UTILITY FLUIDIZED BED: GOALS, OBSTACLES, POTENTIAL

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Much has been and will be written on the subject of Fluidized Bed Combustion (FBC). The technology has gained wide and rapid acceptance within the industrial sector, and growing sincere interest on the part of the utility sector.

Fluidized Bed Combustion is current in our vocabulary, but the concept is far from new. It was invented by Fritz Winkler of the United States in 1921 to manufacture fuel gas by burning coal in suspension. Since that time, substantial development has resulted in the wide application of the FBC process to the industrial steam cycle. The most widely applied FBC process is at atmospheric pressure. Atmospheric Fluidized Bed Combustion (AFBC) operates, as its name would imply, at atmospheric pressure much like a balanced draft power boiler. Another widely discussed process is Pressurized Fluidized Bed Combustion (PFBC). In the PFBC process, the products of combustion are pressurized within the combustor to approximately four atmospheres. This means that all of the combustion and heat transfer reactions occur at rates greater than those within the atmospheric combustor. Thus, for a given capacity, pressurized combustors can be substantially smaller in size. Figure 1 reflects the relative size of the combustor in a pressurized fluidized bed system when compared with an atmospheric combustion system.

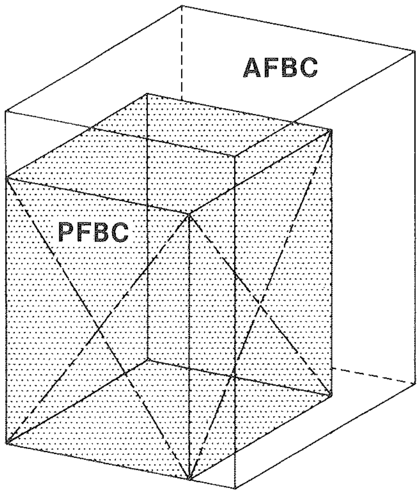


Figure 1 Relative Size of AFBC & PFBC Combustors

There is an apparent advantage for the Pressurized Fluidized Bed boiler considering the higher power density. As in any technology, however, one does not get the advantages without needing to overcome some developmental needs. Whenever a combustion process is occurring at high pressures, the potential for fuel, sorbent and ash leaks is ever present. Typically a pressurized boiler operates at 8 - 10 inches of water pressure, while a PFBC would operate at four atmospheres or approximately 1,600 inches of water pressure. Since PFBC is in the early developmental stages, I will concentrate my discussions today on the AFBC process.

At the heart of a fluid bed combustor, we find a chemical reactor that, with the addition of sorbents such as limestone or dolomite, combusts the fuel under very controlled conditions. By maintaining tight control of the fuel, sorbent, and air, we dictate the combustion rate and, thus, the outcome of the process. This differs from the limitations we have in our direct fired boilers where we cannot control sorbent effectiveness without increasing carbon loss. Figure 2 shows the basic components of a fluidized bed combustor.

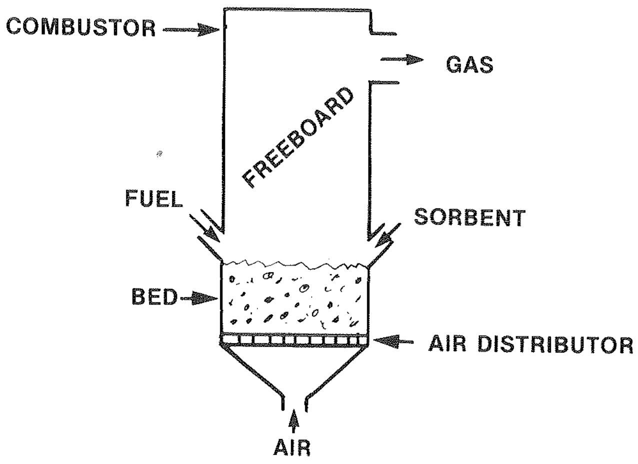


Figure 2

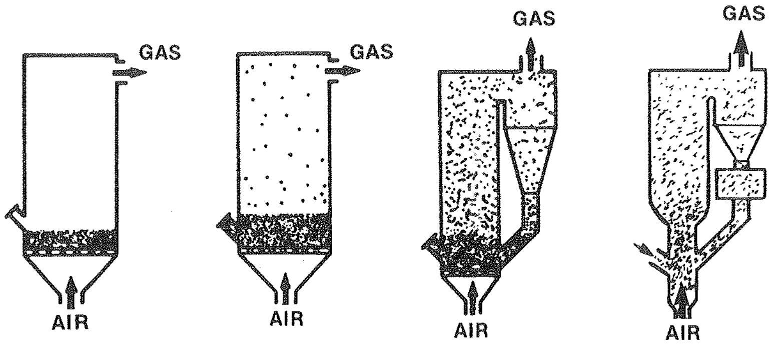
Early applications of AFBC demonstrated its ability to burn fuel in an environmentally acceptable way with adequate combustion efficiencies. This basic AFBC process evolved into several design types, ranging from a bubbling bed with its low velocities and high freeboards, to a dense phase recirculation of solids to enhance retention time and carbon burnout. Figure 3 shows the AFBC types with their respective design criteria.

Each manufacturer has established its own AFBC arrangement, based on the combustion process, manufacturing capabilities, and internal development efforts. This explains the differences in cross sections of AFBC boilers. In addition to the basic combustion process, individual manufacturers deviate in applying steam generation surface within the combustor. You will note in Figure 4 the basic types of surface that can be applied to any of the combustion systems outlined above.

Having reviewed the basic process and how it applies to steam generation, let's ask ourselves what are the goals of AFBC steam generation. The broad goal is clearly that:

> THE AFBC PROCESS PROVIDES THE OPPORTUNITY TO BURN A WIDE RANGE OF SOLID FUELS IN A ENVIRONMENTALLY ACCEPTABLE WAY FOR THE EFFICIENT AND RELIABLE GENERATION OF STEAM.

In applying this goal to a boiler system, we are utilizing the inherent process advantages of AFBC. Figure 5 shows how NO_X formation is very sensitive to combustion temperature, while Figure 6 shows that SO_2 formation is insensitive to combustion temperature. These facts have been the basis of low NO_X burner development, recognizing that the basic combustion process will have little or no impact on the SO_2 generated within



	STOKER	BUBBLING	CIRCULATING	MSFB
FIREBOARD HEIGHT	8-10 FEET	10-20 FEET	30-60 FEET	30-60 FEET
SUPERFICIAL VELOCITY	4 FPS	8 FPS	15 FPS	30 FPS
EXCESS AIR	20-25%	20-25%	10-15%	10-15%
Ca/S RATIO	N.A.	3:1	2.2:1	2.2:1
COAL SIZE	1-¼″ × ¼″	¼″ × 0	½″ × 0	2″ × 0
TURNDOWN	4:1	3:1	3:1	6:1
COMBUSTION EFFICIENCY	85-90%	90-95%	99%	99%
NO_X EMISSIONS	400-600 PPM	300-400 PPM	100-200 PPM	100-200 PPM
SO_X CAPTURE	N.A.	80-90%	90+%	90+%

Figure 3 Comparative Design Criteria

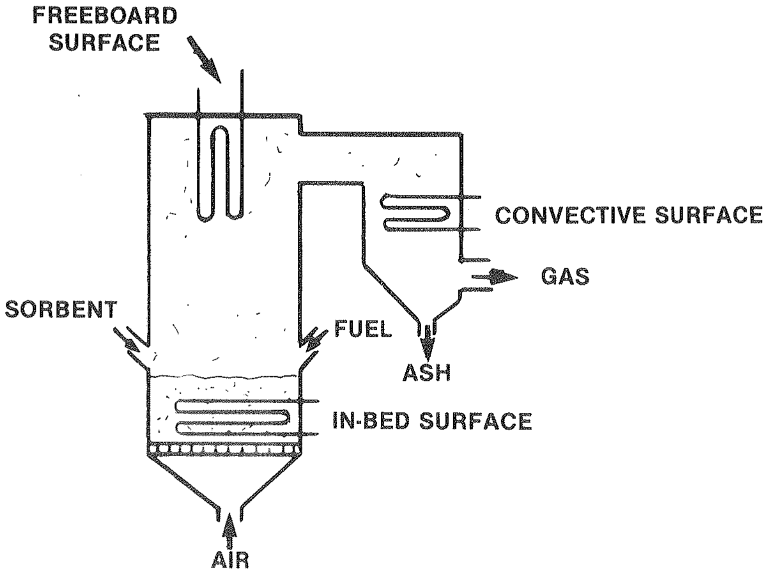


Figure 4 Alternate Surface Arrangements

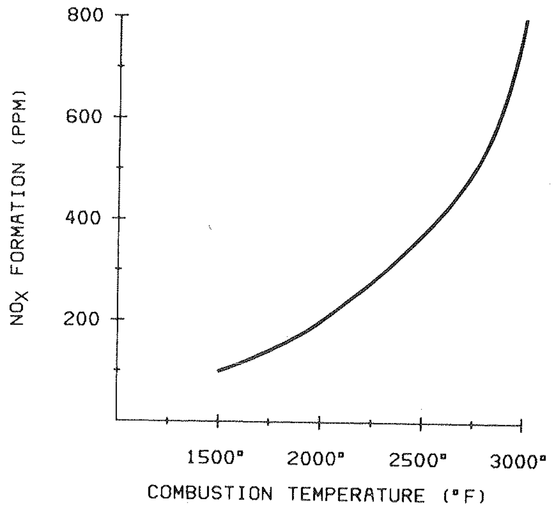


Figure 5

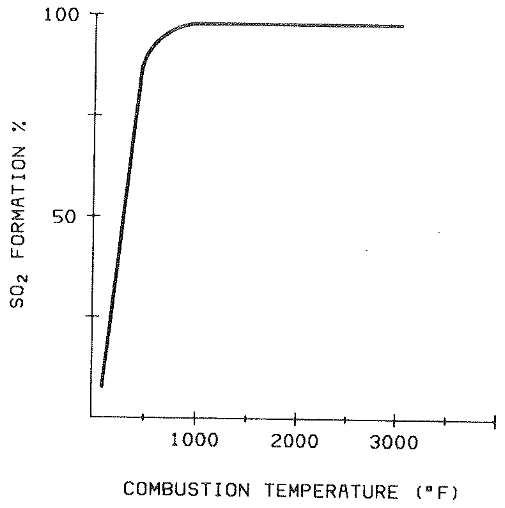


Figure 6

the coal fired boilers. There are optimum temperatures for capturing SO_2 but they are very different temperatures than suggested for minimizing the NO_X formation.

Figure 7 depicts the different temperatures generated by a traditional pulverized coal burner, a low NO_X burner, and AFBC operating temperatures. Note that even the significant temperature differences between the combustion processes is not enough to eliminate the formation of SO_2. Thus, AFBC seeks to operate in a temperature regime that maximizes the capture of SO_2 within the bed itself. Figure 8 shows how establishing the proper operating temperature maximizes the sulfur capture and allows good combustion efficiency. It is this combination of low temperature and ability to absorb SO_2 within the combustion process that makes the fluidized bed combustor an exciting and growing technology to meet the needs of future steam generation in an environmentally acceptable manner.

Riley Stoker Corporation evaluated several AFBC systems before deciding on licensing the Battelle technology known as the Multi-Solid Fluidized Bed process (MSFB). Our evaluation showed that the MSFB process, Figure 9, offers the advantages outlined in Figure 3 over other circulating and traditional bubbling bed systems.

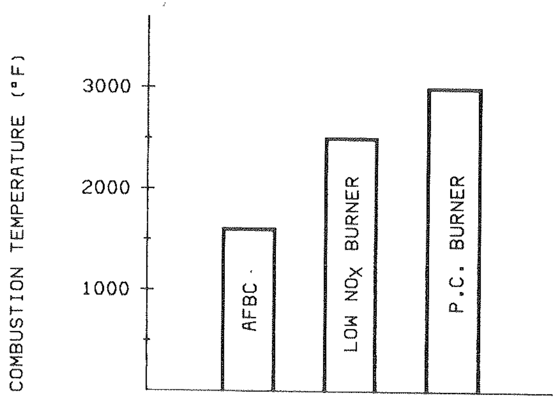


Figure 7

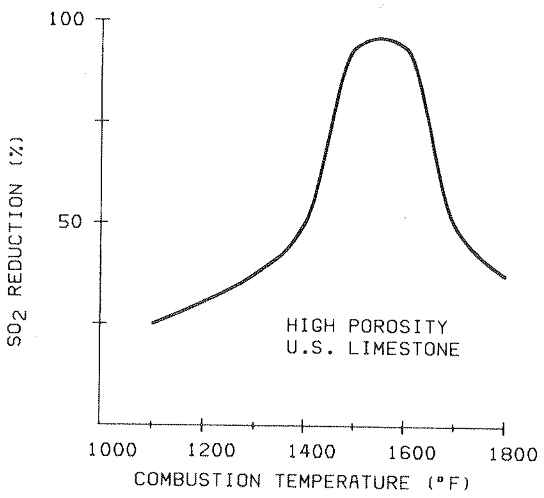
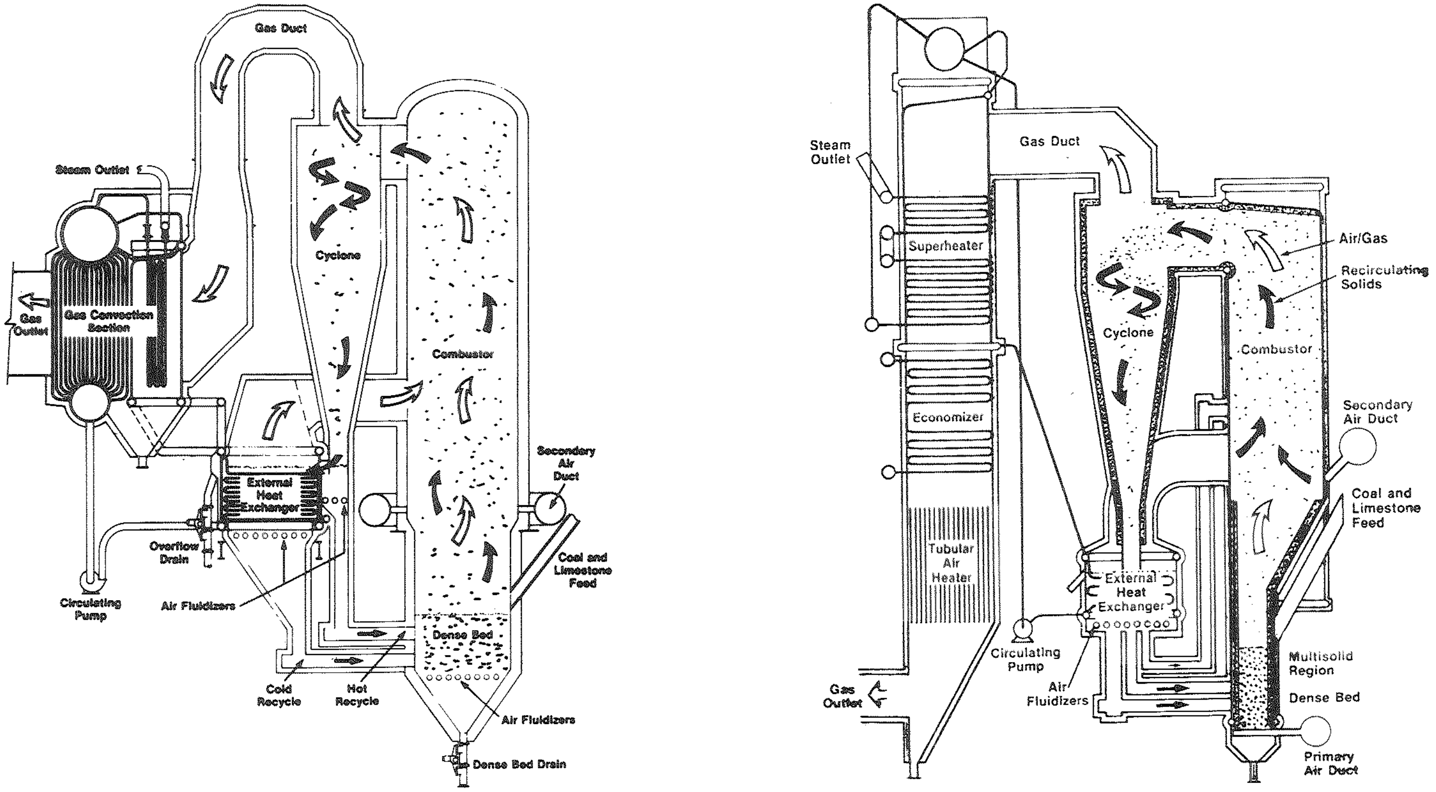


Figure 8



Low Pressure MSFB Design

High Pressure MSFB Design

Figure 9

- MEET OR EXCEED ALL FEDERAL AND STATE EMISSION REQUIREMENTS
- BURN WIDE RANGE OF FUELS
- LOW EVALUATED CAPITAL COST
- HIGH AVAILABILITY/RELIABILITY
- LOW OPERATING COSTS
  - HIGH COMBUSTION EFFICIENCY
  - LOW SORBENT UTILIZATION RATE
  - LOW POWER CONSUMPTION
- EASY OPERATION
- LOW MAINTENANCE COST
- MINIMIZE FUEL PREPARATION
- MINIMIZE SORBENT PREPARATION
- USE DEMONSTRATED TECHNOLOGY

Table I New Boiler Design Goals

- ALL NEW BOILER GOALS
- MATCH EXISTING TURBINE/BOILER CYCLE
- MAXIMIZE USE OF EXISTING AUXILLIARY EQUIPMENT
- FIT WITHIN PHYSICAL PLANT CONSTRAINTS

Table II Retrofit Boiler Design Goals

Another advantage of licensing the technology from Battelle is a full technology exchange between their worldwide licensees. This provides for immediate feedback as new units are brought into service and operated. It is Battelle's intent, through this license exchange, to insure that the latest state-of-the-art knowledge is made known and incorporated into new unit designs.

From an overall boiler design standpoint, we have to separate new boiler designs from retrofit concepts. You will note in Table 1 that we have the same basic criteria that we would have for any new Utility unit. In Table 2, it is assumed that all of the goals established for a new boiler are consistent with retrofit application. The other goals listed relate to site-specific and cycle-specific needs of given power plants. As you can see, new designs and retrofits of fluidized bed combustion within a Utility system require a full analysis of the site-specific cycle and environmental requirements.

It's important to have a perspective of how much experience exists within the industry to substantiate the ability to meet the goals stated above. You will note in Table 3 that the domestic operating experience has basically been limited to low temperature/capacity boilers plus the 20MW boiler development program at TVA.

PLANT OWNER	PLANT LOCATION	1000 PPH CAP.	PSIG OPER. PRES.	°F OPER. TEMP.	COMM. OPER. DATE
TVA	Shawnee, TN	1100	1800/ 450	1000/ 1000	1989
Northern States Power Company	Burnsville, MN	1039	1525	1005	5/86
Colorado Ute Electric Assn.	Nucla, CO	925	1510	1005	NAv
Archer Daniels Midland Company	Iowa	477	1310	900	1986
Archer Daniels Midland Company	Illinois	425	1310	900	1986
General Motors	Pontiac, MI	300	1460	955	NAv
Ultrapower Inc.	W. Enfield, ME	224	1325	955	4/86
Ultrapower Inc.	Chinese Sta., CA	209	1250	950	10/85
California Portland Cement Company	Colton, CA	190	650	825	3/85
TVA	Paducah, KY	170	2400	1000	6/82
General Motors	Ft. Wayne, IN	150	700	755	9/86
Northern States Power Company	Lacross, WI	150	450	750	12/81
Biogen Power Inc.	Ivanpah, CA	135	1500	1000	6/86
B.F. Goodrich Co.	Henry, IL	125	230	400	NAv
Quaker State Oil Refining Corp.	Newell, WV	120	265	525	2/85
Midwest Solvents Co.	Perkin, IL	120	686	755	4/84
GWF Power Systems	Torrance, CA	106	600	1450	11/85
Georgetown University	Washington, DC	100	275	Sat.	7/79
Central Soya Co.	Chattanooga, TN	88	190	Sat.	NAv
Sohio Corp.	Lima, OH	70	650	705	10/84
20 Other Installations Below	70,000 pph				

Table III Units Sold in the United States

- LOW UTIILITY GROWTH RATE
- DIMINISHED INTEREST IN SOLID FUEL R&D
- LOCATING CUSTOMERS WILLING TO COMMIT TO AFBC
- LACK OF NSPS AND/OR ACID RAIN LEGISLATION
- COMPETITION FROM DRY SCRUBBER AND LIMB DEVELOPMENT
- CONCERNS OF CAPACITY/TEMPERATURE SCALE-UP
- LONG TERM IMPACT OF ASH LOADING
- REPUTATION OF EARLY AFBC WORK INFLUENCING FUTURE TRENDS/DECISIONS

Table IV Obstacles to Utility Use of AFBC

While the domestic experience was growing, European experience with large capacity/high temperature circulating fluidized bed boilers also grew. Current European operating experience has been limited to 840,000 pph and temperatures of 850°F. The technology is directly applicable to domestic technology and has increased the domestic confidence level to accept AFBC as a process that can and does work.

Three MSFB systems have been sold to date. The first system was sold to Conoco for their Uvalde, Texas enhanced oil recovery field application. It is a 50,000 pph boiler with an operating pressure of 2,450 psig and a steam temperature of 665°F. It was placed in service in December of 1981 and was the forerunner of later designs. The second unit sold was the Kerry Co-operative unit in Listowel, Ireland supplying steam to a dairy co-operative. It is a 117,000 pph unit operating at 350 psig and 430°F. The third system sold was to General Motors Corporation, Fort Wayne, Indiana, for a new truck factory. It consists of two 150,000 pph units operating at 700 psig and 755°F.

Table 4 outlines the obstacles to a continuing growth and acceptance of AFBC in the United States. For the most part, it centers around capacity/temperature extrapolation and the need for reliable and demonstrated sub-systems. In spite of the obstacles, it is clear that AFBC is and will be a major force in the steam generation marketplace.

As we review the potentials for fluidized bed combustion in the utility market, it is quite evident that new construction coupled to low power growth will be the inhibiting factor controlling the purchase, design and construction of new Utility AFBC bolers. Considering existing power plants, however, the potential for significant fuel savings through the use of retrofit MSFB technology on existing coal, oil and gas fired boilers exists. An MSFB boiler is capable of burning a very wide range of coals, thus allowing fuel procurement to be responsive to market conditions. The fuels can range from lignite to bituminous without major equipment or boiler surface changes being required; a routine operating adjustment is all that is required. In addition to the range of coals identified, the MSFB has successfully burned:

Delayed Coke
Fluid Coke
Char
Anthracite Culm
Rock Containing Bitume
Municipal Waste
Wood Waste
Sewage Sludge
Industrial Waste
Kraft Liquor

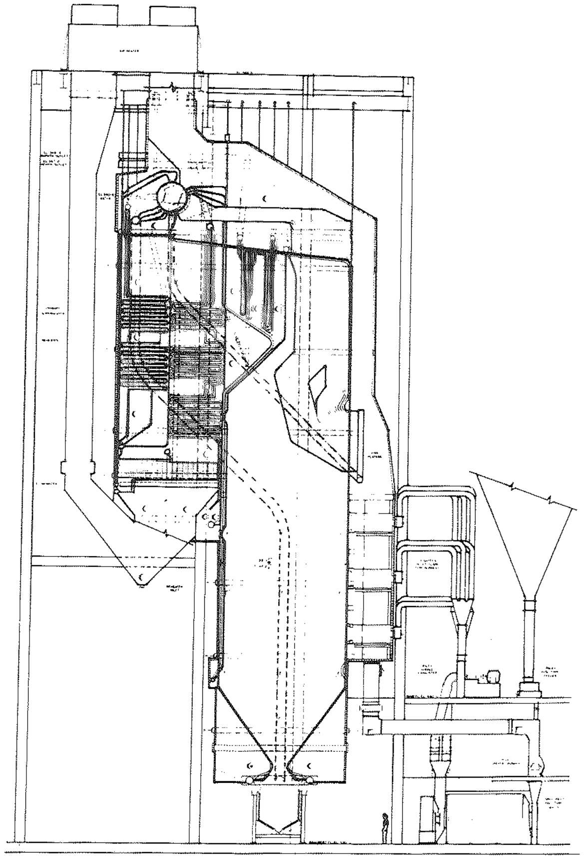


Figure 10 Typical 1,000,000 lbs/hr Utility Boiler

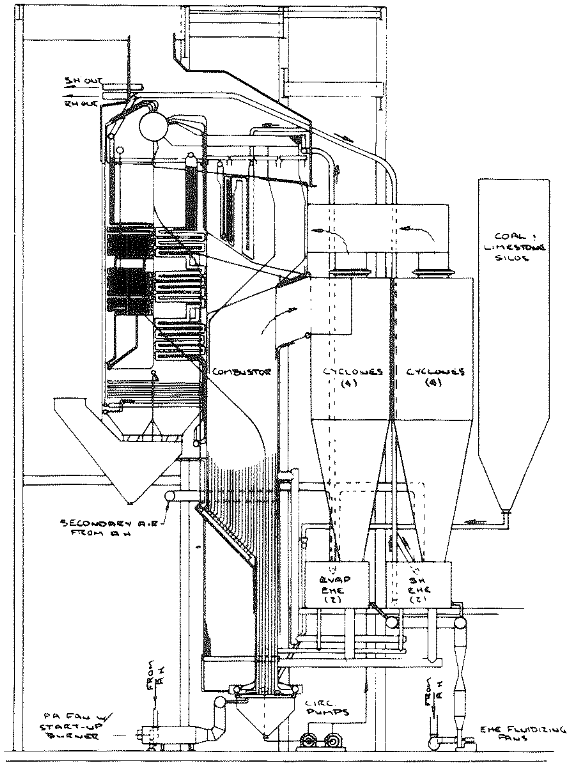


Figure 11 Utility Boiler - After Conversion to MSFB

CHARACTERISTICS	COMBUSTION TYPE		
	OIL	P.C.	MSFB
CAPACITY (LBS/HR)	1,000,000	1,000,000	1,000,000
OPERATING PRESSURE (PSIG)	1850	1850	1850
STEAM TEMPERATURE (°F)	1005/1005	1005/1005	1005/1005
PULVERIZERS (NO/HP)	N.A.	3@ 400	N.A.
FUEL SIZE (MESH)	N.A.	70% < 200	2″ × 0
SORBENT SIZE (MESH)	N.A.	N.A.	10
BOILER EFFICIENCY (%)	86.05	88.85	86.78
OVERALL CAPACITY FACTOR (%)	75	75	75
FUEL PRICE ($/MM BTU)	$4.60	$2.00(1%)	$1.80(3%)
ANNUAL FUEL COST (MM$)	42.32	17.83	16.42

Table V Performance Characteristics of an MSFB Conversion

Riley recently received an inquiry and performed a study to convert an existing Utility boiler to burn high sulfur coal *and* reduce emissions. Figure 10 shows the cross section of the boiler which was studied. Figure 11 shows the same boiler after pressure part and plant arrangement changes were made to incorporate MSFB combustion technology into the plant. One of the interesting side benefits of this conversion study was the potential to integrate pressure part changes with a boiler life extension program. The modified boiler would be capable of achieving state-of-the-art environmental and combustion efficiencies, and last for another 25 to 30 years. Anticipated performance characteristics before and after conversion to an MSFB are shown in Table 5.

While our Utility work to date has been studies, the potential benefit to the utility industry is enormous. Considering the new 160MW unit for TVA, Northern States Power Company's conversion of a 1,000,000 pph unit, and the construction of Colorado Ute Electric Association's new 925,000 pph unit, it is clear that utilities are emerging as accepted users of AFBC technology.