

PD CEN/TR 16911:2015



BSI Standards Publication

# Heat meters — Recommendations for circulation water in industrial and district heating systems and their operation

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### **National foreword**

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The UK participation in its preparation was entrusted by Technical Committee CPI/30, Measurement of fluid flow in closed conduits, to Subcommittee CPI/30/7, Volume flow-rate methods.

A list of organizations represented on this committee can be obtained on request to its secretary.

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Published by BSI Standards Limited 2016

ISBN 978 0 580 90922 1  
ICS 91.140.10

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This Published Document was published under the authority of the Standards Policy and Strategy Committee on 31 January 2016.

### **Amendments/corrigenda issued since publication**

<b>Date</b>	<b>Text affected</b>
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TECHNICAL REPORT

**CEN/TR 16911**

RAPPORT TECHNIQUE

TECHNISCHER BERICHT

December 2015

ICS 91.140.10

English Version

## Heat meters - Recommendations for circulation water in industrial and district heating systems and their operation

This Technical Report was approved by CEN on 16 November 2015. It has been drawn up by the Technical Committee CEN/TC 176.

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EUROPEAN COMMITTEE FOR STANDARDIZATION  
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<b>Contents</b>		<b>Page</b>
European foreword.....		4
Introduction .....		5
1	Scope.....	6
2	Normative references.....	6
3	Terms and definitions .....	6
3.1	General.....	6
3.2	Types of water.....	8
3.3	Units.....	9
3.3.1	General.....	9
3.3.2	Measurands.....	9
4	Symbols and abbreviations .....	9
4.1	Chemical terms .....	9
4.2	Technical terms .....	10
5	Water quality.....	10
5.1	General.....	10
5.2	Effects of the water constituents .....	11
5.2.1	Gases .....	11
5.2.2	Water-insoluble substances.....	12
5.2.3	Water-soluble substances.....	12
5.2.4	Oils/greases .....	13
6	Systems engineering.....	13
6.1	Systems conception .....	13
6.1.1	General.....	13
6.1.2	Materials.....	13
6.1.3	Pressure maintenance and water supply.....	14
6.2	Water treatment techniques.....	15
6.2.1	General.....	15
6.2.2	Filtering .....	16
6.2.3	Demineralization .....	16
6.2.4	Softening.....	16
6.2.5	Degassing .....	16
6.2.6	Catalytic and electrochemical oxygen scavenging.....	16
7	Production technology.....	17
7.1	Standard values for the circulation water .....	17
7.2	Low-salt operation.....	18
7.3	Salty operation .....	18
7.4	Technical aspects related to the operation .....	19
7.4.1	General.....	19
7.4.2	Filling and supplementary water .....	19
7.4.3	Underpressure .....	20
7.4.4	Exceptional operating conditions .....	21
7.4.5	Direct heating.....	21
7.4.6	Indirect heating .....	21
7.4.7	Partial evaporation .....	21

<b>7.5</b>	<b>Conditioning</b> .....	<b>22</b>
<b>7.5.1</b>	<b>General</b> .....	<b>22</b>
<b>7.5.2</b>	<b>pH value increase</b> .....	<b>22</b>
<b>7.5.3</b>	<b>Hardness stabilizing</b> .....	<b>23</b>
<b>7.5.4</b>	<b>Oxygen scavenging</b> .....	<b>23</b>
<b>7.5.5</b>	<b>Corrosion inhibitors</b> .....	<b>24</b>
<b>7.5.6</b>	<b>Water tracing dyes for the circulation water</b> .....	<b>25</b>
<b>7.5.7</b>	<b>Antifreezing agents</b> .....	<b>25</b>
<b>7.6</b>	<b>Monitoring</b> .....	<b>25</b>
<b>7.6.1</b>	<b>General</b> .....	<b>25</b>
<b>7.6.2</b>	<b>Assessment criteria</b> .....	<b>25</b>
<b>7.6.3</b>	<b>Measurement frequency</b> .....	<b>27</b>
<b>7.6.4</b>	<b>Dosing of conditioning agents</b> .....	<b>28</b>
<b>7.6.5</b>	<b>Sampling</b> .....	<b>29</b>
<b>7.6.6</b>	<b>Measurement procedures</b> .....	<b>31</b>
<b>8</b>	<b>Hygienic, toxicological and environmental aspects</b> .....	<b>31</b>
<b>8.1</b>	<b>General</b> .....	<b>31</b>
<b>8.2</b>	<b>Hygienic and toxicological aspects</b> .....	<b>31</b>
<b>8.3</b>	<b>Environmental aspects</b> .....	<b>32</b>
	<b>Bibliography</b> .....	<b>33</b>

## **European foreword**

This document (CEN/TR 16911:2015) has been prepared by Technical Committee CEN/TC 176 “Heat meters”, the secretariat of which is held by SIS.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

## **Introduction**

This document is based on the German Guideline AGFW FW 510 prepared by the German Heat and Power Association (AGFW) that represents the state of the art but does not have a normative status has been reproduced in this Technical Report with the permission of AGFW.

This Technical Report is an informative document that describes a process that may be applied for the operation of district heating facilities and gives recommendations for the water used in such facilities. The water quality described in this Technical Report can be used also during testing of heat meters.

## 1 Scope

This Technical Report applies to industrial and district heating supply by means of high-temperature water heating facilities (flow temperature > 100 °C). This also applies to high-temperature water heating facilities (flow temperature ≤ 100 °C) that are directly connected to district heating networks. In this Technical Report, the aforementioned supply variants will, in the following, be referred to as “district heating facilities”.

This document applies without limitations to new facilities. For existing district heating facilities, the application of this Technical Report is recommended in order to prevent faults due to the chemical composition of the circulation water that would affect the facilities' safe operability and availability.

**NOTE** Informative notes in the form of guidance and recommendations are identified correspondingly and set in italics for better differentiation.

## 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1717, *Protection against pollution of potable water in water installations and general requirements of devices to prevent pollution by backflow*

ISO 11466, *Soil quality — Extraction of trace elements soluble in aqua regia*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

### 3.1 General

#### 3.1.1

##### **district heating**

heat (regardless of its origin) which is supplied by means of a transfer medium (mostly hot water or steam) commercially on the basis of a supply agreement and from the delivery of which no collateral duties arise with regard to leasing regulations

#### 3.1.2

##### **hot-/warm-water heating plants**

hot-/warm-water generating facility in connection with a district heating network

#### 3.1.3

##### **water treatment**

measures taken to remove solid particles, water-soluble substances (salts) and gases from the filling-, supplementary- or circulation water

#### 3.1.4

##### **primary network**

district heating network in indirect (e. g. heat exchanger) or direct connection with the heat generator

#### 3.1.5

##### **secondary network**

district heating network separated from the primary district heating network by a substation with different system parameters



### 3.1.6

#### **tertiary network**

end-user's domestic installation

### 3.1.7

#### **heat exchanger with intermediary medium**

heat exchanger with a safety system for the indirect heating of drinking water and in which the heating side and the drinking water side are separated by two walls; the space between the two walls is filled with a medium

### 3.1.8

#### **chalk/carbonic acid equilibrium**

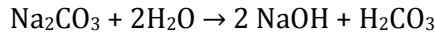
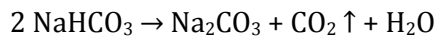
if calciferous water is heated up, the concentration of bonded calcium hydrogen carbonate decreases with increasing temperature, and the so called "chalk/carbonic acid equilibrium" shifts from the side of the calcium hydrogen carbonate through the escaping carbon dioxide towards the side of the calcium carbonate:



### 3.1.9

#### **bicarbonate decomposition**

after softening and in cause of higher temperature, sodium bicarbonate gradually decomposes into at least sodium hydroxid, water and carbon dioxide (at about 55°C, higher pressure)



### 3.1.10

#### **boiler scale**

conglomerate of low-solubility alkaline earth salts which form at temperatures < 100 °C, mainly CaCO<sub>3</sub> and MgCO<sub>3</sub>

### 3.1.11

#### **limescale**

conglomerate of low-solubility alkaline earth salts, mainly CaCO<sub>3</sub>, MgCO<sub>3</sub>, CaSO<sub>4</sub> and CaSiO<sub>3</sub>

Note 1 to entry: They form either by heat conversion of the alkaline earth salts dissolved in the water (carbonate hardness) or by overstepping the point of solubility which is also temperature-dependent. Soluble alkaline earth salts are available as hardness components or neutral salts in drinking water.

### 3.1.12

#### **heat transfer medium according to Class 4 pursuant to EN 1717**

heat transfer medium which contains toxic, very toxic, carcinogenic or radioactive substances

### 3.1.13

#### **water conditioning**

improving certain quality parameters of the circulation water (e.g. increasing the pH value) by means of conditioning chemicals

## 3.2 Types of water

### 3.2.1

#### **untreated water**

water available upstream from the treatment plant, regardless of a possible previous treatment outside the plant

### 3.2.2

#### **soft water**

oxygenated water that has been treated by ion exchange to remove earth alkali (the process is called softening)

### 3.2.3

#### **demineralized water**

oxygenated water that has been treated to remove the major part of dissociated, water-soluble substances and is characterized by a pH value  $< 7$ , a conductance  $< 20 \mu\text{S}/\text{cm}$  and a silicic acid concentration  $< 0,5 \text{ mg}/\text{l}$

### 3.2.4

#### **distilled water**

#### **deionized water**

oxygenated water that has been treated by ion exchange to fully remove all dissociated, water-soluble substances

### 3.2.5

#### **filling water**

conditioned water with which district heating facilities are initially, partly or re-filled

### 3.2.6

#### **supplementary water**

conditioned water with which temperature-related volume differences and losses due to evaporation and leakage are compensated

### 3.2.7

#### **circulation water**

water that flows through the heat generator/heat exchanger, the piping network, heat transfer stations and, if applicable, radiators. The term not only applies to primary networks, but also to water in a secondary network

### 3.2.8

#### **feedwater**

water that is used to feed a steam generator. It consists of supplementary water and condensate water after full treatment and conditioning

Note 1 to entry: Feedwater is considered as salt-free if its cation conductance is  $< 0,2 \mu\text{S}/\text{cm}$  and the silicic acid concentration is  $< 0,02 \text{ mg}/\text{l}$  (not to mistake for distilled water!).

### 3.2.9

#### **boiler water**

water contained in water piping and large-scale water boilers and whose properties differ from those of feedwater due to densification processes during use

## 3.3 Units

### 3.3.1 General

Pursuant to the “Units in Metrology Act”, the below-mentioned water-chemical terms and units apply.

### 3.3.2 Measurands

#### 3.3.2.1

##### **molar amount**

concentration of substances contained in the water is stated in mmol/l or in mg/l

#### 3.3.2.2

##### **pH value**

index for the acidic, neutral or alkaline reaction of water

Note 1 to entry: At a reference temperature of 25 °C, the pH value scale from 0 to 14 applies. Water is acidic at pH values < 7, neutral at a pH value = 7, and alkaline at pH values > 7.

#### 3.3.2.3

##### **electrical conductivity**

the salt concentration is generally determined by measuring the electrical conductivity which includes all dissociated elements of the investigated medium, i.e. bases, acids and salts. In water chemistry, the reference temperature used to measure electrical conductivity is 25 °C, the unit of measurement is  $\mu\text{S}/\text{cm}$

#### 3.3.2.4

##### **sum of alkaline earth (hardness)**

the former term “hardness” has been replaced by the term “sum of alkaline earth”

Note 1 to entry: The former units for the alkaline earth concentration ( $^{\circ}\text{d}$  and mval/l) have been replaced by mmol/l, mol/m<sup>3</sup> and mg/l. The following applies to the conversion of the units:

1 mmol/l = 1 mol/m<sup>3</sup> corresponding to 2 mval/l that will give 56 mg CaO/l

Note 2 to entry: Example of calculation for the conversion of the former units:

3,4 mval/l: 2 = 1,7 mmol/l

Note 3 to entry: Contrary to the concentration indications derived from the term “hardness” ( $^{\circ}\text{dH}$ ), technical expressions such as “water softening” and “softened water” remain in usage.

## 4 Symbols and abbreviations

### 4.1 Chemical terms

Al <sup>3+</sup>	aluminium ion
Ca <sup>2+</sup>	calcium ion
CaCO <sub>3</sub>	calcium carbonate
CaSiO <sub>3</sub>	calcium silicate
CaSO <sub>4</sub>	calcium sulphate
Cl <sup>-</sup>	chloride ion
CO <sub>2</sub>	carbon dioxide

Cu <sup>+</sup> / Cu <sup>2+</sup>	copper(I) ion / copper(II) ion
EDTA	ethylenediaminetetraacetic acid or ethylenediaminetetraacetate
Fe	iron
Fe 2+ / Fe 3+	iron(II) ion / iron(III) ion
KS4.3	acid capacity up to pH value 4,3
KS8.2	acid capacity up to pH value 8,2
Mg <sup>2+</sup>	magnesium ion
MgCO <sub>3</sub>	magnesium carbonate
N <sub>2</sub>	nitrogen
NaCl	sodium chloride (common salt)
NaHCO <sub>3</sub>	sodium hydrogen carbonate
NaOH	sodium hydroxide (caustic soda)
Na <sub>3</sub> PO <sub>4</sub>	trisodium phosphate
Na <sub>2</sub> SO <sub>3</sub>	sodium sulphite
Na <sub>2</sub> SO <sub>4</sub>	sodium sulphate
NTA	nitrilotriacetic acid
O <sub>2</sub>	oxygen
PO <sub>4</sub> <sup>3-</sup>	orthophosphate ion
S <sup>2-</sup>	sulphide ion
SO <sub>3</sub> <sup>2-</sup>	sulphite ion
SO <sub>4</sub> <sup>2-</sup>	sulphate ion
Zn <sup>2+</sup>	zinc ion

## 4.2 Technical terms

EV	expansion vessel
DEV	diaphragm expansion vessel
MIF	magnetic inductive flow measurement
DFR	differential pressure regulator
DOC	dissolved organic carbon
TOC	total organic carbon

## 5 Water quality

### 5.1 General

Untreated water may contain insoluble and, especially, soluble substances as well as gases.

Insoluble substances are frequent in surface water, infrequent in groundwater, whereas water from public supply networks only contains traces of them.

Soluble substances occur in untreated water in the form of inorganic salts (especially calcium-, magnesium- and sodium salts) and organic substances. The soluble gases are mostly oxygen, nitrogen from the air, and carbon dioxide.

In district heating facilities, these water constituents can lead to malfunctions and either have to be removed, or their effects to be limited.

The use of insufficiently treated filling or supplementary water or the inflow of water and/or air into district heating facilities from the outside can lead to system malfunctions due to deposits and corrosion.

When assessing the cost-effectiveness of protective measures to prevent the diverse types of damages, the fact that damage may, under certain circumstances, lead to considerable costs that cannot be calculated in advance has to be taken into account.

When complying with the standard values, the alkalization of the water on metallic surfaces furthers the formation of homogeneous oxidic covering layers which are highly resistant against corrosion. A prerequisite is, however, that the filling and supplementary water be treated correctly.

In district heating facilities, one fundamentally differentiates between low-salt and salty operation, depending on the quality of the circulation water.

Further plant-specific prescriptions and guidance can be found in the Technical Connection Conditions (TCC).

## **5.2 Effects of the water constituents**

### **5.2.1 Gases**

#### **5.2.1.1 General**

Gases enter the circulation water due to the following processes:

- utilization of non-degassed filling and supplementary water;
- air leakage into the system in the event of underpressure (e.g. insufficient pressure maintenance);
- air inclusion during the initial, partial or new filling of the system;
- external water inflow;
- diffusion through permeable components (e.g. diaphragms, plastic pipes, seals).

#### **5.2.1.2 Oxygen**

Oxygen ( $O_2$ ) causes unalloyed and low-alloy ferrous materials to corrode. Oxygen inflow therefore has to be prevented as far as this is technically justifiable.

Damage directly due to corrosion can manifest in the form of perforations in heat generators, pipes and radiators made of unalloyed or low-alloy ferrous materials. The blinding of sieves, measuring equipment and filters due to corrosion products is considered as an indirect consequence of corrosion.

#### **5.2.1.3 Nitrogen**

Nitrogen ( $N_2$ ) is an inert gas and, as a water constituent, only causes problems when its concentration is so high that free nitrogen fractions (gas bubbles) form inside the system. Gas bubbles may occur, since the solubility of gases decreases with increasing temperature and decreasing pressure. Circulation faults, disturbing noises and erosion of protection layers (erosion corrosion) are the consequences.

Experience has shown that no system malfunctions due to nitrogen bubbles have to be expected with nitrogen contents of  $< 10 \text{ mg } N_2$  per litre of water at a positive excess pressure of min. 0,5 bar (at the highest point of the system).

#### **5.2.1.4 Carbon dioxide**

If the circulation water is not sufficiently alkalized, the quantity of water-soluble carbon dioxide (CO<sub>2</sub>) influences the pH value – i.e. increasing CO<sub>2</sub> cause the pH value to drop. Due to the in-creasing solubility of iron(II)-hydroxide occurring at decreasing pH values, deposited corrosion products can be partially dissolved by water having a relatively low pH value (<8). The increased iron(II) ion concentration can lead to an increased formation of magnetite (Fe<sub>3</sub>O<sub>4</sub>) in the form of hard, black deposits on the hot side of heat exchanger surfaces.

This causes the increase of the overall heat transfer resistance and, thus, the thermal performance to decrease. In particularly critical cases, this may even lead to overheating which, in turn, may lead to crack formation.

#### **5.2.2 Water-insoluble substances**

Insoluble substances cause deposits and blockages and have to be removed from the untreated water by means of suitable techniques (mud flaps, filters).

#### **5.2.3 Water-soluble substances**

##### **5.2.3.1 Hardness components (alkaline earth)**

When using unsoftened filling water, especially the alkaline earth ions contained in the water in connection with the hydrogen carbonate ions lead to the formation of hard deposits, mainly containing calcium carbonate (limescale, boiler scale). This causes the increase of the overall heat transfer resistance and, thus, the thermal performance to decrease. In particularly critical cases, this may even lead to overheating which, in turn, may lead to crack formation in heat generators (e.g. heat exchanger, vessels).

##### **5.2.3.2 Chloride and sulphate**

From all the water-soluble anions contained in the water, especially chloride and sulphate, in the presence of oxygen, further local corrosion (e.g. crevice corrosion) in unalloyed ferrous materials.

Under critical conditions (e.g. concentration under deposits or in crevices), chloride ions can lead to pitting corrosion or stress-corrosion cracking in non-corroding steels.

In addition, chlorides can cause corrosion in aluminium materials.

##### **5.2.3.3 Hydrogen carbonate**

The anion hydrogen carbonate primary react with the cations calcium and magnesium and form hardness-causing salt (see 5.2.3.1). By means of a softening unit with a weakly acidic cation exchanger calcium- and magnesium ions will be substituted against sodium ions. This results to sodium bicarbonate which reacts at higher temperature and raised pressure to sodiumcarbonate. As result of so-called soda decomposition arise, that means sodiumcarbonate decompose into soda lye and carbon dioxide gas, which escape out of the system. The formed soda lye result in a selfalkalinization of the circulating water and can cause an increase of the pH-value up to a value of > 10.

##### **5.2.3.4 Organic substances**

Insoluble and soluble organic substances – analytically determined as TOC or DOC – can both affect the water treatment techniques and further microbiological reactions in the circulation water.

## 5.2.4 Oils/greases

The contamination of circulation water by oils or greases – e.g. due to the inflow of operating fluids or due to valves, pipes, heating surfaces, etc. that have been treated with a temporary corrosion protection and with processing aids – can cause massive malfunctions. As a film or coating on heated surfaces, oils and greases hamper heat transfer and can, alone or in connection with other substances, cause malfunctions of the regulation and safety devices. Oils and greases are nutrients for microorganisms and therefore increase the probability of microbiologically influenced corrosion processes.

# 6 Systems engineering

## 6.1 Systems conception

### 6.1.1 General

For reasons related to corrosion, district heating facilities have to be designed and operated in such a way that the inflow of air is, as far as possible, prevented and that water losses are minimized.

System extensions and alterations may only be carried out in consideration of the existing district heating facility.

### 6.1.2 Materials

Water treatment and conditioning play a considerable role with regard to the selection of materials and the possibilities of combining them.

Taking the standard values mentioned in 7.1 into account, unalloyed ferrous materials, non-corroding steels and copper may be used – alone or combined.

With austenitic steels, the risk of alkali- and chloride-induced stress-corrosion cracking (see 7.4.7 and 7.6.2) shall be taken into account. This does not apply to unalloyed steels.

NOTE 1 Selection of materials currently used for steel pipes:

- P235 TR1 (EN 10217-1)
- P235 TR2 (EN 10217-1)
- P235 GH (EN 10216-2, EN 10217-2, EN 10217-5)
- P355 N (EN 10216-3, EN 10217-3)
- E215+N (EN 10305-1)
- E195+N (EN 10305-3)
- 1.4301 (EN 10088)
- 1.4404 (EN 10088)
- 1.4571 (EN 10088)

Aluminium and/or aluminium alloys shall not be used in direct contact with the circulation water, since alkaline-induced corrosion may otherwise occur. They may be used in domestic systems, but only if they are connected indirectly to the district heating network.

Due to the material-related temperature limitation, the use of plastic piping is limited. Furthermore, the oxygen diffusion rate of this material shall be taken into account. It shall be ensured that the other components are not damaged by corrosion processes due to oxygen inflow. If necessary, the system has to be divided.

NOTE 2 Selection of materials currently used for plastic pipes:

- PE-Xa (EN ISO 15875-2)
- PE-Xc (EN ISO 15875-2)
- PB-1 (EN ISO 15876-2)

Materials containing copper may corrode due to the formation of copper sulphide.

With components consisting of a copper/zinc alloy (brass) and which have not been specially treated, damage due to stress-corrosion cracking may occur. A prerequisite is the presence of ammonium ions in connection with mechanical tensile stress.

NOTE 3 Materials currently used for valves in the network:

- cast steel
- cast iron / spheroidal graphite cast iron

### 6.1.3 Pressure maintenance and water supply

Pressure maintenance and water supply should be guaranteed mainly for the following reasons:

- ensuring the operating pressure level and the pressure at rest level;
- compensating volume and pressure variations due to temperature variations, and
- compensating water losses in operation and triggering a corresponding fill-up (water supply).

The appropriate selection and dimensioning as well as the correct integration of the pressure maintenance and of the circulation pumps in district heating facilities have a decisive influence on the inflow of gases, especially oxygen and nitrogen. Attention should be paid to ensuring a positive excess pressure at all times at the high point of the system (recommendation: 0,5 bar positive excess pressure).

Generally, both internal (formation of a steam pressure cushion by evaporation inside the heat generator) and external pressure maintenance (PM) are possible – here, only the static and dynamic types of external pressure maintenance will be dealt with in detail.

The expansion vessel (EV) is available with or without a diaphragm, and as a closed or open system.

The following parameters should be considered when selecting the type of pressure maintenance:

- a) The open, elevated EV without diaphragm is no longer used today due to the risk of an oxygen inflow into the system. The oxygen inflow is particularly high when hot water flows through the EV. In the case of existing facilities, appropriate measures should be taken (e.g. by-pass pipe, the integration of the safety flow pipe, pump design) to prevent hot water from flowing through the diaphragm.
- b) Besides a slower oxygen inflow, an open EV with a diaphragm has the advantage of building a system-internal inert gas cushion beneath the diaphragm.



- c) In the case of a closed EV without a diaphragm, pressure maintenance is only possible if a stable steam or inert gas cushion is always ensured.
- d) In the case of a closed EV with a diaphragm, exclusively inert gas should be used to fill up the gas headspace (e.g. N<sub>2</sub>), because membranes made of elastomers are permeable to gas. This also applies to the separation of the water space from the headspace by means of membranes.
- e) In order to protect the diaphragms from high thermal stress > 70 °C and to minimize the oxygen inflow in the event of volume variations, it makes sense to use buffer vessels (upstream vessel).
- f) In the case of pump pressure maintenance in connection with open EVs, with or without diaphragm, the pressure-control pump used to minimize the oxygen inflow shall be operated intermittently. Under certain conditions, it may make sense to include a degassing system in the return of the system when using open EVs. If the pump is in constant operation, the overflow pipe should not lead into the open EV, but directly to the suction side of the pump.
- g) Compressor pressure maintenance is not recommended – also not in the case of systems equipped with a diaphragm – due to the increased oxygen inflow.

Under chemical considerations related to corrosion, it has turned out that diaphragm EVs that are pressurized with inert gas offer the best possible safety with regard to the oxygen inflow. Table 1 shows a short overview of the essential features of the different pressure maintenance systems.

**Table 1 — Overview of pressure maintenance (PM) procedures**

Type	Static pressure maintenance					Dynamic pressure maintenance			
	open EV		closed EV		diaphragm EV	pump PM		compressor PM	
Design	air		gas mixture, usually steam		inert gas, usually N <sub>2</sub>	gas mixture, usually steam/air		air	
Headspace/ environment	air		gas mixture, usually steam		inert gas, usually N <sub>2</sub>	gas mixture, usually steam/air		air	
Diaphragm in the EV	w/o	with	w/o	with	mandatory	w/o	with	w/o	with

## 6.2 Water treatment techniques

### 6.2.1 General

In district heating, two water-chemical modes of operation are common:

- low-salt operation, and
- salty operation.

These are characterized by the standard values according to Table 2.

The water treatment techniques described below may refer to the supplementary water and/or to a partial flow of the circulation water.

The quality of the circulation water can be adulterated by external water inflow, gas inflow or corrosion processes, and modified by means of conditioning. With the aid of a partial flow treatment plant integrated into the bypass (filtering, degassing and ion exchange), the suspended and dissolved substances contained in the water can be removed.

The dimensioning of partial flow treatment facilities for the circulation water should be such that 1 to 3 % of the circulation water volume are treated by the partial flow treatment plant daily. If this facility is also to treat the supplementary water volume, this should be taken into account for the designing and dimensioning of the facility.

### **6.2.2 Filtering**

When removing water-insoluble substances, various mechanical processes are used in order to prevent deposits and malfunctions in downstream components.

For fine-particle substances,

- candle cartridge filters,
- bag filters, or
- pre-coated candle cartridge filters

can be used.

For larger dirt particles, mud flaps/filters are used.

### **6.2.3 Demineralization**

The salts (cations and anions) dissolved in the water are removed using ion exchanging processes in order to reduce electrical conductance. For this purpose, strongly acidic cation exchangers are normally used in connection with strongly alkaline anion exchangers.

To a large extent, demineralization can be attained with the aid of diaphragms (in general using reverse osmosis). Under the influence of pressure, the ionogenic substances are separated from the water by semi-permeable diaphragms. The water is generally softened upstream in order to protect the diaphragm.

When using the above mentioned processes in partial flow operation, temperature limits have to be observed.

### **6.2.4 Softening**

By using cation exchangers that can be regenerated with common salt (NaCl), the hardness components (calcium and magnesium ions) are exchanged for sodium ions. The water is thus free of hardness components and can no longer cause deposits and limescale. This type of water treatment is commonly used in salty operation.

### **6.2.5 Degassing**

To remove the part of solved gases (such as O<sub>2</sub>, N<sub>2</sub> and CO<sub>2</sub>) naturally present in water, the methods of thermal degassing and vacuum degassing have established themselves in practice.

Also the method of diaphragm degassing can be applied under certain conditions.

Atmospheric degassing procedures basically only remove nitrogen. The standard value required in 6.1 for oxygen cannot be achieved using this method.

### **6.2.6 Catalytic and electrochemical oxygen scavenging**

Contrary to the procedures of thermal degassing and vacuum degassing, in which all gases present in water are removed, the procedures described below only deal with the removal of oxygen.

The procedure of catalytic oxygen scavenging is implemented by converting into water the soluble oxygen present in water with added hydrogen using the catalytic effect of certain noble metals (e.g. palladium).

When considering the electrochemical procedures of oxygen scavenging, one has to differentiate between the galvanic procedure without external current, and the electrolytic procedure with external current.

Galvanic procedures are preferably performed in arrangements where the sacrificial anodes, which are normally used to protect the cathodes, are made of magnesium or zinc and are mounted in a steel vessel in order for them to be metallically conductive.

Electrolytic procedures are preferably performed in arrangements where anodes made of aluminium, magnesium, zinc or iron are insulated to be led through the walls of the vessel, and are loaded with a dc voltage acting between the vessel and the anode.

The iron-, zinc- or magnesium hydroxides, respectively created react in an alkaline manner and, thus, lead to a (desired) pH value increase. The aluminium hydroxide occurring due to the electrolysis of aluminium anodes leads to the formation of protective layers on ferrous materials. The slurry caused by this process has to be regularly removed from the vessel.

The efficiency of an electrochemical procedure, which is characterized by the oxygen removal rate (preferably expressed in g/h), mainly depends on the cathodic surface (size of the vessel) and on the exposure time of the water in the vessel.

## **7 Production technology**

### **7.1 Standard values for the circulation water**

The standard values states in Table 2 apply to the circulation water to ensure the safe and economical continuous operation of district heating facilities.

In the start-up mode and in the event of an incident, deviations from the standard values may occur. These deviations shall be corrected. If potable drinking water is directly heated, the hygienic aspects mentioned in Clause 8 should be observed.

**Table 2 — Standard values for the circulation water of directly or indirectly heated systems**

Property	Unit	Low-salt		Salty
Electrical conductivity at 25 °C <sup>a</sup>	μS/cm	10 – 30	> 30 – 100	≥ 100 – 1500
Appearance <sup>b</sup>		clear, free of suspended substances		
pH value at 25 °C <sup>c</sup>		9,0 – 10,0	9,0 – 10,5	9,0 – 10,5
Oxygen	mg/l	< 0,1	< 0,05	< 0,02
Sum of alkaline earth (hardness)	mmol/l (°dH)	< 0,02 (<0,1)	< 0,02 (<0,1)	< 0,02 (<0,1)

The following aspects have to be taken into account:

<sup>a</sup> Electrical conductivity: at low conductivities, faulty measurements may occur in the case of flow measurements according to the MID principle. In addition, at conductivities < 20 μS/cm, the function of water level electrodes is no longer guaranteed.

<sup>b</sup> Appearance: Water becoming turbid due to the presence of gas bubbles immediately after the sample of circulation water has been taken suggests the possibility of malfunctions in the operating facility.

<sup>c</sup> pH value: A deviation from these values is permitted in facilities that are heated indirectly. For more details, see Section 7.5.2.

## 7.2 Low-salt operation

In circulation water, the lower the electrical conductivity, the smaller the risk of corrosion due to oxidation. An oxygen concentration of 0,05 mg/l or 0,1 mg/l can therefore be tolerated under low-salt operation conditions. The prerequisite for this is that the electrical conductivity has to be limited to < 100 μS/cm. Hence, demineralized water should be used as filling and supplementary water.

Additionally during low salty operation conditions the danger of a microbial growing in the district heating facilities is slight since the nutrients for growing have been removed.

## 7.3 Salty operation

District heating facilities may be operated with salty circulation water if the inflow of oxygen (<0,02 mg/l) and other gases can be practically precluded.

As long as the standard values for the oxygen concentration, the pH value and the electrical conductivity are sure to be complied with in continuous operation, it is not necessary to use oxygen scavengers and/or corrosion inhibitors.

Conditioning with oxygen scavengers or corrosion inhibitors can make sense, for example, to reduce corrosion probability in the event of external water inflow or of oxygenated supplementary water.

In addition, attention should be paid to maintaining the circulation water soft.

## 7.4 Technical aspects related to the operation

### 7.4.1 General

Essential influence factors for flawless operation in practice have turned out to be:

- the constructional design of the pressure maintenance system, including the expansion vessels and their integration into the system;
- the tightness of the potable drinking water boiler in the customer's facilities in the case of a direct connection;
- the quantities of supplementary water for water loss.

The following influence factors, which will be described in more detail in the next sub-sections, are responsible for gas inflow ( $O_2$ ,  $N_2$ ,  $CO_2$ ) into the system and, as potential sources of malfunctions, should be checked during operation:

- filling and supplementary water;
- external water inflow;
- underpressure;
- start-up and shut-down.

Furthermore, operational aspects related to the influence of water constituents in the circulation water from:

- heat generators;
- heat exchangers,

are listed.

### 7.4.2 Filling and supplementary water

Filling water that has not been degassed can lead to increased gas contents in the circulation water:

- when filling new facilities;
- after the facility has been enlarged;
- after cleaning measures;
- after exceptionally high water losses.

Supplementary water is recommended to compensate for water losses which may occur due to volume variation, evaporation, clarifying or small leakages in the district heating facility. Also the supplementary water can be loaded with oxygen and other gases.

Insufficient pressure maintenance or untreated supplementary water can lead to an increased gas content in the circulation water.

Fundamentally, losses due to leakage should be kept as low as possible (localizing the leakage as quickly as possible).

If the pressure of the district heating network is locally lower than that of the potable drinking water network, faulty heat exchangers for the heating of potable drinking water may lead to external water inflow. Increased hardness levels of the circulation water can suggest such an external water inflow. The increased hardness can lead to the formation of deposits on the surfaces of the heat exchanger which, in turn, leads to an increase of the overall heat transfer resistance.

When large volumes of supplementary water are fed into the system, care should be taken that the standard values for the circulation water are complied with – or at least attained again after an appropriate period.

### 7.4.3 Underpressure

Underpressure occurs, for example, when temperature variations lead to volume contractions of the circulation water, so that volume exchange in a closed circuit is insufficient. Air tends to penetrate into the piping especially at seals and automatic bleeders. The nitrogen remaining after the oxygen has been consumed by the process of corrosion can lead to malfunctions in the system due to the formation of free gas bubbles.

Compliance with the following points should be paid attention to in order to prevent air inflow due to underpressure:

- maintaining sufficient at-rest pressure (correct dimensioning of the pressure maintenance system);
- connection point of the expansion vessel with the circulation pump;
- The pressure-control pipe may be connected to the pressure or the suction side of the network circulation pump. If the pressure-control pipe is connected to the pressure side of the network circulation pump, insufficient at-rest pressure in the highest radiator can lead to dropping below the atmospheric pressure, which would cause air to be sucked in through packed valves and bleeders;
- Sufficient dimensioning of the expansion vessels taking account of leakage loss and of volume variations of the network's content;
- Correspondingly, in the case of diaphragm expansion vessels, the upstream pressure shall be adapted to the volume variations of the network's content. The operability of the diaphragm should be checked regularly (diaphragm fault);
- In the case of overflow valves, the predefined upstream pressure should be checked permanently. If the upstream pressure is regulated using air, its temperature dependence should be taken into account;
- Configuration of the differential pressure regulators in domestic stations with direct connection;
- In domestic stations with direct connection, care should be taken that the differential pressure regulators are functional. If the potable drinking water heating system is connected directly, a combined regulator in the inlet could, in the event of a malfunction, cause underpressure;
- Maintaining the pressure maintenance system (e.g. upstream pressure for DEV, filling up with supplementary water, setting of the overflow valve, damage to the diaphragm);
- Checking the filling-up process when supplementary water is filled up automatically.

## **7.4.4 Exceptional operating conditions**

### **7.4.4.1 Shutdown**

In district heating facilities in discontinuous operation (e.g. weekend shutdown, annual closing or summer shutdown) where oxygen inflow is not expected during shutdown, particular measures to stabilize the system are not necessary.

In facilities where oxygen inflow is expected, it might be necessary – especially in facilities operated under salty conditions – to condition the circulation water with corrosion inhibitors and/or an oxygen scavenger.

Circulating the network's content weekly is recommended. The water quality should be checked at regular intervals.

In any case, the at-rest pressure of the district heating facility should be ensured. To ensure the at-rest temperature, the pressure maintenance facility should not be shut down!

When individual heat generators are shutdown, care be taken that they, however, remain connected to the network via a circulation pipe. This reduces corrosion probability in the water circuit and prevents corrosion due to humidity rejection through the flue gas system.

### **7.4.4.2 Start-up/pressure test**

The pressure test with filling water should be performed immediately after scavenging. A repeated purging of the system prior to the start-up should, as far as possible, be avoided. Residual water in the system abets corrosion.

## **7.4.5 Direct heating**

When the walls inside the heat generators are heated directly, deposits (boiler scale and limescale) may form on the water side and corrosion may occur, which might cause damage to the boiler. The water used for the initial filling of the system and for further operation shall be at least softened.

## **7.4.6 Indirect heating**

With indirect heating, e.g. via heat exchangers, the risk of damage due to overheating or insufficient cooling of the heating surface is lower. For this reason, a deviation of up to 0,2 mmol/l from the standard values is tolerated for the alkaline earth content. Due to the formation of limescale – which leads to insufficient heat transfer – using softened water as filling and supplementary water is recommended.

## **7.4.7 Partial evaporation**

Partial evaporation occurs when bubbles form on parts of the heat exchanger surface due to the heat accumulation caused by insufficient flow or by a pressure drop.

Partial evaporation in narrow gaps (e.g. in heat exchangers) leads to the accumulation of water constituents. The accumulation of alkaline can cause intercrystalline stress-corrosion cracking in austenitic chromium-nickel steels and unalloyed ferrous materials (caustic embrittlement). The accumulation of chloride ions can cause pitting corrosion and transcrystalline stress-corrosion cracking in austenitic chromium-nickel steels. Low-salt operation considerably reduces the risk of reaching critical concentrations.

## 7.5 Conditioning

### 7.5.1 General

Adding chemical conditioning agents may be necessary in order to comply with standard values, but it may also be a measure taken to limit the risks of damage due to external water and air inflow, which are, in practice, basically unavoidable. It shall, however, be taken into account that adding conditioning agents increases the electrical conductivity. Attention shall also be paid to material compatibility and to the purity of the chemicals used. In addition, when combining conditioning agents, attention shall be paid to their compatibility with each other.

When using conditioning chemicals, besides hygienic and toxicological aspects, also their environmental impact – especially with regard to their disposal (waste and waste water) – shall be taken into account (cf. Ordinance on Hazardous Substances).

Conditioning agents have to be dosed as precisely as possible and under permanent control. The required quantities of additives are usually low. If a higher dose – which would cause the electrical conductivity to increase – is needed while the facility is in operation, this suggests that the problem originates from avoidable disturbances whose causes have to be eliminated as quickly as possible.

When using demineralized filling and supplementary water and low-salt operation, compliance with the pH value range pursuant to Table 1 is the decisive – and often the only necessary – measure. From experience, negligible and temporally limited overstepping of the limit values for the oxygen concentration does not lead to damage due to corrosion.

In salty operation, however, with the simultaneous presence of oxygen, corrosion probability is increased. In such a case, it may be necessary to add an oxygen scavenger or inhibitors as conditioning agents.

When using boiler scale counteragents, it is recommended that only additives with a suitability test be used.

Combination conditioning agents for the regulation of different standard values are less recommendable than the separate use of each chemical.

The use of friction-reducing additives should be limited to exceptional cases; for this purpose, the system has to be considered as a whole.

To assess the whole system and its changes, a complex approach is necessary; this approach is only possible by documenting precisely the analysis results and the quantities of supplementary water as well as the added quantities of conditioning agents.

### 7.5.2 pH value increase

The pH value is increased in order to repress the dissolving of iron in the water which forms iron(II) hydroxide and for a protective coating of iron oxides (magnetite) to form (at a flow temperature much more than 100 °C).

On principle, to attain a sufficient protective alkalinity, both caustic soda (NaOH) and trisodium phosphate (Na<sub>3</sub>PO<sub>4</sub>) can be used. For hot-water generators, Na<sub>3</sub>PO<sub>4</sub> shall be used in the case of large-scale water boilers and low-salt circulation water.

Where the alkalinizing agent concentrates in gaps due to the design (partial evaporation, see 7.4.7), alkaline-induced stress-corrosion cracking can occur; in these cases, it is preferable to use Na<sub>3</sub>PO<sub>4</sub>.

The optimal pH value to protect iron as a construction material is approx. 9,3.

Practice shows that in the case of indirectly heated facilities, pH values of down to 8,5 are sufficient to ensure disturbance-free operation.



pH values > 9 and locally increased flow velocity represent a risk of erosion corrosion for materials with brass as a main constituent.

If ammonia is used as an alkalizing agent, the corrosion risk is increased at pH values > 9,3 for materials containing copper.

Relatively low quantities of alkalizing agents are sufficient to increase the pH value in low-salt operation. When using caustic soda (NaOH) in the commercially available 50 % concentration, 4 to 8 g/m<sup>3</sup> are necessary. For alkalizing using trisodium phosphate (Na<sub>3</sub>PO<sub>4</sub>), the 3- to eightfold quantity is required. Adding Na<sub>3</sub>PO<sub>4</sub> causes the salt concentration – and, thus, the electrical conductance – to increase more significantly than with caustic soda.

Due to the selfalkalinization of the circulation water caused by the outgassing of CO<sub>2</sub>, as a consequence of the hydrolysis of the hydrogen carbonate ions, the pH value in the filling and the supplementary water in salty operation, should first be increased up to a range comprised between 8,2 and 9,0 only. Before adding more alkalizing chemicals to regulate the pH value, one should wait at least three days in heating operation.

### **7.5.3 Hardness stabilizing**

The water hardness in the circulation water shall be kept within the limits stated in Table 2 using the above-mentioned treatment procedures.

Unavoidable small hardness increases due to external water inflow can be treated by adding hardness-stabilizing agents and boiler scale counteragents.

In practice, phosphate-based chemicals, polyphosphates as well as polyacrylates have stood the test. Besides their property of preventing hard boiler scale deposits, they also have a dispersing effect and can, thus, prevent the deposition of corrosion products and of suspended substances.

Chelating agents, such as EDTA or NTA, are classified as problematic with regard to waste water legislations.

### **7.5.4 Oxygen scavenging**

#### **7.5.4.1 General**

Oxygen inflow cannot always be prevented in district heating networks.

In a mostly closed district heating network without increased need for supplementary water, the oxygen inflow is, in the case of disturbance-free operation, so low that no damage due to corrosion has to be expected. In such cases, it is therefore not necessary to take technical oxygen scavenging measures.

In contrast, oxygen scavenging makes sense when an increased oxygen inflow cannot be precluded due to particular operating conditions.

Oxygen can be scavenged by using partial flow degassing systems, by means of catalytic or electromechanical oxygen scavenging and by adding an oxygen scavenger.

In the event of operational malfunctions with massive oxygen inflow, the reaction speed of the corrosion process shall be expected to exceed at which the oxygen scavenger can eliminate oxygen.

#### **7.5.4.2 Inorganic oxygen scavengers**

##### **Hydrazine**

Due to its classification as carcinogenic substance, hydrazine (N<sub>2</sub>H<sub>4</sub>) may only be used in justified exceptional cases. If a drinking water heating facility is directly connected to the district heating network, the use of hydrazine is strictly forbidden. The same applies to the inorganic oxygen scavenger carbonylhydrazide, since it releases hydrazine when heated up in the circulation water.

## Sodium sulphite

The use of sodium sulphite ( $\text{Na}_2\text{SO}_3$ ) is limited to salty operation, since it constantly increases the salt content of the water – both due to its own salt content and to its reaction product, sodium sulphate. To reduce the risk of corrosion in connection with non-ligated oxygen, a sulphate concentration of 250 mg/l should not be exceeded. The circulation water shall be desalinated if necessary.

When using sodium sulphite as an oxygen scavenger, district heating facilities equipped with copper piping may experience copper corrosion due to sulphide ions, arising by conversion processes, in the simultaneous presence of oxygen.

Sodium sulphite (when complying with the purity requirements) is an additive which is even listed as a permissible substance for water treatment and disinfection pursuant to Section 11 of the Drinking Water Ordinance of 2001.

### 7.5.4.3 Organic oxygen scavengers

Chemicals containing the following active ingredients are available as further oxygen scavengers:

- ascorbic acid or isoascorbate;
- diethylhydroxylamine (DEHA);
- hydroquinone;
- methylethylketoxime (MEKO);
- tannic acids;
- carbohydrazide (see hydrazine).

All chemicals mentioned produce inorganic and/or organic acids or other organic compounds as decomposition products, hence, when using these chemicals, the pH value of the system has to be maintained stable by means of suitable buffer substances (e.g. phosphates). Due to their own colouration, hydroquinone and tannic acids lead to a staining of the circulation water.

### 7.5.5 Corrosion inhibitors

Commercially available corrosion inhibitors are, besides phosphates and silicates, also:

- amines (film-forming and alkalinizing);
- borate;
- molybdate;
- nitrite;
- tannic acid.

Corrosion inhibitors and their reaction products shall, when used properly, neither impede heat transfer, nor cause corrosion. This shall be guaranteed by the manufacturers or the suppliers

Corrosion inhibitors can be expected to deploy their full efficiency only with metallic bright surfaces. If corrosion has already started developing on parts of the surfaces, corrosion inhibitors may, in the presence of oxygen, even aggravate this local corrosion.

### **7.5.6 Water tracing dyes for the circulation water**

Circulation water may be coloured by means of so-called water tracing dyes for easier detection and differentiation of the circulation water from other types of water (surface-, ground- or potable drinking water), e.g. in the event of leakages. The following dyes have proven their worth:

- uranine (sodium salt of fluorescein);
- pyranine (sodium salt of pyrosulfuric acid).

At a dilution ratio of 1:10 million, these fluorescent dyes are still detectable in water, if necessary with the aid of UV light. At the usual temperatures of circulation water, the dyes are chemically very stable. The quantities required to dye the circulation water may be very low and shall be taken from the product description provided by the manufacturer. Before using a water tracing dye, the specifications stated in the product safety data sheet shall be observed; hereby, particular attention shall be paid to selecting exclusively dyes that are classified as non-toxic. The utilization of dyeing agents may interfere with colourimetric analytical procedures used to determine the constituents of the circulation water (e.g. for hardness determination).

### **7.5.7 Antifreezing agents**

Adding antifreezing agents to water circuits should be limited to specific applications (e.g. combined heating/cooling systems, facilities with outdoors installations, combination with solar plants). Since all known antifreezing agents always contain one or a combination of several corrosion inhibitors as well as alkalizing additives, the minimum concentration of antifreezing agent stated by the manufacturer shall be observed. If the dose used is lower than the minimum concentration, inhibition may not be sufficient, whereas the risk of corrosion increases. The antifreezing agent replacement intervals stated by the manufacturer have to be observed imperatively.

Temporary use of antifreezing agents/water mixtures and the subsequent filling up with antifreezing-agent-free supplementary water (e.g. during the construction phase) should systematically be avoided, as it cannot be ensured that the antifreezing agent as well as its potentially deposited decomposition products will have been fully removed by the time the facility is put into operation. Especially the organic acids produced by the decomposition of glycol promote corrosion.

## **7.6 Monitoring**

### **7.6.1 General**

To comply with the water-chemical standard values stated in Table 2 reliably, the circulation, filling and supplementary waters have to be monitored analytically.

The following recommendations are based on experience and practice; they provide guidance with regard to the extent of the effort necessary for the monitoring of the water quality in district heating facilities – both from a chemical and from an economic point of view.

In the combined heat and power plant, the quality and monitoring provisions mostly apply to the higher-ranking medium (i.e. steam and condensate). The more demanding monitoring effort that applies to the operation of steam generators does not necessarily have to be transposed equally when the circulation water of a district heating facility is concerned.

### **7.6.2 Assessment criteria**

A stable district heating network is usually characterized by analytical values of the circulation water that are more or less constant in the long run. This applies to district heating networks both in low-salt and in salty operation.

Besides the fundamental assessment criteria from Table 2:

- appearance;
- electrical conductivity;
- pH value;
- oxygen; and
- hardness/ alkaline earth.

also the following parameters:

- iron;
- copper;
- sulphide;
- sulphate;
- acid capacity KS8.2; and
- acid capacity KS4.3.

can act as valuable signs of malfunctions/corrosion.

If immediately after sampling water become turbid due to the presence of gas bubbles (especially nitrogen), it suggests the possibility of faults in the operating facility.

The electrical conductivity measured includes the conductivity of the alkalizing agents, which the corresponding standard value already takes into account. In the event of frequent earth alkali in-flow, partial flow treatment facilities are recommended.

Determining the total content of iron and/or copper is useful to obtain hints suggesting the presence of insoluble iron- and copper compounds which can lead to deposits and, thus, to malfunctions in slower-flow sections.

Experience shows that concentrations of

- iron (total) < 0,10 mg/l
- copper (total) 0,010 mg/l

are in the “normal range”.

Additional examination as to the presence of sulphide and sulphate in the circulation water is especially recommended if sodium sulphite or sodium-sulphite-containing chemicals are added as chemical oxygen scavengers. If a sulphide concentration ( $S^{2-}$ ) > 0,03 mg/l is exceeded several times, damage due to corrosion can be expected on non-ferrous heavy metals.

Formation of copper sulphide can take place on the one hand by chemical reduction of sulphite/sulphate but also by sulphate-reducing microorganism.

Beside the increased sulphide amount an obvious reduced sulphate content in the circulation water in comparison with the filling water is an indication for a bacterial growing. Microbiologically determinations as an evidence for sulphate-reducing bacteria are difficult and should not suggested as routine.

In addition to the pH value, it makes sense to determine the KS8.2 value. The KS8.2 value verifies the measuring of the pH-value. The “acid capacity up to pH 8,2” (KS8.2) – previously p-value – is, besides the pH value, another way of expressing the alkalinity of water. In low-salt water, a KS8.2 value of 0,05 to 0,2 mmol/l (mol/m<sup>3</sup>) corresponds to a pH value range from approx. 9,0 to 10,5 and means an alkali quantity (referring to NaOH) of 2 to 8 mg/l. In salty water, a KS8.2 value of 0,7 to 2 mmol/l (mol/m<sup>3</sup>) corresponds to a pH value range from approx. 9,0 to 10,5. A direct relationship between the pH value and KS8.2 can be easily established in low-salt water only.

The „acid capacity up to pH 4,3“ (KS4.3) – formerly m value – is used to determine the fraction of hydrogen carbonate ions. The concentration of hydrogen carbonate ions is used as a measure of the ability of water the water for selfalkalinization (see 5.2.3.3).

To assess the oxygen concentrations measured, the sampling location is particularly important since the oxygen present in the circulation water may have been released by corrosion.

If, in addition, other chemicals are used as additives for conditioning (e.g. phosphates), their concentration in the circulation water shall be measured as specified by the manufacturer or supplier of these chemicals.

From experience, in salty operation, a dosing of

— < 5 mg/l for sulphite (as SO<sub>3</sub><sup>2-</sup>)

— < 10 mg/l phosphate (as PO<sub>4</sub><sup>3-</sup>)

is sufficient .

In salty operation and under certain circumstances, also the chloride content of the circulation water may be important with regard to the occurrence of corrosion. This applies especially to cases where parts of the facility made of austenitic, non-corroding steel may be exposed to pitting corrosion or stress-corrosion cracking. Since the concrete corrosion risk depends on several factors (material, water quality, flow conditions, temperature and pressure conditions, design, assembly, etc.), it is not possible to define a limit value applying to all operating conditions. Since an intermittent oxygen inflow cannot be precluded, it is preferable to keep the chloride content as low as possible (e.g. corrosion probability increases at 1,5 mmol/l (53 mg/l) and higher).

In critical areas of facilities (crevices, pores and underneath deposits), the risk of corrosion is increased due to concentration (see 7.4.7).

Depending on the conditions prevailing in a certain network, it may be necessary to test further analytical parameters, such as, e.g. aluminium, zinc, DOC, TOC.

### **7.6.3 Measurement frequency**

On principle, an undisturbed system needs less analytical monitoring than a system prone to malfunctions.

The filling and supplementary water quantities should be documented in order to detect, among other things, water losses in due time.

Circulation water whose chemical parameters hardly vary at 4 weeks' interval will most probably not have experienced significant variations in the meantime. As long as no test intervals are pre-scribed by special terms and conditions (e.g. for the operation of heat generators), it might suffice to test the parameters mentioned on a monthly basis (see Table 3). However, if deviations from the normal value in operation occur in the circulation water or if increased quantities of supplementary water are needed, then tests should be performed more frequently (even several times per day, if necessary).

Independent of the analytical monitoring of the circulation water, the filling and supplementary water should be monitored as to the most important parameters (e.g. conductance, residual hardness, residual oxygen), depending on the working principle of the water treatment plant. In addition, it is recommended that the raw water be tested at longer intervals prior to entering the water treatment plant.

The analytical data shall be recorded and archived carefully. These data serve, on the one hand, to optimize operation and, on the other hand, to produce proof of “operation in accordance with the regulations” vis-à-vis the authorities and the district heating end-users.

**Table 3 — Measurement frequency**

	<b>Circulation water</b>	<b>Filling and supplementary water</b>
<b>Appearance</b>	≤ m	–
<b>Electrical conductivity</b>	≤ m	<b>regularly<sup>a</sup></b>
<b>pH value</b>	≤ m	<b>regularly<sup>a</sup></b>
<b>K<sub>S8.2</sub></b>	<b>if required</b>	–
<b>K<sub>S4.3</sub></b>	<b>if required</b>	–
<b>Sum of alkaline earth</b>	≤ m	<b>regularly<sup>a</sup></b>
<b>Residual oxygen</b>	≤ m	–
<b>Fe (total)</b>	<b>if required</b>	–
<b>Cu (total)</b>	<b>if required</b>	–
<b>Sulphide (S<sup>2-</sup>)</b>	<b>if required</b>	–
<b>Conditioning agents</b>	≤ m	<b>if required</b>
K <sub>S8.2</sub> (K <sub>S4.3</sub> ) = acid capacity up to pH value 8,2 (4,3) Cu = copper; Fe = iron; S <sup>2-</sup> = sulphide m = monthly		
<sup>a</sup> for degassed supplementary water		

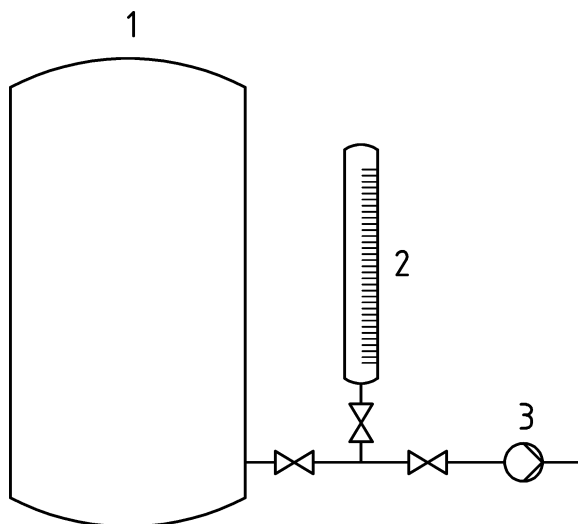
#### **7.6.4 Dosing of conditioning agents**

For the conditioning of circulation water with chemicals, proportioning devices are required; their technical design shall be such that the dosed solution can be controlled with great accuracy.

The quantity of conditioning agents should be roughly estimated prior to the dosing. It depends on the network volume and on the filling and supplementary water quantities, respectively, as well as on the concentrations already present in the water.

Wet calibration is a simple possibility of testing whether the dosing system is working properly.

Since dosing vessels are often designed for long-term stocking, a suitable measuring device (e.g. liquid level height gauge) is necessary (Figure 1).



**Key**

- 1 storage tank
- 2 measuring tube (transparent)
- 3 dosing pump

**Figure 1 — Dosing system**

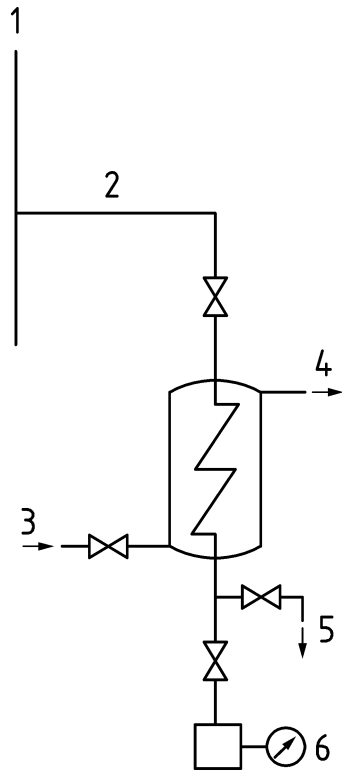
For the filling and supplementary water, the dosing dispensed by the metering pump is, as appropriate, proportional to the quantity of water. In the case of the circulation water, the concentration of conditioning agent present in the water is first measured during operation, then the required quantity of conditioning agent is computed. To prevent concentration peaks, dosing takes place progressively over the total time it takes for the network volume to be circulated once.

Conveniently, the dose of chemicals released into the circulation water is dispensed at the suction side of the circulation pump, whereas the chemicals added to the supplementary water are dosed proportionally to the quantity of water.

The time of rest of the solution inside the storage tank depends on the type of conditioning agent used. When oxygen scavengers are added, the solution shall be provided immediately prior to being released into the water, since it only takes a short rest time for oxygen scavengers to react with the oxygen contained in the air, thereby mostly transforming into inefficient substances. In the case of caustic soda or phosphate, in contrast, a rest time of several weeks is possible. The flawless functionality of the dosing system shall be checked regularly at short intervals.

**7.6.5 Sampling**

A prerequisite for a meaningful chemical analysis is that the water sample under test be taken from an appropriate sampling point (Figure 2), preferably in a vertical pipe section with a sampling pipe as short as possible.



**Key**

- |   |                                     |   |                                    |
|---|-------------------------------------|---|------------------------------------|
| 1 | district heating return flow        | 2 | sample extraction                  |
| 3 | cooling water flow pipe             | 4 | cooling water return pipe          |
| 5 | sampling outlet for sampling vessel | 6 | measuring and analytic instruments |

**Figure 2 — Sampling equipment**

The sampling equipment generally consists in a extraction probe (which should penetrate into approx. 1/3 of the pipe cross-section), an appropriate valve, a sample cooling system, and a grid to park the samples. The sampling equipment shall be made of non-corroding steel (e.g. material 1.4571) in order to preclude bias of the sampled material due to corrosion processes inside the sampling system. Measuring oxygen requires gas-tight joints in the sampling pipe (realized, e.g. by welding). The minimum requirement for the valves is to use welded ball valves.

The determination of the oxygen content has been taken place always in flow-through at the sampling point.

The cooling power shall be calculated for a temperature of the sampled good of approx. 25 °C at a sampling quantity of 30 to 60 l/h. When connecting an analytical system designed for a permanently installed continuous measurement (e.g. conductance, pH value, oxygen), an additional, parallel sampling point for a sampling vessel or analysis shall always be provided.

Prior to sampling water, the sampling pipe needs to be rinsed thoroughly. The rinsing time depends on the length of the sampling pipe. The sampling vessels (glass/plastic) shall be rinsed with the sampled good at least three times a week and be correctly sealed after sampling; they shall then be clearly identified.

Samples shall be taken downstream from the water treatment facility (for filling and supplementary water) and in the circulation water (both flow and return flow).



If critical operating conditions are expected, an inspection section representative of the materials used in the network and equipped with a bypass allows conclusions as to the materials' corrosion behaviour to be drawn.

### **7.6.6 Measurement procedures**

The individual parameters are determined by means of measurement procedures *in situ* or in a laboratory.

But also other suitable analytical procedures may be used (e.g. cuvette tests). In this case, it is recommended that the values measured *in situ* be checked by a competent laboratory at least twice a year.

The registering conductance measurement can be reasonably successfully used to monitor district heating facilities operating with low-salt water in order to detect, as soon as possible, a potential inflow of electrical conductivity-increasing substances such as, e.g. operating fluids, drinking water and hardness.

The manufacturers shall state methods to determine the active ingredient of conditioning agents and/or corrosion inhibitors.

Flash tests are for information only.

Dyed circulation water interferes with colourimetric determinations. If the water is dyed, other, more suitable analytical procedures shall be used.

The water samples shall be investigated immediately. The oxygen content shall always be determined at the sampling point in the flow itself. In addition, in low-salt operation, the pH value and the electrical conductivity shall be determined directly at the sampling place in the overflow.

The sample may be analysed either at an in-plant or at an external laboratory.

If the total concentrations of iron and/or copper have to be determined, it is necessary to perform acid hydrolysis using aqua regia in accordance with ISO 11466.

On suspicion of a bacterial attack it is possible to perform an indirect detection by determination of the metabolic products. Bacterial rapid tests are only limited suitable.

## **8 Hygienic, toxicological and environmental aspects**

### **8.1 General**

Although the circulation water of a district heating facility flows inside a closed system, its uncontrolled release into the environment can – due to, e.g. technical disturbances – not be precluded, so that it might come into contact, directly or indirectly, with man and the environment. Against the background of potential impacts on man and the environment, hygienic, toxicological and environmental aspects shall be taken into account.

### **8.2 Hygienic and toxicological aspects**

Filling and supplementary water for district heating systems is usually fetched from drinking-or surface water and treated by means of adequate procedures. Depending on its origin and the treatment procedure used, the water may be biologically (microorganisms) and/or chemically (additives) contaminated.

Whereas microorganisms only play a secondary role as far as hygiene is concerned, since circulation water is used as a heat transfer medium, chemical additives, conditioning agents or dyes used in the treatment procedure may well be toxicologically relevant. This applies particularly to cases where the circulation water is directly connected to the end-customer's system and used as a heat transfer medium to heat up drinking water.

As long as the circulation water does not contain any substances listed in Category 4 of EN 1717, it belongs to Category 3. It shall be ensured that the heat exchanger used is non-corroding.

If the circulation water contains Category 4 substances such as, e.g. hydrazine, an heat exchanger with intermediary medium shall be used for heating up drinking water.

Besides the protection of drinking water realized by means of technical devices, legal provisions of labour safety, environmental and health protection also have to be observed when handling chemicals or preparations.

### **8.3 Environmental aspects**

Circulation water that flows through a pipe network outside the area of the CHP plant in order to be supplied to the end-customers systems shall not contain any water-pollutants which could pollute the aquatic environment (incl. the groundwater).

The requirements of each country and the national standards has to be considered.

## **Bibliography**

EN ISO 8044, *Corrosion of metals and alloys - Basic terms and definitions (ISO 8044)*





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