Study on Relation Between Industrial Circulating Water Conductivity And Iron Corrosion Velocity

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Abstract
Objective: To study the industrial circulating cooling water in different conductivity of metal corrosion of iron, and then take measures to prevent the pipe network system and equipment corrosion; methods: a rotating hanging plate method combined with electrochemical analysis theory, the relationship of circulating water test in different conductivity and iron corrosion rate; results: circulating water the conductivity in less than 2200 s/cm, the corrosion rate of iron is less than 0.075 mm/a; conclusion: the concentration of sodium hydroxide 30% or 50% sulfuric acid to adjust the pH value of circulating water in 8.5-9.5, or add 2-10 ppm corrosion inhibitor and regular sewage and other measures of circulating water, can ensure the corrosion rate of metal iron is less than 0.075 mm/a, meet the safety requirements of relevant standards within the range.

Keywords
Iron Corrosion Velocity; Industrial Circulating Water; Conductivity

Introduction
Centralized industrial circulating water system are mostly open-style, water temperature is generally between 25~40°C[1], easily suspended solids in the environment, bacteria, oxygen, sulfur dioxide, nitrogen oxide, acid rain, pollution and other substances. In addition, during operation with the continuous water evaporation, water, Ca2+, Mg2+, Fe2+, Cl-, NO3-, HC03-, CO32-, SO42-, SiO42-, PO43- plasma concentration gradually increased, causing conductivity rate increases [2], to a certain extent, resulting in equipment and pipeline corrosion, scaling and causing bacteria, algae, even produce the slime of bacteria and algae and corrosion debris to plug the pipe or equipment, affecting the normal operation of air conditioning systems, resulting in a lot of energy and water waste, can cause severe perforated pipes and equipment, leakage, caused by the production and operation to the enterprise larger losses.

Because the salt content of industrial circulating water conductivity is usually to reflect, so this cooling water by measuring the electrical conductivity and electrical conductivity in different corrosion of metallic iron, from the perspective of macro and micro analysis, combined with the author’s practical work experience, proposed approach to solve the corrosion, water circulation manager for the central air conditioning provide references.

Experimental Test

1.1 Experimental Apparatus
EPC2000-ACT conductivity meter; BT224S electronic balance; 766-3 infrared oven; QYFS-1 type of corrosion rate tester;
PHS-3B model pH meter; HHS electronic water boiler; RCC-1 rotary coupon rate of corrosion testing instrument; 501BS super constant temperature water bath; glass dryer.
1.2 Conductivity Testing

1) The Electrical Conductivity Test Method

Industrial circulating water conductivity mainly reflects the level of salinity, conductivity the greater the higher the salinity of the water cycle, and vice versa. Specific test methods refer to "boiler water and cooling water analysis: determination of electrical conductivity" (GB/T 6908-2005) [3].

2) Preparation of Water of Different Conductivity

According to the actual determination of replenishment of industrial circulating water system the conductivity is usually 650–750 μs/cm. Conductivity 700 μs/cm configured to take the cycle of water as the initial iron corrosion rate of recycled water will be divided into several equal parts, electronic water bath, respectively, in the evaporation, the evaporation of water conductivity was 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, 1900, 2000, 2100, 2200, 2300 μs/cm, and then were tested with different conductivity of industrial circulating water corrosion rate of metallic iron.

1.3 The Iron Corrosion Rate of Test


1.4 Test Results

Conductivity and the relationship between iron corrosion rate results shown in Fig. 1 can be seen from the figure, the beginning of the corrosion rate of up to 0.050 mm/a, mainly due to the surface of metallic iron in the case without any protection, by salts and dissolved oxygen in the circulating water erosion; With time, the metallic iron surface covered with a layer of salt or dirt, metal corrosion rate of iron increases with the conductivity but decreases; With the gradual increase in the conductivity of circulating water, the corrosion rate of metallic iron and gradually increased, when the electrical conductivity increased to 2200 μs/cm above, the corrosion rate of iron than 0.075 mm/a, because the layer of metallic iron formed between the surface and the scale of chemical batteries, the surface of metallic iron electrochemical reaction occurred that the formation of corrosion under the scale, the rate of corrosion under the scale started slow, but with time, corrosion under the harm scale increases, perforated pipe or equipment is so large leak caused.

![Fig. 1 Electrical conductivity and the relationship between iron corrosion rate results](image)

**Conductivity and Corrosion of Metallic Iron Theoretical Analysis**

2.1 Determine The Level of Iron Corrosion

Corrosion of iron the size of the corrosion rate can be expressed, and the evaluation of the corrosion, after many long-term researchers and production managers a summary of safety management from the perspective of the equipment, the corrosion of the metallic iron into the Table 1 several levels[4], if the circulating water system
installed in special precision equipment, is another matter.

### TABLE 1 DETERMINE THE LEVEL OF IRON CORROSION

<table>
<thead>
<tr>
<th>The corrosion rate of iron (/mm/a)</th>
<th>The evaluation</th>
</tr>
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<tbody>
<tr>
<td>&lt;0.05</td>
<td>excellent</td>
</tr>
<tr>
<td>0.05-0.075</td>
<td>good</td>
</tr>
<tr>
<td>0.075-1.5</td>
<td>relatively heavy corrosion</td>
</tr>
<tr>
<td>&gt;1.5</td>
<td>severe corrosion</td>
</tr>
</tbody>
</table>

2.2 Conductivity And Electrochemical Corrosion of Metallic Iron

Corrosion of metal in an electrochemical reaction in aqueous solution, metallic iron corrosion cell model shown in Fig.2. It can be seen from Fig.2, the metal surface to form an anode and cathode corrosion cell isolation, the metal in solution lose electron and become positively charged ions, which is a process of oxidation of the anode. At the same time, the metal surface in contact with aqueous solutions, electronic have plenty of opportunities to be a substance in solution and, in the process and e-reduction process, that the cathode process. Common cathode oxygen is reduced during the hydrogen release, oxidant is reduced and heavy metal deposition.

![Fig.2 THE CORROSION OF METALLIC IRON BATTERY MODEL](image)

Electrochemical reaction in the whole process, always accompanied by changes in current and voltage, resistance and conductivity of the solution also will change, so you can change the conductivity of the iron corrosion rate to reflect the change to more directly reflect corrosion of metals, managers in the usual line of industrial electrical conductivity meter in accordance with the conductivity of the test data, ready to take the necessary measures for circulating cooling water of scientific management, to ensure that the network and equipment safe and stable operation.

### Discussion

3.1 Recycled Water Run-time Control of Electrical Conductivity

Fig.1 combines the conductivity and the relationship between iron corrosion rate curves and criteria in Table 1 can be seen, central air conditioning cooling water during operation, due process and the environmental impact of their own, increasing its salt content, the conductivity increased. When the conductivity 2000 μs/cm below, the metal iron corrosion rate of less than 0.075 mm/a, can basically guarantee the safety of pipelines and equipment; but the conductivity of more than 2000μs/cm, the corrosion rate increases linearly, when conductivity reached 2200 μs/cm above, the corrosion rate of more than 0.075 mm/a, increased corrosion of metallic iron, and if no measures are taken, long run down, Will be on the circulating water pipe network systems and equipment to serious damage.

3.2 Operation of Circulating Water Management Measures

1) Strengthen the Management and Scientific Monitoring

In the industrial circulating water running, water quality management to improve the professional quality and
sense of responsibility, so that they not only know how to loop the importance of water in production, but also fully understand the impact of changes in circulating water quality factors, and water quality of the network equipment corrosion. Only did a pretty good idea to be able to circulating water in the analysis of the technology indicators, indicators of changes in technology for scientific analysis and evaluation, and proceeded to take effective measures to avoid or reduce corrosion, to ensure that industrial circulating water safety equipment and stable network operation.

2) Adding Protective Agents

Protective agent that is inhibitor, adding the right amount of steel corrosion inhibitor can delay and prolong equipment life. Corrosion inhibitor into inorganic and organic corrosion inhibitor, and mixed inhibitor of several classes. The mixed inhibitor to produce different corrosion inhibitor synergies between, inhibition of high efficiency, long duration, in recent years has been widespread application [5-6]. Commonly used corrosion inhibitor in Table 2.

<table>
<thead>
<tr>
<th>Inhibitor type</th>
<th>Inhibitor name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inorganic corrosion inhibitor</td>
<td>phosphate, polyphosphate, nitrite, chromate, molybdate, zinc salts, silicate, tungstate, etc.</td>
</tr>
<tr>
<td>Organic inhibitor</td>
<td>benzo triazole, organic amines, thiourea, poly maleic anhydride, organic phosphates, organic polycarboxylate, etc.</td>
</tr>
<tr>
<td>Mixed inhibitor</td>
<td>organic phosphate, polycarboxylate, organic or inorganic corrosion inhibitors such as a mixture of a certain proportion.</td>
</tr>
</tbody>
</table>

According to the water quality of recycled water (such as salt composition of recycling water, electrical conductivity, materials of the pipe network and equipment, recycled water flow rate, temperature, etc.) and process by adding corrosion inhibitors to selectively add quantity and add ingredients according to what circulating water containing Cl\(^{-}\), SO\(_4^{2-}\) and other anions in the material situation of pipe network and equipment, determined by inhibition tests.

Inorganic corrosion inhibitor is mainly passive in the metal surface protective film or metal oxide film, and its effective when used alone the dosage of 2~3 ppm; organic corrosion inhibitor is adsorbed inhibitor, mainly in the metal surface to form the adsorbed film is not visible, can also block the cathode and the anode reaction [7], the effective use of its single dosage of 1~3 ppm.

Central industrial circulating water corrosion most commonly used method is a combination of recycled water in the water quality regularly and quantitatively by adding organic phosphate, polycarboxylate, organic or inorganic corrosion inhibitor testing to determine the ratio by a mixture of water quality stabilizer, both corrosion inhibition, scale inhibition effect there. General weekly plus twice the dosage of 4~10 ppm, the amount of small but effective.

3) Sewage Scientific

On the central industrial circulating water discharge is an important management measures. Discharge of sewage not only the high concentration of salt and slime and dirt, more importantly, delay the corrosion of pipelines and equipment. Because the circulating water system are mostly open systems, continuously during operation of water evaporation, addition, impurities in the environment likely to be contaminated, even if the additional drug treatment is getting it contains high salt concentration, increasing the conductivity, so only according to the analysis of cooling water sewage scientific test results, and through continuous additional new water, so the conductivity of industrial circulating water to add water drops to 2.5~3 times, can reach the goal of water conservation, and also avoid the purpose of corrosion occurs.

4) Timely Adjustment PH

In the circulating cooling water during operation, due to the external environment, especially the impact of dissolved oxygen, the pH changes in a certain place, if the cooling water pH adjusted to 8.0~9.5, it will help control corrosion of pipes and equipment[8]. The principle can be shown in Fig.3 Fe-H2O system, the relationship
between pH and the electrode potential be described [9]. Fig.3, respectively, solid line and imaginary line marked with oxygen-free when the dissolved oxygen and iron corrosion potential and pH relations. Slash the figure the shaded area is covered by the corrosion of iron zone, above the shaded area is the passive zone, shadow zone below is free of corrosion or stable area, a line represents the balance between H+ and H2, the relationship between potential and pH.

![Figure 3: Fe-H2O System, The Corrosion Behavior of Estimated Figure](image)

It can be seen from Fig.3, in the absence of dissolved oxygen in industrial circulating water, the corrosion potential of iron in the corrosion area, and in a line under the analysis of H2 corrosion occurs at this time. When the pH increases, pitting corrosion potential gradually close to the free zone, the corrosion rate decreased. In the pH value of 9.5~12.5, the corrosion potential corrosion-free zone near the border, in the Fe-H2O equilibrium potential, corrosion rate is very small.

When the presence of dissolved oxygen, iron corrosion potential rise (with no dissolved oxygen than when). In the pH<8.0, although the corrosion potential of iron increased, but still the corrosion area, the corrosion rate is still increasing at this time. When the pH>8.0, the iron corrosion potential rise into the passivation region and are protected, When the pH value rose to 9.5, the curve has a sudden jump upward, forming a virtual line, go to the passivation. Therefore, the operation of air conditioning cooling water process, through online pH meter to monitor changes in pH value, when the pH value of the deviation from 8.0~9.5 range, by adding 30% mass fraction mass fraction of sodium hydroxide or 50 % sulfuric acid to be adjusted to reduce corrosion of metallic iron.

In addition, water circulation system to prevent metal corrosion also anodic and cathodic protection, metal wall surface treatment and other methods, but these methods are now rarely used.

**Conclusion**

Central industrial circulating water during operation continued with the water evaporation and contamination by impurities in the air, the corrosion rate of iron increases, when the conductivity reached 1900μs/cm above, a variety of high salt content, especially Ca2+, Mg2+, such as hardness components and OH-, CO32-, HCO3- and other components while the high alkalinity to a certain value, according to the solubility product theory[10], resulting scale is inevitable, resulting in scale, the likely cause under the corrosion scale, and the danger of corrosion under the scale is a great[11]. So when the conductivity of the circulating water reaches a certain limit, it must take measures to resolve, to ensure the safety of pipe network and equipment.

**REFERENCES**


