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Wastewater Treatment of the Thermal Power Plants for Desulfurization of Flue Gas

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Abstract

The article presents technology by Kazakhstani scientists to reduce volume of sulfur oxides emission reductionfrom flue gases of thermal power plants by treatment of wastewater. Highly mineralized wastewater to be processed with water treatment equipment using ion exchange method, including N cation and N anion filters, as well as wastewater from drum boilers with a pH value of 11.5-12.The draft of the technological solution, including a thermal-mechanical circuit, an environmental impact assessment section, a process automatic control circuit and an equipment power supply scheme has been developed. The project is under independent examination now. The introduction of flue gas desulfurization technology through wastewater treatment is planned at the thermal power plant of the capital of the Republic of Kazakhstan in 2020. The developed technical solutions will allow increasing the degree of sulfur oxide collection efficiency from 12% to 48%.

Keywords: treatment; wastewater; sulfur oxides; flue gas; thermal power plant

Abbreviations

TPP – Thermal power plant;
BKZ – Boiler construction plant of Barnaul;
PS – Pollutant substance.

1. Introduction

The protection of the environment during the operation of thermal power plants is the implementation of a set of technical solutions to prevent a negative impact on the environment. A technological solution was developed to reduce the emissions of sulfur oxides by the main equipment of TPP-2 of Astana-Energy JSC (boiler units BKZ-420-140, station numbers No. 1-6) during operation using waste water from boilers and waste water from ion-exchange filters of neutralizing tanks of water treatment equipment [1-8].

2. Material and method

The thermal power plant TPP-2 is located in the northern industrial zone of the city of Nur-Sultan (Astana). The distance (in meters) to the residential area is presented in table 1.

The environmental component of the sustainable development of the region is an important factor in the territorial development of the city. Whereas, ensuring the sustainable development of the human environment is one of the conditions for the country's sustainable development.

The main share of emissions of pollutants into the atmosphere from TPP-2 is accounted for by emissions with flue gases through chimneys - about 99% of the total emissions. They consist of five pollutant substance (PS) formed during the combustion of coal in boilers: nitrogen oxides and oxides, sulfur dioxide, carbon monoxide, inorganic dust (coal ash). The share of other pollutants in total emissions of TPP-2 is less than 1.0%.

The achieved average content of pollutants at power boilers BKZ-420-140 and the cleaning efficiency according to measurements of the laboratory of environmental protection of JSC Astana-Energy in 2016-2017 are presented in Table 2 and the diagram in Figure 1.

Table 1. The distance from the power plant to residential buildings

Direction points	north	north-east	East	south-east	south	south-west	west	north-west
Distance to residential are	-	-	-	4900	3200	2650	3000	-

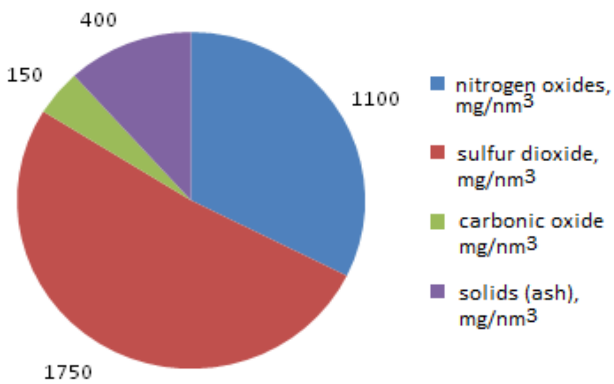

Fig 1. Average pollutant concentration.

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Table 2. Pollutant concentration in flue gases of steam boilers according to instrumental measurements 2016–2017

Boiler number	Boiler load	Concentrations of pollutants in the exhaust gases, mg/nm^3 at O_2 = 6%				Average operational cleaning efficiency,%	
		Nitrogen oxides	sulfurdioxide	carbonoxide	Coal ash	sulfurdioxide	Coal ash
1	390	1100	1750	150	400	10	99.39
2	375	1160	1500	150	400	10	99.35
3	420	570	1682	150	406	10	99.35
4	390	570	1671	150	400	10	99.49
5	420	570	1740	150	400	10	99.26
6	418	740	1800	150	400	10	99.39

The site for the reconstruction of the fuel combustion system is located on the territory of the existing thermal power plant TPP-2. The site is located in the current building of the main campus, in the boiler room.

The reference mark of the clean floor of the main building was taken as the reference mark of 0.000 m, which corresponds to an absolute mark of 357.300.

The temperature of the flue gases from each boiler BKZ-420-140 TPP-2 after the battery emulsifier under normal conditions averages:

- Boiler station No. 1 – 69.5 ºC;
- Boiler station No. 2 - 67.5 ºC;
- Boiler station No. 3 – 68.5 ºC;
- Boiler station No. 4 - 65 ºC;
- Boiler station No. 5 - 65 ºC;
- Boiler station No. 6 - 69 ºC.

The volumes and quality of the purge water from the continuous purge expanders for boilers are selectively presented in Table 3.

The volume of continuous blowdown is 0.5 - 1% of the boiler capacity.

The quality of clarified water from the ash dump fed into the battery emulsifiers:

- Total alkalinity = 0.7 mg-equ/dm^3;
- Total water hardness = 32.0 mg-equ/dm^3;
- Chloride Cl^- = 980.0 mg-equ/dm;
- Sulfate SO_4^{2-} = 683.0 mg/dm^3;
- Solid residue = 4600.0 mg/dm^3.

To increase the degree of sulfur oxide collection efficiency it is proposed to use wastewater from water treatment equipment with high salinity and discharge blow-down water after the 2-stage continuous blowout expanders with a pH of 12, in battery emulsifiers installed on boiler No. 1-6. This will replace 42.13 tons of clarified water per hour, which is 5.07% of the total consumption of clarified water supplied from the ash dump for irrigation of battery emulsifiers.

Average daily balance of neutralizing tanks (Table 4):

- Regeneration (alkaline + acidic) water + wash (demineralized water) - 301.2 tons/day;
- Wash water - 202.4 tons /day;
- Water after backwash - 70.86 tons /day;

Total volume of wastewater from neutralizing tanks: 574.46 tons per day or 23.94 tons per hour.

The total average load of the storage tank will be: 23.94 + 18.19 = 42.13 tons/hour, the maximum load of the storage tank will be: 23.94 + 6 · 4.5 = 50.94 tons/hour.

Prior to the start of installation work it is necessary to:

- to protect the territory of the boiler shop sites at all elevations where the work will be performed and the street area adjacent to the wall of the boiler shop near the axis of the fourth boiler;
- install inventory tubular scaffolding at the place of installation works;
- to provide lighting for the installation site in accordance with existing standards;
- prepare sites for the storage of pipeline sections;
- to bring gas-cutting and electric welding equipment to the installation site, to connect electric welding equipment to the power supply.

Delivery of the expander, pump, pipeline assemblies, valves, electrical cables to power the pump and valve actuators is carried out from the warehouse of Astana-Energy JSC.

TPP-2 provides for a set of measures that, taking into account the expansion, the achievement of established standards, corresponding to modern technological methods, and energy-saving conditions, which do not lead to a decrease in equipment reliability.

In accordance with the developed technological solution, this project considers the use of wastewater from a water treatment plant with high salinity and wastewater after continuous expanders of stage 2 with a pH of 12 in the battery emulsifiers installed on the boiler units, station numbers 1-6.

3. Results and discussion

The project includes the following technical measures aimed at reducing sulfur oxides:

- on the street site near the external wall of the boiler shop, near the axis of the fourth boiler installation of one common continuous purge expander at station boilers No. 1-6 at level 6 mark for complete condensation of the purge steam to be supplied from the existing four purge expanders located mark of the boiler shop;

- Supply of all blowing water from boilers No. 1-6 (with a pH value of about 11.5-12) and all waste water (with high salinity) from neutralizing tanks of the chemical workshop into a storage tank (washing tank, of 75 m^3, which has not been operated for more than 6 years);
- Supply of all collected waste water from the storage tank to the feeder tanks of battery emulsifiers of station boilers No. 1-6 (BKZ-420-140) with uniform distribution between the feeder tanks to the center of the tanks below the overflow outlet level;

At present, the operational degree of sulfur oxide collection in battery emulsifiers in the boilers No. 1-6 is of averages 12%. After the installation of the technological scheme of using wastewater in the gas purification scheme, it is expected to increase to 48%, which will exceed the standard indicators for such a gas purification scheme by 36%.

Table 3. Volume, composition, hardness, pH and alkalinity of the purge water for some boilers on average

Boiler No	Loading, tons per hour	%	alkalinity, mg-equ/dm^3	water hardness, mg-equ/dm^3	Blow off, ton per day	pH average
No.1	350	0.9	141.1/131.7	0.5	75.6	9.81
No.2	340	0.6	167.5/141.7	0.5	48.96	9.86
No.3	330	1.0	202.6/135	0.5	79.2	9.86
No.4	340	1.0	226.2/198.3	0.5	81.6	10.0

Table 4. Analysis of the material balances of the tank feeders of battery emulsifiers

Boiler station number	The volume of clarified water for irrigation without adding purge water, m^3/h	pH of clarified water	Volume of purge water, m^3/h	pH of the purge water after the expander purge of 2 stage, average
No.1	127.1	7.1	3.15	11.5-12
No.2	116.95	7.1	2.04	11.5-12
No.3	192.8	7.1	3.3	11.5-12
No.4	124.23	7.1	3.1	11.5-12
No.5	139.9	7.1	3.4	11.5-12
No.6	129.7	7.1	3.2	11.5-12
Total	830.68		18.19	

In order to achieve the result, the following technical solutions and installation works are necessary to be conducted:

- to include a current tank-feeders a storage tank with a volume of 75 m^3 and a height of 6 meters, installed on the repair site between the fourth and fifth boilers, which has not been used for more than 8 years.
- pipeline with a diameter of 57x3 collecting waste blowing water from the expanders of continuous purging No. 1-4, located at the 12th mark in the boiler shop from the turbine shop, and the pipeline with a diameter of 89x3 to the newly installed expander of the purge to the street.
- to install an additional purge expander (22 m^3/h) intended for complete condensation of the purge steam in the street opposite the end of the boiler unit No. 4 on the side of the fifth boiler. The expander is installed at around 9 meters for the bottom outlet of the purge water.
- pipeline with a diameter of 89x3 from the new expander from the street to the storage tank. The purge water is fed by gravity into the storage tank, the entrance to which is carried out in the upper part of the tank at level 6.
- pipeline with a diameter of 89x3 supplying waste water from neutralizing tanks to the upper part of the storage tank at level 6: inset from the pipeline supplying waste water from neutralizing tanks of a water treatment plant to the hydraulic ash removal system located in the boiler room on the repair site between the fourth and fifth boilers.
- to install an XO80-50-200 pump made of an alloy chemically resistant to corrosion: capacity 50 m^3/h (13.9 l/s), pressure 50 wcm, the allowed cavitation reserve is no more than 4.5 m. wcm, power 380 V, power consumption 10.6 kW., for supplying waste water from the storage tank to the feeder tanks of boiler units No 1-6;
- pipelines for pumping pump XO80-50-200 waste water from the storage tank to the irrigation tanks of boiler units No. 1-6: one pipeline is laid along the end of the fourth boiler from the side of the storage tank and further along the boilers No. 1-4 between battery emulsifiers and smoke exhausters; the second pipeline is laid along the end of the fifth boiler from the side of the storage tank and further along the boilers No. 5 and 6 between battery emulsifiers and smoke exhausters. A tee is installed under each irrigation tank with discharge water flow vertically to the irrigation tanks in the upper part. To avoid leakage of waste water into the overflow tank of the irrigator, the pipeline goes into the tank by 400-600 mm. Diameters of pipelines according to the scheme:

A. From the pump to the tee distribution for 1-4 and 5-6 boilers: 125×4;

B. from the tee to the distribution between the irrigation tanks of boilers 1-4: 108×4;

C. from the tee to the distribution between the irrigation tanks of boilers 5 and 6: to the boiler 5 - 76×3, to the boiler 6 - 57×3;

D. from the distribution pipeline, rise to the tanks-irrigators of boilers 1-5: 57×3, to the tanks of irrigators of the boiler 6: 32×2.

- adjustable valve with electric drive (ball valve with electric drive, Ду50, electro drive, frequency regulation-008: 30 sec/10 W/0.25 A), manual stop valve and non-return valve is installed on pipelines for discharge of waste water from continuous expanders No. 1-4, on the pipeline for supplying waste water from neutralizing tanks to the storage tank, as well as on pipelines for supplying waste water from the storage tank in front of the tanks of battery emulsifiers.

Reconstruction is scheduled for 2020. The total duration of construction and installation works is 6 months. Commissioning operations takes 2 months.

4. Conclusions

The following tasks needs to be included when implementing the project: to include the current washing tank of 75 m^3 volume in the developed flow chart; pipeline of 57 mm diameter for collection of the blowdown water from the continuous blowdown expanders and a 89 mm diameter pipeline to the newly installed blowdown dilator to the street; to install an additional purge expander, designed for complete condensation of the purge steam, at the 9 meters mark for the lower purge water outlet; pipeline with a diameter of 89 mm from the new expander from the street to the storage tank; pipeline with a diameter of 89 mm of supply of waste water from neutralizing tanks into the upper part of the storage tank at the level of mark 6; install an XO80-50-200 pump made of a chemically corrosion resistant alloy to supply waste water from the storage tank to the tanks of the sprinklers of the boiler units; pipeline for supplying waste water from the storage tank to the irrigation tanks of the boiler units; adjustable electrically operated gate valve, a manual shut-off valve and a check valve to be installed in the flow chart. The developed technical solutions will allow increasing the degree of sulfur oxide collection efficiency from 12% to 48%.

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