UTILITY FLUIDIZED BED
WHERE WE ARE TODAY

by
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As we identify the power systems which will be purchased in the future by the Utility Industry, we should organize the technologies along a demonstration continuum. Such an organization is shown in Figure 1.

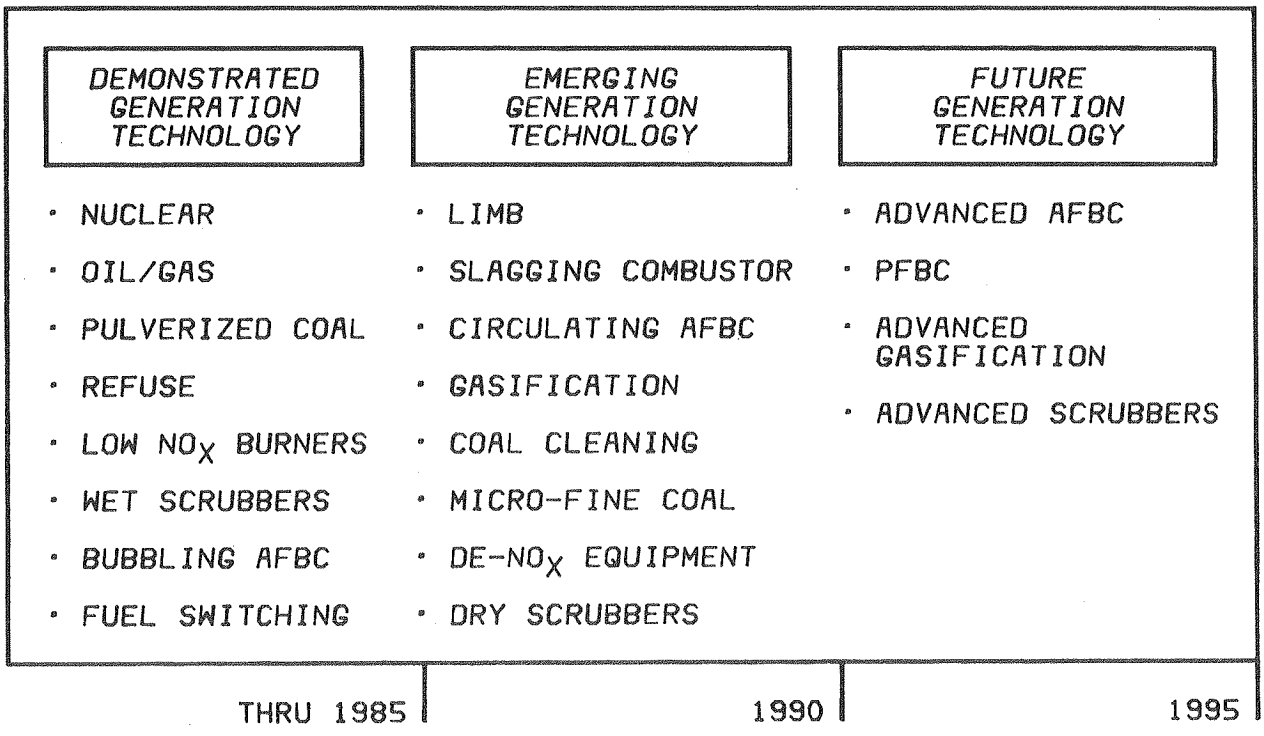


Figure 1 Utility Technology Development

Overlaying the available technologies, we must evaluate what will happen to the price of fuel. Figure 2 shows the oil/gas projection over a two year period. Note the substantial change that we have come to surely realize. While the price of oil in the world market will have an impact in the short term, it is our opinion that the long term energy needs of the Utility Industry will best be served by coal (assuming the Nuclear Industry is not revitalized). To serve this market, Riley is concentrating its' investment and development in the Circulating Fluid Bed area.

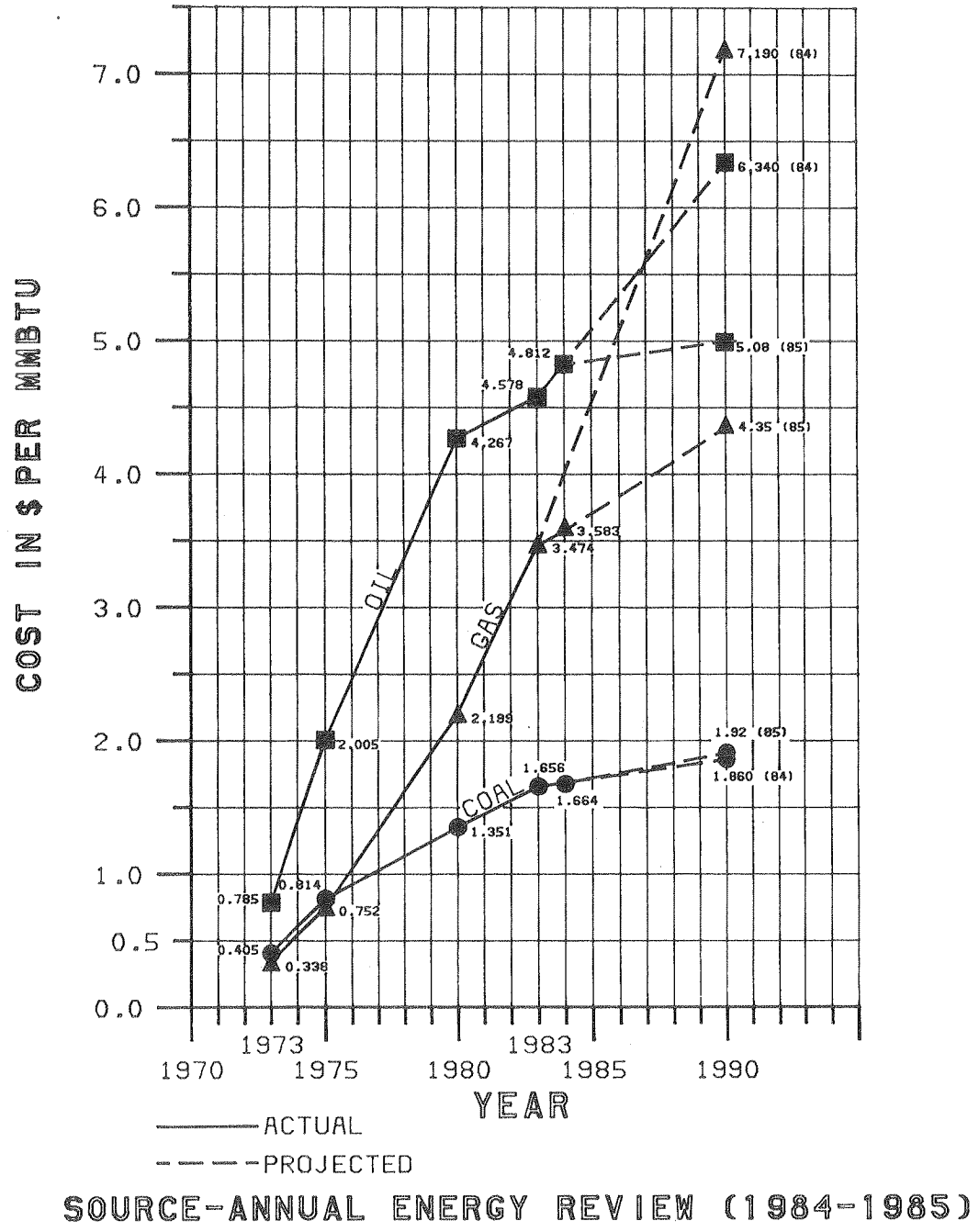


Figure 2 Cost of Fossil Fuels Delivered to Steam-Electric Utility Plants

While Circulating Fluid Bed Technology is identified above as emerging technology, it is rapidly moving to high levels of acceptance within the Industrial Market - and ultimately within the Utility Market. An historic overview of the Circulating Fluid Bed Market within the United States is shown in Figure 3. As the number of units sold increased, the average size of the units also increased, as shown in Figure 4.

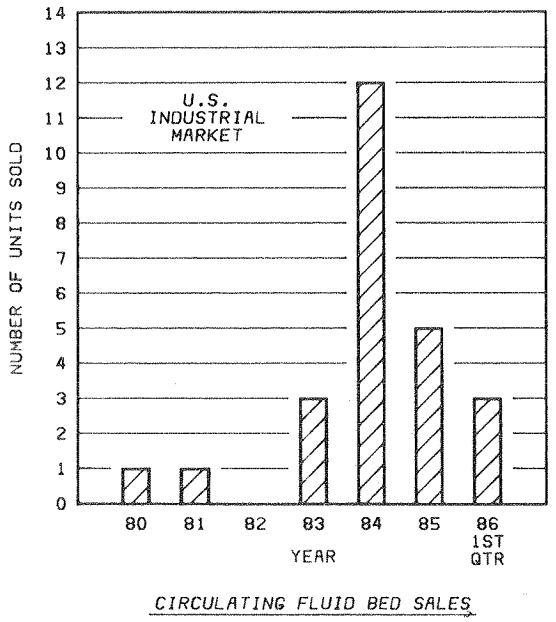


Figure 3

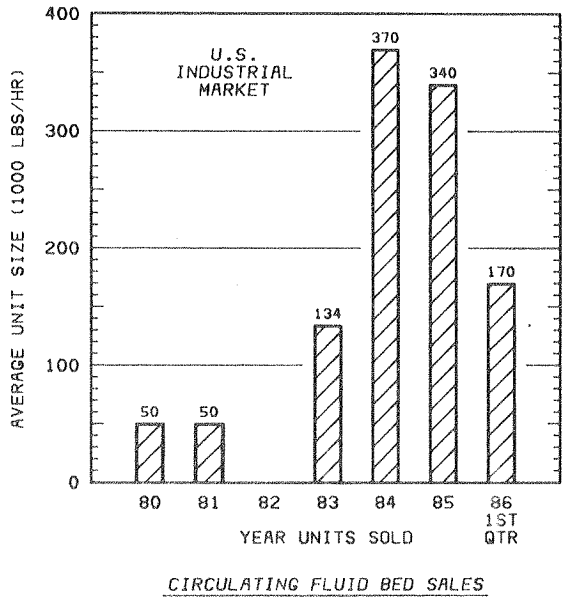
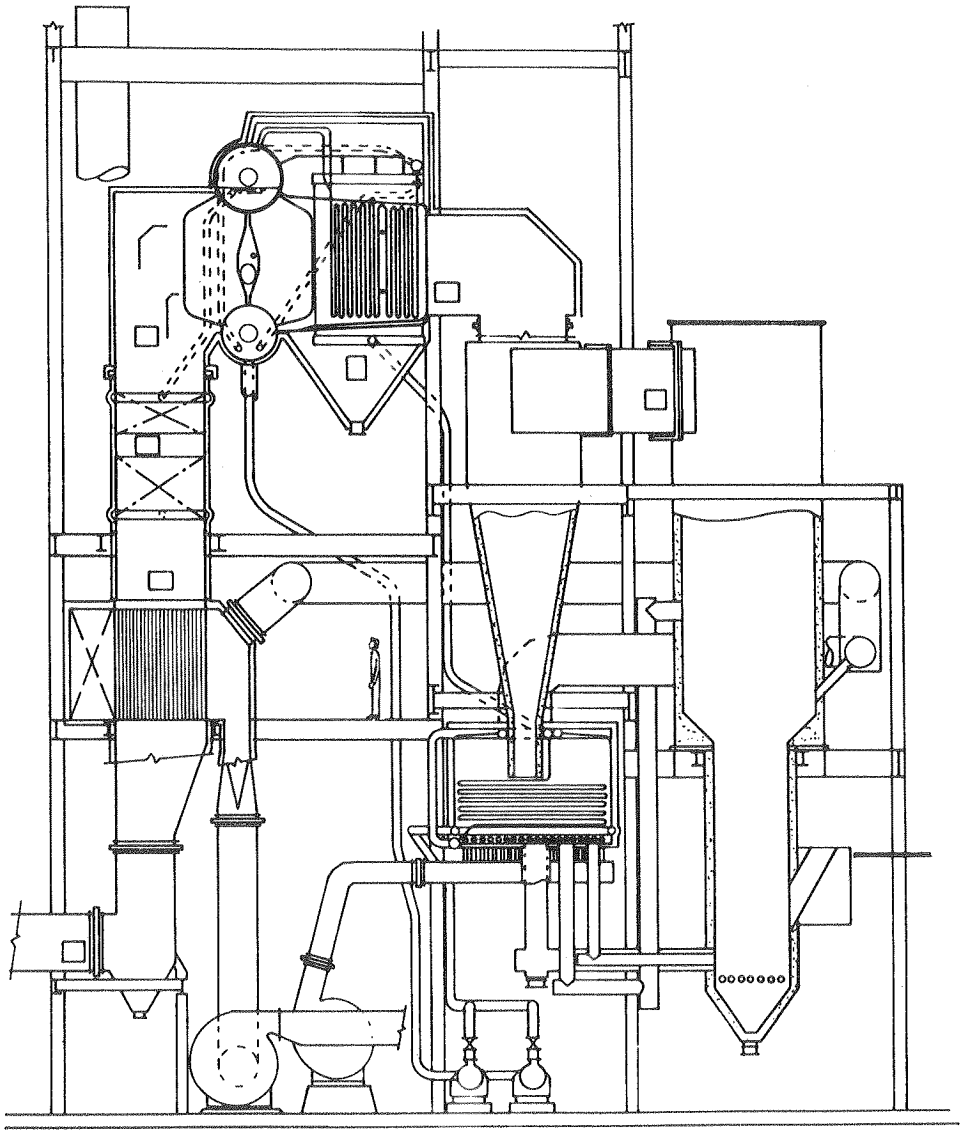


Figure 4

The circulating fluid bed boiler offered by Riley is the Multi-Solid Fluid Bed boiler (MSFB). The basic process technology and patents were licensed from Battelle Memorial Institute, and integrated into Riley's boiler design know-how. The outcome of this team effort is a demonstrated combustion/absorption process coupled to traditional heat transfer components which have previously been used and have demonstrated reliabilities equal to pulverized coal fired boilers.

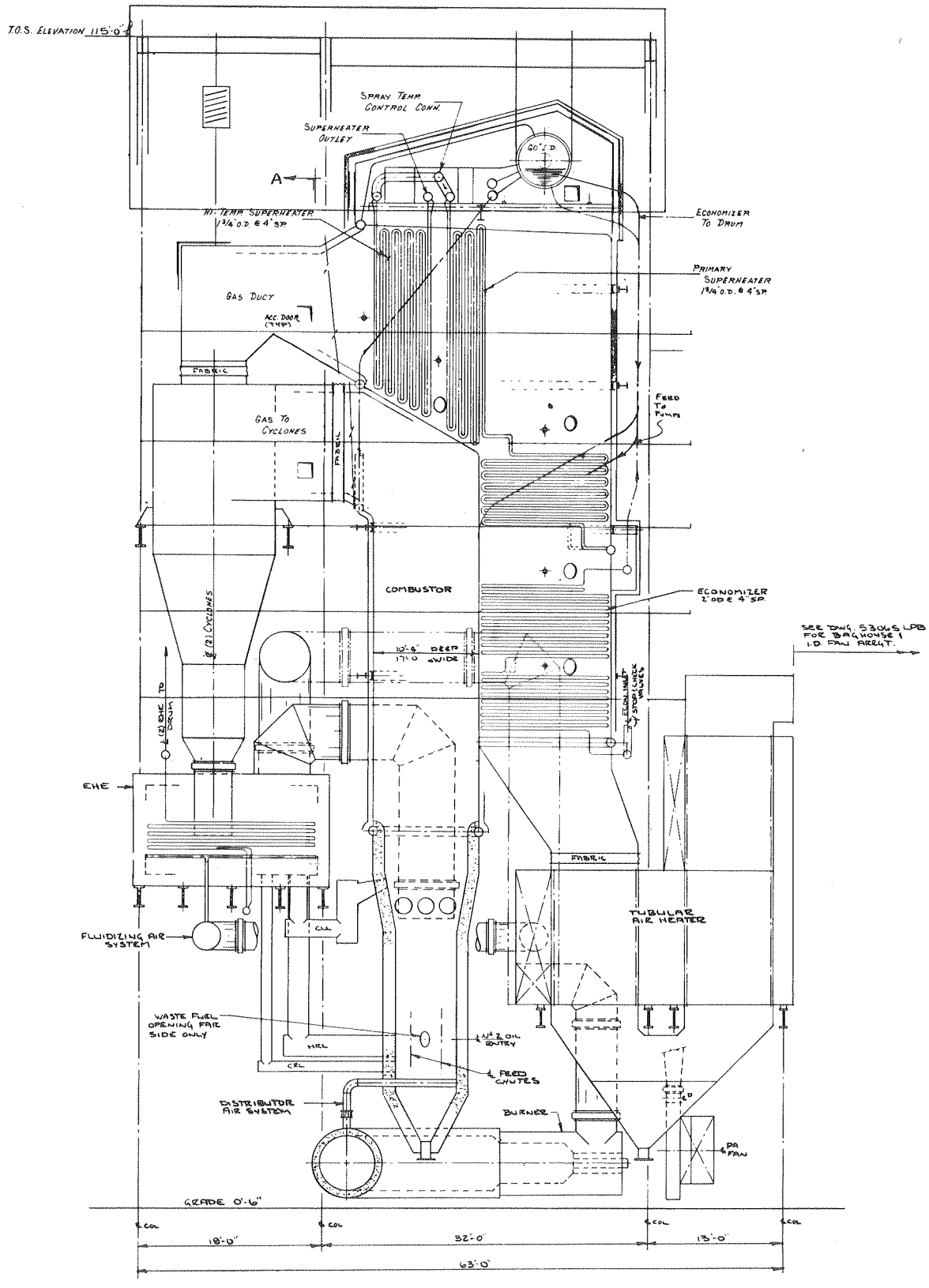
Typically, the Utility Industry has been very conservative and if we examine the unit size growth curve of the early fossil years, we'll see a similar curve to the AFBC growth curves above. One important point exists in the AFBC transition from the Industrial Market to the Utility Market. Industrial boilers today are using high temperatures (900/950° F.) and pressures (1800 psi) to meet co-generation opportunities. This gives the early industrial technology development a springboard to the Utility Market.

Specifically, the transition from early, low pressure/temperature units have seen the MSFB evolve from a two drum process plant design shown in Figure 5 to the single drum unit shown in Figure 6.



150,000 lbs/hr—700 psig operating—755F

Figure 5



320,000 lbs/hr—1500 psig operating—950F

Figure 6

The need for the different designs emanates from the difference in heat transfer surface requirements. Figure 7 shows how the duty changes in the two designs.

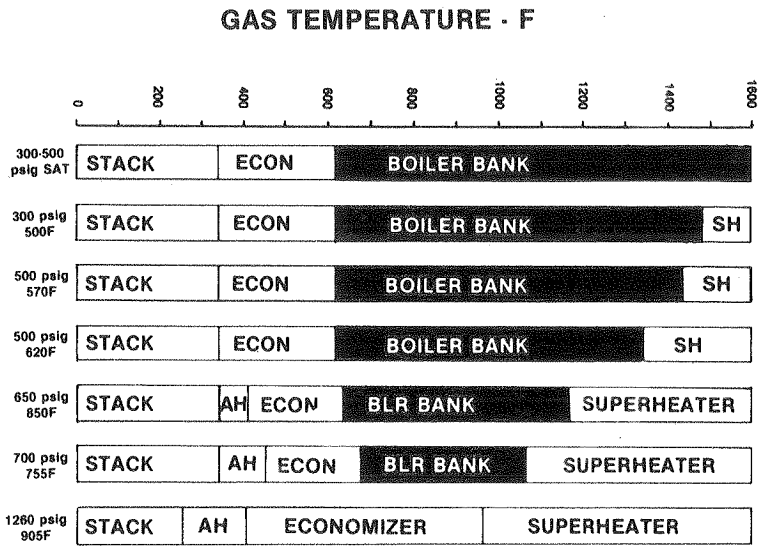


Figure 7 Gas Side Heat Recovery

Our current backlog of MSFB projects is shown on Figure 8. It is of interest to note that the Conoco unit shown was the first circulating fluid bed boiler sold and installed in the United States. The cross sections of these units are typically shown on Figures 5 and 6. This Riley backlog of work shown in Figure 9 represents a growing share of the emerging Circulating Fluid Bed Market.

CUSTOMER	LOCATION	INDUSTRY	APPROXIMATE INITIAL OPERATION	CONDITIONS	FUELS
CONOCO	UVALDE, TEXAS	ENHANCED OIL RECOVERY	12/82 1 UNIT	50 MM BTU/HR 2450 PSIG 80% QUALITY	SEVERAL COALS PETROLEUM COKE
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	9/86 2 UNITS	150,000 LBS/HR 700 PSIG 755°F	COALS INDUSTRIAL WASTES PAINT SLUDGES
KURARAY	JAPAN	TEXTILES	4/86 1 UNIT	154,000 LBS/HR 1280 PSIG 905°F	S. AFRICAN ANTHRACITE DELAYED COKE
ICI	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
U. OF IOWA	IOWA CITY IOWA	UNIVERSITY	9/88 1 UNIT	170,000 LBS/HR 475 PSIG 760°F	COALS

Figure 8 MSFB Units Operating, in Design, or Construction Stage

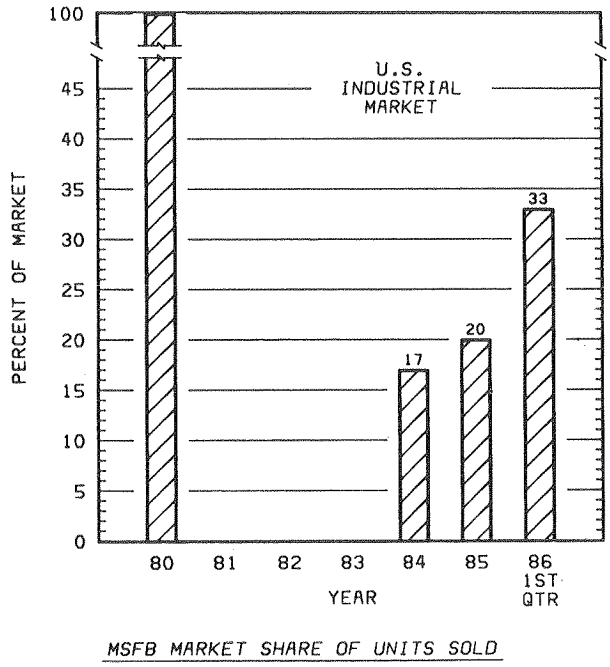


Figure 9

With the trend toward larger units, Riley has performed design studies/proposals for several large units and is now prepared to offer a 100 MW unit with or without reheat. Figure 10 shows examples of study/proposal work being requested.

RECENT MSFB PROPOSALS/STUDIES

CAPACITY (#/HR.)	TEMP(°F.)	PRESSURE(PSI)	FUEL
110,000	950	1,450	Coal
180,000	950	1,500	Anthracite Culm
320,000	950	1,500	Coal
500,000	955	1,550	Coal
500,000	950	1,600	Diatomite
515,000	955	1,550	Diatomite
565,000	1000/1000	2,000	Coke
600,000	960	1,540	Coal/Coke
661,000	1,004	1,800	Coal
790,000	1000/1000	1,625	Coke
1,000,000	1005/1005	1,800	Coal

Figure 10

As stated earlier, the impact of co-generation can be seen in the pressure/temperature requirements of the units outlined in Figure 10.

The transition from 1800 psi to 2400 psi is not difficult and can readily be predicted. Incorporation of reheat steam within the MSFB system is no more difficult than the complexities of a reheat pulverized coal unit. The heat balance can be predicted by manufacturers with reheat unit experience. The industry's known concerns (such as supports, metal temperatures during hot and cold starts, low pressure drops, low mass flows, etc.) must be adequately addressed in the design. Typical designs for large circulating fluid bed boilers are shown on Figures 11 through 13.

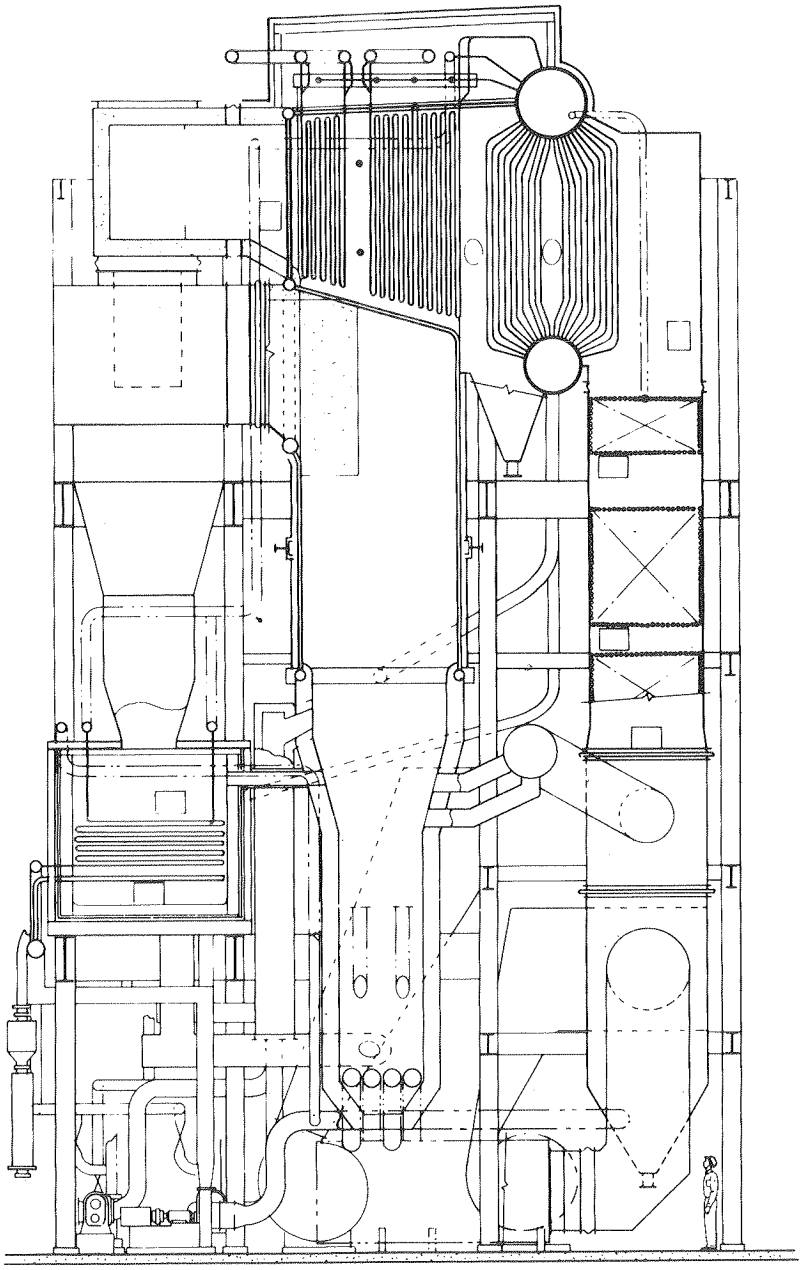


Figure 11

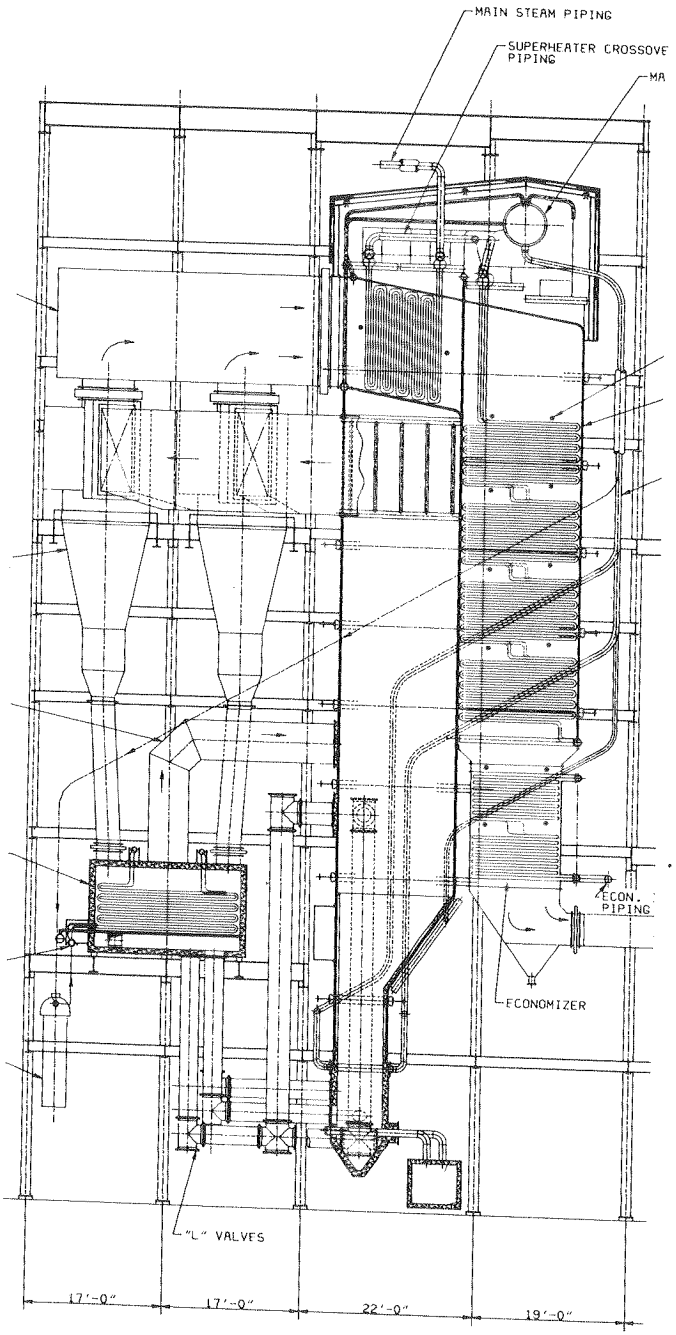

MAIN STEAM PIPING
SUPERHEATER CROSSOVE
PIPING
MA
ECON.
PIPING
ECONOMIZER
"L" VALVES
17'-0"
17'-0"
22'-0"
19'-0"

Figure 12

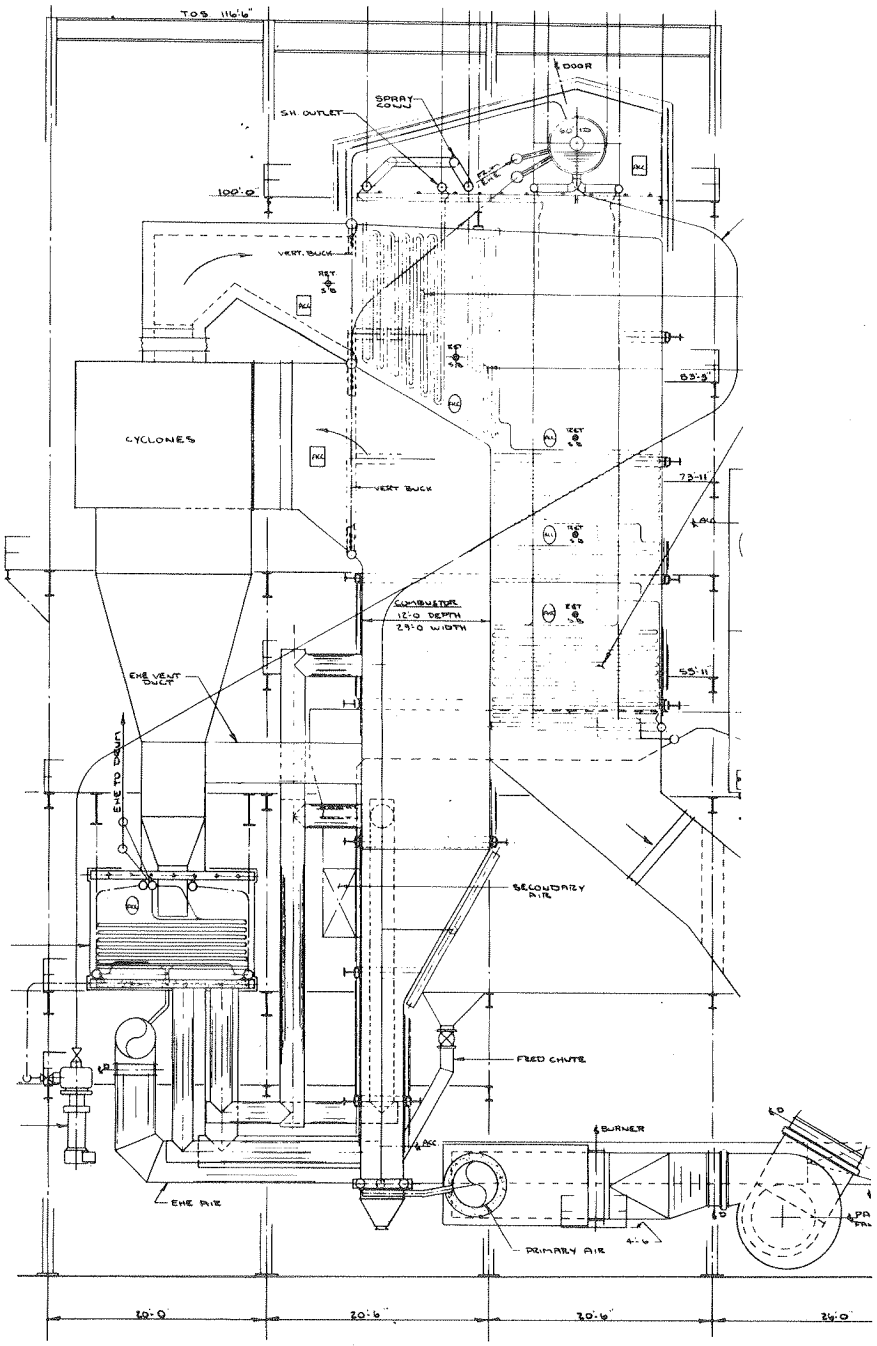

T.O.S 116'6"
DOOR
SPRAY CONN
SH. OUTLET
100'-0"
VERT. BUCK
CYCLONES
VERT BUCK
63'-3
73'-11
55'-11
COMBUSTOR
12'-0 DEPTH
29'-0 WIDTH
EHE VENT DUCT
EHE TO DRUM
SECONDARY AIR
FEED CHUTE
BURNER
EHE AIR
PRIMARY AIR
20'-0"
20'-6"
20'-6"
24'-0"

Figure 13

As we discussed last year, there are obstacles to the acceptance and use of circulating fluid bed combustion. Figure 14 outlines what we believe to be the major industry concerns about the technology. Only time - or aggressiveness - on the part of the Utility Industry will cause these obstacles to be overcome.

- LOW UTILITY GROWTH RATE
- UNCERTAINTIES OF FUEL COSTS/SUPPLY
- LACK OF NSPS AND/OR ACID RAIN LEGISLATION
- LOCATING CUSTOMERS WILLING TO COMMIT TO AFBC
- CONCERNS OF CAPACITY/TEMPERATURE SCALE-UP
- LONG TERM IMPACT OF ASH LOADING
  - — BOILER
  - — LANDFILL
- REPUTATION OF EARLY AFBC WORK INFLUENCING FUTURE TRENDS/DECISIONS
- COMPETITION FROM DRY SCRUBBER AND LIMB DEVELOPMENT

Figure 14 Obstacles to Utility Use of AFBC

Consistent with overcoming the industry obstacles outlined above, Riley has established design goals for new and retrofit utility applications. These goals are outlined in Figure 15 and 16 below.

- 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

Figure 15 New Boiler Design Goals

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

Figure 16 Retrofit Boiler Design Goals

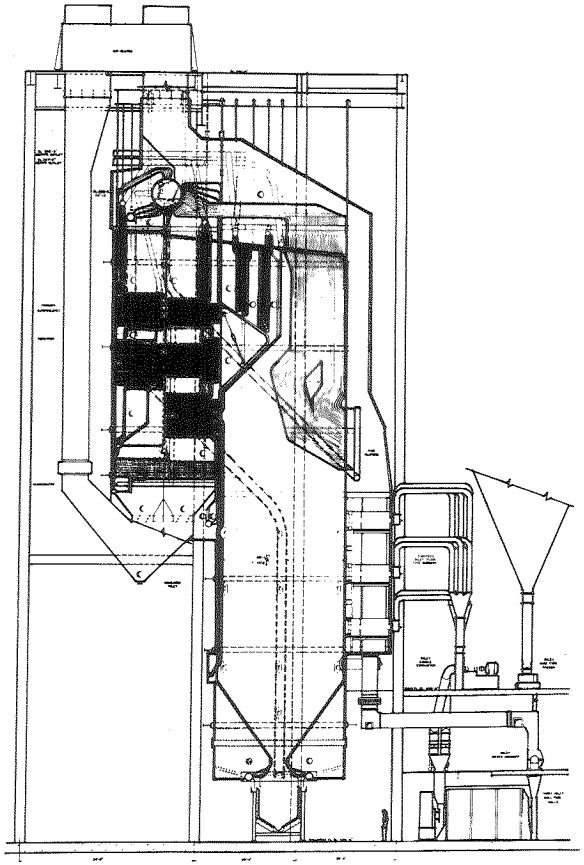


Figure 17 Typical 1,000,000 lbs/hr Utility Boiler

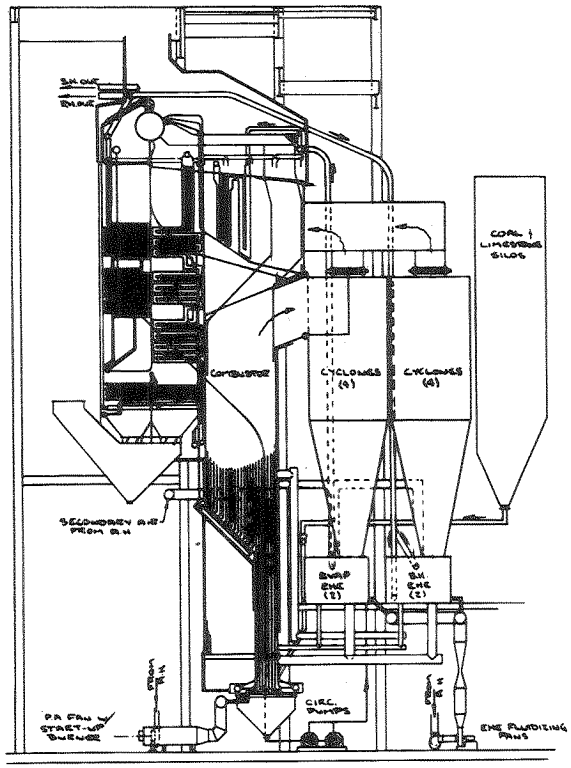


Figure 18 Utility Boiler - After Conversion to MSFB

While the above goals are not different for the Industrial Market, the emphasis and evaluation placed on these areas tend to be industry and customer specific. Within this framework, our analysis shows a new circulating fluid bed system to be performance and cost competitive with pulverized coal/dry or wet scrubbing systems being offered today - while offering some distinct process advantages.

For the Retrofit Market, we have done a study on converting a typical 1,000,000 pound per hour pulverized coal-fired boiler to an MSFB process. The before and after physical arrangements are shown on Figures 17 and 18. Performance characteristics are shown on Figure 19. While the particular study was performed on a coal-fired unit, the cost comparison shown applies equally to an oil or gas conversion. Convective pass spacing on oil and gas units will have to be examined on a unit specific basis and would affect the capital cost, but not the performance figures shown.

CONVERTED BOILER PERFORMANCE CHARACTERISTICS

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 IN $/MM BTU (%)	$ 4.60	$2.00(1%)	$1.80(3%)
ANNUAL FUEL COST (MM$)	$42.32	$17.83	$ 16.42
ANNUAL SORBENT COST (MM$)	N.A.	N.A.	$ .15
ANNUAL FUEL & SORBENT COST	$42.32	$17.83	$ 16.57
NET FUEL/SORBENT SAVINGS (MM$)	BASE	$24.49	$25.75

Figure 19

With substantial detailed design work completed on smaller industrial boilers, detailed contract design work in process on a 661,000 lb/hr. unit, and the extensive studies completed on perspective units, it is clear that the MSFB is ready for the 100 MW size utility unit. Larger sizes can be easily conceptualized as separate modules or designed with a wide, compartmentalized furnace.

In conclusion, it is clear that Riley and its' MSFB process are ready and able to offer a good alternative to the traditional P.C. boiler with scrubber to the Utility Market. The question at hand is when the Utility Market will need capacity and will AFBC be acceptable to a usually conservative market?