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Comprehensive Report to Congress
Clean Coal Technology Program

Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process

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Washington, D.C. 20585

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1.0 EXECUTIVE SUMMARY

In September 1988, Public Law No. 100-446 provided $575 million to conduct cost-shared Clean Coal Technology (CCT) projects which demonstrate emerging clean coal technologies that are capable of retrofitting or repowering existing facilities. Toward that end, a Program Opportunity Notice (PON) issued by the Department of Energy (DOE) in May, 1989, solicited proposals to demonstrate technologies with the potential for commercialization in the 1990s that are capable of (1) achieving significant reductions in the emissions of sulfur dioxide (SO_2) and/or nitrogen oxides (NO_x) from existing facilities to minimize environmental impacts such as transboundary and interstate pollution and/or (2) providing for future energy needs in an environmentally acceptable manner.

In response to the PON, 48 proposals were received by DOE in August 1989. After evaluation, 13 projects were selected for award. These projects involve both advanced pollution control technologies that can be "retrofitted" to existing facilities and "repowering" technologies that not only reduce air pollution but also increase generating-plant capacity and extend the operating life of the facility.

One of the thirteen projects selected for funding is the Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process proposed by Air Products and Chemicals, Inc. (APCI). This project will demonstrate the efficient production of methanol from coal-derived synthesis gas. The low NO_x emissions when burning methanol make it attractive for use in industrial boilers and combustion turbines. In addition, its use in transportation vehicles can reduce particulate emissions and smog. Further, this technology, combined with an Integrated Gasification Combined Cycle (IGCC) plant, can be used to repower existing coal-fired electric generating facilities while meeting stringent acid rain requirements.

Methanol is formed by the catalytically promoted reaction of hydrogen with carbon monoxide and carbon dioxide. The reaction, however, liberates considerable heat. This raises the temperature, which reduces catalyst life and activity. The LPMEOH™ process utilized in this project uses small catalyst particles suspended in a liquid-phase mineral oil. The mineral oil acts as a heat sink and provides a dramatic improvement in the temperature control of the catalyst surface in comparison with conventional gas-phase systems.

The LPMEOH™ technology was developed specifically for use with IGCC power plants to reduce capital costs and to improve the flexibility of electric power production. In this configuration, approximately 15 to 50% of the heating value of the coal gas is efficiently converted to methanol, and the unconverted gases are fired in a combustion turbine/generator(s). Unlike conventional gas-phase methanol processes, the carbon dioxide in the feed gas does not need to be removed; instead, this portion of the high-pressure gas stream can be supplied to the turbine/generator for efficient electrical energy production. The methanol produced can be used to fire the combustion turbine/generator(s) during peak demand periods and/or can be exported off site for other uses. Further, the acid rain emissions from this IGCC/LPMEOH™ plant are extremely small.

The demonstration project will be conducted at the Texaco Cool Water Project (TCWP) facility to be owned by Texaco Syngas Inc. (TSI). This plant is located in Daggett, California, as shown in Figure 1, and will be recommissioned for operation in 1993. A U.S. bituminous coal will be used in the demonstration project. The demonstration project will produce 150 tons/day of methanol product (97% purity). A portion of this methanol product will be vaporized and supplied to the existing gas turbine, modified with low NO_x technology, to demonstrate electric power demand load following. In addition, off-site testing of the methanol produced in the LPMEOH™ process will be performed at several different sites, mainly in the Los Angeles area, to determine its suitability for boiler and transportation fuel applications.

TSI will perform several activities outside the DOE scope of work but will, nevertheless, provide nonproprietary data. These activities include gasifying sewage sludge along with coal, recovering carbon dioxide from the gasifier synthesis gas, and investigating the beneficial use of the gasifier slag.

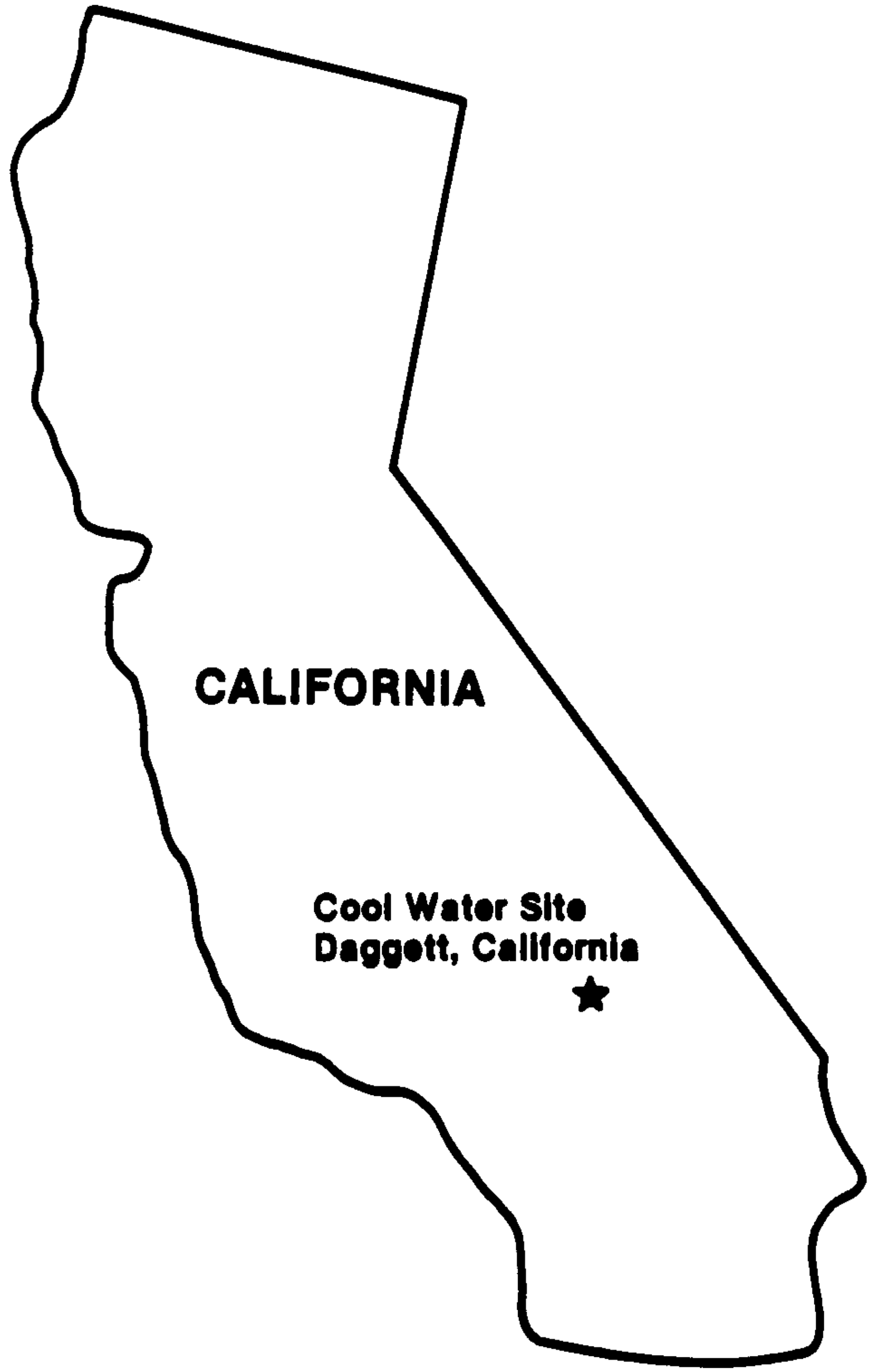


FIGURE 1. LPMEOH™ PROJECT LOCATION

This demonstration project will be performed over 88 months. Project activities include engineering, permitting, procurement, construction, start-up, operations, and fuel methanol demonstrations.

The total project cost is $213,700,000. The DOE share is $92,708,370. The co-funders are Air Products and Chemicals, Inc. ($25,315,000), TSI ($77,241,000), and Acurex ($2,080,000). The remaining Participant cost share of $16,355,630 is project revenue derived from the sale of product methanol. Operation is scheduled to begin in late 1994. Overall project completion is scheduled for the end of 1998.

2.0 INTRODUCTION AND BACKGROUND

2.1 Requirement for a Report to Congress

On September 27, 1988, Congress made available funds for the third clean coal demonstration program (CCT-III) in Public Law 100-446, "An Act Making Appropriations for the Department of the Interior and Related Agencies for the Fiscal Year Ending September 30, 1989, and for Other Purposes" (the "Act"). Among other things, this Act appropriates funds for the design, construction, and operation of cost-shared, clean coal projects to demonstrate the feasibility of future commercial applications of such "... technologies capable of retrofitting or repowering existing facilities ...." On June 30, 1989, Public Law 101-45 was signed into law, requiring that CCT-III projects be selected no later than January 1, 1990.

Public Law 100-446 appropriates a total of $575 million for executing CCT-III. Of this total, $6.906 million are required to be reprogrammed for the Small Business and Innovative Research Program (SBIR) and $22.548 million are designated for Program Direction Funds for costs incurred by DOE in implementing the CCT-III program. The remaining, $545.546 million was available for award under the PON.

The purpose of this Comprehensive Report is to comply with Public Law 100-446, which directs the Department to prepare a full and comprehensive report to Congress on each project selected for award under the CCT-III Program.

2.2 Evaluation and Selection Process

DOE issued a draft PON for public comment on March 15, 1989, receiving a total of 26 responses from the public. The final PON was issued on May 1, 1989, and took into consideration the public comments on the draft PON. Notification of its availability was published by DOE in the Federal Register and the Commerce Business Daily on March 8, 1989. DOE received 48 proposals in response to the CCT-III solicitation by the deadline, August 29, 1989.

2.2.1 PON Objective

As stated in PON Section 1.2, the objective of the CCT-III solicitation was to obtain "proposals to conduct cost shared Clean Coal Technology projects to demonstrate innovative, energy efficient technologies that are capable of being commercialized in the 1990s. These technologies must be capable of (1) achieving significant reductions in the emissions of sulfur dioxide and/or the oxides of nitrogen from existing facilities to minimize environmental impacts such as transboundary and interstate pollution and/or (2) providing for future energy needs in an environmentally acceptable manner."

2.2.2 Qualification Review

The PON established seven Qualification Criteria and provided that, "In order to be considered in the Preliminary Evaluation Phase, a proposal must successfully pass Qualification." The Qualification Criteria were as follows:

(a) The proposed demonstration project or facility must be located in the United States.

(b) The proposed demonstration project must be designed for and operated with coal(s) from mines located in the United States.

(c) The proposer must agree to provide a cost share of at least 50 percent of total allowable project cost, with at least 50 percent in each of the three project phases.

(d) The proposer must have access to, and use of, the proposed site and any proposed alternate site(s) for the duration of the project.

(e) The proposed project team must be identified and firmly committed to fulfilling its proposed role in the project.

(f) The proposer agrees that, if selected, it will submit a "Repayment Plan" consistent with PON Section 7.4.

(g) The proposal must be signed by a responsible official of the proposing organization authorized to contractually bind the organization to the performance of the Cooperative Agreement in its entirety.

2.2.3 Preliminary Evaluation

The PON provided that a Preliminary Evaluation would be performed on all proposals that successfully passed the Qualification Review. In order to be considered in the Comprehensive Evaluation phase, a proposal must be consistent with the stated objective of the PON, and must contain sufficient business and management, technical, cost, and other information to permit the Comprehensive Evaluation described in the solicitation to be performed.

2.2.4 Comprehensive Evaluation

The Technical Evaluation Criteria were divided into two major categories: (1) the Demonstration Project Factors were used to assess the technical feasibility and likelihood of success of the project, and (2) the Commercialization Factors were used to assess the potential of the proposed technology to reduce emissions from existing facilities, as well as to meet future energy needs through the environmentally acceptable use of coal, and the cost effectiveness of the proposed technology in comparison to existing technologies.

The Business and Management criteria required a Funding Plan and an indication of Financial Commitment. These were used to determine the business performance potential and commitment of the proposer.

The PON provided that the Cost Estimate would be evaluated to determine the reasonableness of the proposed cost. Proposers were advised that this determination "will be of minimal importance to the selection," and that a detailed cost estimate would be requested after selection. Proposers were cautioned that if the total project cost estimated after selection is greater *than the amount specified in the proposal, DOE would be under no obligation to* provide more funding than had been requested in the proposer's Cost Sharing Plan.

2.2.5 Program Policy Factors

The PON advised proposers that the following program policy factors could be used by the Source Selection Official to select a range of projects that would best serve program objectives:

(a) The desirability of selecting projects that collectively represent a diversity of methods, technical approaches, and applications.

(b) The desirability of selecting projects in this solicitation that contribute to near term reductions in transboundary transport of pollutants by producing an aggregate net reduction in emissions of sulfur dioxide and/or the oxides of nitrogen.

(c) The desirability of selecting projects that collectively utilize a broad range of U.S. coals and are in locations which represent a diversity of EHSS, regulatory, and climatic conditions.

(d) The desirability of selecting projects in this solicitation that achieve a balance between (1) reducing emissions and transboundary pollution and (2) providing for future energy needs by the environmentally acceptable use of coal or coal-based fuels.

The word "collectively" as used in the foregoing program policy factors, was defined to include projects selected in this solicitation and prior clean coal solicitations, as well as other ongoing demonstrations in the United States.

2.2.6 Other Considerations

The PON provided that in making selections, DOE would consider giving preference to projects located in states for which the rate-making bodies of those states treat the Clean Coal Technologies the same as pollution control projects or technologies. This consideration could be used as a tie breaker if, after application of the evaluation criteria and the program policy factors, two projects receive identical evaluation scores and remain essentially equal in value. This consideration would not be applied if, in doing so, the regional geographic distribution of the projects selected would be altered significantly.

2.2.7 National Environmental Policy Act (NEPA) Compliance

As part of the evaluation and selection process, the Clean Coal Technology Program developed a procedure for compliance with the National Environmental Policy Act of 1969, the Council on Environmental Quality (CEQ) NEPA regulations (40 CFR 1500-1508) and the DOE guidelines for compliance with NEPA (52 FR 47662, December 15, 1987).

This procedure included the publication and consideration of a publicly available Final Programmatic Environmental Impact Statement (DOE/EIS-0146) issued in November 1989, and the preparation of confidential preselection project-specific environmental reviews for internal DOE use. DOE also prepares publicly available site-specific documents for each selected demonstration project as appropriate under NEPA.

2.2.8 Selection

After considering the evaluation criteria, the program policy factors, and the NEPA strategy as stated in the PON, the Source Selection Official selected 13 projects as best furthering the objectives of the CCT-III PON.

Secretary of Energy, Admiral James D. Watkins, U.S. Navy (Retired), announced the selection of 13 projects on December 21, 1989. In his press briefing, the Secretary stated he had recently signed a DOE directive setting a 12-month deadline for the negotiation and approval of the 13 cooperative agreements to be awarded under the CCT-III solicitation. However, for this project the deadline was extended to allow time for the proposer to more fully develop plans for the new site, since the originally proposed site is no longer available for this demonstration, and for the DOE to complete its evaluation.

3.0 TECHNICAL FEATURES

3.1 Project Description

The Liquid Phase Methanol (LPMEOH™) Process will demonstrate an economical method to produce an alternative fuel from coal that is suitable for use in boilers, combustion turbines, and transportation vehicles and results in low NO_x and SO_2 emissions. The proposed demonstration will produce 150 tons per day (TPD) of methanol from coal-derived synthesis gas. It will be the first commercial-scale demonstration of this U.S. developed technology in the world.

The primary advantages of the LPMEOH™ process are that raw synthesis gas from coal gasifiers can be used directly without the need for shifting CO to H_2 and that more high-purity methanol can be produced per reactor pass compared with currently available processes. When used in conjunction with Integrated Gasification Combined Cycle (IGCC), electrical energy can be produced efficiently from coal while significantly reducing acid rain emissions. This is particularly attractive for repowering existing coal-fired power generation facilities.

The demonstration will be conducted at the Texaco Cool Water Project (TCWP) Plant, which will be owned and operated by TSI. This plant is expected to be recommissioned in 1993 and will use a combination of coal and sewage plant sludge as the feedstock. It is a 93 MWe (net) coal gasification, combined-cycle, commercial-scale power plant.

The methanol produced by the LPMEOH™ process at the TSI Plant will be tested both (a) on site in an existing gas turbine, modified with low NO_x burner technology, to demonstrate electric power demand load following capabilities and (b) off site in boiler and transportation fuel application demonstrations directed by the Acurex Corporation.

The project objective is to demonstrate the technical and economic feasibility of the LPMEOH™ technology on a commercial scale and in a commercial configuration. If successful, the process will produce higher purity methanol at lower capital and operating costs than conventional processes.

3.1.1 Project Summary

Project Title:	Commercial-Scale Demonstration of the Liquid Phase Methanol Process
Proposer:	Air Products and Chemicals, Inc.
Project Location:	Texaco Cool Water Project Facility Daggett, California San Bernardino County
Technology:	Production of a clean alternative fuel (methanol) to reduce site CO_2 emissions and NO_x/SO_2 emissions from boilers, combustion turbines, and transportation vehicles
Application:	Repowering of Coal-Fired Power Plants Using Integrated Gasification Combined Cycle and a New Clean Alternative Fuel for Reduced Emissions from Stationary and Mobile Sources
Type of Coal Used:	Western U.S. Bituminous
Product:	New Clean Alternative Fuel
Project Size:	150 Tons/Day of Methanol
Project Start Date:	September 16, 1991
Project End Date:	December 31, 1998

3.1.2 Project Sponsorship and Cost

Project Sponsor:	Air Products and Chemicals, Inc.
Co-Funders:	Texaco Syngas Inc. Acurex Corporation
Estimated Project Cost:	$213,700,000

Project Cost Distribution:

Participant Share (%)	DOE Share (%)
56.62	43.38

3.2 LPMEOH™ Process

3.2.1 Overview of Process Development

The LPMEOH™ process was developed and patented by Chem Systems, Inc. in 1975. Initial research and studies focused on two modes of operation: a liquid fluidized mode where relatively large catalyst pellets are suspended in a fluidizing liquid, and an entrained slurry mode where fine catalyst particles are slurried in an inert liquid. Both modes progressed in parallel from bench-scale reactors, through an intermediate-scale laboratory Process Development Unit (PDU) demonstration, to larger scale demonstrations at DOE's PDU in LaPorte, Texas. Due to its superior performance, the slurry mode of operation was ultimately chosen for further study which has continued both at the LaPorte PDU and in Air Products' laboratories at Allentown, Pennsylvania.

Much of the PDU-scale testing has been performed by Air Products and DOE as part of DOE's indirect coal liquefaction program. Chem Systems, Inc. has been a subcontractor under this PDU testing program, and the Electric Power Research Institute (EPRI) and Fluor Corporation have contributed as private cost-sharing participants.

Bench-scale testing of the slurry reactor concept for the LPMEOH™ process began in late 1979 at Chem Systems' laboratory. The various bench-scale tests verified the concept, expanded the LPMEOH™ data base, and provided support and options for the LaPorte PDU work. From 1984 to 1985 five major methanol synthesis runs were conducted at the LaPorte PDU. During these runs, up to 8 TPD of methanol were produced, reactor performance and catalyst life were demonstrated, improved materials of construction to prevent catalyst poisoning were determined, and over 2500 hours of operating experience were gained. The latest development program was initiated in 1988 to prepare for a commercial-scale demonstration with an optimized and simplified process. Optimization and simplification resulted in elimination of the external slurry loop and redesign of the reactor to incorporate an internal heat exchanger and increased slurry loading. Five major test runs were performed with the optimized process. During these runs up to 13 TPD of methanol were produced, the modified reactor design was proven, catalyst addition/withdrawal and load following were demonstrated, and oil recovery was improved.

In addition to the above, a field program was initiated in the fall of 1989 to evaluate the extent to which the synthesis gas would require cleanup prior to entering the LPMEOH™ reactor system. Further, an advanced gas cleanup system was developed as part of a separate DOE program. This program will determine levels of catalyst poisons and their removal rates. At Air Products' laboratories, preliminary tests on gas with high levels of catalyst poisons have shown successful removal of contaminants.

The successful completion of the PDU program at LaPorte, Texas, demonstrated that the technology is ready for full-scale demonstration on synthesis gas produced by coal gasification.

3.2.2 Process Description

Methanol is formed by the reaction of hydrogen with carbon monoxide and carbon dioxide. The majority of the world's methanol is currently produced by the ICI or the Lurgi gas-phase methanol synthesis processes (which are foreign developed technologies). Both of these technologies require a feed gas to the reactor that is rich in hydrogen and deficient in oxides of carbon to minimize the rate of catalyst deactivation and to maximize the rate of methanol production. This deficiency in carbon oxides concentration, however, imposes a limitation on the amount of methanol that can be produced per pass through the reactor. As a result, any unreacted synthesis gas has to be recycled back to the reactor.

These conventional processes can be integrated with IGCC power generation plants, but because modern coal gasifiers with acid gas removal systems produce a clean synthesis gas stream which is rich in carbon oxides and deficient in hydrogen, the feed gas must be processed further so that it is hydrogen rich and carbon oxide deficient. As shown in Figure 2, this is accomplished by diverting a portion of the clean synthesis gas to a shift converter, where carbon monoxide is reacted with steam to form hydrogen and carbon dioxide. The carbon dioxide is removed from the feed stream using one of several conventional absorption processes. Although shift and carbon dioxide removal technologies are well proven, they are expensive and consume considerable energy. In addition, the carbon dioxide reject stream represents a significant loss of potentially recoverable energy.

The LPMEOH™ process differs significantly from currently available gas-phase technologies for methanol synthesis. In the LPMEOH™ process, the feed gas does not have to be hydrogen rich, there is no need to dilute the feed gas to control catalyst surface temperature, and more methanol is produced per pass through the reactor.

The LPMEOH™ process is based on a catalyst that is similar in composition to the conventional gas-phase catalyst. The primary difference is that the small catalyst particles are suspended in an inert hydrocarbon liquid, usually a mineral oil, which provides better control of catalyst temperature than in conventional gas-phase processes.

Synthesis gas containing carbon monoxide, carbon dioxide, hydrogen, and other, nonreactive gases is preheated to the reaction temperature. This gas is then fed into the LPMEOH™ reactor where it contacts the catalyst/oil slurry. The reactive gases dissolve in the oil phase and diffuse to the catalyst surface, where the methanol formation reaction occurs. The methanol then diffuses through the oil, re-enters the gas phase, and leaves the reactor.

The heat liberated during the methanol synthesis reaction is absorbed by the slurry and is removed by means of an internal heat exchanger, where cooling occurs by steam generation within the heat exchanger tubes.

The crude methanol leaving the reactor has a high purity. Therefore, stripping of the dissolved gases is the only process required to produce methanol product. This is significantly simpler and cheaper than the processes required to upgrade crude methanol produced from gas-phase processes.

The LPMEOH™ process can be integrated with an IGCC plant as shown in Figure 3. In this design the raw synthesis gas is cooled, cleaned, and processed through the LPMEOH™ unit, where a portion of the gas is converted to methanol for use as low-NO_x combustion turbine/generator fuel. Unlike conventional gas-phase processes, the unconverted gases leaving the LPMEOH™ unit are fed directly to a combustion turbine/generator(s) that produces electrical energy. The hot exhaust gases from the combustion turbine(s) are sent to a heat recovery steam generator(s) that produces high-pressure superheated steam. This steam is then supplied to a steam turbine/generator that produces additional electrical energy.

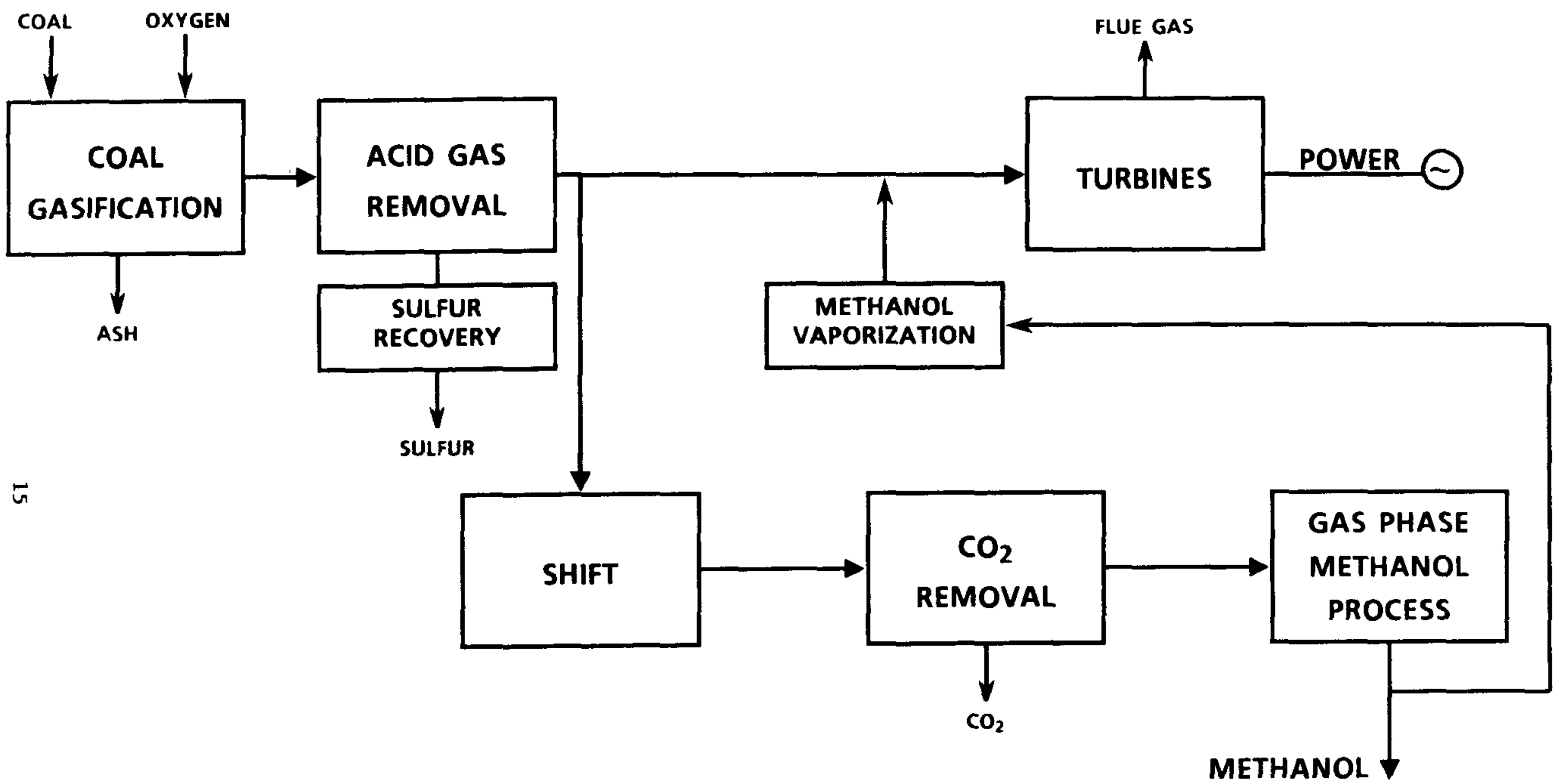


FIGURE 2. COPRODUCTION OF METHANOL AND ELECTRIC POWER VIA CONVENTIONAL GAS-PHASE METHANOL TECHNOLOGY

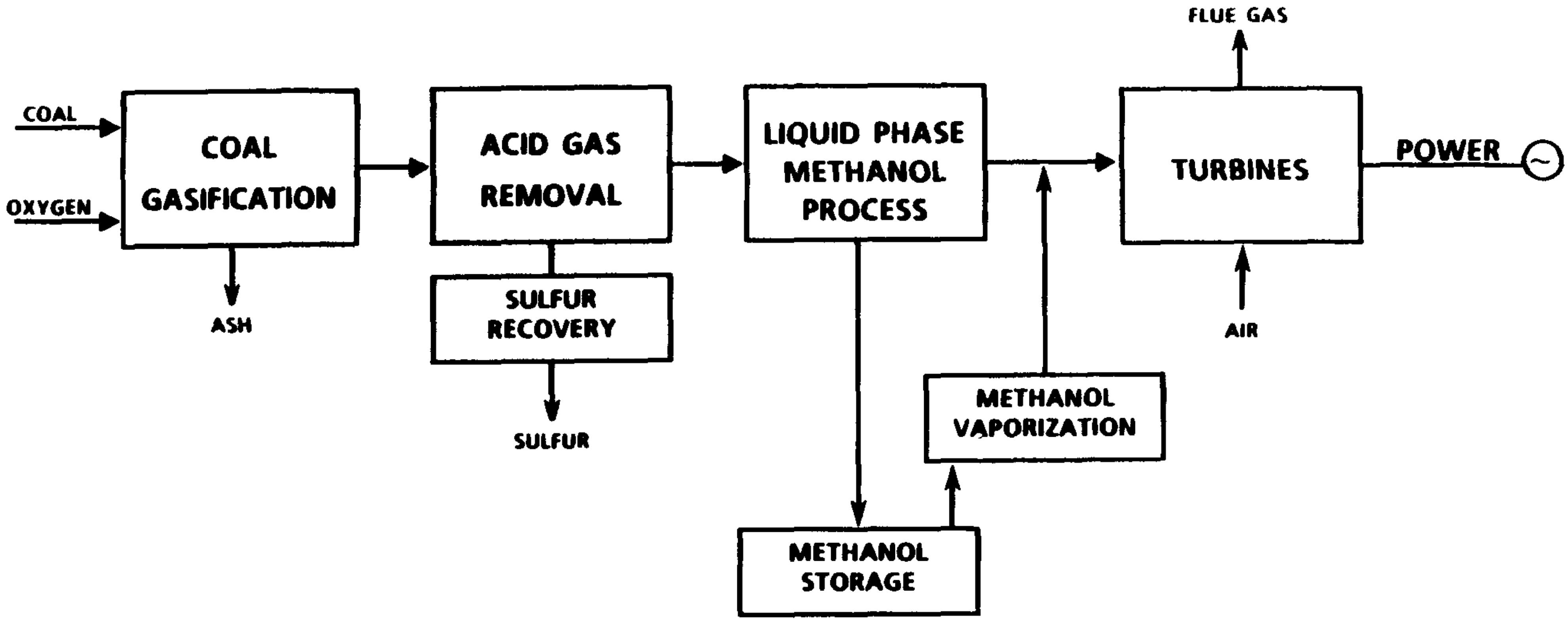


FIGURE 3. IGCC / LPMEOH™ PROCESS GENERIC FLOW DIAGRAM

The sulfur recovery portion of the system removes virtually all sulfur compounds from the synthesis gas and produces a marketable sulfur by-product. The net result of the IGCC/LPMEOH™ process is that electrical energy and methanol product are produced, while NO_x, SO_2, and particulate matter emissions are reduced to levels which surpass all federal emissions standards.

3.2.3 Application of Process in Proposed Project

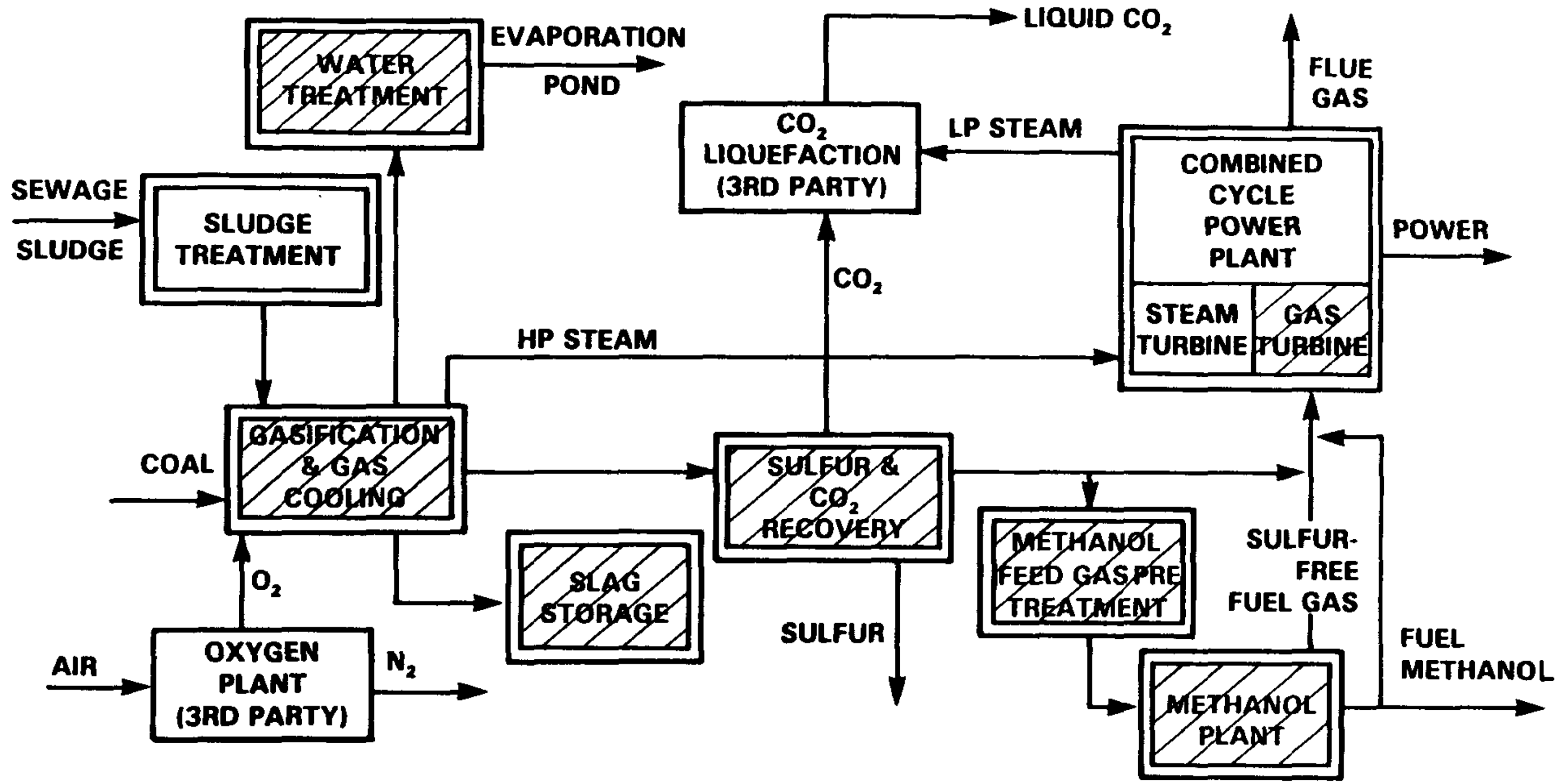
The Cool Water Gasification facility operated between 1984 and 1989 as a successful commercial demonstration of the Texaco gasification process. Under terms of the operating agreements, ownership passed to Southern California Edison (SCE) at the conclusion of the program.

In 1989, TSI secured the rights to obtain the Cool Water Gasification facility from SCE with the intent to operate the facility as a coal/municipal sewage sludge gasification facility. TSI and SCE have executed a sale agreement for the facility, contingent upon a land lease which is currently being negotiated. TSI is negotiating the sale of the electric power to be generated at the TCWP gasification site. TSI plans to use a U.S. bituminous coal which will be delivered by train to the plant site.

TSI also intends to utilize a new application of their proprietary technology which will permit the TCWP facility to convert sewage sludge to useful energy by mixing the sludge with the coal feedstock. TSI has demonstrated that sludge can be mixed with coal and, under high pressures and temperatures, gasified to produce a clean synthesis gas. The facility is designed to receive sewage sludge by truck and rail from wastewater treatment facilities in the Los Angeles area.

At the site, coal is supplied to conventional Texaco gasifiers. The gas from the gasifiers is scrubbed and passed through a cooling unit. Following this step, the sulfur compounds in the synthesis gas are removed in a Selexol unit, and the gas is then saturated with water vapor and fed to the gas turbines.

Figure 4 is an overview of the TCWP, including the LPMEOH™ demonstration technology, and Figure 5 is a simplified flow diagram of the LPMEOH™ demonstration technology that will be integrated into the TCWP. As Figure 5 indicates, a portion of the synthesis gas exiting the Selexol unit is compressed



Note 1: Double lined box denotes nonproprietary operations and environmental data to be provided to DOE.

Note 2: Shaded area denotes DOE funding participation.

FIGURE 4. OVERVIEW OF THE LPMEOH™ PROJECT AT THE COOL WATER SITE

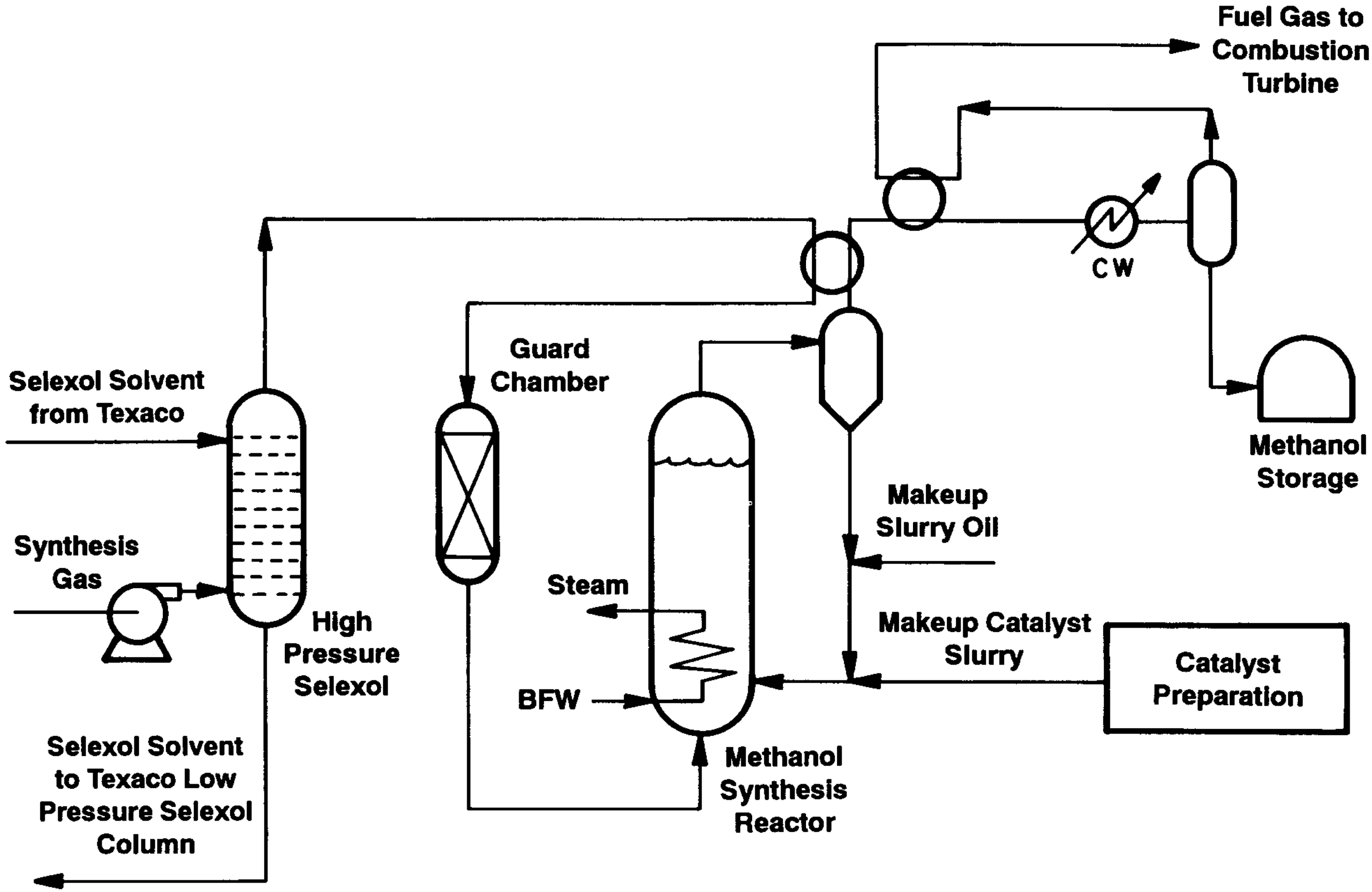


FIGURE 5. SIMPLIFIED FLOW DIAGRAM - LIQUID PHASE METHANOL SYNTHESIS SECTION

and passed through a high pressure Selexol unit for more thorough removal of sulfur compounds. The gas is then passed through a catalyst guard chamber, where the last traces of sulfur are removed before the feed gas enters the methanol synthesis reactor, which is sized to operate at 150 TPD of product, but to demonstrate production at up to 200 TPD. In the reactor, part of the gas is converted to methanol. The reactor effluent passes through a cyclone for removal of entrained slurry. The gas is then cooled to condense the methanol product, which is sent to storage, and the unconverted gas is sent to the combustion turbine. The unit is provided with facilities to prepare fresh makeup catalyst slurry, so that high catalyst activity can be maintained. When needed for electric power demand load following, methanol is withdrawn from storage, vaporized, and mixed with the clean syngas going to the combustion turbine.

The specific objectives of the LPMEOH™ demonstration are to: (1) achieve long-term operation on feed gas produced by coal gasification; (2) demonstrate the cost effectiveness of the technology in a commercial embodiment; (3) demonstrate the quality of the methanol product by user tests in transportation, boiler, and combustion turbine applications; and (4) successfully demonstrate scaleup of the slurry reactor fluid dynamics. In addition to the LPMEOH™ Demonstration Program, the TCWP will develop and demonstrate sewage sludge gasification technology and will recover carbon dioxide from the syngas. Nonproprietary data will be provided on these systems. A long-term objective of the TCWP will be to identify and develop a market for gasifier slag.

3.3 General Features of the Project

3.3.1 Evaluation of Developmental Risk

As a result of the successful LaPorte PDU work, the technology is now ready for full-scale demonstration. Some risks associated with this demonstration involve catalyst poisons in the reactor feed, reactor performance, internal heat exchanger performance, and vapor liquid disengagement. Performance reduction due to poisoning of the catalyst is possible; therefore, continuous monitoring of the composition of the synthesis gas will be performed, and the synthesis gas will be diverted to the flare system, if an upset condition is detected. The estimated frequency of a process upset that would cause poisoning of the catalyst is once in two to three years, and the probability of such an upset going undetected is low. Although there is a possibility that a process upset condition could be undetected for a short period of time, guard beds will be provided to protect the catalyst, and catalyst poisoning is not expected to be a significant problem.

Large-scale slurry reactors must be designed to ensure uniform catalyst dispersion in the liquid without drop-out of solids, uniform synthesis gas distribution, high mass transfer rates, and the ability to tolerate backmixing caused by the turbulent motion of the slurry. Based on the success of the mathematical modeling of reactor performance performed under DOE contract and the PDU work performed at LaPorte, reactor performance is not expected to be a problem.

The internal heat exchanger for the demonstration project will occupy more space than in the PDU unit. This could reduce backmixing and result in a less uniform temperature profile with lower temperatures in the bottom of the reactor and higher temperatures at the reactor outlet. The cooler reactor inlet may result in a decrease in the methanol conversion rate, and the lower backmixing may result in a higher synthesis gas conversion. Based on the modeling that has been performed and on PDU experience, the impact of this effect should be well within the design margins of the LPMEOH™ reactor.

Entrained catalyst slurry in the reactor effluent stream can cause fouling of the heat exchangers and result in lower LPMEOH™ efficiency and increased oil concentration in the methanol product. The PDU operating experience, however, has demonstrated that fouling will not occur with proper design. Further, even if moderate fouling does occur, it will result only in a slight decrease in process efficiency and does not represent a significant operating problem.

3.3.1.1 Similarity of the Project to Other Demonstration/Commercial Efforts

Except for tests conducted by Chem Systems, Air Products, and DOE, no known past or current work is being conducted in regard to the LPMEOH™ process. The LPMEOH™ process represents a significant improvement over commercially available processes, such as the ICI process, and permits enhancement of IGCC technology. Air Products operates a 500 TPD methanol facility in Pensacola, Florida, based on reforming of natural gas and with conventional gas-phase synthesis technology. This operation will provide an excellent basis for comparison to the design and operation of the equipment used in the LPMEOH™ process.

3.3.1.2 Technical Feasibility

Chem Systems, Air Products, and DOE have been developing the LPMEOH™ technology since 1975. The development work at the PDU scale has been completed successfully, resulting in a large experience base, including operation with feed gas compositions representative of a wide variety of commercial or developmental coal gasifiers. Testing has shown that the technology is suited for use with all major coal gasifiers, regardless of the different compositions of the synthesis gas. Additional testing concerning catalyst poisons, sponsored by DOE, will expand the existing data base and improve the expectation that the project will achieve its goals.

The experience of the project team members, combined with the successful test work and the commercial availability of much of the equipment used in the process, indicates that the LPMEOH™ technology is feasible and that this demonstration should achieve its goals.

3.3.1.3 Resource Availability

Adequate resources are available for this project over the 88-month demonstration period. Air Products, TSI, and DOE have committed funds, as discussed in Section 6.1, adequate to cover the proposed project cost. They have also dedicated the needed personnel to conduct the demonstration program.

Sufficient space is available at the TCWP site for erection of the demonstration equipment. The project will use the existing coal handling equipment, as well as the existing recommissioned gasification process equipment.

Coal and the LPMEOH™ catalyst are available commercially and can be supplied readily in the quantities required. Other resources, such as electricity, steam, boiler feedwater, and cooling water can be supplied in the required quantities by the existing plant systems.

3.3.2 Relationship Between Project Size and Projected Scale of Commercial Facility

A major goal of the proposed program is to generate and collect data that will allow evaluation of the technology. To accomplish this, the technology must be demonstrated at the appropriate scale and conditions, and all of the related aspects of the technology must be demonstrated.

The maximum practical size of a coal gasifier varies with the specific application but is approximately 3,000 TPD of coal. IGCC power plants will be comprised of parallel coal gasifier trains to achieve the total desired plant capacity. This same design philosophy will be true for once through methanol production using the LPMEOH™ technology. The maximum practical LPMEOH™ reactor diameter is determined, at least partially, by shipping constraints. Reactor vessels exceeding 14 ft in outer diameter will pose serious transportation problems or require expensive on-site construction. The outer diameter of the reactor for the proposed facility is 8.5 ft. This is at the lower end of commercial-size reactor design.

The 150 TPD LPMEOH™ Demonstration Project is one-half to one-third of the maximum commercial scale. The maximum size commercial reactor will have a larger diameter and lower height-to-diameter ratio, but will have similar catalyst productivities and operate at similar reaction conditions. The LPMEOH™ Demonstration Project converts 40 to 50% of the lower heating value of the feed gas to methanol product, while 15 to 50% will be converted in commercial applications.

The demonstration is at the lower end of commercial application. The transition to maximum size commercial applications will be a modest change of scale or production rate. The data collected in the demonstration will be used directly for maximum commercial size evaluation. No scaleup problems are anticipated.

3.3.3 Role of the Project in Achieving Commercial Feasibility of the Technology

This project will demonstrate, at commercial scale in the commercial IGCC/LPMEOH™ configuration, a new technology to produce methanol from coal. This methanol can be used as an alternative fuel in transportation vehicles, industrial boilers, and in combined-cycle plants, while meeting the most stringent requirements for NO_x, SO_2, and particulate matter emissions. Potentially, IGCC/LPMEOH™ can be utilized in existing pulverized-coal-fired facilities as a means of repowering.

The commercialization of the LPMEOH™ technology requires a comprehensive data base that demonstrates the performance, reliability, emission control capabilities, and cost effectiveness of the technology. The demonstration program will test all operational phases that are anticipated to be encountered in a commercial unit. The operating program will provide long-term operating data which will add credibility to the results of the demonstration. In addition, the planned end-use demonstrations of the methanol produced during the project will further enhance the acceptability and marketability of the technology.

3.3.3.1 Applicability of the Data to be Generated

The demonstration project operating program will be performed over four years and will test all of the operational parameters that are likely to be encountered in commercial applications. Initial baseline demonstration testing will be performed to establish successful scaleup and reliability of the LPMEOH™ process. This testing will address the commercial applications of the technology dealing with the economic production of methanol as a liquid fuel for energy storage in coal-gasification-based electric power plants.

Data collection, analysis, and reporting will be performed during the demonstration phases and will include on-stream factors, material balances, reactor and equipment performance, comparisons with laboratory and PDU results, conversion efficiencies, and catalyst activity. Data to be provided will include not only data on the LPMEOH™ process but also data on firing methanol for electric power demand following. In addition to the LPMEOH™ Demonstration program, the TCWP will develop and demonstrate sewage sludge gasification technology and will recover carbon dioxide from the syngas. Nonproprietary data will be provided on these systems. A long-term objective of the TCWP will be to identify and develop a market for gasifier slag.

The end-use tests in bus, boiler, and possibly van pool operations of the methanol produced in the LPMEOH™ demonstration will add to the data base and aid significantly in the commercialization of the technology.

3.3.3.2 Identification of Features that Increase Potential for Commercialization

Once commercially proven, the LPMEOH™ process will provide an economical and technically acceptable means for the production of methanol from coal, which will reduce acid rain precursors and other emissions when used as a fuel or in conjunction with IGCC. The technology has a cost advantage over methanol produced by conventional processes. In addition, it can lower costs of IGCC facilities, while meeting stringent air quality requirements, which will make it attractive for repowering pulverized-coal-fired facilities.

The LPMEOH™ process mainly comprises proven, commercially-available equipment such as reactors, catalysts, heat exchangers, pumps, and piping.

In summary, commercialization of the technology will be aided by the following positive characteristics:

- The technology produces a low-cost, high-purity, and storable alternative fuel from coal, which has many uses in the power, transportation, and chemical industries.

- The technology produces a clean fuel and synthesis gas which can be used in combined-cycle power plants to repower existing pulverized-coal-fired units while significantly reducing CO, SO_2, NO_x, and particulate emissions.

- The technology can be used with a variety of coals.

- The technology can be used with all types of coal gasifiers.

- The technology provides a load following capability for electric power generating facilities.

3.3.3.3 Comparative Merits of the Project and Projection of Future Commercial Economics and Market Acceptability

The LPMEOH™ process is a viable alternative to conventional gas-phase methanol production processes and, when integrated with IGCC, is an efficient, economical, and environmentally attractive means of repowering existing pulverized-coal-fired electric generating facilities.

Methanol-fueled automobiles have the potential to reduce ozone emissions by as much as 18%. Furthermore, if methanol is used in heavy duty trucks and buses, a substantial reduction in NO_x emissions can also be realized. Compared with diesels, methanol-fueled heavy duty engines emit virtually no particulate matter.

In stationary combustion applications, methanol has the potential to achieve NO_x emission levels that are comparable to emission levels when firing natural gas. In addition, methanol is essentially free of sulfur compounds and so does not produce SO_2 emissions.

4.0 ENVIRONMENTAL CONSIDERATIONS

The NEPA compliance procedure, cited in Section 2.2, contains three major elements: a Programmatic Environmental Impact Statement (PEIS); a pre-selection, project-specific environmental analysis; and a post-selection, site-specific environmental analysis. DOE issued the final PEIS to the public in November, 1989 (DOE/EIS-0146). In the PEIS, results derived from the Regional Emissions Database and Evaluation System (REDES) were used to estimate the environmental impacts expected to occur in 2010 if each technology were to reach full commercialization, capturing 100% of its applicable market. These impacts were compared with the no-action alternative, which assumed continued use of conventional coal technologies through 2010 with new plants using conventional flue gas desulfurization to meet New Source Performance Standards.

The preselection, project-specific environmental review, focusing on environmental issues pertinent to decision-making, was completed for internal DOE use. The review summarized the strengths and weaknesses of each proposal in compliance with the environmental evaluation criteria in the PON. It included, to the extent possible, a discussion of alternative sites and processes reasonably available to the offeror, practical mitigating measures, and a list of required permits. This analysis was provided for consideration of the Source Selection Official in the selection of proposals.

As the final element of the NEPA strategy, the Participant (Air Products and Chemicals, Inc.) submitted to DOE the environmental information volume specified in the PON. This detailed site- and project-specific information formed the basis for the NEPA documents prepared by DOE. This document, prepared in compliance with the Council on Environmental Quality regulations for implementation of NEPA (40 CFR 1500-1508) and DOE guidelines for NEPA compliance (52 FR 47662), must be approved before federal funds can be provided for detailed design, construction, and operation activities.

In addition to the NEPA requirements outlined above, the Participant must prepare and submit an Environmental Monitoring Plan (EMP) for the project. The purpose of the EMP is to ensure that sufficient technology, project, and site environmental data are collected to provide health, safety, and environmental information for use in subsequent commercial applications of the technology.

5.0 PROJECT MANAGEMENT

5.1 Overview of Management Organization

The project will be managed by an Air Products Program Manager. This individual will be the principal contact with DOE for matters regarding the administration of the Cooperative Agreement between Air Products and DOE. An Air Products Project Manager and a TSI Project Manager will also be assigned to the project and will report to the Air Products Program Manager. The DOE Contracting Officer is responsible for all contract matters, and the DOE Contracting Officer's Technical Representative (COTR) is responsible for technical liaison and monitoring of the project. LPMEOH™ technology consultants from Air Products will provide technical counsel to all aspects of the program.

5.2 Identification of Respective Roles and Responsibilities

DOE

The DOE shall be responsible for monitoring all aspects of the project and for granting or denying approvals required by the Cooperative Agreement. The DOE Contracting Officer is DOE's authorized representative for all matters related to the Cooperative Agreement.

The DOE Contracting Officer will appoint a COTR who will be the authorized representative for all technical matters and will have the authority to issue "Technical Advice" which may:

- Suggest redirection of the Cooperative Agreement effort, recommend a shifting of work emphasis between work areas or tasks, or suggest pursuit of certain lines of inquiry which assist in accomplishing the Statement of Work.
- Approve those technical reports, plans, and items of technical information required to be delivered by the Participant to the DOE under the Cooperative Agreement.

The DOE COTR does not have the authority to issue technical advice which:

- Constitutes an assignment of additional work outside the Statement of Work.
- In any manner causes an increase or decrease in the total estimated cost or the time required for performance of the Cooperative Agreement.

- Changes any of the terms, conditions, or specifications of the Cooperative Agreement.

- Interferes with the Participant's right to perform the terms and conditions of the Cooperative Agreement.

All Technical Advice shall be issued in writing by the DOE COTR.

Participant

The following organizations will interact effectively to meet the intent of the PON and to assure a timely and cost effective implementation plan from conceptual design to start-up and operation of the proposed LPMEOH™ Demonstration facility:

- Air Products and Chemicals, Inc.
- Texaco Syngas Inc. (TSI)
- Dakota Gasification Company (DGC)
- Acurex Corporation

Air Products will be primarily responsible for reporting to and interfacing with DOE and for subcontracting phases of the work to TSI, DGC, and Acurex. Air Products will be responsible for the design, construction, and operation phases of the project.

The overall project approach of the above Participants will consist of, but not necessarily be limited to, the following:

A single program manager will be responsible to DOE and all project participants for all three project phases.

Air Products will manage the design and construction phases of the LPMEOH™ Demonstration project. Air Products will utilize the assistance of EPRI and DOE, which have been intimately involved in the development of the LPMEOH™ technology. EPRI and DOE will provide reviews of the technology, design, test planning, data analysis, scaleup issues, and reports. Air Products will be responsible for developing equipment, design, and construction specifications; developing a bid list; evaluating bids; and awarding subcontracts to equipment suppliers and contractors for the design and construction phases of the LPMEOH™ Demonstration facility. TSI will have the right to review and comment on major equipment items purchased by Air Products' and on all design and construction specifications and drawings. During the construction phase of the LPMEOH™ facility, Air Products' construction management team will monitor the contractor's performance and compare progress to the construction schedule and cost budgets. Air Products' construction management team will also ensure that each contractor complies with all design and construction standards and specifications.

In performing overall management of the LPMEOH™ project, "Air Products Systems and Procedures for Project Management and Cost and Schedule Control" will be employed. These are based on similar systems and procedures developed by Air Products and approved for use in other DOE-sponsored programs. Air Products will develop the overall project schedule, cost forecasting per activity, and reporting techniques for each activity.

Maximum use will be made of the competitive bidding process in the purchase of equipment, material, engineering, and construction services for the demonstration project. Bids will be evaluated on both technical and commercial criteria, and those bids providing the highest value to the program will be selected.

Air Products will be responsible for developing procurement documents for equipment, engineering services, and construction in the LPMEOH™ Demonstration facility. Air Products will also monitor the performance of vendors, engineering service contractors, and construction contractors to assure timely delivery of equipment to support construction activities.

TSI will be responsible for the synthesis gas feed supply, gas turbine modifications, and other outside battery limits work at the TCWP facility. TSI will engage and manage an engineering contractor to provide the design for modifications to the TCWP synthesis gas facility to upgrade and recommission the plant, to make the needed modifications to the gas turbine to burn vaporized methanol, and to provide the process and utility tie-ins to the LPMEOH™ facility.

Acurex Corporation's responsibilities will be largely confined to the off-site demonstration of the methanol product as fuel. Acurex will monitor, collect data, and provide reports on the use of the methanol product as a fuel supplement in the TCWP gas turbine. Acurex will also collect data and provide reports on the use of the methanol product in transit buses of the Kanawha Valley Regional Transit Authority (KVRTA), Charleston, WV, and the Southern California Rapid Transit District (SCRTD), in a vanpool fleet, in water tube and fire tube boilers, and in generators. In addition to data gathering and report writing, Acurex will be responsible for activities involved in providing the necessary methanol storage and handling facilities and in arranging for the supplies of methanol product.

DGC's role will be to review the overall integration between the LPMEOH™ plant and the TCWP plant and to recommend modifications to improve the operability of the LPMEOH™ plant.

Air Products will interrelate between the government and all other project sponsors as shown in Figure 6, Project Organization.

5.3 Summary of Project Implementation and Control Procedures

All work to be performed under the Cooperative Agreement is divided into three phases. These phases are:

Phase I: Design (29 months)
Phase II: Construction (25 months)
Phase III: Operation (48 months)

As shown in Figure 7, the total project encompasses 88 months. There will be a 19-month overlap of Phase I and Phase II and a 12-month overlap of Phase II and Phase III, not including fuel methanol demonstrations.

Three budget periods will be established. Consistent with P.L. 100-446, DOE will obligate funds sufficient to cover its share of the cost for each budget period. Throughout the course of this project, reports dealing with the technical, management, cost, and environmental monitoring aspects of the project will be prepared by Air Products and TSI and provided to DOE.

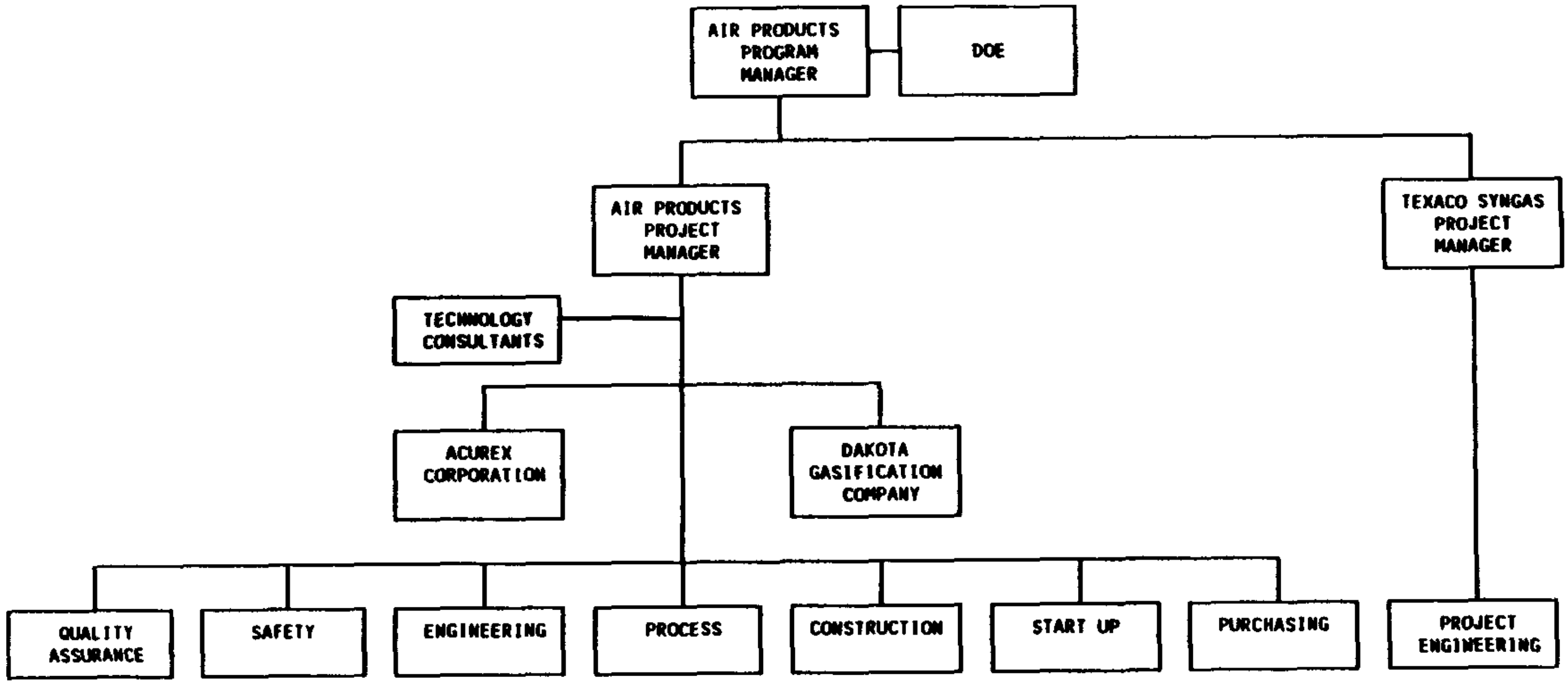


FIGURE 6. PROJECT ORGANIZATION FOR LPMEOH™ DEMONSTRATION

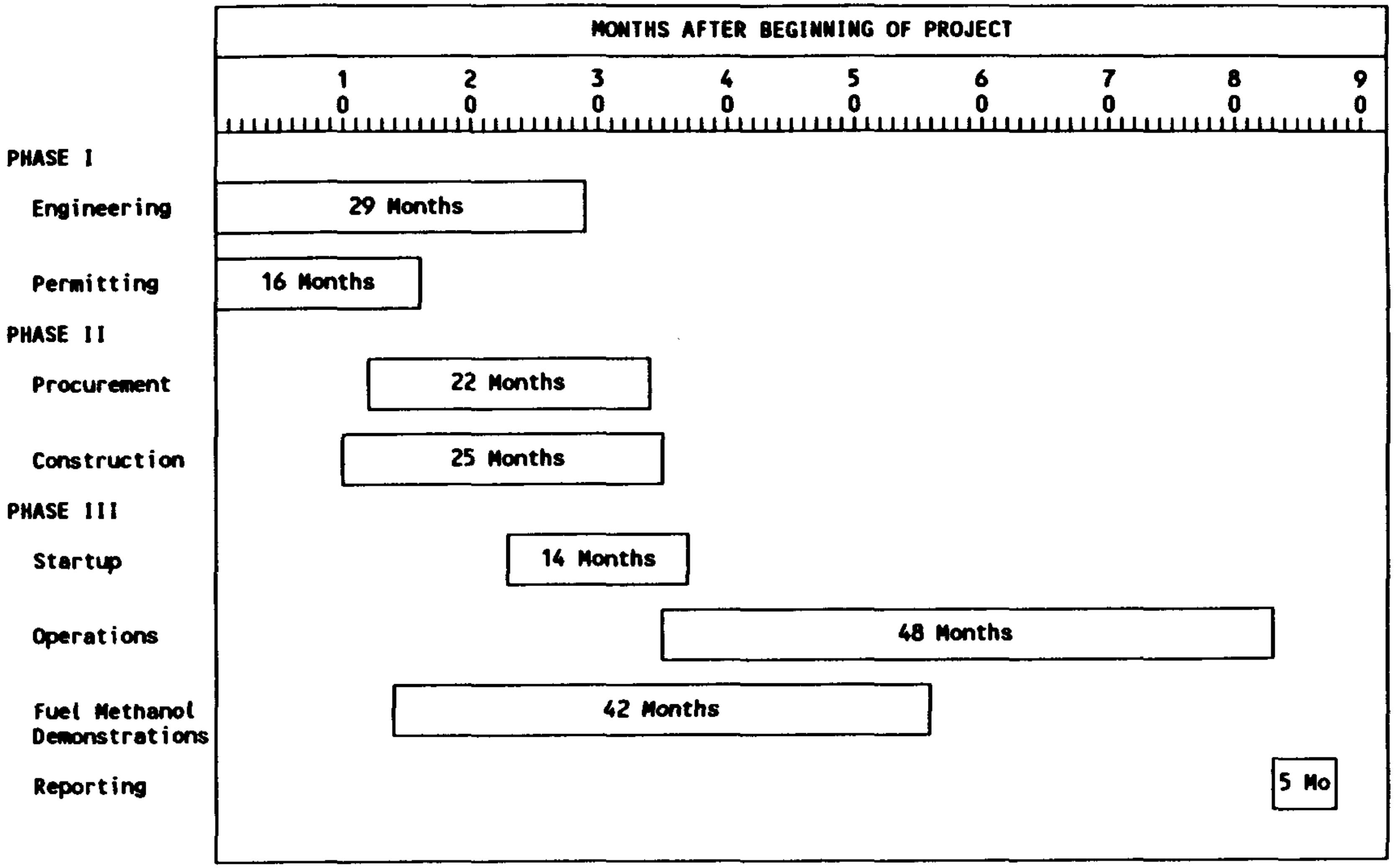


Figure 7. OVERALL PROJECT SCHEDULE FOR LPMEOH™

5.4 Key Agreements Impacting Data Rights, Patent Waivers, and Information Reporting

During the course of the project, Air Products may employ certain commercial process technologies and catalysts. Under the terms of licenses or purchasing agreements with the vendors and/or licensors of these processes and catalysts, certain process details and compositional information may be considered proprietary and may not be disclosed in reports to DOE. Examples of such proprietary data are the compositions of methanol synthesis, CO-shift, and COS hydrolysis catalysts.

5.5 Procedures for Commercialization of the Technology

Air Products will be responsible for marketing and commercializing the LPMEOH™ process. Since Air Products markets chemicals and oxygen plants internationally and since IGCC/LPMEOH™ projects will involve a plant to provide oxygen, Air Products will be well positioned to market the technology. In the U.S., Air Products is the leading supplier of tonnage oxygen gas and oxygen plants. Air Products' position in the manufacture and sale of oxygen plants and its contacts with major gasifier manufacturers and utilities will provide an early opportunity to sell the process to IGCC repowering and grass roots projects. Air Products also has substantial experience in selling process technology and in tolling and own/operate commercial-product concepts. Air Products has an existing national and international sales and marketing organization in place.

The U.S. market for the LPMEOH™ technology should develop rapidly because of stringent domestic regulations that create the need for a much cleaner source of coal-based electric power and for much cleaner fuels in general. Besides the TCWP, there are currently at least two other facilities in the U.S. where the LPMEOH™ technology could be retrofitted. These facilities are the Dow Plaquemine IGCC power facility in Louisiana and Tennessee Eastman's chemicals-from-coal complex in Kingsport, Tennessee.

At the present time the commitment to achieve clean air goals is much stronger in the U.S. than in many other countries. As pollution problems associated with electric power production and transportation become more of an issue in other countries and national and international pollution regulations are enacted to deal with these problems, foreign markets for the LPMEOH™ process will develop. Both Western Europe and Japan should be good candidates for IGCC projects involving coproduced methanol. Holland recently announced plans to build a 250 MWe IGCC demonstration plant, which will be a candidate for the LPMEOH™ process. Japan was a participating member of the Cool Water Coal Gasification Program.

Air Products will offer potential customers three commercial product alternatives: process license, technology package, and catalyst supply; tolling of synthesis gas into methanol; or on-site supply of clean liquid and gaseous fuels.

The first alternative, process license, technology package, and catalyst supply, will provide the customer with a license to operate a methanol plant or plants under any and all Air Products patents. A technology package specific to the requirements of the particular customer will be provided. The package will include a complete process design, equipment specifications, operating and start-up manuals, and start-up assistance. In addition, the initial charge of the LPMEOH™ catalyst, a commitment to provide replacement catalyst, and guarantees on the performance of the process and catalyst will be provided.

In the tolling alternative, Air Products will consider designing, constructing, owning, and operating the LPMEOH™ facility in return for a monthly fee.

In the on-site supply alternative, Air Products will consider designing, constructing, owning, and operating the fuel-generating facilities and selling the fuel to the owner of a combined-cycle electric power or other type plant.

All of the equipment in a commercial LPMEOH™ plant is of the type generally employed in chemical process plants. Although some equipment items, such as the methanol synthesis reactor, will require special design, no items require special manufacturing techniques. Competitive bidding can be used for major equipment, such as the reactor, slurry preparation tank, and internal heat exchanger. Air Products has qualified a number of commercial catalysts and commercial slurry liquids for use in the LPMEOH™ plant.

6.0 PROJECT COST AND EVENT SCHEDULING

6.1 Project Baseline Costs

The total estimated cost for this project is $213,700,000. The Participant's share and the Government's share in the costs of this project are as follows:

	Dollar Share ($)	Percent Share (%)
Pre-Award		
Government	4,468,140	43.38
Participant	5,831,860	56.62
Phase I		
Government	19,250,000	50.00
Participant	19,250,000	50.00
Phase II		
Government	53,100,000	50.00
Participant	53,100,000	50.00
Phase III		
Government	15,890,230	27.07
Participant	42,809,770	72.93
Total Project		
Government	92,708,370	43.38
Participant	120,991,630	56.62

The project will be co-funded by DOE, Air Products, TSI, and Acurex as follows:

DOE	$ 92,708,370
Air Products	$ 41,670,630
TSI	$ 77,241,000
Acurex	$ 2,080,000
TOTAL	$213,700,000

At the beginning of each budget period, DOE will obligate funds sufficient to pay its share of expenses for that budget period.

6.2 Milestone Schedule

The overall project will be completed in 88 months. The project schedule, by phase and activity, is shown in Figure 7.

Phase I, which involves engineering and permitting began before award and will continue for 29 months. Phase II, procurement of materials and construction, will overlap Phase I by 19 months and last a total of 25 months. Phase III, operations, will last a total of 48 months.

6.3 Repayment Plan

In response to the stated policy of the DOE to recover an amount up to the Government's contribution to the project, the Participant has agreed to repay the Government in accordance with the Repayment Agreement, which is consistent with the model repayment agreement in the CCT III PON.