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To take a clean technology as a strategy for pollution control in industry

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Abstract— A clean technology in thermal power station by adding of limestone into coal for getting the co-melted compounds was studied. Comparing with conventional technology, the quantity of ash discharged is decreased from 85% to 15%, the water consumption is 80% less than traditional method. The slag discharged could be used as raw materials for cement and bricks. In addition, the SO_2 content is decreased as well.

Keywords: thermal power station; pollution control; clean technology.

INTRODUCTION

Industrial pollution is the major environmental pollution in China. According to incomplete statistics in 1988, nearly 26.8 billion tons of wastewater, 8238.2 billion m^3 of waste gas and 560 million tons of solid wastes are discharged into the environment by industrial enterprises.

The government takes a clean technology as a strategy for pollution control in industry. Enterprises and factories are encouraged to modify their technology and its industrial processes for production, to reduce, minimize or eliminate their pollution to the environment.

Major measures are as follows:

1. The proposed renovated plan and measures for modifying industrial processes for production should be acceptable both from the economic and environmental point of view. Enterprises are encouraged to employ new technology and new equipment, which would be able to maximize the efficiency of turning resources and energy into products.

2. To give preferential policy to the recovery and comprehensive utilization of industrial wastes.

3. To organize major coherent research projects for tackling key problems.

4. To organize case studies: for example, to organize a case study for the employment of clean technology in coal thermal power station.

CLEAN TECHNOLOGY IN THERMAL POWER STATION

China is a big coal producing country. In 1988 China produced 1.0 billion tons of coal. Among them 220 million tons were used for power generation. Coal is still used as the major source of energy. Most of power stations are using pulverized coal, as a consequence, there were 6.399 million tons of fly ash produced in 1988, only 24.2% of which were comprehensively utilized, others were water-washed to the storage dams. It was estimated that 10 – 15 tons of water is needed for flowing one ton of fly ash to its storage dam, and 350 m^2 of land is occupied for keeping 10 thousand tons of ash. In most cities, because of the lacking of land for disposal, tremendous amount of fly ash was directly discharged into the rivers, seriously polluting the water body and limiting the development of power industry. In addition, since coal used to contain much sulfur, the use of mixed coal by adding some coal of low sulfur content as adjustment is quite common, and since the cost of desulphurization is high, thus the transportation and power generating costs were increased accordingly. Even though, it still seems difficult to control the SO_2 emission in accord with the promulgated criterion. The power generation becomes one of the vital environmental issues in nowadays China. Many institutions have carried on researches on comprehensive utilization of fly ash, or dedusting and desulphurization. Some useful experiences have been accumulated. For solving the problem a new technical process which employs a vertical cyclic boiler with the adding of calcium to the coal, with slag discharged in liquid state has been developed. Researches on environmental assessment for this process has been carried out. Tracing back in history, this process is nothing new and had been developed in the thirty and forty and abandoned in the seventy in view of the NO_X emission which contaminated the air.

The process experiments described in this paper at its initial stage were attempting to form the co-melted compounds with low melting point by adding limestone to the coal to lower the melting point and the burning temperature in the boiler aiming at the reduction of the NO_X emission. While meeting with the aforesaid considerations, this process not only reduced the contamination to air and water during the operation but also opens up a bright prospect for slag utilization.

EXPERIMENTAL RESULTS

Test results

1. By adding 7−28% of limestone to the coal (the content of CaO in slag is less than 40%), the boiler works satisfactorily and it's efficiency rises 1% to 2%.

2. The melting point of the slag is lowered from 1500 ℃ to 1400 ℃, which let the burning temperature in the boiler be controlled at 1600 ℃, the NO_x emission are equalvalent to, or a little lower than the NO_x emission with the same volume by using pulverized coal.

3. If the content of CaO is 40%, the efficiency of desulphurization could reach 30%.

4. 75% of fly ash is turned into slag and discharged from the bottom of the boiler, with a consequence, the volume of dedusting work is reduced by 50%.

5. The amount of water used for treating per ton of fly ash and slag is reduced from 10−15% tons for disposing the fly ash to the dam to 0.5 ton, only for slag granulation, thus saving large amount of water.

6. By adding limestone to the coal the content of CaO in slag is raised from 10% to a little less than 40% to enhance the bonding activation of slag, which makes possible for the slag to be used as high quality raw materials for making cement, concrete and satisfying other constructional needs.

Brief trialing results

1. Considerations of the trials

Trials were carried out at a 5 mW power station, four operational conditions were considered.

(1) When limestone additives were 21−22%, CaO content in slag was 32−33%.

(2) When limestone additives were 13−14%, CaO content in slag was 24−26%.

(3) When limestone additives were 26−27%, CaO content in slag was 39−41%.

(4) When limestone additives were 5−7%, CaO content in slag was 11−15%.

The principle for selecting the aforesaid operational condition:

(1) For effective power generation, to keep the CaO content as high as not to erode or harm the lining of the cyclic boiler, to keep the CaO content as low as providing the smooth flow of slag not to plug the slag hole.

(2) Viewing from the environmental protection attitude, the impact of added quantity of limestone on the effect of desulphurization and NO_x emission should be carefully observed and controlled at permitting criteria.

(3) From the view point of slag utilization, enhancement of the slag quality as satisfactory as possible in order to be widely used should also be emphasized.

2. Environmental assessment on the basis of experimental results

(1) For desulphurization, the smoke collecting and sampling installation for testing the concentration of SO_2 were arranged on both sides of the stack in front of the dedusting equipment.

Measured results are described in Table 1.

Table 1 Desulphurization effect by adding limestone

Operating conditions	Quantity of added limestone, %	CaO content in the slag, %	Rate of desulphurization, %
1	21.66	32.82	24.76
2	13.61	25.66	15.58
3	28.13	39.74	31.42
4	7.16	13.04	10.01

Note: The results measured in another two power stations are similar to the above results

From Table 1, desulphurization rate is increased with the increase of limestone additives and desulphurizaiton happens during the heat exchanging stage. One reason is that the decomposition of $CaCO_3$ does not occur at high temperature, but reacts only at the back part of the furnace with a lower burning temperature of 850 ℃ .

The decomposition is as follows:

$$CaCO_3 \xrightarrow{850\,℃} CaO + CO_2 \uparrow$$

emitted through stack

$$CaO \longrightarrow mCaO.nSO_2 + yCaO.2Al_2O_3$$

slag formed and discharged from the bottom of boiler

900 ℃ ↓

fCaO into smoke and in the convectional heating surface.

The CaO reacts with SO_2 and SO_3 contained in the gas, forming $CaSO_3$ and $CaSO_4$. Thus SO_2 and SO_3 were removed.

Evaluation: When 28% limestone is added, CaO content in the slag is 39.74%, 31.42% of sulfur could be removed. Although the rate of desulphurization is not sufficiently high, not so ideal, but the technology and equipment are simple and the cost is very low in comparison with the installation of the additional desulphurization equipment in stacks.

(2) NO_X emission

Under working conditions of 2.2 mW, measurements were taken, the results are shown in Table 2.

Table 2 Experimental results of NO_x emission

Percentage of added limestone, %	Temperature of boiler's heart, ℃		Concentration of the emitted NO_x at the boiler's end, ppm
	Cyclic room	Secondary room	
21	1550	1550	480
22	1488	1580	440–460
22	1480	1540	447
13.6	1486	1575	306 -335
13.6	1492	--	378–401

Table 2 shows that when the limestone additive is 13.6–22%, the emitted NO_x from the boiler end is within 306 to 480 ppm. The reason that the NO_x emission is not high is the fact the burning distance in the cyclic boiler is long and the burning could be considered as two stages, thus it is beneficial to the entire temperature level. Besides, the cycle easily keeps the relatively low coefficient of surplus air, and when limestone is added, the melting point of fly ash is lower and the boiler temperature is thus lowered, too. We can see that the NO_x emission of the vertical cyclic boiler with calcium added is not higher than any other types of boiler, verifying that this kind of boiler possesses great potentials of development.

(3) Utilization of fly ash and slag with additives of calcium

The slag is immediately water quenched as soon as it flows out from the bottom of the boiler. When CaO content of slag is more than 30%, its chemical components are near those of the blast furnace slag which has its potential bonding, activation With the lithofacies microscopic analysis by X-ray diffraction and thermal differential analysis, there are 97% of vitreous body and feldspar crystal in it. When the granulated slag is ground and some cement clinker or lime or gypsum are added it gets the bonding performance and can be used as cement, concrete and for wall and construction materials.

As the granulated slag is rich in vitreous body it can be used as sand and it also could be used as thermal insulation material because of its porosity.

For effective utilization of calcium-added slag, many institutions undertake researches and experimental constructions in use of the slag as mixed materials with cement. It plays an important role in solving the problem of the shortage in supply of the blast furnace slag on market.

Table 3 Chemical analysis of calcium-added slag

List	Coal limestone ratio, %		Chemical components, %						
	Coal	Limestone	CaO	SiO	Al_2O_3	FeO	MgO	Burn	Total
1	100	0	7.75	52.00	29.53	4.29	2.86	3.57	100
2	89	11	33.45	37.73	22.97	3.19	1.52	1.14	100
3	85	15	38.85	33.56	20.08	2.53	1.43	3.55	100
4	82	18	41.70	33.41	19.96	2.96	1.09	0.88	100
5	Blast furnace slag		36.49	35.27	13.61	1.18	9.62	3.83	100

Table 4 describes the slag utilization and experimental results of utilization of calcium-added as additives to the cement. In case 20% of slag is added to the cement, the grade of cement does not change but the output of cement increases by 20%. When 50% of slag is added the grade of cement decreases by one level, the output of cement is doubled. The financial benefit is remarkable. Another feature of adding this slag to cement is that the cement has lower strength in its early stage but has higher strength in its later stage.

Table 4 Impact on strength of cement by amount of adding slag with calcium additives to cement

Mixed ratio, %			Specific surface area,	Stability	Set time, h: m		Breaking stength rupture strength, kg/cm			Pressure resisting strength, kg/cm		
Slag	Gypsum	Clinker	cm/g		Per-set	Final-set	3 days	7 days	28 days	3 days	7 days	28 days
—	4	96	3309	Accepted	3:47	6:42	58	69	85	288	378	509
20	4	76	2900	"	4:50	6:19	47	58	79	224	317	516
30	4	66	3043	"	5:38	7:10	34	49	79	116	254	484
40	4	56	2883	"	5:10	6:30	32	46	70	139	273	458
50	4	46	3097	"	4:51	6:36	27	43	66	119	207	413
60	4	36	3189	"	6:04	7:46	23	37	55	97	197	354

The more the slag added, the higher the strength in the later stage (Fig. 1). Other physical, mechanical performances could all meet the requirements.

From the above mentioned results of the comprehensive performances of this by-product material and the environmental assessment, one can find this power generation

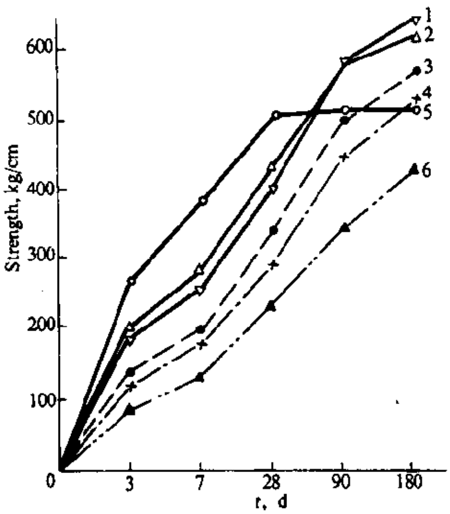

Fig. 1 Effect of added calcium-slag on the compressive strength of cement (1 – 6 are the percentage of added calcium-slag and represent 30, 20, 40, 50, 0, 60, respectively)

process, using vertical cyclic and calcium-added boiler, is a good clean technology, worthy to be employed by developing countries.

(4) Thermal-electric generation combined with cement production

To produce melting slag, limestone is added into the coal for burning in the vertical vortex furnace of electric power station. The calcium enriched slag is particlerized using a high pressure spray. The slag particles are excellent blending materials for cement industry to produce a variety concrete products. The melting slag could also be spun into slag wool as an excellent thermal insulation material.

During the combustion process in the furnace, the SO_2 in the coal is reduced by adding limestone and the coal ash is liquified. The fly ash during combustion is reduced 80% compared to a conventional coal burning generator with no increase in NO_x concentration. Since this cleaner production process reduces sulfur emission and utilizer coal ash, it has been implemented in several dozen thermal-electric power stations.

1. Shenyang Thermal Power Station using the melting slag produce the rock wool.

The rock wool production line of Shenyang Thermal Power Station is the first line in China which produces rock wool directly using the vertical vortex furnace by increasing calcium and melting slages. The production line has a total capacity of 5000 tons per year.

The features of the rock wool production are low volumetric weight, low heat conductivity factor, non-corrosive and non-combustible, can be used at high temperature.

They can be used not only as heat-insulating materials but also as noise-abating materials in architecture and industry. The character of rock wool production is much better than the traditional heat-insulation materials and its special function of absorbing noises provided a new way to dispel noise pollution from industrial and civil engineering.

The performance rock wool productions has conformed to the Criterion Q/JC 4-86 of Beijing Rock Wool Enterprise Standard and it is qualified by Beijing Architecture Material Quality Control Center.

2. The property and scope of rock wool products

(1) Usage scope

The melting temperature of the rock wool fibers is about 900－1000 ℃ and there is no change at 700 ℃ in permanent use. It has excellent properties of forming, chemical stability and water-abomination. It is the best material for making rock wool productions.

The rolled rock wool: Volumetric weight is 83－87 kg/m; heat-transfer factor is 0.0328 W/mK; operating temperature is 650 ℃; diameter of fibre is 6.65u; contents of slag particle is < 7%.

(2) Usage scope (for tube heat-insulation)

Rock wool tubes can be used at the temperature of 600 ℃ as heat-insulation for diameter 18－324 mm steel tubes. As for the thickness of insulation exceeds 80 mm, one can use double layer rock wool tubes and make the seams staggered. For the extreme diameter tubes rock wool felt can be used. Finally it will be covered with galvanized steel plates, aluminum metal plates or various kinds of protection materials if necessary.

Rock wool heat-insulating tubes: volumetric weight is 180－200 kg/m; inside diameter is 18－427 mm; thickness is 30－100 mm; length is 950 mm.

(3) Usage scope (for tanks and equipments)

Rock wool felt can be used on the big curved diameter tanks and equipments as heat-insulating materials according to the requirement. On tremendous areas of heat-insulating, supporting iron bars are required to prevent the falling off of the heat-insulating layers. As final outside protection, various materials should be added.

Rock wool felt: volumetric weight is 100－150 kg/m; dimension is 3000×910×50.100; operating temperature is 600 ℃.

(4) Usage scope

Heat insulation, sound insulation, fire prevention, house-fitting up for huge diameter tanks, towers, boilers, heat-exchangers and walls, floors, ceilings of industrial buildings.

Semi-stiff plate of rock wool: volumetric weight is 80－120 kg/m; length is 600－1200 mm; width is 600－900 mm; thickness is 30－100 mm.

(5) Usage scope (sound-absorbing for ceilings and walls of buildings)

Sound-absorbing plate of rock wool: volumetric weight is 150－180 kg/m; length is 600 mm; width is 600 mm; thickness is 12－20 mm.

CONCLUSIONS

This paper describes a technology used in the thermal power station.

By adding of the limestone into the vertical cyclic furnace, the liquid slag with the rich content of calcium could be obtained. This technology is beneficial to the desulphurization, the comprehensive utilization of slag as well as decreases the water consumption.

It is a clean technology featuring in combination of the economical effect and environmental protection.

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