

Research on the thermal concentration reduction technology of desulfurization wastewater

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Abstract. This paper conducts experimental research on the low-temperature flue gas concentration reduction process of desulfurization wastewater in coal-fired power plants. Combined with the system situation of the units that have been put into operation, the control of operating parameters in multi-effect flash evaporation technology is analyzed and studied using platform simulation methods, providing a basis for subsequent process optimization and transformation.

1 Introduction

At present, the "limestone-gypsum" wet desulfurization technology is widely used in the desulfurization systems of large-scale coal-fired power plants in China. This technology is mature, reliable in operation and economically favorable. However, to control the chloride ion concentration in the system, the system needs to discharge wastewater regularly. The desulfurization wastewater volume of a 300MW unit is about 5 tons per hour^[1]. The desulfurization wastewater has the characteristics of high salinity, high hardness, easy scaling, strong corrosiveness, high turbidity and excessive content of harmful heavy metals, making it one of the most difficult types of wastewater to treat.

Along with the national environmental protection policy is increasingly tightening, coal-fired thermal power plants have been strictly prohibited wastewater discharge, which requires thermal power plants must be desulphurisation wastewater must be treated in depth, the current stage of the implementation of zero wastewater discharge process route for thermal power plants are mainly pre-treatment, concentration and reduction, end curing, etc., concentration and reduction section is mainly used in the membrane method and the thermal method, the membrane method is due to the cost and the harsh conditions of the influent water, the thermal method is the use of a low-cost heat source of wastewater for Thermal method is to use low-cost heat source to evaporate and concentrate wastewater. Therefore, most of the zero-discharge desulfurization wastewater systems of power plants that have been put into operation at present adopt concentration tower and multi-effect flash evaporation technology^[2].

Existing thermal low-temperature flue gas concentration process in the operation process, the concentration tower exposed a number of problems and technical defects, mainly in the following areas: First, the low-temperature flue gas evaporation of all the wastewater back to the main flue gas system and is captured by the desulphurisation system, the water balance of the system has an impact; secondly, the concentration of high multiplication rate, the ionic salts are in a saturated state, easy to corrode the internal components of the equipment or fouling; thirdly, the evaporation Thirdly, during the evaporation process, there is an environmental risk of escape of gaseous pollutants, and when the sealing is poor, there is a pungent odour that affects the perception of the system operation.

Multi-effect flash evaporation technology in the operation process, the system operating parameters control requirements are high, often due to uneven vacuum control caused by the local concentration multiplier is too high and caused by the scaling of the clogging, which leads to a high frequency of maintenance, system stability is poor, but also the end of the curing system water intake solids, salinity are high, the spray gun clogging and other problems.

At present, there are many researches on thermal concentration reduction technology^[3-8], so as to better study the problems of thermal method in pretreatment and concentration, this paper takes the concentration and reduction system based on multi-effect heater as the research object, explores the operation status and concentration effect of the system under different conditions, and collects experimental data to provide corresponding technical support for the subsequent system upgrading and optimisation.

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2 Test Device and Method

2.1 Principle of experiment

Desulfurisation wastewater into the separator, the separator temperature control 80 °C, vacuum to produce 75 ~ 80 °C steam, steam through the electric heating produced by more than 90 °C wet steam, wet steam through the heat exchanger, desulfurisation wastewater heated into the separator, in the separator for evaporation and concentration, after the separator vacuum to produce steam, so that the steam does not have a phase change energy loss, energy savings, while recycling heat, to improve system energy efficiency. Improve the efficiency of the system energy use, heat exchanger generated by the cooling water recycling.

2.2 Test process

This system mainly consists of two parts: evaporation system and slurry circulation system.

Evaporation system: External steam heats and heats up the desulfurization wastewater in the first-effect heater. The condensate of the first-effect heater and the second-effect condensate merge into the condensate tank. The non-condensate gas of the first-effect heater enters the condenser and the cooling water to exchange heat; the slurry in the first-effect separator generates secondary steam through heating and evaporation, and the secondary steam enters the second-effect heater heats the slurry, and the condensate liquid enters the condenser and the cooling water to exchange heat; the condensate liquid in the condenser enters the condenser and the non-condensate gas is discharged through the vacuum pump.

Slurry circulation system: desulphurisation wastewater enters into the feed tank, through the feed pump into the first-effect separator, circulating heating in the separator, after heating the slurry into the second-effect separator, the slurry is circulating heating in the second-effect separator, and is discharged through the discharge pump after concentration.

2.3 Test system equipment parameters

The main equipment parameters included in the test system are listed as the Table 1 below:

Table 1. Test system main equipment parameter table

ID	Device name	Specification	Quantity	material
1	First -effect heater	φ 300*H1500 area: 3.8m ²	1	2205/ 304
2	Second -effect heater	φ 300*H1500 area: 3.8m ²	1	2205/ 304
3	First -effect separator	φ 800*H2600	1	2205/ 304
4	Second -effect separator	φ 800*H2600	1	2205/ 304
5	Condenser	φ 300*H1500 area: 3.8m ² ,	1	304
6	Condensate	DN125*H1600	1	304/

ID	Device name	Specification	Quantity	material
	tank			FRP
7	Feed pump	Flow rate: 2m ³ /h, head: 20m	1	FRP
8	Circulation pump	Flow rate: 180m ³ /h, head: 2m	2	2205
9	Discharge pump	Flow rate: 2m ³ /h, head: 20m	1	2205
10	Condensatio-n water pump	Flow rate: 3m ³ /h, head: 24m	1	304
11	Vacuum pump	Air pumping volume: 52m ³ /h	1	304

2.4 Experimental system interface

Feed: Connected from the wastewater buffer box of the desulfurization process building.

Discharge: connect to the trench on the first floor of the desulfurization process building.

Steam: connect the steam main pipe of the self-supported steam connection box outlet.

Condenser cooling water: connected to process rinse water from the desulphurisation area.

Condenser cooling water return water: connect to the trench in the desulfurization absorption tower area.

Pump machine sealing cooling water: connect to the cooling water pipe of the pump room machine sealing cooling water pipe.

Pump seal cooling water return water: connect to the trench of the desulfurization circulation pump room.

3 Test process and results

3.1 Test process

The experiment was carried out in an intermittent influent thickening mode. The designed thickening ratio was 2 times, the slurry level in the separator before and after thickening was maintained, and the batch experiment was ended when the water intake reached the experimental requirements.

3.1.1 Evaporation test of desulfurization wastewater at different steam temperatures

Batch experiments were carried out after the inlet steam temperature was adjusted to 120°C (a total of 8 batch experiments) and 140°C (8 batch experiments) respectively.

3.1.2 Operation flow of different desulfurization wastewater

The liquid level of the separator was maintained at the lower edge of the first observation mirror (operating flow of desulfurization wastewater was 1730L, 8 batches of experiments) and the lower edge of the second observation mirror (operating flow of desulfurization wastewater was 2087L, 8 batches of experiments), respectively.

3.1.3 Test under different concentration of desulphurization wastewater

Desulphurization waste water liquid (8 batches of experiments) and diluted desulphurization waste water (8 batches of experiments) were respectively used for the test.

3.2 System operation

(1) Check whether the power supply, cooling water and steam are normal; check whether the opening and closing of various valves of the equipment are normal.

(2) Inject desulfurization wastewater into the feed tank. When the liquid level in the tank is greater than 70%, open the inlet and outlet valve of the feed pump, open the first-effect feed valve, open the feed pump, observe whether the feed pump discharge is normal, observe the liquid level of the feed pump, and stop the pump manually when the liquid level is less than 20%.

(3) Observe the separator liquid level. When the liquid level of the first-effect separator and the second-effect separator reach the lower edge of the first observation video, stop feeding and record the feed flow.

(4) Start the first-effect circulation pump and the second-effect circulation pump in turn, and adjust the pump frequency by 45HZ;

(5) The opening of the heater hand valve is adjusted to one quarter of the position; the opening of the condensing tank feed valve is adjusted to one quarter of the position;

(6) Start the vacuum pump and observe the pressures of the vacuum pump inlet, first-effect separator, and second-effect separator. When the inlet pressure of the vacuum pump reaches -0.08MPa, prepare to turn on external steam;

(7) Slowly open the steam inlet valve, observe the steam temperature, and reach the temperature required for the test;

(8) Wait for the system to heat up and observe the liquid level of the condensate tank. When the liquid level is greater than 50%, open the inlet and outlet valve of the condensate pump, start the condensate pump, open the outer discharge valve of the condensate pump, adjust the return valve, and maintain the liquid level of the condensate tank at 50%~80%

(9) Observe the equipment instrument, start recording data when the slurry temperature of the first-effect separator reaches above 70°C, and record a set of data every hour, and feed the separator regularly according to the experimental design;

(10) When the feed volume reaches the design requirements, the liquid level of the separator is the same as at the beginning of the experiment, the experiment will be completed.

3.3 Test results

For details of the relevant test results during the test, please refer to Figure 1-Figure 4 below:

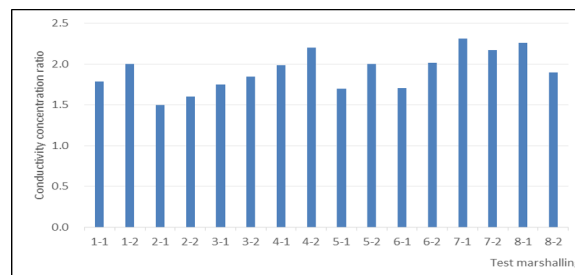


Fig. 1. Evaporation from different batches of experiments.

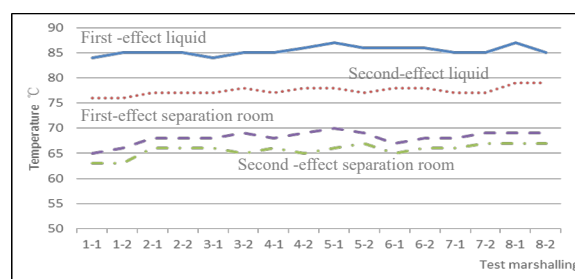


Fig. 2. Equipment operating temperatures for different batches of experiments.

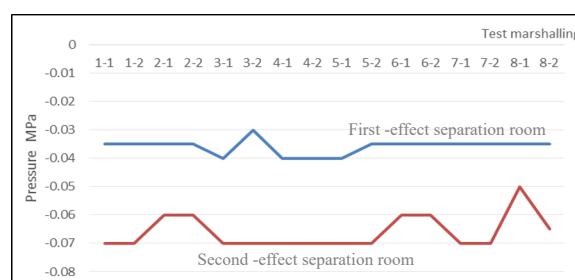


Fig. 3. Equipment operating pressure for different batches of experiments.

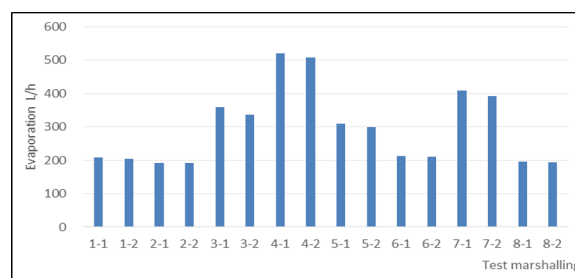


Fig. 4. Conductivity concentration ratio for different batches of experiments

A simple test of the inlet and outlet water quality of the system during the test, and the relevant results are shown in Table 2 below:

Table 2. Test water sample detection data record table

ID	pH	Conductivity	pH	Conductivity
	inlet		outlet	
1-1	6.72	50.0	6.47	89.5
1-2	6.63	47.5	6.37	122.3
2-1	6.37	79.1	6.22	118.5
2-2	6.47	74.2	6.11	118.9
3-1	6.46	72.6	6.14	127.1
3-2	6.43	76.7	6.24	141.7

4-1	6.53	52.0	6.40	103.4
4-2	6.66	49.1	6.08	117.4
5-1	6.26	84.7	6.45	114.9
5-2	6.41	69.2	6.13	163.5
6-1	6.77	52.0	6.43	88.6
6-2	6.74	53.0	6.57	107.1
7-1	6.71	47.4	6.46	109.7
7-2	6.78	44.4	6.55	96.4
8-1	6.47	72.0	6.17	162.7
8-2	6.34	80.1	6.13	139.7

3.4 Test results

The operating temperature and pressure parameters of each batch of experimental equipment are relatively stable. The temperature of primary effect feed liquid is 84 ~ 87°C, the temperature of primary effect separation chamber is 76 ~ 79°C, the temperature of secondary effect feed liquid is 63 ~ 67°C, the temperature of secondary effect separation chamber is 65 ~ 70°C, and the pressure of primary effect separation chamber is -0.03 ~ -0.04MPa. The pressure of the secondary separation chamber is -0.05 ~ -0.07MPa.

At the same wastewater flow rate and concentration, the higher the evaporation temperature, the higher the wastewater evaporation, but not in a linear relationship, the higher the conductivity concentration ratio.

Under the same evaporation temperature and wastewater concentration, the change in wastewater flow rate has little impact on the evaporation effect.

Under the same evaporation temperature and wastewater flow rate, the initial concentration of wastewater has little effect on the evaporation effect.

During the test, the system did not tend to be fouled.

4 Research conclusions

Under the same conditions, the higher the inlet steam temperature is, the faster the evaporation rate is. The effect of running water quantity on evaporation rate is not obvious, the lower the running water quantity is, the higher the evaporation quantity is. The initial concentration of desulphurization wastewater has no obvious effect on the evaporation rate, and the lower the initial concentration of desulphurization wastewater, the higher the evaporation rate. After evaporation and concentration of desulfurization wastewater, the pH value is slightly reduced, and the electrical conductivity value is about 2 times that of raw water.

This experiment proves the feasibility of using flue gas waste heat to concentrate and reduce the amount of desulfurized wastewater without adding agents. Under the same conditions, the thermal concentration cost is good compared with the traditional membrane method, which can reduce the amount of agent added and sludge disposal costs. The cost of wastewater treatment per ton can save 45-65 yuan, and the production cost can be saved about 1.68 million yuan per year, which is more conducive to the promotion and application of zero-emission wastewater technology.

References

1. Jiangtao Zhang, Hongmei Cao, Haiyan Li, et al. (2022) Research progress in desulfurization wastewater concentration technology in thermal power plants [J]. *Water Treatment Technology*, 48 (10): 26-32
2. Xiaoyue Ma, Xiuguang Liang. (2023) Research on the concentration reduction technology of desulfurization wastewater based on waste heat utilization [J]. *Modern Chemical*, 43 (S1): 76-80
3. Juan Zhang, Panping Xia, Qing Hao, Jie Li, Huan Zhou. (2022) Modeling the salt analysis law of the total concentration process of desulfurization wastewater in coal-fired power plants [J]. *Salt Science and Chemical Engineering*, 51 (11):4-9
4. Yehu Zhang, Wenwei Dong, Xing Wei. (2024) Research on boiling point during evaporation and concentration of desulfurization wastewater [J]. *Electric Power Technology and Environmental Protection*, 40 (06):669-676. M. Ben Rabha, M.F. Boujmil, M. Saadoun, B. Bessaïs, *Eur. Phys. J. Appl. Phys.* (to be published)
5. Yurui Wang , Lingxiao Zhan, Heng Chen, Juecen Mao, Haijie Chen, Xiaoyue Ma, Linjun Yang .(2024) Study on the evaporation performance of concentrated desulfurization wastewater and its products analysis, *Journal of Water Process Engineering*, 58:104862F. De Lillo, F. Cecconi, G. Lacorata, A. Vulpiani, *EPL*, **84** (2008)
6. Xiangzheng Cui, Zhikang Wang, Rihong Xiao, Kaiyan Long Zhuo Xiong, Yongchun Zhao, Junying Zhang. (2024) Heavy metal migration and enrichment in desulfurization wastewater during low-temperature triple effect evaporation process. *Journal of Cleaner Production*, 478:143989
7. Rahman Izadi, Danial Assarian, Ali Altaee, Mostafa Mahinroosta. (2023) Investigation of methods for fuel desulfurization wastewater treatment, *Chemical Engineering Research and Design*, 190:198-219
8. Lingxiao Zhan, Dawei Hou, Heng Chen, Yurui Wang, Suoqi Zheng, Zhihao Li, Hao Wu, Haijie Chen, Xiaoyue Ma, Linjun Yang. (2024) Occurrence states and migration of water during the evaporation of desulfurization wastewater. *Desalination*, 578:117435