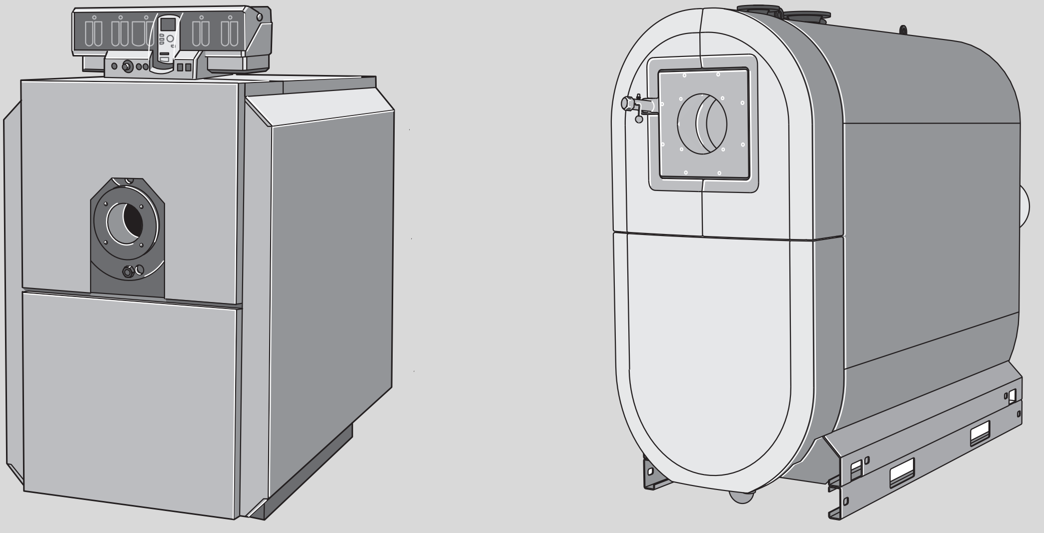
Operator’s log

Water quality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For heat appliances made from stainless steel with operating temperatures up to 100 °C

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About this document

This operator's log includes important information on the treatment of heating water for heat appliances made from stainless steel and combinations of different materials with operating temperatures ≤ 100 °C.

The details given below in respect of our heat appliances are based on our experience over many years and service life tests, and specify the maximum amounts of fill and top-up water subject to output and water hardness. This ensures that local regulations (e.g. VDI 2035 for Germany) are met.

This document explains how you can keep an operator’s log on water treatment. Examples will show how to carry out and record essential calculations.

At the end of this document you will find an operator’s log table which you can complete.

This operator’s log is intended for system operators and heating contractors who, due to their training and experience, are familiar with heating systems.

Warranty claims for the heat appliances will only be considered provided the water quality requirements have been met and the operator’s log has been maintained.

Important information

Important information where there is no risk to people or property is indicated with the adjacent symbol. It is bordered by lines above and below the text.

Symbols

Symbol	Meaning
▶	Action step
•	List/list entry

Tab. 1

1 Water quality

Water quality is an important requirement for the perfect operation, high energy efficiency and long service life of the heat appliance and all the system components. Sludge, limescale and dirt particles in the water can cause irreparable damage to the heat appliance, even over a short period of time and irrespective of the quality of the materials used.

1.1 Physical backgrounds

1.1.1 Formation of limescale in the heat appliance

Limescale is formed when water is heated because the calcium and magnesium hydrogen carbonate which are dissolved in the water at an ambient temperature precipitate out of the water.

$Ca(HCO3)_2$ ---- temperature increase ----> CaCO3 + H2O + CO_2
$Mg(HCO_3)_2$ ---- temperature increase ----> $Mg(OH)_2$ + $2CO_2$

During precipitation, calcium carbonate and magnesium hydroxide form compact, insoluble, adhesive deposits (limescale) with a very high thermal insulation capacity. Limescale is primarily deposited in the warmest areas of the heat appliance. This is why calcification often only occurs in localised areas; generally, in areas with a high heat input. A thin limescale layer of only 0.1 mm will reduce the cooling effect of the sheet metal below. If the limescale layer continues to build up, this can overheat the metal components and, in an extreme case, can cause them to break due to thermal overloading.

1.1.2 Corrosion in the heat appliance

Oxygen corrosion

When it comes into contact with water, non-alloyed steel (water jacket) adsorbs the oxygen in the water and forms the typically red iron oxide Fe_2O_3 (rust). This process is referred to as corrosion.

$4Fe + 3O_2 \rightarrow 2Fe2O3$ (iron oxide, rust)

Constant oxidation will inevitably lead to a reduction in wall thickness. Oxygen corrosion can be identified by localised attacks to the metal surfaces (water jacket) in the heat appliance as a whole, and by the presence of circular, crater-like indentations in the metal surface. If the permanent entry of oxygen into the system is prevented, the oxygen content will decrease continuously as this will lead to a partial oxidation to black magnetite (Fe_3O_4). Magnetite protects against corrosion.

$3Fe + 2O_2 \rightarrow Fe_3O_4$ (iron (III) oxide, magnetite)

Acid corrosion

Hydrogen or acid corrosion is a form of corrosion affecting metals which leads to the formation of elemental hydrogen and metal ions when water is present but there is a lack of oxygen. For acid corrosion to occur, there must be acidic water present ($pH < 7$). Acid corrosion usually occurs when heating water is softened incorrectly or because carbon dioxide is present, having been produced during the formation of limescale in the heat appliance (see chapter 1.1.1, page 2). Acid corrosion attacks non-alloyed steel (water jacket) in the form of surface corrosion, and generally occurs evenly throughout the whole heat appliance.

1.2 Maintaining an operator’s log

For heating systems with a total boiler output ≥ 50 kW, the installation of a water meter and maintenance of an operator’s log are required.

▶ Record the required values in the operator’s log to verify the water quality.

> i Water quality is an essential factor for increased efficiency, functional reliability, long service life and for maintaining the constant operational condition of a heating system. For this reason, we generally recommend using treated water (see chapter 1.5).

▶ As well as the amount of fill and top-up water, record the concentration of calcium hydrogen carbonate [$Ca(HCO_3)_2$] and enter this in the operator’s log.

> i You can ask your water supply utility to advise you of the $Ca(HCO_3)_2$ concentration or determine it in accordance with the calculation basis (→ chapter 1.5, page 4).

1.3 Prevention of corrosion damage

Additional protection against corrosion

Damage through corrosion occurs if oxygen constantly enters the heating water, for example through the following:

- inadequately sized or faulty expansion vessels (EVs),
- incorrectly adjusted pre-charge pressure or
- open vented systems.

▶ Check the pre-charge pressure and pressure maintaining ability annually.

In systems with correctly functioning and sized pressure maintaining ability, the oxygen introduced via the fill and top-up water is rapidly broken down and therefore requires no further attention.

If a regular oxygen ingress cannot be prevented, for example if using plastic pipes permeable to oxygen in underfloor heating systems or when major amounts of top-up water are required, corrosion prevention measures are necessary, e.g. by system separation with the aid of a heat exchanger. A further possible corrosion prevention measure for heat appliances with parts made from non-alloyed steel (e.g. water jacket made from iron, heating surfaces made from stainless steel) is the use of oxygen binders. In this connection, observe the manufacturer's instructions on the necessary dosing excess.

pH value

The pH value of untreated heating water should be between 8.2 and 10.0 for heat appliances with parts made from non-alloyed steel. It should be noted that the pH value will change following commissioning, in particular through the degradation of oxygen and limescale separation (self-alkalising effect). We recommend checking the pH level after several months of heating system operation.

In the case of heat appliances with parts made from non-alloyed steel, the water can be alkalised by adding trisodium phosphate if necessary.

Additives

If additives or antifreeze (where approved by the heat appliance manufacturer) are used in the heating system, check the heating water regularly in accordance with the manufacturer's instructions and carry out any necessary corrective measures.

Dirt trap

> i If the unit is installed in an existing heating system, impurities may build up in the heat appliance, leading to local overheating, corrosion and noise.

We therefore recommend the installation of a dirt trap and blow-down facility.

▶ Install the dirt trap and blow-down facility in the immediate vicinity of the heat appliance and the lowest point of the heating system, ensuring good accessibility to both.

▶ Clean the dirt trap and blow-down facility during every service.

1.4 Water hardness

Fill the system with clean water only.

To protect the appliance from limescale damage throughout its service life and ensure trouble-free operation, the overall quantity of substances that cause hardness in the fill and top-up water of the heating circuit must be limited.

The details given below in respect of our heat appliances are based on many years of experience and service life tests, and specify the maximum amounts of fill and top-up water subject to output and water hardness.

1.5 Checking the maximum amounts of fill water, subject to water quality

If the total amount of fill and top-up water exceeds the calculated allowable water volume V_{max}, damage to the heat appliance may result.

If, through a failure to meet these requirements, damaging deposits have already occurred inside the heat appliance, then it is most likely that the service life will already have been reduced as a result. Removing these deposits can be one option for restoring operational viability. Ask a qualified contractor to remove the limescale deposits.

To check the permissible amounts of water subject to the fill water quality, either perform the following calculations or consult the graphs.

In multi-boiler systems with heat appliances made from different materials, the graph or formula with the most stringent requirements applies (→ see the respective operator's logs for heat appliances made from ferrous materials and aluminium).

1.5.1 Basis for calculation

The fill and top-up water has to meet certain requirements depending on the total boiler output and the resulting water volume of a heating system. Use the following formula to calculate the maximum amount of water for heat appliances made from stainless steel up to 600 kW that may be introduced untreated:

Calculation variables:

$$Vmax = 0,0626 \times \frac{Q}{Ca(HCO_3)_2} \frac{(kW)}{(mol/m^3)}$$

V_{max} = Maximum amount of fill and top-up water in m^3 that may be introduced over the entire service life of the heat appliance.

Q = Boiler output in kW (< 600 kW)

$Ca(HCO_3)_2$= Concentration of calcium carbonate in mol/m^3.

The concentration of calcium hydrogen carbonate may be no more than 2.0 mol/m^3 for a heating output of up to 200 kW (corresponds to 11.2 °dH), and 1.5 mol/m^3 for a heating output of up to 600 kW (corresponds to 8.4 °dH). For higher concentrations of calcium hydrogen carbonate, the water must be treated, irrespective of V_{max}.

From 600 kW upwards, generally use only treated fill and top-up water. This also satisfies local regulations (e.g. VDI 2035, Germany).

Information about the calcium carbonate ($CaCO_3$) concentration of the mains water can be obtained from your water supply utility. If the water analysis does not include this information, the calcium carbonate concentration can be determined from the carbonate hardness and the calcium hardness, as follows:

Example:

Calculation of the maximum permissible fill and top-up volume V_{max} for a heating system with a total boiler output of 150 kW.

Details of water analysis figures for carbonate hardness and calcium hardness in measuring unit ppm.

Carbonate hardness: 10.7 °dH

Calcium hardness: 8.9 °dH

The following can be calculated from the carbonate hardness:

$$Ca(HCO_3)_2 = 10,7°dH \times 0,179 = 1,91\ mol/m^3$$

From the calcium hardness, we obtain:

$$Ca(HCO_3)_2 = 8,9°dH \times 0,179 = 1,59\ mol/m^3$$

The lower of the calcium or carbonate hardness levels calculated is the definitive figure for calculating the maximum permissible amount of water $V_{max.}$

$$Vmax = 0,0626 \times \frac{150}{1,59} \frac{(kW)}{(mol/m^3)} = 5,9\ m^3$$

mg/l or ppm as calcium carbonate equivalent	Grains per US Gallon	Degrees Clark or English	Degrees German	Degrees French
100	5.8	7	5.6	10
200	11.6	14	11.2	20
300	17.4	21	16.8	30
400	23.2	28	22.4	40
435	25.2	30.5	24.4	43.5

1.5.2 Requirements for heat appliances made from stainless steel

Total boiler output (kW)	Requirements for water hardness and volume V_{max} of fill and top-up water
≤ 50 kW	No requirements for V_{max}
50 – 600 kW	Vmax calculated according to Fig. 1 and Fig. 2
> 600 kW	Water treatment is generally required (total hardness to VDI 2035 < 0.11 °dH)
independent of output	For systems with very large water content (> 50 l/kW), water should always be treated

Tab. 2 General conditions and limits of use of the graphs for heat appliances made from stainless steel

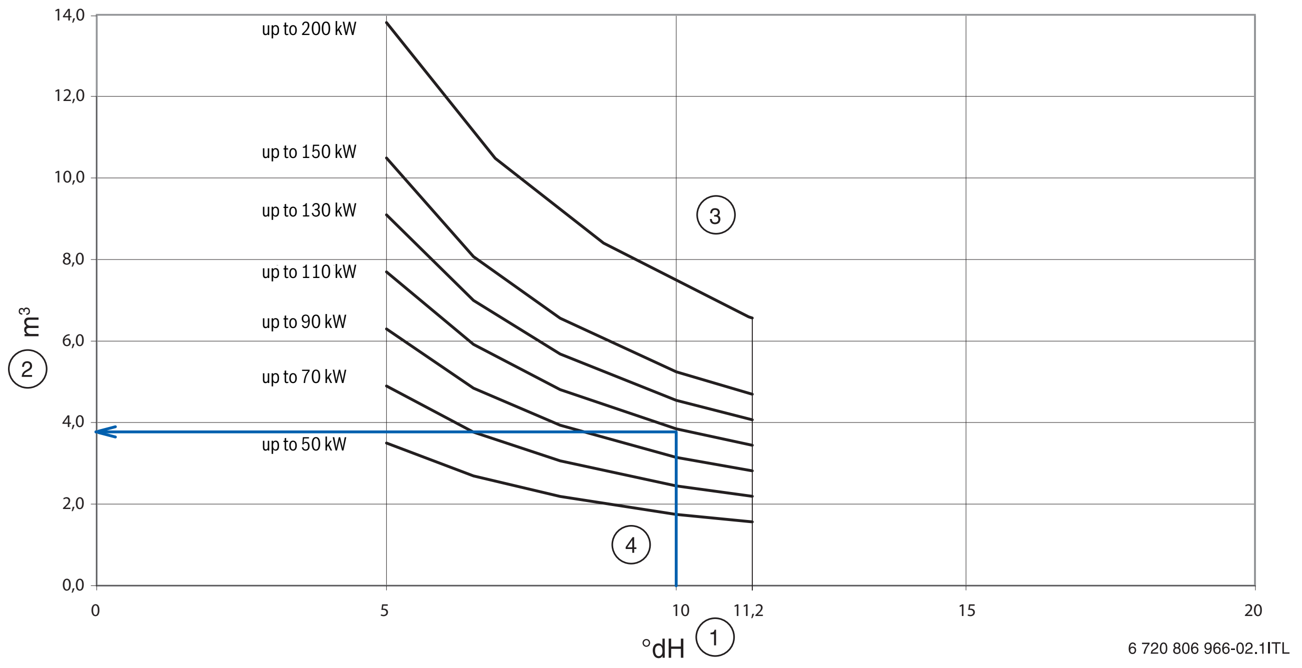

Fig. 1 Requirements for the amount of fill and top-up water for heat appliances made from stainless steel up to 200 kW

[1] Total hardness in °dH (for the purposes of simplification, it is assumed that this total hardness equals the carbonate hardness)

[2] Maximum possible water volume over the service life of the heat appliance in m^3

[3] Measures are required above these output curves and for a water hardness greater than 11.2 °dH; fill with untreated tap water below the curves.
For multi-boiler systems (<= 600 kW total output), the output curves for the smallest single boiler output apply.

[4] Example reading from the graph:
heat appliance output 105 kW, system volume approx. 1.5 m^3.
At a total water hardness level of 10 °dH, the maximum amount of fill and top-up water is approx. 3.8 m^3.
Result:
The system can been filled with untreated water.

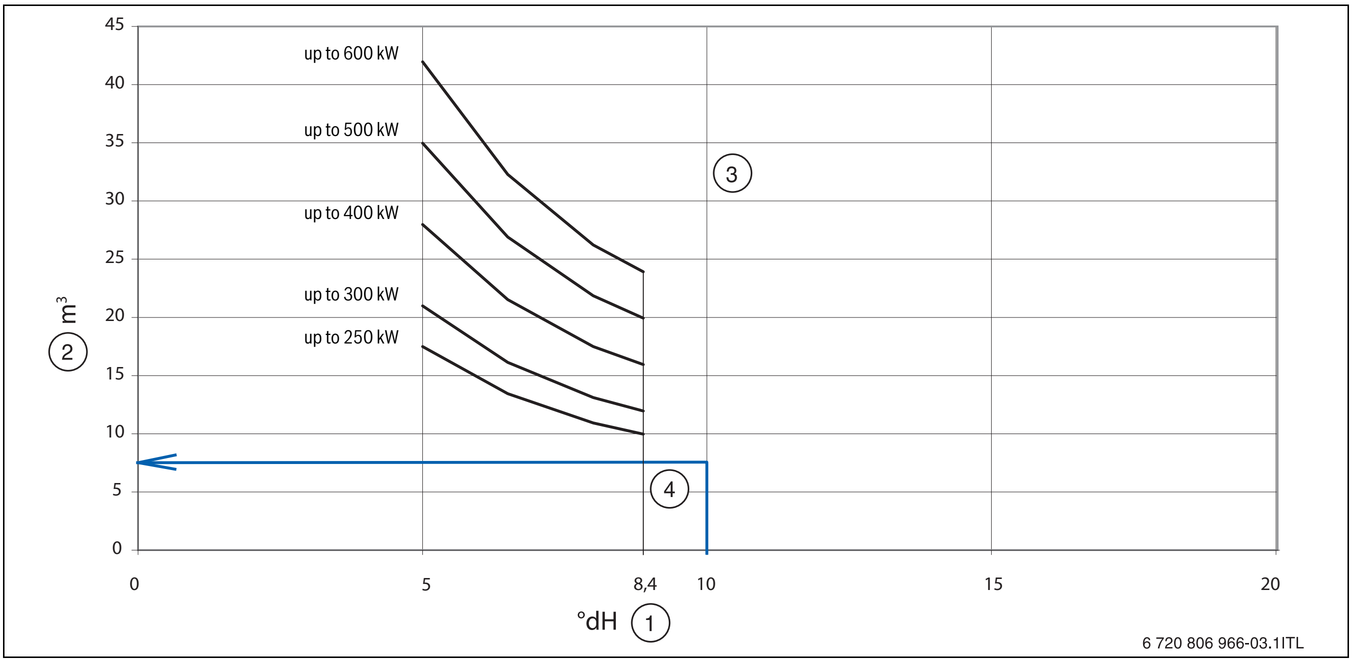

Fig. 2 Requirements for the amount of fill and top-up water for heat appliances made from stainless steel from 200 to 600 kW

[1] Total hardness in °dH (for the purposes of simplification, it is assumed that this total hardness equals the carbonate hardness)

[2] Maximum possible water volume over the service life of the heat appliance in m^3

[3] Measures are required above these output curves and for a water hardness greater than 8.4 °dH; fill with untreated tap water below the curves.
For multi-boiler systems (≤ 600 kW total output), the output curves for the smallest single boiler output apply.

[4] Example reading from the graph:
Heat appliance output 295 kW, system volume approx. 7.5 m^3, total hardness is 10 °dHFor a total hardness above 8.4 °dH, the water must generally be treated.
Result:
The system must be filled with treated water.

1.6 Approved water treatment methods

If the amount of fill water actually required is less than V_{max}, untreated water may be introduced (area below the limit curves).

If the amount of water actually required is

- greater than V_{max}, or
- the concentration of calcium hydrogen carbonate exceeds 2.0 mol/m^3 for a heating output of up to 200 kW (corresponds to 11.2 °dH), or
- the concentration of calcium hydrogen carbonate exceeds 1.5 mol/m^3 for a heating output of up to 600 kW (corresponds to 8.4 °dH),

then the water must be treated (area above the limit curves).

The following water treatment methods are approved for heat appliances made from stainless steel and combinations of different materials.

Full softening

During full softening, all limescale-building constituents, such as calcium and magnesium ions (total alkaline earths) are removed from the water and replaced with sodium. In the case of boilers made from ferrous materials, full softening of the fill and top-up water has proved to be a reliable method of preventing limescale build-up for a long time.

Full softening is not suitable for combinations of heat appliances made from stainless steel and aluminium materials.

Full desalination

With full desalination, not only the hardness constituents, such as lime, but also the corrosive agents, such as chloride, are removed from the fill and top-up water. The system should be filled with fill and top-up water with a conductivity of <= 10µS/cm (µS/cm, micro Siemens per cm). Fully desalinated water with this conductivity can be provided by so-called mixed bed cartridges (with anion and cation exchanger resin) as well as by osmosis plant.

Filling the heating system with fully desalinated water will result in a low-saline operating mode after several months of heating operation. When operating in low-saline mode, the system water has reached an ideal state: it is free from all hardness constituents, all corrosive agents have been removed and the conductivity is at an extremely low level. The low tendency towards corrosion has therefore been reduced to a minimum.

Full desalination is a suitable water treatment for any heating system.

2 Operator’s log

Heating system details:______________________________					
Commissioning date:______________________________					
Max. amount of water V_{max} ____________ **m^3 at $Ca(HCO_3)_2$ concentration:**__________ **mol/m^3**					
	Date	Volume of water (actual) m^3	$Ca(HCO_3)_2$ concentration* mol/m^3	Total volume of water m^3	Company name (stamp) Signature
Total fill water in m^3					
Top-up water in m^3					

Tab. 3 Operator’s log

* Conversion:

Hardness in [°dH] x 0.179 = $Ca(HCO_3)_2$ concentration in [mol/m^3]
Hardness in [°fH] x 0.1 = Ca $(HCO_3)_2$ concentration in [mol/m^3]

Hardness in [°e] x 0.142 = $Ca(HCO_3)_2$ concentration in [mol/m^3]
Hardness in [gpg] x 0.171 = $Ca(HCO_3)_2$ concentration in [mol/m^3]

Heading system details:____

Commissioning date:____

Max. amount of water V_{max} ____________ **m^3 at $Ca(HCO_3)_2$ concentration:**__________ **mol/m^3**

	Date	Volume of water (actual) m^3	$Ca(HCO_3)_2$ concentration* mol/m^3	Total volume of water m^3	Company name (stamp) Signature
Total fill water in m^3					
Top-up water in m^3					

Tab. 4 Operator's log

* Conversion:

Hardness in [°dH] x 0.179 = Ca $(HCO_3)_2$ concentration in [mol/m^3]
Hardness in [°fH] x 0.1 = Ca $(HCO_3)_2$ concentration in [mol/m^3]
Hardness in [e] x 0.142 = $Ca(HCO_3)_2$ concentration in [mol/m^3]
Hardness in [gpg] x 0.171 = $Ca(HCO_3)_2$ concentration in [mol/m^3]

Notes

Notes

Original Quality by
Bosch Thermotechnik GmbH
Sophienstraße 30-32
D-35576 Wetzlar/Germany