The Mechanism Research of Cooling Tower Scaling Factors in HVDC Valve Cooling System

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ABSTRACT: By the method of field test, from the heating power, abandoned water, temperature of circulating water, flow of spray water altogether four aspects, to study the causes of scaling in cooling tower, and through the way of crosscheck in water quality analysis and scaling test, to find out the trend and degree of the influence of fouling rate, and through the analysis of the results, the rationalization proposal is put forward.
KEYWORD: physical chemistry; valve cooling system; scale; contrastive analysise

1 GENERAL INSTRUCTIONS

In south of China, HVDC valve cooling system cooling mainly by water. The principle of closed cooling tower is that when water spray on the surface of heat exchange coil, it evaporate and take heat away. It has good heat dissipation efficiency, while in the operation process, dirt follows.

The formation process of fouling on heat transfer surface is the result of a comprehensive effect of momentum exchange, heat exchange, and dynamic exchange. It is a complex process, and the influence factors are so many, such as fluid properties, surface temperature of heat exchange coil, fluid velocity, surface condition of heat transfer, etc[1].

As fouling process involves wide scope of disciplines, and variable factors and scaling rate mostly is nonlinear relationship between[2], it is often difficult to obtain effective progress to comprehensive study the fouling process.

Through the research achievements of Zhenhua Quan, we make the preliminary judgment: In thermal power, the greater the scale, the more serious; The smaller of abandoned water, the more serious of scaling; The higher the temperature of the circulating water, the more serious of scaling; While spray water flow's influence on the fouling existence the minimum point.

2 THE MODEL AND TEST CONDITIONS

To maintain the test environment is the same with the HVDC valve cooling system, we choose anshun converter station as the test site, which is representative and has a poor water quality.

The model of the test apparatus is as shown in figure

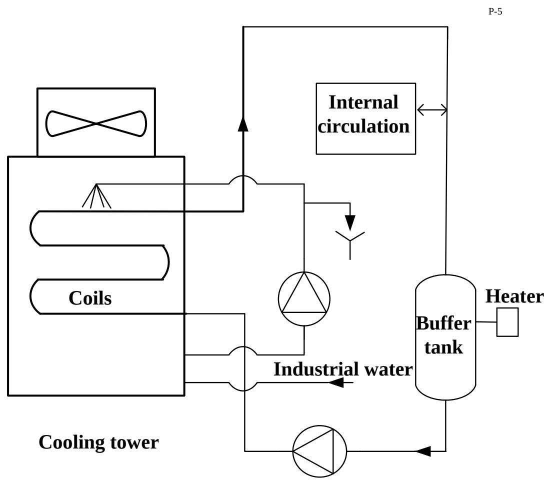

Fig 1 Test unit

The equipment contains internal water circulation and spray water circulation.

The internal circulation put pure water as medium. The medium flows through the buffer tank, circulating pump, cooling tower coil to transfer the heat to the external circulation. Then by spray water circulation to release the heat to environment.

Spray water circulation put the industrial water as medium. The medium flows through the spray water pump, and then to the top of cooling tower, finally spray to heat exchange coil to cooling the internal medium, while at the same time by evaporation and concentration, a small amount of dirt attached to the heat exchange coil.

The industrial water quality parameters of Anshun converter station is as shown in table1:

Table 1 Industrial water quality parameter

total hardness mg/L	pH	total alkalinitymmol/L	Ca^{2+} mg/L	Cl^{-}mg/L	NO_3^{-}mg/L	SO_4^{2-}mg/L	SiO_2mg/L
179.89	7.91	2.65	49.41	0.23	9.81	20.75	64.61

We select the Langelier saturation index, Ryznar stability index and PSI scaling index to analysis the results. The specific formula is as follows:

$$PHs=pK_2-pKs+p[Ca^{2+}]+p[M]+2.5\sqrt{u} \quad (1)$$

General: [M] — Total alkalinity With methyl orange as indicator;

K_S — The solubility product of calcium carbonate;

K_2 — The second ionization constant of carbonate;

K_S — The solubility product of calcium carbonate expressed in activity;

u — Ionic strength.

$$PHs = (9.70+A+B)-(C+D) \quad (2)$$

General: A — Total dissolved solids;

B — The temperature coefficient;

C — Calcium hardness coefficient;

D — Basicity coefficient.

Calculation formula of Langelier Saturation index:

$$LSI=PH-PHs \quad (3)$$

Calculation formula of Ryznar Stability index:

$$RSI=2PHs-PH \quad (4)$$

Calculation formula of PSI scaling index:

$$PHeq=1.465\times lg[M] + 4.54 \quad (5)$$

$$PSI=2PHs-Pheq \quad (6)$$

The judgement standard of fouling or corrosion trend[3] is as shown in table2:

3 EXPERIMENT

3.1 *Experiment of thermal power*

We set the abandon water, internal water temperature and spray water flow as the setting value, by changing the number of heater to control the heat transfer power. And thermal power will directly affect the spray water concentration ratio on the heat exchange coil.

Table2 Judgement standard of fouling or corrosion

Item	Index	Judgement
LSI	< 0	corrosion
	0~0.5	stable
	0.5~1.0	Light scaling
	＞1.0	Serious scaling
RSI	4.5~5.0	Serious scaling
	5.0~6.0	Light scaling
	6.0~7.0	stable
	7.0~7.5	Linght corrosion
	7.5~9.0	Serious corrosion
	> 9.0	Acute corrosion
PSI	> 6.0	corrosion
	=6	stable
	< 6.0	scaling

When experiment started, we regularly observe the surface of coil, until the dirt can be clearly seen, then record the running time. Select a length of coil of 5 cm, which the size is: 31.57 mm × 21.75 mm, weighing the dirt on the surface, and calculate the average scaling rate.

The parameters of the test is as shown in table3:

Table3 Parameter Settings

Internal water flow l/min	Inlet water temperature℃	Outlet water temperature℃	Heat power kW	Spray water flow l/min	Abandon water l/min	Frequency of fan HZ
112	48.5~49.5	41.5~42.5	15/22.5/30	185	0.25	0~50

The relationship between power and scaling rate is as shown in table 4:

Table 4 Relationship between power and scaling rate

Thermal power kw	15	22.5	30
Scaling rate g/d	0.01	0.06	0.18

This table illustrates that: scaling rate along with the change of thermal power increases.

In 49 ℃ temperature, we calculate the saturation index , stability index and scale index whith the formula 1 to 6 , and judge the trend of scaling with our calculate result. The calculation results are as shown in table5

Table5 Decision table of water quality

Thermal power KW	LSI index	Result	Ryznar index	Result	PSI index	Result
15	2.09	Serious scaling	4.71	Serious scaling	5.56	scaling
22.5	2.14	Serious scaling	4.59	Serious scaling	5.4	scaling
30	2.19	Serious scaling	4.46	Serious scaling	5.2	scaling

From the table above, we can see that water in this experiment have more serious trend of scaling with the increase of heat power. The results and the corresponding coil fouling condition prove that along with the increase of heat power, coil surface fouling rate increased.

3.2 *Experiment of abandoned water*

In converter station, we keep the balance of water saving and water quality by adjusting abandoned water. Generally when we reduce abandoned water, ion concentration ratio of spray water will increase, which may lead fouling or corrosion. While when the abandoned water increases, water resources will be wasted.

During the experiment of abandoned water, we keep heat power, internal circulating water temperature, spray water flow remain unchanged, by changing the abandoned water to control ion concentration ratio and then observe the dirt on the coil.

The relationship between abandoned water and scaling rate is as shown in table 6.

Table6 Relationship between abandoned water and scaling rate:

Abandoned water L/min	0.4	0.25	0.1
Scaling rate g/d	0.05	0.12	0.27

This table illustrates that: scaling rate will increase with the decrease of the abandoned water.

Table7 Decision table of water quality

Abandoned water L/min	LSI index	result	Ryznar index	result	PSI index	result
0.4	1.96	Serious scaling	4.86	Serious scaling	5.57	Scaling
0.25	1.94	Serious scaling	4.86	Serious scaling	5.55	Scaling
0.1	2.23	Serious scaling	4.52	Serious scaling	5.40	Scaling

It can be seen from the table that, water in this experiment have more serious trend of scaling with abandoned water decrease. The results and the corresponding coil fouling condition, prove that with abandoned water decrease, coil surface fouling rate increased.

3.3 *Experiment of temperature*

The influence of internal circulating water temperature on fouling maily in the prompting the Ca (HCO3) 2 decomposition, increasing the PH value, promoting the precipitation of Mg2+ and reducing the solubility of some chemical compound, and so on.

During the experiment of temperature, we keep the heat power, abandoned water, spray water flow remain unchanged, by setting the frequency of fan to adjust internal circulating water temperature, and then observe the scale formation on cooling coil.

The relationship between temperature and scaling rate is as shown in table 8.

Table 8 Relationship between temperature and scaling rate:

Inlet water temperature℃	44	48	52
Scaling rate g/d	0.01	0.05	0.23

This table illustrates that: scaling rate will increases with inlet water temperature increases.

we caculate the saturation index, stability index and scaling index in the temperature of 52℃, 48℃,44℃, and the result are as shown in table9.

Table 9 Decision table of water quality:

Inlet water temperature℃	LSI index	result	Ryznar index	result	PSI index	result
52	2.14	Serious scaling	4.59	Serious scaling	5.51	Scaling
48	1.87	Serious scaling	4.93	Serious scaling	5.73	Scaling
44	1.73	Serious scaling	5.18	Lignht scaling	5.95	Scaling

It can be seen from the table that, with the decreasing of inlet water temperature, the scaling has a tendency to slow down. The result and the corresponding coil fouling condition proved that with the decrease of inlet temperature of circulating water, coil surface fouling rate decreased.

3.4 *Experiment of spray water flow*

During the experiment of spray water flow ,we keep the thermal power, abandoned water, internal circulating water temperature remain unchanged, by adjusting the operation frequency of the spray pump to control the spray water flow, and then observe the fouling on cooling coil.

The relationship between spray water flow and scaling rate is as shown in table 10:

Table 10 Relationship between spray water flow and scaling rate:

Flow L/min	160	220	260
Scaling rate g/d	0.17	0.07	0.14

From this table we can see that when the flow around the 220 L/min, scaling rate is the least, while the increase or decrease of spray water flow will speed up the scaling rate.

we caculate the saturation index, stability index and scaling index in the temperature of 49℃, and the result are as shown in table 11:

Table 11 Decision table of water quality

Spray water flow L/min	LSI index	result	Ryznar index	result	PSI index	result
160	2.24	Serious scaling	4.36	Serious scaling	5.14	Scaling
220	1.83	Serious scaling	4.85	Serious scaling	5.36	Scaling
260	2.03	Serious scaling	4.61	Serious scaling	5.25	Scaling

From the point of each water quality index, we can see that when the spray water flow is 220 L/min, the scaling trend is relative minimum. The result and the corresponding coil fouling condition prove that spray water flow have the best value, at this value the scaling rate is relative minimum.

4 CONCLUSION

Based on the analysis of these experiments, it can be seen that in the factors which affect the coil surface fouling, the ions in water is the determining factor. When the ion concentration reaches a certain extent, fouling begin. Temperature will also speed up the scaling rate to some extent.

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REFERENCES

[1] Zhenhua Quan, Yongchang Chen,Chongfang Ma. Simulation analysis of influencing factors of calcium carbonate on heat transfer surface scaling Journal of Engineering Thermophysics. 2008;29(11):1944~1946.

[2] Shanrang Yang, Lingfang Sun,Zhiming Xu. Research status and prospect of fouling on heat exchange equipment. Chem Ind Eng Prog. 2004;23(10):1091~1098.

[3] Huan Zhu, Yingmin Chen, Liqing Guan, etc. The influence of concentration ratiocirculating of cooling water to the condenser pipe corrosion and fouling tendency. Electric Power Environmental 2009; 25(4):52~54.