CHAPTER 3

LITERATURE SURVEY OF FLUIDIZED BED COMBUSTION OF RICE HUSK

3.1 Basic Principle of Fluidization

For clear understanding in the oncoming sections, the following terminologies must be understood

Bed	A place where an action or reaction take place.
Elutriation	The lifting out of the small elements in a mixture of solid particles by a stream of high speed gas.
Fluidization	The state of suspending particles in a rapidly moving stream of gas or vapor, the particles are close enough together and interact in such a manner that they give the impression of a boiling liquid.
Fluidized Bed	A gathering of small solid particles maintained in balanced suspension against gravity by the upward motion of a gas or liquid.
Fluidized Bed Combustion	The burning of fuels in a fluidized bed.
Residence Time	The period of time spent by a typical particle in a particular zone of a fluidized bed.

BASIC PRINCIPLES OF FLUIDIZATION

In FBC the packed bed consists of solid materials confined in a vessel, usually cylindrical in shape. The force of gravity causes the solid materials to pack together inside the vessel. The relative position of the packed material remains constant without the application of additional forces. The packing material rests on a distributor which, as the name implied, is employed to keep up flowing fluids (gases or liquids) evenly distributed inside the packed bed, and which supports. If a stream of air is introduced at the bottom through the distributor. The pressure drop across the packed bed, P, which is monitored by a manometer, increases as the velocity of gas, V, through the packed bed increases. At the beginning, the pressure drop varies linearity with the gas velocity, but, as the velocity increases, the pressure remains steady. At this point the surface of the packed bed is absolutely level sd if it were a liquid. This is the transition point at which the packed bed has become a fluidized bed.

If the gas velocity is further increased, sufficient air is introduced to "fluidized" the packed bed by causing the packing material to be suspended, and to behave like a fluid. The gravitational force acting on the solid is balanced by the action of the frictional force exerted by the up flowing air.

Minimum fluidization is generally not a clear-out point. It possesses the following characteristics:

- The top bed surface become level, which is indicative of fluid behavior.
- The interparticulates contact is no longer continuous. Unlike the packed bed it cannot transmit a force along the direction of application.

As the gas fluidization velocity is further increased, the gas can no longer pass through the interstices between the bed particles without the formation of gas bubbles. The gas bubbles inside a fluidized bed will cause the volume of the bed to expand. The upward movement of the gas bubbles promotes in-bed solid-bed mixing through a bubble will retard gas-solid contact for the gas trapped inside the bubble.

If the velocity of fluidization air continue to increase, the bed material become entrained. Instead of remaining inside the confines of the vessel, the bed material are blown out of the bed in a manner almost identical to pneumatic air conveying. No bubbles are formed, no bed material will remain inside the vessel. This phenomena is known as an entrained bed.

3.2 Basic principles of Fluidized Bed Combustion Technology

Fluidized bed combustion is an application of the fluidization technique to the process of combustion. The advantages of fluidized bed combustion includes (Bottlerill, 1975):

- An extremely large area of contact between solid and fluid. This very large surface area permits the achievement of high overall rate of heat and mass transfer between the solid and fluid.
- The comparative ease with which fluidized solids can be handled.
- The reduction of temperature gradients to negligible proportions through the bulk of the bed as a consequence of the

high degree of solids mixing that can occur in gas-fluidized systems, i.e. a very high effective internal conductivity.

- High rate of heat transfer the fluidized solids and immersed surface.

Furthermore, fluidized bed combustion technology offers another advantage in terms of emision control where sulfur can be retained in the bed and nitrogen oxide reduced.

This chapter, as its scope, provides the historical development and literature survey of the fluidized bed combustion technology.

3.2.1 Basic Phenomena

In fluidized bed combustion, the bed consists of granular inert particles and air is blown up through a distributor in the floor of the bed causing the particles to move as a churning turbulent mass. Fuel is fed into the bed. The fuel may constitute less than one percent of the material in the bed. The combustion of fuel keeps the bed at a certain temperature. The surface of the bed looks like bubbling molten lava. The turbulence of the churning bed keeps the temperature stable, so that the bed does not get rapidly hotter or cooler. Heat is transferred within the bed, and from the bed to the surrounding walls or boiler tubes, by the direct impact of the heat transfer there is in a conventional boiler.

As fresh fuel is added, even through it may much cooler initially, its temperature rises rapidly compared to the whole hot bed. Accordingly, even very low-quality fuel, e.g. low-grade coal, urban refuse, even wet sludge, which cannot be burned in any conventional firebox, can be combusted.

The fluidized bed delivers heat from the burning fuel to the boiler wall or boiler tubes, which in turn delivers it to the water or steam being heated. Because the heat is delivered by the direct impact of particle, good quality high-temperature high-pressure steam can be produced while operating a fluidized bed combustor at a temperature much lower than that in the fire-makes it possible to reduce dramatically the formation of nitrogen oxides. Furthermore, at such a temperature ash dose not melt. This avoids the problems caused by molten ash, including corrosion of boiler tubes.

The fluidized bed transfers the heat out of the bed comparatively rapidly. It is therefore possible to produce more output per unit time in a given of firebox. Accordingly, a fluidized-bed combustor can be physically much smaller than a conventional boiler of the same heat output. This in turn means that the fluidized bed boiler is likely to cost less, may be built more rapidly, and transported more easily.

If the fuel to be burned in the fluidized bed combustor is coal, it may contain small but troublesome amounts of sulfur. Such coal, when burned in a conventional boiler, releases sulfur dioxide and sulfur trioxide, nox-ious gases which need to be remove by addition processing step before discharging through smokestacks to the surrounding environment. A fluidized bed combustor offers an elegant approach to solve this problem. Crushed limestone or dolomite is fed into the bed along the high sulfur coal. The sulfur in the coal combines chemically with the calcium in the crushed stone, to form solid calcium sulfate. Under suitable conditions and with suitable quality limestone, it is in this way possible to trap more than 90 percent of the sulfur, which remains with the solid ash and is discharged with it from the combustor. (Patterson & Griffin, 1978)

3.2.2 Historical Development of Fluidized bed Combustion Technology

The concept of the fluidized bed was first conceived in the 1920s in Germany. Coal was first burned in a fluidzed bed combustor in 1928 where a spouting fluidzed bed boiler was developed to combust crushed coal (Stratton, 1928). A unit with the capacity of 5000 lb of coal/hr. was installed at a U.S. Gypsum Company paper mill. This early process had no tubes in the bed.

From 1944 onwards, several companies in the United State and Germany developed designs for fluidzed bed systems to burn fuel in the bed to boiler water and produce steam, but nothing came of these schemes. In France, a fluidzed bed boiler using two-stage combustion of coal (the "Ignifluid" boiler) was developed and was successful commercially, but attracted little attention. (Patterson & Griffin, 1978)

In the 1950 a number of fluidized bed combustion processes were proposed employing fluidized-bed with cooling surface which were immersed in, or surrounding the beds (Union Carbide, 1963; Combustion Engineering 1955 & 1957; Standard Oil Development Corp., 1952). Unfortunately, during this time, emphasis in energy research and development shifted away from solid fossil fuel towards oil, natural gas and nuclear electricity. Technology for the combustion of coal, no matter how elegant or ingenious, elicited very little high-level interest and minimal financial support.

In the early 1960s the concept of rotating fluidized bed was initiated at the Brookhaven Laboratory by the investigation of hydrogen cooled rotating fluidized bed nuclear rocket (Demircan et al, 1978). Since 1963, research and development work on fluidized bed combustion of coal has been in process in the U.K. (Skinner, 1971). Experimental efforts and conceptual of fluidized combustion systems i.e.

(i) atmospheric pressure utility-sized system
(ii) pressurized fluidized bed combustion system
(iii) industrial shell boiler and
(iv) packed water tube boiler

The nominal gas velocity was designed at 0.6 m/s (2 ft/s) for utility boilers and 3-4.25 m/s (10-14 ft/s) for industialboiler. Experimental data at 800 degree celcius (1073 K) gave an overall combustion efficiency of 99 percent for the former and 95 percent for the latter when elutriated fines were recycled. Preliminary economic study indicates a capital cost saving of 9 percent for fluidized bed boiler plants as compared to pulverized coal boiler plant.

In 1964, Maoming Petroleum Company started the research on fluidized bed combustion with a pilot unit in China, in order to utilize the oil shale fine refuse from refinering. (Cao & Feng, 1983)

In 1965, Pope, Evens and Robbins (PER) built three atmospheric fluidized bed test ring. The largest of these, a 0.5 MW (thermal) unit at Alexandria, Virginia, started up in 1965. Meanwhile in China, Maoming Petroleum Co., Tsinghuauniversity, Fushun Petroleum Institute and others designed the first fluidized bed boiler in China to burn shale fines and capable to generate 14.5 tons per hour of 13 kg/cm^2, 250 degree celcius superheated steam by consuming 300 tons oil shale per day. This plant was installed at Maoming Petroleum Co. which started the operation in November 1965. Maoming oil shale fines contain 62.21% ash, 18.0% moisture, and its lower heating value of 1034 kcal/kg.

In 1968, PER fed limstone along with high-sulfur coal into a fluidized bed combustor and observed a low sulfur dioxide content in the off gas. In this year Douglas Elliott and Raymond Hoy of British Coal Utilization Research Association (BCURA) began to investigate the possibility of enclosing the fluidized bed system in a shell pressurized to several atmospheres.

By 1969, BCURA built at its location an 8 MW (thermal)facility and since that time fluidized bed system have always been divided into two sub-classes, i.e. atmospheric and pressurized. In China, on the basis of the design and operating experience from the Maoming fluidized bed boiler, Tsinghua University converted its experimental power plant for burning local anthracite and coal washer refuse sucessfully for generating 14 tons per hour of 24 kg/cm^2 and 260 degree celcius superheated steam. The application of fluidized bed boiler has spread quickly all over China since that time.

A study on fluidized bed combustion of various American coal was done by the U.S. Burean of Mines (Coats and Rice, 1970). For coals with high ash content, the results indicate that the ash could be usedas bed material.

The creation of the U.S. Environmental Protection Agency (EPA) in 1970 lead almost immediately to a joint research program between the EPA and the British National Coal Board, to study fluidized bed combustion as a way of reducing the production of sulfur and nitrogen oxide from boiler. The program, completed in 1971, indicated that up to 95 percent of the sulfur in high-sulfur and could be captured in a fluidized bed and that the sulfated dolomite can be regenerated.

Both American and British research teams quickly established that calcium-containing materials, in particular limestone and dolomite, reacted chemically in a hot fluidized bed with sulfur from coal, trapping the sulfur as solid calcium sulfate. The effectioness of the so-called "sorbent" stonevaried with the temperature of the bed, the size of the sorbent particles, and the system pressure. Some research suggested that limestone was more effective in an atmospheric fluidized bed, while dolomite was more effective in a pressurized fluidized bed, while dolomite was more effective in a pressurized fluidized bed. The optimum calcium to sulfur ratio appeared to be between 2.5 and 4 to 1, but varied considerably, not least between limestone and dolomite.

The office of Coal Research (OCR) and Evans, and Robbins (Robinson et al, 1972) developed a fluidized bed industrial packaged boiler using a modular cell concept with water wall and high gas velocity (2-4.25 m/s (6-14 ft/s)). A carbon burnt up cell concept was also developed to complete the combustion of elutriated carbon.

In 1972, Pope, Evans and Robbins built a 30 MWe prototype atmospheric fluidized bed power plant at Rivesville, West Virginia, U.S.A.. It was started up in August 1977. In 1973, the Combustion Power Company converted a 1 MWe pressurized fluidized bed incinerator unit to coal firing.

Progress on atmospheric systems has been more rapid. In Britain, the National Coal Board as a partner in the newly-established Combustion System Limited (CSL) agreed in 1974 to convert a boiler at the Babcock & Wilcox, Limited (B&WLTD) factory in Renfrew , Scotland to fluidized bed firing. The 40,000 pound per hour Renfrew boiler started up in August 1975, and for two years was the largest operating fluidized bed boiler in the world.

Meanwhile, elsewhere in Britain, a radically new approach to fluidized bed system was taking shape. Douglas Elliott has taken out patents on system using fluidized beds, much shallower than usual (a few inches as compared to a foot or more).

In 1978, Demircan et al (1978) disclosed the resultant research using a cylindrical rotating fluidized bed combustor with an inside diameter of 20 cm. The rotational speed used was between 100-1000 RPM (1-100 gravity loading). Propane gas oil and coal (2-4 mm diameter) were burned in the bed at temperature between 700-900 degree celcius. The results demonstrated that the rotating fluidized combustion can produce considerable higher combustion intensities, has a much better turn-down (lowering the rate of heat production in the bed without allowing its temperature to drop too low to sustain fuel combustion) rang, and a more rapid start-up (raising the bed temperature from room temperature until it would sustain fuel combustion) than a conventional fluidized combustor. These results are confirmed by the experiment of Metcalfe and Howard (1978). However , the rotating bed is mechanically more complication than the stationary bed, there by the large scale application tend to be limited.

In Sweden, the ability of fluidized bed combustion systems to burn virtually any fuel led the town of Enkoeping, near Stockholm, the town's direct heating system. The Enkoeping boiler on stream in February 1978 burning heavy oil and subsequently coal.

In 1979, Georgetown University and Department of Energy (DOE), in a joint research program, designed and operated a 100,000 lb/h capacity coal-fired fluidized bed steam generator with the purpose to demonstrate industrial and instructional application of fluidized bed combustion using high sulphur coal in an environmentally acceptable manner in a populated area (Gamble, 1980).

In U.K. the National Coal Board (NCB) conducted test on there prototype boiler at commercial size (Highly, 1980). The three prototype s tested were vertical shell boiler, horizontal boiler, and Vosper Thornycroft (U.K.) open hearth design and a Babcock Power Ltd. composition water tube/shell concept. A packaged design of water tube fluidized bed boiler viable up to 46,000 lb/h has been developed by Stone Platt Fluidfire Ltd. (Virr, 1980).

The Royal Dutch Shell unit represents the first coal-fired fluidized bed cogeneration system to be installed in a refinery environment. The operation began in the third quarter of 1982. This unit installed in the Europort oil storage facility near Rotterdam produces 13.9 kg/s (110,000 lb/h) of superheated steam at 8.1 MPa gauge (1175 lb/in) and 475 C.(925 F.) The steam produced is used to generate 6.6 MWe and heat the tank farm in a cogeneration application. This Foster Wheeler generation facility which operates under complete automatic control, fires bituminous coal using an over bed spreader feed system (Phillip & Taylor, 1983).

A facility designed by Foster Wheeler for Ashland

Petroleum Company demonstrates the versatility of fluidized bed technology through its operation with a fuel consisting of high temperature, low heating-value process off-gas. Each of the two units generates up to 40.6 kg/s (325,000 lb/h) of superheated steam. The first unit was started up in March 1983 (Phillip & Taylor, 1983).

Nowadays, many companies actively market the atmospheric fluidized beds. The capacity of currently industrial steam generators is now up to 75.8 kg/s (600,000 lb/h) with full commercial warrantee.

Pressurized fluidized bed technology has also come a long way but has not yet become a commercial reality. However, a near term pressurized fluidized bed commercial demonstration has been proposed by the Electric Power Research Institute (EPRI). This groghram if successful will permit the integration of the pressurized fluidized bed technology into the utility market (Phillips & Taylor, 1983).

3.3 Development of Fluidized Bed Combustion Technology in Thailand

Research and development in fluidized bed combustion technology has been established only recently in Thailand at the beginning of 1980. The research activities have been conducted on various aspects of FBC at Chulalongkorn university (both at the Department of Chemical engineering and department of Chemical Technology), Asian Institute of technology (Division of Energy Technology), and King Mongkut Institute of Technology, Thonburi (Department of Chemical Engineering). The R $ D efforts have concentrated on three main types of fuels i.e. lignite, oil shale and biomass. The experiments were all carried out in laboratory scale combustor operating at atmospheric pressure . The objectives of the researches were primarily to get better understanding of the FBC technology and to determine effect of operation variables and parameter on the system performance with an aim of providing basis for design and scale up. The review is devied into three parts according to the type of fuel.

The research and development of fluidized bed combustion in Thailand is summerized in table 3.1.

Lignite

Due to the availability and the already established utilization of lignite, a great deal of efforts have been put into the work on fluidized bed combustion of lignite. Sribuangarn et al (1984) conducted a set of experiments in a 15-cm diameter combustor to determine combustion characteristics of lignite at atmospheric pressure. Details of the combustor and the experiments are summarized in table 3.1. There was no boiler tubes in the system. Fuel calorific values are not reported. Suitable operating conditions were recommended, but the criteria for establishing the recommended operating conditions were not clearly stipulated. This work represents an initial effort to get familiarized with the technology. It did achieve conditions when fluidized bed combustion could be sustained. The advantages of FBC in desulfurization and emission control were not investigated. Another work on that matter was by Preusprivong et al (1984). The system configuration is similar to that of Sribuangarn et al (1984) but with 20-cm diameter combustor and with water jacket around the bed. Start-up procedure and sustained fluidized bed combustion were established. At about the same time Preasertham and Sangjun(1984) conducted experiments in a 23-cm combustor to find the overall heat transfer coefficients using lignite as fuel. limestone was added to control sulfur dioxide emission. Results were obtained for a limited number of runs and no correlation of heat transfer coefficients was established. effect of air velocity on bed temperature was elucidated to confirm the natural phenomena of fluidized bed combustion. Sulfur emissions were recorded for some runs and were found to be within EPA limit.

Different bed cross section was used by Babel(1984) who conducted experiments in a 15 x 15 cm bed in order to investigate the effects of air-to-fuel ratio, bed temperature, and feed rate of lignite on the combustion efficiency and to establish a correlation to predict the combustion efficiency. No boiler tubes were employed and the system was run without using calcium-contaning compound to control sulfur emission. Higher combustion efficiencies were obtained at lower feed rates and at higher air-to-fuel ration and at higher mean bed temperatures. An empirical correlation was established for predicting parameters as a function of the above operating parameters.

A mathematical model was made for the prediction of carbon combustion efficiency in the fluidized bed combustion as a function of the above operating parameters. A mathematical model for the prediction of carbon combustion efficiency in the fluidized bed combustion of lignite was developed by Vanichseni et al (1985). The model was based on the population balance of carbon particles in the bed and other subsystem model of the low film theory of Adesian and Davison , the Merrick and highly correlation for elutriation constant and others. The experiments were conducted in 15-cm diameter bed with details shown in Table 3.1. The mathematical model prediction of carbon combustion efficiency agreed well with the experimental data. The model sensitivity to the change in subsystem model was also carried out. The model was used to simulate the effect of various operating parameters on the carbon combustion efficiency and a simplified model was also proposed. The Ca/S ratio used in the work was higher than normally necessary but it is expected to have no effect on the model validity.

Oil Shale

Vanichseni et al 1984) conducted preliminary experiment of fluidized bed combustion of oil shales in a 15-cm fluidized bed combustor with boiler tubes submerged in bed and arranged in freeboard. Details of the experiments are listed in Table 3.1. Results showed that oil shale can be used as fuel in fluidized bed combustion (Vanichseni et al, 1986). The combustion of oil shale presents a problem of high ash content and low calorific value which translate into difficulties in start-up and operation.

In using oil shale as fuel in fluidized bed combustion , Calcium content in oil shale acts as sulfur capture and subsequently the emission of sulfur is controlled without having to add limestone or dolomite as in the case of lignite. For the case of Thailand with reserves both in lignite and oil shale, the combined combustion of lignite and oil shale represents a synergistic effect of both fuels in term of fuel utilization. The low calorific value of oil shale can be enhanced by lignite while at the same time oil shale acts as asource of calcium required for sulfur capture. Results show that carbon combustion efficiency and desulfurization efficiency increases with calcium to sulfur or oil shale to lignite ratio and fluidizing velocity. The optimum calcium to sulfur ratio is about 3. At constant temperature , calcium to sulfur ratio has no effect on nitrogen oxide emission while higher fluidizing velocity .

3.3 Development of Fluidized Bed Combustion of Biomass and Rice husk in Thailand

Limited work has been done on the fluidized bed combustion of biomass in Thailand. The research efforts have been in fluidized bed gasification. Sagetong (1983) conducted some experiment on the fluidized bed combustion of rice husk in a 15 cm.on bed. No other bed material was used and the feed was intermittent being used to control bed temperature. Ash was removed by entrainment and cycline separation. Experiments were conducted for around 15 min or less for each run of 500 grams of rice husk. Results indicate that ash accumulate in the bed. The research finding are limited due to the nature of the system design and experiments. Bhattacharya,Shah and Alikhani (1989) used a fluidized bed combustion for rice husk. The air distributor was a plate with holes of 0.1 cm diameter, drilled in a square pitch of 1 cm. Copper tubes were welded around the furnace walls so that by changing the water flow rate, the bed temperature could controlled. The bed material was 350-421 um sand particles. Feeding of husk was done by means of a screwfeeder and a channel and had a water cooling jacket around it,to keep its temperature low which presented the combustion of the husk before entering the bed. Secondary air passing through the feed channel ensured smooth feeding. Air for combustion was supplied in two parts:

1 primary air, which served as fuidization air and supplied the major portion of combustion air.

2 Secondary air , which was supplied through a feed channel .

The test showed a combustion intensity of about 530 kg/h in^2 of distributor area could be achieved. There was no problem in the feeding system, when husk was fed. The efficiency of combustion ranged from 81 to 98% and was found to increase with the air flow rate.

The problem of sand carry-over by the flue gases was also repressed. The anthers pointed that there was considerable sand entrainment with sand particle smaller than 350 um and too large particles would not be good with the husk, resulting in poor combustion. The carry over increased sharply with an increase in air flow. Meanwhile it was noted that the amount of inert sand particles in the bed was an important variable which influenced the maximum combustion intensity , if no make-up sand was added to the combustor

For a given fuel rate,the bed stopped functioning as a result of sand carry-over as the feed rate exceeded the maximum rate for the reduced sand level.

TABLE 3.1
SUMMARY OF RESEARCH AND OVELOOPMENT OF FLUIDIZED BED COMBUSTION IN THAILAND

REF	YEAR	FUEL TYPE	FUEL CALORIFIC VALUE KCAL/KG	COMBUSTOR DIMENSION (CM) SIZES	COMBUSTOR DIMENSION (CM) DIAMETER	BED HIGHT	FREEBOARD	DISTRIBUTOR	BOILER TUBES	FEED SYSTEM
68	1984	LIGNITE	NA	1-2 M; 2-1	25	11, 15, 20	50	PERFORATED PLATE	NONE	SCREW
58	1984	LIGNITE	NA	1-2	28	NA	NA	PERFORATED PLATE	MATER JACKET	SCREW
56	1984	LIGNITE	3288-4600	1.34	15	38	114	PERFORATED PLATE	BED,FREEBOARD	SCREW
5	1984	LIGNITE	3752	1 - 6.3	15 N 15	25	NA	PERFORATED PLATE	NONE	SCREW
80	1985	LIGNITE	4166	0.95; 2.4	15	38	114	PERFORATED PLATE	IN FREEBORAD	SCREW
78	1984	OIL SHALE	2088	1.15; 2.29	15	38	114	PERFORATED PLATE	BED,FREEBORAD	SCREW
79	1985	OIL SHALE	1598	2.61; 1.44	15	38	114	PERFORATED PLATE	BED, FREEBORAD	SCREW
		& LIGNITE	2978	2.59						
11	1984	RICE HUSK	3488-3958(DRIED)		15 H 15	10 STATIC	NA	PERFORATED PLATE	NONE	SCREW
61	1983	RICE HULL	2982	2.18EQUIVALENT	15	NA	NA	PERFORATED PLATE	IN FREEBORAD	SCREW
71	1986	SAW DUST	4158 DRY BASIS	NA	17.5 H 17.5	15 STATIC	105	PEBBLE BED	BED,FREEBORAD	STAR/PNE

REF	BED MATERIAL	FUEL PRESSURE	TEMPERATURE (C)	COMBUSTOR DIMENSION (CM) FEED RATE	AIR VELOCITY (CM/S)	EXCESS AIR (H)
68	LIGNITE ASH	ATMOSPHERIC	689 - 930	85-141* KG/M2H	1116 - 161 (147)	NA
58	LIGNITE ASH	ATMOSPHERIC	758 MAK	NA	2 - 2.6 M3/MIN	NA
56	LIMESTONE	ATMOSPHERIC	178	5.4	49 - 115 (ANB)	NA
5	LIGNITE ASH	ATMOSPHERIC	615 - 925	4.5-6.7 KG/H	28 - 48 M3/H	NA
80	LIMESTONE ASH	ATMOSPHERIC	758 - 1865	3.3-6 KG/H	64 - 97 (ANB)	85 - 138
78	OIL SHALE ASH	ATMOSPHERIC	758 - 900	7.7;9.5 KG/H	30 - 85 M3/H(ANB)	58
79	OIL SHALE	ATMOSPHERIC	617 - 857	5.8 - 30 KG/H	25 - 83 M3/H(ANB)	10 - 343
	& LIGNITE ASH	ATMOSPHERIC				
11	358-428 MI SAND	ATMOSPHERIC	760	200-530 KG/H	15 - 30 M3/H(ANB)	na
61	RICE HUSK	ATMOSPHERIC	500 - 800	30-46 GM/S	.36 - .47 M3/MIN	108 - 241
71	3-508 MICRON SAND	ATMOSPHERIC	738 - 958	3 , 4 KG/H	80 - 90	50 - 180