COMMERCIALIZATION OF COAL-WATER SLURRIES - II

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B&W considers Coal-Water Mixtures (CWMs) to be the most advantageous alternative to oil and gas fuels because the need for on-site coal handling and preparation equipment is excluded and because the use of oil is completely eliminated. In addition, if a low-ash coal is used in the mixture or if the coal is beneficiated, derating of the units will be minimized. Recent work has enabled a number of organizations to prepare pumpable mixtures (slurries) containing approximately 70 percent pulverized coal and 30 percent water. These slurries are stabilized to retard the settling of coal particles and to tailor the rheological properties so as to insure good flow through the careful variation of grinding processes and additives. Limited scale combustion tests have been performed to date and have answered affirmatively the critical question of whether direct-fired undewatered slurry can achieve stable combustion without requiring support fuel. Consequently, once it had been determined that direct firing was feasible, a CWM commercialization program was initiated and is presently underway.

COAL WATER MIXTURE COMMERCIALIZATION PROGRAM

Our initial presentation[1] in this series identified the elements we perceived to be critical to obtaining commercial utilization of this new fuel. That presentation concentrated on the availability of coal-water mixtures (CWMs) and on our laboratory work involving the development of a combustion system suitable for the direct firing of high density CWM's. This presentation will overview recent progress in those areas while concentrating on the methodology utilized to develop percent derates and the estimated costs for several typical industrial and utility units which will ultimately use this fuel.

Availability of Fuel

Several CWM suppliers currently are capable of providing the fuel. Babcock & Wilcox has investigated the rheological and combustion properties of mixtures produced by Slurrytech and by Atlantic Research, Inc. under joint B&W/Slurrytech and B&W/EPRI funding. Additional slurries produced by Carbogel, Gulf & Western and Oxidental will be investigated under a current B&W/EPRI program. The manufacturers claim that they can produce the fuel on a continuous basis and that it can meet a top size, viscosity, Btu and percent solids specification; also, that it can be produced in quantities great enough for a 25 MW industrial or utility demonstration during 1982. Some of the potential suppliers plan to have larger preparation plants on stream with the capacity to support a 100 MW utility demonstration in 1983. Major strides have been made in understanding the grinding and chemical effects of CWM's but additional work is required to control product quality on a large enough scale to fuel a utility demonstration.

B&W now has experience with slurries produced from 15 different parent coals, and therefore, has confidence that the fuel will be available as stated when a host site is located.

Combustion System

The burner/atomizer optimization program has been completed at the 5-million Btu test furnace level. That program has produced a hardware configuration that provides stable ignition, reasonable turndown and efficient carbon utilization. Results with the T-jet atomizer/flexible burner design are most encouraging. Turndowns of 4:1, secondary air temperatures between 300F and 600F (150C-315C), atomizing air consumption less than 0.1 lb. per pound of coal water slurry (0.1 kg/kg) and CO emissions consistently below 100 ppm have all been attained. The atomizer/burner optimization program also has demonstrated cold furnace light-off capability and identified erosion prone areas in the atomizer. The combustion program identified the importance of as-fired volatile content in the CWM, necessary for stability, turndown, slurry heating and air preheat.

Atomizer optimization work continues both in the field and in the laboratory on a single burner provided by a utility to permit wear tests on various coal-oil mixtures (COMs), CWMs, sewage sludge and other potential fuels. A new laboratory atomization facility currently under construction will use laser diagnostic techniques to quantitively and quantitively characterize the atomization obtained with a variety of test fluids.

Fuel Characteristics

Characterization of the fuels during the initial series was necessary to permit comparisons between the first five parent coals and their associated coal-water slurrys. The results indicate that similar relationships exist between a coal and its coal-water slurry.

Fuel Ash Analysis

Ash chemistry is a major factor that affects steam generator design criteria such as furnace sizing, the clear side spacing required for convection pass heat transfer surfaces, and the number and location of sootblowers. Indices of the base-to-acid ratio in the ash, coupled with the amounts of sodium and sulfur, have been used for many years to classify bituminous coals for slagging and fouling potential. The classification establishes base design requirements. If the ash chemistry has a higher slagging or fouling classification (e.g., the sodium or sulfur increases), additional conservatism must be designed into the steam generator to permit operation at the same Maximum Continuous Rating (MCR).

A comparison of the elemental ash analysis of the CWM to that of the parent coal shows that the production of a CWM results in increased sodium content. However, the magnitude of the increase is not sufficient to change the CWM fouling index from that of the parent coal. Also, because the sulfur content did not increase, our slagging classification did not change from that indicated by the parent fuel. CWM's can, therefore, be evaluated on the ash characteristics of the parent coal. Each CWM alternative fuel would have to be evaluated with respect to the compatability of its fuel ash properties, with the design of the steam generator being considered for fuel conversion.

Pumping and Handling

A CWM pumping and handling facility was constructed to investigate mixture rheology. Data indicated the mixtures were pseudoplastic, thixotropic and temperature sensitive (apparent viscosity decreased as temperatures increased).

Settling Rate

The CWMs provided to B&W for test burns were not specifically stabilized by the manufacturers for long shelf life, however, their shelf life was adequate. A barrel left undisturbed for one week indicated a solids distribution of 71.6% (top), 74.4% (middle) and 78% (bottom). Additional barrels, using different coals and stabilized with different chemicals, have been shipped to France, Italy, England and Japan, via truck and ship. None have arrived in a hardpack condition. The Italian experiment indicated a 1.2% difference, bottom (74.8% solids) to top (73.6%), which was excellent stability for the four-month transit time. The elemental analysis indicated greater silica in the bottom half (50% vs 47%), with aluminum greater in the top half (29% vs 27%). Truck and air transport have both indicated several hardpack transits and so additional work is required in this area of stability.

The fuel is available, displaying characteristics fairly well understood; a combustion system exists to burn it directly and the shelf/shipping life appears adequate. Additional scale-up work is required in all areas to develop a product specification which can be met in large-scale daily production, where the combustion/delivery system is adequate when scaled from 5×10^6 Btu/hr to 150×10^6 Btu/hr, and where large-scale tanker transport in bulk is feasible. The progress made to date is encouraging and work will continue in those areas identified, but the availability of a suitable host site to permit a firing demonstration is a necessary link in the commercialization chain. B&W studies have reviewed conversion capabilities for oil designs and coal designs presently firing oil. The options studied include possible conversion to a combination of alternative fuels, including conventional pulverized coal, coal-oil mixtures and coal-water mixtures. Another alternative is the replacement of the steam generator in total with a 100 percent MCR, conventionally-fired, pulverized-coal steam generator.

Approach

If cost comparisons between the fuel options are desired, Reference 1 can provide that information. This paper will review coal-water fuel conversion costs only. The studies have been limited to B&W's normal scope of supply, and therefore, the costs presented here for conversions/modifications do not include items such as coal storage silos, coal inventory, land for bulk storage, coal handling and unloading equipment. In addition, it has been assumed that compliance coal is available and the addition of a SO_2 scrubber is not necessary to meet local air pollution codes. The studies have indicated that each situation candidate and its associated coal is unique and must be studied individually.

The approach taken with all the liquid coal base fuels is to maintain full unit capability by retaining the existing oil firing system. By retaining the oil firing capability at all times, the risk of conversion to coal mixtures is not significant as the unit would be available for extended periods of time. A new piping system would be supplied for the coal-mixture fuel, based on information gained in laboratory development work.

The studies attempted to answer these questions:

1. What capacity is available when firing a CWM?

2. What are the costs associated when converting to a CWM?

The major load-limiting factors are furnace design (slagging), furnace outlet temperatures (fouling), superheater and reheater metal temperatures, attemperation spray quantities, and gas side erosion. The environmental restrictions (e.g., particulate, SO_2, NOx, and ash) apply equally to all the coal base options. We have completed engineering studies on units ranging in size from 15 MW to 400 MW, including both coal-capable and oil-capable designs.

The following specific studies have been selected from the range to demonstrate the methodology utilized to answer the two most often-asked questions. It cannot be emphasized enough that the actual fuel to be utilized and the specific-site considerations make each case unique and each site specific.

The three industrial and two utility type steam generator retrofit studies have been evaluated using similar criteria. That criteria is presented here in general to insure your familiarity with the areas and our restrictions. These criteria, or standards, have been developed both empirically and analytically over the history of the company and have been applied with good success.

Furnace Design

Proper furnace design is paramount for reliable boiler operation and performance. The furnace must be designed large enough to complete combustion in coal-fired boilers, to be able to sufficiently cool the flue gas before it enters the convection pass, and to minimize slagging on furnace wall tubes and on surfaces located in the upper furnace. The furnace should further be designed to provide uniform flue gas flow and temperature profile at the furnace outlet to prevent slagging, fouling, and metal temperature problems in the convection banks of the boiler. (Fig. 1).

Six important factors that affect slagging in the furnace are:

- Heat input per burner
- Clearance between burners, furnace walls and the lower hopper
- Heat input per ft^2 of furnace cross sectional areas – "plan area heat release rate"
- Burner zone heat release rate (HA/SC_1)
- Furnace volume heat release rate – furnace liberation
- Mass gas flow at the furnace arch

Heat Input Per Burner

On new units designed for pulverized-coal firing, the maximum burner input is limited to about 220 MBtu/hr.

Burner Clearances

Experience on coal-fired boilers has indicated that there are minimum clearances between burners and water-cooled surfaces (i.e., vertical walls, hopper slopes, and furnace arches) necessary to avoid excessive slagging and excessive localized absorption rates.

Plan Area Heat Release

A most important criteria for evaluating furnace slagging potential is the level of heat input per ft^2 of furnace plan area in utility units. The present B&W limit for coal-fired boilers is in the range of 1.5 to 1.9 MBtu/ft^2-hr (17,000 to 21,500 MJ/m^2-hr), and is dependent upon the slagging severity (classification) of the coal ash. B&W design limits (established in the 1960s) previously were higher, in the range of 2.1 MBtu/ft^2-hr (23,800 MJ/m^2-hr). It is not practical to enlarge the furnace to reduce this value, but division walls or water walls could be added to a utility steam generator to avoid massive derating of unit capacity. The actual furnace and actual fuel are the final judge in this heat release criteria and predictions must be conservative.

Burner Zone Heat Release

Present standards for utility coal-fired boiler burner zone heat release values are approximately 400 to 550 MBtu/ft^2-hr (4540 to 6240 GJ/m^2-hr). This level is used both as a slagging indicator and as a NOx generation correlator.

Furnace Liberation Rate

In industrial pulverized-coal-fired steam generators (smaller than loo MW), liberations up to 30,000 Btu/ft^3-hr (1.125 GJ/m^3-hr) were not uncommon. Increasing this rate to 40,000 Btu/ft^3-hr (1.5 GJ/m^3-hr) would increase the carbon loss slightly, due to the shortened residence time. Decreasing this rate to 10,000 Btu/ft^3-hr (.4 GJ/m^3-hr) would increase the carbon loss due to the cooler furnace holding properties such as volatile levels, ash content, and coal quality. The larger utility steam generators currently being specified (1980s mean size - 580 MW), coupled with EPA NOx emission limitations, have forced larger plan areas. The increased sophistication in predicting slagging/fouling behavior has placed limits on furnace exit gas temperatures which in turn has forced larger (taller) furnaces to control the exit temperature. The combination of these factors has reduced present liberation rate levels to about 13,000 Btu/ft^3-hr (.5 GJ/m^3-hr). The potential increase in carbon loss has been offset by increased burner turbulence and by an increase in residence time. Furnace liberation rate, as an index of carbon loss, therefore has lost much of its importance as a design index on the large unit, but continues to be valuable in the industrial sizes.

Mass Gas Flow at the Furnace Arch

To help ensure a uniform flow pattern at the furnace exit, B&W's utility maximum mass flow at the base of the arch is 4000 lb/ft^2-hr (19,500 KG/m^2-hr). If that level is obtained, experience indicates that gas side imbalances are minimized.

Furnace Exit Gas Temperature (FEGT)

To keep the heating surfaces clean in the areas of the upper furnace and at the inlet to the convection pass, the furnace should be designed so that it absorbs sufficient heat without exceeding the maximum exit gas temperature permitted by the slagging and fouling classifications of the coal used. The proper selection of this temperature is based on the ash fusion characteristics of the fuel, its accurate prediction and maintenance during operation, and the required heat content in the flue gas to attain the necessary superheat/reheat absorption.

The retrofit case presents a fixed clear-side spacing in the superheater, reheater and generating bank. The allowable gas side temperature entering these banks is restrained to control slagging and fouling and is related to the tube metal temperatures and ash characteristics of the base fuel.

There are three approaches possible to control the temperature/side spacing restriction. They are: a) the addition of surface in the furnace, b) a reduction of surface (i.e., increased side spacing) in the convection passages and c) a reduction in load. A utility design offers greater flexibility in applying the surface modification approach but usually will require both new surface added in the furnace, plus side spacing opened to maximize the MCR on coal-water firing.

Convection Pass Design

Good convection pass design starts in the furnace. If the furnace becomes slagged, the flue gas temperatures in the convection pass increases and slagging will progress into the more closely-spaced convection banks, where it is increasingly more difficult to control. In addition to lowering the furnace exit gas temperature sufficiently to prevent fouling of the heating surfaces in the convection pass, the convection pass must be designed with sufficient free-flow area between tubes to avoid excessive erosion and subsequent metal loss of the heating surfaces.

Current B&W standards for pulverized-coal-fired boilers limit gas velocities for the average erosive ash to 65 ft/sec (19.8 m/sec) in the convection pass. Previous standards (used in the 1960s) limited velocities to 75 ft/sec (22.9 m/sec). The erosion index for the study coal ash permitted 75 ft/sec (22.9 m/sec) as a reasonable velocity limit to avoid excessive erosion.

Estimated Costs to Convert a Potential Host for Permanent Coal-Water Mixture Fuel - June, '81 Dollars

Reviewers have suggested that the cost per kilowatt be calculated on the coal capable kilowatt base only, rather than on the original design. The original design MCR capability continues to be available if oil is utilized; therefore, the original KW base has been retained. The cost per kilowatt has been calculated on the coal-capability only (derate) is indicated in parenthesis.

Specific Units

A) Industrial Retrofit

Retrofit Study "A" is a steam generator producing 60,000 pounds (27,000 kg) of saturated steam per hour at 175 psig (12.3 kg/cm^2)

designed to fire natural gas, low Btu gas (113 Btu/ft^3, 4,236 MJ/m^3) and #6 oil. The unit was desinged in 1951, went into service in 1952, and is required at present to produce maximum continuous rating all winter long. It is described within B&W as an Integral Furnace Type FJ. Initially, no air heater or economizer was supplied. The client has added an extended surface economizer (3 fins/inch) to increase efficiency. The initial five burners are B&W circular, scroll-type, and each rated for an input of 22x10^6 Btu's per hour (23.2 GJ/hr). (Fig. 2).

Coal Water Evaluation

Furnace Design - The slagging and clearance limits are all met for a burner input of 22x10^6 Btu/hr. The furnace does not have an ash hopper and the field demonstration will indicate the necessity of adding one after the actual ash split between bottom ash and flyash is determined. The Type FJ has a furnace hopper standard design that can be retrofitted at a reasonable cost if tests prove it necessary.

Furnace Exit Gas Temperatures - Calculated FEGT's using the base CWM fuel are 1920F (1048 C). This temperature level is located directly in front of the furnace outlet screen tubes and is lower than the ash fusion temperature (2390F, 1310C) of the coal-water mixture. A retractable sootblower would be added in front of the screen to remove deposits.

Convection Pass Design - The gas flow enters the generating bank with tubes spaced on 5 inch (12.7 cm) centers. The low gas temperatures and low tube metal temperatures associated with saturated steam indicate deposit removal would not be a problem, but a sootblower would be added in front of this bank to insure deposit removal. Velocities in the bank were calculated and, in no case, exceed 40 ft/sec (12 m/sec) on CWM's; therefore, requiring no modification.

The last heat trap in the convection pass is the add-on economizer with extended surface. We are concerned about pluggage and so recommended removal of selected sections or flue bypassing to insure that pluggage in that area does not effect availability.

This unit, although designed for gas and oil, is capable of obtaining full original MCR on a coal-water mixture. Costs to convert to CWM's including burner changes, atomizer updates, a separately fired air heater to heat secondary air to 600F (315 C), a CWM heater, a CWM variable-speed progressive cavity pump, sootblowers, economizer revision and 98% efficient precipitator are estimated to be $847,000 or 138/kw on a delivered and erected bases. The use of a bag house would reduce costs by 50% in this low gas weight flow simplication.

B) Industrial Retrofit

Retrofit Study "B" is a steam generator producing 200,000 lbs. steam per hour (90,700 kg/hr) at 175 psig (12.3 kg/cm^2) and 475F (246 C) designed to fire oil and acid sludge tower bottoms. The unit was designed in 1954, went into service in 1955, and is required at present to produce 90% MCR in summer and 100% MCR in winter. It is described within B&W as an Integral Furnace Type FH boiler. This base frame design has been supplied for coal firing.

A tubular-type air heater was supplied and provides 348F (175C) maximum secondary air temperatures for combustion. The four burners are B&W circular type, each rated at 63x10^6 Btu hour (66.45 GJ/hr) at MCR. (Fig. 3).

Coal Water Evaluation

Furnace Design - The slagging and clearance limits are all met for a burner input of 63x10^6 Btu's per hour (66.45 GJ/hr) for the proposed coals. The furnace does not have an ash hopper and the field demonstration will indicate, once again, the necessity of adding one after the actual ash splits are determined. This design series and the FJ discussed previously do have the capability to add furnace ash hoppers.

Calculated FEGT's using the base coal-water fuel and combustion air temperatures of 600°F (315C) are 2280°F (1240C) at MCR and 2100°F (1149C) at 90% MCR. Those temperatures are located directly in front of the furnace outlet screen tubes. The specified is indexed as low slagging/ low fouling potential and presents a low risk for uncontrolled furnace slagging. The furnace screen tubes are on 9" (58 cm) centers and are saturated surface, operating at less than 450F (232C) tube mean metal temperatures. A retractable sootblower will be added just in front of the screen tubes to insure that the surface is kept open and free of deposition.

Convection Pass Design - The FEGT is 2100F (1149C) at 180,000 pounds (81,650 kg) steam per hour (90% MCR). This temperature level is considered conservative when applied to a unit design for a medium slagging/ medium fouling bituminous fuel and a high duty cycle (2400 psig - 1000F/1000F) (168 kg/cm^2-538C/538C). The side spacing required for these mean metal temperatures/gas temperatures and fuel conditions is 18 inches (457 mm). If that same criteria were applied to the subject unit, the FEGT would be limited to 1950F (1066C) limited by the 9" (228 mm) saturated furnace screen side spacing. The maximum recommended percent MCR would respectively drop to 63% to insure a temperature lower than 1950F (1066C) at the screen. The superheater on this unit has 4" (102 cm) side spacing with tube mean metal temperatures below 740F (393C). Applying modern day high-duty cycle gas temperature limitations to this heat trap would also limit MCR to 63%. However, applying these high-duty cycle limitations to a 150 psig-475F (10.55 kg/cm^2-246C) cycle is overly conservative but does present a "worst case" condition for economic analysis. Experience indicates that deposition on the furnace screen should be easily removable with the addition of a sootblower. The superheater at 4" (10.2 cm) spacing creates a fouling concern but the worst-possible derated condition is identified and retractable sootblower blowers are already installed in this zone.

If the retractable sootblowers are not effective in controlling deposition, alternate superheater elements could be removed to open the side spacing 8" inches (20.3 cm). The removal of surface would reduce final steam temperatures and increase pressure drop (drum to outlet) but is a possible low-cost modification that has not, as yet, been proven necessary.

Velocities are at /or below 75 ft/sec (22.8 m/sec) throughout the convection pass. The maximum velocity occurs at the 180F degree turn leaving the superheater. It will be reduced to 60 ft/sec (18.3 m/sec) by reducing the turn baffle by 1.5 feet (457 mm).

The unit, although designed for oil, can achieve 63% MCR easily and is believed capable of attaining 90% MCR with minor modifications. A test scheduled for later this year will permit the actual rating to be compared with that predicted. Costs to convert to CWMs are estimated to be $2,100,000 or $102/KW ($114/KW) delivered and erected and include the following:

- burner changes
- atomizer updates
- separately-fired air heater
- four retractable sootblowers
- electrostatic precipitator
- on site CWM storage using an existing oil tank
- new piping
- existing plunger (transfer) pumps
- new strainers and new progressive cavity pumps
- coal-water mixture heaters
- two phase (air or steam) atomization

C) Industrial Retrofit

Retrofit Study "C" is a steam generator producing 150,000 pounds of steam per hour at 680F (360C) and 600 psig (42.19 kg/cm^2) designed and sold to fire oil initially with coal future. The unit was designed in 1976 and in June of 1978 went into commercial service firing oil. It is described as a two-drum Stirling power boiler and the coal firing equipment (future) would include the removal of the furnace floor and installation of an ash hopper and spreader stoker. (Fig. 4).

Furnace Design - The unit was designed for coal and the furnace is adequate for the base CWM fuel with the addition of furnace wall sootblowers. A modified floor would be required to provide an ash hopper. Burner/atomizer and air heater revisions would be required to handle the CWM on a long-term basis.

The alternate solid fuel system would require similar furnace sootblowers but, in addition, the furnace floor and lower front wall would have to be removed and the spreader stoker and feeders installed. The stoker ash hopper, siftings hopper, cinder return lines and overfire air connections would be installed and the oil burner furnace openings plugged. The air heater would not require revisions to obtain "hotter" air.

Convection Pass Design - The convection section would have to add the "future coal" sootblowers for either the CWM or stoker retrofit.

Air Temperatures - The laboratory development of the combustion system to handle a wide variety of CWMs has indicated that the availability of secondary air temperatures up to 600F (315C) is beneficial. It is likely that this air temperature requirement can be relaxed as a function of the fuel characteristics and final combustion system that is commercially applied. However, for this study, it was considered necessary to modify the cold end of the unit to increase air temperatures. The unit was supplied with a regenerative air heater designed to heat the air to 310F (154C) at at full load. Removing the economizer and increasing the size of the preheater would permit 500F (260C) secondary air temperatures to be supplied. The cost associated with this revision is included in the CWM conversion estimate.

Environmental - A baghouse would be added in both the stoker or CWM retrofit.

This unit, designed for future coal, is capable of full MCR on either stoker or CWM firing. Costs to convert from oil to stoker, scoped from the coal feeders to the baghouse, are estimated at $1,800,000 ($117/W). Not included in that number are the coal unloading, storage, stacking, reclaiming, and hopper storage equipment costs; none of which are presently in place. Costs to convert from oil to CWM are estimated at $1,700,000 ($111/W), with the major unique cost associated with the air heater rebuild. For comparison, a new coal-fired boiler, designed to the same scope, is estimated to cost $7,000,000 ($457/W).

D) Utility Retrofit - Study Unit "D" is a B&W steam generator, rated at 1,450,000 lb/steam/hr (220 MW), designed for oil firing only. It is 36 ft wide (11 m), 28 ft deep (8.5 m), firing horizontally-opposed with 8 burners arranged four-high on the front wall and four-high, two-wide, on the rear wall. The steam generator type is referred to as "El Paso" and is typical of B&W's utility standard design for oil/gas firing. The maximum continuous load was specified as five percent overpressure, overflow, and low feed-water temperature condition. These conditions result in a steam flow of 1,535,000 lb/hr (696,000 kg/hr) at 1005F/1005F (540C/540C) and 2150 psig (151 kg/cm^2) generating 243 MW. All percent-MCR references are to this overload condition. (Fig. 5).

Furnace Design - Burner inputs, plan area heat release, burner zone heat release, furnace liberation rates and mass gas flow at the furnace arch, all meet present-day utility coal-fired design criteria for 75% MCR input. The required burner clearances to the sidewalls, to the division walls and to the rear wall are met as well. The clearance from the top burner to the furnace outlet (residence time) is exceeded by two ft. (500 mm).

The FEGT at MCR on oil was 2575F (1413C). The maximum recommended FEGT for the coal-water-mixture fuel is 2250F (1232C). The 62% MCR corresponds to a temperature level of 2250F (1232C), producing steam temperatures of 1005F/990F (540C/532C). Removal of superheater surface to increase the side spacing, permitting a higher FEGT, would permit the attainment of higher MCR's (75%).

A furnace hopper was integral with the initial design and is suitable for coal, but an ash removal system will have to be added and is included in the estimate.

Convection Pass Design - Removal of SH surface was not studied. The initial constraint revolved around velocity limits and cleanability (bank depth) of the reheater. Two iterations were studied to remove these constraints. Removing every other reheat element to reduce velocities and increase allowable entering gas temperatures was the first and resulted in satisfactory velocities but reduced reheat outlet temperatures. The second iteration exchanged primary superheater surface for reheater surface and returned final reheat temperatures to acceptable levels.

This unit was designed for oil firing only and can fire CWM up to 62% MCR (151 MW) without major internal modifications. Burners, deasher, new flues and ducts, sootblowers, precipitator, ID fans and controls are the required added equipment and would cost about $17,740,000 or $81/W ($118/W). More extensive convection pass surface rearrangement would permit recommended loadings to 75% MCR (183 MW) and is estimated to cost $20,740,000 or $94/W ($113 W).

E) Utility Retrofit

Study Unit "E" is a steam generator of Combustion Engineering design rated at 2,550,000 pounds steam/hour (1,157,000 kg/hr) (375 MW) designed for oil firing and future coal. The furnace is 45 ft wide (13.7 m), 40 ft deep (12.2 m) utilizing corner firing, with 4-nozzle elevations on oil, 5 future ones for coal (not installed), and pump assisted circulation. (Fig. 6).

Furnace Design - The furnace was designed with a hopper suitable for coal, partial division walls (54" (1.371 m) side spacing), steam-cooled upper front wall and pendant superheater platen banks on 18" (45.7 cm) side spacing.

FEGTs as measured on oil firing were 2500F (1371C) and predicted to be 2525F (1385C) on coal-water mixture fuel at 100% MCR. Fuel quality, as related to existing side spacing, prohibited that temperature level. Our experience indicated 2300 (1260C) as a maximum reasonable FEGT for the candidate coal-water mixture. (That temperature level corresponds to 70% of MCR (263 MW)).

Convection Pass Design - The superheater spray flow at 100% MCR was 17.6% of MCR steam flow; reheat attemperator flow was 2.8% of MCR steam flow. Both values are extremely high and the superheater flow remained high (26%) at 70% of MCR. The study removed the upper front wall, steam-cooled surface to reduce spray flow by one-third. The side spacing was too tight for the fuel and gas temperature levels so wingwalls were added between the existing partial division walls to reduce the FEGT. This revision acted to further reduce SH spray by 50% in CWM and by 80% on oil. Due to field constraints (drum stress relieving), a 5" connection is the maximum permitted and this controlled the number of risers and supplies required for the new circuit. Two circulating pumps would be added for this circuit which is in parallel with the existing furnace circuits. One pump is required for circulation and one extra is considered prudent.

The unit was designed to fire coal but velocities, temperatures and side spacing were all too restrictive to permit operation at any-thing above 70% MCR (263 MW) on the specified CWM. The major modifications were curtain wall removal and a wingwall pump addition to permit operation to 85% MCR (319 MW). Additional equipment would be new burners, sootblowers, furnace bottom ash system, upgraded superheater metals, ignitors and controls. The estimated cost for material is $2,915,000 and for construction is $4,670,000 or $20.2/W ($23.8/W). No environmental package was included in this study.

Summary

Manufacturers claim demonstration quantities of coal-water slurries will be available starting in 1982 at a selling price competitive with imported fuel oil. Burner designers and boiler manufacturers are involved in laboratory-scale demonstrations that appear promising. Laboratory work already completed indicates that the slagging, fouling, erosion, stability and carbon utilization characteristics of the mixtures are predictable if the parent coal is known, and a retrofitable combustion system is being developed for this fuel.

Finally, studies of potential host sites indicate conversion costs from oil to coal-water are significantly less than conversion costs from oil to direct pulverized coal for selected units, fuels and locations.

B&W estimates that, in the utility market alone, approximately 20,000 MWe of boiler capacity were originally designed for coal firing but are currently firing some alternative fuel. These units could fire a CWM with a minimum amount of modifications. In addition, approximately 100,000 MWe of capacity designed for oil firing could be converted to fire a CWM with some combination of boiler modification and derating. Finally, new steam generators which have unique transportation, siting or environmental problems may utilize CWMs as an economically attractive alternative to a direct pulverized-coal-fired boiler.

Our short term plans are to participate in a small (25 MWe) firing demonstration during 1982 and a larger (100 MWe) demonstration late in 1983 to satisfy questions concerning the commercial applicability of coal-water mixtures.

<u>References</u>

1. Barsin, J. "Investigation of Coal-Water Mixtures." Presented at "Coal: Phoenix of the '80s", Halifax, Nova Scotia, June 1981.

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3. Barsin, J. "Commercialization of Coal-Water Slurries I." Presented at 9th Energy Technology Conference, Washington D.C., February, 1982.

Figure 1 Furnace definitions.

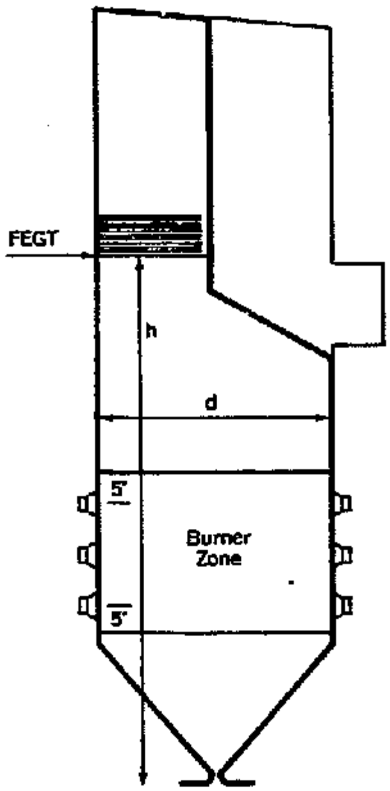
Figure 2 Study unit "A".

Figure 3 Study unit "B".

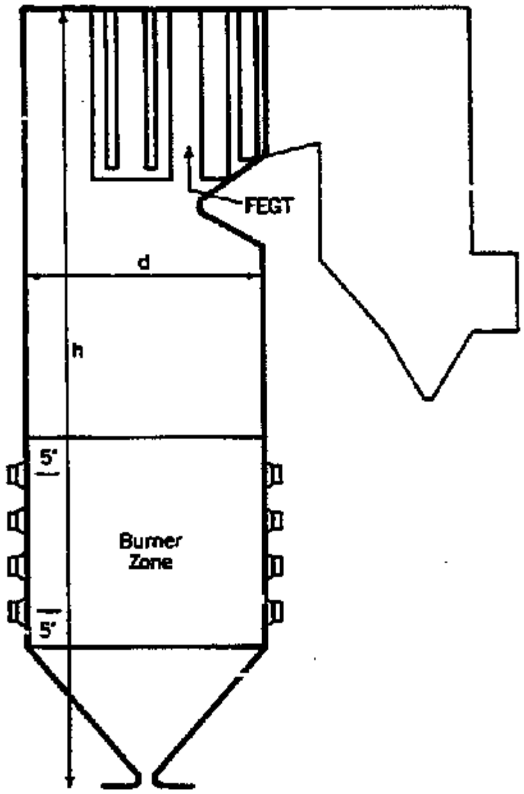
Figure 4 Study unit "C".

Figure 5 Study unit "D"

Figure 6 Study unit "E"



Typical oil and gas fired unit



Typical coal fired unit

Plan area release rate .... Btu/ft² hr

$$\left[\frac{\text{input in fuel-Btu/hr}}{\text{w-d - ft}^2}\right]$$

Burner zone release rate...Btu/ft²/hr

$$\left[\frac{\text{heat release-Btu/hr}}{\text{effective burner zone area-ft}^2}\right]$$

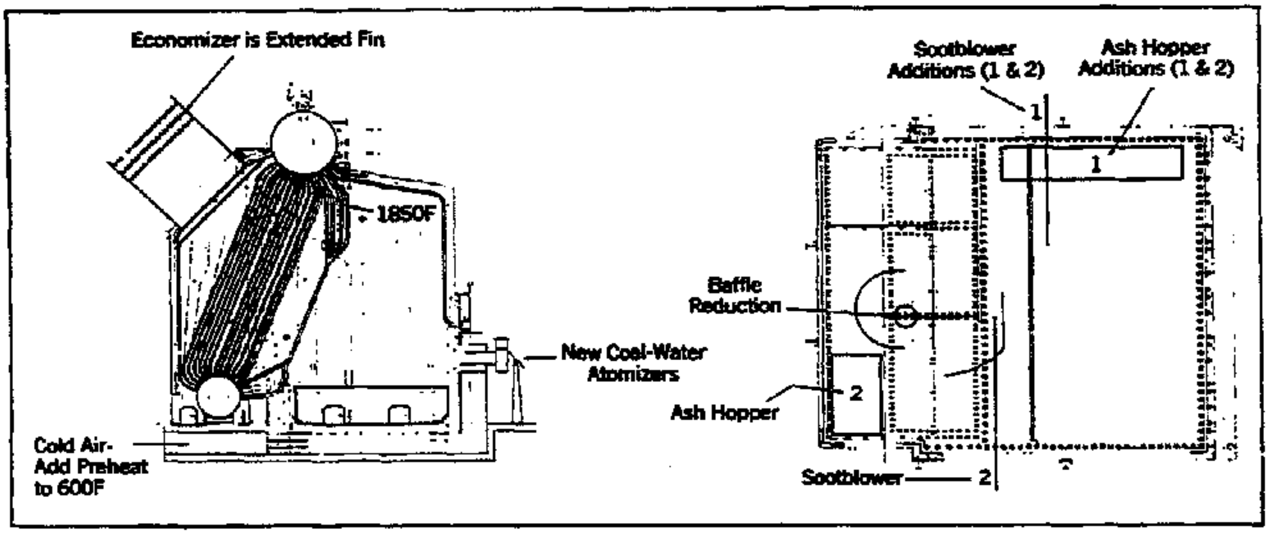
Furnace release rate ....Btu/ft²/hr

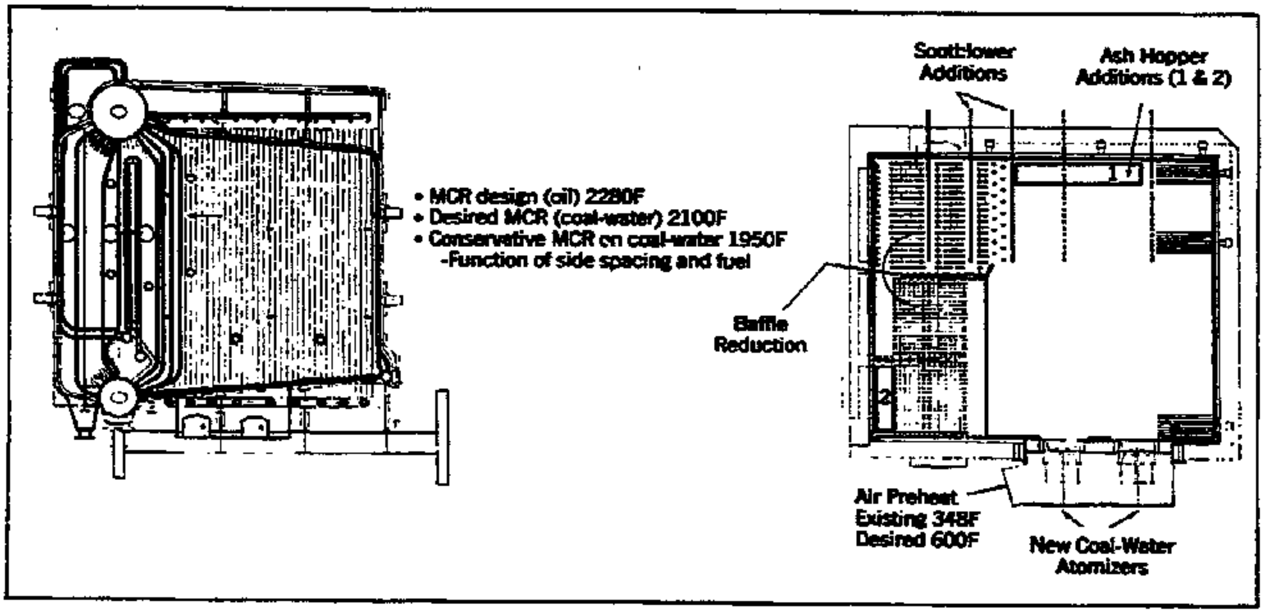
To convection surface

$$\left[\frac{\text{heat release-Btu/hr}}{\text{furn. flat projected area-ft}^2}\right]$$

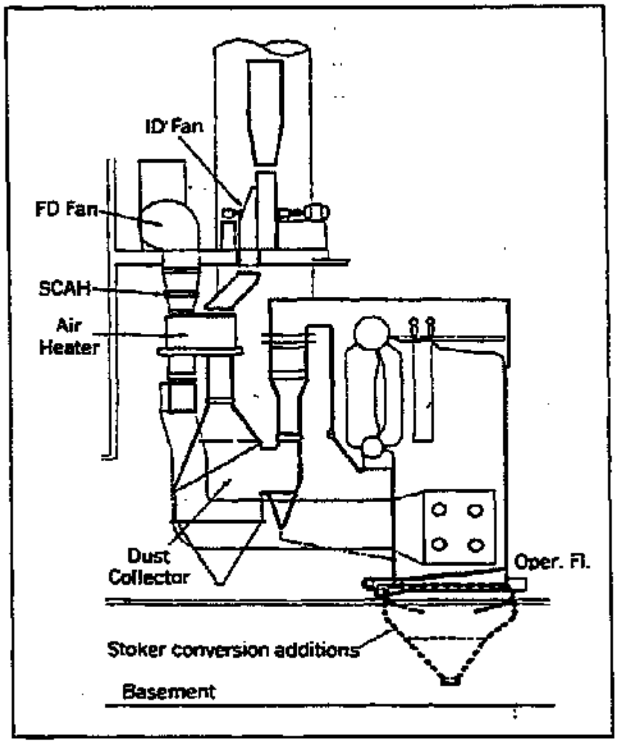
Furnace liberation... Btu/ft³ hr

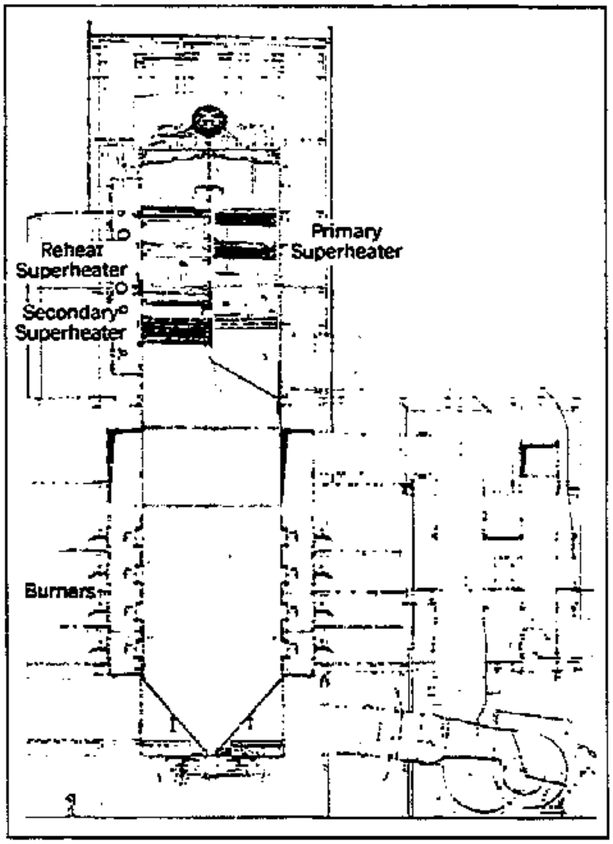
$$\left[\frac{\text{input in fuel-Btu/hr}}{\text{w-d-h-ft}^3}\right]$$

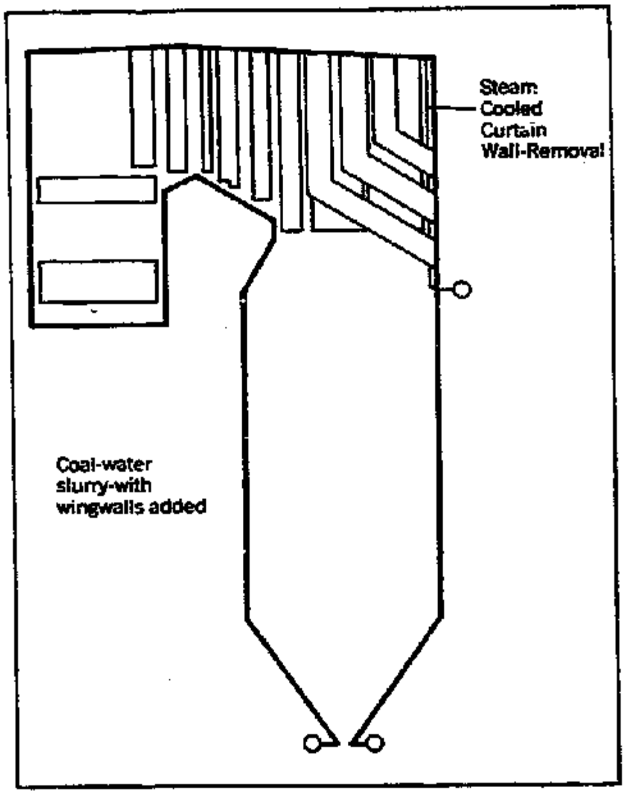

Economizer is Extended Fin
1850F
New Coal-Water Atomizers
Cold Air-
Add Preheat
to 600F
Sootblower
Additions (1 & 2)
Ash Hopper
Additions (1 & 2)
1
1
Baffle
Reduction
Ash Hopper
2
Sootblower
2



- MCR design (oil) 2280F
- Desired MCR (coal-water) 2100F
- Conservative MCR on coal-water 1950F
  - -Function of side spacing and fuel


ID Fan
FD Fan
SCAH
Air Heater
Dust Collector
Oper. Fl.
Stoker conversion additions
Basement


Reheat Superheater
Primary Superheater
Secondary Superheater
Burners


Steam Cooled Curtain Wall-Removal
Coal-water slurry-with wingwalls added