# TEXACO COAL GASIFICATION PROCESS: COMMERCIAL PLANT APPLICATIONS

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## INTRODUCTION:

The Texaco Coal Gasification Process (TCGP) has been employed at several commercial scale facilities worldwide, and has matured to the point where it is now an attractive alternative for use in chemical and power facilities. The successful use of the process at existing facilities has yielded valuable performance data and operating experience which can help in optimizing the efficiency of all future TCGP operating plants. This process has been employed for the production of chemicals in the U.S., Japan and West Germany. Other TCGP chemical plants in China, Sweden, West Germany, and the U.S. are now being planned or are under construction.

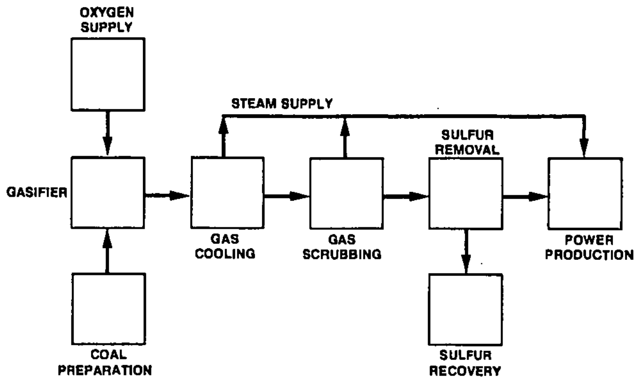
The commercial viability of TCGP for large scale production of electric power has been proven at the 120 MW Cool Water facility in Southern California. The economic and environmental characteristics of the process make it the leading technology option for future electric utility use. One major utility has publicly announced its intent to use gasification in their next power plant and many others are including it in their formal planning process.

## PROCESS DESCRIPTION:

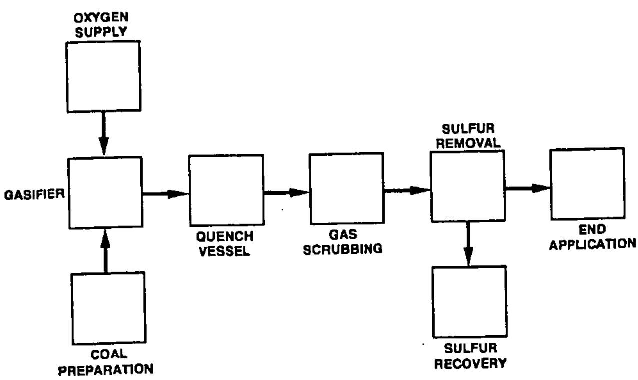
The technical details of the Texaco Coal Gasification Process will not be presented here in any depth. Numerous other papers have been published which adequately cover the details of how the process works and its technical development. (1,2,3). Figures 1 and 2 show two configurations of the process. Figure 1 shows a block flow diagram for maximum heat recovery (i.e., power plants); Figure 2 shows a minimum investment design used widely for production of synthesis gas as a chemical feedstock. Design variations from each of these options are possible to suit the requirements of a given application. For example, a gas cooler could be added to the total quench design (Figure 2) to allow for the generation of additional steam.

Utilizing Figure 1, the total process can be described. Coal is ground, slurried, and pumped to a gasifier where it reacts with oxygen. The concentration of oxygen in the gasifier is not sufficient for complete combustion, but does support partial combustion which generates heat. This heat breaks down the coal to form synthesis gas, a medium BTU product composed primarily of carbon monoxide and hydrogen. This synthesis gas is cooled, cleaned, and sent to the desired application. In Figure 1, the application is power production.

## FIGURE 1
## TEXACO COAL GASIFICATION PROCESS
## MAXIMUM ENERGY RECOVERY




## FIGURE 2
## TEXACO COAL GASIFICATION PROCESS
## MINIMUM INVESTMENT DESIGN



The steps between the gasifier and the desired end use employ proven commercial technology. The ash in the coal forms a slag material which is removed from the gas cooling section. This slag is a non-hazardous material suitable for landfill or other applications. The steam generated in the gas cooling process is utilized in a steam turbine for additional electric power production. After the gas is sufficiently cooled and scrubbed of particulate matter, it is directed to a sulfur removal and recovery stage. Sulfur contained in the coal is transformed primarily into $H_2S$, due to the gasification reactor temperature and oxygen deficient environment. This $H_2S$ can be separated from the syngas using commercially available units. The $H_2S$ is transformed to elemental sulfur which can be sold as a by-product.

EXISTING APPLICATIONS:

Nuclear fusion, photovoltaics, magnetohydrodynamics, coal liquefaction, wind power, geothermal energy, gasohol, and coal gasification were among the answers proposed for the energy crisis of the late 70's. The crisis is viewed differently in the mid 80's due to current energy economics. The petroleum and natural gas supply problems which caused the 1970's crises may have subsided, but they have not disappeared. In the years ahead, there will be a need for clean energy conversion from feedstocks other than oil and gas. Of the technologies listed as alternatives, only coal gasification has been proven on a commercial scale as an attractive option for chemicals and power production. Of the coal gasification designs proposed, only the Texaco process has met the necessary standards for wide spread acceptance and use.

For electric power production, the Cool Water Plant, in Barstow, California, has been operating for over a year and a half, gasifying 1,000 tons per day of coal in an integrated gasification combined cycle (IGCC) power plant. The plant's capacity factor (plant electric production/rated capacity) for 1985 was higher than the 1984 average for all conventional coal fired power generating stations of 50 MW or greater in the U.S. (4). Environmental data from Cool Water has shown its performance to far surpass EPA standards, as well as being environmentally superior to other new fossil fuel power plants of equivalent size.

For production of chemicals, TCGP is becoming increasingly popular for feedstock generation. Tennessee Eastman utilizes the process for the production of acetic anhydride, which is used in the photographic industries. They recently reported a 97% on-stream factor for the final six months of 1984 (5). Ube Industries gasifies 1650 tons per day of Australian and South African coals for the production of ammonia. Commercial scale ammonia plants using TCGP are now being planned for Sweden and China. A TCGP facility for the manufacture of oxo-chemicals from coal is being constructed in West Germany.

FUTURE APPLICATIONS

Electric Power Production

Application of the Texaco Coal Gasification Process for the large scale generation of electric power is clearly on the horizon. Some utilities have publicly stated their desire to use gasification for power production (6,7). Many others are internally evaluating the technology for power facilities to be commissioned in the 1990's. The Electric Power Research Institute has established a Utilities Coal Gasification Association to "encourage the development of coal gasification for the production of electricity..." (8). Utility membership in this group has grown steadily, and interest among utilities in the technology is keen.

The merits of TCGP must be viewed in relative terms compared to other power generation technologies. There are currently four leading methods of power generation in the U.S. These are nuclear fission, oil or gas combustion, coal combustion, and hydropower. 99.4% of all U.S. nameplate capacity for electric power generation utilizes these technologies (9). Each of these technologies, however, has limitations which restrict future usage. No new nuclear fission plant is being planned, and the last plants under construction are currently scheduled to start up in the early 90's. The social, political, and engineering factors which doomed this industry have been widely discussed and speculated upon. Oil and gas combustion are limited by the future supply of the fuel. The average age of an oil or gas plant retired from service in 1984 was approximately 31 years (10). Thus, in considering a power plant construction project, it is necessary to consider the price and availability of fuel not just today, but also in the decades ahead. Most forecasts suggest severe escalation for petroleum products within this time frame. Data Resources Inc. predicts inflation for oil and gas to average in excess of 10% per year throughout the 1990's, while coal prices will remain relatively stable in real terms over the same period (11).

As for coal, supply is adequate but environmental concerns may restrict its use in a direct fired mode. Hydropower has no limitations other than its availability. Expansion of the use of hydro requires the rivers to exist in sufficient concentrated quantities for large scale power generation. Unfortunately, such resources are not abundant. Ecological concerns also are present with the construction of hydropower facilities.

This situation indicates that revisions or new methods of power generation will be required for the future. As noted earlier, the Texaco Coal Gasification Process is the most successful alternate technology to emerge in recent years. New power generation methods must prove themselves to be fully competitive in terms of economic viability and operability on a commercial scale. The performance of Cool Water has proven the operability of TCGP, and the experience gained there will enhance the performance of future plants. The economic viability of TCGP has been attested to in various engineering studies (12).

Coal gasification is not the only viable option for power generation in the 1990's. Site specific considerations will make other technologies the preferred option in some instances. However, a certain percentage of new plants will be designed for IGCC due to its long range attractiveness. The North American Electric Reliability Council (NERC) forecasts 113,200 MW of new electricity generation capacity will be added by 1994 (13). Planned coal and nuclear plants account for much of that addition. With the halt in nuclear planning, new construction beyond 1994 will be predominately coal based. Due to the economic comparability and environmental superiority of the Texaco Process as compared with traditional coal utilization methods, this process will emerge as the technology of choice for many of the capacity additions in the 1990's.

Some traits of the plants to be built in the 1990's will distinguish them from the Cool Water facility. In efficiency, it has been estimated that a 600 MW facility could be constructed with a net heat rate of 9,000 BTU/KWH (14). This rating is competitive with efficiencies found in existing power generation facilities. Some 600 MW facilities will be built, but a recent trend in power plant construction is toward smaller size, and phased modular construction. A typical plant could be 400 MW in total size, constructed in four 100 MW phases. This allows the utility to gain an economy of scale on some components while delaying capital expenditures until they are needed. Economic efficiency of the construction process can be greatly enhanced with this phasing technique. Gasification facilities are well suited to these construction methods.

Power plants being constructed in the 1990's must have a great deal of operating flexibility. Cool Water has verified the ability of TCGP to load follow (i.e., reduce or increase output quickly) and, as noted, the capacity factor for the plant has already surpassed the competitive level. From these results, it is expected that TCGP can meet the operating requirements of a base load power station. To do so on a practical basis requires flexibility of feedstock requirements. Table 1 shows a list of coals which have been gasified at Texaco's Montebello Research Laboratory. Several are now in use at commercial scale plants worldwide. Although there are differences in gasifier operations for different coals, experience has shown that all bituminous and sub-bituminous coals, and petroleum coke can be successfully gasified.

Environmentally, the performance of Texaco coal gasification plants will probably be the standard which other fossil fuel facilities will have to meet. Furthermore, environmental records of future IGCC plants could surpass that of Cool Water, which has already been characterized as the cleanest coal burning plant in operation today. Figure 3 illustrates a comparison of actual emissions for Cool Water vs. the EPA standards. Clearly, this is a strong asset of TCGP in assessing its future use in large scale power production.

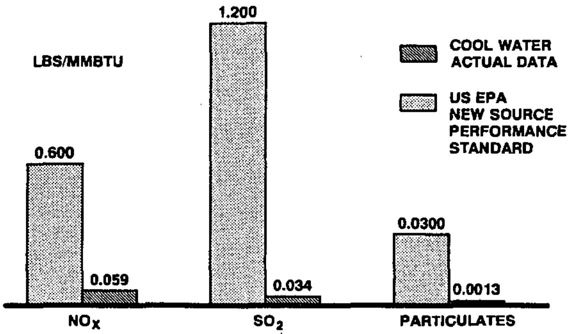
It is not certain which utilities will be among the first to begin utilizing IGCC plants. It could be expected that a need for capacity, an environmentally sensitive operating region, and a proximity to coal reserves, will be among the traits of those initial utilities. Perhaps more important is a corporate mindset which accepts business risk, and seeks to improve their operating efficiencies. Particularly attractive to such firms might be the abilitv of the process to co-produce other saleable products such as methanol, hydrogen, and steam.

A final aspect of future IGCC power plants which will distinguish them from those currently in service may be the ownership structure. The Public Utility Regulatory Policy Act of 1978 (PURPA) has encouraged the private ownership of electric power production facilities. The concept of power plant partnerships between utilities and power users, utilities and power industry firms, and between utilities and other utilities will become more common particularly for projects using relatively new technologies. The utility/power user partnership concept could become especially prevalent if deregulation procedes on an aggressive course as some suggest.

## CHEMICALS PRODUCTION:

The basic product of coal gasification is synthesis gas, a mixture

## FIGURE 3
## ENVIRONMENTAL PERFORMANCE




## TABLE 1
## FEEDSTOCK FLEXIBILITY
## SOLID FUELS GASIFIED AT
## TEXACO'S MONTEBELLO RESEARCH LABORATORY

| BITUMINOUS COALS | SUB-BITUMINOUS COALS |
|---|---|
| PITTSBURGH | WYOMING |
| KENTUCKY 9 | ARIZONA |
| ILLINOIS 6 | UTAH |
| UTAH | JAPAN |
| TENNESSEE | **LIGNITES** |
| GERMANY | TEXAS |
| AUSTRALIA | NORTH DAKOTA |
| SOUTH AFRICA | GREECE |
| CANADA | **PETROLEUM COKES** |
| ITALY | FLUID |
| CHINA | DELAYED |
| | CALCINED |

## FIGURE 4
## CHEMICAL COMPOSITION OF SYNTHESIS GAS - CLEAN & DRY BASIS

| COMPONENT | VOLUME % |
|---|---|
| CO | 42.5 |
| $H_2$ | 38.2 |
| $CO_2$ | 18.6 |
| $CH_4$ | 0.3 |
| AR & $N_2$ | 0.4 |
| $H_2S$ & COS | 50PPM |

of several components primarily carbon monoxide and hydrogen. Figure 4 shows a typical breakdown of its composition on a dry basis after cleanup. As was indicated, this gas can be used as a medium BTU fuel for the production of electrical power. It can also be used as a chemical feedstock in the production of hydrogen, ammonia, methanol, oxo-chemicals, and other substances. The growth of these industries is expected to be strong in the early 1990's (15). However, existing overcapacity for many of these products makes capacity addition forecasting difficult.

One of the key factors in assessing the prospects for TCGP in the chemicals manufacturing industries is the competition. As a chemical feedstock, synthesis gas must compete directly with natural gas. In today's market, natural gas is relatively inexpensive and supply is plentiful. The future of this market must be viewed in assessing feedstock alternatives. The popular belief among forecasters is that in the long-term, inflation rates and security of supply will be much more favorable for the consumer of coal as opposed to the natural gas user. Therefore, if a plant is being designed to securely fulfill a long term need for the plant output, coal gasification would be a preferred option.

Multi-product facilities based upon coal gasification will probably see some use in the coming years. NASA is considering the construction of a coal gasification plant to supply all of their hydrogen, oxygen, electricity, nitrogen, fuel gas, and heated water needs. Because coal, air, and water are the only feed streams needed to produce the desired products, the security of supply is not expected to be a problem. If NASA so opted , the proposed facility could also export any of the produced products as well as argon and sulfur. Such decisions would hinge upon the commercial marketplace.

Because of the many uses of synthesis gas, multi-product projects, similar to that proposed by NASA, will probably be considered in the future. In such facilities, steam, electricity, sulfur, and possibly other products will be produced. Under federal cogeneration guidelines, export electricity produced in this type of facility must be purchased by the local utility who must also supply backup power to the site.

Several types of possible chemical facilities could use TCGP for feedstock generation and cogenerated power production. Based upon the current trends in the chemicals markets, we believe TCGP will play a major role in the chemical industry by the mid-1990's. As has been true to date, no single application will dominate, but plants of varying size and product slate will be constructed.

## SUMMARY:

The development of the Texaco Coal Gasification Process has now reached a stage of maturity. Already employed on a commercial scale in the chemicals and electric utility industries, the process is now being widely considered for use in the new facilities in both these sectors. Benefitting from the experience obtained in the existing plants, new facilities can expect operating efficiencies and process economics which are competitive, and in some cases, superior to other technologies.

The process not only meets the necessary economic, operational, and environmental standards for use today, it also uses technology which will become even more attractive with future energy economics and environmental regulations. Natural gas and petroleum feedstocks are forecasted to become more expensive and more scarce. Conventional coal technology, even with scrubbers, may be subject to continuous capital outlays to meet changing environmental standards. A Texaco Coal Gasification Facility will not be as seriously affected by either of these expected trends.

Notes:


1. Kolaian, J. H. and Schlinger, W. G. "The Texaco Coal Gasification Process". Energy Progress. Vol. 2, No. 4. December 1982.

2. Moss, S. H. and Schlinger, W. G. "Coal Gasification". Lubrication. Vol. 66, No. 3. 1982.

3. Schlinger, W. G., Kolaian, J. H., Quintana, M. E., and Dorawala, T. G. "Texaco Coal Gasification Process for Production of Clean Synthesis Gas from Coke". Presented at American Institute of Chemical Engineers Spring Meeting, March 1985.

4. National Coal Association. Steam Electric Plant Factors. 1985 Edition.

5. Horton, E. and Gockenback, K. "Chemicals From Coal: A Reliable And Economical Alternative". Presented at Coal Gasification and Synthetic Fuels For Power Generation Symposium sponsored by the Electric Power Research Institute and Forschungsanlage Julich, April 1985.

6. Electric Utility Week. "PEPCO Outlines Plans For Next Capacity Addition - Coal Gasification, Combined Cycle." April 22, 1985.

7. Public Service Company of Indiana. Form 10-K. December 1984.

8. Utility Coal Gasification Association. Charter. 1985.

9. Energy Information Administration. Inventory of Power Plants in the United States 1984. DOE/EIA - 0095 (84). 1985.

10. National Coal Association. Steam Electric Plant Factors. 1985 Edition.

11. Data Resources Inc. Energy Review. Summer 1985.

12. Electric Power Research Institute. Cost and Performance for Commercial Applications of Texaco Based Gasification - Combined Cycle Plants. Prepared by Fluor Engineers. EPRI AP-3486. April 1984.

13. North American Electric Reliability Council. Electric Power Supply and Demand 1985-1994. 1985

14. Skarbek, R. L. "The Status of the Cool Water Coal Gasification Program". Presented at Synfuels 5th Worldwide Symposium. November 1985.

15. Data Resources Inc. U.S. Long-Term Review. Fall 1985