FLUIDIZED BED LIGNITE COMBUSTION FOR SMALL-SCALE INDUSTRIAL USE

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ABSTRACT

This project was initiated under the ASEAN-Australia Energy Project : Phase II, with the aim of promoting the application of fluidized bed boilers for small-scale industrial use. The system design was carried out by Thai researchers led by Dr Solot Suwanayuen, in cooperation with an Australian expert. The boiler is a water-tube type with designed steam capacity of 3 tons/hr. Fabrication was undertaken by a local boiler manufacturer (Bangkok Industrial Boiler, BIB). The boiler unit was installed at the Mae Chan Royal Food Processing Plant which is the project's industrial collaborator.

This report summarizes the work that has been accomplished during the initial phase of this project.

COLD MODEL STUDY

A full scale model of the fluidized bed system was set up as depicted in Figure 1. The bed was 1.2 x 2.4 m^2 with 0.25 m static bed height of sand (mean diameter = 200 μm). The air distributor was a sparger type having an orifice size of 6 mm. Dimensions and details of the air distributor are shown in Figure 2. Plugging-up problems due to leakage of sand into the main air duct were found when the angle of drilled holes was 30° from the horizontal axis (see Fig. 2). This problem was overcome by changing the angle of drilled holes to 45°. Total bed pressure drop as a function of bed superficial velocity is shown in Figure 3. The minimum fluidization velocity was found to be about 0.037 m/s. Visual observation of fuel (rice hull char) mixing showed that at low superficial velocity (0.15 m/s) the circulation pattern is similar to a multi-spouted bed. Fuel particles formed several thin layers along the bed height and bed expansion was small, with the spouting fountains at or about the bed surface (Fig. 4a). When the superficial velocity was increased to 0.22 m/s, complete mixing of fuel particles in the bed could be approximated (Fig. 4b) and the fountain height was also considerably increased.

The concentration profile of fuel particles in the upper and lower sections of the bed were also tested. It was found that uniform mixing of the bed can be obtained for both sections 6-7 minutes from start-up (See Fig. 5).

BOILER SYSTEM

System design and selection has been described in detail elsewhere [1/3]. The main components of the system are briefly described as follows :

Boiler

A standard D-type water tube boiler with stoker fire was chosen and modified. The stoker component was replaced by a fluidized bed of inert sand with a sparger type air distributor (Fig. 6). The bed dimensions comprise 1.25 x 2.6 m^2 cross-sectional area and 0.3 m static bed height. To keep the free-broad temperature high enough for volatile combustion, the tube wall of the combustion chamber was insulated, except for the lower part (0.8 m from air distributor) which was designed to extract the convective heat from the fluid bed. A 30 hp force draft fan was used to supply the fluidizing air which was also used for combustion.

Fuel Handling System

Since the boiler was designed to fire both lignite and rice hulls, two separate fuel handling systems were provided. For lignite, a bu cket conveyor was used to transport the fuel from the storage warehouse to a screw feeder and then into a 3 m^3 feed bin beside the boiler unit (Fig. 7a). Lignite particles ($<$ 2 in. diameter) were fed over the bed into the boiler by use of a magnetic shaker (Fig. 7b). Rice hulls were similarly transported from the storage yard into the rice hull feed bin (6 m^3). A rotating table and two consective screw feeders were then used to feed rice hulls from the bin into the boiler at a position slightly below the fluidizing bed surface (Fig. 8).

LPG Start-up System

The ignition temperatures of most solid fuels are generally above 400°C, therefore a warm-up system using either liquid or gas burner is needed. An LPG burner with an automatic ignition system was chosen in this project. The main fuel gas pipe was inserted into the main air duct and gas distributed separately into the air sparger at row numbers 4-9 (Fig. 2). The main pre-mixed flame was ignited by two pilot burners installed with a 45° inclination angle about 1 m above the bed surface (Fig. 9). Two glass windows were also provided for pilot flame observation. Safety equipment such as a leak detector, flame detectors and interlocking circuit were also provided.

Emission Control System

Particulate emission from the combustion chamber is captured in a water jacketed cyclone. The remaining fraction is continually scrubbed in a special type of mechanically induced spray scrubber [2] which consists of a water spray system and an induced draft fan. Water spray provides fine droplets for picking up particulates while the fan is used to enhance the mixing and capturing of fines. Wet gas is then passed through a knock-out drum to settle out the water before discharge to the atmosphere. The spray water was recycled after the particulates were separated out by using simple sand filter. The system is shown in Figure 10.

In situ treatment of sulphur dioxide is accomplished by using limestone as an absorbing medium.

Instrumentation and Control

The main instrumentation and control devices for this fluidized bed boiler are summarized in Table 1. The main control panel with flow diagram and alarm is shown in Figure 11.

PRELIMINARY TEST

As it was planned that the boiler be installed at a food processing plant in Chiang Rai province, which is quite far from Bangkok, the system was pre-installed and tested at the boiler manufacturer's factory. The preliminary start-up was made in manual operation mode. It took about 2.5 hours to warm-up the bed to about 700°C . The warm-up time is expected to be reduced to 0.5-1 hour when the operator has gained more experience. Combustion of lignite ($<$ 2 in. diameter) was completed and the shrinking core mode was found to be applicable from observation of residual coal ash (Fig. 12). Particulates were successfully captured in the cyclone and the water spray scrubber system.

FUTURE WORK

At present, installation and commissioning of the system at the site in Chiang Rai has been completed (Fig. 13). Inspection and testing of all components and start-up have been carried out. Future work plan and studies intended are :

- erosion and corrosion of boiler tube
- in-bed capturing of SO_2 with limestone
- in-bed and free-board heat transfer
- long term boiler performance

REFERENCES

1. Suwanayuen S. et al., ***A Multifuel Fluidized Bed Boiler for Small Scale Industrial Use.*** 1st National Chem. Eng. Conference, Dec. 17-19 1990, Bangkok, Thailand.

2. Spink D.R., ***Handling Mists and Dusts,*** Chemtech, June, 1988.

3. Suwanayuen S. et al., ***Multifuel Fluidized Bed Boiler for Small-Scale Industrial Use: System Design.*** ASEAN Workshop on Fluidized Bed Combustion, 6-9 November 1991, Bangkok/Chiang Rai, Thailand.

TABLE 1. INSTRUMENTATION AND CONTROL.

Sensors	Measuring position	Control mode	Control equipment	Function/ adjustment
TC	Sand bed	PID	Lignite shaker or rice hull rotating table	Fuel feed rate
PT	Steam drum	PID	Damper at forced draft fan outlet	Combustion air flow rate
PT	Above bed	PID	Damper at induced draft fan outlet	maintain negative pressure inside the combustion chamber
LS	Steam drum	on-off	boiler feed pump	maintain water level
PS	Steam drum	on-off	alarm	-
LS	Fuel storage	on-off	bucket conveyor and screw feeder	feeding fuel into bin
FD(IS)	pilot burner	on-off	main LPG solenoid valves	feeding LPG into the bed
FD(IR)	boiler roof (veiwing to the bed)	on-off	all solenoid valves in LPG system	prevent LPG flow into the combustion chamber if main flame extinction occurs
LS	water feed tank	on-off	pump	maintain water levels

TC = Thermocouple, PT = Pressure transmitter, LS = Level switch, PS = Pressure switch
FD = Flame detector, IS = Ionization, IR = Infrared

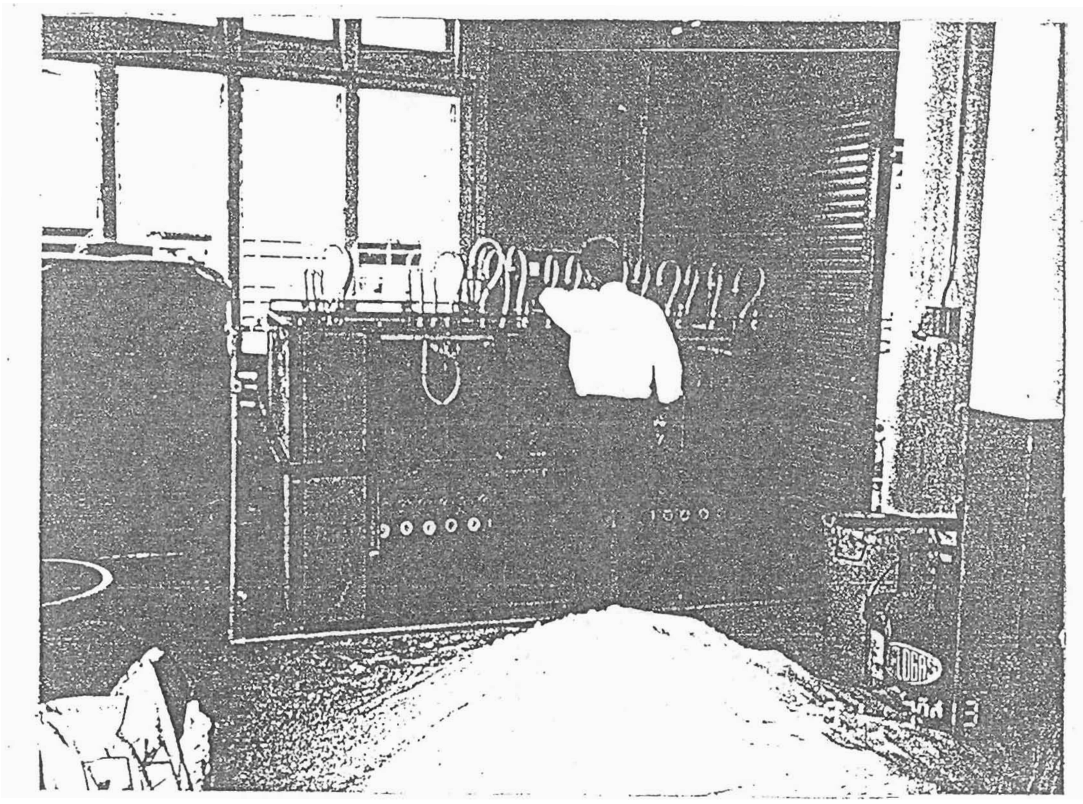


Figure 1. Full Scale Model of Fluidized Bed for Hydrodynamic Study.

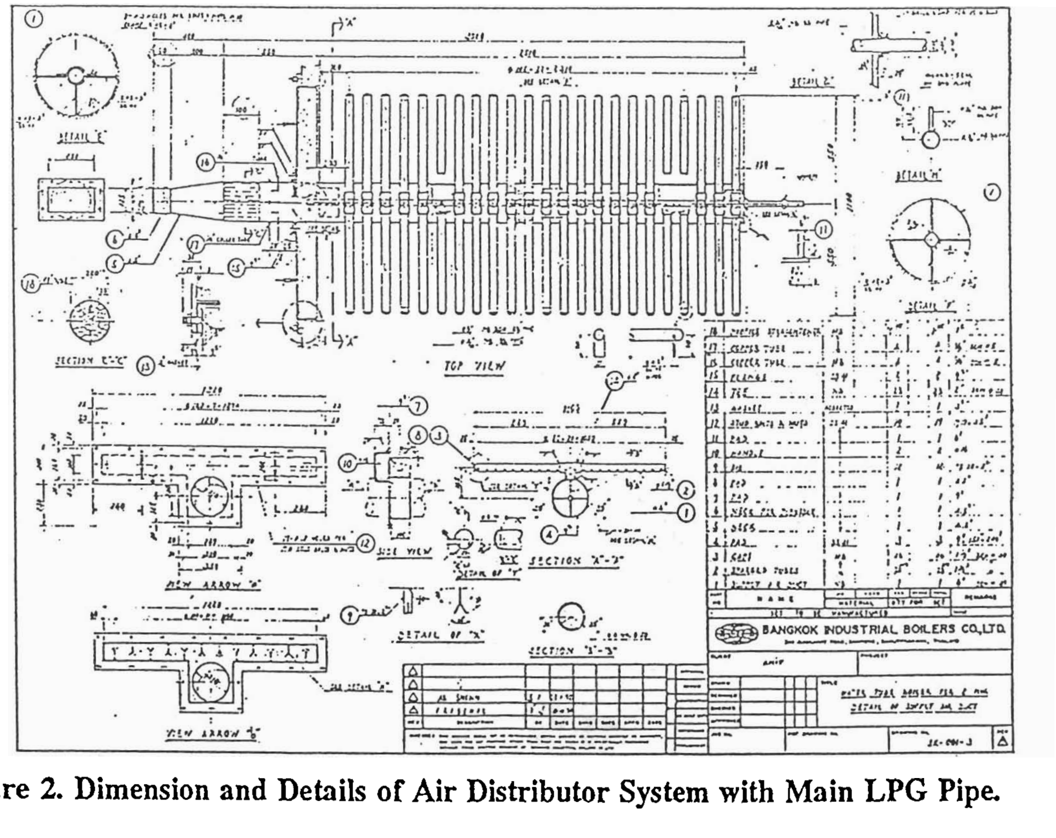
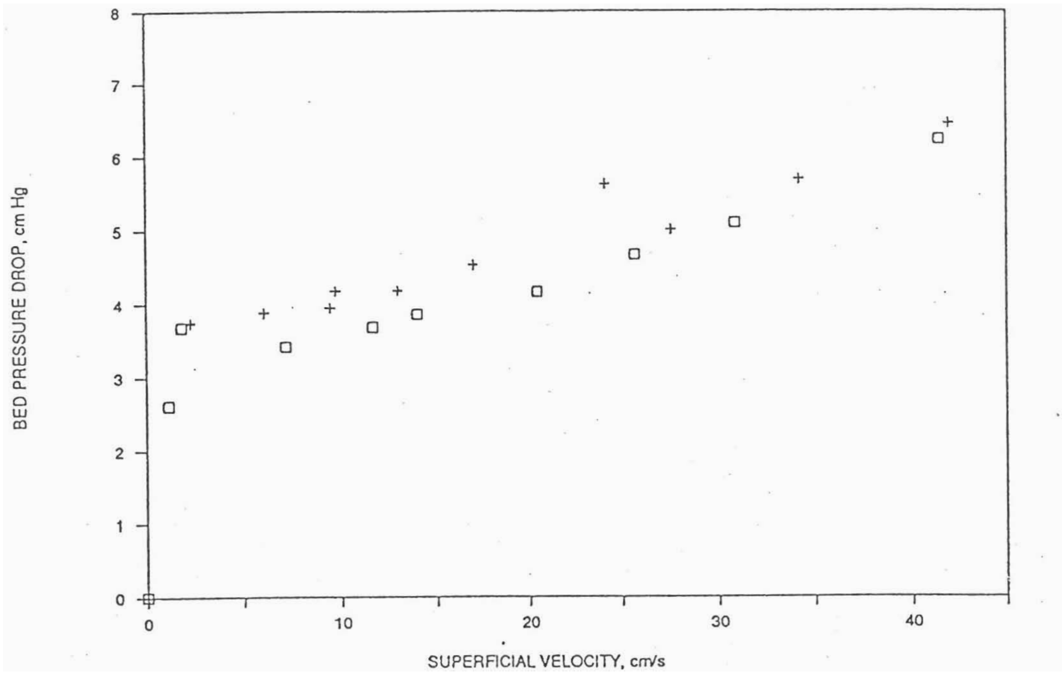


Figure 2. Dimension and Details of Air Distributor System with Main LPG Pipe.



(+ increasing velocity, □ decreasing velocity)
Figure 3. Total Bed Pressure Drop as a Function of Bed Superficial Velocity.

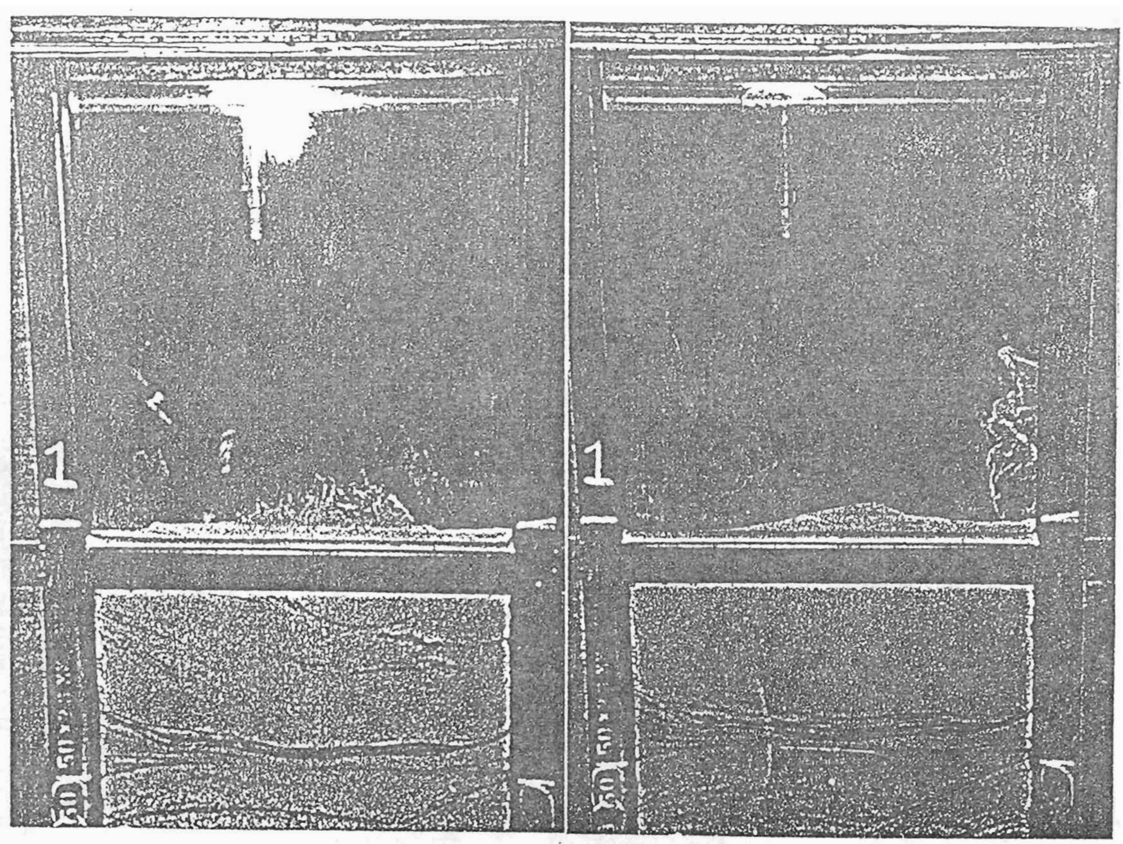
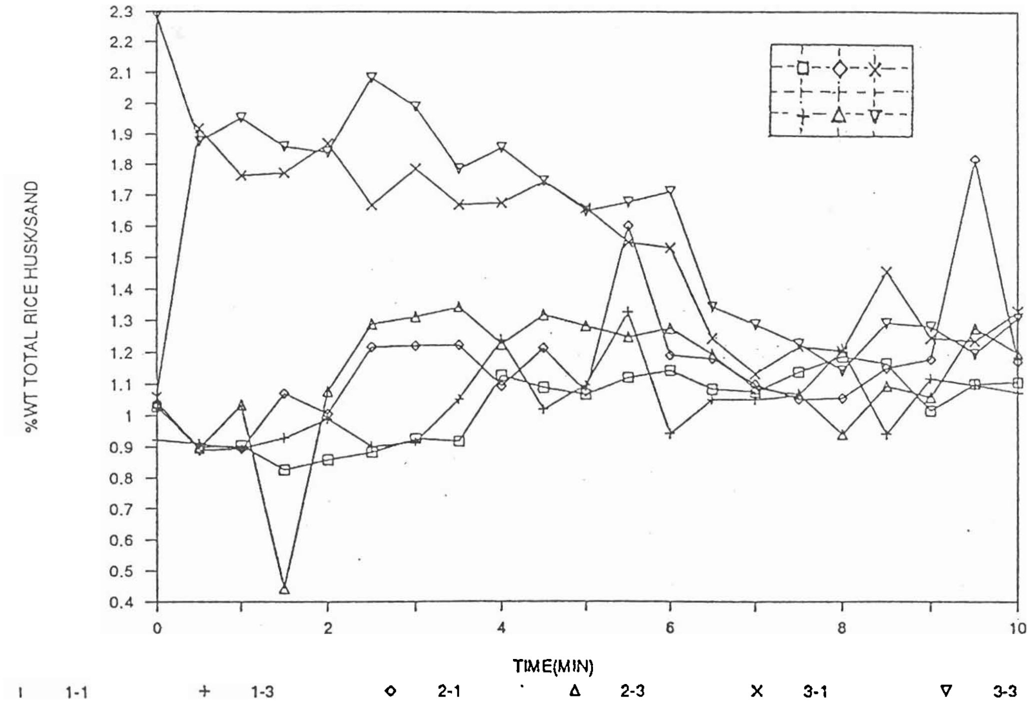


Figure 4. Fuel Mixing Pattern at Bed Superficial Velocity of (a) 0.15 m/s and (b) 0.22 m/s.



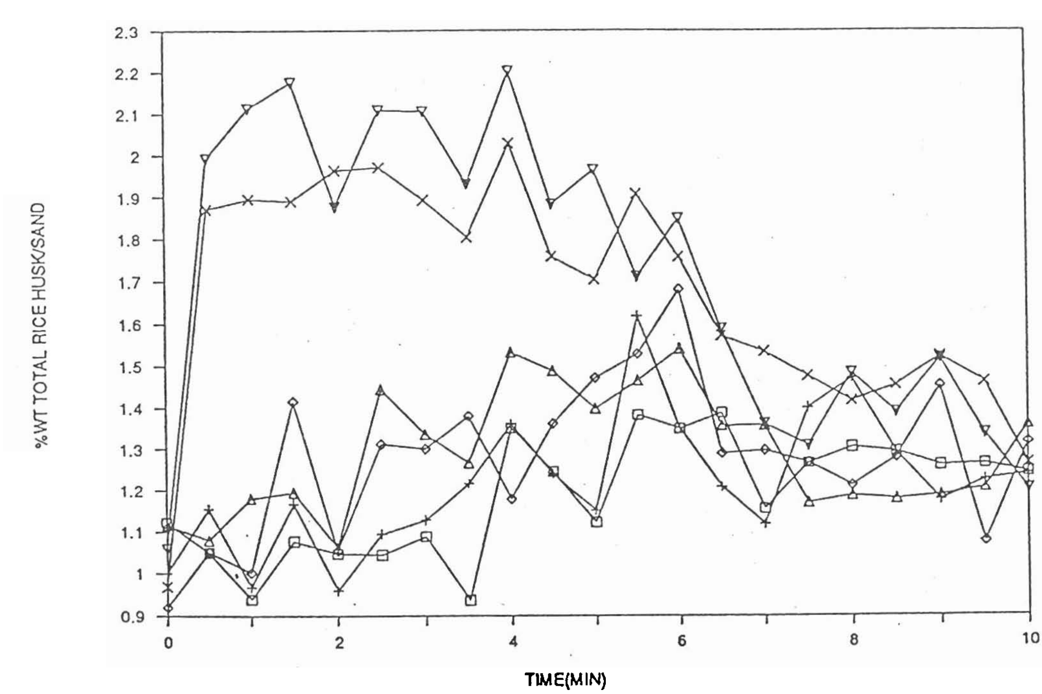
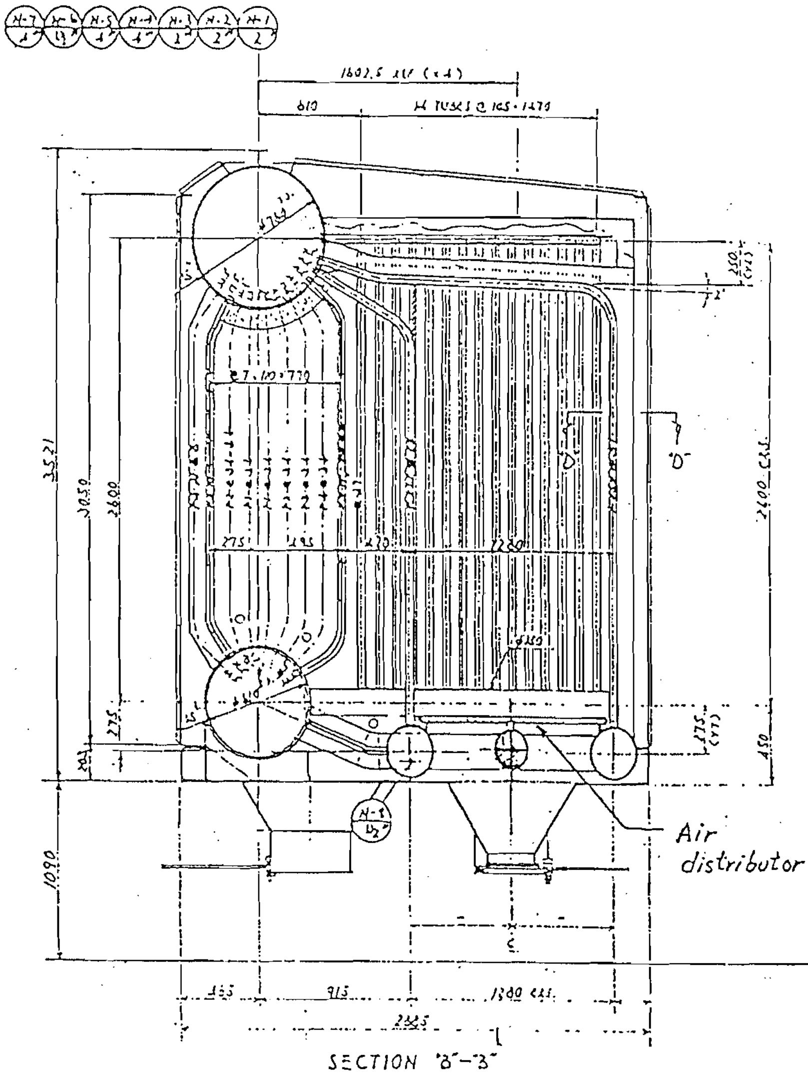


Figure 5. Concentration Profile of Fuel Particles at Various Positions; (a) Upper Section and (b) Lower Section.



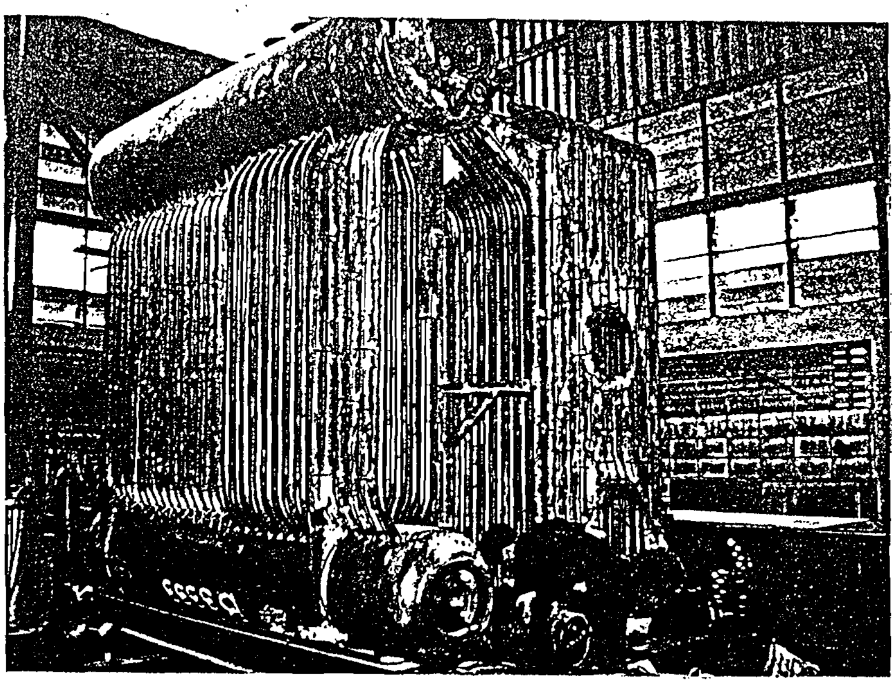


Figure 6. D-type Water Tube Boiler.

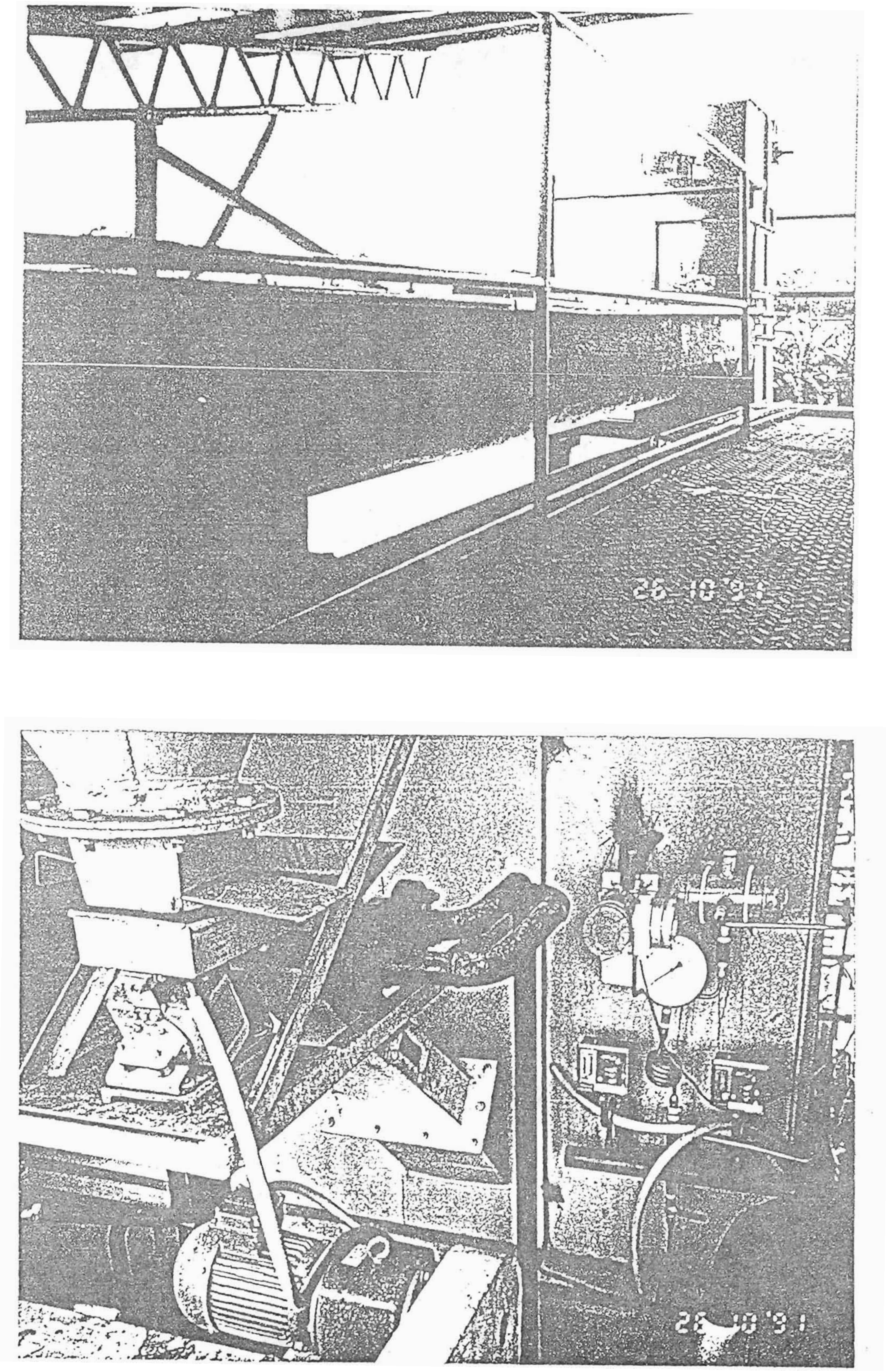


Figure 7. Lignite Feeding System : (a) bucket conveyor and screw feeder and (b) magnetic shaker.

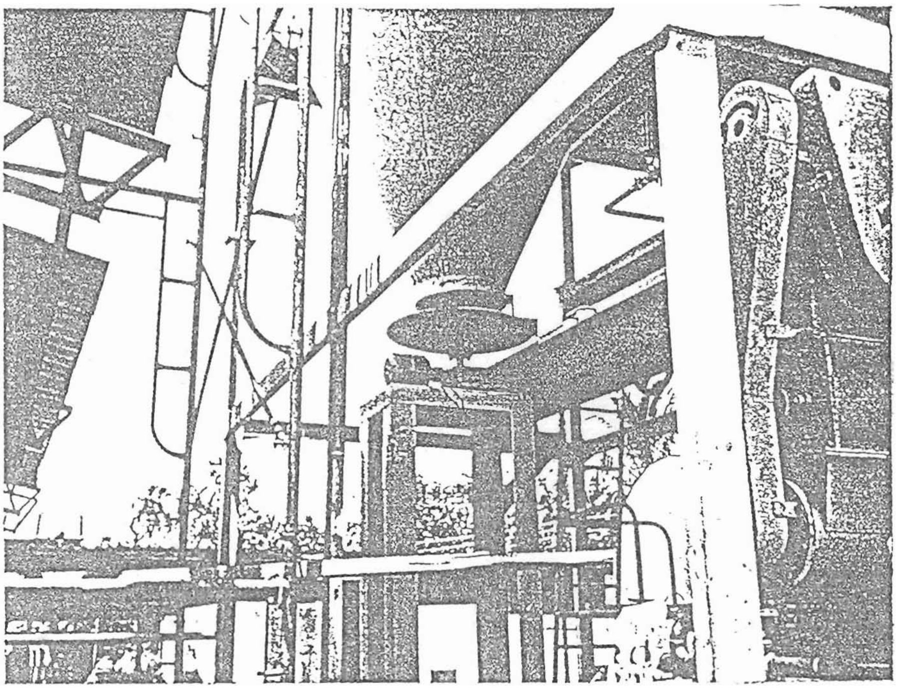


Figure 8. Rice Hull Feeding System.

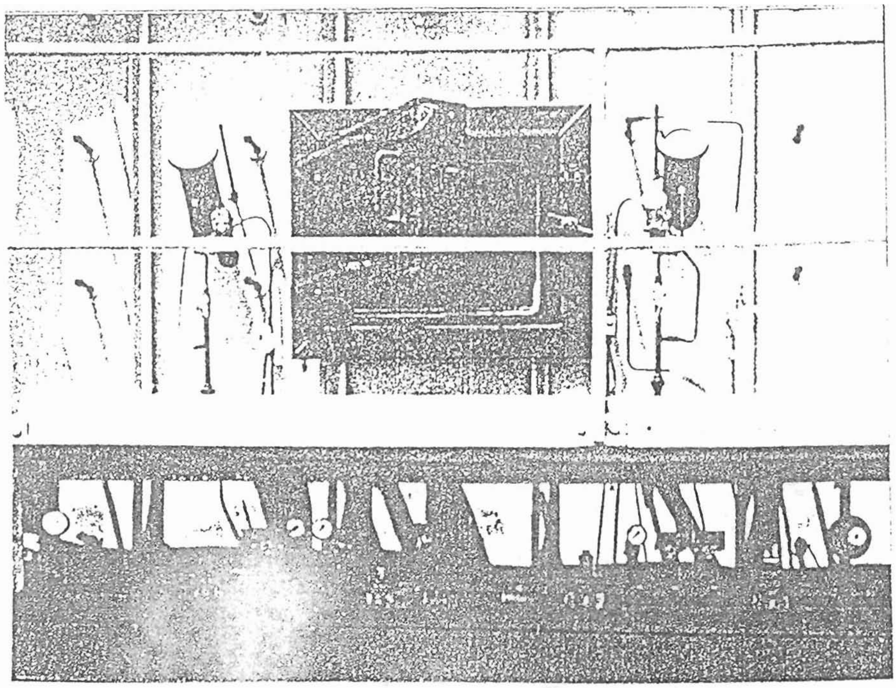


Figure 9. Pilot Burners and Observation Glass Windows.

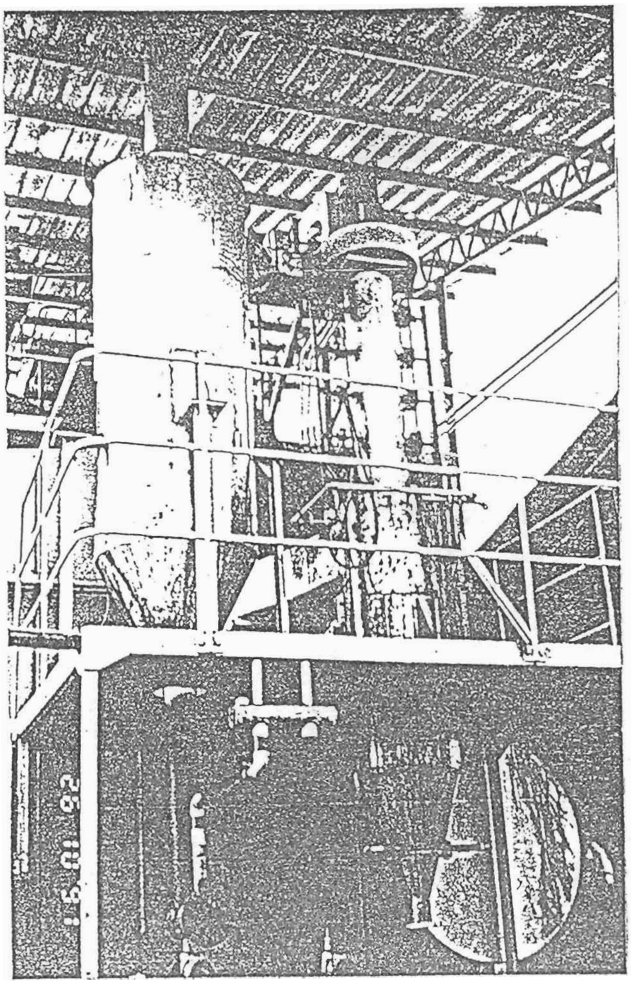


Figure 10. Jacketed Cyclone and Spray Scrubber.

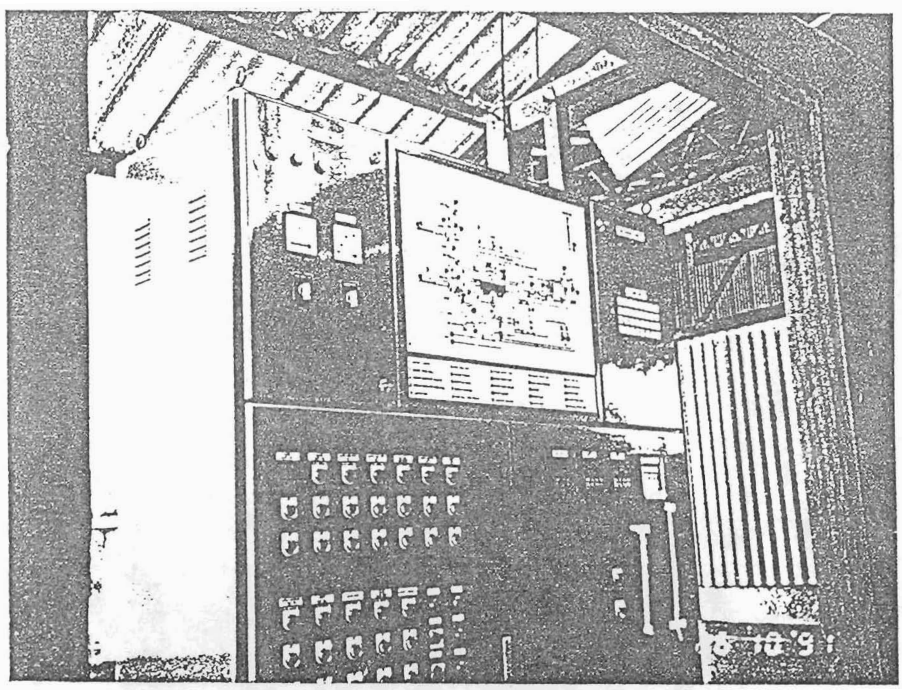


Figure 11. Main Control Panel.

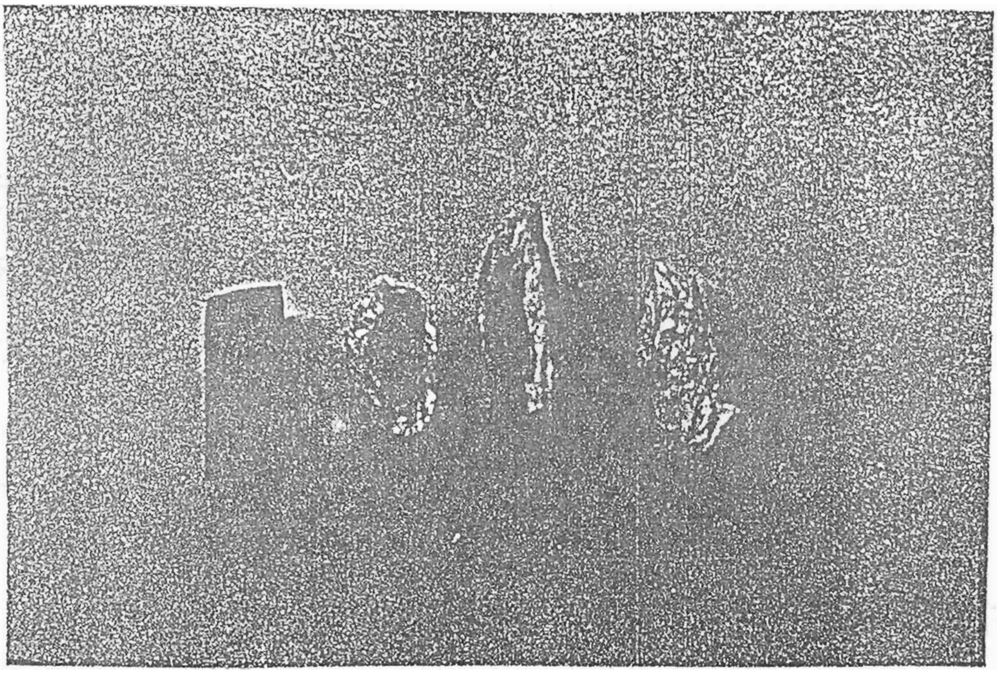


Figure 12. Residual Coal Ash Showing Shrinking Core Model Combustion.

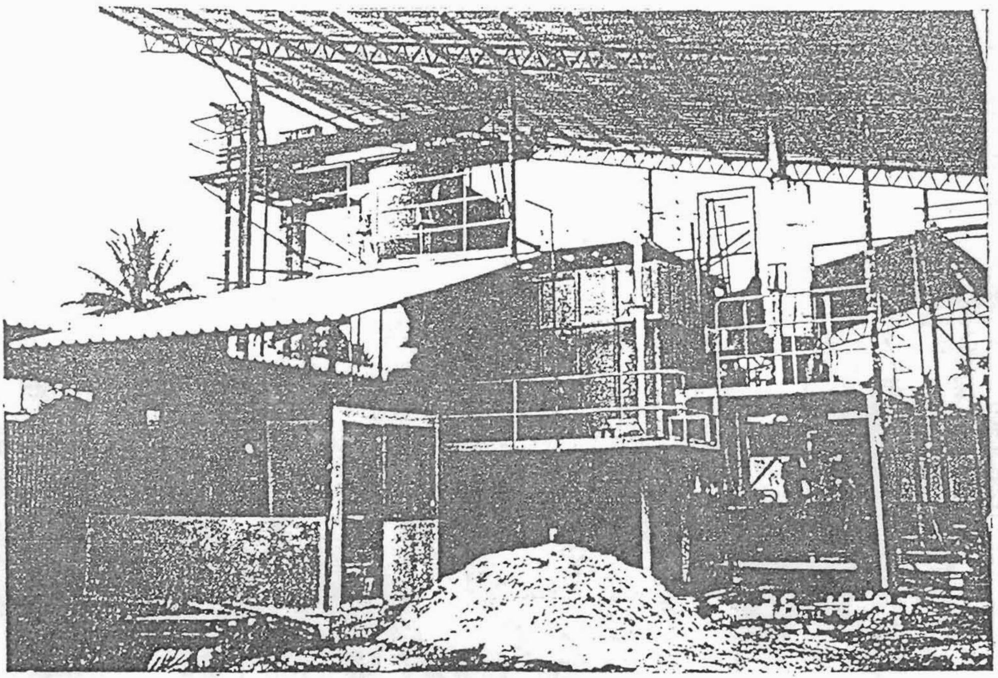


Figure 13. Fluidized Bed Boiler System Installed at Chiang Rai.