GE Energy

Minhang Power Plant, Shanghai Electric Power Co., Ltd.

Performance Evaluation Test Report for the Combustion Optimization System of #8 Boiler

TPRI
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Abstract

Performance evaluation test for the combustion optimization system for #8 boiler in Minhang Power Plant, Shanghai Electric Power Co., Ltd., contains:

1. 100 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill B and coal mill C;
2. 100 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill A and coal mill C;
3. 120 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill A and coal mill B.

Conclusion

1. For coal mills B and C that operated under a 100 MW load, the measured boiler efficiency improved by 1.08% when the combustion optimization system was put into service; the electricity consumption by the blower and suction fan saved 227.9 kW; and the average NO_x emission reduction was 118 mg/m^3 (standard condition).
2. For coal mills A and C that operated under a 100 MW load, the measured boiler efficiency improved by 0.44% when the combustion optimization system was put into service; the electricity consumption by the blower and suction fan saved 157.9 kW; and the average NO_x emission reduction was 169 mg/m^3 (standard condition).
3. For coal mills A and B that operated under a 120 MW load, the measured boiler efficiency improved by 0.37% when the combustion optimization system was put into service; the electricity consumption by the blower and suction fan saved 377.3 kW; and the average NO_x emission reduction was 39 mg/m^3 (non-standard condition).

1. Introduction

1.1 Boiler Installation

The #8 boiler in the Minhang Power Plant, Shanghai Electric Power Co., Ltd., is a G400/150-50408 supercritical reheat boiler produced by Shanghai Boiler Works. The boiler has full open-air configuration, equipped with the steam turbo generator unit with 135.1 MW rated power. The boiler was suspended and converted into a coal boiler in June 1982. On December 2, 2000, the boiler was shut down again for the transformation to increased capacity and consumption reduction for #8 unit. It was connected to the grid and put into service again on April 14, 2001. See *Table 1* for key design specifications of the boiler, *Table 2* for designed coal properties, and *Table 3* for actual coal properties.

Twelve burners are deployed quadrilaterally into 3 elevations. Eight oil pistols are extruded into the furnace through secondary air nozzles on the middle-upper and bottom layers. After retrofit, three layers of primary air are changed from a centralized arrangement to an alternative one. For the adaptability of staged operation mode, the 3 primary layers are spaced 1000 mm evenly, while the assumed tangential circle is

Item	Unit	Value		
		Original Design	After Transformation for Coal	After Capacity Increase
Superheated Steam Flow	t/h	400	360	390
Reheat Steam Flow	t/h	330	305	329
Steam Drum Operating Pressure	MPa	15.2	15.2	15.2
Superheat Steam Pressure	MPa	13.73	13.73	13.73
Reheat Steam Inlet Pressure	MPa	2.5	2.14	2.55
Reheat Steam Outlet Pressure	MPa	2.35	2.0	2.40
Superheat Steam Temperature	°C	555.0	540.0	540.0
Reheat Steam Inlet Temperature	°C	335.0	320.0	308.0
Reheat Steam Outlet Temperature	°C	555.0	5400	540.0
Water Feed Temperature	°C	240.0	240.0	238.0
Hot Blast Temperature	°C	320.0	285.0	271.0
Air Temperature	°C	20.0	20.0	20.0
Flue Gas Temperature	°C	107.0	130.0	137.0
Boiler Efficiency	%	92.8	92.7	91.6
Stack Loss	%	--	--	6.47
Carbon Loss	%	--	--	1.5
Computational Boiler Thermal Efficiency	%	--	--	92.14
Guaranteed Efficiency	%	--	--	91.64
Fuel Consumption	t/h	--	--	60.3
Computational Fuel Consumption	t/h	--	--	59.4
Superheater Water Spray (level 1)	t/h	--	--	11.5
Superheater Water Spray (level 2)	t/h	--	--	5.76

Table 1. Boiler Design Specifications

Item	Unit	Value
As-received Base Carbon C	%	51.32
As-received Base Hydrogen H	%	2.64
As-received Base Oxygen O	%	7.66
As-received Base Nitrogen N	%	0.69
As-received Base Sulfur S	%	0.22
Full Moisture Content Mt	%	10.4
As-received Base Ash Content A	%	27.07
As-received Base Volatile Matter V	%	23.54
As-received Base Fixed Carbon FC		38.99
As-received Base Net Calorific Value Q net	MJ/kg	19.97
Friction Coefficient K_{km}		1.3
Deformation Temperature t1	°C	1500

Table 2. Designed Coal Properties

centralized to zero—therefore the primary air are concentrated to one point. Moreover, the included angles between central line of the burner and the waterwall are enlarged. The two levels of secondary air nozzles among three levels of primary air are provided with 15° (middle-upper secondary air nozzle) and 15° (middle-lower secondary air nozzle) deflection structure to drive airflow rotation inside the boiler. The rich/lean burner separates the fuel flow into different concentrations, resulting in an oxygen-rich condition near the waterwall side of the furnace. The ceiling secondary air uses 12° reverse deflection construction that reduces left- and right-side fume temperature difference of furnace outlet through regulation.

Superheater: Mixing superheater with radiant convection. Steam process: steam drum ➔ cladding superheater on both walls ➔ rear wall cladding superheater ➔ ceiling superheater ➔ front shield superheater ➔ stage-one direct contact spray desuperheater ➔ rear shield superheater ➔ stage-two direct contact spray desuperheater ➔ convection superheater ➔ steam collector (extracted from east and west sides) ➔ steamer high pressure cylinder.

Reheater: The reheater is located in the middle of the tail flue, arranged in upper and lower units along adverse current in line arrangement. Exhaust from the steamer high-pressure cylinder enters the reheater from both sides and is introduced to the medium pressure cylinder of the steamer from east and west loops of two outlet headers. The inlet pipeline of the reheater is equipped with an emergency sprayer.

The coal pulverizing system of positive pressure direct flow type is equipped with three 10 E medium-speed coal mills imported from the U.K. In normal conditions, two of the three coal mills will be in service and the other is for standby. The coal consumption of the boiler is about 60 t/h under full load.

The boiler is equipped with two blowers, two primary air fans and two induced draft fans, which form a fume system of balanced ventilation.

1.2 Combustion Optimization System

GE Energy, along with Minhang Power Plant, Shanghai Electric Power Co., Ltd., chose to use the combustion optimization system based on GE's KN3 (modeling, optimization, and control). In general, the optimization starts from four aspects: primary air flow; secondary air shutter openness; total air flow; and coal feeder offset—thereby improving distribution of air burning inside the boiler and combustion efficiency, while reducing in-factor electricity consumption and bringing about optimized combustion performance.

Item	Unit	Pingdingshan	Mengyuan (Mengshi, Kaizhong)	Datong (Datong mixed coal)
As-received Base Moisture Content	%	8~12	8~12	8~12
As-received Base Ash Content	%	23.07~25.97	25.35~30.22	16.30~17.72
Dry Base Volatile Matter without Ash	%	22.71~28.0	19.87~24.88	24.74~30.28
Net Calorific Value	kJ/kg	23238~22400	21354~20516	24703~24075
Ash Deformation Temperature	°C	>1500	>1500	>1480

Table 3. Actual Coal Properties

2. Purpose

Testing performance of the combustion optimization system from the #8 boiler.

3. Content

1. 100 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill B and coal mill C;
2. 100 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill A and coal mill C;
3. 120 MW load, comparative test for the start and stop of the combustion optimization system under combined operation of coal mill A and coal mill B.

4. Reference

Performance test code for utility boiler GB10184-1988.

5. Measuring Point, Method and Instrumentation

5.1 Flue Temperature Measurement

Measuring points were defined for the inlet and outlet flues for the air preheater based on constant section grid method for testing flue temperature. Twelve thermocouples were mounted on either side of the air preheater inlet flue, for a total of 24 thermocouples. The thermocouples are linked to IMP temperature data acquisition system with a compensating line. See *Figure 1* for details of the flue temperature measurement system. Data was collected every two seconds during testing in order to calculate the average value after testing.

5.2 Sampling and Analysis

Measuring points were defined for the inlet and outlet flues for the air preheater based on a constant section grid method. Flue samples were analyzed on a point-by-point basis during the oxygen consumption field calibration to determine representative points. The flue samples were extracted from the representative points and then introduced into the respective blending tanks for mixing. The samples were gathered by the

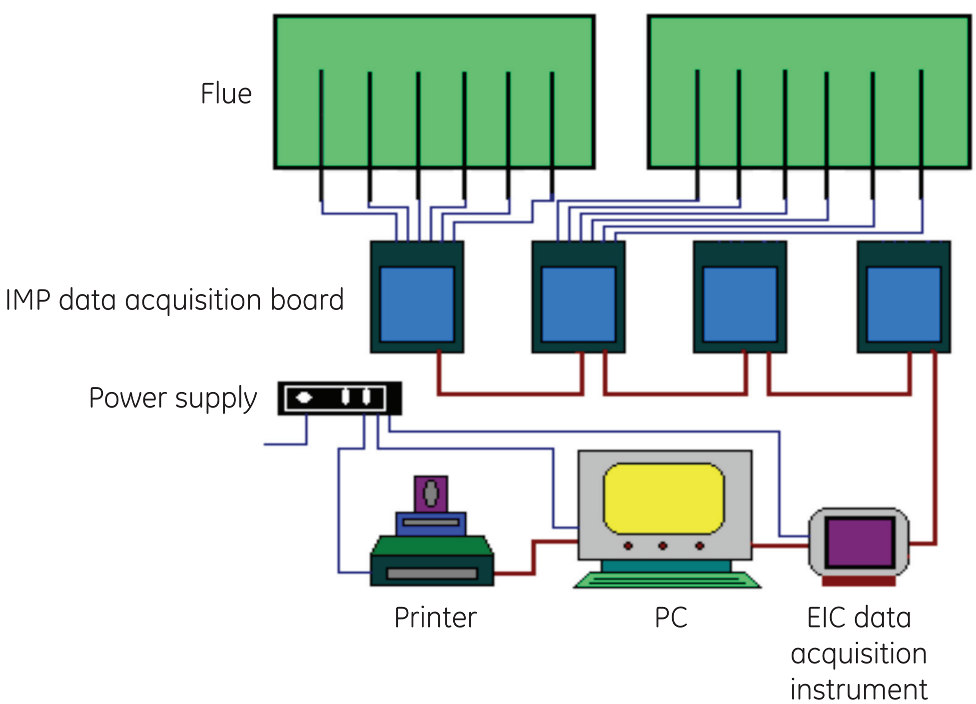

Figure 1. Flue Temperature Measurement System

flue testing system via rubber hose. See *Figure 2* for details of the flue sampling system. The components during flue analysis include O_2, CO_2, and CO. Applicable instruments include NGA2000 paramagnetic O_2 tester, NGA2000 infrared CO_2 tester, NGA2000 infrared CO tester, and NGA2000 UV NO tester. Measurement and analysis was conducted every 10 minutes during testing.

Figure 3. Raw Coal Cutting Down

5.3 Raw Coal Sampling and Analysis

Raw coal was sampled in front of feed belt during feeding, based on test time. Raw coal samples were put into a container and sealed to prevent moisture evaporation. All the raw coal samples collected under any possible working conditions were mixed and cut down into one sample. The sample was handed over to the Quality Supervision and Inspection Center of Coal for Power Generation in the Power Industry, which is affiliated with the Thermal Power Research Institute, for element analysis and caloric power analysis. The results were utilized by all types of relevant calculations as official data. The raw coal was cut down based on quartering for several times of cutting down as shown in *Figure 3*.

5.4 Fly Ash Sampling and Analysis

Samples of fly ash were collected with PND-32 flue fly ash sampling gun at constant speed sampling hole on the air preheater outlet flue. The sampling system consisted of a sampling gun, cartridge filter, U tube pressure gauge, rubber hose, and air ejector, as shown in *Figure 4*.

Fly ash sampling was based on a zero pressure constant speed method. The sampling process was conducted on a point-by-point basis according to grid method. Sampling was performed for five minutes per point. The effective sampling time was equal to the time of a boiler test working condition.

The cutting down process for the fly ash samples from the constant speed method was identical to that of the raw coal sample. Fly ash samples were analyzed by the Quality Supervision and Inspection Center of Coal for Power Generation in the Power Industry affiliated to the Thermal Power Research Institute. The key aspect of the analysis dealt with combustible content in the ash. The results were utilized by all types of relevant calculations as official data.

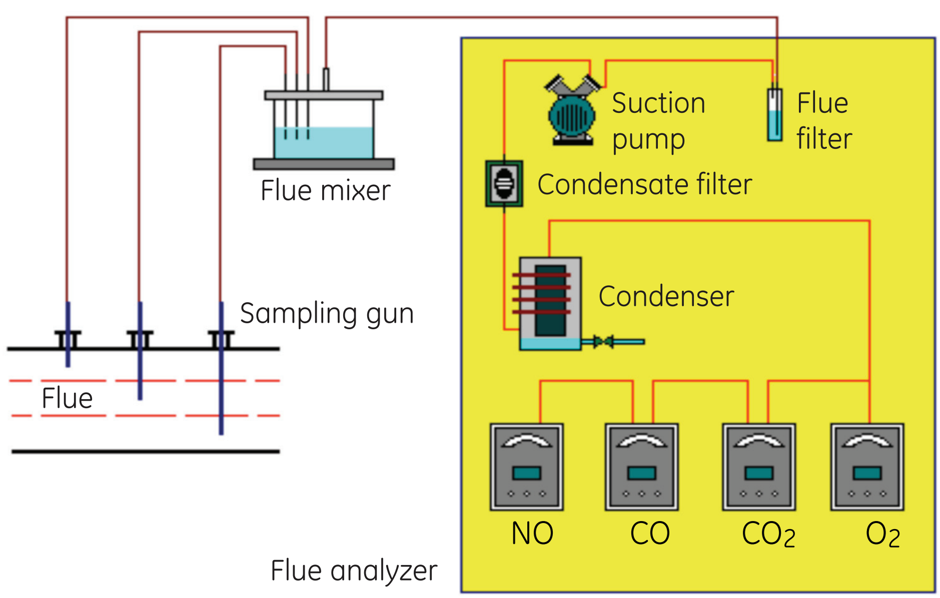

Figure 2. Flue Sampling System

5.5 Slag Sampling and Analysis

Slag was sampled from the scum pipe located at the furnace floor. Sampling was performed one time for each working condition during testing.

The sample was handed over to the Quality Supervision and Inspection Center of Coal for Power Generation in Power Industry affiliated to the Thermal Power Research Institute for analysis. The analysis primarily deals with combustible content in the slag. The results were utilized by all types of relevant calculations as official data.

5.6 Environmental Condition Measurement

Atmospheric pressure and dry and wet ball temperature measurement was performed at the inlet of blowers. A record was made every 20 minutes.

5.7 Operating Parameter Record

Other key operating parameters were printed out with an electronic monitoring panel.

6. Test Conditions

1. The testing was attended by all three parties: Minhang Power Plant of Shanghai Electric Power Co., Ltd., Shanghai Xinhua Control Engineering Co., Ltd., and Thermal Power Research Institute.
2. Each party conducted an overall check of the boiler installation before testing and submitted to the proper authorities, any equipment conditions that were not up to test standards for timely disposal.
3. Minhang Power Plant, Shanghai Electric Power Co, Ltd., prepared for a sufficient amount of test coal to ensure stability of coal quality during testing.
4. Shanghai Xinhua Control Engineering Co., Ltd. was responsible for normal switching of the combustion optimization system.
5. Upon conclusion of the test, the results were deemed effective as no party raised any questions and all situations were normal during testing.

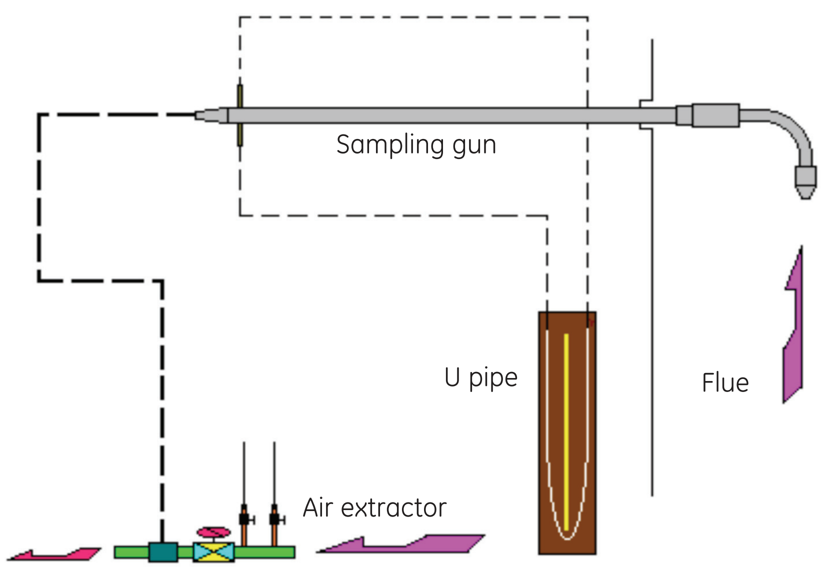

Figure 4. Fly Ash Sampling System

7. Operating Requirements

1. There were no operations affecting normal working conditions during testing, including soot blowing and sewage discharge.
2. Before measurement during testing, the boiler operated stably for one hour under designated conditions. Once the test started, operators were no longer adjusting the boiler system.

8. Data Processing

8.1 Boiler Efficiency

1. Boiler efficiency was calculated based on thermal loss method in the Performance test code for utility boiler GB10184-88, whereas the thermal loss calculation considers the following aspects:
   - Thermal loss from fume exhaust q_2;
   - Thermal loss from incomplete combustion of combustible gas q_3;
   - Thermal loss from incomplete combustion of solid q_4;
   - Dissipation heat loss q_5;
   - Physical thermal loss of ash q_6.
2. Ash balance ratio in thermal efficiency calculation:
   - Slag 10%
   - Fly ash 90%
3. Boiler efficiency correction

The benchmark temperature for efficiency calculation is 20°C. Where there was deviation of actual air intake temperature and design value, correction was made based on the national standard Performance test code for utility boiler GB10184-1988. The same standard also applies to deviation of test coal from the design value.

8.2 Blower Fan Consumption

In the 6kV distribution room, the electric meter rotation was measured with a stopwatch. Calculation was performed based on the following equation:

$$P = \frac{nK_{PT}K_{CT}}{Kt} = 3600 \text{ kW}$$

Where: P – tested equipment power, kW;

n – turns made by electric meter dial during the time t, r;

K_{PT} – voltage transformer transformation ratio (60);

K_{CT} – current transformer transformation ratio (60);

K – three-phase three-line active embedded electric meter, 1800r/(kW·h) electric meter constant;

T – measurement time s.

8.3 NO_X Effluent Concentration

Measurement result is the arithmetic mean of the tested parameters according to the emission standard of all pollutants for thermal power plants GB13223-2003.

$$NO_X = 2.054 \times (NO_X)_{\text{test result}} \times \frac{21 - 6.0}{21 - (O_2)_{\text{test result}}} \ mg/m^3$$

Test result;

Where: NO_X is the corrected data, $(NO_X)_{\text{test result}}$ and $(O_2)_{\text{test result}}$ are the measured data during testing in unit of μL/L.

9. Test Results

9.1 Oxygen Consumption Field Calibration

Oxygen consumption field calibration represents how the inlet flue cross section of the air preheater is divided into 6 (hole) × 2 (dot) grids of equal area on either side, and the outlet flue cross section of the air preheater is divided into 6 (hole) × 2 (dot) grids of equal area on either side. The central flue sample was extracted for each grid on a point-by-point basis. Then, oxygen concentration was analyzed for the oxygen consumption distribution field of the flue. Representative points of oxygen consumption were selected, and used as representative points for flue sampling.

The inlet/out oxygen consumption field calibration was performed for the air preheater at 12:00-14:00 on May 10, 2008, under the following conditions: 125 MW electric load; 13.24 MPa overheating steam pressure; 537.2°C overheating steam temperature; and 4.11% average oxygen quantity on either side of the dial. For more details of the calibration results, see *Table 4, Table 5, Table 6,* and *Table 7*.

Dot/Hole	I	II	III	IV	V	VI
1	4.09	4.17	4.32	4.79	4.72	4.82
2	4.39	4.67	4.36	4.18	4.17	4.84
Hole average	4.24	4.42	4.34	4.49	4.45	4.83
Field average	4.46					
Representative point	2	1	2	1	2	1

Table 4. Result of Inlet Flue Oxygen Consumption Field Calibration from Side A of Air Preheater (Unit: %)

Dot/Hole	I	II	III	IV	V	VI
1	4.33	5.00	4.17	5.23	4.70	4.96
2	5.03	5.62	4.35	4.48	4.62	4.68
Hole average	4.68	5.31	4.26	4.86	4.66	4.82
Field average	4.76					
Representative point	2	1	2	1	2	1

Table 5. Result of Inlet Flue Oxygen Consumption Field Calibration from Side B of Air Preheater (Unit: %)

Dot/Hole	I	II	III	IV	V	VI
1	7.03	6.64	6.06	6.12	6.68	6.44
2	7.06	7.04	6.54	5.98	6.13	6.65
Hole average	7.05	6.84	6.30	6.05	6.41	6.55
Field average	6.53					
Representative point	2	1	2	1	2	1

Table 6. Result of Outlet Flue Oxygen Consumption Field Calibration from Side A of Air Preheater (Unit: %)

Dot/Hole	I	II	III	IV	V	VI
1	6.75	6.87	6.08	6.55	7.10	6.72
2	6.87	6.67	6.21	6.24	6.60	6.87
Hole average	6.81	6.77	6.15	6.40	6.85	6.80
Field average	6.63					
Representative point	2	1	2	1	2	1

Table 7. Result of Outlet Flue Oxygen Consumption Field Calibration from Side B of Air Preheater (Unit: %)

9.2 Comparative Test of Coal Mills B and C under 100 MW Operating Load

A comparative test for the start and stop of the combustion optimization system under a 100 MW load of coal mills B and C was performed on May 12, 2008. Working condition T-01 represents the original regular working condition in the power plant, and working condition T-02 represents the instructive working condition by the combustion optimization system. For results of the comparative test, see *Table 8, Table 9,* and *Table 10.*

Item		Unit	T-01	T-02
Load		MW	103.8	103.5
Total air flow		t/h	404	382
Main steam temperature	E	°C	538.1	538.0
	W		538.1	538.2
Reheat steam temperature	E	°C	534.9	529.9
	W		514.6	513.5
Excess Oxygen	E	%	4.0	3.4
	W		4.2	3.6
Primary air flow	B	t/h	60.0	51.8
	C		50.8	43.8
FD Fan Motor current	A	A	38	35
	B		34	31
ID Fan Motor current	A	A	51	46
	B		55	49
Flue Gas temperature	A	°C	140.2	127.1
	B		142.4	130.4

Table 8. Comparison of Key Operating Parameters (coal mills B and C operating under 100 MW load)

Item			Unit	T-01	T-02
Air preheater Inlet Measured parameter	O_2	A	%	4.58	3.71
		B		4.75	3.76
	CO	A	μL/L	0	0
		B		0	0
	NO	A	μL/L	351	305
		B		344	303
	θ'	A	°C	335.8	331.0
		B		337.4	330.9
Air preheater Outlet Measured parameter	O_2	A	%	6.64	5.88
		B		6.42	5.60
	CO_2	A	%	12.87	13.52
		B		13.03	13.75
	t_{py}	A	°C	133.7	121.5
		B		134.4	123.6
Atmospheric condition	Dry bulb temperature		°C	22.3	19.3
	Wet bulb temperature		°C	14.6	12.9
	Atmospheric pressure		kPa	101.60	101.90
Raw coal analysis	As-received Base Carbon		%	46.31	46.31
	As-received Base Hydrogen		%	3.07	3.07
	As-received Base Nitrogen		%	0.61	0.61
	As-received Base Oxygen		%	7.27	7.27
	As-received Base Total Sulfur		%	0.46	0.46
	Total Moisture		%	11.0	11.0
	As-received Base Ash Content		%	31.28	31.28
	As-received Base Lower Calorific Value		MJ/kg	17.12	17.12
Ash, slag Combustible	Fly Ash Combustible	A	%	1.02	0.95
		B	%	1.14	1.06
	Slag Combustible		%	5.18	2.72

Table 9. Comparison of Key Measured Parameters (coal mills B and C operating under 100 MW load)

Item		Unit	T-01	T-02
Stack loss		%	5.76	4.90
Thermal loss from incomplete combustion of combustible gas		%	0.00	0.00
Thermal loss from incomplete combustion of solid		%	0.94	0.74
Actual dissipation loss		%	0.76	0.76
Physical thermal loss of ash		%	0.29	0.27
Measured boiler efficiency		%	92.24	93.33
Corrected boiler efficiency		%	92.61	93.66
FD Fan power	A	kW	304.8	257.1
	B		346.5	311.5
ID Fan power	A	kW	349.0	269.8
	B		370.2	304.3
NO_X emission value (standard status O_2=6%)	A	mg/m^3	690	570
	B		684	567

Table 10. Comparison of Calculation Results (coal mills B and C operating under 100 MW load)

9.3 Comparative Test of Coal Mills A and C under 100 MW Operating Load

A comparative test for the start and stop of the combustion optimization system under a 100 MW load of coal mills A and C was performed on May 13, 2008. Working condition T-03 represents the original regular working condition in the power plant, and working condition T-04 represents the instructive working condition by the combustion optimization system. For results of the comparative test, see *Table 11*, *Table 12*, and *Table 13*.

Item		Unit	T-03	T-04
Load		MW	100.4	100.3
Total air flow		t/h	395	372
Main steam temperature	E	°C	537.2	536.8
	W		536.8	533.6
Reheat steam temperature	E	°C	532.6	516.1
	W		535.1	521.0
Excess Oxygen	E	%	3.5	3.0
	W		3.6	3.4
Primary air flow	A	t/h	60.4	57.2
	C		52.0	46.3
FD Fan Motor current	A	A	35	34
	B		31	28
ID Fan Motor current	A	A	46	44
	B		51	46
Fume exhaust temperature	A	°C	142.8	129.5
	B		140.1	128.6

Table 11. Comparison of Key Operating Parameters (coal mills A and C operating under 100 MW load)

Item			Unit	T-03	T-04
Air preheater Inlet Measured parameter	O_2	A	%	4.47	3.57
		B		4.89	3.43
	CO	A	μL/L	0	0
		B		0	0
	NO	A	μL/L	397	339
		B		385	316
	θ'	A	°C	338.8	331.0
		B		331.3	323.15.
Air preheater Outlet Measured parameter	O_2	A	%	6.51	5.64
		B		6.59	5.37
	CO_2	A	%	12.24	13.68
		B		12.91	13.93
	t_{py}	A	°C	133.9	124.5
		B		131.7	123.1
Atmospheric condition	Dry bulb temperature		°C	23.5	24.5
	Wet bulb temperature		°C	15.8	15.5
	Atmospheric pressure		kPa	102.00	101.90
Raw coal analysis	As-received Base Carbon		%	46.31	46.31
	As-received Base Hydrogen		%	3.07	3.07
	As-received Base Nitrogen		%	0.61	0.61
	As-received Base Oxygen		%	7.27	7.27
	As-received Base Total Sulfur		%	0.46	0.46
	Total Moisture		%	11.0	11.0
	As-received Base Ash Content		%	31.28	31.28
	As-received Base Lower Calorific Value		MJ/kg	17.12	17.12
Ash, slag Combustible	Fly Ash Combustible	A	%	0.98	134
		B	%	0.97	2.16
	Slag Combustible		%	5.73	5.31

Table 12. Comparison of Key Measured Parameters (coal mills A and C operating under 100 MW load)

Item		Unit	T-03	T-04
Stack loss		%	5.73	4.89
Thermal loss from incomplete combustion of combustible gas		%	0.00	0.00
Thermal loss from incomplete combustion of solid		%	0.92	1.33
Actual dissipation loss		%	0.79	0.79
Physical thermal loss of ash		%	0.29	0.28
Measured boiler efficiency		%	92.27	92.71
Corrected boiler efficiency		%	92.65	93.04
FD Fan power	A	kW	260.4	241.5
	B		280.9	244.8
ID Fan power	A	kW	286.8	239.8
	B		301.2	245.3
NO_X emission value (standard status O_2=6%)	A	mg/m^3	775	628
	B		772	581

Table 13. Comparison of Calculation Results (coal mills A and C operating under 100 MW load)

9.4 Comparative Test of Coal Mills A and C under 120 MW Operating Load

A comparative test for the start and stop of the combustion optimization system under a 120 MW load of coal mills A and B was performed on May 14, 2008. Working condition T-05 represents instructive working condition by the combustion optimization system, and T-06 represents the original regular working condition in the power plant. For results of the comparative test, see *Table 14, Table 15,* and *Table 16*.

Item		Unit	T-05	T-06
Load		MW	120.9	121.2
Total air flow		t/h	454	492
Main steam temperature	E	°C	534.3	535.2
	W		534.4	534.7
Reheat steam temperature	E	°C	528.8	530.0
	W		538.3	537.7
Excess Oxygen	E	%	2.5	3.5
	W		3.0	3.8
Primary air flow	B	t/h	56.9	56.7
	C		52.6	57.5
FD Fan Motor current	A	A	40	46
	B		40	45
ID Fan Motor current	A	A	53	60
	B		71	81
Flue Gas temperature	A	°C	139.1	146.3
	B		140.3	151.1

Table 14. Comparison of Key Operating Parameters (coal mills A and B operating under 120 MW load)

Item			Unit	T-05	T-06
Air preheater Inlet Measured parameter	O_2	A	%	4.12	4.30
		B		3.54	4.94
	CO	A	μL/L	0	0
		B		0	0
	NO	A	μL/L	384	414
		B		413	386
	θ'	A	°C	354.2	351.8
		B		352.9	363.0
Air preheater Outlet Measured parameter	O_2	A	%	5.86	6.27
		B		5.64	6.71
	CO_2	A	%	13.42	13.08
		B		13.70	12.62
	t_{py}	A	°C	132.6	139.6
		B		133.0	143.2
Atmospheric condition	Dry bulb temperature		°C	24.0	22.7
	Wet bulb temperature		°C	16.0	15.8
	Atmospheric pressure		kPa	102.10	102.10
Raw coal analysis	As-received Base Carbon		%	46.31	46.31
	As-received Base Hydrogen		%	3.07	3.07
	As-received Base Nitrogen		%	0.61	0.61
	As-received Base Oxygen		%	7.27	7.27
	As-received Base Total Sulfur		%	0.46	0.46
	Total Moisture		%	11.0	11.0
	As-received Base Ash Content		%	31.28	31.28
	As-received Base Lower Calorific Value		MJ/kg	17.12	17.12
Ash, slag Combustible	Fly Ash Combustible	A	%	1.98	1.40
		B	%	1.71	1.26
	Slag Combustible		%	5.20	3.48

Table 15. Comparison of Key Measured Parameters (coal mills A and B operating under 120 MW load)

Item		Unit	T-05	T-06
Stack loss		%	5.45	6.22
Thermal loss from incomplete combustion of combustible gas		%	0.00	0.00
Thermal loss from incomplete combustion of solid		%	1.38	0.97
Actual dissipation loss		%	0.66	0.66
Physical thermal loss of ash		%	0.29	0.30
Total thermal loss		%	7.78	8.15
Measured boiler efficiency		%	92.22	91.85
Corrected boiler efficiency		%	92.59	92.27
FD Fan power	A	kW	334.2	396.4
	B		380.3	448.4
ID Fan power	A	kW	376.5	482.3
	B		523.1	664.2
NO_X emission value (standard status O_2=6%)	A	mg/m^3	735	800
	B		764	776

Table 16. Comparison of Calculation Results (coal mills A and B operating under 120 MW load)

10. Conclusion

1. For coal mills B and C that operated under a 100 MW load, the measured boiler efficiency improved by 1.08% when the combustion optimization system was put into service; the electricity consumption by the FD and ID fan saved 227.9 kW; and the average NO_x emission reduction was 118 mg/m^3 (standard condition).

2. For coal mills A and C that operated under a 100 MW load, the measured boiler efficiency improved by 0.44% when the combustion optimization system was put into service; the electricity consumption by the FD and ID fan saved 157.9 kW; and the average NO_x emission reduction was 169 mg/m^3 (standard condition).

3. For coal mills A and B that operated under a 120 MW load, the measured boiler efficiency improved by 0.37% when the combustion optimization system was put into service; the electricity consumption by the FD and ID fan saved 377.3 kW; and the average NO_x emission reduction was 39 mg/m^3 (standard condition).

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