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Raising the efficiency of boiler installations

Deliverable 2.2: Definition / Glossary of relevant terms

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Contents

DELIVERABLE OBJECTIVES

The general objective of work package 2 is to gather and condense information on existing boiler installations.

The particular aim of deliverable D2.2 is to compile a glossary with the most relevant terms related to boilers, such as annual energy use efficiency, flow rate, feed temperature and heating value. The target group of this document are installers and boiler manufacturers.

Furthermore, this deliverable not only provides the definitions of some of these specific and technical concepts, but also gives an explanation about other general questions connected to the field of boiler installations and their related components: types of boilers and characteristics of each one, types of control systems and their components, pipe system, etc.

GLOSSARY

1 Boiler

A boiler is an appliance designed to produce hot water for space heating (and in some cases also for domestic hot water preparation) through the combustion of a fuel.

There are many boiler categories and definitions according to the existing EU product and building standards. Next, the main principles of categorisation will be explained:

1.1 Fuel type

According to the fuel type, we can distinguish between:
- Gas-fired boilers
- Oil-fired boilers
- Coal-fired boilers (very reduced market)
- Biomass boilers (wood logs, wood pellets, hay, peat)
- Electric boilers (electric resistance boiler, "Joule effect" boilers)
- Solar-assisted boilers (Solar collectors are mostly used for domestic hot water preparation, but they can also contribute to space heating in a bivalent system)
- Heat pump water heaters (they can be used for air heating and cooling but also for water heating in central heating systems)

1.2 Functionality (output)

It refers mainly to the ability of the boiler to provide hot sanitary water. In that sense the following classification applies:

1.2.1 Regular boiler

A boiler which does not have the capability to provide domestic hot water directly. It may nevertheless provide domestic hot water indirectly via a separate hot water storage cylinder. [1]

1.2.2 Combination boiler ("combi")

A boiler with the capability to provide domestic hot water directly, in some cases containing an internal hot water store. We can distinguish between:
- Instantaneous combination boiler → Without internal hot water store
- Storage combination boiler → With internal hot water store [1]

1.3 Storage configuration and capacity

Boilers can have a storage facility for
- Primary store of CH[1]-water
- Secondary store of Domestic Hot Water

[1] CH = central heating

In general, storage facilities are used to solve a mismatch between heat input and heat output. For primary stores the mismatch may be that the heating system requiring a continuous or semi-continuous heat at a lower power level than the burner can provide. For secondary stores the mismatch is between a user that requires instantaneous hot water and a burner plus exchanger that require some time to heat up or that may not be powerful enough to provide the required hot water comfort.
A second function of buffers may be in bivalent systems, where the output of multiple heat generators (e.g. solar and gas) with different characteristics are brought together to provide a single output performance.

1.3.1 Primary store of CH-water

Primary store combi-boilers can roughly be subdivided into:

- No primary store (water content of heat exchanger smaller than 5 l.)
- No primary water storage tank, but merely a boiler with high water content and/or mass
- Integrated thermal store → Is designed to store primary hot water, which can be used directly for space heating and indirectly for domestic hot water.
- Hot water only thermal store → Is designed to provide domestic hot water only and is heated by a boiler.
- Combined primary storage unit (CPSU) → A single appliance designed to provide both space heating and the production of domestic hot water, in which there is a burner that eats a thermal store which contains mainly primary water which is in common with the space heating circuit.

1.3.2 Secondary store of Domestic Hot Water

Secondary store options are:

- No secondary store (“instantaneous combi-boiler”) → In the instantaneous boiler the sanitary hot water is led through a coil that is heated directly by the burner.
- Keep hot facility → Facility in an instantaneous boiler (<15 litres) whereby water within the boiler may be kept hot while there is no demand. The water is kept hot either solely by burning fuel, or by electricity, or both by burning fuel and by electricity, though not necessarily simultaneously. Its function is to realize short waiting time.
- Instantaneous storage combi → The storage tank of this storage combination boiler may be any size. The sensor is placed near the cold water inlet and with (almost) every draw-off results in burner action to keep up with the hot water demand.
- Non-instantaneous storage combi → The storage tank of this storage combination boiler may be any size but is usually from 45 litres onwards. This storage combi is not triggered immediately by the hot water demand, whereby the water is heated when it is most convenient/efficient for the heat source.

1.4 Water heater flue gas

This classification only applies to gas-fired appliances (dedicated water heaters and combi-boilers). The classification is characterised by one letter (B or C) and two digits (Bxx or Cxx).
Both *Type B* and *Type C* use a chimney for the flue gases, but:

- *Type B* boilers take the combustion air from the indoor water heater room
- *Type C* boiler take the air from the outdoors

With *Type B* there is an open connection between the burner and the inside of the house (“open system”), whereas Type C is “room-sealed”.

With *Type B* appliances the first digit indicates whether or not the flue gas duct is precede by a flue gas damper. With *Type C* appliances the first digit indicates the configuration of the air intake and flue gas ducts.
The second digit indicates the presence and the position of the combustion air/flue gas fan.

1.5 Burner flue gas

For burners, the EN standards distinguish between:

1.5.1 Forced-draught boilers

The air intake is regulated by a fan located before or after the burner.

1.5.2 Atmospheric boiler

The air intake is not fan assisted. The burner attracts the required quantity of air from its surroundings and only the quantity of gas is regulated.

1.6 Condensation

Depending on the total heat exchanger surface, the resistance to corrosion and the resistance to certain temperatures, the heat exchanger can technically be seen as standard, low temperature or condensing.

1.6.1 Standard boiler

In standard boilers, the average water temperature can be restricted by design. [1]

1.6.2 Low temperature boiler

Low-temperature boilers operate with infinitely variable temperature control. As a result, they operate with distinctly lower heating water temperatures than used to be the case with constant-temperature boilers.
Since the flue gas loss and the heat loss through the boiler surface are distinctly lower, these low-temperature boilers achieve standard efficiency values of 92 % to 96 %.[3]

1.6.3 Condensing boiler

A boiler designed to condense permanently a large part of the water vapour contained in the combustion gases. [1]
A condensing boiler operates with infinitely variable temperature; unlike conventional boilers, it additionally utilizes the condensation heat contained in the flue gas. The condensing boiler cools the flue gases so that the water vapour contained in the flue gas condenses. The heat liberated in the process is used for heating purposes. Gas-fired condensing boilers achieve standard efficiency values of up to 110 %. [3]

1.7 Burner power control system

1.7.1 ON/OFF boiler

A boiler that only has a single fuel burning rate for space heating. This includes appliances with alternative burning rates set once only at time of installation, referred to as range rating. [1]

1.7.2 Modulating boiler

A boiler with the capacity to vary the fuel burning rate whilst maintaining continuous burner firing. [1]

1.8 Power class (residential/commercial)

For gas- or oil-fired boilers (including combi-boilers) the classification according to boiler power class may be relevant:

- The EN standards distinguish between <70, 70-300, 300-1000 kW and 1MW.
- The boiler efficiency Directive distinguishes between a class of 4-400 kW and above 400kW.
- Market statistics distinguish between “residential” and “commercial”, whereby the exact split varies per country.

1.9 Burner/water heater configuration

The EN standards make a distinction between:

- Burner / boiler assembly → There are different requirements for the jet burner and the assembly of boiler body plus burner.
- Integrated boiler → The burner is not sold/ tested separately.

1.10 Mounting position

In market statistics there can be a distinction between:

- Floor-standing
- Wall-hung water heaters and combi-boilers

Wall-hung boilers are typically lighter (30-60 kg), whereas floor-standing boilers typically weigh over 100 kg.

1.11 Ignition type

- Electronic (through glowing plug or spark plug)
- Pilot flame (almost extinct in new boilers)

1.12 Materials

A classification can be:
- Steel / iron
- Copper
- Aluminium

The EN standards give a more specific range of materials to be used, but this is not normally used for classification.

2 Heating surfaces

The heating surfaces are the components of the heating system where the heat is released to the room. The quantity of energy which is released by a heating surface depends on the surface, the temperature difference between the heating surface and the room temperature, the design of the heating surface, etc.
The heating surfaces can be:
- Radiators
- Convectors
- Panel heating (Floor heating, ceiling heating, wall heating)

3 Control system

The purpose of the heating control system is to ensure that each room is heated in accordance with individual requirements. Depending on the configuration, it can control one or more heating circuits with different feed and return flow temperatures. It can also coordinate the production of hot water or the incorporation of additional heating systems, such as a solar thermal system, into the existing heating system. [3]

3.1 Type of control

3.1.1 Room-temperature-based control (thermostat valve control)

According to the room temperature, the thermostat valve is open or close in order to maintain the room temperature at the selected set point. [2]

3.1.2 Control based on outside temperature (feed temperature control)

Depending on to the outside temperature, a specific feed temperature will be required (the hotter the outside temperature, the lower the feed temperature). The control system has to maintain the feed temperature at the selected set point with the help of a sensor located in the heating water.

The relationship between momentarily prevailing outside temperature and the feed temperature to be selected is reflected in the heating characteristic set on the controller. [3]

3.1.3 Control based on pressure head of the circulation pump

This type of control permits to adequate the pump power to the heating needs.
If the heating loop requires less heating water (for example because the sun supply a part of the required heat in a room), the pump can be operated with less electrical energy to adapt the quantity of heat supplied to the need of the room. [2]

3.1.4 Control based on return temperature

The return temperature control (RTC) is designed to provide an economical and effective means of boiler protection from thermal shock and sustained condensing operation. The RTC monitors the boiler return water temperature and operates a three-way diverting valve and boiler circulator to maintain a minimum return temperature or greater. Not all the boilers require this type of control.

3.1.5 Clock controlled / control based on schedule

The Boiler Control System incorporates a microprocessor based design and provide the operating control function of the boiler system and modulation control of fuel and combustion air as well as the firing rate motor to meet system demand.

3.2 Boiler water temperature control

- Fixed (manual setting at installation) within a certain bandwidth, on/off controlled by the room thermostat. For rooms without room thermostat, the temperature control may be supplemented by thermostatic radiator valves or separate electronic systems with or without optimiser.
- Modulating (systems with room compensator) → PID-type of control on a special modulating room thermostat. The room thermostat is usually typical for a brand. For rooms without room thermostat, the temperature control may be supplemented by thermostatic radiator valves or separate electronic systems with or without optimiser.
- Weather controlled (systems with “weather compensator”) → An outdoor sensor is setting the operating point for the boiler temperature, along a curve (set at installation) that is typical for the lay-out and type of heating system. This system is often combined with thermostatic radiator valves or separate electronic systems with or without optimiser.

3.3 Burner combustion control

Burner combustion control in principle applies to all fossil fuel fired boilers and combi-boilers.
The following types can be distinguished:

- Forward control loop → "Pneumatic control" whereby the air-fuel ratio is determined with the venture principle. Air factor is determined by a gas flow rate. This is the most common today.
- Backward control loop → The air factor is determined on the basis of the combustion (ionisation sensor) and/or the combustion products (e.g. CO sensor).
- Forward & backward control → Based on a combination of the above.

3.4 Control temperatures

3.4.1 Boundary heating temperature

It is the outside temperature under which the heating system has to be switched on in autumn and over which it has to be switched off in spring.
In other words, it is the boundary value of the outside temperature over which the building does not need to be heated any more since the useful heat gains are enough to compensate the heat losses of the building. [4]
A typical value is 15ºC. But the boundary heating temperature of a building depends on many factors like for example the building thermal insulation, the heat gains (sun, persons, etc.)

3.4.2 Feed temperature

The feed temperature is the temperature of the heating water which flows from the heat generator to the radiators. [3]

3.4.3 Return temperature

The return temperature is the temperature of the heating water which flows from the radiators back to the heat generator.

3.4.4 Temperature level

The temperature level of a heating system is obtained in a simplified way as the average temperature in the heating pipes of the whole heating system.
In the feed pipes from the heat generator to the radiator, the temperature is almost the same in the whole heating loop. In the return pipes from radiators to heat generator, the temperature is generally differing from one point to the other, depending on the quantity of heat which has been released in each radiator.
The temperature level depends on the heating system: in floor heating systems, the required heating temperature is much lower than in case of radiators. It also depends on the outside temperature: if the outside temperature is higher, the temperature level is lower (this change is made by the control system). [2]

3.5 Components of the control system

3.5.1 Differential-pressure controller

It is an optional module of a heating system which can be integrated in the installation when the feed pressure has to be maintained constant in the system in order to have a uniform heating water and heat supply.
This element is often added later if the existing pump produces too high pressure and can not be replaced by another smaller one. [2]

3.5.2 Thermostat valve

Thermostat valves are the controllers of the radiators. They work without electricity supply.
They are composed of 2 parts: the valve base (generally in metal) and the valve head with read-out graduation (generally from 1 to 5).
Thermostat valves permit to select a set point for the room temperature and to maintain this temperature nearly constant by regulating the heating water flow into the radiator. [2]

3.5.3 Presetting device

A presetting device is an optional element of a heating system which can be integrated in the thermostat valve.
It permits to pre-set the regulation of the heating water inflow and thus of the heat flow in the radiator. In this way, it allows to adapt the power of a radiator to the room and its use.
Return screw connection is an alternative to presetting (see bellow). [2]

3.5.4 Return screw connection

A return screw connection can be located on the return pipe of a radiator, where the heating water is conducted back to the heat generator.
Like a presetting system, it permits to regulate the power of a radiator by regulating the heating water flow through the radiator. But unlike the presetting system which is located on the feed side of the radiator (in the thermostat valve), the return screw connection is located on the outflow side of the radiator.

3.5.5 Heating curve

It is the part of the regulation of a heating system which permits to adequate the heating water temperature to the outside temperature.
It is an electronic module indicating which heating water temperature is appropriate according to the outside temperature. If the weather is very cold outside, the heating water which is dispensed to the building has to be hotter than the case when the outside weather is warmer.
The heating curve has to be adjusted during the installation of the heating system by the installer, who sets the maximum required feed temperature in case of extremely cold weather after this temperature has been determined by a calculation. [2]

4 Efficiency

4.1 Boiler efficiency

The boiler efficiency indicates the percentage relation between the useful thermal energy produced and the energy consumed in a defined operating point according to a standardised measuring system. The standard efficiency enables a comparison between different boiler types and between the products of different manufacturers. [3]

4.2 Boiler seasonal efficiency

Seasonal operating efficiency is the ratio of the total seasonal heat output actually used by the facility to the total seasonal fuel input. This efficiency is dependent on the boiler's steady-state efficiency, standby losses, and cycling losses, all of which constitute the *Total Seasonal Input*. [5]

Seasonal efficiency = Total Useful Seasonal Output / Total Seasonal Input

Theoretically, it could be determined by the integration over the time of instantaneous efficiencies obtained during a whole period of boiler working (a period of heating). In practice, many methodologies have been proposed to measure and estimate the boiler seasonal efficiency. According Annex E of prEN 15378, the available methods are:

- Database reference
- Default tables
- Boiler directive data
- Boiler cycling method
- Total stand-by losses method

4.3 Efficiency of the boiler installation

The efficiency of a boiler installation consider the efficiency of each one of the components of the heating system: boiler, piping, heating surfaces to evaluate the effective efficiency of the complete installation. It is the percentage relation between the useful heating energy supplied to the rooms and the energy consumed.

4.4 Seasonal efficiency of the boiler installation

It is the percentage relation between the useful heating energy supplied to the rooms and the energy consumed over a whole period of heating.

4.5 Losses of the boiler installation

The following losses occur in a heating system:

4.5.1 Flue gas losses

The flue gases which are produced by the combustion present a higher temperature than the intake combustion air and thus have an higher heat content which has been extracted from the fuel. Additionally, the flue gases content unburnt gases which have been exhausted without releasing its energy contents.

4.5.2 Boiler losses

The boiler losses include:

- Radiation, convection and piping losses.
- Internal losses.

4.5.3 Transport losses

These losses of heat are due to the transport or distribution of the hot water to the final users through the distribution net.

4.5.4 Stack losses

Stack losses represent the heat in the flue gas that is lost to the atmosphere upon entering the stack. Stack losses depend on fuel composition, firing conditions and flue gas temperature. They are the total of two types of losses: Dry Flue Gas Losses – the (sensible) heat energy in the flue gas due to the flue gas temperature; and the Flue Gas Loss Due to Moisture – the (latent) energy in the steam in the flue gas stream due to the water produced by the combustion reaction being vaporized from the high flue gas temperature.

4.5.5 Losses from poor insulation

Heat losses due to a poor insulation in any point of the heating system: boiler, pipes, valves, etc.

4.5.6 Stand-by losses

Standby losses account for thermal energy lost from the boiler while the equipment is in a non-firing or standby mode. Although this energy may provide heat for the mechanical room in indoor installations, it is otherwise lost from the system. The amount of standby loss is primarily dependent upon three factors; system to ambient differential temperature, boiler design, and boiler operating practices.

4.6 Calorific value

The calorific value is the heat per unit mass produced by complete combustion of a given substance. Calorific values are used to express the energy values of fuels; usually these are expressed in mega joules per kilogram

4.6.1 Net calorific value

The net calorific value indicates the amount of heat that is released when the fuel is burned without taking into account the heat that is released as water vapour together with the flue gases. [3]

4.6.2 Gross calorific value

The gross calorific value indicates the amount of heat that is released when the fuel is burned, including the heat contained in the flue gases (so-called condensation heat).[3]

5 Piping

The heating system piping includes all pipes installed for the heat supply of the building. They are filled with heating water.

Layout of the pipe network: the hot water which is produced by the heat generator flows in a broad main pipe. The main pipe is then divided in several secondary pipes (horizontal distribution, generally in cellar). Afterwards the up-stream pipes raise the heating water in the different storeys. Finally, from the up-stream pipes, there are additional derivations to the different radiators.

Feed pipes are all pipes which conduct heating water to the radiators. Return pipes conduct the heating water from the radiators back to the heat generator. Heating water is colder in return pipes than in feed pipes since heat has been released in the radiators. Generally, return pipes are installed parallel to feed pipes with the same network layout. [2]

6 Pumps

Pumps can be

- Autonomous (not integrated in the boiler and no link to the boiler control)
- Integrated in the boiler and thereby (also) controlled by the boiler-CPU

Furthermore, there is a distinction between pumps with:

- Variable speed
- Discrete speed steps
- Fixed speed (set at installation)

Variable and discrete speed pumps usually control the flow rate on the basis of the resistance in distribution and emitter system.

There is a voluntary energy efficiency labelling scheme by EuroPump for central heating pumps using the “A-G” rating and the basic lay-out of the EU Energy Label.

7 Pressure drop

The pressure drop corresponds to the energy losses due to friction.
Heating water which flows in the heating system continuously in closed loop, rubs against the inner walls of the pipes and other units like radiators, making that a part of the pressure energy is transformed in heat energy.

This pressure drop has to be compensated permanently by the pump: the heating water has the higher pressure energy when it leaves the pump. It losses about a half of the pressure energy in the radiators and when it enters the pump again, it has lost almost its whole pressure energy. [2]

8 Flow rate

It is the quantity of water which flows through a heating system (or a part of it: radiator, pump, etc.) during a given period of time. It is usually expressed in L/hr. [2]

9 Hydraulic balance

The hydraulic encompasses all problems and questions related to the heating water circulating in the heating system.
The hydraulic balance handles the following problem: By which technical measures the heating water can be conducted in a closed heating system so that each radiator receives the appropriate heating water quantity?
By nature, water chooses the way in the heating system with the lower resistance. Through long and thin pipes flows less water than through short and broad pipes.
Thus, the objective of the hydraulic balance is to conduct the appropriate quantity of heating water to each point of the building heating network, through the integration of bottle necks in the short and broad pipes. [2]

10 Circulation pump

It is a core piece of the heating system hydraulic. It is generally located in the cellar of the building, or can also be directly integrated in compact heating systems like wall-hung boilers.
With help of electrical energy, it moves the heating water in the heating system in a constant cycle.
The pump has the function of equalling the pressure losses (friction losses), to which the heating water is submitted while flowing into the heating system.

Circulation pumps can be classified according to the way it is controlled:

- Uncontrolled when it works at fixed speed
- Regulated when it works with discrete speed steps
- High efficient when it works with variable speed

Additionally, circulation pumps can be autonomous (not integrated in the boiler and no link to the boiler control) or integrated in the boiler and thereby (also) controlled by the boiler-CPU. [2]

11 Pressure head

It is a characteristic property of a pump.
With the help of electrical energy, the pump brings the heating water forward and at the same time loads it with pressure energy. This means that water will be pushed in the pipes with a given force.

The pressure raise which occurs in the pump is also called pressure head.
A pump will be chosen so that the pressure head (= possible pressure raise) is sufficient to push the water through the piping.
It is usually expressed in meters, where 1 meter pressure head corresponds to 0.1 bar pressure raise. [2]

12 Heat load

It is the heat power which is required by a room / house to be heated adequately.
It is an indicator of the range of heat losses of a room / house which have to be compensated by the heating system.
The heat load depends on the properties of the walls and the ventilation rate of each room. The design heat load is generally calculated for a low outside temperature and a typical inside temperature.
Results of the heat load calculation permit to determine the size and power of the radiators and heat generators. [2]

13 Heating period

It is the period during which the heating system is operating. [2]

14 Optimisation

The optimisation of a heating system consists in adjusting an (existing) heating system to the heating needs of the building.
This is carried out so that no energy dissipation occurs in the system, while maintaining normal comfort conditions.
Concretely this consists in limiting the heating water flow rate through the radiators and the pressure head to adequate values, as well as reducing the temperature in the piping to avoid excessive heat losses. [2]

15 Over sizing

Modules of a heating system are normally chosen so that they suit to the building and use (small buildings have smaller heat generators than huge buildings, big rooms with many windows have larger radiators, etc.)
This task to select the appropriately sized modules for the heating system is called sizing. It supposes a calculation of required size and power.

Over-sizing means that the heating system modules are too large for the intended use.
In case of radiators, this can happen for example if the exterior walls of a room are additionally insulated in a retrofit action. The radiator is then too large (has more power than necessary).

Over-sizing also happens in some cases just because no calculation has been realised (for cost reasons). In such cases, the modules are approximately selected

and usually it is considered that a too large module is always better as a too small one.
Oversized elements usually bring problems by operating the system and lead to energy wasting.[2]

SOURCES

[1] Eco-design Boilers, Task 1, Final

[2] Optimus project, Grundbegriffe und Grundlagen der Optimierung

[3] Glossary of heating technology terms:
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[4] http://www.bauwerk-verlag.de/baulexikon/index.shtml?HEIZGRENZTEMPERATUR.HTM

[5] Optimal boiler size and its relationship to seasonal efficiency:
http://www.energy.rochester.edu/efficiency/optimal_boiler_size.pdf

Project partners:

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