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FLUIDIZED COMBUSTION OF COAL

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ABSTRACT

A new combustion technology has been developed in the last decade that permits the burning of low quality coal, and other fuels, while maintaining stack emissions within State and Federal EPA limits.

Low quality fuels can be burned directly in fluidized-beds while taking advantage of low furnace temperatures and chemical activity within the bed to limit SO_2 and NO_x emissions. The excellent heat transfer characteristics of the fluidized beds also result in a reduction of total heat transfer surface requirements. Tests on beds operating at pressures of one to ten atmospheres, at temperatures as high as 1600°F, and with gas velocities in the vicinity of four to twelve feet per second, have proven the concept. The progress that has been made in the development of fluidized-bed combustion technology and work currently underway are discussed.

I. COMBUSTION IN A FLUIDIZED BED

Our organization has been involved in combustion technology since 1906, and, through the decades, has designed many first-of-its-kind facilities for industry, to burn waste or by-product fuels, in addition to fossil fuels.

One of the more promising technologies which will enable the use of low grade fuels in an environmentally acceptable manner is atmospheric pressure fluidized-bed combustion.

Direct-contact heat transfer Fluidized-Bed Combustion (FBC) involves the burning of fuels in a bed of inert granular material (ash, limestone or dolomite), which has been held in suspension by the injection of air through a distribution grid at the bottom of the bed. Combustion within the fluidized-bed is very intense with high volumetric heat release, and very high heat transfer rates are obtained with immersed heat exchange surface. As a result, furnace size as well as the amount of heat transfer surface and hence, cost, is reduced.

Fluidized-beds have been used for decades in the chemical industry to enhance reaction rates, but their use in steam generators is a new concept. In early 1965, I started a hardware development program to prove that fluidization could be applied to coal burning. With funding from DOE's predecessor agency, the Office of Coal Research, we designed and built in Alexandria, Virginia, the world's first fluidized bed boiler in late 1965.

Tests at our laboratory, as well as those performed in later years by others, on beds several feet in size and several feet deep, operating at temperatures around 1600°F, and with gas velocities in the four to twelve feet per second range have proven the concept. Tests have also demonstrated a capability of burning low-grade fuels, and transferring heat at average rates several times those expected in conventional boilers.

II. FUELS USED

Fuel types are unlimited. Unlike a conventional coal-fired boiler, ash properties are not a significant factor here. Also, the bed temperature is too low for the ash to soften. It is a universal machine in that the same basic design applies for all fuels. All fuels are burned at a heat release rate equivalent to 100,000 Btu/per square foot of effective projected radiant surface (EPRS).

III. OPERATION

Start-up of the combustor requires heating a portion of the bed to a temperature hot enough to ignite the fuel used. After ignition, the temperature of the bed rises rapidly until the system achieves thermal equilibrium.

Operating characteristics of the bed dictate an optimum design temperature range of 1500 - 1600°F, with excess oxygen at about 3 percent. At these conditions, about 50 percent of the heat released by the burning fuel is absorbed in the immersed tubes.

Solid and liquid fuels burn rapidly. The rate is so high that at any point in time a sample of bed material would analyze at about 2 percent carbon.

Fireside corrosion is avoided, because the sodium, potassium and vanadium in the fuels, if released, are picked up by the bed particles.

IV. RIVESVILLE

The Department of Energy (DOE) financed 30 MW_e demonstration unit at Rivesville, West Virginia ranks as the largest of the world's growing family of operational test installations. Situated at a Monongahela Power Company generating station, the systems were designed, and their construction supervised by Pope, Evans and Robbins (PER). The boiler proper was built by Foster Wheeler.

The Rivesville unit features an array of four cells, with overall dimensions of 12 ft wide by 39 ft long by 20 ft high. It burns 14 tons/hr of coal to raise 300,000 lbs of steam per hour at 1300 psig and 925°F for power generation by the Power Company.

The steam output capacity of the Rivesville unit would more than satisfy most industrial users.

The central station installations will have to wait for a larger demonstration unit, now planned for the early 1980's.

V. POLLUTION CONTROL

Tests performed by federal agencies on our pilot unit established that both NO_x and SO_2 emissions were held below federal EPA emission standards for new plants. Test data showed emissions well under 1.20 lb $SO_2/10^6$ Btu while burning coal with 4.8 percent sulfur; and NO_x readings of 0.11 to 0.17 lbs per 10^6 Btu.

The solid fuel fed to the combustor is normally crushed, not pulverized, to a 1/4 - 3/4 inch size. A good fraction of the ash remains in the fluidized-bed where it is drawn off, or if carried out with the products of combustion, is separable in a cyclone collector. However, in order to comply with current pollution control regulations, the use of bag-house filters, or electrostatic precipitators are required.

Sulfur dioxide in the fluidized-bed is controlled by the use of limestone as bed material. The bed is kept reactive either by the addition of fresh limestone, in a once-through system, or by regeneration to recover sulfur dioxide in useful concentrations.

Four studies are now being undertaken by EPA to develop alternate plans for calcium sulfate ($CaSO_4$) disposal. We have used it as a soil conditioner to grow successful crops of peanuts and corn.

To encourage wide-spread use of FBC, DOE is co-funding demonstration units for process steam and for direct and indirect heating of other fluids. One of these, which we are designing, is a 100,000 pph unit at Georgetown University in Washington, D.C., to prove that coal can be burned, in an urban area, without polluting. This is a two cell, rather simple unit designed for industrial/institutional use. We are using a spreader to feed the coal. Note that we are burning a coal with 3+% sulfur. For California area coals and to meet Bay area emission standards of 0.6 lb/MMBtu, about a 70% sulfur reduction is necessary - limestone requirements would be in the range of 1# of limestone for 8# of coal. Current major AFBC projects are being funded by DOE and the State of Ohio. DOE is not carrying the entire burden of FBC facilities' sponsorship in the United States. EPA is funding a test unit at Exxon Research in Linden, New Jersey. Exxon's mini-plant has a broad range of operating capabilities; pressures up to 10 atm, and bed depths of 20 ft. It completed shakedown in 1976, and has accumulated 1,100 hours of operating time, including a 10 day sustained run.

The Electric Power Research Institute (EPRI) in Palo Alto is sponsoring an FBC test unit too, with Babcock & Wilcox at its Alliance, Ohio research center. That facility, capable of burning 3,000 lbs of coal per hour was recently put into its initial phase of test operation.

Together with B & W (U.K.), Combustion Systems Ltd. of Great Britain designed and constructed at Renfrew, Scotland, what's claimed to be the largest FBC unit running in Europe today. Started up in June, 1975, the 10 sq ft atmospheric pressure combustor (a converted stoker-type, water tube boiler) produces 23,000 lb/hr of steam.

American Electric Power Co. is pursuing the pressurized FBC system which utilizes gas turbines as the main electric power producer. A small pilot plant at Leatherhead, England, which has been operating since the late 1960's, has developed most of the technology on which the company bases its system.

Meanwhile, the National Coal Board is shepherding a $25 million project of the International Energy Authority. This calls for construction in England, of a pressurized FBC pilot plant by 1980. The unit is expected to operate at 20 atm and yield about 20 MW_e. Elsewhere in Europe, West Germany's state-owned coal mining and energy company announced a cooperative agreement with the Coal Board.

Also, back in the United States, by 1980/1981, an elevated-pressure unit should also be turning out 13 MW_e from an expansion turbine, fed both by combustion off-gas and air, heated in the coils. DOE awarded a $25 million contract for the 13 MW_e plant to Curtiss-Wright Corp.

DOE is also planning a pair of facilities to check on the compatibility and possible modifications of various FBC system components. An atmospheric pressure system rated at about one-third of the capacity of the Rivesville installation, will be built at DOE's Energy Research Center at Morgantown, West Virginia, and a similar size high pressure boiler will be constructed at its Argonne, Illinois laboratory. DOE expects both of the units to be onstream in the early 1980's.

VI. EXPECTED BENEFITS

Fluidized-bed combustion is expected to make it possible to build industrial, process and utility combustors within the next several years that will produce the following benefits:

1. Low grade fuels, including petroleum coke, municipal waste, biomass and wood chips can be efficiently and economically burned, meeting clean air criteria, without the use of stack gas clean-up systems.

2. Sulfur dioxide emissions are reduced by the limestone bed, and NO_x emissions are reduced by the low combustion temperatures.

3. Smaller in size and lower in cost than presently available combustor types, capable of burning high-sulfur fuels within clean air standards. The technical factors that make this possible are the higher heat release rates and higher heat transfer rates.

4. Plant space and construction time savings, due to shop fabrication of the component cell sections with expected increase in equipment quality.

5. Solid fuels of higher ash content may be economically burned, since crushing is limited.

6. Requirements for pulverizers are eliminated since it is not necessary to reduce the size of the coal below ¼ inch.

7. Slagging problems are eliminated since the combustion temperature is maintained below the ash fusion temperature.

8. Independently controlled multiple modules should result in high operational availability and the ability to "stay on-line" if a mechanical failure occurs in a module.

9. Modular design minimizes capacity scale-up problems.

New Federal EPA regulations are now being debated. We anticipate a reduction in new source performance standards to .03# of particulate per 10^6 Btu, and to 0.6# of NO_x for 10^6 Btu. For sulphur, the battle rages between 80-90% sulphur removal. A compromise will be reached.

The Energy bill, still stalled in Congress, has provisions for mandatory coal conversion that have been agreed to by both the House and the Senate. All new boiler plants with capacity over 100,000,000 Btu must burn coal as the primary fuel.

The options now available to industrial steam users are few. So called compliance coal, low in sulphur, will lose its designation with the new EPA regulations requiring sulphur reduction.

In summation, it is apparent that California must learn to live with coal for the next 50 - 75 years, if it wishes to maintain its standing in the economic community.

Since Amory Lovins has blessed FBC by including it in the category of "soft technologies", I recommend it to California.

VII. BIBLIOGRAPHY

President Carter's Energy Proposals, A Perspective. Staff Working Papers, June 1977.

Gordon, R. L., Historical Trends in Coal Utilization and Supply, prepared for U.S. Bureau of Mines, August 1976.

Mesko, J. E., and Gamble, R. L., Atmospheric Fluidized-Bed Steam Generators for Electric Power Generation, American Power Conference 1974.

P.A.T., Fluidized Bed Steam Generators for Utilities, Environmental Science and Technology, November 1974.

Mesko, J. E., Materials for Direct Combustion Fluidized-Bed Steam Generating System, ASM, April 1976, Conference on Materials for Coal Conversion Systems Design.

Iammartino, N. R., Fluidized Bed Combustion, A Better Way to Burn Coal?, Chemical Engineering, (McGraw Hill), June 1976.