Pilot Plant of a Coal Fired Fluidized Bed Boiler in Japan

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A pilot plant of an atmospheric fluidized bed combustion boiler which is capable of evaporating 20 t/h at the steam conditions of 60 atg and 540°C was constructed and started operation at the beginning of April, 1981.
A description of the project and its results are presented in this paper.

1. Introduction

Brief History of FBC Development in Japan

The project named 'Research on Fluidized Bed Combustion Technology' was started in 1978 to support Japan's national effort for coal utilization technology development. This project has been financially supported by the government and steered by a joint committee of several related agencies and companies. The Coal Mining Research Center has been filling the leading role in this committee since it was organized in 1978.

During 1978 and 79 component tests and fundamental studies using bench scale units were performed. In parallel with these a feasibility study for a 500 MW power generation unit was carried out. The previously expected advantages of fluidized bed boilers over the conventional pulverised coal combustors were examined. It has been found that most of the advantages of fluidized bed combustion such as the possibility of eliminating flue gas desulfurization and denitrification and the capability of handling wide range of coal types are still effective for Japanese social and economical situations.

The whole program of the fluidized bed boiler development is shown in Table 1. A pilot plant with a 20 t/h evaporation capacity was constructed in Wakamatsu Thermal Power Plant of the Electric Power Development Co. and the test runs are performed for testing the instrumentations and components and determining the optimum operating conditions of the fluidized bed boiler. A survey program on the design conditions for various components and devices for a 240 t/h class demonstration plant is also running.

Organization

To carry out this project effectively, the pilot plant program Steering Committee was organized by The Coal Mining Research Center, Electric Power Development Co., Kawasaki Heavy Industries, Ltd. and Babcock-Hitachi K.K. As a sub-committee of the Steering Committee, the Pilot Plant Executive Office was organized. This Office has taken charge of the construction, test and operation of the pilot plant.

Wakamatsu Pilot Plant Test Items

The planned pilot plant test items are as follows:

(1) NOx and SOx emission control
(2) Reduction of the required quantity of desulfurizing sorbent
(3) Controllability of the fluidized bed boiler
(4) Reliability of the fluidized bed boiler
(5) Suitable types of coal
(6) Performance of the dust collector

2. 20 t/h Pilot Plant

Basic Concepts

The fluidized bed boiler consists of a main bed cell (MBC) and a carbon burn-up cell (CBC). The design was made so that various imported coals and low grade coals can be burned.

Crushed coal has been used as a feed coal. Before feeding, the coal is pretreated-drying, crushing screening, etc. Coal feeding is done by both pneumatic feeders and overbed spreaders.

Fine grain coal is fed to the bottom of the bed through a pneumatic conveyer and coarse grain coal sprinkled over the fluidized bed by a spreader. The capacity of the feeders are designed so that total required quantity of coal can be fed by one of these two method. Natural limestone whose sizing has been completed at the mine is used as a desulfurizing sorbent. The sorbent is fed through a pneumatic conveyor.

A multi-cyclone is installed at the outlet of the MBC. The design was made so that the collected coal ash can be reburned either in MBC or CBC.

A balanced draft systems is used.

MBC was designed so that it can be diveded into two parts. The installation position of heat exchange tubes in the free board of MBC can be changed. The duct connected to the rear flue can be removed so that the height of free board can be changed.

Hot stoves and over bed burners are used for starting up the boiler. Steam generated by the boiler is changed back to water by an air condenser. The water can be reused. Discharged ash is wetted and transferred to the ash yard to be discarded.

After the fiscal year 1982, the following expansion or modification will be made.

A. A sorbent regeneration unit: applicable for both limestone and synthetic sorbent.

B. A new dust — collector for testing is planned for the dust discharge quantity 10 mg/Nm^3, and for the gas flow rate of approximately 1,000 Nm^3/h.

Design Conditions

(1) Main boiler specification

Boiler type:	Natural and forced circulation type drum boiler; indoor type.
Evaporation:	20 t/h
Steam pressure:	60 kg/cm^2 G at the outlet of the superheater
Steam temperature:	540°C at the outlet of the superheater
Feedwater temperature:	133°C at the inlet of the fuel economizer
Boiler efficiency:	87.37% (high calorific value base)
Fuel consumption:	2,450 kg/h (wet coal base)
Fuel calorific value:	7,100 kcal/kg (high heating value for dry coal.) 6,603 kcal/kg (high heating value for wet coal)
Combustion flue gas:	20,293 Nm^3/h (wet)

(2) Target value of emission control

SOx: 95% desulfurization for coal containing 3% S

NOx: 60 ppm for coal containing 1% N and O_2 6% equivalent.

(3) Properties of planned coal: Refer to Table 2.

(4) Desulfurizing sorbent: natural limestone and synthetic sorbent

Plant Outline

(1) Boiler

Fig. 1 shows a section of the boiler elevation.

The MBC consists of the combustion furnace which is composed of a natural circulation membrane structure water wall and the refactory wall rear flue. In the fluidized bed with a 2.17 m x 4.34 m area, the forced circulation type evaporator by a boiler circulating water pump and the primary and secondary superheaters are installed. The fluidized bed is divided into two parts so that one side operation can be done.

Outside the bed, the evaporator and flue economizer are installed. This evaporator, as shown in Fig. 2, can be removed to the free board of the combustion furnace or rear flue. This, together with a change in the installation level of the duct connecting to the rear flue, enables the test for a change in free board conditions. In the free board of the combustion furnace, double stage combustion air feeding ports (8 rows x 5 stages) are installed to enable various comparison tests to be conducted.

CBC is composed of a natural circulation water wall (0.91 m x 0.91 m). In the free board of the CBC, a fuel economizer is installed.

The height of the overflow is variable. Overflow ash is cooled by air. To monitor the temperature distribution in the fluidized bed and the temperature behavior in the major parts of the boiler tubes, tens of thermocouples are installed and connected to a data processor evaluate and analyse the test operating conditions and performance of the boiler.

(2) Coal and Limestone Feeder

The coal charged into the feed coal hopper is temporalily stored in the feed coal bunker and sent to the dryer to remove moisture, then crushed screened for classification into fine and coarse fractions of coal.

The coal dryer of an indirect steam heating type.

Coal is crushed in two stages before drying. Limestone whose grain size has been adjusted at the mine is used and supplied into MBC together with fine grain coal through pneumatic conveying.

(3) Instrumentation

The instrumentation of this plant consists of the boiler control system, a centralized operation monitoring system and a precessing system. The data further can be displayed on the color CRT screen.

(4) Ash handling Equipment

Ash discharged from the overflow pipe of MBC and CBC is cooled and sent to the overflow tank, then sent to the ash storage silo by the pneumatic conveyer system.

3. Present State of the Test

Outline of the results of the operation up to June, 1981 together with several examples of the operation data are as follows:

(1) Operation Results

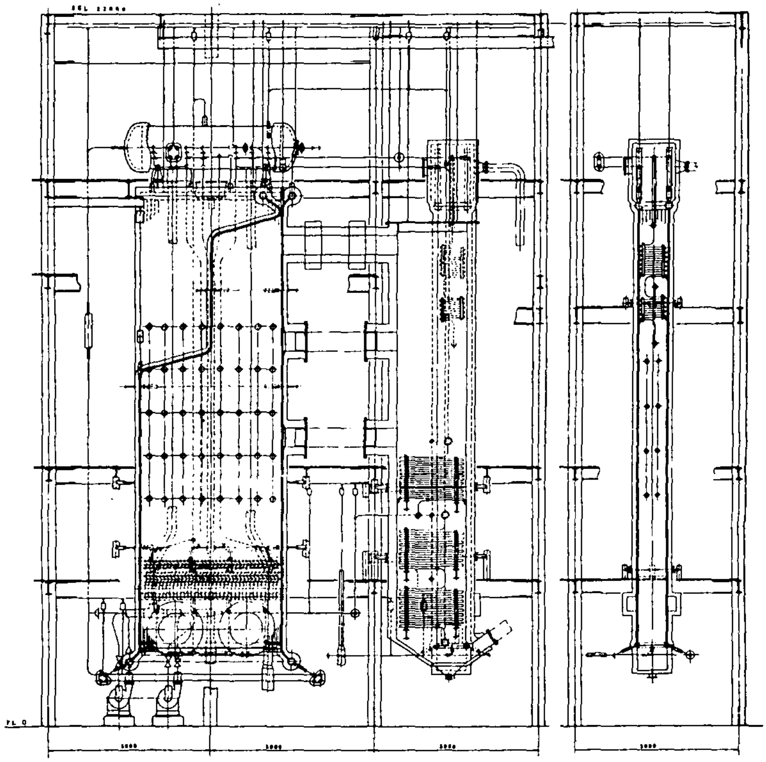
Since coal feeding started in early May, 1981, operation time has accumulated to 628 hours by September, 1981. Taiheiyo coal, typical low sulfur non swelling bituminous coal of Japan, is currently used. Properties of this coal and limestone are shown in Table 3 and Table 4 respectively.

The size of coal is -6 mm and the average particle diameter is about 2.5 mm. The limestone size is -3 mm.

Up to now so far, 10 cold starts and 17 hot starts have been carried out.

(2) Operation Data

Table 5 shows an example of operation data. In the Table, the NOx values are from the single stage and two stage combustion. These values are sufficiently low compared to the values of the government regulation. The SOx value is for the present low S coal. The desulfurization performance will be checked by using medium S coal in later test.



MBC CBC

Fig. 1 Boiler Structure

Fig. 2. Possible configulation of free board and tube arrangement in 20 t/h Fluidized Bed Boiler Test Module

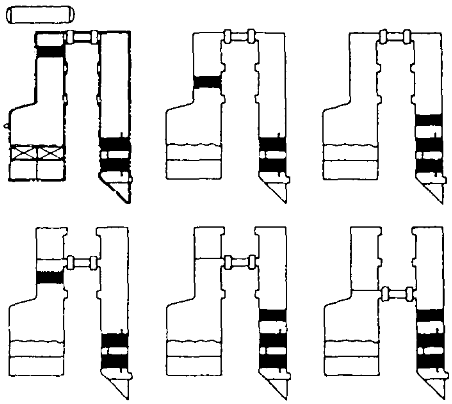


Table 1. Fluidized Bed Boiler Development Program

Item \ Fiscal year	1978	'79	'80	'81	'82	'83	'84	'85	'86
Preliminary study									
Feasibility study 500 MW plant									
20 t/h pilot plant		Design	Manufacture and installation	Operating test					
240 t/h demonstration plant (75 MW class)				Design		Manufacture and installation		Operating test	

Table 2. Coal Properties

Type of coal			Planned coal
Drycoal high heating value (kcal/kg)			7100
Surface moisture			7.0
Proximate analysis	Moisture	(%)	2.8
	Ash	(%)	9.5
	Volatile matter	(%)	28.5
	Fixed carbon	(%)	59.2
Ultimate analysis	C	(%)	73.8
	H	(%)	4.0
	N	(%)	0.8
	O	(%)	11.0
	Total sulfure	(%)	0.8

Table 4. Properties of Limestone

	Item		Analysis
Component	CaO	(%)	55.38
	MgO	(%)	0.30
	SiO_2	(%)	0.28
	Fe_2O_3	(%)	0.03
	Al_2O_3	(%)	0.10
	Others	(%)	0.90

Table 3. Properties of Coal

Type of coal			Taiheiyo coal
High Heating Value (Kcal/kg)			6330
Surface moisture (%)			1.6
Proximate analysis	Moisture	(%)	3.0
	Ash	(%)	15.3
	Volatile matter	(%)	44.2
	Fixed carbon	(%)	37.5
Ultimate analysis	C	(%)	64.1
	H	(%)	5.8
	N	(%)	0.8
	O	(%)	13.4
	Combustible S	(%)	0.1
	Incombustible S	(%)	0.1