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An Experimental Study on the Performance of Storage Pulverizing System after Renovation of Importing Hot Air

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ABSTRACT

A thermal power plant of Sinopec has 9 boilers, which generally have problems of high exhaust gas temperature and high flying ash carbon content. In order to improve the adaptability of coals, the stability of coal powder ignition, the burn-off rate of pulverized coals and the boiler efficiency, a series of renovation projects about importing hot air into mill exhauster are proposed. For the sake of verifying the renovation effects, an efficiency performance test is conducted on the renovated #5 boiler. The test result shows that the boiler heat efficiency has improved by 0.4% and it operates more safely and reliably after the renovation. At last, this paper recommends an optimized operation mode.

Keywords: Storage Pulverizing System; Importing Hot Air Renovation; Performance Test; Operation Optimization

1. Introduction

#1-8 boilers(8×220 t/h) in a thermal power plant of Sinopec are designed to equip the storage pulverizing systems with exhaust air used as primary air. And coals are pulverized by ball mills. Each boiler is equipped with 2 pulverizing systems. The air temperature of exhauster inlet is about 80-100℃ when the pulverizing systems use warm air as primary air, and about 65-75℃ when the exhaust air is used as primary air, which helps the inferior coals to burn steadily and burn off to some extent.

In order to improve the adaptability of coals, the stability of pulverized coals ignition, the burn-off rate of pulverized coals and the boiler efficiency, the plant takes #5 boiler as a pilot to renovate the pulverizing system with hot air being imported into the exhausters. The #5 boiler is renovated with 2 hot-air ducts, hot-air dampers, observation points, testing points and so on. The diagram of renovated pulverizing system is shown in **Figure 1**.

The #5 boiler is manufactured by Harbin Boiler Factory Co.Ltd. Its type is HG-220/100-10. And it is a natural circulation drum boiler, which was built and operated in August, 1998. The rated evaporation of the boiler is 220t/h, the rated main-steam pressure is 9.8 MPa, the rated main-steam temperature is 540 ℃, designed feed-water temperature is 215℃, designed supply air temperature is 30℃, designed flue gas temperature is 138 ℃ and designed Boiler heat efficiency is 91.64%. Bituminous coal from Shanxi Liujialiang is the designed coal for the boiler. For the pulverizing system, the main equipments' standards and parameters are shown in **Table 1**.

2. Testing Contents and Method

The test is aiming at mastering the influence of the aforementioned renovation on pulverizing system and boiler's performance indexes. Also it will help to ensure the system's safe operation, improve the Boiler heat efficiency and optimize the operation mode.

The test was performed according to the standards of GB10848-88(*Performance test code for utility boiler*) and DL/T 467-2004(*Performance test for pulverizers and pulverizing systems of power station*) and with a steam capacity of 200t/h. During the test pulverized air rate, flame temperatures were measured and samples of powders and ashes were taken, which were analyzed afterward. Besides, the combustion condition inside the furnace was observed and important variables of the boiler system and pulverizing system were recorded.

The schedule of the whole test is as follows:

1) Diagnostic test under the running condition of importing hot air in mill exhauster inlet. Boiler heat efficiency and pulverized air rate were measured with only side a pulverize in operation. The tests were labeled Test 1 and Test 2.

2) Hot air importing tests under various mill exhauster outlet pressures. The tests were performed under three different mill exhauster outlet pressure specifically and

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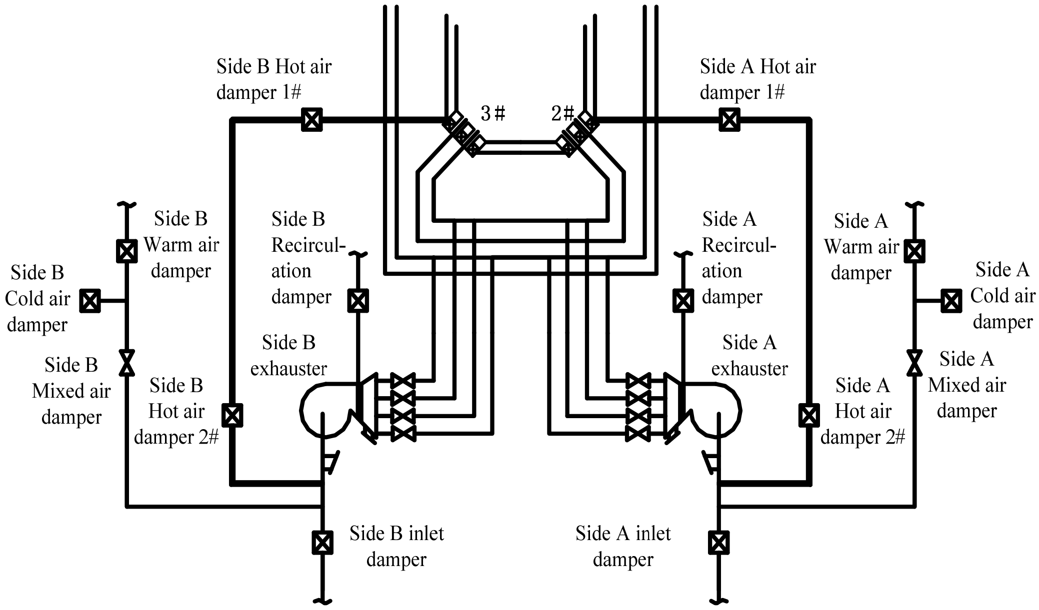

Figure 1. Diagram of renovated pulverizing system installed with hot ducts.

Table 1. Standards and Parameters of main equipments in the pulverizing system.

Item	Type or Standard	Parameters	NO. per boiler
Coal feeder	ZS-2540	Standard output 40t/h	2
Pulverizer	DTM290/410	Standard output 14t/h, maximum charge of balls 30t, Rotating speed 19.34 r/min	2
Exhauster	M6-31 No.17D	Air quantity 52700t/h, total pressure 10523Pa	2
Classifier	HW-CB-II-Φ3400, centrifugal	Diameter Φ3400mm	2
Cyclone collector	HW-GXBT-I-Φ2350, centrifugal	Diameter Φ2350mm	2

were labeled Test 3, Test 4 and Test 5.

3) Hot air importing test under different ways of operation of the pulverizing system. Boiler heat efficiency and pulverized air rate were measured with side a pulverizer in operation only, side B pulverizer in operation only and both pulverizers in operation specifically. The tests were Test 6 - Test 9.

3. Results and Analysis

3.1. Diagnostic Tests

The diagnostic tests were both performed with only side a pulbverizer in operation, the tests being Test 1 and Test 2. In Test 1 the system was running under the condition that there was no hot air importing in the mill exhauster inlet. And in Test 2 there was. In order to guarantee that the system load and air rate are the same for the two tests, mill exhauster outlet pressure was 300 Pa higher Test 2 than Test 1, the specific hot air rate being 20000 m^3/h; for the sake of operation personnel, mill exhauster outlet pressure was kept 2000-2300 Pa, with which they feel comfortable. Thus the hot air rate of side B exhauster is 6900 m^3/h, which is much less than that of side A. The relevant test data are listed in **Table 2**.

It can be known from **Table 2** that with mill exhauster outlet pressure fixed to 2000-2300 Pa, the corrected boiler efficiency\corrected heat loss due to flue gas\ heat loss due to mechanical incomplete combustion are specifically 92.44% \5.88% \0.89% and 92.71% \5.66% \0.85%. For Test 2, Boiler heat efficiency is 0.27% higher, mainly due to reduction in heat loss due to flue gas which is 0.22%. Reduction in mechanically unburned coal heat loss is barely countable, the value being 0.04%. So it can be concluded that measures must be taken to reduce the heat loss due to mechanical incomplete combustion in order to increase boiler efficiency.

3.2. Tests under Various Mill Exhauster Outlet Pressure

Mill exhauster outlet pressure gets higher as the rate of hot air being imported increases, and so does the mill exhauster outlet air temperature. This can help make ignition of coal powder easier and exhauster gas temperature lower. In order to estimate the influence of mill exhauster outlet pressure on system performance, unburned coal in flying ash and flame temperature were tested under various mill exhauster outlet pressures in Test 3-Test 5. For these three tests, both pulverizers were in operation with hot air importing only in Test 4 and Test 5. Side A/B mill exhauster outlet pressures were specifically 2445 Pa /2427 Pa, 2634 Pa /2629 Pa, 2840 Pa /2940 Pa. Variation of flame temperature and unburned carbon in flying ash and slag are shown in **Figure 2** and **Figure 3.**

In Test 4, mill exhauster outlet pressure is relatively lower after hot air importing in and result in the decrease of air rate of side B. Although the system was running up to one hour, the pulverizer was popping out powder afterward anyway. It is thought that if mill exhauster outlet pressure maintained regular level when importing in hot air, air rate will drop to an unreasonable low value, which consequently results in the reduction of mill output, 1] and even causes powder popping out and mill blocking. So mill exhauster outlet pressure should be adjusted to a higher than regular level if hot air is to be imported in.

It can be known from **Figure 2** that flame temperatures at 10m and 14m height monotonically increase as the mill exhauster outlet pressure gets higher, which indicates the lowering of the flame center. This will make the coal powder ignition more stable and enable the system to a variety of coals. [2]

Table 2. Data of diagnostic boiler heat efficiency test with hot air imported into exhauster.

Variables		Unit	Test 1	Test 2
Mill operation		/	Side A	Side A
Importing hot air or not [a]		/	No	Yes
Exhauster outlet pressure	A	Pa	1995	2301
	B	Pa	2198	2254
Air quantity of pulverizing system	A	m^3/h	42457	42077
	B	m^3/h	-	-
Hot air quantity of exhauster inlet	A	m^3/h	-	20502
	B	m^3/h	-	6932
Steam flow		t/h	196.2	197.1
Testing boiler heat efficiency		%	91.90	92.16
Corrected boiler heat efficiency		%	92.44	92.71
Designed boiler efficiency		%	91.64	91.64
Difference between designed and corrected efficiency		%	0.8	1.07
Corrected flue gas temperature		℃	149.4	145.3
Excess air coefficient		/	1.3	1.3
Designed excess air coefficient		/	1.39	1.39
Corrected heat loss due to flue gas		%	5.88	5.66
Content of combustibles in fly ash		%	1.3	1.5
Content of combustibles in slag		%	6.6	4.8
Heat loss due to mechanical incomplete combustion		%	0.89	0.85
Heat loss due to chemical incomplete combustion		%	0	0
Heat loss due to sensible heat in refuse		%	0.25	0.24
Heat loss due to radiation		%	0.56	0.56

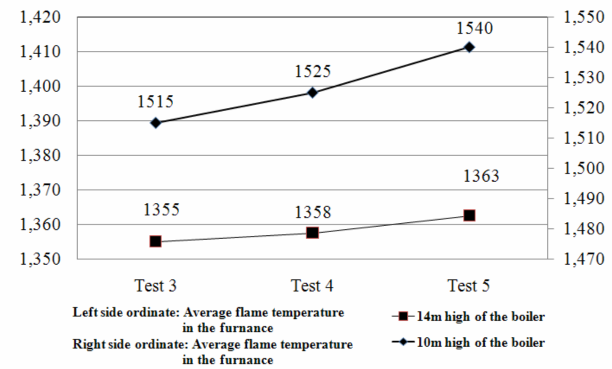

Figure 2. Flame temperature under different mill exhauster outlet pressure (℃).

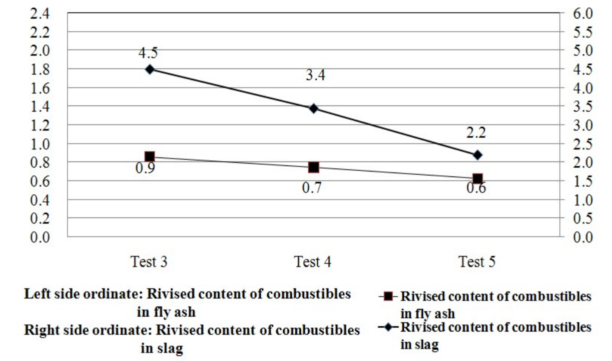

Figure 3. Unburned carbon under different mill exhauster outlet pressure.

It can be known from **Figure 3** that unburned carbon in both flying ash and slag decrease as the mill exhauster outlet pressure gets higher, causing a reduction in heat loss due to mechanical incomplete combustion up to 0.12%, which is noticeably higher than that during the diagnostic test.

To summarize up, after the renovation of importing hot air into the mill exhauster inlet, the more mill exhauster outlet pressure is, the more hot air will be imported, improving the rigidity of the mixture flow of powder and air, increasing the primary air temperature and making the primary flow rush into the furnace in a better pattern. Besides, the lowering of the combustion center and the increasing of the flame temperature can make the ignition more stable and thus enable the system to a variety of coal with low heat loss due to mechanical incomplete combustion. So it is recommended that mill exhauster outlet pressure should be maintained high (2900-3000 Pa) to get the improvement mentioned above.

3.3. Hot Air Importing Test under Different Ways of Operation of the Pulverizing System

Maintaining mill exhauster outlet pressure at 2900-3000Pa, Boiler heat efficiency and pulverized air volume rate were measured with side A pulverizer in operation only, side B pulverizer in operation only and both pulverizer in operation specifically. In Test 6 no hot wind was imported in mill exhauster inlet. And hot air was imported to both side pulverizers in Test 7-9.

Test results are shown in **Table 3**, **Table 4**, **Figure 4** and **Figure 5**. Influence of hot air in mill exhauster inlet to performance indexes is as follows:

Heat loss due to flue gas

Corrected exhaust heat loss of Test 7-9 are 5.79%, 5.83% and 5.64% respectively, which are all less than Test 6 when no hot air imported in mill exhauster inlet. Considering the different excess air ratio in Test 9, if the same excess air ratio can be maintained as other Tests, heat loss due to flue gas may approximately increase 0.1% [3] considering influence of both excess air ratio and exhaust gas temperature. So the heat loss due to flue gas should be about 0.3% in Test 9. Therefore, when mill exhauster outlet pressure is 2900-3000Pa, importing hot air to mill exhauster inlet can decrease about 0.24%. Moreover, importing hot air in Pulverize a working method can achieve a comparatively high efficiency.

Heat loss due to mechanical incomplete combustion

In Test 7-9, when hot air was imported in mill exhaust inlet, the 14m and 10m average flame temperature was increased compared with without hot air. The heat loss due to mechanical incomplete combustions were 0.86%, 0.84% and 0.83% respectively in Test 7-9, lower than in Test 6 and the average reduction is 0.16%. Analysis expressed the decreased heat loss due to mechanical incomplete combustion was related with high mill exhauster outlet pressure and flame temperature in the furnance.

Boiler heat efficiency

In Test 7-9, mill exhauster outlet temperature is 50^{o}C higher than Test 6, which will lead to earlier ignition of primary air. Meanwhile, importing of primary air and coal powder will lead to more moisture precipitate from coal powder, which increases void fraction of it. Large void fraction makes it easier for excess oxygen to diffuse to internal voids. Thus coal powder can easily ignite and burnout. Corrected Boiler heat efficiency in Test 7-9 is 92.55%, 92.53% and 92.73%, average higher 0.4% than Test 6 without imported hot air. The result is better than diagnostic tests, mainly due to the positive influence of high mill exhauster outlet pressure and temperature on mechanically unburned carbon.

Mill exhauster motor current

Normal mill exhauster motor current is 16.5-18.5A, considering the effect of flue gas recirculation, feed coal quantity, primary wind pressure etc., the average mill exhauster motor current should be about 17.5A. With imported hot air the mill exhauster motor current should

Table 3. Boiler heat efficiency and losses before and after importing hot air into exhauster.

Parameter	Unit	Test 6	Test 7	Test 8	Test 9
Mill operation	/	Both	Both	Side B	Side A
Importing hot air or not [a]		No	Yes	Yes	Yes
Steam flow	t/h	194.6	193.6	195.2	195.2
The testing boiler heat efficiency	%	92.92	93.34	93.44	93.62
Revised boiler heat efficiency	%	92.17	92.55	92.53	92.73
Revised flue gas temperature	℃	151.1	146.1	147.1	144.6
Excess air coefficient	/	1.32	1.32	1.32	1.30
Revised heat loss due to flue gas	%	6.02	5.79	5.83	5.64
Content of combustibles in fly ash	%	1.54	1.56	1.29	1.09
Content of combustibles in slag	%	6.92	4.18	5.43	6.98
Heat loss due to mechanical incomplete combustion	%	1.00	0.86	0.84	0.83
Heat loss due to chemical incomplete combustion	%	0	0	0	0
Heat loss due to sensible heat in refuse	%	0.26	0.25	0.26	0.25
Heat loss due to radiation	%	0.57	0.57	0.56	0.56

Table 4. Parameters of pulverizing system before and after importing hot air into exhauster.

Parameter		Unit	Test 6	Test 7	Test 8	Test 9
Mill current	A	A	40.9	41.1	-	41.2
	B	A	48.9	50.6	51.3	-
Exhauster current	A	A	18.1	18.3	16.1	18.1
	B	A	18.4	18.2	18.2	16.4
Rotating speed of coal feeder	A	rpm	377	366	-	331
	B	rpm	369	360	330	-
Opening of exhauster inletdamper	A	%	52	58	0	55
	B	%	65	70	72	0
Opening of recirculation damper	A	%	50	100	0	50
	B	%	50	65	55	0
Opening of exhauster hot air secondary air door	A	%	0	100	95	95
	B	%	0	58	58	62
Negative pressure of classifier outlet	A	Pa	-4130	-3290	-	-3177
	B	Pa	-4110	-3250	-3356	-
Exhauster outlet pressure	A	Pa	2550	2910	2970	3030
	B	Pa	2630	2920	3060	2900
Air quantity of pulverizing system	A	m^3/h	51031	43742	-	43688
	B	m^3/h	50277	44010	44010	-
Hot air quantity of exhauster inlet	A	m^3/h	-	19949	18423	18410
	B	m^3/h	-	15175	15175	16710
Opening of mill warm air damper	A	%	42	13	0	7
	B	%	100	62	19	0
Opening of mill hot air damper	A	%	70	62	0	67
	B	%	56	51	62	0
Air temperature of exhauster outlet	A	℃	76.7	122.3	146.8	120.6
	B	℃	76.8	116.2	115.6	145.6
Air temperature of exhauster inlet	A	℃	155.9	321.9	328.6	326.4
	B	℃	132.6	320.7	327.4	327.7
Fineness of pulverized coal R_{90}	A	%	20.8	20.8	-	20.8
	B	%	21.2	16.0	16.0	-
Fineness of returned coal R_{90}	A	%	70.4	60.4	-	3.2
	B	%	82.8	68.4	68.4	-

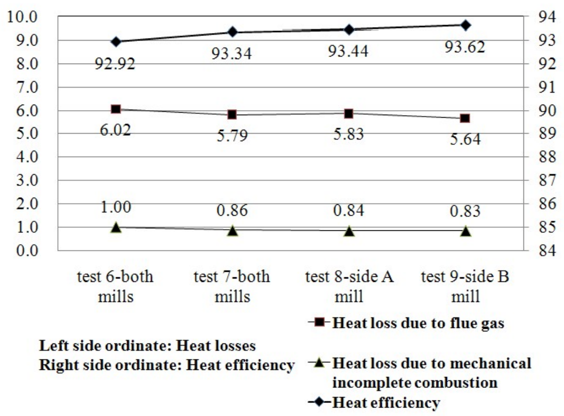

Figure 4. Boiler efficiency and losses under various operation modes (%).

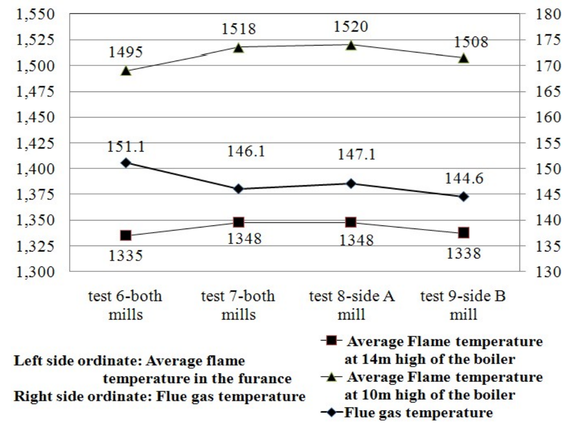

Figure 5. Flame temperature and exhaust flue gas temperature under various operation mode.

be 18.5A or above. The importing hot air test was performed under the constant pulverizing system output, thus there is no significant change of pulverizer current. When the pulverizer is in operation, imported hot air will increase total air rate. However, due to the initial wind pressure of hot air, mill exhauster motor current only increase slightly.

After the renovation of pulverizing system, maintaining the pulverizer output and mill exhauster outlet pressure at 2900-3000Pa, hot air increases 0.4% boiler efficiency. Meanwhile, current of pulverizer and mill exhauster only increases slightly. So the benefit is evident compared with renovation cost.

4. Recommended Operation Method of Pulverizing System after Importing Hot Air

Principles for determining the recommended operation method is as follows:

1) System ventilation air rate should be maintained in normal rate, avoiding ventilation output decrease and mill blocking due to low air ventilation rate;

2) Pulverizer output should be maintained the same as it is without hot air imported in;

3) High pressure should be maintained at mill exhauster outlet, thus more hot air can be imported and the Boiler heat efficiency can be higher;

4) Coal powder fineness R90 should be 20-22%;

5) According to *DL/T* 5121-200*0, Technical code for design of thermal power plant air& flue gas ducts/ raw coal& pulverized coal piping*, flow velocity of recirculation should be above 25m/s, lower value may lead to accumulated powder in duct [5].

According to thermal calculation of pulverizing sysm[6] and experimental result, recommended operation method of pulverizing system after importing hot air are expressed in **Table 5**.

Table 5. The recommended optimized mode of operation with hot air imported.

Operation Parameter	units	Side A	Side B
Exhauster Current	A	18.5	18.5
Exhauster outlet pressure	Pa	≥2800	≥3000
Negative pressure of classifier outlet	Pa	≥-3500	≥-3500
Opening of recirculation damper	%	50-100	40-70
Opening of exhauster hot air secondary air door	%	90-100	50-70

Under the condition without imported hot air, when recirculation is not in operation, ventilation rates of two sides of pulverizing system are 43000 m^3/h and 40000-5000 m^3/h; when recirculation is in operation, ventilation rates of both sides of pulverizing system are 45000- 0000 m^3/h; according to theoretical calculation, designed value of the milling system ventilation rate should be about 47000 m^3/h. Considering the actual operation conditions, air rate of pulverizing system with imported hot air should be about 46000m^3/h to maintain the pulverizing system output. Moreover, the coal powder fineness of both sides is 20%-22%.

Mill exhauster outlet pressure and temperature will increase with imported hot air, and the circulation flow velocity can be 50-70m/s. Therefore, powder won't accumulate in recirculation duct when recirculation is in operation. However, recirculation air may wear the duct more severely, which should be treated in another renovation.

On account of the primary air quantity changing a little or remaining unchanged, and the hot air imported into exhauster has to return into mills through recirculating ducts, the dampers of recirculating ducts should be wide open when importing hot air. On conditions that the dampers of recirculating ducts are leakproof, it is security to control the air temperature of exhauster outlet only when importing hot air. In a word, it is suggested that the air temperature and exhauster outlet pressure should be controlled at 140-150℃ and 2900 Pa around on conventional operation.

5. Conclusions and Suggestions

- Based on the diagnostic test, when only the mill of side A operates and the outlet pressure of exhauster is holding within the conventional range of 2000-3000Pa, the results show that the corrected Boiler heat efficiency is 92.71% after importing hot air into the exhauster. It is 0.27% higher than before. The improvement lies mainly in the heat loss due to flue gas. It decreases by 0.22%, while the decline of heat loss due to mechanical incomplete combustion falls only 0.04%.
- By comparing between the tests of different outlet pressures of exhauster, it is found that more hot air can be imported into the exhauster as the pressure increases. It is beneficial for promoting the rigidity of air flow and the temperature of primary air. Also the organization of pulverized coal and air flow will be strengthened. In addition, the furnace temperature raises and the flame kernel drops with more hot air imported. In a word, it is significant to improve the adaptability of coals, the stability of pulverized coals ignition and the burn-off rate of pulverized coals. Thus it is suggested that when more hot air is imported under the situation of conventional air quantity in the pulverizing system, high outlet pressure of exhauster within 2900-3000 Pa is appropriate and useful to reduce the heat loss due to mechanical incomplete combustion.
- Under the test conditions of two mills operation altogether, one mill of side A and one mill of side B each running alone, hot air is controlled to import into the exhauster, while the outlet pressure of exhauster maintained within 2900-3000 Pa. After importing hot air, the air temperature of exhauster outlet and the flame temperature in furnace raises significantly. So the combustion condition is better. The test results shows that the corrected heat loss due to flue gas and mechanical incomplete combustion is less than the operation of two mills without hot air importing. The average decreasing amplitude is 0.24% and 0.16% respectively. Also the corrected boiler heat efficiency is 0.4% higher equally, better than the diagnostic test as well. The main reason is that higher air pressure and temperature of exhauster outlet is beneficial to reduce the heat loss due to mechanical incomplete combustion.
- When the output of mills is stable and the exhauster outlet pressure is maintained within 2900-3000 Pa, there is not much increase in the amount of exhauster current. For this reason, the renovation benefits obviously outweigh the costs.
- In order to achieve the optimized operation after the renovation of the pulverizing system, a recommended mode of operation is presented, which is shown in **Table 5**.

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