**The Concept of Condensing Boilers**

**ENERGY SAVINGS AND ENVIRONMENTAL COMMITMENT**

Energy conservation is becoming a global necessity in the face of depleting natural resources. As a result, the technology of condensation is emerging as a powerful heating option that promotes a more rational use of energy.

Condensation is simply the change of state from vapor to liquid, producing heat that can then be re-directed into a heating system. This economical heating method provides average savings in fuel consumption of 35% compared to traditional heating systems. It also provides emission savings reaching 90% CO and 80% NOx.

Condensing boilers put important sources of energy to use that a traditional boiler would normally lose through the flue. For instance, using condensing technology with a central heating boiler eliminates two restrictions on a traditional boiler, namely:

- The need to avoid condensation of the steam generated by combustion; the condensate is acidic and incompatible with components of a traditional boiler.
- The need to maintain a high temperature differential between the flue temperature and the outside air temperature; this allows combustion products to be discharged in traditional open-flue boilers.

**THE PROCESS OF COMBUSTION**

To understand the concept of condensation, it is important to be familiar with the chemical dynamics of the combustion of hydrocarbons. Combustion is a chemical reaction with heat generation, between a fuel such as methane (CH₄) and a comburent such as oxygen (O₂). The formula for the process of combustion is:

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + \text{HEAT} \]

The products of this reaction are carbon dioxide (CO₂), and water (H₂O) in the form of steam. The water absorbs the majority of the heat generated by combustion; this causes it to change state from liquid to steam, and it is exhausted with the high temperature flues. To burn one cubic meter of methane requires ten cubic meters of air. This combustion produces 1 cubic meter of carbon dioxide and 2 cubic meters of steam.

Combustion also produces polluting emissions, such as nitrogen oxide (NOₓ) and carbon oxide (CO). The nitrogen oxide is produced because of the high temperature of the combustion process, and the chemical composition of air (approximately 21% oxygen and 79% nitrogen). Carbon oxide forms because of the lack of oxygen in the combustion process.

In a traditional boiler, the flue gases exit at a temperature of more than 120°C/248°F. In a condensing boiler, the flue gases exit at much cooler temperatures (i.e., between 50°C/122°F and 80°C/176°F). In order to condense the gases in the venting, the flue temperature must be lower than the dew point temperature. At the dew point, the steam will condense into liquid form, causing it to release the energy (heat) that was previously absorbed in order to change from liquid to vapor. Lowering the temperature in the flues, therefore, can dramatically improve the combustion efficiency of a heating appliance.

It is important to note that the dew point temperature relies on the presence of carbon dioxide (CO₂) in the products of combustion. This allows the steam in the combustion flue to condense into water. Figure 1 shows the change in dew point temperature as the CO₂ content in the combustion flue increases.
As the percentage of carbon dioxide in the products of combustion increases, the dew point temperature increases. In the case of stoichiometrical combustion of methane (11.7% of CO₂ in the flues), the dew point temperature is 59°C/138°F.

The percentage of carbon dioxide in the products of combustion also relates to the excess air value. An increase of air in the combustion process decreases the percentage of carbon dioxide, with the consequent decrease of the dew point temperature, as shown in Figure 2.

LOWERING THE TEMPERATURE OF THE FLUE UNDER THE DEW POINT

To achieve optimal efficiency, the maximum amount of latent heat must be recovered from the flues. This requires condensing the exhaust gases, which, in turn, release the latent heat of vaporization of the water. In condensing boilers, this result can be achieved in the following ways:

- Increase the exchange surface area of the primary exchanger
- Decrease the temperature of the water going into the primary heat exchanger.

That is how a condensing boiler is able to reach a maximum efficiency. Figure 3 compares the typical efficiency values of a condensing boiler (A-B) to those of a traditional boiler (C) when functioning in the heat input mode.

The efficiency of a boiler is the ratio of the fuel energy input to the resulting heat output. The energy that is generated by one cubic meter of fuel is called the heating power. The science of thermodynamics has defined two types of heating power:

- **Superior heating power** (shp does not consider lost heat. This value represents the highest quantity of heat that can be supplied by 1 cubic meter of fuel...
• **Inferior heating power** \((ihp)\), which does consider lost heat.

For example, methane at 15°C/59°F and 1013 mbar gives:

\[ \text{shp} = 37.8 \text{ MJ/m}^3 (9024 \text{ kcal/m}^3) \]
\[ \text{ihp} = 34.0 \text{ MJ/m}^3 (8116 \text{ kcal/m}^3) \]

The difference between these values is roughly 11% for methane gas. By comparison, oil produces a value of 6%. Historical reasons (e.g. locomotives, conventional thermal plant, etc) and regulatory issues (e.g. the 94/42 CEE directive) prescribe that the estimate of the efficiency has to be referred to the inferior heating power. This is because it was previously impossible to exploit the residual heat retained by water vapor that went out through the vent. It is now possible to use superior heating power with a condensing boiler.

If superior heating power were to replace inferior heating power, Figure 3 would be revised to look like Figure 4.

![Figure 4: Comparison of the efficiencies of a condensing boiler and a traditional boiler, using superior heating power](image)

For example, the condensate amount generated by a condensing boiler at a flow temperature of 80°C/176°F is very small. With a 40°C/104°F flow temperature (as the maximum heat output), the boiler generates an average of 2.4 ltr/0.6 US gal of condensate per hour. The condensate that is generated is acidic with a pH reading between 3 and 5 -- an equivalent level of acidity found between vinegar and clean rainwater. The dilution of the condensate with domestic wastewater increases the pH to neutral values (about 6.5).

![Figure 5: pH level of condensate from gas condensing boilers](image)

The condensate is discharged to the drainage system through a siphon, a useful device to ensure the products of combustion do not follow the condensate discharge. According to laws in many European countries, the water level inside the siphon has to be equal to the amount of the maximum fan pressure (inches of water column), measured inside the combustion chamber, plus 25 mm/0.9" as a safety margin. All BAXI condensing boilers have a safety margin of 100mm/4" for the water level in the siphon.

![Figure 6: Condensate discharge siphon](image)
The condensate contains traces of pollutants (e.g., heavy metals, acids, etc.) deriving from the air, the fuel, and the metals used in the construction of the burner and the primary exchanger. For this reason, countries where condensing boilers are most prominent (the Netherlands, Germany, U.K., Austria, and Scandinavian countries) have set limits on the presence of these elements in the condensing water. BAXI manufactures its condensing boilers to meet these strict standards.

EMISSIONS

Condensing technology effectively reduces the emission of pollutants into the environment. This is accomplished through efficient control of the air/gas mixture, which minimizes surplus air. In this way, the amount of nitrogen oxides produced by the combustion process is decreased because air contains a high percentage of nitrogen.

European classification for gas boilers (EN297 for B type boilers and EN483 for C type boilers) involves five categories, differentiated according to the production of nitrogen oxides (NOₓ). BAXI condensing boilers have the highest rating -- in the Class 5, involving the lowest NOₓ emission.

<table>
<thead>
<tr>
<th>NOₓ Class</th>
<th>NOₓ emission limits in mg/kWh</th>
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<tbody>
<tr>
<td>1</td>
<td>260</td>
</tr>
<tr>
<td>2</td>
<td>200</td>
</tr>
<tr>
<td>3</td>
<td>150</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>70</td>
</tr>
</tbody>
</table>

Figure 7: Categories of gas condensing boilers

BAXI CONDENSING TECHNOLOGY

For BAXI high-efficiency boilers, condensing technology is designed to achieve average efficiency values up to 98% (calculated according to DIN 4702-T8). This level of performance is a testimony to the quality of the heat exchanger, the stainless steel burner (with a radial flame), and the modulating system (that mixes air and gas, and maintains an optimal relation between the two elements according to the heat output change). All of these components allow BAXI boilers to achieve the best performance with respect to high operating efficiencies as well as low emissions.

If used in low temperature heating systems, the boilers can achieve fuel consumption savings of 35% and more, when compared to traditional heating systems. This saving is directly related to the average return temperature -- the lower the return temperature, the higher the efficiency of the system.

The heat recovery operation is enhanced by the work of an advanced microprocessor with a double central processing unit (CPU) that features the ability to:

- Make an advance diagnosis through a control system for the working of all the internal components before and during use
- Communicate with the user via the QAA73 controller, where the working parameters and set values may be read
- Regulate the boiler’s internal parameters and the desired temperature values by using the buttons on the control panel; once these values are set, the boiler uses its own advanced system to optimize its operation
- Connect to the boiler and manage a series of external accessories, specified on the following pages, with the aim to optimize fuel consumption and comfort.
CHARACTERISTICS OF BAXI CONDENSING BOILERS

BAXI condensing boilers are state-of-the-art appliances, featuring:

- A self-check automatic control system;
- Innovative electronics and software, including double CPU microprocessor ensuring the highest boiler efficiency optimization;
- Thermoregulation accessories for a full range of installations;
- High quality components, made with the most corrosion-resistant materials to guarantee long-lasting reliable operation of the boiler.

At present, here are only two different casings for the BAXI HT range of boilers:

- 30"Hx18"Wx13"D for heating only/combination boilers up to 135,000 BTU heat output
- 37"Hx24"Wx18"D for storage boilers and heating only above 113,000 BTU output

All BAXI models have a sealed combustion chamber, creating hermetic combustion with respect to the installation room. Flue exhaust is created by means of a modulating fan through suitable ducts, which could be:

- Coaxial systems 60/100 mm (2.4”/3.9”) for boilers up 113,000 BTU heat output
- Coaxial systems 80/125 mm (3.2”/4.9”) for boilers above 113,000 BTU output
- Dual flue systems 80/80 mm (3.2”/3.2”)

BAXI condensing boilers above 113,000 BTU output are certified for B type installation, meaning in-take air may come from the installation room, requiring only an exhaust duct. BAXI venting includes special accessories cascading of up to three boilers above 113,000 BTU heat output. Venting for condensing boilers must resist the formation of condensation; because of the low temperature of the products of combustion, polypropylene or treated aluminum may be used instead of stainless steel.

In the primary heat exchanger (see Figure 9), heat is transferred into the central heating water. This exchanger is made of a nickel-chrome stainless steel (AISI 316 L) with high resistance to corrosion. The exchanger is made of ring-shaped coils; the central heating water flows inside the coils while the stainless steel burner heats the external surface of the exchanger. In the rear section of the exchanger, the combustion products are cooled to reach the dew point and condense. The condensate is drained through a collector positioned on the bottom of the exchanger. The combustion chamber is included in the primary exchanger casing; this minimizes radiation losses.

The pre-mixing system includes a modulating fan and a calibrated Venturi. This system maintains an optimum air/gas ratio, regardless of the boiler’s heat output. The gas valve allows a 1:1 gas/excess air ratio, operating in conjunction with the pressure reduction created by the fan. As a safety precaution, should the pressure signal be lost in the event of a flue duct obstruction or fan failure, the gas valve will shut off immediately.
storage tank in the Modulo is made of stainless steel; this system reduces waiting time and meets immediate demand for hot water. The Modulo is ideal for system applications involving hydro massages, baths, or multi-jet showers.

**BAXI Luna HT Sequence of Operation**

### CENTRAL HEATING (CH) MODE

Central Heating mode is initiated by a demand for heating conveyed from a room thermostat, a remote controller or a programming timer. This causes the three-way valve to switch to the CH circuit, causing the pump to circulate water through the primary circuit, as shown in Figure 11. At a predetermined pressure and flow rate the central heating differential pressure switch operates, allowing the fan to start the pre-ventilation sequence. The fan speed is detected by a Hall sensor and electronics assure that the fan speed is correct. The length of the pre-ventilation sequence

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**Figure 10: Pre-mixing (air/gas) system**

**LEGEND**

- \( \text{Pa} \)  Air signal pressure
- \( \text{Pc} \)  Mixing chamber pressure
- \( \text{PIN} \)  Inlet gas pressure test point
- \( \text{PINT} \)  Outlet pressure test point
- \( \text{POUT} \)  Additional outlet pressure test point (version with gas/air ratio adjuster)
- \( \text{Pa-Pc} \)  Pressure drop across air restrictor
- \( \text{PINT-Pa} \)  Pressure drop between outlet gas pressure and air signal

During operation conditions, when gas valve is open this is called “offset”.

Combination Central Heating (CH) and Domestic Hot Water (DHW) models include a separate secondary heat exchanger made of stainless steel plates; this compact solution ensures a rapid heat exchange and a high efficiency. The secondary DHW exchanger has a wide exchange surface in order to permit the boiler to operate with a lower temperature in the primary circuit and maximize condensation during DHW production.

The combination boiler has a built-in electronic three-way valve for models up to 113,000 BTU heat output. The Baxi Luna HT boilers have built-in electronic anti-freeze protection. The pump will operate automatically and the burner will light when the temperature in the boiler drops below 5°C/41°F.

Heating-only models also have a built-in three-way valve; that allows a fast and easy connection to be made to an indirect storage tank, such as the Modulo. The insulated DHW...
varies according to the operational conditions.

At the end of the pre-ventilation period, the ignition sequence is activated. The fan increases speed, the gas valve opens, and a spark is generated at the ignition electrode for about 5 seconds (for three attempts). If the lighting of the burner is successful and the flame-sensing electrode detects the flame, the burner output is adjusted to maintain the set temperature.

Depending on the difference between the set temperature and the real temperature measured by the Heating Negative Temperature Coefficient (NTC) sensor, the boiler works at a certain output and modulates through a Proportional Integral Derivative (PID) controller. At the end of the heating demand, the burner goes out, the fan continues to run for 10 seconds and the pump continues to operate for 3 minutes.

**DOMESTIC HOT WATER (DHW) MODE**

Domestic Hot Water production always has priority with respect to Central Heating demands. When a hot water tap opens, the DHW flow sensor operates and the three-way valve prioritizes to the DHW loop. At the same time, the pump circulates water through the primary circuit. At a predetermined pressure and flow rate, the central heating differential pressure switch operates, allowing the fan to start the pre-ventilation sequence. A Hall Sensor detects the fan speed, and electronics assure the fan speed is correct.

At the end of the pre-ventilation period, the ignition sequence is activated. The fan increases speed, the gas valve opens, and a spark is generated at the ignition electrode for about 5 seconds (for three attempts). If the lighting of the burner is successful and the flame-sensing electrode detects the flame, the burner output is adjusted to maintain the set temperature.

Depending on the difference between the set temperature and the real temperature measured by the DHW NTC sensor, the boiler works at a certain output and modulates through a PID controller. (Note: The CH NTC sensor is still functioning during this process.) When the hot water tap is turned off, the burner goes out, the fan continues to run for 10 seconds and the pump continues to operate for 50 seconds.

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*Figure 12: Domestic Hot Water mode*
BAXI LUNA HT FEATURES

MODULATING GAS SYSTEM
- Gradual automatic ignition and continuous flame modulation
- Modulating gas valve with pneumatic air/gas ratio controller
- Modulating fan
- Stainless steel AISI 316L premix gas burner
- Spark generator
- Ignition and flame sensing electrodes

HYDRAULIC SYSTEM
- Stainless steel AISI 316L primary exchanger
- Stainless steel plates DHW exchanger (combination models)
- Electric three-way valve
- Circulating pump with built-in automatic air vent
- Built-in automatic by-pass
- Pressure relief valve on heating circuit operating at 30 PSI
- Built-in Central Heating expansion vessel
- CH circuit filling and draining taps
- Connection to indirect cylinder option (heating-only models)

TEMPERATURE REGULATION SYSTEM
- Heating temperature range from 25 to 80°C (77 to 176°F)
- Domestic hot water range from 35 to 60°C (95 to 140°F) in combination models
- Remote controller BAXI by Siemens option
- Outdoor sensor option
- Installation with mixing valve option
- Cascade system installation option

CONTROL AND SAFETY SYSTEM
- Digital boiler programming, setting and control
- Electronic temperature control by NTC sensors
- Self-diagnostic automatic control system
- Safety thermostat to protect the primary exchanger from overheating
- Flue thermostat to protect the boiler from excess vent temperatures
- Flame sensing electrode to assure the safe cut-off of the gas valve (in the case of lack of gas or ignition problems)
- Differential pressure switch to prevent boiler operation in the event of low water or seized pump
- Pump overrun to reduce residual thermal inertia in the primary heat exchanger
- Anti-frost protection on both the CH and DHW circuits
- Pump and three-way valve anti-sticking system operating every 24-hour time period without heating demand
- Radio interference filtering system

ACCESSORIES (included in package)
- Gas shut-off valve
- Domestic cold water intake valve with filter
- Heating flow and heating return valve with filter
- Swedged copper pipe connections
- Fixing screw and plugs
- Wall template

FROST PROTECTION MODE
Built-in frost protection functions if the CH or DHW circuit temperature falls below 5°C/41°F, the boiler will heat at its minimum setting until a flow temperature of 30°C/86°F is reached. If the burner does not light after an interruption of the gas supply, the pump circulates as a freeze protective measure. Frost protection operates only if the boiler has a sufficient supply of gas and electricity.

PUMP PROTECTION
In the event that there is no need for heat for the central heating system or the DHW system for 24 consecutive hours, the pump will automatically run for 10 seconds so long as the power is on.

THREE-WAY VALVE PROTECTION
If there is no heat demand for a period of 24 consecutive hours, the three-way valve automatically opens and closes so long as the power is on.