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COMMERCIAL-SCALE DEMONSTRATION OF THE LIQUID PHASE METHANOL (LPMEOH™) PROCESS

TECHNICAL PROGRESS REPORT NO. 9

For The Period

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and

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for the
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Acronyms and Definitions

Acurex	Acurex Environmental Corporation
Air Products	Air Products and Chemicals, Inc.
AFDU	Alternative Fuels Development Unit - The "LaPorte PDU."
Balanced Gas	A syngas with a composition of hydrogen (H_2), carbon monoxide (CO), and carbon dioxide (CO_2) in stoichiometric balance for the production of methanol
Carbon Monoxide Gas	A syngas containing primarily carbon monoxide (CO); also called CO Gas
DME	dimethyl ether
DOE	United States Department of Energy
DOE-PETC	The DOE's Pittsburgh Energy Technologh Center (Project Team)
DOE-HQ	The DOE's Headquarters - Clean Coal Technology (Project Team)
DTP	Demonstration Test Plan - The four year Operating Plan for Phase 3, Task 2 Operation
DVT	Design Verification Testing
Eastman	Eastman Chemical Company
EIV	Environmental Information Volume
EMP	Environmental Monitoring Plan
EPRI	Electric Power Research Institute
HAPs	Hazardous Air Pollutants
Hydrogen Gas	A syngas containing an excess of hydrogen (H_2) over the stoichiometric balance for the production of methanol; also called H_2 Gas
IGCC	Integrated Gasification Combined Cycle, a type of electric power generation plant
IGCC/OTM	An IGCC plant with a "Once-Thru Methanol" plant (the LPMEOH™ Process) added-on.
KSCFH	Thousand Standard Cubic Feet per Hour
LaPorte PDU	The DOE-owned experimental unit (PDU) located adjacent to Air Product's industrial gas facility at LaPorte, Texas, where the LPMEOH™ process was successfully piloted.
LPDME	Liquid Phase DME process, for the production of DME as a mixed coproduct with methanol
LPMEOH™	Liquid Phase Methanol (the technology to be demonstrated)
MTBE	methyl tertiary butyl ether
NEPA	National Environmental Policy Act
OSHA	Occupational Safety and Health Administration
Partnership	Air Products Liquid Phase Conversion Company, L.P.
PDU	Process Development Unit
PFD	Process Flow Diagram(s)
ppb	parts per billion
Project	Production of Methanol/DME Using the LPMEOH™ Process at an Integrated Coal Gasification Facility
psia	Pounds per Square Inch (Absolute)
psig	Pounds per Square Inch (gauge)
P&ID	Piping and Instrumentation Diagram(s)
SCFH	Standard Cubic Feet per Hour
Sl/hr-kg	Standard Liter(s) per Hour per Kilogram of Catalyst
Syngas	Abbreviation for Synthesis Gas
Synthesis Gas	A gas containing primarily hydrogen (H_2) and carbon monoxide (CO), or mixtures of H_2 and CO; intended for "synthesis" in a reactor to form methanol and/or other hydrocarbons (synthesis gas may also contain CO_2, water, and other gases)
Tie-in(s)	the interconnection(s) between the LPMEOH™ Process Demonstration Facility and the Eastman Facility
TPD	Ton(s) per Day
WBS	Work Breakdown Structure
wt	weight

Executive Summary

The Liquid Phase Methanol (LPMEOH™) Demonstration Project at Kingsport, Tennessee, is a $213.7 million cooperative agreement between the U.S. Department of Energy (DOE) and Air Products Liquid Phase Conversion Company, L. P. (the Partnership). The LPMEOH™ Process Demonstration Unit is being built at a site located at the Eastman Chemical Company (Eastman) complex in Kingsport.

On 4 October 1994, Air Products and Chemicals, Inc. (Air Products) and Eastman Chemical Company (Eastman) signed the agreements that would form the Partnership, secure the demonstration site, and provide the financial commitment and overall management for the project. These partnership agreements became effective on 15 March 1995, when DOE authorized the commencement of Budget Period No. 2 (Mod. A008 to the Cooperative Agreement). The Partnership has subcontracted with Air Products to provide the overall management of the project, and to act as the primary interface with DOE. As subcontractor to the Partnership, Air Products will also provide the engineering design, procurement, construction, and commissioning of the LPMEOH™ Process Demonstration Unit, and will provide the technical and engineering supervision needed to conduct the operational testing program required as part of the project. As subcontractor to Air Products, Eastman will be responsible for operation of the LPMEOH™ Process Demonstration Unit, and for the interconnection and supply of synthesis gas (syngas), utilities, product storage, and other needed services.

The project involves the construction of an 80,000 gallons per day (260 tons per day (TPD)) methanol unit utilizing coal-derived synthesis gas from Eastman's integrated coal gasification facility. The new equipment consists of synthesis gas feed preparation and compression facilities, the liquid phase reactor and auxiliaries, product distillation facilities, and utilities.

The technology to be demonstrated is the product of a cooperative development effort by Air Products and DOE in a program that started in 1981. Developed to enhance electric power generation using integrated gasification combined cycle (IGCC) technology, the LPMEOH™ process is ideally suited for directly processing gases produced by modern-day coal gasifiers. Originally tested at a small, DOE-owned experimental unit in LaPorte, Texas, the technology provides several improvements essential for the economic coproduction of methanol and electricity directly from gasified coal. This liquid phase process suspends fine catalyst particles in an inert liquid, forming a slurry. The slurry dissipates the heat of the chemical reaction away from the catalyst surface, protecting the catalyst and allowing the methanol synthesis reaction to proceed at higher rates.

At the Eastman complex, the technology is being integrated with existing coal-gasifiers. A carefully developed test plan will allow operations at Eastman to simulate electricity demand load-following in coal-based IGCC facilities. The operations will also demonstrate the enhanced stability and heat dissipation of the conversion process, its reliable on/off operation, and its ability to produce methanol as a clean liquid fuel without additional upgrading. An off-site product testing program will be conducted to demonstrate the suitability of the methanol product as a transportation fuel and as a fuel for stationary applications for small modular electric power generators for distributed power.

The four-year operating test phase will demonstrate the commercial application of the LPMEOH™ process, to allow utilities to manufacture and sell two products: electricity and methanol. A typical commercial-scale IGCC coproduction facility, for example, could be expected to generate 200 to 350 MW of electricity, and to also manufacture 45,000 to 300,000 gallons per day of methanol (150 to 1000 TPD). A successful demonstration at Kingsport will show the ability of a local resource (coal) to be converted in a reliable (storable) and environmentally preferable way to provide the clean energy needs of local communities for electric power and transportation.

This project may also demonstrate the production of dimethyl ether (DME) as a mixed coproduct with methanol if laboratory and pilot-scale research and market verification studies show promising results. If implemented, the DME would be produced during the last six months of the four-year demonstration period. DME has several commercial uses. In a storable blend with methanol, the mixture can be used as a peaking fuel in gasification-based electric power generating facilities, or as a diesel engine fuel. Blends of methanol and DME can be used as chemical feedstocks for synthesizing chemicals, including new oxygenated fuel additives.

The project was reinitiated in October of 1993, when DOE approved a site change to the Kingsport location. DOE conditionally approved the Continuation Application to Budget Period No. 2 (Design and Construction) in March of 1995 and formally approved it on 1 June 1995 (Mod M009). Since then the project has been in Phase 1 - Design activities; and also moved into Phase 2 - Construction activities in October of 1995. The project required review under the National Environmental Policy Act (NEPA) to move to the construction phase. DOE prepared an Environmental Assessment (DOE/EA-1029), and subsequently a Finding of No Significant Impact (FONSI) was issued on 30 June 1995. The demonstration unit is scheduled to be mechanically complete at the end of December of 1996.

During this quarter, the Continuation Application was submitted, requesting authorization to transition from Budget Period No. 2 (Design and Construction) to the final Budget Period (Commissioning, Startup, and Operation). The Project Evaluation Report for Budget Period No. 2 was prepared. A recommendation for approval is being reviewed by the DOE.

A draft Topical Report on Process Economics Studies is being prepared. This report shows that methanol coproduction, with IGCC electric power utilizing the LPMEOH™ process technology, will be competitive in serving local market needs. The results will also be incorporated into a paper "Fuel and Power Coproduction", being prepared for presentation at the DOE's 5th Annual Clean Coal Technology Conference.

A decision on whether to continue with DME design verification testing is to be made, by the participants, in December of 1996. The laboratory R & D results are confirming that the new Liquid Phase Dimethyl Ether (LPDME) catalyst system will have reasonable long-term activity and stability. The market application of DME is promising, for example as diesel engine transportation fuels, either directly as DME, or indirectly by conversion to liquid additives for the diesel fuel pool. A recommendation to continue with DME design verification testing is likely.

The off-site product testing plan is to be updated by May of 1997. During this quarter, Air Products and Acurex were developing a list of contacts for product methanol fuel-use testing. Prospective Federal, State, and University product test participants, involved in fuel cell, transportation, and stationary power plant developments, are being included.

A project review meeting was held in Kingsport in early September. The vent stack was at the site, and all of the other equipment was installed. The construction and operation permits have been obtained. The operator training, commissioning, startup, and initial operation plans were reviewed.

An updated cost forecast shows $38 million for the Kingsport portion of the LPMEOH™ Process Demonstration Project for the Phase 1 and 2 tasks. This is an increase of about 10% from the cost plan submitted at the start of Budget Period No. 2. The increase is off-set by lower costs for the Project pre-award work, and by projected lower Phase 3 Operation costs. The total Project cost remains the unchanged at $213.7 million.

Construction (Task 2.2) is 72% complete, as of the end of September of 1996. The targeted completion date has slipped by about three weeks, to 31 December 1996. Commissioning activities (Task 2.3) will start in mid-October of 1996, and should be completed in mid-January of 1997. Startup of the utility systems is scheduled to begin in late January.

Eighty-one percent (81%) of the $38 million of funds forecast for the Kingsport portion of the LPMEOH™ Process Demonstration Project for the Phase 1 and Phase 2 tasks have been expended (as invoiced), as of 30 September 1996.

A. Introduction

The Liquid Phase Methanol (LPMEOH™) demonstration project at Kingsport, Tennessee, is a $213.7 million cooperative agreement between the U.S. Department of Energy (DOE) and Air Products Liquid Phase Conversion Company, L. P. (the Partnership). A demonstration unit producing 80,000 gallons per day (260 TPD) of methanol is being designed and constructed at a site located at the Eastman Chemical Company (Eastman) complex in Kingsport. The Partnership will own and operate the facility for the four-year demonstration period.

This project is sponsored under the DOE's Clean Coal Technology Program, and its primary objective is to "demonstrate the production of methanol using the LPMEOH™ Process in conjunction with an integrated coal gasification facility." The project will also demonstrate the suitability of the methanol produced for use as a chemical feedstock or as a low-sulfur dioxide, low-nitrogen oxides alternative fuel in stationary and transportation applications. The project may also demonstrate the production of dimethyl ether (DME) as a mixed coproduct with methanol, if laboratory- and pilot-scale research and market verification studies show promising results. If implemented, the DME would be produced during the last six months of the four-year demonstration period.

The LPMEOH™ process is the product of a cooperative development effort by Air Products and the DOE in a program that started in 1981. It was successfully piloted at a 10-TPD rate in the DOE-owned experimental unit at Air Products' LaPorte, Texas, site. This demonstration project is the culmination of that extensive cooperative development effort.

B. Project Description

The demonstration unit, which will occupy an area of 0.6 acre, will be integrated into the existing 4,000-acre Eastman complex located in Kingsport, Tennessee. The Eastman complex employs approximately 12,000 people. In 1983, Eastman constructed a coal gasification facility utilizing Texaco technology. The synthesis gas generated by this gasification facility is used to produce carbon monoxide and methanol. Both of these products are used to produce methyl acetate and ultimately cellulose acetate and acetic acid. The availability of this highly reliable coal gasification facility was the major factor in selecting this location for the LPMEOH™ Process Demonstration. Three different feed gas streams (hydrogen gas, carbon monoxide gas, and balanced gas) will be diverted from existing operations to the LPMEOH™ demonstration unit, thus providing the range of coal-derived synthesis gas ratios (hydrogen to carbon monoxide) needed to meet the technical objectives of the demonstration project.

For descriptive purposes and for design and construction scheduling, the project has been divided into four major process areas with their associated equipment:

- *Reaction Area* - Synthesis gas preparation and methanol synthesis reaction equipment.
- *Purification Area* - Product separation and purification equipment.
- *Catalyst Preparation Area* - Catalyst and slurry preparation and disposal equipment.
- *Storage/Utility Area* - Methanol product, slurry, and oil storage equipment.

The physical appearance of this facility closely resembles the adjacent Eastman process plants, including process equipment in steel structures.

- *Reaction Area*

The reaction area will include feed gas compressors, catalyst guard beds, the reactor, a steam drum, separators, heat exchangers, and pumps. The equipment will be supported by a matrix of structural steel. The most salient feature is the reactor, since with supports, it is approximately 84-feet tall.

- *Purification Area*

The purification area features two distillation columns with supports; one is approximately 82-feet tall, and the other 97-feet tall. These vessels resemble the columns of the surrounding process areas. In addition to the columns, this area includes the associated reboilers, condensers, air coolers, separators, and pumps.

- *Catalyst Preparation Area*

The catalyst preparation area consists of a building with a roof and partial walls, in which the catalyst preparation vessels, slurry handling equipment, and spent slurry disposal equipment are housed. In addition, a hot oil utility system is included in the area.

- *Storage/Utility Area*

The storage/utility area includes two diked lot-tanks for methanol, two tanks for oil storage, a slurry holdup tank, a trailer loading/unloading area, and an underground oil/water separator.

C. Process Description

The LPMEOH™ demonstration unit will be integrated with Eastman's coal gasification facility. A simplified process flow diagram is included in Appendix A. Synthesis gas is introduced into the slurry reactor, which contains a slurry of liquid mineral oil with suspended solid particles of catalyst. The synthesis gas dissolves through the mineral oil, contacts the catalyst, and reacts to form methanol. The heat of reaction is absorbed by the slurry and is removed from the slurry by steam coils. The methanol vapor leaves the reactor, is condensed to a liquid, sent to the distillation columns for removal of higher alcohols, water, and other impurities, and is then stored in the day tanks for sampling before being sent to Eastman's methanol storage. Most of the unreacted synthesis gas is recycled back to the reactor with the synthesis gas recycle compressor, improving cycle efficiency. The methanol will be used for downstream feedstocks and in off-site fuel testing to determine its suitability as a transportation fuel and as a fuel for stationary applications in the power industry.

D. Project Status

The project status is reported by task, and then by the goals established by the Project Evaluation Plan for Budget Period No. 2 (see Appendix B). Major accomplishments during this period are as follows:

Task 1.2 Permitting

For this task the Project Evaluation Plan for Budget Period No. 2 establishes these goals:

- Issue the final Environmental Information Volume (EIV) to support the DOE's Environmental Assessment/Finding of No Significant Impact.

  - The NEPA review was completed 30 June 1995 with the issuance of an Environmental Assessment (DOE/EA-1029) and Finding of No Significant

Impact (FONSI). The DOE's comments on the May 1996 Draft EIV were incorporated into the EIV in August. The DOE approved the final EIV on 29 August 1996, and copies of the final EIV were distributed in September of 1996.

- Obtain permits necessary for construction and operation.

  - The construction and operation permits have been obtained.

Task 1.3 Design Engineering

For this task the Project Evaluation Plan for Budget Period No. 2 establishes these goals:

- Prepare the Environmental Monitoring Plan (EMP).

  - The DOE's comments on the May 1996 draft of the EMP were incorporated into a final draft EMP, which was released for review on 1 August 1996. The DOE approved this final draft EMP on 29 August 1996, and copies of the final EMP were distributed in September of 1996.

- Complete the design engineering necessary for construction and commissioning. This includes Piping and Instrumentation Diagrams, Design Hazard Reviews, and the conduct of design reviews.

  - The focus of attention for the project has transitioned from detailed design to construction. This Task 1.3 Design Engineering is 99% complete, with only a few items remaining. During this quarter, the programming of the Honeywell Digital Control System (DCS) continued, and was 80% completed. The last two construction bid packages; (Final Grading and Painting) were completed, and are now out for bid.

Task 1.4 Off-Site Testing (Definition and Design)

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Prepare the fuel-use demonstration plan for Phase 3, Task 4 Off-Site Product Use Demonstration. This off-site test plan will be incorporated into an updated, overall (fuel and chemical) product-use test plan (in Phase 1, Task 5).

<u>Discussion</u>

The fuel-use test plan, developed to support the demonstration at the original Cool Water Gasification Facility in 1992, has become outdated. Since the site change to Eastman, the original fuel-use test plan under-represents new utility dispersed electric power developments, and possibly new mobile transport engine developments. The updated fuel-use test plan will attempt for broader market applications and for commercial fuels comparisons. The objective of the fuel-use test plan update will be to demonstrate commercial market applications for the "as produced" methanol as a replacement fuel and as a fuel supplement. Fuel economics will be evaluated for the "as produced" methanol for use in municipal, industrial and utility applications and as fuel supplements for gasoline, diesel, and natural gas. These fuel evaluations will be based on the U.S. energy market needs projected during the 1998 to 2018 time period when the LPMEOH™ technology is expected to be commercialized.

The fuel-use test plan will be developed to enhance the early commercial acceptance of central clean coal technology processing plants, making coproducts of electricity and methanol, to meet the needs of the local community. One of those local needs will be for clean fuels (see Part Four - Methanol Fuel Applications, on page 4 of the outline in Appendix C). One of the advantages of the LPMEOH™ process, for coproduction from coal-derived syngas, is that the as-produced, stabilized (degassed) methanol product is of unusually high quality (e.g. less than 1 wt. % water). This quality may be suitable for the premium fuel applications. Cost savings (10 to 15%) of several cents per gallon of methanol can be achieved, if the suitability of the stabilized product can be demonstrated. The applications: as a hydrogen source for fuel cells, and as a clean transportable, storable fuel for dispersed power, will require testing of the product to confirm its suitability.

A limited quantity (up to 400,000 gallons) of the methanol product as produced from the demonstration unit will be made available for fuel-use tests. Fuel-use tests will be targeted for an approximate 18 to 30-month period, commencing in the second year of demonstration operations. The methanol product from the demonstration unit will be in Kingsport, Tennessee. Air Products, Acurex Environmental Corporation (Acurex), and the DOE will develop the final fuel-use test plan.

<u>Activity during this quarter</u>

- The fuel-use test plan is targeted to be updated by May of 1997. This will allow 12 months for proper implementation of the tests, which will be conducted for an 18 to 30 month period commencing in May of 1998. The Demonstration Test Plan (see Task 2.3) indicates methanol for testing (as-produced from CO-rich syngas) will first be produced in May of 1998. Air Products and Acurex are developing a list of contacts for methanol fuel-use testing. The DOE's Office of Energy Efficiency and Renewable Energy is being utilized for guidance in developing the list. Air Products and Acurex are planning a meeting for November of 1996, to review fuel-use test prospects, and to establish milestones, priorities, and responsibilities for developing the updated plan.

Task 1.5 Planning and Administration

Task 1.5.1 Product-Use Test Plan

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Update the (fuel and chemical) product-use test plan to better meet the technical objectives of the project and serve the needs of commercial markets.

  - Air Products and Eastman have updated plans for the on-site product-use demonstrations. The schedule for on-site product-use tests was established for August to October of 1997. Methanol product from the LPMEOH™ Process Demonstration Unit will be used as a chemical feedstock. Eastman will perform fitness-for-use tests on the methanol product for use as a chemical feedstock and provide a summary of the results.

Task 1.5.2 Commercialization Studies

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Complete economic studies of important commercial aspects of the LPMEOH™ process to enhance IGCC electric power generation. These studies will be used to provide input to the LPMEOH™ Process Demonstration Unit operating test plan (Phase 2, Task 3).

Discussion

A number of areas have been identified as needing development to support specific commercial design studies. These design options include: a) Product Purification; b) Front End Impurity Removal; c) Catalyst Addition/Withdrawal; and d) Plant Design Configuration. Plant sizes in the range of 300 TPD to 1800 TPD and plant design configurations for the range from 20% to 70% synthesis gas conversion will be considered. The Kingsport demonstration unit design and costs will be the basis for value engineering work to focus on specific cost reduction targets in developing the initial commercial plant designs.

Activities during this quarter

- Completion of the high priority design work for Task 1.3 (Design Engineering) has allowed significant progress on Task 1.5.2 to be made during this quarter. The Process Economics Study - Outline was updated, and is included in Appendix C. The four-part outline addresses several needs for this Task 1.5.2 Commercialization Study:

a) to provide process design guidance for commercial plant designs.
b) to meet the Cooperative Agreement's technical objectives requirement for comparison with Gas Phase Methanol technology. This preliminary assessment will help set demonstration operating goals, and identify the important market opportunities for the Liquid Phase technology.
c) to provide input to the Demonstration Test Plan (Task 2.3).
d) to provide input to the Off-site Testing (Task 1.4) fuel-use test plan update.

- Part One of the Process Economics Study - Outline, "Coproduction of Methanol", has been completed, and is being distributed, for review and comment, as a draft Topical Report. This Topical Report develops plant design options for the LPMEOH™ process, as an add-on to IGCC power plants for the coproduction of methanol and power. Part One also compares the LPMEOH™ (LP) process with gas phase (GP) methanol process. Surprisingly, the LP technology can coproduce methanol at less than 50 cents per gallon, even at relatively small (400 to 1200 TPD) methanol plant sizes. LP's advantage over GP is 6 to 9 cents per gallon. Therefore, when baseload IGCC power is viable, the LP technology makes coproduction viable.

- The Demonstration Test Plan (Task 2.3) has been updated to include all the important commercial aspects that were identified by this study.

- Part Four of the Outline - "Methanol Fuel Applications", is being used as the basis to update the fuel-use test plan (see Task 1.4).

- Part Two of the Outline - "Baseload Power and Methanol Coproduction", will be developed during the next quarter, for incorporation into the paper, "Fuel and Power Coproduction". This paper will be prepared for presentation at the DOE's Fifth Annual Clean Coal Technology Conference in January of 1997.

Task 1.5.3 DME Design Verification Testing

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Perform initial Design Verification Testing (DVT) for the production of dimethyl ether (DME) as a mixed coproduct with methanol. This activity includes laboratory R&D and market economic studies.

Discussion

The first Design Verification Testing decision milestone, on whether to continue with DME DVT, is targeted for 1 December 1996. DVT is required to provide additional data for engineering design and demonstration decision-making. The essential steps required for decision-making are: a) confirm catalyst activity and stability in the laboratory, b) develop engineering data in the laboratory, and c) confirm market(s), including fuels and chemical feedstocks. The DME Milestone Plan, showing the DVT work and the decision and implementation timing, is included in Appendix D.

Action during this quarter included Market Economic Studies and Laboratory R&D.

Market Economic Studies

Work on the feasibility study for the coproduction of DME and electric power continued. The product DME would be used as a domestic liquid cooking fuel, to replace imported LPG, for the China and Pacific Rim regions.

The market application of DME for diesel engine transportation fuels is promising, either directly as DME, or indirectly by conversion to liquid additives to the diesel fuel pool. DME is an ultra clean (high Cetane) diesel fuel; and an 80% DME mixture with methanol and water is now being tested by others. A blend of oxygenated compounds derived from DME chemistry is being studied under the DOE's (DOE Contract No. DE-FC22-95PC93052) Liquid Fuels Program. The concept of adding a blend of oxygenated compounds to diesel fuel in order to enhance Cetane value and cold start properties is being investigated.

Laboratory R&D

Synthesis of DME concurrently with methanol in the same reactor was viewed as a way of overcoming the synthesis gas conversion limitations imposed by equilibrium in the LPMEOH™ process. Higher synthesis gas conversion would provide improved design flexibility for the coproduction of electric power and liquid fuels from an IGCC facility. The liquid phase DME (LPDME) process concept seemed ideally suited for the slurry-based liquid phase technology, since the second reaction (methanol to DME) could be accomplished by adding a second catalyst with dehydration activity to the methanol-producing reactor. Initial research work determined that two catalysts, a methanol catalyst and an alumina-based dehydration catalyst, could be physically mixed in different proportions to control the yield of DME and of methanol in the mixed product. Proof-of-concept runs, in the laboratory and at the Alternative Fuels Development Unit (AFDU), confirmed that a higher synthesis gas conversion could be obtained when a mixture of DME and methanol is produced in the liquid phase reactor.

Subsequent catalyst activity maintenance experiments have shown the catalyst system utilized in the proof-of concept runs experienced relatively fast deactivation compared to the LPMEOH™ process catalyst system. Further studies of the LPDME catalyst deactivation phenomenon were therefore initially undertaken under DOE Contract No. DE-FC22-95PC93052, and are being continued under Task 1.5.3. This LPDME catalyst deactivation research has determined that an interaction between the methanol catalyst and the dehydration catalyst is the cause of the loss of activity. Parallel research efforts--a) to determine the nature of the interaction; and b) to test new dehydration catalysts--was undertaken. In late 1995, the stability of the LPDME catalyst system was greatly improved, to near that of an LPMEOH™ catalyst system, when a new aluminum-based (AB) dehydration catalyst was developed. This new AB catalyst development showed that modification of the LPDME catalyst system could lead to longer life. During this quarter, laboratory work concentrated on developing the LPDME catalyst system based on the AB series of catalysts.

Summary of Laboratory Activity and Results

- Laboratory testing of the dual catalyst system containing the new aluminum-based (AB) dehydration catalyst continued to show promise. The Liquid Phase DME (LPDME) test run using AB series 05 catalyst was stopped after 934 hours on stream. Catalyst activity remained much higher than the standard system. However, the methanol catalyst showed increased deactivation in the latter part of the run. Efforts are being made to understand a) if this is an experimental artifact, b) if not, what the real cause is, and c) if this deactivation pattern holds for catalyst systems containing other AB series dehydration catalysts.

- The performance of the AB dehydration catalysts shows a strong dependence on preparation parameters. Increased washing did not improve performance, while changing calcination temperature improved performance in one of three tests. A systematic study of the preparation variables is underway.

- The methanol catalyst from the LPDME aging test using AB05 has been analyzed. The results show that the accelerated catalyst deactivation is not due to a) the quality of the slurry oil, nor b) caking or crusting of the catalysts caused by the loss of oil. Based on elemental and x-ray diffraction analyses, contamination and sintering of the methanol catalyst were ruled out as possible causes. The problem could be due to the rehydration of the catalyst surface. Modifying the calcination temperature of the catalyst during preparation, with the goal of generating a more rehydration-resistant surface, did not improve the stability of the methanol catalyst.

- The LPDME run using catalyst mix AB06 was continued, but at different conditions. Changing space velocity, or the feed gas composition, showed significant effects on the methanol catalyst deactivation. A correlation is yet to be established.

- Observation that catalyst aging is enhanced using (Texaco-type) syngas as the feed allows the aging experiments to be performed faster so that the long-term aging for catalysts previously tested can be examined. No improvement in catalyst stability using catalyst mix AB01 was obtained. This test demonstrates that the aging observed in previous experiments is real and not an artifact of a single preparation.

- Development and testing of the LPDME catalyst system will be continued, but in the next fiscal year (e.g. - next quarter) under the DOE Contract No. DE-FC22-95PC93052, Alternative Fuels Program. Laboratory work under this Task 1.5.3 will end in fiscal year 1996.

Task 1.5.4 Administration and Reporting

The Continuation Application for Budget Period No 3 was submitted on 2 August 1996. The Project Evaluation Report for Budget Period No. 2 was prepared and submitted with the Continuation Application. A copy of the Continuation Application letter, and of the Project Evaluation Report, are included in Appendix E.

A project review meeting was held on 4 and 5 September 1996 in Kingsport. Attendees from Air Products, Eastman, and DOE participated. The project status was reviewed. The Design and Procurement tasks were essentially complete, and the Construction task was 61% complete at the time of the meeting. The construction site was visited, where the process building steel was now installed. The commissioning and startup plans and schedule were reviewed. The status of the updated fuel-use test plan, of the DME design verification testing, and other matters were also reviewed. The meeting notes, extracts from the meeting handouts, and the meeting agenda are included in Appendix F.

The monthly reports for July, August and September, were submitted. These reports include the Milestone Schedule Status Report, the Project Summary Report, and the Cost Management Report.

The Milestone Schedule Status Report and the Cost Management Report, through the period ending 30 September 1996, are included in Appendix G. These two reports show the current schedule, the percentage completion and the latest cost forecast for each of the Work Breakdown Structure (WBS) tasks. The demonstration unit is scheduled to be mechanically complete at the end of December of 1996. Construction progress photographs, taken on 1 October 1996, are also included in Appendix G. Eighty-one percent (81%) of the $38 million of funds forecast for the Phase 2 tasks have been expended (as invoiced), as of 30 September 1996.

The schedule, for completion of the major Phase 2 Construction Tasks, has slipped about three weeks. Construction (Task 2.2) is now forecast for completion by 31 December 1996 (originally 2 December 1996). Commissioning activities (Task 2.3) will commence in mid-October of 1996, and will be completed in mid-January of 1997 (originally 23 December 1996). Start-up (Phase 3, Task 1) is forecast to be initiated on 20 January 1997 (originally 27 December 1996), and to be completed by 25 February 1997 (originally 1 February 1997). Methanol Operation (Phase 3, Task 2.1) is now scheduled to start on 17 February 1997 (originally 26 January 1997).

The construction schedule slipped three weeks due to the late completion of the design and fabrication of the process building structural steel. The process building structure for the main reactor is 30-feet wide by 30-feet long and 121-feet tall. It supports the reactor process equipment and piping. The final design of the steel members took longer than anticipated, because the piping loads, imposed by the high temperature process piping, were larger than normal. This added to the sizing of the steel members, and some special order items were required. The sizing and stress analysis of the safety relief valves and vent header piping also took longer than scheduled. The overall impact was a delay in finalizing the process building steel design, its fabrication, and delivery to the site. The overall impact to the project has been an increase to engineering and construction costs plus a delay to completion of these efforts.

July 1996 Cost Forecast

The reactor and steel delivery delays were discussed at the DOE Project Review Meeting in June of 1996. From that meeting, an action item was to complete a major cost forecast update in late July, after the remaining major construction uncertainties were resolved. The remaining uncertainties were: a) the reactor was delivered and erected, b) the process building structural steel was delivered to the site, c) the insulation bids were received, and d) the schedule and manpower loading impacts on the Mechanical and the Instrument & Electrical Contractors were resolved.

These uncertainties are now resolved. Unfortunately, the Construction costs could not be brought in under budget to off-set cost growth experienced in Engineering areas. A major cost forecast update of all of the Phase 3 - Operation tasks, as well as of the cost to complete the Kingsport Project Design and Construction Phase tasks, was completed in July. This updated forecast was submitted (on 8 August 1996 as the preliminary Annual Cost Plan for fiscal year (FY) -1997) and used for the estimated project costs submitted with the Continuation Application. The updated cost forecast is also included in the Cost Management Report in Appendix G. In summary, the total Project Cost of $213.7 million is adequate to complete construction of the facility and operation as defined in the Demonstration Test Plan.

Discussion of Cost Forecast changes

The updated cost forecast (FY-1997 Cost Plan) is compared to the FY-1995 Cost Plan submitted (in September of 1994) with the Continuation Application for Budget Period No. 2. These two Cost Plans are summarized in the Cost Forecast Summary Table, included at the end of this section. There was no change in the total cost forecast for the Project. However, there were significant variations within the Work Breakdown Structure (WBS) tasks, as shown in the Table, and discussed in the following.

Non-Kingsport Portion of Project

The costs for the non-Kingsport portion of the Project have been reduced by about $1.0 million. About half of this reduction reflects costs incurred prior to the site change to Kingsport (prior to Mod 002). The costs for the earlier period now reflect the final audited costs. The other half of the cost reduction reflects the lower off-site testing costs for the updated fuel-use test plan (see Task 1.4).

Cost Forecast Summary Table (Costs in $1,000's) Task // Date Submitted:	FY - 1997 Cost Plan (Prel) 8 Aug. 1996	FY - 1995 Cost Plan 26 Sept. 1994	Change in Forecasted Costs
Non-Kingsport Portion of Project:			
1.1 Pre-award & Proj. Def. (Prior to Mod 002):	$ 16304	$ 16851	$ (547)
1.4 Off-site Testing (Plan and Design)	$ 276	$ 324	$ (48)
2.4 Off-site Testing (Construction)	$ 256	$ 305	$ (49)
3.4 Off-site Testing (Operation)	$ 3451	$ 3792	$ (341)
Sub-Total; Non-Kingsport Portion of Project:	**$ 20287**	**$ 21272**	**$ (985)**
Kingsport Portion of Project (Phase 1 & 2):			
1.1 Project Definition	$ 1051	$ 1230	$ (179)
1.2 Permitting	$ 238	$ 288	$ (50)
1.3 Design Engineering	$ 11335	$ 8206	$ +3129
1.5 Planning, Admin. & DME DVT	$ 2870	$ 1663	$ +1207
2.1 Procurement	$ 9703	$ 10953	$ (1250)
2.2 Construction	$ 11550	$ 11500	$ + 50
2.3 Training & Commissioning	$ 1115	$ 897	$ +218
2.5 Planning & Admin.	$ 1015	$ 681	$ + 334
Sub-Total; Kingsport Phase 1& 2 Portion:	**$ 38877**	**$ 35418**	**$ +3459**
Kingsport Portion of Phase 3 Operation:			
3.1 Startup	$ 680	$ 3435	$ (2755)
3.2.1 Methanol Operation	$146485	$147287	$ (802)
3.2.2 DME Design, Mod., Oper. at Kingsport*	$ 1790	$ 2340 *	$ (550)
3.2.3 LPMEOH Dismantlement	$ 515	$ 425	$ + 90
3.3 On-Site Testing	$ 4	$ 4	$ 0
3.5 Data Analysis & Reports	$ 2670	$ 1926	$ +744
3.6 Planning & Admin. & DME at LaPorte**	$ 2392 **	$ 1593	$ +799
Sub-Total; Phase 3 (Operation at Kingsport)	**$ 154536**	**$ 157010**	**$ (2474)**
Total Project Cost Forecast	**$ 213700**	**$ 213700**	**$ 0**

Notes: * The FY-95 Plan inadvertently included the LaPorte DME test run in Task 3.2.2 ($860K). This should, per the Statement of Work, have been included in Task 3.6.

** The FY-97 Plan includes the LaPorte DME test run in Task 3.6 ($875K).

Kingsport Portion of Project (Phase 1 & 2)

Summary: The Kingsport Portion of the Project (Phase 1 & 2) for Design and Construction has a cost growth of $3.5 million, or about 10%. The cost growth is due to the higher Engineering and Administration costs for Tasks 1.3, 1.5, and 2.5, and is partly off-set by the lower Procurement (Task 2.1) costs.

The Project Definition (Task 1.1) and Permitting (Task 1.2) tasks are now complete. These costs are reduced by about $0.2 million. The reduction in Tasks 1.1 and 1.2 at Kingsport reflect the good cooperation of the three (DOE/Eastman/Air Products) participants in defining the scope and the management basis for the Project at Kingsport, and the early completion of these Budget Period No. 1 tasks.

The Design Engineering (Task 1.3), and the Planning, Administration, & DME-DVT (Tasks 1.5 and 2.5) tasks are about completed. The cost forecast for these tasks was increased by about $2.0 million in the December of 1995 Cost Management Report, was up $0.4 million in March of 1996; and an additional $0.7 million in the June of 1996 Cost Management Reports. The overall Engineering and Administration cost increase reflects the following:

a) The impact of the unexpected 3 to 4-month delay in transitioning from Budget Period No. 1 to Budget Period No. 2. The project team was kept together during the transition approval period, in order to not lose momentum, and to try and hold the schedule for start-up in December of 1996. Some initial process design work was accomplished during this transition period, but the delay in initiating Procurement (Task 2.1) necessarily delayed the availability of the engineering details of the process equipment needed to initiate the foundation and structural engineering design. This required extra engineering design revision, as the final equipment design details differed from the preliminary designs incorporated in the construction bid packages.

The overall schedule anticipated by the FY-95 Schedule Plan was 25 months overall (Budget Period No. 2 approval in December of 1994, and Methanol Operation in December of 1996). The schedule as currently forecast is 23 months overall (approval in March of 1995, Methanol Operation forecast for February of 1997). Spending extra engineering effort up front did improve the overall schedule. Part of that improvement has been lost toward the end of construction, with late design changes and delivery of materials to the site.

b) The detailed engineering design requirements were underestimated in the initial Cost Plan budget. The first-of-a-kind, pioneer plant design effort that was needed to provide the scale-up to commercial size was underestimated. The acquisition of the operational data to support future engineering designs, as better defined in the Environmental Monitoring Plan and in the Demonstration Test Plan (DTP) documents, added an unanticipated engineering effort for the final design.

Procurement (Task 2.1) is now complete. The cost forecast is reduced by about $1.2 million, reflecting actual expenditures, and commitments. The reduction in the cost forecast reflects the good initial process scope definition (from Task 1.1), and favorable competitive bidding.

There were small, off-setting, changes in the other WBS tasks. The commissioning work (Task 2.3) has been better defined during the DTP development, and some of the work estimated to be in the Start-up (Task 3.1) should have been included in Task 2.3. The Phase 3 cost reflects the lower cost for Start-up (Task 3.1). The Construction costs (Task 2.2) were lower due to favorable bidding on the early construction bid packages, but the late design and procurement deliverables schedule has adversely impacted the later costs.

Kingsport Portion of Phase 3 Operation

The Kingsport portion of the Phase 3 (Operation) costs are lower by about $2.5 million, due primarily Eastman's lower syngas costs, and to the better defined Demonstration Test Plan. The start-up (Task 3.1) costs were adjusted to reflect the Demonstration Test Plan, by moving the syngas costs for catalyst reduction and initial shakedown operation, to Task 3.2.1 (Methanol Operation). The reporting and administration cost forecast (Tasks 3.5 and 3.6) was increased slightly, to reflect the higher costs for these tasks as experienced during Phases 1 and 2. Overall, the lower Phase 3 cost have off-set the Phase 1 and 2 cost increases.

Task 2.1 Procurement

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Complete the bidding and procurement for all equipment and Air Products-supplied construction materials.

  - The 230-foot vent stack arrived at the site in August, and will be erected in October. All of the other equipment items have been received, and are installed.
  - The final sections of prefabricated structural steel, for the reactor building and for the catalyst building, were received at the site. The bulk materials (prefab piping, valves, instrumentation, and electrical) have also been received on site.
  - Task 2.1 Procurement was essentially completed during this quarter.

Task 2.2 Construction

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Provide construction management for contractor coordination and compliance with design, construction, and quality control standards.

  - Air Products construction site manager, lead electrical superintendent, lead mechanical superintendent, clerk, and secretary are now overseeing the construction activities at the site. Construction activities are at a peak.

- Erect the major equipment and structural steel. Install the large bore piping, electrical, and insulation such that instrument checkout and equipment commissioning work can be completed during the 60-day Continuation Application approval period.

  - The reactor was off loaded and erected into position on 2 July 1996. The reactor was passivated in place in August. The erection of the process building structural steel for all areas was essentially completed during this quarter. Minor punch list work remains. The Mechanical Contractor has 21 large bore piping spools (out of 640) left to install. Installation of small bore piping is 65% complete. Pressure testing of some of the piping circuits should begin by mid-October.

  - The Instrument and Electrical (I&E) Contractor is completing work in the areas west of the main process building. This area will be ready for Instrument Loop Checking by mid-October. The Honeywell distributed control system (DCS) cabinets were installed in the DCS room. Installation of cable trays and wiring is continuing in the reactor and distillation areas of the facility. Overall, the I&E work is 52% complete.

  - The Insulation and Fireproofing Contractor began work in early September, insulating equipment items. Work on piping insulation will begin in late October.

  - The last two construction contracts are out for bid, and will be awarded in October. These two small contracts are for Final Grading and Paving, and for Painting.

- Complete mechanical construction so that checkout and commissioning can be started in Budget Period No. 3.

  - Overall, Construction is 72% complete as of the end of September of 1996. The targeted completion date has slipped about three weeks, to 31 December 1996. Commissioning activities are scheduled to start in mid-October, and should be complete by mid-January. Startup activities are scheduled to begin 20 January 1997. Methanol operation is scheduled to start in February of 1997.

Task 2.3 Training and Commissioning

The Project Evaluation Plan for Budget Period No. 2 establishes the following goals for this task:

- Prepare a four-year test plan for Phase 3, Task 2 - Operation.

  - Comments received on the (May of 1996) draft Demonstration Test Plan (DTP) were incorporated into a revised final draft, which was released for review in July of 1996. The (July of 1996) final draft DTP was approved on 3 September 1996 for issue as final. The final DTP was distributed on 27 September 1996. The DOE approval letter, and a summary (Table 5-1) of the four-year schedule and test plan are included in Appendix H.

- Prepare the operating manual and initiate the operator training program.

  - Operator training is scheduled for four one-week sessions, from 28 October through 22 November, 1996. The operating manuals are being prepared.

The main commissioning effort, instrument loop checking and commissioning of equipment by area, will begin in mid-October. Commissioning of the steam and utility systems will be in January of 1997. The Commissioning and Startup Schedule is included in Appendix I.

Task 2.4 Off-Site Testing (Procurement and Construction)

The Project Evaluation Plan for Budget Period No. 2 establishes the following goal for this task:

- Prepare the final off-site product-use test plan.

  - The off-site product-use test plan update is being reported under Task 1.4 Off-Site Testing (Definition and Design).

Task 2.5 Planning and Administration

The Project Evaluation Plan for Budget Period No. 2 establishes the following goals for this task:

- Prepare annually an updated (Partnership) plan for the remaining activities. The first annual plan will update the remaining Phase 1 and Phase 2 activities, and the second will include an updated Phase 3 Demonstration Test Plan.

  - The first update of the Partnership Annual Operating Plan was prepared and submitted in September of 1995 (see Quarterly Technical Progress Report No. 5). The main goal and objective for this first annual plan is to continue construction so that the LPMEOH™ demonstration unit will be ready for commissioning and start-up in 1996; and to complete the Project Evaluation Report for Budget Period No. 2 and submit it to the DOE along with the Continuation Application for Budget Period No. 3.

  - The second update of the Partnership Annual Operating Plan was being prepared during this quarter, and will be submitted in October of 1996.

- Submit all Project status, milestone schedule, and cost management reports as required by the Cooperative Agreement.

  - The DOE reporting tasks are being performed and reported under Task 1.5.4 (Administration and Reporting).

E. Planned Activities for the Next Quarter

- Complete the erection of the vent stack, and installation of piping and instrumentation.
- Complete operator training.
- Initiate commissioning of the equipment, by area of the facility.
- Make a recommendation on whether to continue with DME design verification testing.
- Initiate contacts for off-site fuel-use test planning (Acurex and Air Products).
- Issue the first draft of the Process Economics Study as a Topical Report.
- Issue the second update of the Partnership's Annual Operating Plan.
- Modify the Cooperative Agreement, authorizing the transition to Budget Period No. 3.
- Submit the final version of the "Fuel and Power Coproduction" paper for the 5th Annual Clean Coal Technology Conference.
- Hold a Project Review/Update Meeting at the construction site in December.

F. Summary

The Continuation Application was submitted on 2 August 1996, requesting authorization to transition from Budget Period No. 2 (Design and Construction) to the final Budget Period (Commissioning, Startup, and Operation). The Project Evaluation Report for Budget Period No. 2 was prepared. A recommendation for approval is being prepared and reviewed by the DOE.

A draft Topical Report on Process Economics Studies was being prepared. This shows that methanol coproduction, with IGCC electric power utilizing the LPMEOH™ process technology, will be competitive in serving local market needs. The results will also be incorporated into a paper "Fuel and Power Coproduction", being prepared for presentation at the DOE's 5th Annual Clean Coal Technology Conference.

A decision on whether to continue with DME design verification testing is to be made, by the participants, in December of 1996. The laboratory R & D results are confirming that the new LPDME catalyst system will have reasonable long-term activity and stability. The market application of DME is promising, for example as diesel engine transportation fuels, either directly as DME, or indirectly by conversion to liquid additives for the diesel fuel pool. A recommendation to continue with DME design verification testing is likely.

The off-site product testing plan is to be updated by May of 1997. During this quarter, Air Products and Acurex were developing a list of contacts for product methanol fuel-use testing. Prospective Federal, State, and University product test participants, involved in fuel cell, transportation, and stationary power plant developments, are being included.

A project review meeting was held in Kingsport in early September. The vent stack was at the site, and all of the other equipment was installed. The construction and operation permits have been obtained. The operator training, commissioning, startup, and initial operation plans were reviewed.

An updated cost forecast shows $38 million for the Kingsport portion of the LPMEOH™ Process Demonstration Project for the Phase 1 and 2 tasks. This is up about 10% from the Budget Period No. 2 Cost Plan. The increase is off-set by lower actual costs for the Project pre-award work, and by lower projected costs for Phase 3 Operation. The total Project cost remains the same at $213.7 million.

Construction (Task 2.2) is 72% complete, as of the end of September of 1996. The targeted completion date has slipped by about three weeks, to 31 December 1996. Commissioning activities (Task 2.3) will start in mid-October of 1996, and should be completed in mid-January of 1997. Startup, of the utility systems, is scheduled to begin in late January.

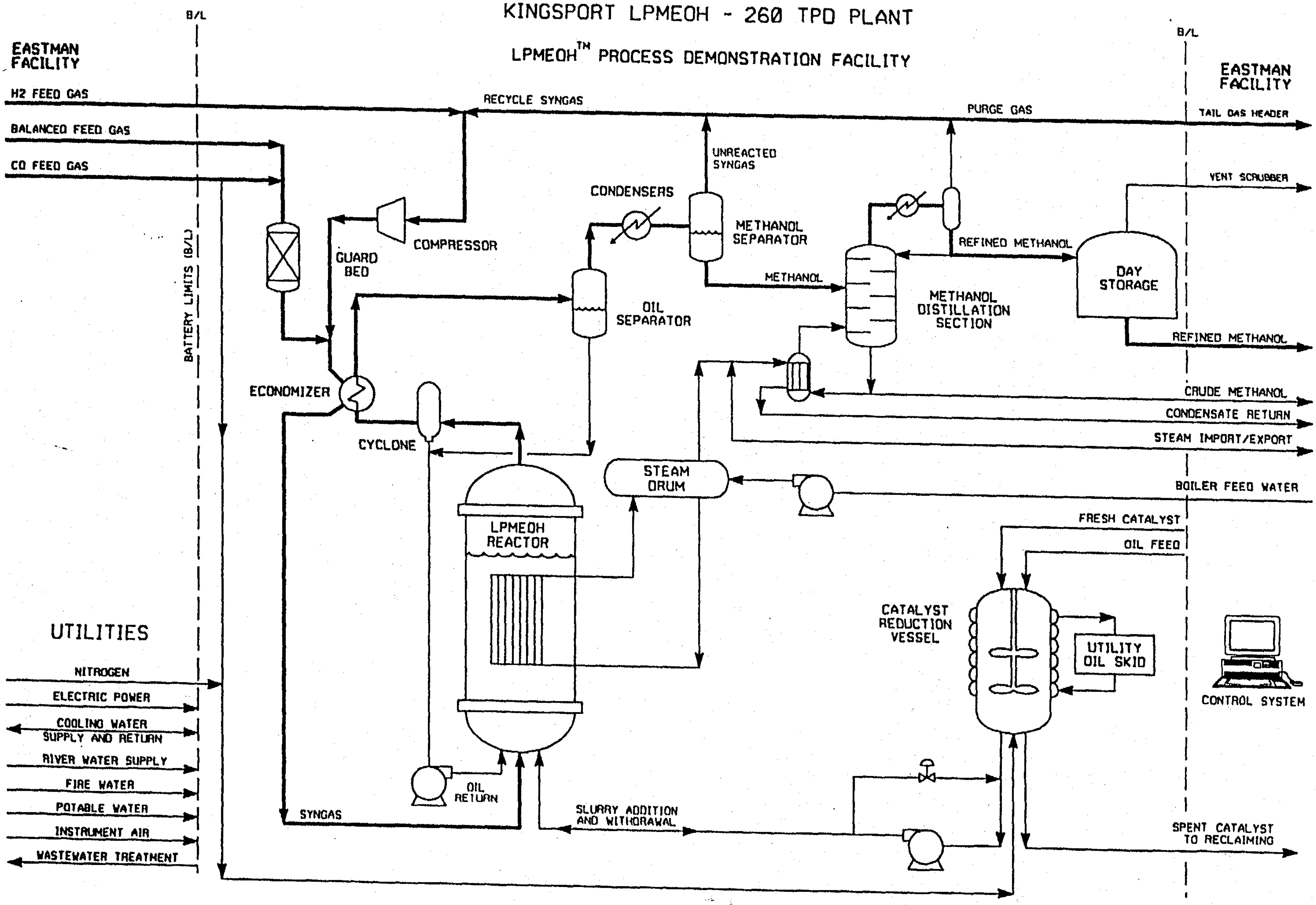
Eighty-one percent (81%) of the $38 million of funds forecast for the Kingsport portion of the LPMEOH™ Process Demonstration Project for the Phase 1 and Phase 2 tasks have been expended (as invoiced), as of 30 September 1996.

APPENDICES

APPENDIX A - SIMPLIFIED PROCESS FLOW DIAGRAM

SIMPLIFIED PROCESS DIAGRAM
KINGSPORT LPMEOH - 260 TPD PLANT

LPMEOH™ PROCESS DEMONSTRATION FACILITY



APPENDIX B - PROJECT EVALUATION PLAN FOR BUDGET PERIOD NO. 2

COMMERCIAL-SCALE DEMONSTRATION
OF THE
LIQUID PHASE METHANOL (LPMEOH™) PROCESS
COOPERATIVE AGREEMENT
NO. DE-FC22-92PC90543

PROJECT EVALUATION PLAN FOR BUDGET PERIOD NO. 2

The work to be performed during Budget Period No. 2 consists of Phase 1 Design and Phase 2 Construction of the LPMEOH™ Process Demonstration Facility at Eastman Chemical Company's integrated coal gasification facility located in Kingsport, TN. Completion of these Budget Period No. 2 activities will essentially ready the LPMEOH™ Process Demonstration Facility for commissioning, startup, and operation to begin in the final Budget Period No. 3. The Statement of Work for the Project subdivides these Phase 1 and Phase 2 activities into Tasks. This Project Evaluation Plan for Budget Period No. 2 will meet the following criteria aligned by the Statement of Work tasks:

1. **Phase 1 - Task 2 - Permitting**

    - Issue the final Environmental Information Volume to support the U.S. Department of Energy's (DOE's) Environmental Assessment/Finding of No Significant Impact.

    - Obtain permits necessary for construction and operation.

2. **Phase 1 - Task 3 - Design Engineering**

    - Complete the design engineering necessary for construction and commissioning. This includes Piping and Instrumentation Diagrams, Design Hazard Reviews, and conducting design reviews.

    - Prepare the Environmental Monitoring Plan.

3. **Phase 1- Task 4 - Off-site Testing (Definition and Design)**

- Prepare the fuel-use demonstration plan for Phase III, Task 4 Off-site Product Use Demonstration. This off-site test plan will be incorporated into the overall product-use test plan (in Phase 1, Task 5).

4. **Phase 1 - Task 5 - Planning, Administration and DME Verification Testing**

- Update the (fuel and chemical) product-use test plan, that will better meet the technical objectives of the Project and serve the needs of commercial markets.

- Complete economic studies of the important commercial aspects of the LPMEOH™ Process to enhance Integrated Gasification Combined Cycle (IGCC) electric power generation. These studies will be performed by Air Products and Chemicals, Inc. and the Electric Power Research Institute, and used to provide input to the LPMEOH™ Process Demonstration Facility operating test plan (Phase 2, Task 5).

- Perform initial Design Verification Testing for the production of dimethyl ether (DME) as a mixed coproduct with methanol. This activity includes laboratory R&D and market economic studies.

- Submit all Project status, milestone schedule, and cost management reports as required by the Cooperative Agreement.

5. **Phase 2 - Task 1 - Procurement**

- Complete the bidding and procurement for all equipment and Air Products supplied construction materials.

6. **Phase 2 - Task 2- Construction**

- Complete mechanical construction so that checkout and commissioning can be started in Budget Period No. 3.

- Erect the major equipment and structural steel. Install the large bore piping, electrical, and insulation such that instrument checkout and equipment commissioning work can be completed during the 60-day Continuation Application approval period.

- Provide construction management for contractor coordination and compliance with design, construction, and quality control standards.

7. **Phase 2 - Task 3 - Training and Commissioning**

- Prepare a four (4)-year test plan for Phase 3, Task 2-Operation.

- Prepare the operating manual and initiate the operator training program.

8. **Phase 2 - Task 4 - Off-Site Testing (Procurement and Construction)**

- Prepare the final off-site product-use test plan.

9. **Phase 2 - Task 5 - Planning and Administration**

- Prepare annually an updated plan for the remaining activities. The first annual plan will update the remaining Phase I and Phase II tasks. The second annual plan will include an updated Phase III Operating Plan, identifying specific goals and milestones for the first twelve months of operation, and a general plan for the remaining years to achieve the Project's market penetration objectives.

- Submit all Project status, milestone schedule, and cost management reports as required by the Cooperative Agreement.

Completion of the above work activities will essentially ready the LPMEOH™ Process Demonstration Facility for commissioning, startup, and operation to begin in the final Budget Period No. 3. These criteria will be the basis of the Project Evaluation Report which shall be submitted to the DOE for approval along with the Project Continuation Application, at least 60 days before the end of Budget Period No. 2. Construction of the Facility will be essentially completed during the 60-day approval period for the Continuation Application.

At the time that the Project Evaluation Report for Budget Period No. 2 is submitted with the Continuation Application; Air Products will also prepare an update on the expected technical and economic performance of the mature unit. This update will demonstrate the commercial potential of the LPMEOH™ process technology to enhance IGCC electric power generation with coproduct methanol. This IGCC enhancement is expected to reduce the cost of electricity for retrofit, repowering, replacement, and new applications for electric power generation from coal.

WRB/jjs/Proeva.

APPENDIX C - TASK 1.5.2 - PROCESS ECONOMICS STUDY - OUTLINE
(Draft - four pages)

including

Part Four - Methanol Fuel Applications
(for Task 1.4 - Off-site Testing Plan)

Process Economics Study - Outline
LPMEOH™ Process, as an add-on to IGCC for Coproduction

Part One - Coproduction of Methanol

1. Introduction

1.. Process Design Options.

- Develop process flow diagram and plant design options for the LPMEOH™ process, for design variables such as: a) feed gas pressure, b) feed gas compositions, and c) % syngas conversion.

2. Liquid Phase (LP) Methanol Advantage versus Gas Phase (GP) Methanol.

2.1. Syngas Conversion Cost for Methanol Production from CO-Rich syngas.

- For the various LPMEOH™ process (LP) design options (from 1.1) develop plant capital and conversion costs derived from the Kingsport Project costs and design basis. Develop conversion costs for:
  - 500 t/d Plant size, with 500 psi feed gas pressure;
  - 500 t/d Plant size, with 1000 psi feed gas pressure
  - Impact of Plant Size on Conversion Costs

- Summarize in a series of graphs, conversion costs, in cents per gallon over the range of syngas conversion from 18% (LP - Once-through) to 94% (GP), for baseload annual coproduction operation. This will show LP's advantage at higher feed pressures and lower conversions; and will highlight areas for LP design development/demonstration improvements. *(For future: include plant size impact on product distribution (freight) cost, assuming that local markets are served. Freight cost will increase with plant size, as the distribution radius increases.).*

2.2. Methanol Product Purification Cost.

- Develop capital and operating costs for these product purification design alternatives:
  - MTBE Grade;
  - Fuel Grade;
  - Chem. Grade;

Over a range of feed gas compositions, summarize LP's advantage versus the GP process (in cents per gallon), especially for MTBE and Fuel Grade from CO-rich feed gas at low syngas conversions.

2.3. Feedgas (Syngas) Composition Variations: (Impact on LP vs. GP).

- Higher Sulfur content in the feedgas will have a negative cost impact on LP at low syngas conversion, relative to GP at high conversions. Conversely, higher feedgas inert content will have a negative relative cost impact on GP.
  - Sulfur content variation; over the above range of syngas conversion
  - Inert gas content variation; over the above range of syngas conversion

2.4. Syngas Usage (Btu per Gallon) - Impact on IGCC Power Plant.

- Summarize differences in syngas utilization (Btu per gallon of methanol), and in mass flow loss/gain to the combustion turbine (kwh production loss/gain per gallon of methanol); for the cases in 2.1 above.

2.5. Summary of Cost Advantage(s) - (LP Vs GP).

- Summarize the cost impact (cents per gallon) of the above design variables and syngas utilization differences. Show the impact of methanol plant size on the conversion costs. Also (separately show) the impact of 90% and 70% annual load utilization for use with Section 4. - "Intermediate Load Coproduction and Stored Energy" of this Economics Study.

2.6. Recommendations for Further Study.

- Recommend areas for process design value engineering work; and areas for demonstration at Kingsport.

Part Two - Baseload Power and Methanol Coproduction

3. Baseload Coproduction with Methanol Sales - Impact on Electric Power Cost -

For baseload coproduction, the gasifier must be sized for both the power and methanol products. The results of Part One indicate the LP technology can make coproduction economic, even at small methanol plant sizes (400 to 1200 TPD) suitable to serve local markets near the power plant.. The LP technology's advantage (over GP) is also greatest at the lower (up to 34%) Syngas Conversions which are consistent with these methanol plant sizes. A matrix of power plant and methanol plant sizes of interest, at up to 34% Syngas Conversion to methanol, is shown in the following tables. These examples are based on Advanced Gas Turbine Technology *(reference (G.E.'s) published paper)* with the base gasification plant sized for two gasifiers, of about 1525 x 10^6 Btu(HHV)/hr. output each.

3.1 Gasification Plant Size Fixed

- **With a given gasification plant size,** the methanol plant and power plant can be sized to accommodate a range of Methanol to Power output ratio's.

Syngas Conversion	Power Plant Size	Methanol Plant Size	Methanol to Power Ratio	Gasification Plant Size
0 %	500 MW	0 T/D	0 T/D per MW	Base
20%	400 MW	651 T/D	1.6 T/D per MW	Base
33%	333 MW	1086 T/D	3.3 T/D per MW	Base

3.2 Power Plant Size Fixed

- **With a given power plant size,** the gasifier size may be increased to accommodate the coproduction of methanol. For Gasification Plant size increases of up to 50% (to say, three x 1525 x 10^6 Btu(HHV)/hr. gasifiers), the methanol to power coproduction ratio's could be:

Syngas Conversion	Power Plant Size	Methanol Plant Size	Methanol to Power Ratio	Gasification Plant Size
0.0 %	500 MW	0 T/D	0 T/D per MW	1.00 x Base
16.7 %	500 MW	651 T/D	1.3 T/D per MW	1.20 x Base
25.0 %	500 MW	1086 T/D	2.2 T/D per MW	1.33 x Base
33.3 %	500 MW	1629 T/D	3.3 T/D per MW	1.50 x Base

- The impact of coproduction on electricity generation costs will be shown in graphs of electricity cost Vs. methanol net back price.

End of Part Two.

Part Three - Coproduction for Intermediate Electric Load Following.

4. Intermediate Load Coproduction and Stored Energy.

4.1. Syngas Value.

4.1.1 Syngas value as a function of (time of day) Power Value.

Our earlier load following work indicates that an LPM coproduction add-on optimizes for intermediate peak-load power in the 1000 to 2500 hr./yr. range. This means the methanol plant operates during "off--peak" power in the 7760 (88% utilization) to 6260 (71% utilization) hr./yr. range (8760 hr./yr. = 100% = total hr./yr.), with up to 200 annual daily stop/start operations for the daily on/off peaks.

- *Time of day example: A given Lambda Curve might provide data at 2000 and 1500 peak hr./yr. such as: a)* 3.4 cent off-peak power (6760 hr.) plus 7.8 cent intermediate-peak power (2000 hr.) equals 4.4 cent baseload power (8760 hr.). b). 3.5 cent off-peak (7260 hr.) plus 8.6 cents intermediate-peak power (1500 hr.) equals 3.6 cent baseload power (8760 hr.). Time of day syngas values can be derived, based on the alternative value of using syngas for power (in CC or CT power plants).

4.1.2. Syngas value as function of seasonal opportunity fuels/feeds.

- *Natural gas may be available seasonally, for use in the CC power plant, allowing syngas to be used for conversion in an LPM add-on. Other feeds?*

4.2. Intermediate Load Coproduction - for Methanol Sales.

- For all intermediate load coproduction cases, redundant investment to utilize syngas on/off-peak is required; so that when the methanol plant shuts down during peak power periods, all of the syngas can be converted to electric power. There are many intermediate load coproduction power plant design choices; a) CC power plant turned down, or b) baseload CC power plant with CC or CT power plant(s) for peak; which may be combined with c) many methanol plant choices such as size/% conversion/and on-off operating hours. To do these studies properly, we need to have good time of day power values (also called Lambda Curves) as well as the Section 2. (above) Methanol Plant design choices completed.

4.3. Intermediate Load Stored Energy Production, with Methanol Fuel for Peak Power Production.

- The design optimization for this is quite complex. The IGCC/OTM plant design has an additional variable: the peaking power plant size and hours of operation is an independent variable. We may be able to use a specific (--) study with a published paper as a goal. An alternative study option is to compare ourselves (IGCC/OTM) to the various published EPRI (IG-Cash, et. al.) studies, which provide Lambda Curve examples for energy storage.

  When other back up fuels are not available, or are too expensive, then methanol may also be used to enhance power plant availability. Coproduction with multiple gasifier trains may also be used to enhance power plant availability. (e.g. - Three by 50%, where Baseload Power = 2 x 50%; Peaking Power = 1x 50% plus methanol fuel; Methanol Plant = 1 x 50%, but operates only when all three gasifiers are operating and peak power is not required.)

4.4. Intermediate Load Stored Energy Production, with Methanol for Dispersed Energy.

- Methanol transported to remote **existing** or new power plants on the Utilities grid system.

End of Part Three.

Part Four - Methanol Fuel Applications

5. Premium Methanol Fuel Applications

- At 46 cents per gallon, methanol as a fuel ($6.90 per mmBtu) will not compete with oil in most applications ($20/bbl crude = $3.30/mmBtu; $24/bbl diesel = $4.00 /mmBtu). However, methanol coproduced at a central IGCC power station, may be a valuable premium fuel for two evolving developments: as an economical Hydrogen source for small fuel cells, and as an environmentally advantaged fuel for dispersed electric power.

- "Central clean coal technology processing plants, making coproducts of electricity and methanol; to meet the needs of local communities for dispersed power and transportation fuel" - meets the DOE Clean Coal Technology Program's objectives. Serving (initially) small local fuel markets also builds on LP's (the LPMEOH™ process) strengths; good economics at small methanol plant sizes, fuel grade product distillation savings, and a freight advantage in local markets vis a vis large off-shore remote gas methanol. Baseload methanol coproduction studies show that 46 cent per gallon methanol can be provided from an abundant, non-inflationary local fuel source.. *We need to show when (at what oil price) we can compete, and to arrange fuel tests to confirm the dispersed energy environmental advantage.*

5.. Hydrogen Source for

- Hydrogen fuel cells, being developed for transportation applications, can achieve 65% system efficiency, as compared to 45% for diesel IC engines and 32% for gasoline IC engines. Methanol is a storable, transportable liquid fuel which can be reformed under mild conditions to provide H2. For small H2 applications, *and at low utilization factors,* methanol reforming is a more economical source of hydrogen than : a) natural gas reforming, b) distillate (oil) reforming; and is cheaper than LH_2.

5.1.1. Fuel Cells for Transportation

5.1.2. Fuel Cells for Stationary Power
(See also dispersed power below).

5.1.3. Industrial Applications - Small Hydrogen Plants
Small pressurized methanol reformers for transportation applications may be suitable for adapting to meet the needs of small commercial hydrogen gas requirements.

5.2. Dispersed Power

- Dispersed power is getting a lot of favorable publicity. . The world wide package (0.2 MW to 10 MW) power plant market is large. A variety of technologies (combustion turbine, internal combustion engine, fuel cell) are being packaged to provide power and heat locally, at the use point. Environmental and Economic advantages include Methanol for Fuel Cells = clean stationary local power; no need for natural gas pipelines; no new high voltage power lines.

5.3. Dimethyl Ether as an Enhancement to Methanol in Premium Fuel Applications
Can coproduced mixtures of methanol and dimethyl ether improve upon methanol, in the above?

End of Part Four.

APPENDIX D - TASK 1.5.3 - DME MILESTONE PLAN

TABLE 5-2

DME MILESTONE PLAN

1. **Design Verification Testing:**

A.	Laboratory R&D, Verification	
1.	Catalyst Activity and Stability Testing, and Engineering Data	Mar. '95 - Aug. '96
B.	Market Verification	
1.	Up to 3 wt% DME, as M-100 Diesel Replacement Engine Tests - (SCAQMID) - and Market Acceptance Study	by Jan. '96 **** Completed ****
2.	Up to 8 wt% DME for GCC Energy Storage a. Re-review economics	by Aug. '96
3.	About 80 wt% DME with Methanol, as a Diesel Replacement Fuel, or as Chemical Feedstock at Kingsport a. Economics, process basis study	by Aug. '96
C.	Decision to Continue or Drop Demonstration	by Dec. '96

2. **Process Development Unit Design Verification Test (Provisional):**

A.	LaPorte AFDU Tests	by Sep. '97
B.	Decision to Continue or Drop Demonstration	by Mar. '98

3. **Implementation (Provisional) Plan:**

A.	Design, Procurement, and Construction at Kingsport, of Add-on Equipment, and Operation	Start July '98 to Jan. '01