Research and Application of Cleaning and Coating for Condenser

He Fengyuan1*, Niu Ruqing1, Wang Fei1, Li Yao1 and Liu Chengming 2
1 Huadian Electric Power Research Institute Co., Ltd
2 Shenyang Jinshan Energy Co., Ltd. Jinshan Thermal Power Branch
*Corresponding author's e-mail: 15840268787@139.com

Abstract. The scale on the water side of condenser copper pipe of unit 3 in a power plant has exceeded 1mm and "dezincification corrosion" has occurred. The condenser copper tubes were cleaned and coated by static and dynamic tests. After the completion of the project, the inner wall of the copper pipe is cleaned and the coating is in good condition, achieving the expected effect.

1. Introduction
The condenser model of unit 3 in a power plant is N-P75-1, and the copper tube material of condenser is HSn70-1A. As the condenser copper pipe has been running for many years, a layer of 1mm thick scale has been formed on the water side surface of the condenser copper pipe, and there is a layer of slime on the scale surface. Through the research on the previous literature, the scaling of the copper pipe will result in the increase of the resistance of the water flow in the copper pipe and of the temperature difference between the outlet cooling water and its steam side, as well as the reduction of cooling water's flowing and of the vacuum degree in the condenser, thus affecting the thermal efficiency of the unit.

In order to ensure the normal operation of the condenser and the unit, chemical cleaning was carried out on the copper tube of the condenser during the overhaul of the unit. The cleaning part is all cooling surfaces of the condenser, and the cleaning medium is hydrochloric acid composite agent.

2. Study on chemical cleaning and coating process of condenser

2.1. Small scale test of chemical cleaning process
Pickling process: The concentration of hydrochloric acid is 1.0%, 2.0%, 3.0%, 4.0% respectively, and the concentration of inhibitor is 0.3%. The concentration of stripper is 500mg / L and 1000mg / L respectively. The flow rate of cleaning solution is controlled at 0.25-0.30m/s in dynamic state, and the temperature of cleaning solution is controlled at room temperature.

First, static test is used, and some data are obtained, then dynamic test is used. First, peel off with stripping agent solution for 20 hours, clean the slime and then clean with hydrochloric acid. After 2-3 hours of cleaning, all the scale is cleaned and the surface of copper tube is clean.

The results of small-scale cleaning test show that all slime and scale are removed, and the corrosion inhibition efficiency of inhibitor is over 98%. Through test comparison, the cleaning concentration of
hydrochloric acid is 2-4%, and that of inhibitor and stripping agent is respectively 0.3% and 1000mg/L, and the cleaning flow rate is 0.25 ~ 0.30m/s.

Coating process: control Fe2+ =200~300mg/L (add FeSO4·7H2O) in the coating solution, and pH = 5.5 ~ 6.5 (adjust with Na2CO3), and circulation flow rate of the coating solution is 0.25 ~ 0.3m/s, and temperature of the coating solution is normal temperature, and time is 84 hours, intermittent gas burst. After coating, a uniform dark brown film is formed on the inner wall of the copper tube, which is firmly attached.

2.2. Relevant parameters and technical data of condenser of unit 3

See Table 1 for technical parameters involved in cleaning and film making operation.

| Number | Equipment name          | Company    | Data     |
|--------|-------------------------|------------|----------|
| 1      | Pipe specification      | mm         | φ20×1    |
| 2      | Pipe material           | -          | HSn70-1A |
| 3      | Number of pipe          | -          | 3432     |
| 4      | Pipe length             | mm         | 4585     |
| 5      | Total surface area of pipe | m²      | 889      |
| 6      | Condenser water chamber volume | m³ | 8        |
| 7      | Total volume of cleaning system | m³ | 25       |

2.3. Quantity of chemicals used for chemical cleaning

The quantity of chemicals needed for chemical cleaning can be estimated by small-scale test and main parameters of condenser. The calculation of total hydrochloric acid is shown below:

\[
G = \frac{(0.73 \times 889 \times 0.001 \times 2930 + 500)}{0.31} = 7746 \text{ kg}
\]

total hydrochloric acid required: 7746 kg

The dosage of other drugs is calculated according to the total volume of small test and cleaning solution.

See Table 2 for the name, specification and quantity of chemicals required for chemical cleaning and film-forming anticorrosion of condenser.

| Number | Material              | Specifications | Weight |
|--------|-----------------------|----------------|--------|
| 1      | hydrochloric acid     | HCl≥31%        | 8000 kg|
| 2      | Corrosion inhibitor   | ≥30%           | 120 kg |
| 3      | Stripper              | ≥40%           | 100 kg |
| 4      | Defoamer              | —              | 50 kg  |
| 5      | FeSO4                 | Fe2+≥20%       | 1200 kg|
| 6      | Na2CO3                | Na2CO≥98%      | 1000 kg|
| 7      | NaOH                  | NaOH≥80%       | 1500 kg|
3. Work to be done before chemical cleaning and coating of condenser copper tube

Install the temporary cleaning system according to the chemical cleaning system diagram of the condenser of unit 3. After the installation of the condenser cleaning and coating temporary system, the system shall be rechecked by a specially assigned person, the valves in the system shall be numbered, and the system process shall be marked.

Prepare enough chemical cleaning and coating agents according to the technical requirements of chemical cleaning and coating anti-corrosion for condenser of unit 3. All reagents shall be tested before use to meet the required quality standards.

According to the requirements of condenser cleaning scope, the relevant equipment and systems of circulating water system not involved in cleaning shall be effectively isolated.

Prepare HSn70-1A copper test piece and A3 steel test piece with the specification of 25 × 50 × 1mm (3mm). Prepare chemical analysis instruments, instruments and chemical analysis reagents required for chemical monitoring during condenser cleaning and film forming.

The industrial water system connected in the temporary system of condenser cleaning has the capacity of continuously supplying industrial water of more than 100m³/h. The drainage and cleaning waste liquid neutralization treatment facilities in the steam turbine workshop are unblocked.

Prepare 2 axial flow fans for the gas burst during the film forming process of condenser copper pipe.

4. Parameters of chemical cleaning control

4.1. Scope of chemical cleaning of condenser

The scope of chemical cleaning of condenser includes water side of condenser copper pipe, water chamber before and after condenser and some circulating cooling water pipes.

4.2. Chemical cleaning process of condenser

Closed cycle cleaning and open circuit water washing are adopted for chemical cleaning and coating of condenser; closed cycle one-time coating is conducted by intermittent gas burst during coating.

The circulating circuit adopts: circulating cleaning acid tank → cleaning pump → temporary pipeline at the inlet of condenser water chamber → water chamber of left and right condenser → water chamber of left and right condenser → temporary pipeline at the outlet of water chamber of condenser → circulating cleaning acid tank.

4.3. Technical parameters for chemical cleaning of condenser

The chemical cleaning and coating process of the condenser is determined based on the results of scale composition analysis and combined with the laboratory static and dynamic small-scale test data. See Table 3 for the process parameters.

| Cleaning procedure                  | Cleaning medium | Medium concentration | Control parameters           |
|-------------------------------------|-----------------|----------------------|-----------------------------|
| Full water protection at steam side of condenser | Desalted water | pH=8.0~9.0          | ---                         |
| Water washing before cleaning       | Industrial water| ---                  | Normal temperature, 4 hours |
| Slime stripping and cleaning        | Stripper        | 1000mg/L             | Normal temperature, 20 hours|
| Pickling                            | HCl             | 2~4%                 | Normal temperature, 4 hours |
| Open water flushing                 | Industrial water| ---                  | pH≥6.0                     |
| Coating process                     | FeSO₄·7H₂O      | Fe²⁺=200~300mg/L     | Fe³⁺≤50mg/L                 |
|                                     |                 | pH=5.5~6.5           |                             |
5. Chemical supervision during chemical cleaning of condenser

See Table 4 for chemical supervision indexes and requirements of condenser during chemical cleaning and coating stage.

| Cleaning procedure                  | Test items               | Test frequency | Test method              |
|------------------------------------|--------------------------|----------------|--------------------------|
| Water washing before pickling      | Turbidity                | once / 15 minutes | Turbidimeter             |
| Slime stripping and cleaning       | Turbidity, calcium, total Fe | once / 30 minutes | Turbidimeter, Complexometric titration |
| Pickling                           | HCl%, YD, Fe²⁺, Fe³⁺    | once / 15 minutes | Complexometric titration |
| Open water flushing                | pH                       | once / 15 minutes | PH meter                 |
| Coating process                    | Fe²⁺, Fe³⁺, pH           | once / 30 minutes | Complexometric titration, PH meter |

6. Treatment and discharge of cleaning waste liquid

The cleaning waste liquid is discharged into the comprehensive wastewater treatment system of the power plant. After adding solid NaOH and adjusting the pH value to 6-9, it can meet the environmental protection requirements.

7. Conclusion

Fouling deposition in the water side of condenser in thermal power plant not only affects the heat exchange efficiency of the equipment, but also increases the corrosion degree of copper pipe, which will bring potential threat to the safe and economic operation of the unit.

According to the corrosion degree of water side of condenser and the deposition of slime and scale of unit 3 in power plant, the slime and scale on the water side of condenser were peeled and cleaned with hydrochloric acid compound cleaning agent through small-scale test and careful preparation before cleaning and film forming, and the surface of copper tube of condenser was treated with ferrous sulfate for one-time film forming. The practice shows that the technology of cleaning and film-forming is reliable, and the expected cleaning and film-forming effect has been achieved. At the same time, it also provides a reference for the chemical cleaning and film-forming anti-corrosion work of similar condenser in the future.

Acknowledgement

The cleaning and coating work of the condenser was greatly supported by the power plant, and also helped by colleagues. Thanks a lot.

References

[1] Sun,Q.,(2016) Chemical cleaning of condenser in a power plant. Cleaning World, 32:22-25.
[2] Xu,J.W.,Jiang,G.C.(2009) Chemical Cleaning of Cainless Cteel tube Ccondenser of 330 MW Thermal Power Plant. Cleaning World,25:38-42.
[3] Zhu,Y.J.,Liu,W.,Liu,G.,Hang,X.F.(2012) Review of CondenserCleaning Technology. Cleaning World,28:34-37.
[4] Wang,Y.L.,Yao,L.C.,Liu,X.C.,Wang,M.Z.(2012) Implementation of the new type of acid pickle process of condenser unit 135 MW. Industrial Water Treatment,32:90-92.
[5] Liu,Q.D.(2012) Application of Nitric Acid Cleaning Technology for Stainless Steel Condenser. Guangxi Electric Power, 35(01):53-54.