GAS CONDENSING TECHNOLOGY

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Abstract

Hoval has realized the condensing technology with the condensing boilers UltraGas®. The construction of the UltraGas® is a single pass boiler and the flue gas side components in the inside of the boiler are made out of stainless steel. The UltraGas® is available at a capacity range of 50kW to 650kW as a single unit and from 250kW to 1300kW as a twin unit boiler. The design with the down firing premix burner and the vertical aluFer® tube construction is to achieve a self cleaning effect. The principal item of the UltraGas® construction is the Hoval patented aluFer® heat exchanger with the extended heating surface design. The Ultraclean® premix burner is made of high temperature resistant Fecralloy metal fibre and the girder is made of stainless steel. The combustion of the homogeneous gas air mixture is almost flameless. The solid body radiation of the burner surface cools the flame and enables extremely low emissions. Essential factors for the production of the carbon dioxide are the carbon to hydrogen ratio of the fuel and the CO₂ production of oil- and gas boilers depends on the used technique too. Condensing boilers show deeper CO₂ values clearly. In comparison to conventional boilers (values about 0.40 kg CO₂/kWh) oil condensing boilers have values down to 0.25 kg CO₂/kWh and gas condensing boilers down to 0.18 kg CO₂/kWh. In condensing technology the theoretical maximum of the nominal efficiencies are at oil 106.44 % and at gas 110.7 %. The standards in Europe are referring to the efficiency calculation of the net calorific value (Hₙ). Therefore these dubious efficiencies of over 100 % are reached. Normally, modern burners are operated over stoichiometry (approx λ 1.2). During the combustion CO₂ and H₂O as vapour develop. The nitrogen and the remaining oxygen leave the combustion almost without reaction. For condensing operation the following general conditions apply: high content of hydrogen in the fuel, high content of water vapours in the flue gas, low return temperature of the boiler and large heating surfaces. The task of the heat exchanger is to cool down the flue gas temperature from 1200° down to approx 40°C respectively 5 – 20K above return.

1 Carbon dioxide

An essential factor for the production of the carbon dioxide is the carbon to hydrogen ratio of the fuel, for example coal has a ratio of H/C = 0.5/1 and methane H/C = 4/1. Brown coal produces approx 0.4 kg CO₂/kWh, wood 0.36 CO₂/kWh, coals 0.33; oil 0.26 and natural gas 0.20 CO₂/kWh. If one considered the CO₂ production of oil- and gas boilers in dependence to the used technique, thus the following results:
An oil boiler, approx. 25 years old with an efficiency of $\eta_{\text{ges}} = 0.65$ produces about 0.40 kg CO$_2$/kWh, a gas boiler of the same age, same state ($\eta_{\text{ges}} = 0.65$) about 0.31 kg CO$_2$/kWh; conventional heating boilers for oil 0.29 respectively for gas 0.22 kg CO$_2$/kWh. Condensing boilers show deeper values clearly, oil condensing boilers have values down to 0.25 kg CO$_2$/kWh and gas condensing boilers down to 0.18 kg CO$_2$/kWh.

1.1 Nominal efficiencies

In condensing technology the theoretical maximum of the nominal efficiencies at oil are calculated with the ratio gross to net calorific values at oil (12.56/11.80 = 1.064) 106.44 % and at gas (11.14/10.06 = 1.107) 110.7 %. Another criterion simplifying the realisation of the condensing technology with gas is the higher condensation temperature (dew point) of gas than oil. That means, when cooling down the flue gas, the vapour (steam) starts to condensate and flows out as water, this effect starts at approx 56°C for natural gas and at 47°C for oil. If one represent the gross calorific value ($H_o$) and the calorific value graphically it is clearly shown what potential lies in the use of condensing technology. Respectively what energy can be transformed from the latent heat by using condensing technology. The standards in Europe are referring to the efficiency calculation of the calorific value ($H_o$). Therefore these dubious efficiencies of over 100 % are reached. If one looks at the different fuels and the ratio $H_o / H_u$ it becomes clear that the highest saving can be achieved (approx 11%) with methane and the condensing technology.

1.2 Chemical reaction

The chemical reaction during the combustion of natural gas is elementary the following: $\text{CH}_4 \Rightarrow \text{C} + \text{O}_2 \Rightarrow \text{CO}_2, \text{H}_4 + \text{O}_2 \Rightarrow 2 \text{H}_2\text{O}$. There is a very small amount of sulphur (<ca. 50ppm) in the natural gas, which reacts with oxygen to sulphur dioxide $\text{S} + \text{O}_2 = \text{SO}_2$ during the combustion. Theoretically, approx 9.5 m$^3$ air is needed for the combustion of 1 m$^3$ natural gas. This includes approx 2.3 m$^3$ oxygen. Normally, modern burners are operated over stoichiometry (approx $\lambda$ 1.2), resulting in an air surplus of 1.5 m$^3$. During the combustion CO$_2$ and H$_2$O as vapour develop. The nitrogen and the remaining oxygen leave the combustion
almost without reaction. The volume is substantially expanded by the combustion, from 12 m³ to 20 m³. After the cooling down of the flue gas the volume has shrunk to approximately the same volume as at the beginning.

1.3 Conditions of condensing operating

For condensing operation the following general conditions apply:

1. High content of hydrogen in the fuel. The higher the content of hydrogen, the higher the dew point temperature maximum.
2. The higher the content of carbon dioxide, the higher the water vapours content in the flue gas.
3. The return temperature should be lower than the dew point of the used combustible.
4. Very large heating surfaces result in low flue gas temperatures.

1.4 Construction of condensing boilers

Conventional boilers have flue gas temperatures between 140° and 190°C. Condensing boilers have temperatures only some degrees above the return. The task of the heat exchanger is to cool down the flue gas temperature from 1200° down to approx 40°C respectively 5 – 20K above return. The dew point of the flue gas depends on the value of CO₂, but also on the temperature of the boiler wall. If the boiler walls are colder than the dew point, the flue gas will be condensed on the boiler walls. Decisive for good condensation are very large heat exchanger surfaces and a low return temperature. As mentioned the dew point depends on the content of CO₂ in the flue gas. First one regards the lower diagram for natural gas. Typical settings for condensing boiler operating with natural gas are a CO₂ values between 7 – 10%. The most important criterion for condensing technology is the return temperature and the large heat exchange surface. In comparison between the low temperature boiler and the condensing boiler at the same operating conditions the efficiency increases approx 10%. If the conditions are changed to lower return temperature the efficiency is increased 5% in addition. The following rule of thumb can be applied: per 20 Kelvin lower flue gas temperature the efficiency is increased by 1%. By condensation of water vapour in the flue gas the latent heat is given to the heating water. (0.66 kWh/kg incurred condensates).
2 Hoval condensing boilers UltraGas®

The UltraGas® is a floor standing natural circulating gas condensing boiler without minimum water circulation requirements. The construction is a single pass boiler and the flue gas side components in the inside of the boiler are made out of stainless steel. The UltraGas® can be fired with natural as well as liquid gas. The premix Burner gets the right adjustment just through setting the gas valve. The counter flow heat exchanger is made out of aluFer® composite tubes. The UltraGas® is available at a capacity range of 50kW to 650kW as a single unit and from 250kW to 1300kW as a twin unit boiler.

2.1 Construction of the UltraGas®

As you see in the boiler cross section the stratification of the water volume is optimised. The design with the down firing premix burner and the vertical aluFer® tube construction is to achieve a self cleaning effect. A plastic condensate collector tub below the boiler body provides a safe draining of the condensate. The plastic – tub consists of PPS (Polypropylene – heavy – inflammable) and is of course absolutely corrosion resistant. The UltraGas® has a robust boiler design (large water volume), thus high resistance regarding calcification and sludge accumulation. No minimum water flow and simple hydraulic implementation. Furthermore it is not necessary to have a minimum water flow that makes the implementation in a hydraulic system very simple. The new aluFer® heat exchanger design provides an ideal solution for the demands of a condensing boiler and helps to recover the flue gas heat up to the physical limits.

2.2 aluFer® heat exchanger

The main item of the UltraGas® construction is the Hoval patented aluFer® heat exchanger with the extended heating surface design. It provides the ideal solution for the demands of a condensing boiler and helps to recover virtually all the latent heat of the flue gas. The aluFer® composite tube consists of an outer stainless steel (1.4571 – (316 Ti)) tube and an aluminium profile inside. The stainless steel tube is on the water side and the
aluminium profile on the flue gas side. Compared with stainless steel aluminium has a 10 times higher heat conductivity. The optimised design characteristics of the aluminium profile with its fins and its microstructures produces a very large heat transfer surface. On one side the microstructure produces the large heat surface on the other side it is liable for a turbulent flow pattern, which intensifies the heat transfer essentially. Through the vertical position of the tubes in the UltraGas® a self cleaning effect is achieved. By this self cleaning effect a reduction in boiler efficiency due to deposits on the heat transfer surface is avoided. The aluFer® tube is divided into eight flow channels by fins, which share the flue gas into turbulent flow in each channel and a hot core stream is avoided as a result of this physical effect.

2.3 Burner system Ultraclean®

The UltraGas® burner is a premix burner system and is called Ultraclean®. It has four main advantages in comparison to a conventional burner system:
- Ultra clean combustion
- modulating range 20-100%
- Ultra low noise emissions
- Very low consumption of electrical power

The Ultraclean® premix burner system is composed of five core parts, the venturi, the gas valve, the blower, the ignition and the burner cylinder. The blower sucks in the air through the venturi and produces also over pressure for the combustion. The venturi mixes gas and air in dependence of the entering velocity of the air. The UltraGas® premix burner cylinder is made out of high temperature resistant Fecralloy metal fibre and the girder is made out of stainless steel. The combustion of the homogeneous gas air mixture is almost flameless. The solid body radiation of the burner surface cools the flame and enables extremely low emissions. The flexible metal fabric prevents thermal stresses, resulting in a long lifetime of the Ultraclean®- premix burner.