SESSION 3C

ADVANCES IN ESP TECHNOLOGY

DEVELOPMENT OF ADVANCED DUST COLLECTING SYSTEM FOR COAL-FIRED POWER PLANT

T. Tanaka
Chubu Electric Power Co., Inc.
Toshin cho 1-banchi, Higashi-ku,
Nagoya, Japan

H. Fujishima
Y. Tsuchiya
Mitsubishi Heavy Industries, Ltd.
5-1, Marunouchi 2-chome, Chiyoda-ku,
Tokyo, Japan

ABSTRACT

The fly ash in flue gas from coal-fired boilers generally has a high electrical resistivity, and sparks or back corona are caused by the high resistivity dust in dry type electrostatic precipitator (dry ESP), which make it difficult to precipitate the dust efficiently.

Chubu Electric Power Co., Inc. and Mitsubishi Heavy Industries, Ltd., as a coopeative research work, have developed an advanced dust collecting system with high performance, which can solve the many years' problem of high resistivity fly ash collection.

In this system, the gas temperature through the ESP is reduced to the 90℃ ~100℃ range from the conventional 130℃~140℃ range, by placing the ESP downstream of the gas-gas-heater in FGD plant. This decreases the electrical resistivity of the dust, thereby improving the efficiency of dust collection.

A verification test on a pilot plant proved the concept of achieving very high collecting efficiency with the ESP, which can attain ESP outlet dust burden such as low as $30mg/m^3N$. Therefore it can be expected to reach a dust emission level below $10mg/m^3N$ without a wet ESP.

INTRODUCTION

The Japanese utility companies have continued to convert the fuel from oil to coal for their thermal power plants, occasioned by the two oil crises of 1973 and 1978, and in line with the International Energy Agency's (IEA) recommendation in 1979 for reduction of oil consumption. In view of the importance of coal as an energy source for electric power generation hereafter,many new power plants are now being planned on this basis.
The recently built coal-fired plants in Japan are featured for their use of various imported coals having wide ranges in their characteristics and in a general way having flue gas treatment system fully equipped with dry selective catalytic recovery unit (DeNOx), dry type electrostatic precipitatior (ESP),wet type flue gas desulfurization unit (FGD) and regenerative rotary type gas-gas heater (GGH) for reheating the flue gas, as shown in Fig. 1-(1).
In spite of the provision of such environmental protection system the dust emission would be generally limited only upto around 30mg/m^{3}N.On planning of 3x700 MW coal-fired units for Hekinan Power Station of Chubu Electric Power Company Co., Inc., the site condition is required low dust emission level to be almost equivalent to that from oil-fired units, that is below 10mg/m^{3}N. In order to cope with this requirement, a design comprising non-leakage type GGH together with wet type ESP downstream of FGD was adopdted to provide a system with stable low dust emission level, as shown in Fig. 1-(2).
Hekinan Unit 1 and 2 started on commercial operation in 1992 and Unit 3 is now in trial operation, and the flue gas treatment system has been showing favorable operation results.
Notwithstanding such severe restiructions of low emission level, however, it was required that the more simplified, economical and compact system with further adaptability to various brands of imported coals would be developed at the planning stage for the next new plant. Accordingly, a cooperative research was undertaken by Chubu Electric Power Company and Mitsubishi Heavy Industries, Ltd. to develop "Advanced Dust Collecting System" which comprises Dry ESP, non-leakage type GGH and FGD, as shown in Fig.1-(3) for practical appalication for the next power plant.
This research was mainly conducted in a pilot plant installed in Shin Nagoya Thermal Power Station of Chubu Electric Power Company and with supplementary test in the laboratory of Mitsubishi Heavy Industries.
On completion of the test, the Advanced Dust Collecting System has proved to be suitable for practical application.
This paper describes the features of the Advanced System and the test results briefly regarding ESP which is the main component for high efficent dust collection.

DESIGN CONSIDERATION AND FEATURES OF ADVANCED DUST COLLECTING SYSTEM

Design Concept

ESP performance for coal-fired boiler is mainly affected with the fly ash

resistivity and it varies significantly, depending on type of coal. In case of power plants in Japan that must use various kinds of imported coal available world - wide, it is very important for them to keep the ESP performance without any limitation of coal to be used.
Therefore, considering the generation mechanism of back corona due to high resistivity dust, various countermeasures have been proposed and some of them are already in practical use as shown in Fig. 2.
The Advanced System is developed to notice that the dust resistivity tends to decline and the ESP performance is remarkably improved when gas temperature of ESP is lower.

System Constitution

In the Advanced Dust Collecting System, the temperature of gas passing through ESP is brought down to the 90~100℃range from the conventional 130~140 ℃ range by placing the ESP downstream of heat extractor of non - leakage type GGH instead of the conventional practice of placing it upstream of GGH.
It becomes possible to reduce dust resistivity and consequently delete the generation of the back corona as well as the frequent intensified spark - over in ESP and thereby obtain stable voltage and current for dust collection.
While wet type ESP is needed to attain the strict low emission requirement such as below 10mg/m^3 N in the conventional system, it is possible to attain it economically in the Advanced System without wet type ESP

Adoption of Non - leakage Type GGH

Dust burden in heat extractor of GGH in the Advanced Dust Collecting System becomes more than 100 times that of the conventional system due to the difference of GGH location.
The regenerative rotary type GGH has been usually used in the conventional system.
If this type would be applied for the Advanced System, the leakage of high dust content from heat extractor side to reheater side of GGH is anticipated.
Therefore, non - leakage type GGH which uses water as a heating medium, is applied for the Advanced System.
Furthermore, Steel Shot Cleaning System (SSCS) is adopted as dedusting method for heat transfer tubes of GGH instead of soot blowing in order to avoid peak dust emission.

Features of Advanced System

The development of the Advanced System can be expected to produce good effects and merits on the planning of flue gas treatment system for coal fired power plant as follows.

(a) Attainment to low emission level
Dry type ESP collecting performance is significantly improved by lowering gas temperature and it can attain lower dust emission level such as below 10mg/m^3 N without wet type ESP.

(b) Increasing availability of coal
The availability of coals to be supplied increases, because dust resistivity for all kinds of coals becomes the adequate level for good precipitation.

(c) Economical and compact design
The drastical improvement in terms of construction cost, running cost and installation space is expected in comparison with the conventional system, because both wet type ESP and dedusting equipment in cooling tower of FGD can be deleted.

PILOT TEST

In this research for practical application, as shown in Table 1, tests were conducted at first for confirming the basic characteristics of the Advanced Dust Collecting System and picking up its related problems. The problems were then investigated and solved through the laboratory supplementary tests and the pilot plant was finally subjected to the practical application test.

Pilot Plant

The layout of pilot plant is shown in Fig. 3 and the specifications of main equipment of the pilot plant are shown in Table 2.
The pilot plant capacity is 15 t/h of steam rate quantity equivalent to 5,000 kW and flue gas volume is 17,000 m^3N/h.
In order to conduct the test of both conventional and advanced system, it is possible to reverse the arrangement of ESP and GGH by changing duct.

Test Coal

Seven (7) brands of coal were used in this test and they were classified into four precipitability ranks as follows.
"Moderate" rank : A, B, C, E, coal
"Bad"rank : D coal
"Worse"rank : F coal
"Worst"rank : G coal
The four (4) brands of coals selected from each rank, namely C, D, F, G coal were used for the test on the Advanced System.
The analysis data of coals are shown in Table 3.

Test Results

ESP Performance Characteristics

The transition of ESP collecting performance due to aging during the pilot test is shown in Fig. 4. In the Advanced System the ESP collecting performance was maintained to be high with slight difference in performance between the coal brands. The dust concentration at the ESP outlet was also sufficiently lower than the design value of 30 mg/m^3N. When the system was changed over from the Advanced System to the conventional system from the 16th week onwards, however, the ESP performance deteriorated drastically showing significant difference in performance between the coal brands.

The relationship between gas temperature and ESP collecting efficiency is shown in Fig. 5. The dust collecting efficiency even for D, F, G coal which was low in the 130～140℃ temperature range of the conventional system was improved substantially in the 90～100℃ temperature range of the Advanced System. The reason is, as shown in Fig. 6, that with lowering of the gas temperature the dust electric resistivity drops to eliminate back corona and frequent intensified spark - over phenomena of the conventional system and thereby stable electrical conditions are obtained.

Special mention should be made in particular that the G coal, which was considered difficult to be used with the conventional system because of its worst ESP collecting performance among the import coal brands in Japan, showed the good performance equivalent to the other coal brands with the Advanced System. The comparison of ESP collecting performance of G coal for both systems is shown in Table 4.

Meanwhile it was comfirmed that unexpected phenomena occurred. The amount of reentrained dust from collecting electrodes increased because the dust resistivity becomes lower. The mechanism of this phenomena was inevestigated on the laboratory test, however, and this problem was solved by the adoption of power - off rapping system on off - flow condition which has usually been applied for ESP of oil fired boiler.

Operational and Structural Problems of ESP

It was also confirmed in these tests that concerns, such as increased corrosion and dust adhesion in ESP anticipated due to lowering of the gas temperature, were equivalent in degree to those in the conventional system and there was found no special problem as follows.

(a) Corrosion investigation test

To investigate possible corrosion of the materials due to lower gas temperature, some test samples of collecting plate and discharge wire were placed in each ESP chamber and they were measured before and after operations to determine their decrements of weight. Absence of any substantial decrement in the test samples suggested that the Advanced Dust Collecting System have had no particular problem concerning material corrosion.

(b) Dust adhesion

The state of dust adhesion due to lower gas temperature was investigated as well. In the upstream side section of ESP, dust adhesion was observed to be similar to those in the conventional systems but in the downstream side section it was extremely small.

(c) Effect on ash handling equipment

A vacuum pneumatic ash handling equipment was provided and it tended to have ash clogging at ESP hopper for some brands of coals in the Advanced Dust Collecting System. This could have been by the resulting drop in hopper ash fluidity due to lower ash temperature caused by the decreased gas temperature. In the design of actual plants it will be thus necessary to specify ash handling equipment with more sophisticated anti - ashclogging measures for the ESP hopper.

Desulfurization System

Dust removal effect of the Advanced Dust Collecting System is also extremely higher in the desulfurization system as shown in Fig. 7. The reasons can be estimated as follows.
In the conventional system with ESP where the gas temperature is in the 130 ~ 140 ℃ range, dust resistivity is higher to cause back corona phenomenon which makes the voltage too low to be effective in electrostatic precipitation. Therefore, ESP outlet dusts comprise mainly relatively smaller size particles which have passed through ESP without getting adhered onto the collecting electrodes due to back corona phenomena.
On the other hand, in the Advanced Dust Collecting System where gas temperature passing through the ESP is lowered to 90 ~ 100 ℃ with the provision of GGH (heat extractor) upsteam ESP, the dust resistivity gets decreased to permit stable charging. As a result, current and voltage become so high that the dust is properly precipitated and collection efficiency is remarkably improved. Hence, the ESP outlet dust mainly comprises the coarse particles formed by agglomeration of dusts once adhered on to the collecting electrodes and partly reentrained by the electrode hammering etc. It has been proven from the test result that dust particle size at FGD inlet becomes larger in the Advanced System.
Thus, the dust removal performance at FGD is improved in the Advanced System, as shown in Fig. 7, of which outlet dust emission is quite low, such as below 10mg/m^3N without wet type ESP.

Gas Gas Heater

(a) Basic performance of GGH
The GGH (heat extractor) for the Advanced System is exposed to comparatively higher dust concentration conditions with significant increase in dust adherence rate on its heat transfer tubes than that of the conventional systems. The highly effective dust removal performance of SSCS, however, ensures the stable heat transfer rate and pressure loss without any problem over a prolonged period of time. It can thus be stated that SSCS with excellent dust removal effect has achieved the expected target.

(b) Dust removal characteristics of SSCS
Dust removal effect comparable to that of the conventional systems has been proved for SSCS even under high dust concentration condition with appropriate scatter of steel shots.

CONCLUSION

Based upon the test results obtained hitherto, it is concluded that;

1. Dry ESP's collecting performance for high resisitivity fly ash is improved and increased, and is not affected by any kinds of coal.
2. In FGD, dust removal efficiency is improved as well.
3. The system can reach quite low dust emission below $10mg/m^3N$ without wet type ESP.
4. The system is confirmed liable during long operation period.
5. The system can improve construction and running costs and installation space, because wet type ESP and dedusting equipment in cooling tower of FGD can be deleted.

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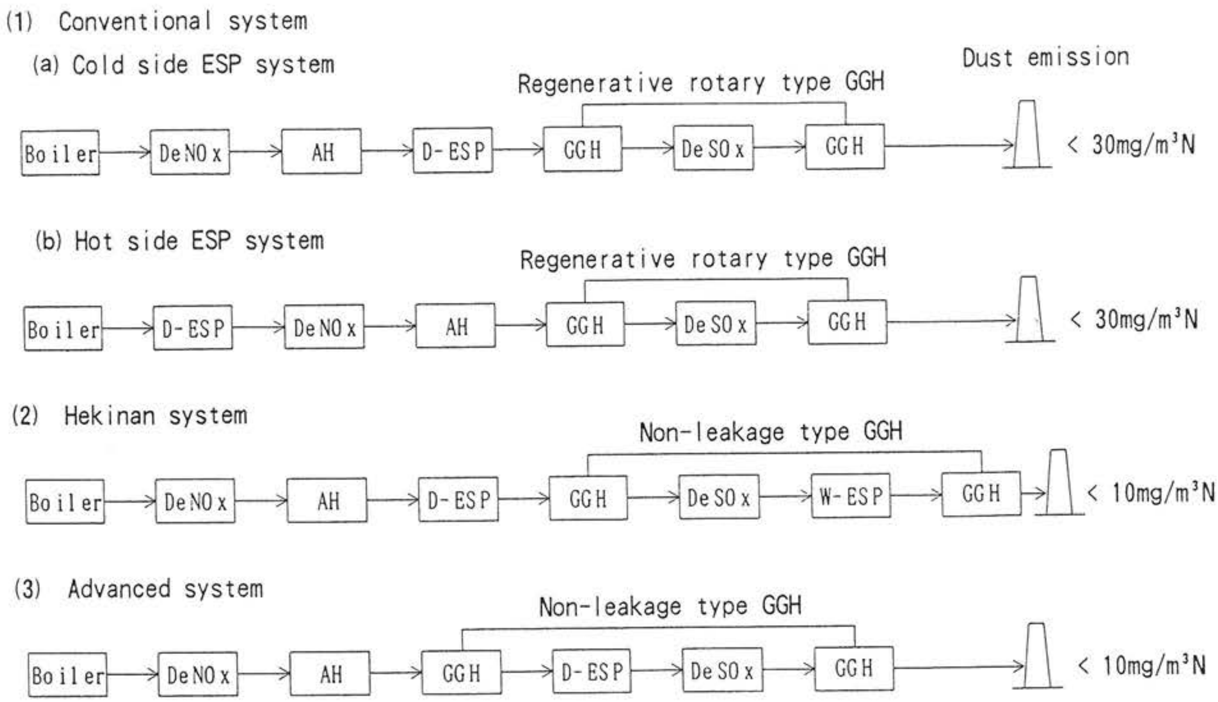

Fig. 1 Flue Gas Treatment Systems for Coal-Fired Power Plant

Starting condition of back corona		Improvement technique for high resistivity dust		
		Countermeasure	Method	Technique
$Ed = \rho d \times id > Edb$	(1)	Dust layer removal	removing dust on electrode completely	Wet type ESP, Movable electrode
	(2)	Resistivity decreasing	Increasing gas temp.	Hot side ESP
			Decreasing gas temp.	Advanced System ESP
			Gas conditioning	Injection of water, SO_3, NH_3 etc.
			Mix firing	Mix firing with good coal
Ed = Electric field strength in dust layer ρd = Dust resistivity id = Current density in dust layer Edb = Break down electric field strength	(3)	Current control in dust layer	Electrical Control	Intermittent energization, Pulse energization

Fly ash resistivity and gas temperature

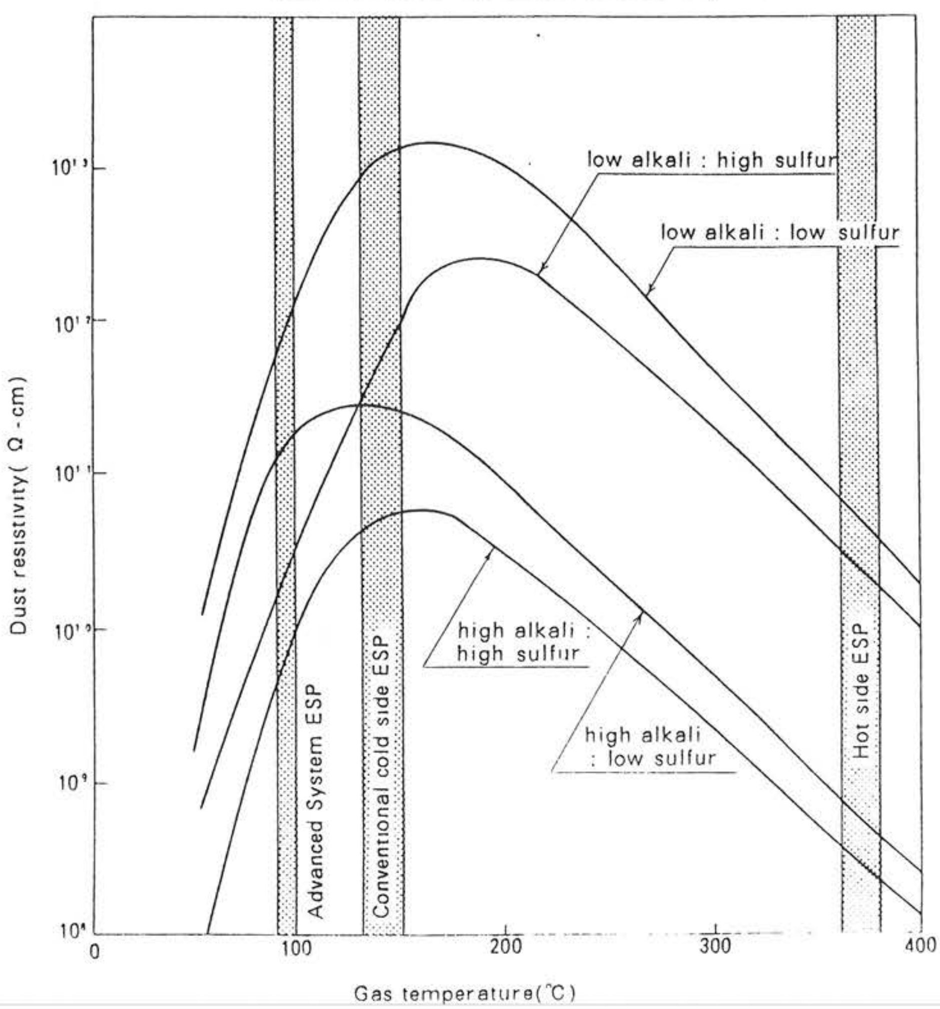

Fig.2 Precipitability Improvement Technique for High Resistivity Fly ash

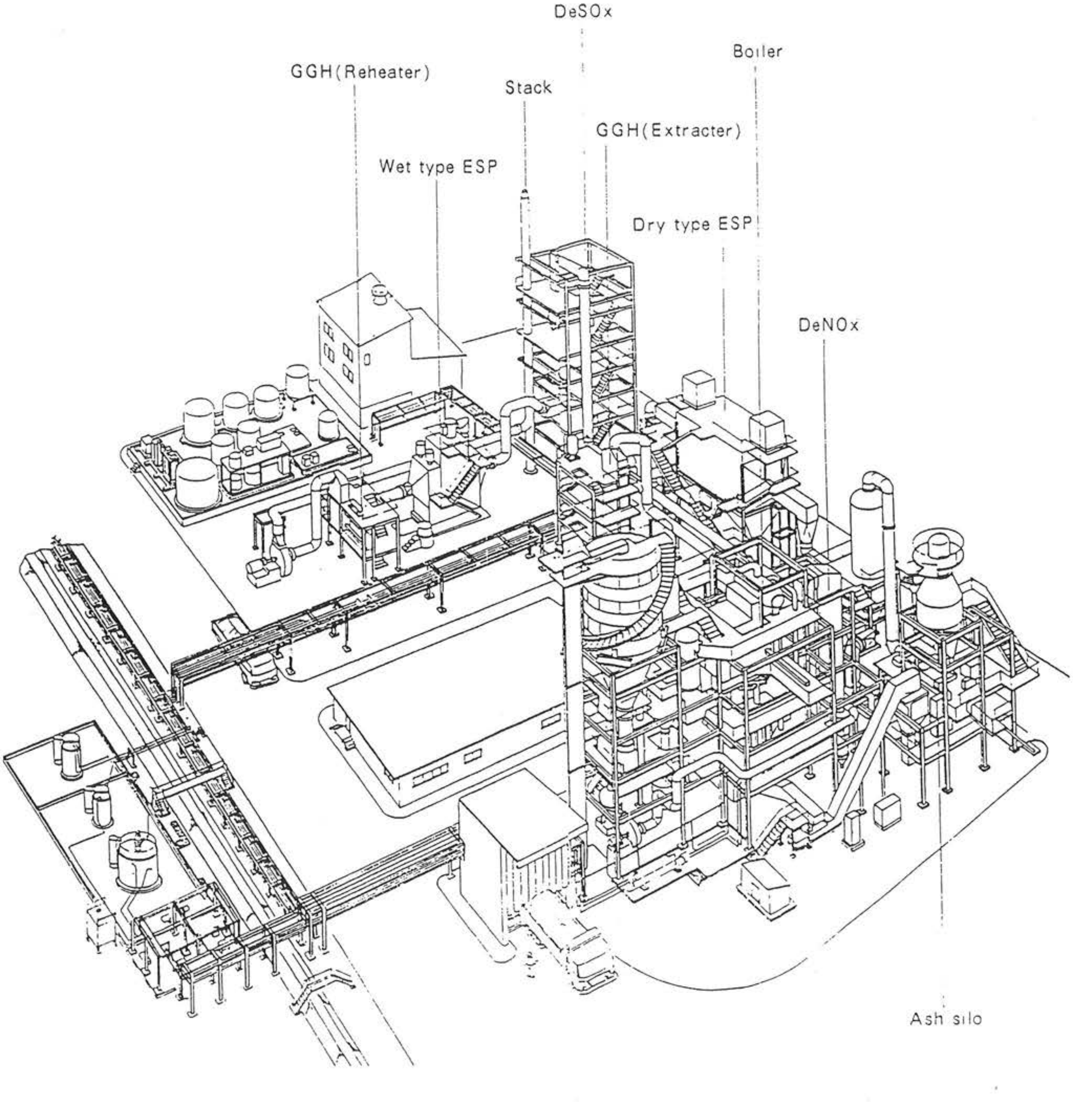

Fig.3 Pilot Plant Layout

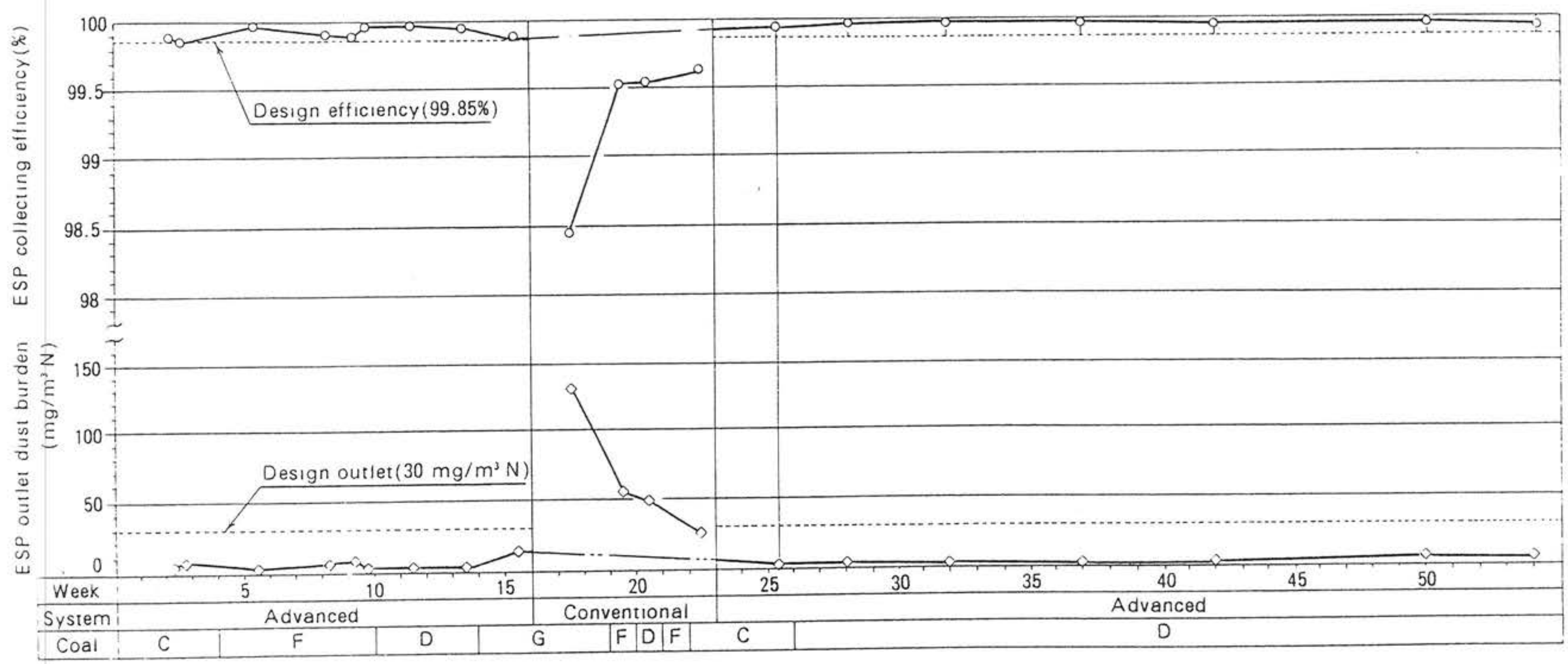

Fig.4 ESP Operating Data of Pilot Plant

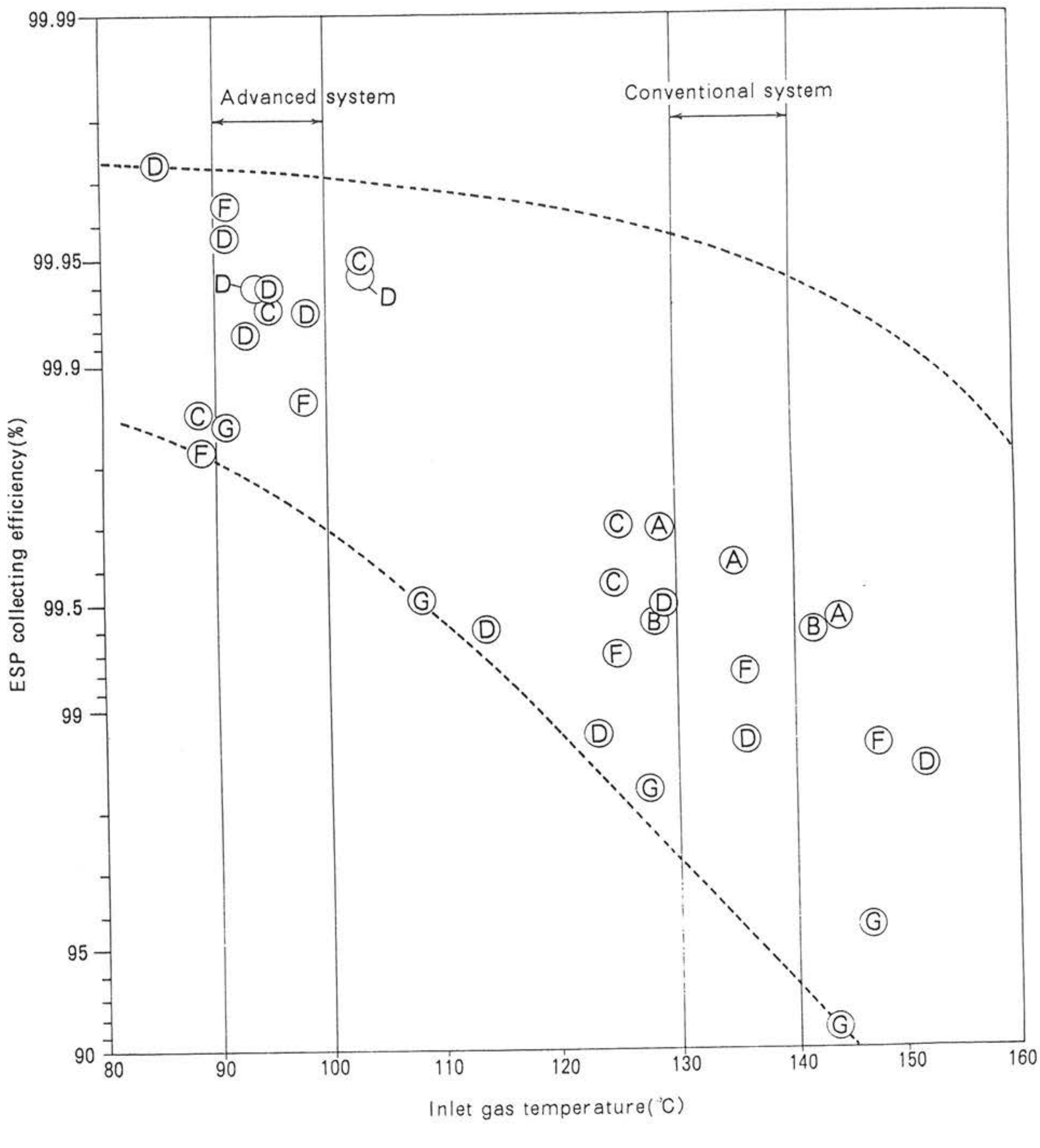

Fig.5 ESP Performance vs.Inlet Gas Temperature

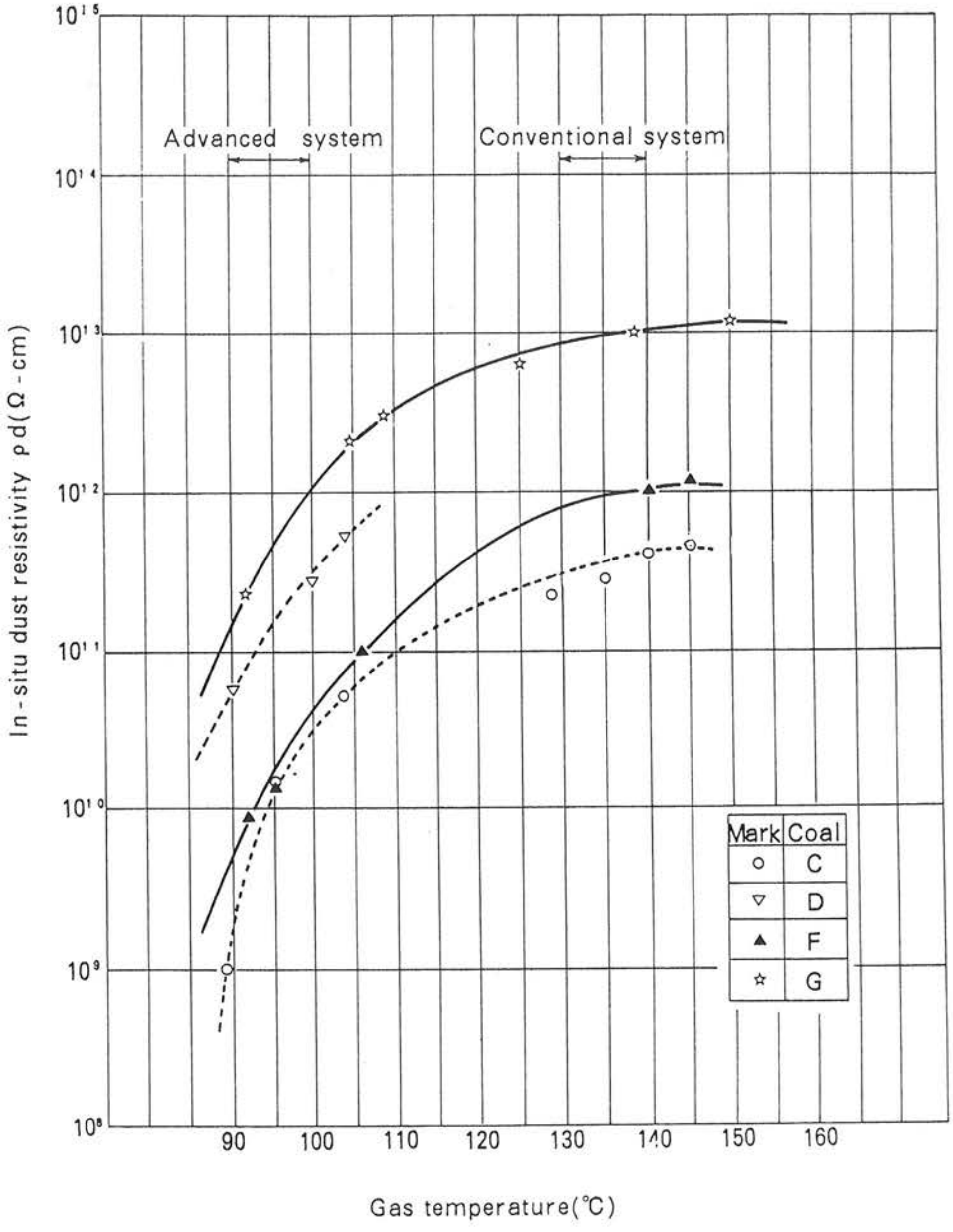

Fig.6 In-Situ Dust Resistivity of ESP Inlet Flying Ash

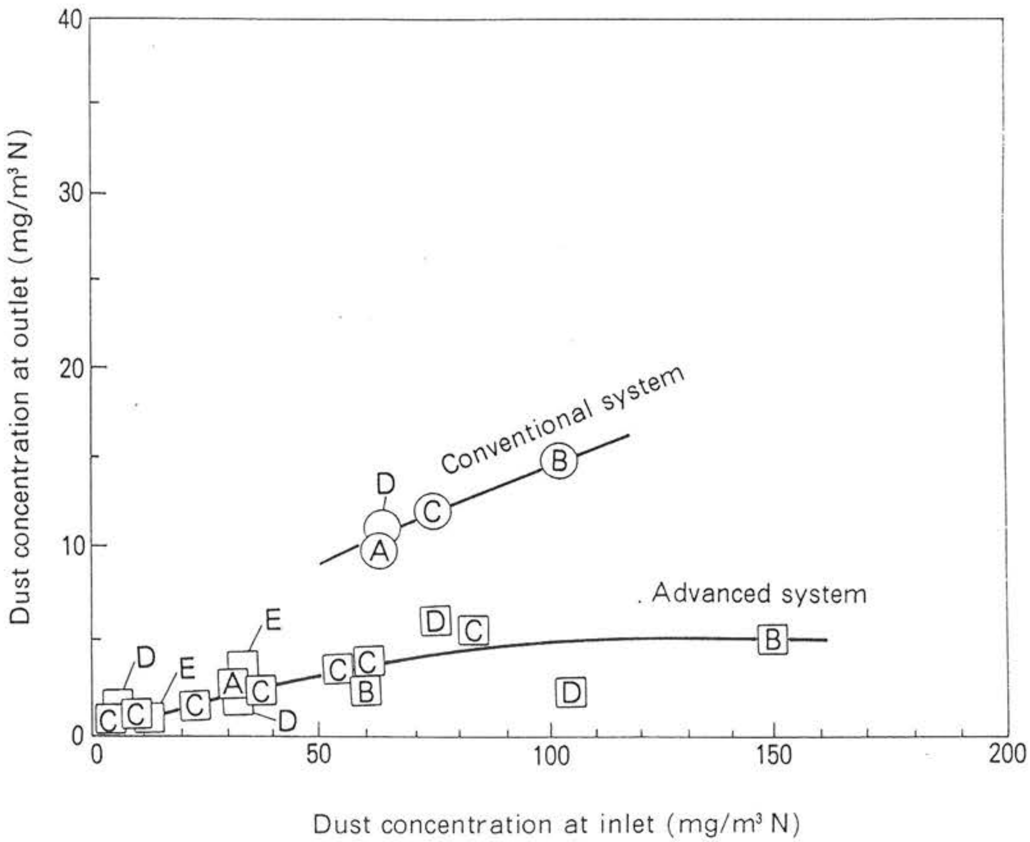

Fig.7 Dedusting Efficiency in the Desulfurization System

Table 1. Test Schedule of Advanced Dust Collecting System

	Test item	Test coal	1989 (4 – 10)	1990 (4 – 10)	1991 (4 – 10)	1992 (4 – 10)
Pilot Test	Confirmation test of basic characteristics	A, B, C D, E				
	Practical application test	C, D F, G		Equipment modification		Equipment modification
Lobo. Test	Model ESP test	C				
	Large scale model ESP test	C. F				

Table 2 Specifications of Main Equipment of Pilot Plant for Advanced Dust Collecting System

Equipment		Specification
Boiler		
Type		Forced circulation type corner firing
Steam condition		Pressure ; 10kg/cm² Temperature; 200 ℃
Steam rate		Nominal Valve ; 15 t/h (equivalent to 5,000 kW)
Number of pulverized coal burners		12 pcs (3 stage x 4 corners)
Flue gas cleaning system	Design conditions	
	Flue Gas Volume treated	17,000 m^3N/h
	Emission SOx Concentration	50 ppm or less
	Emission NOx Concentration	45 ppm or less
	Emission Dust Concentration	10 mg/m^3N or less
	Emission Gas Temp.	90 ℃ or more
	◆ NOx removal system	
	Type	Dry selective ammonium catalytic reduction method
	◆ Electrostatic precipitator (ESP)	
	Type	Dry horizontal type
	Electric Charging method	Continuous energization (Intermittent, Pulse ; available)
	Hammering type of CE	Intermittent
	of DE	Continuous
	◆ Desulfurization System	
	Type	Wet lime-gypsum Absorber type
	◆ Gas heater	
	Type	Non-leakage tube type
	Dedusting method ; Extractor	Steel ball scattering type
	; Reheater	none

Note ; Wet type ESP is equipped with conventional flue gas treatment system as well.

Table 3 Analysis data of test coal

Coal brand		C	D	F	G
Calorific Value (kcal/kg)		6,780	6,560	6,500	6,410
Inherent moisture (%)		7.1	3.1	2.6	3.7
Ash (%)		8.0	17.4	17.3	17.7
Volatile matter (%)		26.1	28.2	29.2	27.8
Fixed carbon (%)		58.8	51.3	50.9	50.8
Total Sulfur (%)		0.21	0.48	0.27	0.56
Ash Content	Na_2O (%)	0.26	0.06	0.28	0.05
	K_2O (%)	0.91	2.64	0.77	0.53
Precipitability		moderate	bad	worse	worst
Country		Australia	Australia	Australia	Australia

Note ; A brand : Chinese Coal

B brand : Australian Coal

E brand : Japanese Coal

Table 4 ESP Collecting Performance for G Coal

	Conventinal System	Advanced System
Gas temperature (℃)	125	92
In-situ dust resitivity (Ω-cm)	7×10^{12}	3×10^{11}
Inlet dust burden (g/m^3N)	8.6	12.9
Outlet dust burden (mg/m^3N)	133	15
Collecting efficiency (%)	98.45	99.87
Enhancement factor (Wk base)	1.0	2.3