ElectraTherm

BY BITZER GROUP

# ElectraTherm POWER+ GENERATOR
# Water Quality Guidelines

## Water Quality Guidelines

Corrosion, deposition (scaling) or obstruction by strained solids can become problematic if water quality is not managed. Deposits and solids can often be removed by back flushing and/or treatment with dilute acids, but should be avoided in the first place for best machine efficiency. Corrosion, particularly pitting, must be strictly avoided as it can lead to a heat exchanger breach, which is detrimental to the performance of the ORC. If not caught early, corrosion of the heat exchanges can have expensive repair implications. Fortunately, these requirements for long service life on heat exchangers are well known and practiced.

## Avoiding Corrosion

Table 1 shows typical values for the water to be used. There are different types of corrosion that may occur in a plate heat exchanger, which are described in Table 2.

**Table 1 - Recommended Water Quality Limits for Water on Primary Side[1]**

| Quality Class | Untreated | Softened | Partly Desalinated | Desalinated |
|---|---|---|---|---|
| Description | Tap Water | Softened | Softened or Desalinated | Desalinated |
| Appearance | Clear | Clear | Clear | Clear |
| Smell | No Smell | No Smell | No Smell | No Smell |
| Particles | < 10mg/L | < 10mg/L | < 5mg/L | < 1mg/L |
| Oil and Grease | < 1mg/L | < 1mg/L | < 1mg/L | < 1mg/L |
| pH at 25°C | 8.0 ± 1.0 | 9.8 ± 0.2 | 9.8 ± 0.2 | 9.8 ± 0.2 |
| Residual Water Hardness | < 0.5 dH | < 0.5 dH | < 0.2 dH | < 0.1 dH |
| Conductivity at 25°C | < 1500 µS/cm | < 1500 µS/cm | < 500 µS/cm | < 25 µS/cm |
| Oxygen Levels | --- | < 0.02mg/L | < 0.02mg/L | < 0.02mg/L |
| Chloride Levels | < 300mg/L | < 300mg/L | < 50mg/L | < 3mg/L |
| Sulphate Levels | < 100mg/L | --- | --- | < 2mg/L |
| Sulphide Levels | < 1mg/L | < 1mg/L | < 1mg/L | < 1mg/L |
| Nitrate Concentration | < 100mg/L | --- | --- | --- |
| Free Chlorine Levels | < 0.5mg/L | --- | --- | --- |
| Ammonia Levels | --- | < 10mg/L | < 5mg/L | < 5mg/L |
| Total Iron Content | --- | < 0.1mg/L | < 0.1mg/L | < 0.05mg/L |
| Total Copper Content | --- | < 0.02mg/L | < 0.02mg/L | < 0.01mg/L |

**Table 2 - Typical Corrosion Phenomena in Copper Brazed Stainless Steel Plate Heat Exchangers[1]**

| Corrosion Mechanism | Description |
|---|---|
| Localized Corrosion | Normally the heat exchanger is free of crevices, but crevices can be formed under deposits from scaling as well as imperfect brazing joints. |
| General Corrosion | If general corrosion takes place, typically copper corrodes preferentially over the stainless steel. Severe loss of copper will result in loss of mechanical strength and leaks in the heat exchanger. |
| Galvanic Corrosion | The metallic contact between copper and stainless steel in the surrounding water can initiate a corrosive attack on the more electronegative metal, in this case, copper. Some allowance is made for copper to act as a protective anode. |
| Stress Corrosion | Stress corrosion can occur in stainless steel if tensile stresses and a high amount of chloride are present. An increase in temperature will furthermore increase the risk of stress corrosion, particularly above 60°C. |
| Intergranular Corrosion | Stainless steel can experience intergranular corrosion due to formation of chrome carbide in the grain boundaries during an improper heat treatment. Areas with decreased chrome content will be vulnerable to corrosion. |
| Liquid Metal Embrittlement | If the brazing process takes place at too high of a brazing temperature, copper will diffuse into stainless steel and decrease the strength of the stainless steel plates. |

The limits given above are general guidelines to avoid most corrosion mechanisms. Since stainless steel is less likely to corrode in tap water than copper, these levels are determined mainly by copper corrosion. Normally, stainless steel will only corrode in tap water with both high chloride levels and elevated temperature. The parameters that determine corrosion and additional species-specific guidance (including a special caution on chloride, Table 3) are detailed below:

- Temperature: In general, an increase in temperature will increase the corrosion rate. For copper, the likelihood of pitting is higher at temperatures above 60°C. Stainless steel is also at risk of stress corrosion cracking at temperatures above 60°C. This applies mainly to the pre- heater and evaporator of the Power+ Generator. See additional discussion of temperature and chloride pitting of stainless steel below.

- pH: The risk of corrosion due to pH is lowest when the pH is between 9.0 and 9.5. In normal tap water, pH is around 7.0. It is recommended to avoid acidic water (pH below 7.0). Ammonia shouldn't be used for pH conditioning due to the risk of copper corrosion. Sodium hydroxide (NaOH) or tri-sodium phosphate ($Na_3PO_4$) should be used to increase the pH of the water.

- Water Hardness: Copper is susceptible to corrosion in very soft water and the [$Ca^{2+}$, $Mg^{2+}$] / [$HCO_3$] ratio should be less than 0.5. See next section on deposits and scaling.

- Conductivity: High conductivity in tap water indicates that the water has a high concentration of ionic substances in general. An increase in conductivity will increase the galvanic corrosion rate. A maximum conductivity of 500 µS/cm is an appropriate limit value for most metals.

- Alkalinity: If the amount of hydrogen carbonate is very low (i.e. below 60 mg/L), products from copper corrosion will dissolve and be released into the system. It is also recommended to not exceed a $HCO_3^-$ concentration of 300 mg/L. See next section on deposits and scaling.

- Oxygen: If the oxygen content is high, the risk of corrosion will increase. The recommended oxygen level is less than 0.02 mg/L. However, the oxygen content is often higher in practice, especially for evaporative cooling towers. To limit the risk of corrosion due to high oxygen levels, meeting the other guidelines in Tables 1 and 3 is generally sufficient.

- Chloride: The presence of chloride in water increases the risk of localized corrosion (pitting) of stainless steel. The limit is temperature dependent, as shown in Table 3:

**Table 3 - Recommended Chloride Limits at Various Temperatures[1]**

| Temperature | Chloride Limit |
|---|---|
| 25°C | 1000mg/L |
| 50°C | 300mg/L |
| 80°C | 100mg/L |
| >100°C | 0mg/L |

- Nitrate: Nitrate ions have an influence similar to that of sulfate. A maximum concentration of 100 mg/L is recommended.

- Sulfate: High concentrations of sulfate will increase the risk of pitting in copper. A maximum sulphate concentration of 100 mg/L is recommended, but corrosion can also take place at lower concentrations if [$HCO_3^-$] / [$SO_4^{2-}$] is less than 1.

- Free Chlorine: Chlorine is commonly added to tap water for sanitary reasons. Chlorine is highly oxidizing and lowers the corrosion resistance of stainless steel. The concentration of free chlorine should be kept below 0.5 mg/L.

### Water Hardness, Deposits and Scaling

The ability to transfer heat in plate heat exchangers can be reduced by deposits. Solid particles greater than 2 mm across tend to be screened by the channels in the unit, and may accumulate rapidly leading to plugging. Problematic deposits and scaling are usually caused by the presence of calcium and magnesium carbonates in the water supply. General Hardness (GH) is the measure of calcium and magnesium ions in the water. GH is commonly expressed in parts per million (ppm) of calcium carbonate ($CaCO_3$) or degrees hardness (dH). See Table 4 below:

**Table 4 - Water Hardness Guidelines[1]**

| mg/L of $CaCO_3$ | dH | Description |
|---|---|---|
| 0 - 50 | 0 - 3 | Soft |
| 50 - 100 | 3 -6 | Fairly Soft |
| 100 - 200 | 6 - 12 | Slightly Hard |
| 200 - 300 | 12 - 18 | Moderately |
| 300 - 540 | 18 - 30 | Hard |
| 540+ | 30+ | Very Hard |

Heating of hard water may cause the precipitation of limestone ($CaCO_3$) which will appear as a layer of scale on the plate surface. Carbonate scaling and other solids (except silica) can be removed by back flushing the heat exchanger with a mild acid. However, frequent acid flushing can also cause corrosion.[1]

Maintain the recommended water quality levels and periodically check heat exchanger pressure drops for optimum efficiency and system life. Always obtain expert advice for geothermal applications

## References

[1] Polaris (2004). *Brazed Plate Heat Exchanger Operations Manual.* Edison.