

Coal Gasifier Cogeneration Powerplant Project

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Until about a generation ago, stationary sources of power and heat—whether utility, industrial, residential, or otherwise—generally relied on coal as their fuel. This practice continued until the 1950's, when plentiful supplies of low-cost oil and natural gas almost entirely displaced coal. New power and heat plants were constructed, and many existing plants converted, to use these cleaner, more easily handled fuels. Conversions were commonplace by the 1960's, with the trend accelerated by the Nation's increasing environmental concerns. The process continued without letup into the first years of the past decade.

The OPEC oil embargo of 1973 created a startling awareness of a growing vulnerability: an increasing dependence on a dwindling supply of insecure and expensive foreign petroleum. For this reason the United States has been challenged to find a suitable way to return to coal as a significant factor in our fuel mix for power and heat. This is particularly so because America's domestic coal reserves are greater than those of any other nation in the world and exceed, on an energy content basis, the world's known reserves of oil.

The revival of coal use must be carried out in a manner consistent with both the spirit and the letter of justifiable environmental concerns. This is especially difficult for the Eastern States, including Ohio, where high-sulfur coal is the predominant variety.

The NASA Lewis Research Center is a typical example of present fuel usage in power and heat generation. Natural gas is used to fire boilers at the Center to provide steam for heating. Electric power is purchased from the Cleveland Electric Illuminating Company (CEI).

As a step toward dealing with America's future energy needs, National energy policy dictates that Government buildings and installations conserve natural gas and oil and, wherever practical, convert to coal in an environmentally acceptable manner. NASA Lewis is now investigating an approach to meet these requirements and, at the same time, to undertake demonstration of technology that could substantially benefit both industry and utility users and also the high-sulfur coal producers of the country.

National Energy Policy

National Energy Policy is directed toward conservation of oil and natural gas. Specifically, Public Law 95-620, the Power Plant and Industrial Fuel Use Act of 1978, prohibits new oil or gas firing for major fuel-burning installations and encourages the conversion to coal in existing facilities where practicable. The National policy is clearly aimed at the expanded use of coal in an environmentally acceptable manner. This is particularly difficult for potential users of high-sulfur coal because of the emission of sulfur oxides and the potential formation of so-called acid rain.

In attempting to meet these National objectives we have established a set of requirements with respect to the use of coal in a cogeneration mode of operation. Since we will likely have to buy coal on the spot market—as is the case with most other small coal users—we have established the requirement to burn not only high-sulfur coal, but also a wide variety of coal types and qualities. In

addition, these coals must be burned in an environmentally acceptable manner that minimizes not only stack emissions of particulates, sulfur, and nitrogen oxides, but also other controlled trace elements and all other waste streams.

We must also meet our seasonal steam heating demand, which varies from a summer low of 20 000 pounds per hour to a winter peak of 100 000 pounds per hour. NASA Lewis, along with other Government agencies and industry, has an ongoing need to conserve energy. This added requirement would not be met by simply substituting coal for oil or gas.

The requirement of satisfactory payback time is also of vital importance for Lewis. For industry it is essential.

The powerplant must use state-of-the-art technology for two reasons. First, the latest technology will be more efficient and reliable. And second, it will be more adaptable to future improvements with growth potential. This is particularly true for turbomachinery and combustion components.

And, finally, there is the critical requirement (particularly important to small users) of having waste products that are suitable for sanitary landfill without further treatment. Waste products must be disposable without treatment at reasonable cost and with minimum handling and logistics.

Approaches for Use of High-Sulfur Coal

There are a number of approaches that can be considered for the use of high-sulfur coal. Atmospheric fluidized-bed combustion is currently being used in some applications. Pressurized fluidized beds have not yet been commercialized. In either concept the coal is intimately mixed with a sorbent—usually limestone for the atmospheric fluidized bed. The coal is desulfurized directly in the fluidized bed, with the resultant formation of calcium sulfate. This approach requires materials handling of limestone as well as coal as feedstock and handling of ash and spent sorbent as waste products. This combination of waste products must be removed from the site and permanently disposed of.

Flue gas desulfurization has been adopted by many utilities with varying degrees of success. With high-sulfur coal the stack or flue gases—products of combustion containing sulfur oxides—are scrubbed with water and a sorbent to form a sludge waste product. This approach typically exhibits problems of reduced reliability and availability, increased water use, increased energy use, and difficulty in handling and disposing of sludge wastes. In addition, the scrubbers are a significant parasitic electric load that degrades overall powerplant efficiency.

Other approaches for high-sulfur-coal use are being studied but are not yet commercialized. A promising approach is coal beneficiation—a technique that precleans and/or pretreats the coal to insure environmental acceptance of the combustion products.

Gasification is the approach that is under consideration for application at the NASA Lewis site. The rationale for this selection is as follows: It is the only process that can use high-sulfur coal with proven, commercially available acid-gas-removal cleanup techniques. In addition, since gasification requires only partial combustion, the consequent removal of acid gas (hydrogen sulfide) involves treatment of only a small fraction of the volume that would be treated by flue gas desulfurization methods. Under some conditions this fraction is as low as 1 percent.

Some gasification techniques have the potential for accepting a wide variety of coal types and qualities. This is particularly important for small coal users who may have to buy on the spot market. Waste-handling problems are minimized because the low product volumes (ash and elemental sulfur) are suitable for direct landfill use. Also there is good potential for achieving gaseous fuel emission standards, rather than solid (coal) fuel standards. This is due to the need for particulate and sulfur cleanup before gas turbine combustion to minimize corrosion in the turbine hot section. Also, when low-Btu gas is burned, the products of combustion—specifically oxides of nitrogen—are well within the new-source stationary emission standards without additional treatment techniques.

The potential for high electrical conversion efficiency exists when gasification is integrated with a combined-cycle powerplant. In addition, the cogeneration option can provide significant gains in coal utilization efficiency by using waste heat from the gas turbine to raise steam for process heating.

Coal Gasifier Cogeneration Powerplant Concept

A simplified schematic diagram of the concept is shown in figure 1. Coal and oxidant are reacted in a pressurized gasifier to generate a hot, dirty fuel gas whose temperature depends on the gasifier type and can range from 700° F to about 2600° F. The sensible heat of the fuel gas is recovered in a cooler by raising high-pressure steam. The cooled fuel gas is then routed to a commercial sulfur cleanup process. Cold fuel gas of "pipeline quality" cleanliness is then combusted in a gas turbine and produces electricity and a high-temperature combustion product exhaust. The exhaust is used to generate high-pressure steam in a heat-recovery steam generator. After combination with the high-pressure steam from the cooler, the total steam flow is passed through a steam turbine to generate additional electricity. By using a commercial extraction steam turbine low- or intermediate-pressure steam for heating can be removed for on-site use. In addition, it is important that the steam used for heating has performed shaft work in the steam turbine before extraction. This not only increases electrical output, but also allows the extraction steam turbine to follow steam load demand variations while the gasifier and gas turbine components operate at steady state or full load.

COAL TO GAS COGENERATION POWERPLANT CONCEPT

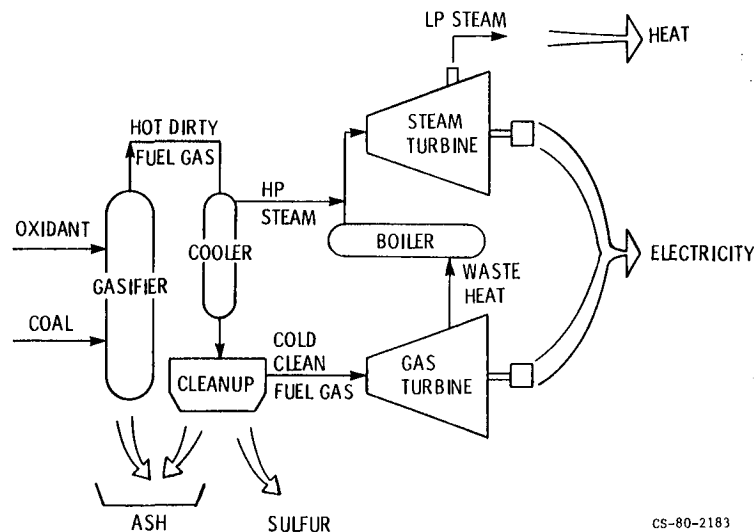


Figure 1

Coal Gasifier Cogeneration Powerplant Study

Study Rationale

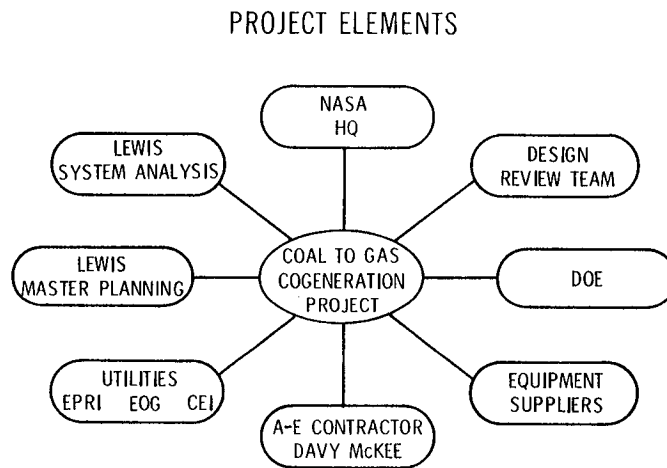
The major reasons for NASA Lewis' interest in this system concept are as follows: The National requirement to convert to coal firing is based on conserving oil and natural gas. The National need for an efficient, economically attractive option for burning high-sulfur Eastern coal exists both for industrial plants and Federal installations like NASA Lewis. It is believed that the coal gasifier combined-cycle powerplant is that option and that there is an urgent need for a timely demonstration of this technology.

In converting to high-sulfur coal firing the Lewis Research Center must modify or replace its existing steam plant. It is this confluence of needs that creates the opportunity for the Federal Government to meet National requirements and at the same time characterize and demonstrate this important technology for industry and the utilities.

Study Elements

The key groups that comprise the interactive elements of the study are shown in figure 2. The Lewis Systems Analysis Group has put to use their considerable experience in analyzing industrial cogeneration and utility systems. The Lewis Master Planning Group has the responsibility for all future facilities and their effect on the Center. The local utilities involved in the study are the Cleveland Electric Illuminating Company and the East Ohio Gas Company. The Electric Power Research Institute, because of their background in coal gasification and their interest in commercialization of large coal gasifier combined-cycle powerplants, is kept informed of the progress and results of this study.

After initial studies by the Systems Analysis Group, a competitive procurement was completed, and the Davy McKee Corporation was selected as the architect-engineer to conduct a conceptual design study to further evaluate the technical and economic feasibility of a coal gasifier cogeneration powerplant to be sited at NASA Lewis. The \$205 000 contract began December 21, 1979, and ended in July 1980. To ensure objectivity in the study results, a Design Review Team of technical specialists was appointed to provide an ongoing independent review and to prepare recommendations for NASA management. The NASA Headquarters role in this study has been to provide initial financial support and to integrate this program with energy savings and coal conversion programs within NASA.



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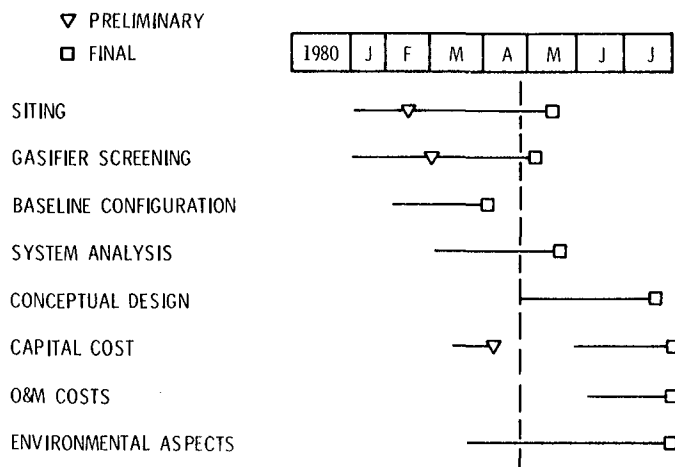
Figure 2

Feasibility Study

The feasibility study contract elements and schedule are shown in figure 3. Initial effort was aimed at selecting a suitable site at Lewis and performing a detailed screening and selection of feasible gasifiers. From an initial list of about 35 candidate gasifiers, five were selected that best fit the evaluation criteria. A reference case baseline configuration was then subjected to an initial system capital cost estimate. Component and system selections, siting, performance, and costs were evaluated by the Design Review Team.

An important consideration of the study was powerplant size or output. The factors that affect plant size are shown in figure 4. These include available gas turbomachinery package size, acceptable coal- and waste-handling facilities and logistics, available sizes of gas particulate and sulfur removal cleanup systems, maximum steam demand for cogeneration, manpower and operating cost constraints, size-related regulations for siting and emissions, and capital cost.

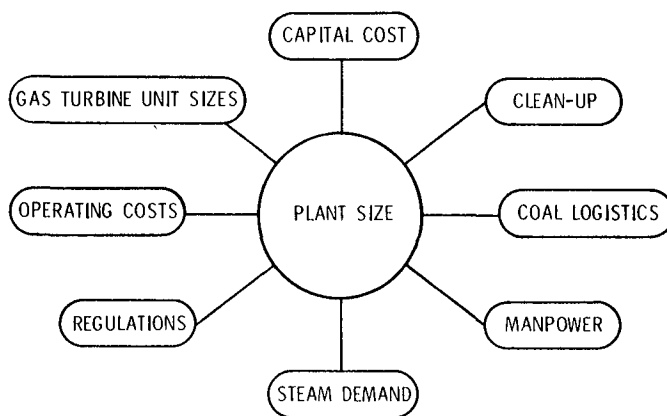
STUDY PLAN



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Figure 3

SIZING FACTORS



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Figure 4

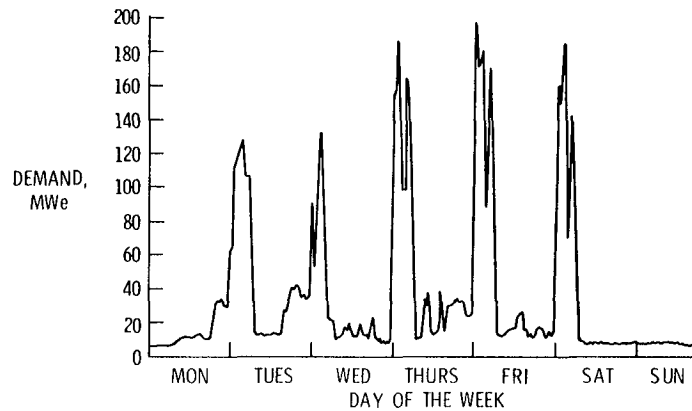
An additional size-related factor that is peculiar to the NASA Lewis Research Center is related to electricity demand, as shown in figure 5. A typical week shows a weekend load of about 5 megawatts and workday evening peaks to 200 megawatts. These high loads are due to operation of supersonic wind tunnel facilities. Evaluating these widely varying demands with other sizing factors led us to a baseline-configuration nominal output of about 20 megawatts electric.

The impact of this output is shown in the electric load duration curve of figure 6. This curve is based on an annual integration of hourly data and shows that the load will typically exceed 20 megawatts about 25 percent of the time. The upper levels of the curve are not shown but would indicate that the maximum load of about 220 megawatts is only attained for a few hours every year. During the summer, when steam demand is low (20 000 lb/hr), the extraction steam turbine generates more electricity than in the winter, when steam demand may reach 100 000 pounds per hour.

At those times when electrical demand exceeds the powerplant rating, electricity is imported from the utility. When electrical demand is less than the plant rating, electricity is available for export to

EXAMPLE OF DAILY ELECTRIC DEMAND

AUGUST 1979

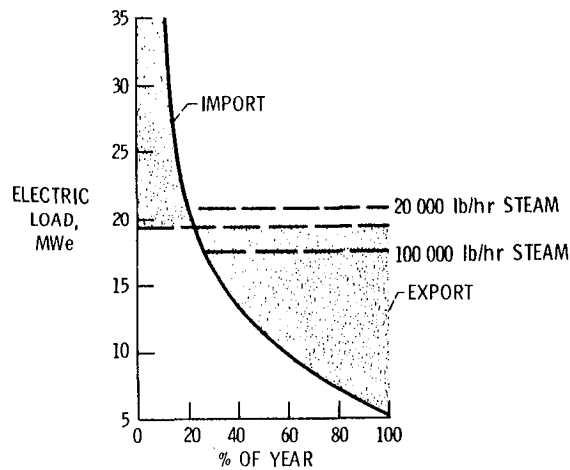


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Figure 5

OPERATION OF PRELIMINARY BASELINE CONFIGURATION

20 MWe NOMINAL RATING



CS-80-2400

Figure 6

the utility grid. For a nominal 20-megawatt-electric plant rating the total energy imported is about equal to that exported, although the curve indicates that power is purchased only 25 percent of the time and sold 75 percent of the time. Also, both import and export can occur on any typical day.

The initial tasks of the feasibility study were the establishment of gasifier selection criteria and subsequent screening and selection of a baseline gasifier. Two of the key discriminators of the total of 20 used are the ability to use a wide variety of coals (including Ohio coal) and the near-commercial status of development. The candidate gasifiers that survived screening were the Westinghouse fluidized bed, the IGT U-gas fluidized bed, the Texaco entrained flow, the B&W entrained flow, and the British gas slugging fixed bed. Of these, the Westinghouse fluidized-bed gasifier was selected for the baseline conceptual design. The other major components of the powerplant—the cleanup system,

the turbomachinery, the heat exchangers, and the coal-handling equipment—are all commercially available hardware.

The heat-exchanger category includes a raw-fuel gas cooler that will cool 1850° F gas to 400° F by generating 750° F steam for use in the steam turbine. At these temperatures materials problems in the gas cooler should be minimized and should permit current commercial design practice to be used.

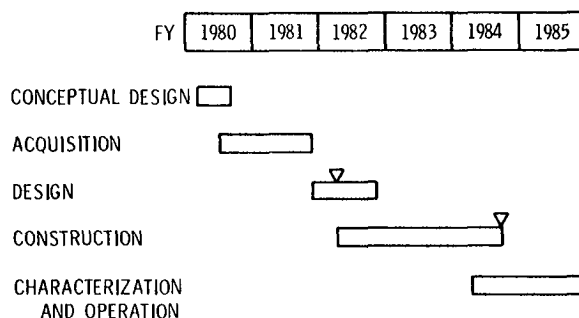
After all system components had been identified, a preliminary cost comparison was made between the coal gasifier cogeneration powerplant and two alternative concepts. The two alternative systems are (1) a high-sulfur-coal-fired steam plant with flue gas desulfurization (scrubber); and (2) a low-sulfur-coal-fired steam plant with an electrostatic precipitator (baghouse). Both of these alternative concepts produce steam for heating only and do not generate electricity.

The scrubber and baghouse concepts are characterized by relatively low capital costs, but both exhibit negative first-year operating savings. However, for the coal gasifier cogeneration powerplant, first-year annual savings of \$2 to \$7 million dollars are estimated—depending on both the electrical rate structure and the fuel cost scenario assumed. These savings are comparable to the total current annual utility costs for the Center.

A technical assessment of the key components of the gasifier cogeneration powerplant was made, with the following results: For the gasifier selected, a modest size increase from the current process-development unit would be required. Coal feed for the NASA Lewis powerplant will be about 120 tons per day for each of two gasifiers operating in parallel. Integration of two simultaneously operating gasifiers has not been demonstrated but is desirable to verify multiple module operation for larger applications. The gas turbine combustor must be modified for low-Btu-gas firing, and compressor and turbine flow rates must be matched. These turbine modifications do not appear to be major technical problems. The design of an integrated controls system has not been demonstrated for this system, but it is not expected to represent a major technical barrier once the dynamic and transient performance of each major component has been adequately characterized. This characterization is an important part of system demonstration. In summary, no fundamental technical feasibility issues are seen for the powerplant concept.

A preliminary environmental assessment of the concept has concluded that no barriers to environmental acceptance are foreseen. The concept will result in minimum waste-handling requirements, flue gas effluents will be well under environmental standards, and the selection of a low-Btu gasification process will allow combustion without water injection for NO_x suppression. In addition, as part of this study, we envision conducting an environmental impact assessment so as to establish a precedent for potential industrial applications.

GASIFIER COGENERATION POWERPLANT



CS-80-2390

Figure 7

Study Schedule

In terms of the overall study schedule a total of 5 years is estimated from start of conceptual design to completion of system characterization (fig. 7). Included in this schedule are significant time periods for acquisition, or procurement, and for characterization of the powerplant. A 2-year system characterization time would be used to check out all components and to completely define all system operating parameters. This effort is aimed at reducing risk for subsequent commercial application and is a key part of our study philosophy.

Conclusions

To be considered as a significant coal alternative in a broad sense, the cogeneration powerplant must satisfy a variety of requirements. Some important current utility and industrial cogeneration requirements are

Utility requirements:

1. 50 Percent backout of oil by 1990
2. No new oil or natural gas primary fuel firing
3. Environmental compliance (no acid rain)
4. Siting flexibility
5. Increased reliability and availability
6. Ability to accommodate unpredictable load growth
7. Reduced construction times
8. Economic competitiveness
9. Improved efficiency
10. Growth potential
11. Flexibility

Industrial requirements:

1. Rapid payback
2. Attractive ROI
3. Ability to use wide range of coal
4. Siting flexibility
5. Minimum logistics
6. Lowest emissions potential (minimize offsets)
7. Growth potential
8. Acceptable reliability and availability
9. Minimum land requirements
10. Short construction times

The technical and economic feasibility study for a combined-cycle gasifier cogeneration powerplant to be located at the NASA Lewis Research Center has tentatively shown that most of the utility and industrial requirements can be met. In addition, the study results have provided the basis for evaluating the practicality of this powerplant, whose completion would provide a system technology demonstration that would verify the following potential benefits:

1. Ability to use a wide range of coals including Eastern high-sulfur coal
2. Minimum environmental emissions and wastes
3. High efficiency
4. Rapid modular construction
5. Siting flexibility
6. Economic attractiveness
7. Potential for repowering existing oil and natural gas utility capacity
8. Only near-term alternative with growth potential, but needs system technology demonstration

The coal gasifier cogeneration powerplant being considered will not only meet the needs of the NASA Lewis Research Center, but, at the same time, will also reduce the commercial risk for industry and utilities by fully verifying and demonstrating this important technology. The powerplant would, if funded, also represent a cooperative venture of industry and Government to accelerate commercialization so as to achieve wide-spread implementation and thereby make a significant contribution to energy independence while minimizing environmental intrusion.