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CIRCULATING FLUIDIZED BED COMBUSTION VIA MULTI-SOLID FLUIDIZED BEDS (MSFB)

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CIRCULATING FLUIDIZED BED COMBUSTION VIA MSFB (MULTI-SOLID FLUIDIZED BEDS) by William J. Place PRODUCT MANAGER, FLUIDIZED BED and Karl Berntson STAFF ENGINEER, FLUIDIZED BED RILEY STOKER CORPORATION WORCESTER, MA

INTRODUCTION

The utility market is perceived as a conservative one and chances are it will remain so in the future. Will circulating fluid bed technology meet the utilities' requirements? The industrial sector in the past four (4) years has chosen the circulating fluid bed route with over 50 units in the U.S. committed. With fluid bed units for TVA, Northern States Power, and Colorado Ute nearing completion we can see growing acceptance in the utility sector for fluid beds. Texas-New Mexico, Montana-Dakota, and Wisconsin Electric have also chosen fluid bed units.

Fuel flexibility and the ability to meet stringent emission requirements have been the major reasons for choosing fluid bed. Whether the utility considers retrofitting existing units, repowering an existing turbine or building new plants, fluid bed systems will be considered.

Coal provides a long term low cost fuel for power production. Fluidized bed provides an economically attractive system from both a capital and operating cost standpoint to meet the most stringent emissions requirements.

CFB's are ready now for the 100 to 150 MW class and conceptualized designs are available for units up to 300 MW.

The Multi-Solid Fluid Bed (MSFB) system offered by Riley Stoker in the industrial and utility sectors is a circulating fluid bed system employing a dense bed in the lower reducing zone and an external heat exchanger. The technology is licensed from Battelle Memorial Institute in Columbus, Ohio.

PROCESS DESCRIPTION

The combustion and steam generating system consists of five (5) basic types of components (Figure 1):

The Combustor Vessel

All combustion of fuel takes place in the combustor vessel which is a circulating fluid bed type called a Multi Solid Fluid Bed (MSFB). The combustor vessel is divided into two zones with different cross sectional areas:

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The lower reducing zone contains a dense bed of large particles with a size range between $\frac{14}{4}$ and $\frac{34}{4}$. This dense bed provides a stable combustion zone and increases the residence time of fine bed particles. Fuel is added into this region and primary combustion air is introduced by an air distribution grid. The quantity of air is less than half that required for stoichiometric combustion of the fuel. This serves to minimize NO_x generation and reduce fan power. The bed normally operates at a superficial velocity of about 25 ft/sec. Up to $2'' \times 0$ coal can be fed to an MSFB unit.

An upper oxidizing zone, where the complement of air required to achieve complete combustion and reach the desired level of excess air is provided via a secondary air fan as well as a small portion from the external heat exchanger vent. This provides the appropriate gas residence time to complete combustion and sulfur dioxide retention. This zone normally operates at a superficial fluidizing velocity of about 30 ft/sec.

High efficiency cyclone(s)

The fine particles leaving the top of the combustor vessel are separated from the flue gas flow by high efficiency hot gas cyclones. The cyclones are refractory lined conventional designed units. The separated solids leave the bottom of the cyclones and pass to the external heat exchanger (EHE). The hot flue gases leave the top of the cyclones and are ducted to a conventional convective boiler system to generate a portion of the total steam required.

External heat exchanger (EHE) with evaporative, superheat and/or reheat surface and solids return system via non-mechanical "L" valves

The separated solids from the bottom of the cyclones pass through the external heat exchanger (EHE). The EHE contains a non-combusting, gently fluidized, conventional bubbling bed. The fluidizing air for the EHE and air for the solids lines represents only a small portion of the total system air. The normal superficial fluidizing velocity is about 1 ft/sec. The EHE fluidizing air is set at a constant mass flow. After passing through the bed, the air is ducted from the EHE to the combustor vessel to form a small portion of the combustion air.

Because of the environment and the very low velocities, corrosion and erosion of pressure parts and supports is virtually undetectable. The heat transfer rate in the EHE is high and wide variations in operating conditions can be handled without a significant effect on combustion and sulfur dioxide retention. The high heat transfer rates also permit compactness of design and arrangement.

The EHE consists of cold and hot compartment(s). The solids from the cold compartment(s) at 1,100-1,200F are used both in the oxidizing and reducing zones to control temperature. As boiler load varies, the rate of solids is varied by controlling the non-mechanical "L" valves. This causes the EHE bed temperature to change which in turn alters the rate of heat transfer to the in-bed surface, and consequently, varies the amount of heat extracted and the degree of cooling provided by the recycle material in the combustor. Thus, the optimum operating temperatures in both the reducing and oxidizing zones can be maintained at a constant value over a wide load range completely independent from the combustion air and fuel feed controls.

The cold compartment(s) contain(s) the heat transfer tubes. The heat transfer surface is normally evaporative or a mixture of evaporative and superheat and/or reheat which generates the complement of the steam requirement (about 60% of the total duty).

The hot chamber(s) contain(s) a reservoir of hot solids where there is no heat transfer surface. The hot solids are first discharged from the cyclones into this compartment(s). The hot solids recycle rate may be set to provide an optimum total solids recycle rate to maximize combustion and sulfur dioxide retention efficiency. It has negligible effect on the MSFB system heat balance. Each of the compartments discharges into its own "L" valves and solids return pipe system.

Heat transfer surface

In addition to EHE, heat transfer can take place in the upper combustor waterwalls, if used, and via hot flue gases from the cyclone passing to a conventional convective boiler system followed by the use of an economizer and/or air heater located downstream of the boiler for final heat recovery.

Baghouse and ID fan

The flue gases from the heat transfer equipment described above normally pass to a baghouse for final particulate cleanup and then to the ID fan. The ID fan is controlled to maintain a negative pressure at the point of fuel introduction into the reducing zone of the combustor vessel. This minimizes the risk of blowbacks from the combustor and simplifies the fuel feeding system.

SYSTEM OPERATIONAL ASPECTS

Start-up

Start-up of the unit is effected by an oil or gas fired burner is series with, and between, the primary air fan and combustor. The primary air, and consequently, the dense bed and combustor is gradually heated until temperatures high enough to sustain stable combustion of main fuel are attained. Main fuel feed is then initiated, and start-up fuel reduced, to achieve a smooth transition to full solid fuel firing at a unit load of 6-10% MCR.

Since the temperatures of both zones of the combustor are separately controlled at very low operating loads good stable combustion of the main fuel can be maintained without the need for using an intermediate auxiliary fuel firing stage. Thus, the use of more expensive start-up fuels is minimized.

Load Response and Turndown

Depending on the boiler operating parameters, the load response rate varies from 5 to 15% of MCR per minute. This is compatible with conventional coal fired boilers.

As previously indicated, the actual load turndown ratio is high for a solid fuel fired boiler, with stable loads on main fuel firing as low as 10% MCR being attainable. The normal minimum operating load while maintaining very low levels of NO_X formation is 20-30% MCR depending on the stringency of the allowable NO_X emission level.

Emissions

High sulfur dioxide retention efficiencies of typically 80 to 95% can be achieved by the MSFB process. The required calcium to sulfur molar ratios consistent with this are 1.5 to 3.5 depending on a number of factors, the main one, of course, being the desired sulfur dioxide emission limit.

 NO_x and carbon monoxide levels of less than 100 ppmv each at MCR have been measured and these pollutants can be readily controlled below present day emission limits.

A major factor in the generation of all the above mentioned pollutants is combustion temperature. The realtive ease and degree of controllability of temperatures within the MSFB combustor make the system particularly suited to the optimization of emission control over a wide load range.

As previously mentioned, the emission of particulates to atmosphere is regulated by the use of a bag filter.

The process described provides an MSFB system, offering maximum FUEL FLEXIBILITY and the ability to meet STRINGENT EMISSIONS of NO_x and SO_2 .

MSFB UNITS OPERATING IN DESIGN OR CONSTRUCT STAGE

There are presently 12 MSFB units worldwide ranging in size from 85,000 to 660,000 lbs/hr (refer to Table I). Also note, the diversity of industries choosing fluid beds.

The largest single unit employing an MSFB is scheduled for start-up in the 3rd quarter of this year. The unit will be supplied to Idemitsu, a refinery operation in Japan. This unit shown in Figure 2 will handle several fuels and produce 660,000 lbs/hr at 1,865 psig and 1,004°F. The project evaluation involved a comparison of a pulverized coal system vs circulating fluid beds (both one and two units). The total operating and capital

	CUSTOMER	LOCATION	INDUSTRY	APPROXIMATE INITIAL OPERATION	CONDITIONS	FUELS & SORBENT
	соносо	UVALDĘ, TEXAS	ENHANCED OIL RECOVERY	12/82 1 UNIT	50 MM BTU/IIR 2450 PSIG 80% QUALITY	SEVERAL COALS PET. COKE LIMESTONE
	KERRY COOP	LISTOWEL, IRELAND	DAIRY PRODUCTS	4/84 1 UNIT	117,000 LBS/HR 350 PSIG 435°F	COALS, PEATS WOODCHIPS SAWDUST ANTHRACITE
	 GENERAL MOTORS TRUCK AND BUS GROUP 	FORT WAYNE, INDIANA	AUTOMOTIVE	11/86 2 UNITS	150,000 LBS/HR 700 PSIG 755°F	COALS, WASTES PAINT SLUDGES LIMESTONE
	• KURARAY	JAPAN	TEXTILES	9/86 1 UNIT	154,000 LBS/HR 1280 PSIG 905⁰F	ANTHRACITE DELAYED COKE LIMESTONE
<i>n</i>		SCOTLAND	CHEMICALS	3/87 1 UNIT	85,000 LBS/HR 650 PSIG 850°F	COALS, PEATS HEAVY OIL PLASTIC WASTES
	• U. OF MISSOURI	COLUMBIA, MO.	UNIVERSITY	9/87 1 UNIT	200,000 LBS/HR 950 PSIG 850°F	COALS LIMESTONE
	• U. OF IOWA	IOWA CITY IOWA	UNIVERSITY	9/88 1 UNIT	170,000 LBS/IIR 475 PSIG 760°F	COALS LIMESTONE
	• IDEMITSU	JAPAN	REFINERY	6/87 1 UNIT	660,000 LBS/HR 1865 PSIG 1004°F	COALS LIMESTONE
	• A.E. STALEY	DECATUR, ILLINOIS	FOOD PROCESSING	10/88 2 UNITS	375,000 LBS/HR 1265 PSIG 955°F	COALS
	* ARCHBALD POWER CORP.	ARCHBALD, PENNSYLVANIA	COGENERATION	10/89 1 UNIT	200,000 LBS/HR 1335 PSIG 955°F	ANTHRACITE CULM LIMESTONE

* Designed under license with or supplied by Riley Stoker



IDEMITSU KOSAN CO. CHIBA REFINERY LTD.

Figure 2

cost evaluation of a single chamber 660,000 lbs/hr Multi-Solid Fluid Bed (MSFB) unit was chosen. Mitsui Engineering and Shipbuilding as a sublicensee of Riley Stoker is supplying this unit. The unit, a single chamber combustor, will utilize waterwalls in the upper combustor and the external heat exchanger where evaporative duty as well as some superheat duty will be performed in separate compartments. For large units employing reheat the external heat exchanger provides flexibility to separately control the reheat. This will be discussed in the next section.

The largest MSFB units presently in the U.S. are the A.E. Staley jobs for a food processing operation in Decatur, Illinois. There will be two units each rated at 375,000 lbs/hr at 1,265 psig and 955°F. Figure 3 shows a cross section of this unit.

Riley Stoker will use an MSFB to burn anthracite culm north of Scranton in Archbald Borough to produce over 20 MW of power to be sold to Pennsylvania Power and Light and utilize steam for a greenhouse facility which will produce lettuce.

Riley Stoker will construct the power plant and greenhouse on a turnkey basis and will operate and maintain the plant under a 15 year contract.

The key again with all the units is fuel flexibility and emissions. The units can handle coal $2'' \times 0$ at the inlet to the combustor as well as anthracite fines. The dense bed holds down fines and breaks up the larger particles. The other unique feature of the MSFB is the external heat exchanger which allows variations in heat content, moisture, and ash with essentially independent control from the combustion process. The separate chambers allows flexibility of control for reheat applications.

UTILITY SIZE UNITS WITH REHEAT

Figure 4 depicts a 140 MW unit designed for 1,005°F superheat and 1,005°F reheat temperatures. As can be seen, this unit is not significantly different from the units without reheat shown in Figures 2 and 3. The real difference is the reheater which is located in a separate compartment in the EHE. By the use of this configuration, no heat will be transmitted to the reheater until the solids recirculation is initiated through the compartment by the L-Valves dedicated to it. Thus, the reheater is automatically protected during start-up.

The main reheat temperature control is affected by control of the hot solids flowing through the reheat compartment of the EHE. A reheat spray system is provided for fine tuning only.

To date, this 140 MW unit is the largest single unit MSFB designed. The utility industry is concerned about scale-up. At this point, the upper limit for a single combustor has not been determined. The limiting factors will be the configuration of the peripheral equipment and not the combustor size itself with an MSFB.

SUMMARY

Because of cogeneration as a driving force in the industrial sector the units use relatively high temperatures (90/950F) and pressures (1,800 psi). Although smaller in capacity (up to 100 MW equivalent), these units provide a realistic proving ground for utility class design. The transition from 1,800 psi to 2,400 psi cycles is not difficult and can readily be predicted. Utility choice of fluid bed in the 100 to 150 MW size is a reality today. With units conceptualized up to 300 MW, units in the 100 to 300 MW class will be a reality in the near future.

Riley Stoker's MSFB (Multi-Solid Fluid Bed) system with a dense bed provides enhanced flexibility with respect to fuel and sorbent selection allowing the opportunity to optimize costs. The external heat exchanger, as an integral part of the system, provides an environment for efficient heat transfer essentially independent of the combustor. With the external heat exchanger separate compartments to control evaporative duty, superheat and/or reheat duty provides system flexibility. Large units with reheat can have independent control of reheat steam temperature over the load range with protection of reheat surface during start-up.



A.E. STALEY DECATUR, ILLINOIS

Figure 3



1,000,000 lbs/hr @ 1,005°F and 1,890 psig

Figure 4

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Circulating fluid beds will be a proven technology in larger size range in the near future. Riley's MSFB (Multi-Solid Fluid Bed) is ready to serve the utility sector.

The Company reserves the right to make technical and mechanical changes or revisions resulting from improvements developed by its research and development work, or availability of new materials in connection with the design of its equipment, or improvements in manufacturing and construction procedures and engineering standards.