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Clean Fuel from Coal for Electric Power Generation

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FOR ELECTRIC POWER GENERATION

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INTRODUCTION

Several strategies have been studied and applied for the reduction of sulfur-dioxide emissions from power generation sites. These include switching to low sulfur fuels, stack gas processing, and a greater reliance upon nuclear power. One area of interest is the processing of fuel prior to combustion through the total gasification of coal to produce a fuel gas suitable for combustion in utility boilers and gas turbines. Specifically, this paper will deal with need for coal as a fuel in the generation of electric power, the production from coal of a clean power fuel gas of approximately 150 to 200 Btu and its application to present and future coal-fueled generating units.

With an anticipated scarcity of all clean fuels, the electric utility options until recently were nuclear fuel, natural gas, low-sulfur oil, and low-sulfur coal; however, due to the recent oil embargo and regulatory actions, oil is subject to very serious supply disruptions and it has been suggested that many utilities who converted to oil convert back to coal.

Estimates of the United States natural gas supply-demand balance clearly shows the critical natural gas shortage faced by the U.S. projected deficit by 1985 of over 30% is a quantity generally agreed upon. Even if the demand for natural gas is reduced by price increases or by restrictions on end-use, it is apparent that the use of natural gas for power generation, other than peaking and ignition, is questionable.

Nuclear fuel is not presently limited by supply. Its major use is of course for the production of electric power. Shortages, that have occurred, have mainly been caused by vacillating and rapidly changing regulatory and environmental constraints. In general, nuclear units are presently competitive only for base-load generation and there is still a need for intermediate and peak load generating capacity.

Low-sulfur coal may not satisfy the future demand for low-sulfur fuels over the long term. In the short term, the mining and transportation industries will have difficulty responding adequately to a rapid shift in demand. Also, a rapid shift to low-sulfur coal may create significant economic dislocations in both of these industries with the resultant effect of making the large tonnages needed in the future more difficult to obtain.

Another indication of the seriousness of problems associated with coal is related to existing plant. A warning issued by the Federal Power Commission in a report[2] release in late February pointed to potentially critically deficient power supply reserves in seven of nine designated electric reliability areas if compliance with present 1975 air quality ordinances is mandated. Choices are limited to (a) compliance with the installation of scrubbers which are not yet proven, (b) request for a variance, or (c) shutdown. In the area of MAIN (Mid-America Interpool Network), it was reported that 13 generating plants with a capacity of 10,817 mw would not be able to comply with the standards. The effect is to reduce the estimated reserve from 17.3% to 14.4% <u>deficit</u>. Unless variances are granted curtailment of electric service can be predicted.

There are only two significant resources which will provide long-term solutions; they are coal and nuclear fuel.

Of course, coal is one of the largest resources of fossil fuels in the United States; however, by ordinance, most of it is environmentally unacceptable. Against the background of a scarcity of available clean fuels, most knowledgeable sources predict a need for coal and estimate an increase in coal consumption well into the next century and beyond. The bulk of the Midwest's coal reserves are high sulfur and almost off limits to the power plant market[3]. Environmental ordinances would eliminate a significant part of the coal being mined in the Midwest. If it is assumed that 3.0% maximum level of sulfur is allowable, 81% of Illinois' coal reserves and all of the coal in Missouri would not be acceptable as would be the case with much of the other Midwest states' coal reserves. If the coal industry is to be preserved, it is necessary to make high-sulfur coal acceptable as fuel, or modify environmental goals.

During 1974, it is estimated that Commonwealth Edison projected requirements are that uranium will provide fuel for 34.5%, coal 54%, oil 9% and natural gas 2.5% of the total estimated kilowatthours of production. Of the 54% from coal, 30.5% points will be Illinois coal and 23.5% points low sulfur Western coal. Estimated 1982 fuel mix is 50% nuclear, 40% coal and 10% oil. Moreover, although the percentage of coal in the total estimated fuel mix drops from 54% to 40%, the annual tonnage predicted for 1982 is considerably more than requirement. It is apparent there is a significant commitment to nuclear power generation; however, it is clear that coal will play a vital role in the fuel supply scenario.

Proposed methods of using coal and meeting environmental ordinances have centered about stack-gas clean-up systems. We are pessimistic about all sulfur-dioxide removal processes which have been developed thus far. Commonwealth Edison has installed two such processes at a cost of about $25 million. Despite continuing efforts, neither process is working satisfactorily, although more than two years have passed since their December 1971 service dates.

If it were reasonable to assume that a system installed in the near future would operate satisfactorily with the required reliability, the economics appear to be still highly unfavorable. Recently, proposals for sulfur-dioxide removal equipment, which was to be installed on a proposed new generating unit, were received from a number of manufacturers that have experience in this technology. These proposals either did not comply with specified sulfur-dioxide removal guarantees, were developmental proposals without cost guarantees, had unrealistically high power requirements, or were a combination of these items. Moreover, capital costs were considerably higher than had been anticipated. More recent experiences by other electric utilities has confirmed these facts.

CLEAN FUEL FROM COAL INVESTIGATIONS[5]

Over a period of about 5 years, Commonwealth Edison engineers* studied many clean fuel from coal processes. As a result of this intensive activity, we arrived at two fundamental conclusions: one, no clean fuel from coal technology had been developed to the point where it could be applied on the large scale and with the reliability needed for power generation purposes; two, there is a potential that clean fuel from coal processes may become economically feasible and could play an important role in electric power generation. Further, it has been concluded that only low Btu pressurized gasification has a reasonable chance of being economically produced on a commercial scale within the near term. Although fuel processing is attractive, it is the author's view that it is unrealistic to commit power systems to an immature technology on existing plants or those already planned and on order.

Significant development efforts are being directed to converting coal to pipeline quality gas and to liquid fuel. In addition, other programs are being directed to converting coal to pipeline quality gas and to liquid fuel. In addition, other programs are being directed toward the production of low Btu gas by the removal of undesirable ash and chemical constituents to provide a clean fuel. Low and intermediate Btu gas differs from natural gas in both its energy per unit volume and chemical constituents. Natural gas has approximately 1000 Btu/SCF and is about 95% methane. Depending on the production process, low Btu gas with 150-200 Btu/SCF would have about 5% methane with the remaining energy mostly in the form of hydrogen and carbon monoxide. Intermediate Btu gas would have about the same chemical constituents as low Btu gas. Oxygen is used to gasify the coal for intermediate Btu; whereas air is used for low Btu gas production. For power generation, the processes involved may utilize commercial equipment adapted to the task, but assembled and operated in a new and unique fashion. Thus, there is significant risk involved in developing low Btu gas through the pilot and demonstration plant stages.

When comparing processes for the production of low Btu gas versus pipeline quality gas, it is found that low Btu gas production process is much simpler since there are no oxygen, methanation, and CO_2 shift conversion facilities required. For these simpler processes, lower capital requirements, a lower operating cost and higher energy recovery efficiency are predicted. Moreover, direct integration with a power plant will permit recovery of sensible heat and an 80 percent or more overall efficiency for a low Btu gasification process is expected.

Studies indicate that the use of low Btu gas in a new conventional coal-fired station may be competitive with stack-gas scrubbing.

Although the cost of retrofitting is viewed as being considerably higher than for a new plant, the use of low Btu gas may not only be environmentally superior to stack-gas scrubbing, it also has the potential of being equal to, or less costly than, retrofitting stack-gas clean-up systems. Detailed studies of specific backfit installations are required for a determination of the most economical system. These studies would include items such as the age and remaining life of the existing plant, space requirements, and boiler derating (capacity loss) due to the lower heating value of the gas. For some cases, an intermediate Btu gas may be appropriate as a retrofit to boilers design for natural gas. Generalization of cost estimates for retrofit entail a risk of large inaccuracies.

A previous publication[6] pointed to the combined-cycle plant (with low Btu gas production) as promising environmental superiority, higher efficiency, lower cost and further improvement in the utilization of coal. This is contrasted with the "dead-end" technology of stack-gas clean-up systems which misuse resources and which may never meet the reliability and environmental ordinances required of power generation. When one compares the two technologies it is found that low Btu gas technology leads to many new options for improved power generation. Looking toward the future, it is believed that nothing on the horizon that can be done at the back-end (cleaning products of combustion) that can compete with the potential benefits that could result from combined cycle systems. The future of low Btu gasification in power generation lies in the development and use of improvements. To make these options available, the successful development of a low Btu gas production system is needed.

GENERAL PROCESS DESCRIPTION

The fuel processing scheme determines the resulting fuel gas properties and thus, overall plant efficiency levels. For the major development project which we call the Powerton Project: Clean Power Fuel Test Facility a pressurized gasification process was chosen which uses water scrubbing to remove particulate matter, a chemical was (hot potassium carbonate) process for removal of sulfur compounds, and a Claus kiln for reduction to elemental sulfur.

Six major functions of this coal gasification system are used as a basis for comparison[7]:

1. Gasification - wherin proportioned amounts of coal and high-pressure steam and air react to form gas.
2. Scrubbing - wherein the produced gas' undesirable constituents are removed by a washing process.
3. Purification - wherein hydrogen sulphide (H_2S) is removed.
4. Sulfur reduction - wherein elemental sulfur is produced from H_2S.
5. Gas heating - wherein the gas is heated to a temperature such that the fuel gas conditions - following expansion in the expander turbine will be suitable for power plant combustion.
6. Expansion compression - wherein a gas expansion turbine drives an air compressor providing air for the gasification section.

COMPARATIVE ECONOMICS

Detailed economic analyses comparing a new conventional plant with stack-gas scrubbing against a plant with low Btu pressurized coal gasification have been made with the processes integrated into the steam-generating plant. Costs for the low Btu gasification process were based on present technology.

For new integrated plants, the expected capital cost of a large scale gasification process is about $85 to 90 per kw. This was compared with a stack-gas scrubbing process at $100 per kw. In addition, when using gasification, equipment elsewhere in the power plant will be eliminated resulting in cost reductions. These reductions result from savings in the boiler and associated equipment (as compared to a coal-fired unit) and from an increase in the capacity of the plant due to a difference in auxiliary power. Reductions are estimated to range up to $45 per kw. The total capital cost differential could be as much as $45 per kw in favor of gasification.

The overall plant efficiency could be from 15 percent to 20 percent greater for some stack-gas scrubbing processes. This presumes that stack-gas clean-up can be made to operate satisfactorily. Some of the most recently proposed "dry type" stack-gas clean up systems may have requirements for a clean fuel input (as a reducing agent) that could result in significantly lower efficiencies.

The results of these studies show that the total cost of power from a fossil-fired steam-generating plant could be lower with low Btu gas as compared to using high sulfur coal and stack-gas scrubbing. This conclusion needs confirmation by actual experience, however, studies by others have arrived at the same conclusions.[8]

The most significant economic advantage of low Btu gasification has been considered.[6] Upgrading coal through pressure gasification allows coal to be used for power-production cycles presently restricted to premium fuels. This opens the door to potentially greater capital savings and higher efficiencies of the combined steam and gas turbine cycle.

POWERTON PROJECT: CLEAN POWER FUEL TEST FACILITY

Commonwealth Edison jointly with the Electric Power Research Institute is sponsoring a major research and development project leading toward the production of a clean fuel from coal for electric power generation in the shortest practical time and thus clarify the economics and environmental impact of future large scale plants.

Construction should begin late in 1974 on the proposed Powerton Project: Clean Power Fuel Test Facility. This project is designed around Lurgi technology. There is a sense of urgency to develop technology to use high-sulfur coal.

This project should bring together power generation and chemical processing industry technology. The engineer, chemical or power oriented, must learn to respond to operational requirements required by power systems. In addition to welding these two technologies, we will proceed to investigate the problems of reacting coal at a rate which is several orders of magnitude slower than practiced in the power industry while working within economic constraints differing from the chemical industry.

One major goal of this Test Facility is to provide engineers and management with data regarding costs, safety, flexibility, and controlablility and possibly proceed to demonstrate the combined-cycle plant. The first step is to build a Clean Power Fuel Test Facility which will provide fuel for existing boilers. (See Figure)

Goals of this test facility are:

. . . demonstrate that various agglomerating and non-agglomerating coals can be successfully gasified (at least 6 U. S. coals will be tested),

. . .demonstrate that substantially all the particulates can be removed from the gas,

. . .demonstrate desulfurization of the (remove about 90 percent of the sulfur),

. . .show that the production of oxides of nitrogen upon combustion are reduced,

. . .demonstrate that low Btu gas can be reliably burned in present and future boilers,

. . .demonstrate that the various systems will perform in concert probably for the production of power,

. . .demonstrate that such a system can be substantially automated to minimize manpower requirements,

. . .demonstrate that these systems operating in concert can be responsive to system load,

. . .demonstrate that gas quality can be maintained,

. . .provide economic and design data for large conventional and combined cycle plants.

ENVIRONMENTAL ASPECTS

The production of a low Btu clean gas from high-sulfur coal should result in significant reductions of contaminants to the environment. The degree of reduction will be dependent on the gasification and the desulfurization processes selected.

Reductions of about 90 percent in sulfur dioxide, virtually 100 percent in particulates, and significant reductions of nitrogen oxides are expected. Ash should present no unusual disposal problems, such as those presently encountered with wet flue gas SO_2 removal processes. Water treatment processes are generally available for the small quantities of contaminants generated in the coal gasification particulate scrubber.

A NEED

There have been many discussions which have centered on the relative advantages of various gasification, liquifaction and clean-up technologies. This paper has not attempted to argue the merits of today's state of the art technology versus that yet to be developed. There is need for clean power fuel from coal today and in the future. Although the starting point described is the fixed-bed pressurized gasifier, it does not preclude the development of fluidized-bed, entrained-bed, molten-bath, underground gasification, and liquifaction which all may contribute unique advantages to producing electricity and mitigate energy resource problems for utilities and the nation. A recent report from the National Academy of Engineering said: "The need of industry and utilities for a clean fuel is so great that it is decidedly in the national interest to develop as quickly as possible the lowest cost reliable gasification process."

That is what the Clean Power Fuel Test Facility is all about. It is designed to prove or disprove the technical capability of coal gasification and gas purification to produce a clean power fuel to supply electric power generation in the shortest practicable time.

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