Net values should always be used except where gross is specified.

The net calorific values of common fuels typically used in NZ are as follows:

- Natural Gas – 50.1MJ/kg or 34MJ/m^3
- LPG – 46.1MJ/kg. or 24.4MJ/L (specific gravity 0.53)
- Diesel Oil – 43.0MJ/kg or 35.7MJ/L (specific gravity 0.83)
- Light Fuel Oil – 41.5MJ/kg or 37.3MJ/L (specific gravity 0.90)
- Heavy Fuel Oil – 40.6MJ/kg or 38.4MJ/L (specific gravity 0.95)
- Kerosene (Jet Fuel) – 43.4MJ/kg or 34.3MJ/L (specific gravity 0.79)

The analysis of natural gas will vary according to the source of the gas, as various gas fields have different properties. Similarly, LPG fuels are a mixture, and typically consist of a 60/40 Propane/Butane mixture. If a propane enhanced 80/20 mixture is used, there is a small increase in the calorific value.

A Joule is a Watt second. Therefore conversion to Watt hours requires a multiplier of 3600.

Efficiencies

Efficiencies are quoted in various ways and can be confusing. Descriptions of the efficiency are as follows:

Combustion Efficiency – Is an indication of the burner's ability to burn fuel. The amount of unburned fuel (hydrocarbons and carbon monoxide) in the flue gases and the flue gas temperature is used to assess the burner's combustion efficiency. Combustion efficiency is usually calculated using a combustion analyser to measure the flue gases and there will be some excess air required to achieve complete combustion.

Thermal Efficiency – Is a measure of the effectiveness of the heat exchanger of the boiler. It measures the ability of the boiler vessel to transfer heat from the combustion process to the water or steam in the boiler. It usually excludes radiation and convection losses and is not a true indication of the boilers fuel usage.

Boiler Efficiency – Is a term, which needs to be defined before being used, as it may represent different measures of efficiency.

Fuel to Water/Steam Efficiency – Is a measure of the **overall efficiency** of a boiler. It accounts for the effectiveness of the heat exchanger as well as the casing radiation and convection losses. The measurements compare the heat input from the fuel with the heat output, taking into account the flue losses and the radiation and convection losses. **This gives a true measure of the boiler efficiency** and is the basis of the efficiencies claimed by European manufacturers in their literature.

It is normal for European Manufacturers to quote net efficiencies. To convert net efficiencies to gross efficiencies the following factors may be used.

Natural Gas: 0.902 (10.7%) Diesel oil: 0.938 (6.6%) Heavy oil 0.944 (6.0%)

These figures may vary in accordance with the varying hydrogen/carbon make up of fuels from different sources.

Fuel Consumption

The fuel consumption of a boiler can be simply calculated:

Fuel Consumption = Boiler Input / Net Calorific Value of fuel

The boiler input is typically in kW (kJ/s). The net calorific value is typically MJ/m³ for gaseous fuels and MJ/kg for liquid fuels, therefore a conversion must be made to standard units.

- For Natural Gas, this is reported in m³/h.
- For LPG, this is reported in kg/h.
- For Diesel Oil, this is reported in L/h.

As an example, a 1000kW output steam boiler at 90% net efficiency will have a net input of 1111kW. Therefore fuel consumption will be as follows:

- NG (1111/34000)*3600 = 117.6m³/h
- LPG (1111/46100)*3600 = 86.8kg/h
- Diesel (1111/35700)*3600 = 112L/h