CHALLENGE EFFICIENCY

Recommendations regarding water for BPHEs in district energy systems

SWEP
A DOVER COMPANY

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Introduction

This document aims to explain the importance of good water quality in a district energy system. It focuses on the parameters that help prevent corrosion and fouling in a brazed plate heat exchanger (BPHE). Good water quality in a district energy system results in a lower risk of corrosion, fouling, and scaling. This will in turn reduce maintenance costs for the entire system.

Background

As with most things, water can come in different qualities. In district energy systems, the most common water qualities used are untreated, demineralized, partly demineralized, or softened water. The quality of the water is an important factor, since the concentrations of certain substances can change with the water quality. Conductivity illustrates this. Demineralized water has a much lower conductivity than does untreated water because demineralization removes ions that confer conductivity. It is important to understand all water qualities in the system, from the circulating district energy water to the added make-up water. The make-up water can be used to regulate to some extent the water quality in the district energy system at the recommended levels. It is not easy to establish the quality of the district energy system water. However, testing the water regularly keeps the status of the district energy water under control and reduces the risk of corrosion and particle formation.

Appendix A, at the end of this document, consists of SWEP's recommendations for water quality when our BPHEs are being used. The table covers the various grades of stainless steel and the various brazing materials used in our BPHEs. It is based on tap water at room temperature, and examines several important chemical components. However, corrosion itself is a very complex process influenced by many different factors in combination. Appendix A can help decide whether a water quality is suitable for a SWEP BPHE. If you have any questions regarding this document or Appendix A, please talk to a SWEP sales representative.

Corrosion of various materials

Stainless steel

Stainless steel has good corrosion resistance and is therefore encountered frequently in district energy systems. All our BPHEs use stainless steel for their channels plates, with various grades available. However, chloride at certain levels can initiate the corrosion of stainless steel. The most common form here is pitting corrosion, with the chloride attacking only a small area of the steel. Pitting corrosion is hard to detect until it is too late and the unit has started to leak. Another common and very similar type of corrosion for stainless steel is crevice corrosion, when corrosion starts in crevices. Table 2 in Appendix A shows which stainless steel we recommend for channel plates for a range of chloride concentrations.

Copper

The majority of our BPHEs use copper as the brazing material, which has good resistance to corrosion in the majority of district energy water qualities encountered. If the water quality is very bad, the copper can start to corrode or dissolve in the water. For more information about whether a copper-brazed unit is suitable, please see the table in Appendix A. The Danish District Heating Association's publication 'W*ater treatment and corrosion prevention*' recommends keeping the oxygen content below 0.02 mg/l. Copper is very sensitive to ammonia and sulfide. Ammonia may be used in district energy systems to regulate the pH. If copper is used as the brazing material, it is recommended that the ammonia level be kept very low. We recommend that another chemical be used to regulate pH, for example sodium hydroxide.

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Oxygen

Factors that accelerate the corrosion process are oxygen and/or temperature. The higher the temperature, the faster the corrosion. The presence of oxygen increases the risk of corrosion beginning, so the oxygen content should be kept as low as possible. When adding make-up water, it is important to make sure that either the water has been de-oxygenated or that additives to bind the chemicals have been used. Table 3 in Appendix A shows the recommended oxygen level in the water depending on the conductivity of the water.

Fouling

Fouling refers to the tendency of a fluid to form a film or scale on the heat transfer surface. The term fouling includes the build-up of both organic and inorganic material. Inorganic materials may crystallize as salts, which results in scaling. Organic deposits include biofilms or microbial organisms. If inorganic or organic material starts to build up inside the BPHE, it will result in lower heat transfer and a higher pressure drop.

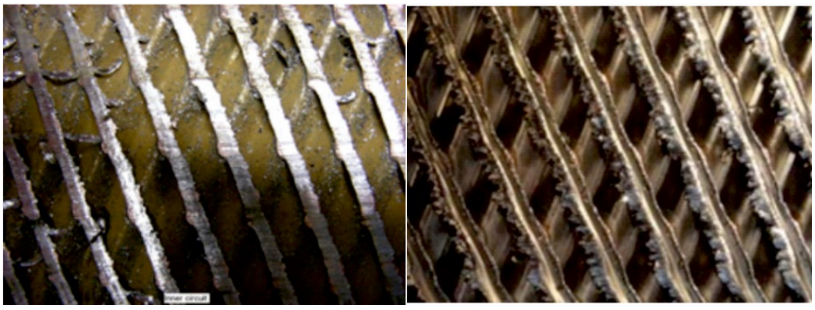


Figure 1.Left picture: Visual reference, tap water circuit. Right picture: Cleaned tap water circuit

Scaling

Scaling is a type of fouling caused by inorganic salts in the water circuit of the BPHE, which may precipitate and form a scale on the heat transfer surface. It occurs when the fluid velocity is low (laminar flow) and the liquid is distributed unevenly through the passages on the heat transfer surface. It is highly temperature-dependent.

Most scaling is due to the precipitation of either calcium carbonate or calcium sulfate. Certain inorganic salts, most notably those two salts, have an inverted solubility curve, i.e. the solubility in water decreases with increasing temperature. When the cold water makes contact with the warm surface, these salts are deposited on the surface.

The important factors that influence scaling are water quality, temperature, turbulence, velocity, flow distribution, and surface finish. Estimating the tendency of natural water to scale involves several parameters that must be analyzed and determined:

- pH
- Calcium content
- Alkalinity
- Ionic strength of the water

The first three parameters are relatively straightforward to determine. The ionic strength, however, depends on the total amount of dissolved, dissociated compounds, i.e. salts and acids, as well as their relative concentrations.

The inorganic salts that result in scale usually come from drinking water, due to a leakage or from the tap water side if the BPHE is used in a substation for tap water heating. They can also come from the make-up water.

To reduce the risk of scaling, use the highest possible water pressure drop. A high pressure drop implies higher shear stresses, which are always beneficial in the event of scaling. The shear stresses work as a descaler by constantly applying forces to the adhered material that pull the particulate material away from the surface, as shown in Figure 2. The shear stresses also help prevent the deposition of suspended particles. For a BPHE with a temperature above 70 °C (158 °F) on the hot side and/or very hard water (and a high risk of scaling), the pressure drop should be increased as much as possible on the cold-water side and reduced on the hot side. This reduces the wall temperature on the cooling water side and increases the shear stresses, making it more difficult for the scaling compounds to adhere. The normal practice is to have the cold water entering the lower port whenever possible, because if it enters through the upper port, it may encourage debris to enter the channels.

Figure 2. An illustration of how the turbulent flow and shear stresses help keep the BPHE clean.

Organic deposits/biofilms

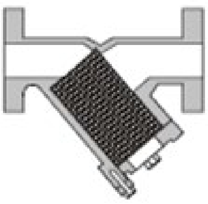
If bacteria enter the district energy systems, their small size (about 1 μm) enables them to penetrate all technical systems. They can enter systems in various ways, for example:

- Make-up water
- Contamination following pipe fractures
- Lack of cleaning of new and modernized plants
- Mixing with central heating water from newly connected plants
- Leaky BPHEs and hot-water tanks

Organic deposits/biofilms can reduce the heat transfer in the BPHE. The can also clog entire channels in the BPHE, which then also increases the pressure drop. The deposits can also result in microbial corrosion.

Filters and strainers

The water side channels in a BPHE may clog if particles such as silt, pipe slag, biological matter, etc., are not prevented from entering the unit. These particles could otherwise block the channels, causing bad performance and increased pressure drop. In a closed loop system, the piping system must be properly flushed before the BPHE is connected to ensure that no additional material that could cause fouling or clogging enters the system. For open loop systems, and to increase safety in closed loop systems, the components necessary to filter out particulates must be installed before the BPHE.



To reduce the risk of a particulate sludge forming inside the BPHE, a filter or strainer should be installed. Strainers can provide the necessary protection against blockage. If any of the media contain particles larger than 1 mm, we recommend that a strainer with a size of 20 mesh (number of openings per inch) be installed before the BPHE.

For applications with a high concentration of magnetite in the water, such as open loop or closed loop with high leak rate, a filter with a magnet function is highly recommended. It will not only prevent the BPHE from clogging but will also protect the water pump against erosion.

Dirt separator

Besides filters, our substations are also offered with state-of-the-art dirt separators that remove even the smallest dirt particles, reducing maintenance needs and further boosting performance.

Best practices for preventing and clearing blockages and scaling

Protection from blockages and scaling starts with a good installation manual that provides guidance on when and how to clean the BPHE. The only way to clean out a blockage, short of replacing the BPHE, is by backwashing. The only way to perform a backwash is to have the necessary ports and valves to isolate the BPHE and allow the water to drain during the backwash. Our BPHEs can be fitted with ports on the unit itself for cleaning.

If there is a reluctance to have these ports on the BPHE, then the installing contractor will have to add the ports and valves.

Another useful tip is to provide water flow/pressure drop tables covering the BPHE and the internal water piping system. They will help field technicians determine whether backwashing or descaling is necessary.

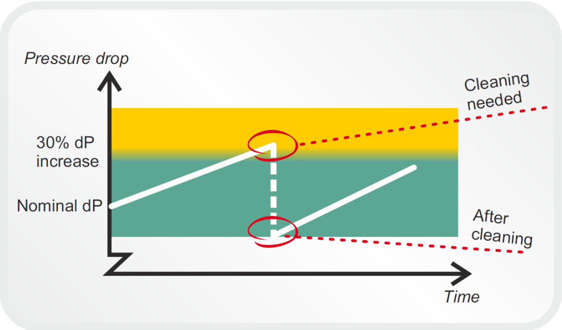


Figure 3. A 30% increase in pressure drop indicates cleaning is needed.

Appendix A Water recommendations

Table 1, corrosion resistance of stainless steels and brazing material in water at room temperature

The guide below is an attempt to give a picture of the corrosion resistance of stainless steels and brazing material in water at room temperature. In the table, a number of important chemical components are listed, however the actual corrosion is a very complex process influenced by many different components in combination. **This document is therefore a considerable simplification and should not be overvalued!**

Table key	**Important Note:** The following paratmeters can also influence the corrosion resistence
+ Good resistance under normal conditions	Temperature: The data in the table are based water temperature of 20°C unless otherwise is stated.
0 Corrosion problems may occur especially when more factors are valued 0	Presence of oxidants in the environment: guidelines regarding the oxygen content are shown in Table 3.
- Use is not recommended	Product form, heat treatment and presence of intermetallic phases: The data in the table is based on untreated raw material.

			Plate Material		Brazing Material		
WATER CONTENT	**CONCENTRATION (mg/l or ppm)**	**TIME LIMITS Analyze before**	**AISI 304**	**AISI 316**	**COPPER**	**NICKEL**	**STAINLESS STEEL**
Alkalinity (HCO_3^-)	< 70	Within 24 h	+	+	0	+	+
	70-300		+	+	+	+	+
	> 300		+	+	0/+	+	+
Sulphate[1] (SO_4^{2-})	< 70	No limit	+	+	+	+	+
	70-300		+	+	0/-	+	+
	> 300		+	+	-	+	+
HCO_3^- / SO_4^{2-}	> 1.0	No limit	+	+	+	+	+
	< 1.0		+	+	0/-	+	+
Electrical conductivity[2] *(Refer to Table 3 for oxygen content guidelines)*	< 10 µS/cm	No limit	+	+	0	+	+
	10-500 µS/cm		+	+	+	+	+
	> 500 µS/cm		+	+	0	+	+
pH [3]	< 6.0	Within 24 h	0	0	0	+	0
	6.0-7.5		+	+	0	+	+
	7.5-9.0		+	+	+	+	+
	9.0-10		+	+	0/+[4]	+	+
	>10.0		+	+	0	+	+
Ammonium (NH_4^+)	< 2	Within 24 h	+	+	+	+	+
	2-20		+	+	0	+	+
	>20		+	+	-	+	+
Chlorides (Cl^-) *(Refer to Table2 for temperature- dependent values)*	<100	No limit	+	+	+	+	+
	100-200		0	+	+	+	+
	200-300		-	+	+	+	+
	300-700		-	0/+	0/+	+	-
	>700		-	-	0	+	-
Free chlorine (Cl_2)	< 1	Within 5 h	+	+	+	+	+
	1-5		-	-	0	+	-
	> 5		-	-	0/-	+	-
Hydrogen sulfide (H_2S)	< 0.05	No limit	+	+	+	+	+
	>0.05		+	+	0/-	+	+
Free (aggressive) carbon dioxide (CO_2)	< 5	No limit	+	+	+	+	+
	5-20		+	+	0	+	+
	> 20		+	+	-	+	+
Total hardness[5] *(Refer to "Scaling Document" for scaling aspect of hardness effect)*	4.0 - 11 °dH 70 - 200 mg/l CaCO3	No limit	+	+	+	+	+
Nitrate[1] (NO_3^-)	< 100	No limit	+	+	+	+	+
	> 100		+	+	0	+	+
Iron[6] (Fe)	< 0.2	No limit	+	+	+	+	+
	> 0.2		+	+	0	+	+
Aluminium (Al)	< 0.2	No limit	+	+	+	+	+
	> 0.2		+	+	0	+	+
Manganese[6] (Mn)	< 0.1	No limit	+	+	+	+	+
	> 0.1		+	+	0	+	+

Please see next page for the table footnotes!

Influence of water composition on corrosion resistance

[1] Sulfates and nitrates act as inhibitors for pitting corrosion caused by chlorides in pH-neutral environments.

[2] Electrical conductivity and Total Dissolved Solids (TDS) are connected and can be converted to each other.

[3] In general low pH (below 6) increases corrosion risk and high pH (above 7.5) decreases corrosion risk.

[4] In District Energy systems, due to good control over water quality, pH values up to 10 are considered safe: +

[5] **Total Hardness/corrosion:** water with high hardness can cause corrosion problems due to its high ion content (Ca+2, Mg+2, Fe+2) which also means a high electrical conductivity as well as a high total dissolved solid (TDS). For this reason, too high hardness values should be avoided not only due to higher risk of scaling but also for corrosion risk.
On the other hand, soft water, but not necessarily cation exchange softened water, may in contrast have a low buffering capacity and so be more corrosive. If the hardness values are outside the recommended range, other parameters such as oxygen content, conductivity and pH values should be considered to evaluate the corrosion risk.

[6] Fe^{3+} and Mn^{4+} are strong oxidants and may increase the risk for localized corrosion on stainless steels in combination with brazing material copper.

Table 2. Maximum chloride concentrations as a function of temperature for different plate material (Data for SS-316 and are based on Outokumpus Corrosion handbook, 11th edition, 2015).

CHLORIDE CONTENT	MAXIMUM TEMPERATURE					
	20°C	30°C	60°C	80°C	120°C	130°C
= 10 ppm	SS 304	SS 304	SS 304	SS 304	SS 304	SS 316
= 25 ppm	SS 304	SS 304	SS 304	SS 304	SS 316	SS 316
= 50 ppm	SS 304	SS 304	SS 304	SS 316	SS 316	Ti
= 80 ppm	SS 316	SS 316	SS 316	SS 316	SS 316	Ti
= 200 ppm	SS 316	SS 316	SS 316	SS 316	Ti	Ti
= 300 ppm	SS 316	SS 316	SS 316	Ti	Ti	Ti
=700 ppm	SS 316	SS 316	Ti	Ti	-	-
=1000 ppm	SS 316	Ti	Ti	Ti	-	-
> 1000 ppm	Ti	Ti	Ti	Ti	-	-

Table 3. Oxygen concentration guide values for heating water depending on the conductivity of the water according to VDI 2035 /part 2.

Oxygen content: *Corrosion reactions in water installation are determined by presence of oxygen. To avoid corrosion damage, oxygen concentrations in all parts of a water heating system should be kept as low as possible and a constant input of oxygen should be avoided. The higher the conductivity (and salt content) of the water, the lower level of oxygen is recommended to avoid corrosion.*

		Low saline (low salt content)	Saline (high salt content)
Electrical conductivity at 25°C	µS/cm	< 100	100 - 1500
pH value at 25°C		8,2-10	
Oxygen	mg/l or ppm	< 0,1	< 0,02

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Challenge efficiency

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SWEP is a world-leading supplier of brazed plate heat exchangers for HVAC and industrial applications. With over 1,000 dedicated employees, carefully selected business partners, global presence with production, sales and heartfelt service, we bring a level of expertise and customer intimacy that's redefining competitive edge for a more sustainable future. SWEP is part of Dover Corporation, a multi-billion-dollar, diversified manufacturer of a wide range of proprietary products and components for industrial and commercial use.

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