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DE-FC22-92PC90543-12

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**Commercial-Scale Demonstration of the Liquid  
Phase Methanol (LPMEOH<sup>TM</sup>) Process**

**Quarterly Report  
April 1 - June 30, 1997**

Work Performed Under Contract No.: DE-FC22-92PC90543

For  
U.S. Department of Energy  
Office of Fossil Energy  
Federal Energy Technology Center  
Morgantown, West Virginia

By  
Air Products and Chemicals Inc.  
Allentown, Pennsylvania

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## Abstract

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). Air Products and Chemicals, Inc. (Air Products) and Eastman Chemical Company (Eastman) formed the Partnership to execute the Demonstration Project. The LPMEOH™ Process Demonstration Unit was built at a site located at the Eastman complex in Kingsport.

During this quarter, comments from the DOE on the Topical Report "Economic Analysis - LPMEOH™ Process as an Add-on to IGCC for Coproduction" were received. A recommendation to continue with design verification testing for the coproduction of dimethyl ether (DME) and methanol was made. DME design verification testing studies show the liquid phase DME (LPDME) process will have a significant economic advantage for the coproduction of DME for local markets. An LPDME catalyst system with reasonable long-term activity and stability is being developed. A recommendation document summarizing catalyst targets, experimental results, and the corresponding economics for a commercially successful LPDME catalyst was issued on 30 June 1997.

The off-site, product-use test plan was updated in June of 1997. During this quarter, Acurex Environmental Corporation and Air Products screened proposals for this task by the likelihood of the projects to proceed and the timing for the initial methanol requirement. Eight sites from the list have met these criteria. The formal submission of the eight projects for review and concurrence by the DOE will be made during the next reporting period.

The site paving and final painting were completed in May of 1997. Start-up activities were completed during the reporting period, and the initial methanol production from the demonstration unit occurred on 02 April 1997. The first extended stable operation at the nameplate capacity of 80,000 gallons per day (260 tons per day) took place on 06 April 1997.

Pressure drop and resistance coefficient across the gas sparger at the bottom of the reactor increased over this initial operating period. The demonstration unit was shut down from 08 May - 17 June 1997 as part of a scheduled complex outage for the Kingsport site. During this outage, the gas sparger was removed, cleaned, and reinstalled. After completion of other maintenance activities, the demonstration unit was restarted, and maintained stable operation through the remainder of the reporting period. Again, the gas sparger showed an increase in pressure drop and resistance since the restart, although not as rapidly as during the April-May operation. Fresh oil was introduced online for the first time to a new flush connection on the gas inlet line to the reactor; the flush lowered the pressure drop by 1 psi. However, the effects were temporary, and the sparger resistance coefficient continued to increase. Additional flushing with both fresh oil and entrained slurry recovered in the cyclone and secondary oil knock-out drum will be attempted in order to stabilize the sparger resistance coefficient.



Catalyst activity, as defined by the ratio of the rate constant at any point in time to the rate constant for a freshly reduced catalyst (as determined in the laboratory autoclave), declined more rapidly than expected. A catalyst slurry sample was taken during the May/June 1997 complex outage for analysis.

Overall, the LPMEOH™ Demonstration Unit operated well during the initial campaign. The availability of the LPMEOH™ Demonstration Unit was 94.9% during the reporting period. All methanol produced (a total of 2,900,692 gallons) was used by Eastman in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. The start-up was successfully completed in a safe and environmentally sound manner.

Ninety-eight percent (98%) 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 June 1997. Five percent (5%) of the \$158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1997.

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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 <sub>2</sub> ), carbon monoxide (CO), and carbon dioxide (CO <sub>2</sub> ) in stoichiometric balance for the production of methanol
Carbon Monoxide Gas	-	A syngas containing primarily carbon monoxide (CO); also called CO Gas
Catalyst Age ( $\eta$ -eta)	-	the ratio of the rate constant at any point in time to the rate constant for a freshly reduced catalyst (as determined in the laboratory autoclave)
Catalyst Concentration	-	Synonym for Slurry Concentration
Catalyst Loading	-	Synonym for Slurry Concentration
CO Conversion	-	the percentage of CO consumed across the reactor
Crude Grade Methanol	-	Underflow from rectifier column (29C-20), defined as 80 wt% minimum purity; requires further distillation in existing Eastman equipment prior to use
DME	-	dimethyl ether
DOE	-	United States Department of Energy
DOE-FETC	-	The DOE's Federal Energy Technology Center (Project Team)
DOE-HQ	-	The DOE's Headquarters - Coal Fuels and Industrial Systems (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
Fresh Feed	-	sum of Balanced Gas, H <sub>2</sub> Gas, and CO Gas
Gas Holdup	-	the percentage of reactor volume up to the Gassed Slurry Height which is gas
Gassed Slurry Height	-	height of gassed slurry in the reactor
HAPs	-	Hazardous Air Pollutants
Hydrogen Gas	-	A syngas containing an excess of hydrogen (H <sub>2</sub> ) over the stoichiometric balance for the production of methanol; also called H <sub>2</sub> 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
Inlet Superficial Velocity	-	the ratio of the actual cubic feet of gas at the reactor inlet (calculated at the reactor temperature and pressure) to the reactor cross-sectional area (excluding the area contribution by the internal heat exchanger); typical units are feet per second
K	-	Sparger resistance coefficient (term used in calculation of pressure drop)
KSCFH	-	Thousand Standard Cubic Feet per Hour
LaPorte PDU	-	The DOE-owned experimental unit (PDU) located adjacent to Air Products' 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)
MeOH	-	methanol
Methanol Productivity	-	the gram-moles of methanol produced per hour per kilogram catalyst (on an oxide basis)
MTBE	-	methyl tertiary butyl ether
MW	-	molecular weight, pound per pound mole
NEPA	-	National Environmental Policy Act
OSHA	-	Occupational Safety and Health Administration
$\rho$	-	density, pounds per cubic foot
$\Delta P$	-	pressure drop, psi
Partnership	-	Air Products Liquid Phase Conversion Company, L.P.
PDU	-	Process Development Unit

## ACRONYMS AND DEFINITIONS (cont'd)

PFD	-	Process Flow Diagram(s)
ppbv	-	parts per billion (volume basis)
Project	-	Production of Methanol/DME Using the LPMEOH™ Process at an Integrated Coal Gasification Facility
psi	-	Pounds per Square Inch
psia	-	Pounds per Square Inch (Absolute)
psig	-	Pounds per Square Inch (gauge)
P&ID	-	Piping and Instrumentation Diagram(s)
Raw Methanol	-	sum of Refined Grade Methanol and Crude Grade Methanol; represents total methanol which is produced after stabilization
Reactor Feed	-	sun of Fresh Feed and Recycle Gas
Reactor O-T-M Conversion	-	percentage of energy (on a lower heating value basis) in the Reactor Feed converted to methanol (Once-Through-Methanol basis)
Reactor Volumetric Productivity	-	the quantity of Raw Methanol produced (tons per day) per cubic foot of reactor volume up to the Gassed Slurry Level
Recycle Gas	-	the portion of unreacted syngas effluent from the reactor "recycled" as a feed gas
Refined Grade Methanol	-	Distilled methanol, defined as 99.8 wt% minimum purity; used directly in downstream Eastman processes
SCFH	-	Standard Cubic Feet per Hour
Slurry Concentration	-	percentage of weight of slurry (solid plus liquid) which is catalyst (on an oxide basis)
Sl/hr-kg	-	Standard Liter(s) per Hour per Kilogram of Catalyst
Syngas	-	Abbreviation for Synthesis Gas
Syngas Utilization	-	defined as the number of standard cubic feet of Balanced Gas plus CO Gas to the LPMEOH™ Demonstration Unit required to produce one pound of Raw Methanol
Synthesis Gas	-	A gas containing primarily hydrogen (H <sub>2</sub> ) and carbon monoxide (CO), or mixtures of H <sub>2</sub> and CO; intended for "synthesis" in a reactor to form methanol and/or other hydrocarbons (synthesis gas may also contain CO <sub>2</sub> , 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
V	-	volumetric flowrate, thousand standard cubic feet per hour
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). Air Products and Chemicals, Inc. (Air Products) and Eastman Chemical Company (Eastman) formed the Partnership to execute the Demonstration Project. The LPMEOH™ Process Demonstration Unit was designed, constructed, and has begun start-up at a site located at the Eastman complex in Kingsport.

On 04 October 1994, Air Products and Eastman signed the agreements that would form the Partnership, secure the demonstration site, and provide the financial commitment and overall project management for the project. These partnership agreements became effective on 15 March 1995, when DOE authorized the commencement of Budget Period No. 2 (Modification No. 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 provided the engineering design, procurement, construction, and commissioning of the LPMEOH™ Process Demonstration Unit, and is providing the technical and engineering supervision needed to conduct the operational testing program required as part of the project. As subcontractor to Air Products, Eastman is 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 syngas from Eastman's integrated coal gasification facility. The new equipment consists of syngas 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 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-use test 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 1,000 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 01 June 1995 (Mod M009). After approval, the project initiated Phase 1 - Design - activities. Phase 2 - Construction - activities were initiated 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 Cooperative Agreement was modified (Modification No. A011) on 08 October 1996, authorizing the transition from Budget Period No. 2 (Design and Construction) to the final Budget Period (Commissioning, Start-up, and Operation). This modification provides the full \$213,700,000 of authorized funding, with 56.7% participant cost share and 43.3% DOE cost share.

During this quarter, comments from the DOE on the Topical Report "Economic Analysis - LPMEOH™ Process as an Add-on to IGCC for Coproduction" were received. The study concludes that methanol coproduction, with IGCC electric power utilizing the LPMEOH™ process technology, will be competitive in serving local market needs.

A recommendation to continue with DME design verification testing was made. DME design verification testing studies show the liquid phase DME (LPDME) process will have a significant economic advantage for the coproduction of DME for local markets. The market applications for DME are large. An LPDME catalyst system with reasonable long-term activity and stability is being developed. Planning for a proof-of-concept test run at the

Alternative Fuels Development Unit (AFDU) in LaPorte, TX was recommended. A recommendation document summarizing catalyst targets, experimental results, and the corresponding economics for a commercially successful LPDME catalyst was issued on 30 June 1997.

The off-site, product-use test plan was updated in June of 1997. During this quarter, Acurex Environmental Corporation (Acurex) and Air Products screened proposals for this task by the likelihood of the projects to proceed and the timing for the initial methanol requirement. Eight sites from the list have met these criteria. The formal submission of the eight projects for review and concurrence by the DOE will be made during the next reporting period.

An interim project review meeting was held in Allentown in late April of 1997. An update on the performance of the demonstration unit was provided, and the status of the DME recommendation and the off-site, product-use test plan were discussed.

The site paving and final painting were completed in May of 1997. Start-up activities were completed during the reporting period, and the initial methanol production from the demonstration unit occurred on 02 April 1997. The first extended stable operation at the nameplate capacity of 80,000 gallons per day (260 TPD) took place on 06 April 1997. Pressure drop and resistance coefficient across the gas sparger at the bottom of the reactor increased over this initial operating period. The demonstration unit was shut down on 08 May 1997 as part of a scheduled complex outage for the Kingsport site. During this outage, the gas sparger was removed, cleaned, and reinstalled. After completion of other maintenance activities, the demonstration unit was restarted on 17 June 1997, and maintained stable operation through the remainder of the reporting period. Again, the gas sparger showed an increase in pressure drop and resistance since the restart, although not as rapidly as during the April/May operation. Fresh oil was introduced online for the first time to a new flush connection on the gas inlet line to the reactor; the flush lowered the pressure drop by 1 psi. However, the effects were temporary, and the sparger resistance coefficient continued to increase. Additional flushing with both fresh oil and entrained slurry recovered in the cyclone and secondary oil knock-out drum will be attempted in order to stabilize the sparger resistance coefficient.

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Overall, the LPMEOH™ Demonstration Unit operated well during the initial campaign. The availability of the LPMEOH™ Demonstration Unit was 94.9% during the reporting period. All methanol produced (a total of 2,900,692 gallons) was used by Eastman in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. The start-up was successfully completed in a safe and environmentally sound manner.

Ninety-eight percent (98%) 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 June 1997. Five percent (5%) of the \$158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1997.

### **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). Air Products and Chemicals, Inc. (Air Products) and Eastman Chemical Company (Eastman) formed the Partnership to execute the Demonstration Project. A demonstration unit producing 80,000 gallons per day (260 TPD) of methanol was designed, constructed, and has begun operation at a site located at the 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 occupies an area of 0.6 acre, is 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 (syngas) 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 syngas 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* - Syngas 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 includes feed gas compressors, catalyst guard beds, the reactor, a steam drum, separators, heat exchangers, and pumps. The equipment is 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. A vent stack for safety relief devices is located in this area.

### **C. Process Description**

The LPMEOH™ demonstration unit is integrated with Eastman's coal gasification facility. A simplified process flow diagram is included in Appendix A. Syngas is introduced into the slurry reactor, which contains a slurry of liquid mineral oil with suspended solid particles of catalyst. The syngas 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 syngas is recycled back to the reactor with the syngas recycle compressor, improving cycle efficiency. The methanol will be used for downstream feedstocks and in off-site, product-use testing to determine its suitability as a transportation fuel and as a fuel for stationary applications in the power industry.

#### **D. Results and Discussion**

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 Final Environmental Information Volume was approved by the DOE on 29 August 1996. 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 approved the Draft Final EMP on 29 August 1996. 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.
  - Task 1.3 Design Engineering is complete.

### **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 product-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).

#### Discussion

The product-use test plan, developed in 1992 to support the demonstration at the original Cool Water Gasification Facility site, has become outdated. Since the site change to Eastman, the original product test plan under-represents new utility dispersed electric power developments, and possibly new mobile transport engine developments. The updated product-use test plan will attempt for broader market applications and for commercial fuels comparisons. The objective of the product-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 product-use test plan will be developed to enhance the early commercial acceptance of central clean coal technology processing facilities, coproducing electricity and methanol to meet the needs of the local community. 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) which 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 as a fuel 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 product-use tests. Product-use tests will be targeted for an approximate 18 to 30-month period, commencing in the first year of demonstration operations. The methanol product will generally be available for shipment from the demonstration unit in Kingsport, Tennessee; methanol for some of-site tests may be shipped from the inventory held at the Alternative Fuels Development Unit in LaPorte, TX. Air Products, Acurex Environmental Corporation (Acurex), and the DOE will develop the final off-site, product-use test plan.

### Activity during this quarter

- Acurex and Air Products have been working to identify a variety of sites and applications for product-use tests. During the 29-30 April 1997 interim review meeting, Air Products presented a status update on these activities to the DOE. A total of 22 projects have been screened by their likelihood to proceed and the timing for the initial methanol requirement. Eight sites from the list have met these criteria. Appendix C contains a synopsis of all projects screened, and a table summarizing the best eight candidates. At present, full proposals and cost breakdowns are being developed by Acurex and each of the eight possible participants. Due to the timing and quantities of methanol required by the earliest four tests, Air Products and DOE are considering the use of methanol produced from carbon monoxide (CO)-rich syngas feeds from the LaPorte Alternative Fuels Development Unit (AFDU). This will allow for some initial testing to occur during calendar year 1997, when some of these projects will be ready to proceed. The Demonstration Test Plan indicates methanol for the remaining four tests (as-produced from CO-rich syngas) will first be produced in May of 1998. The formal submission of the eight projects for review and approval by the DOE will be made during the next reporting period.

### ***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's Demonstration Test Plan (Phase 2, Task 3).

### Discussion

Several areas have been identified as needing development to support specific commercial design studies. These include: a) product purification options; b) front-end impurity removal options; c) catalyst addition/withdrawal options; and d) plant design configuration options. Plant sizes in the range of 300 TPD to 1,800 TPD and plant design configurations for the range from 20% up to 70% syngas 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.

The Process Economics Study - Outline has been prepared to provide guidance for the overall study work. The four part Outline is included in Appendix D. This 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) product-use test plan update.

### Activities during this quarter

- Part One of the Outline - "Coproduct of Methanol" has been written for release as a Topical Report. Comments from DOE on the 31 March 1997 draft of the Topical Report "Economic Analysis - LPMEOH™ Process as an Add-on to IGCC for Coproduction" were received during the reporting period. 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 processes in the environment of coal-derived syngas. 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. An update of this draft Topical Report is expected to be released for comment in September of 1997.
- Part Two of the Outline - "Baseload Power and Methanol Coproduction", has been incorporated into the paper, "Fuel and Power Coproduction", that was presented at the DOE's Fifth Annual Clean Coal Technology Conference in January of 1997.

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

### ***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 decision milestone, on whether to continue with DME DVT, was targeted for 01 December 1996. This milestone was relaxed to July of 1997 to allow time for further development of the LPDME catalyst system. 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 E.

Action during this quarter included a recommendation to continue with DME DVT, Market Economic Studies, and Laboratory R&D.

#### ***DME DVT Recommendation***

Air Products made a recommendation to continue with the design verification testing to coproduce DME with methanol, and to proceed with planning a proof-of-concept test run at the DOE's AFDU in LaPorte, Texas. A copy of the recommendation (dated 30 June 1997) is included in Appendix E. The recommendation was based on the results of the Market Economic Studies and on the LPDME catalyst system R&D work, and is summarized in the following.

The Market Economic Studies show that the LPDME process should have a significant economic advantage for the coproduction of DME with methanol for local markets. The studies show that the market applications for DME are large. DME is an ultra clean diesel fuel; and an 80% DME mixture with methanol and water is now being developed and tested by others. DME is a key intermediate in a commercial syngas-to-gasoline process, and is being developed as an intermediate for other chemicals and fuels. An LPDME catalyst system with reasonable long-term activity and stability has been developed from the Laboratory R&D work. The markets and this catalyst system is sufficiently promising that proof-of-concept planning for the LaPorte AFDU is recommended. A summary of the DME DVT recommendation is:

- Planning for a DME test run at the LaPorte AFDU, in conjunction with other DOE Liquid Fuels Programs, should be initiated. Test plans, budgets, and a schedule for these LaPorte AFDU tests should now be developed. Up to \$875,000 of Clean Coal Technology Program budget support from the LPMEOH™ Project budget could be made available to support a suitable LPDME test run at LaPorte.
- An implementation decision, made mutually by the DOE's Clean Coal Technology Program (DE-FC22-92PC90543) LPMEOH™ project participants, and by the DOE's Indirect Liquefaction Program (DE-FC22-95PC93052) project participants, should be made in time to implement testing at LaPorte.

The recommendation to continue design verification testing to coproduce DME with methanol at the LaPorte AFDU is now under consideration. LPDME is not applicable to hydrogen (H<sub>2</sub>)-rich syngas; and it is unlikely that a substantive LPDME demonstration will be recommended for Kingsport. Therefore, a convincing case that the test-run on CO-rich syngas at LaPorte will lead to successful commercialization must be made, prior to approving the final test-run plan. The strategy for commercialization must present the technical logic to combine the results of the following two areas:

- 1) catalyst performance (productivity, selectivity, and life) for the LPDME catalyst system under CO-rich syngas from the proof-of-concept testing at the LaPorte AFDU; and
- 2) reactor performance (methanol catalyst activity and life, hydrodynamics, and heat transfer) from the LPMEOH™ Process Demonstration Unit

The productivity and life of an "acceptable" LPDME catalyst system must be better defined, and then confirmed in the laboratory. A recommendation document summarizing catalyst targets, experimental results, and the corresponding economics for a commercially successful LPDME catalyst was issued on 30 June 1997.

### ***Market Economic Studies***

Work on the feasibility study for the coproduction of DME and methanol with electric power continued. The product DME would be used as a domestic liquid cooking fuel, to replace imported Liquid Petroleum Gas, for the China and Pacific Rim regions. The results to date, are included in the DME recommendation in Appendix E.

### ***Laboratory R&D***

Initially, synthesis of DME concurrently with methanol in the same reactor was viewed as a way of overcoming the syngas conversion limitations imposed by equilibrium in the LPMEOH™ process. Higher syngas conversion would provide improved design flexibility for the coproduction of 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. Previously, proof-of-concept runs, in the laboratory and at the Alternative Fuels Development Unit (AFDU), confirmed that a higher syngas 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, initially undertaken under the DOE's Liquid Fuels Program (Contract No. DE-FC22-95PC93052), was continued under this Task 1.5.3 through Fiscal Year 1996, and is now again being continued under the DOE Liquid Fuels Program. 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 long life. During this quarter, laboratory work continued on developing an LPDME catalyst system based on the AB series of catalysts.

#### *Summary of Laboratory Activity and Results*

- Experiments using an alternative methanol catalyst with the AB dehydration catalyst have given the highest productivity seen for a stable catalyst system. A new reduction procedure, one which reflects plant procedure, was also used. No sign of the accelerated long-term catalyst deactivation was observed following 1030 stream hours of testing.
- This new reduction procedure has given good stability in a run at low feed rates on a syngas typically produced by a Shell coal gasifier. This run is part of a matrix of experiments to understand the effects of space velocity and feed gas composition on catalyst stability.
- Air Products has begun discussing scale-up of the production of the AB dehydration catalyst with two catalyst manufacturers. The key technical issue at this point is whether nitridation is (a) commercially feasible and (b) technically desirable in light of recent laboratory successes in improving the stability of non-nitrided material.

#### **Task 1.5.4 Administration and Reporting**

The Cooperative Agreement was modified (Modification No. A011 on 08 October 1996), authorizing the transition from Budget Period No. 2 (Design and Construction) to the final Budget Period (Commissioning, Start-up, and Operation). This modification provides the

full DOE cost share of \$92,700,000 of authorized funding, with the remaining \$121,000,000 being provided by the participants. A copy of the approval memorandum, dated 03 October 1996, is included in Appendix F.

The remainder of the DOE reporting tasks are being performed and reported under Task 3.6 (Planning and Administration).

### ***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.
- Task 2.1 Procurement is complete.

### ***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.
- Erect the major equipment and structural steel. Install the large bore piping, electrical, and insulation such that instrument check-out and equipment commissioning work can be completed during the 60-day Continuation Application approval period.
- Complete mechanical construction so that check-out and commissioning can be started in Budget Period No. 3.
- All major construction contract work has been completed. During the reporting period, site paving/grading and the painting of large- and some small-bore piping systems was completed in May 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.

- The four-year Demonstration Test Plan (DTP) was approved and issued in September of 1996.
- Prepare the operating manual and initiate the operator training program.
  - The operator training was completed in December of 1996. Final additions to the operating manual were made in January of 1997.
  - Task 2.3 Training and Commissioning is complete.

#### ***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 the 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 update of the 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 was to continue construction so that the LPMEOH<sup>TM</sup> demonstration unit would be ready for commissioning and start-up in 1996; and to complete the Project Evaluation Report and to 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 prepared and submitted in November of 1996 (see Appendix G). The main goal and objective for this second annual plan is to initiate Phase 3 - Operation of the LPMEOH<sup>TM</sup> demonstration unit and to achieve 30 weeks of operation (Task 2.1.1 Operation) by September of 1997 in accordance with the Demonstration Test Plan. Other objectives include continuation of DME design verification testing, and updating the plan for off-site product-use testing.
- 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 3.6 (Planning and Administration).

### **Task 3.1 Start-up**

Start-up activities were completed on 02 April 1997 with the initial production of methanol.

### **Task 3.2 LPMEOH™ Process Demonstration Facility Operation**

#### **Task 3.2.1 Methanol Operation**

Upon completion of the activation of the nine batches of methanol synthesis catalyst (reported in Technical Progress Report No. 11), the catalyst slurry was transferred from the 29D-02 slurry storage tank to the 29C-01 reactor (refer to Appendix A for the simplified process flow diagram). A portion of the slurry was pumped by the 29G-02 slurry return pump; the remainder was pressure-transferred using nitrogen at 45-50 psig on the slurry storage tank. Heat-up of the catalyst slurry by injecting 600 psig steam into the risers of the internal heat exchanger on the reactor proceeded smoothly. Balanced Gas was introduced to the LPMEOH™ demonstration unit at 0900 hours on 02 April 1997, but several coincidental interruptions in feed gas supply delayed extended, stable operation for several more days. The first stable operation at the nameplate methanol capacity of 80,000 gallons per day (260 TPD) was achieved on 06 April 1997. The Test Authorization for the initial operating campaign at the LPMEOH™ demonstration unit is provided in Appendix H.

The summary table of performance data over the entire reporting period for the LPMEOH™ demonstration unit is included in Table 3.2.1-1. These data represent daily averages, typically from a 24-hour material balance period; those days with less than 12 hours of stable operation are omitted from this table. Appendix J contains samples of the detailed material balance report which are representative of the operation of the LPMEOH™ demonstration unit during the reporting period.

Appendix I, Table 1 contains the summary of outages for the LPMEOH™ demonstration unit. This table also calculates the availability of the LPMEOH™ demonstration unit over the reporting period.

The following discussion of performance results will focus on the distinct operating periods during the quarter and detailed reporting of specific performance parameters.

#### Initial Operating Period - 02 April - 08 May 1997

The frequent feed gas interruptions continued for several more days, so that the first stable 24-hour material balance period occurred on 12 April 1997. The highest methanol production rate over a 24-hour period occurred on 19 April 1997 (89,900 gallons per day, or

Table 3.2.1-1 - DATA SUMMARY FOR LPMEOH™ DEMONSTRATION UNIT  
April/June 1997 Operating Period

Case	Date	Gas Type	Temp (Dag C)	Pres. (psig)	Balanced			Recycle Gas Velocity (ft/sec)	Inlet Sup. Velocity (ft/sec)	Space Velocity (lhr/kg)	Slurry Conc. (wt% ox)	Gas Holdup (vol%)	Gassed Slurry Hgt (ft)	Catalyst Inventory (lb)	Catalyst Age (eta)	CO Conv. (%)	Reactor O-T-M Conv. (%)	Syngas Util. (SCF/lb)	Raw MeOH Production (TPD)	Catalyst MeOH Prod. (gmol/lhr-kg)	Reactor Vol. Prod. (TPD/Cu ft)	Sparger dP (psi)	Sparger Resistance ("K")
					CO Gas (KSCFH)	H2 Gas (KSCFH)	Gas (KSCFH)																
1	12-Apr-97	Balanced	248	719	758	0	0	1,375	0.50	6,203	30.5	50.2	54.9	20,300	1.30	54.8	33.1	37.6	242.3	30.74	0.105	6.23	10.87
1	13-Apr-97	Balanced	249	716	792	0	0	1,536	0.55	6,783	30.8	50.6	54.9	20,300	1.24	52.5	31.7	37.5	253.8	32.19	0.110	8.69	12.72
1	14-Apr-97	Balanced	249	705	789	0	0	1,619	0.58	7,014	30.9	52.0	56.1	20,300	1.18	50.5	30.5	37.5	252.4	32.00	0.107	10.50	14.17
1	15-Apr-97	Balanced	249	705	818	0	0	1,601	0.58	7,019	30.8	50.9	55.1	20,300	1.29	51.7	31.2	37.9	258.9	32.84	0.112	11.05	14.88
1	16-Apr-97	Balanced	248	705	904	0	0	1,527	0.59	7,094	30.9	54.5	54.3	20,300	1.78	55.8	33.6	38.5	281.9	35.82	0.123	14.17	18.78
1	17-Apr-97	Balanced	249	704	887	0	0	1,746	0.63	7,629	32.0	53.0	54.3	20,300	1.24	49.8	30.0	39.4	270.5	34.35	0.119	17.61	20.28
1	18-Apr-97	Balanced	249	705	841	0	0	1,843	0.64	7,828	32.1	51.9	53.4	20,300	1.14	48.2	29.1	37.8	267.0	33.86	0.119	18.17	21.35
1	19-Apr-97	Balanced	249	703	964	0	0	1,779	0.66	7,970	32.0	52.2	53.8	20,300	1.43	51.1	30.7	40.0	288.8	36.80	0.128	20.47	21.69
1	20-Apr-97	Balanced	249	708	958	0	0	1,994	0.70	8,562	32.2	51.5	52.4	20,300	1.17	48.3	29.2	39.4	292.2	36.60	0.133	21.59	19.36
1	21-Apr-97	Balanced	249	708	913	0	0	2,114	0.72	8,771	30.3	50.5	55.8	20,300	1.03	47.1	26.4	39.8	275.5	34.77	0.117	21.64	20.31
1	22-Apr-97	Balanced	249	709	859	0	0	2,108	0.71	8,635	30.2	47.5	53.0	20,300	0.94	47.5	25.6	39.5	261.1	32.83	0.117	22.28	21.90
1	23-Apr-97	Balanced	249	709	793	0	0	2,086	0.69	8,376	29.5	45.2	52.5	20,300	0.91	49.0	24.6	39.2	242.7	30.65	0.110	21.59	23.04
1	24-Apr-97	Balanced	249	702	865	0	0	2,028	0.70	8,419	29.9	43.1	49.3	20,300	0.93	44.6	26.2	39.8	261.0	33.17	0.126	24.25	23.16
1	25-Apr-97	Balanced	248	700	835	0	0	1,921	0.67	8,019	31.8	44.9	47.0	20,300	0.89	44.6	26.2	40.4	248.2	31.58	0.126	23.48	24.80
1	26-Apr-97	Balanced	246	694	864	0	0	1,878	0.67	7,980	32.8	45.6	45.5	20,300	0.83	41.6	26.0	41.9	247.8	31.38	0.130	25.38	26.81
1	27-Apr-97	Balanced	247	690	902	0	0	1,793	0.66	7,842	32.8	44.9	45.0	20,300	0.83	39.7	26.9	42.9	252.2	31.87	0.134	26.18	27.29
1	28-Apr-97	Balanced	247	696	783	0	0	1,903	0.65	7,817	30.9	43.3	47.5	20,300	0.75	42.7	24.4	41.9	224.4	28.35	0.113	24.49	27.11
1	29-Apr-97	Balanced	249	700	810	0	0	1,922	0.66	7,951	29.3	45.2	53.0	20,300	0.81	42.1	25.6	40.9	238.0	30.05	0.107	26.26	26.76
1	30-Apr-97	Balanced	249	699	794	0	0	1,912	0.66	7,872	29.1	43.6	52.0	20,300	0.79	43.0	25.1	41.3	230.8	29.24	0.106	26.13	27.67
1	1-May-97	Balanced	249	699	798	0	0	1,932	0.66	7,945	29.9	44.0	50.5	20,300	0.74	41.1	24.5	42.0	228.0	28.85	0.108	26.28	27.32
1	2-May-97	Balanced	249	700	757	0	0	1,898	0.64	7,728	29.7	43.0	50.0	20,300	0.71	42.8	23.7	42.2	215.4	27.32	0.103	25.91	29.72
1	3-May-97	Balanced	249	699	782	0	0	1,886	0.65	7,767	30.4	43.1	48.5	20,300	0.68	40.5	23.9	42.8	219.5	27.66	0.108	26.05	29.24
1	4-May-97	Balanced	249	700	789	0	0	1,901	0.65	7,831	30.5	44.0	49.0	20,300	0.64	38.9	23.4	43.4	218.1	27.43	0.106	26.24	29.58
1	5-May-97	Balanced	249	699	798	0	0	1,901	0.66	7,856	30.1	43.6	49.5	20,300	0.63	37.5	23.4	43.7	218.9	27.76	0.105	26.26	28.88
1	6-May-97	Balanced	249	700	776	0	0	1,923	0.65	7,835	30.4	42.5	48.5	20,300	0.65	38.1	23.3	42.8	217.3	27.85	0.108	26.26	28.83
22	8-May-97	BGL	249	700	215	40	0	1,051	0.32	3,813	30.8	36.9	43.0	20,300	0.64	8.6	15.1	44.4	68.0	8.83	0.038	14.81	33.22
5	18-Jun-97	Balanced	248	724	718	0	0	1,938	0.62	8,062	25.6	45.9	61.4	19,500	0.61	39.3	22.5	42.0	205.3	26.95	0.079	2.99	3.37
5	19-Jun-97	Balanced	249	711	638	0	0	1,938	0.62	7,905	26.6	45.3	57.8	19,500	0.63	42.6	21.4	40.7	188.3	24.77	0.077	3.05	3.52
5	20-Jun-97	Balanced	249	707	651	0	0	2,079	0.66	8,294	27.1	44.9	56.0	19,500	0.59	39.2	20.2	41.3	189.4	24.99	0.080	3.45	3.71
5	21-Jun-97	Balanced	249	707	687	0	0	2,109	0.67	8,465	27.6	45.2	55.0	19,500	0.59	35.5	20.8	41.4	199.9	26.14	0.086	4.00	3.90
5	22-Jun-97	Balanced	249	707	625	0	0	2,097	0.65	8,203	28.2	44.2	52.7	19,500	0.50	33.4	19.5	41.3	181.5	23.85	0.082	3.96	4.11
5	23-Jun-97	Balanced	249	707	762	0	0	2,021	0.67	8,456	28.4	43.6	51.6	19,500	0.57	33.6	21.5	43.8	208.8	27.35	0.096	4.51	4.38
5	24-Jun-97	Balanced	249	708	781	0	0	1,991	0.67	8,412	29.0	44.5	50.9	19,500	0.56	33.2	21.2	45.6	205.4	26.90	0.096	5.04	4.93
5	25-Jun-97	Balanced	248	707	739	0	0	2,003	0.66	8,338	29.2	43.3	49.4	19,500	0.57	33.7	21.0	44.0	201.5	26.62	0.097	5.33	5.31
5	26-Jun-97	Balanced	249	707	737	0	0	2,080	0.68	8,559	28.9	46.3	54.8	19,500	0.55	33.0	20.7	43.4	203.5	26.65	0.088	5.64	5.38
5	27-Jun-97	Balanced	249	706	736	0	0	2,326	0.74	9,252	26.7	46.6	59.0	19,500	0.53	29.7	19.5	42.8	206.5	26.68	0.083	7.34	5.74
5	28-Jun-97	Balanced	249	707	691	0	0	2,307	0.72	9,079	27.5	45.8	56.0	19,500	0.53	31.0	19.3	41.5	199.6	25.84	0.085	8.12	6.67
5	29-Jun-97	Balanced	249	708	710	0	0	2,267	0.72	8,942	27.7	43.9	53.5	19,500	0.53	30.0	18.5	42.6	202.3	26.24	0.080	9.33	7.65
5	30-Jun-97	Balanced	249	706	711	0	0	2,263	0.72	8,919	28.1	43.9	52.5	19,500	0.51	29.9	19.1	43.0	198.4	25.77	0.080	9.29	7.90

292.2 TPD); for shorter balance periods (approximately 12 hours), methanol production rates of 92,900 to 94,500 gallons per day (302 to 307 TPD) were measured.

During the first days of operation, several strainers in the reactor loop became blocked with debris remaining in the piping systems from construction and hydrotesting. Outages were taken to clean screens at the inlet to the 29C-40 carbonyl guard bed and the 29C-03 high-pressure methanol separator. The carbonyl guard bed was bypassed from 04 April 1997 until 18 April 1997; the decision to bypass the carbonyl guard bed was based upon the results of the carbonyl survey completed in March (as reported in Technical Progress Report No. 11) and an autoclave test performed at the Kingsport site in May/June 1996. A draft Topical Report has been issued on that study (Design and Construction of the Alternative Fuels Field Test Unit and Liquid Phase Methanol Feedstock and Catalyst Life Testing at Eastman Chemical Company (Kingsport, TN)).

As noted in Technical Progress Report No. 11, the 29G-03 oil make-up pumps were unable to deliver fresh oil to the reactor loop at the required pressure of approximately 700 psig. These pumps also provide the required high pressure seal flush to the 29G-01 condensed oil circulation pumps, which return oil and catalyst collected in the 29C-06 cyclone and the 29C-05 secondary oil knock-out drum to the reactor (refer to Appendix A for the simplified process flow diagram). One of the features included in the design of the LPMEOH™ Demonstration Unit was the capability to free-drain condensed and entrained oil and catalyst slurry back to the reactor. Furthermore, fresh make-up oil could be added to the process by using the 29G-30 slurry transfer pump, which was designed to transfer catalyst slurry from the 29C-30 catalyst reduction vessel to the reactor. Oil was batch-transferred from the 29D-30 oil storage tank to the catalyst reduction vessel, and then pumped to the reactor by the slurry transfer pump. The slurry transfer pump has packing which also requires flush from the oil make-up pumps; however, it was determined that operation of the slurry transfer pump in services with clean oil or low solids concentration would not adversely affect the service life of the pump.

The free-drain line showed intermittent plugging or vapor-locking during operation. Early in the operating campaign, blockages could be cleared by opening a transfer line between the secondary oil knock-out drum and catalyst reduction vessel and briefly blowing down to low pressure; piping connections to provide flush oil were rendered useless by the inoperable oil make-up pumps. However, on 25 April 1997, a blockage in the free-drain line occurred in a location which could not be removed by this method. Since the slurry concentration of the entrained oil and catalyst was relatively low, it was determined that the slurry transfer pump could pump this material without packing flush on the pump. Condensed oil was batch-transferred from the secondary oil knock-out drum to the catalyst reduction vessel, and then pumped to the reactor. The frequency of the transfer to the catalyst reduction vessel was about every 3 hours, and the catalyst reduction vessel was pumped to the reactor about every 10 hours. The rate of accumulation of entrained/condensed slurry (1.5 to 2.0 gallons per minute) matched the expected liquid traffic within the oil/catalyst collection equipment.

A two-day test using a CO-rich reactor feed ( $H_2/CO = 0.43$ ) was performed on 07-08 May 1997. The Test Authorization for this trial is included in Appendix K. At the conclusion of



this test, the LPMEOH™ Demonstration Unit was shut down in preparation for a biannual outage at the Eastman coal-to-chemicals facility. Catalyst slurry was pressure-transferred from the reactor to the slurry storage tank for storage under a reducing atmosphere during the outage.

Throughout this initial operating period, pressure-drop measurements across the gas sparger at the bottom of the reactor showed a steady increase during normal operation. Pressure drop can be expressed in the following equation:

$$\Delta P = \frac{K * (V * MW)^2}{\rho}$$

where:             $\Delta P$  = pressure drop across sparger, pounds per square inch  
                      K = sparger resistance coefficient  
                      V = vapor volumetric flowrate, thousand standard cubic feet per hour  
                      MW = vapor molecular weight, pounds per pound mole  
                       $\rho$  = vapor density, pounds per cubic foot

This equation shows that pressure drop readings can be influenced by changes in gas flowrate and/or gas composition. The resistance coefficient (K) can be used to determine any change in the vapor flow path through the gas sparger. For a given vapor volumetric flowrate and density, an increase in K (caused by a restriction in the flow path, for example), will result in an increase in pressure drop.

Appendix I, Figure 1 plots K over time since the start-up of the LPMEOH™ Demonstration Unit. (Note that K as reported contains an arbitrary factor to make the value more manageable, and therefore has meaning only in a relative sense.) The data for this plot, along with the corresponding pressure drop measurement, are included in Table 3.2.1-1. Pressure drop and resistance increased with time on stream, and extended periods with no vapor flow through the gas sparger (noted on Figure 1) appear to have no impact on this trend.

#### Maintenance Activities During May/June 1997 Complex Outage

Most of the activities in the LPMEOH™ Demonstration Unit during the complex outage focused on the inspection of equipment associated with the reactor, particularly the gas sparger. About 800 pounds of residual catalyst was removed from the bottom head of the reactor during this exercise. A solid material (presumably methanol synthesis catalyst) appeared to block about 50% of the flow path through the sparger; a small amount of catalyst was found in the inlet piping to the sparger. There was no discernible pattern to the blockage by the catalyst, and no significant construction debris was found in the inlet piping or in the sparger. The sparger was removed from the reactor and cleaned. The only modifications to the sparger itself were changes to increase the maximum allowable pressure drop; no change to the flow distribution characteristics was made.

Another effect of the commissioning problems associated with the oil make-up pumps is the loss of oil flush provided by the condensed oil circulation pumps to the walls of the cyclone. At the LaPorte AFDU, liquid flush to the cyclone improved the efficiency of solids removal. During the complex outage, the inlet to the tubesheet of the 29E-02 feed/product heat exchanger (immediately downstream of the cyclone) was removed to check for catalyst accumulation. The tubesheet was generally clean except for a small, off-center accumulation on the upper left quadrant. The catalyst slightly obstructed the entrance to these tubes, but did not completely block any tube. No catalyst was visible within any of the tubes. The surface catalyst was removed, and the feed/product heat exchanger was reassembled.

During the initial operating period, the blockage in the free-drain line provided evidence that the ability to flush piping systems in slurry service was an important operability requirement. Since a replacement for the oil make-up pumps had not yet been identified, the slurry transfer pump was connected into the flush piping system originally designed to be supplied by the oil make-up pumps. A flush connection was also added to the gas inlet line to the reactor; this could be used to flush out the piping and gas sparger during normal operation, at those times when gas flow to the reactor is lost, or in preparation for maintenance.

Other maintenance activities focused on repair of minor leaks in the steam system.

#### Unit Restart and Operation - 17-30 June 1997

After the catalyst slurry was pressure-transferred from the slurry storage tank to the reactor, the reactor was heated using 600 psig steam in the same manner as the April start-up. Balanced Gas was introduced to the LPMEOH™ Demonstration Unit at 1400 hours on 17 June 1997. Operation of the facility has continued uninterrupted since the restart. The free-drain piping from the secondary oil knock-out drum and cyclone to the reactor plugged again shortly after restart, but flush oil from the slurry transfer pump successfully dislodged the blockage.

Again, the gas sparger has shown an increase in pressure drop and resistance since the restart, although not as rapidly as during the April-May operation. The plot of sparger resistance coefficient with time for both operating periods is provided in Appendix I, Figure 1. The value for the resistance coefficient is lower for the latest start-up of the reactor; this may be a result of additional attention to maintaining vapor flow through the sparger during the slurry transfer operation. On 26 June 1997, fresh oil from the slurry transfer pump was introduced for the first time to the new flush connection on the gas inlet line to the reactor; the flush lowered the pressure drop from 5.5 psi to 4.5 psi. However, the effects were temporary, and the resistance coefficient continued to increase. Additional flushing with both fresh oil and entrained slurry will be attempted in order to stabilize the resistance coefficient. Fresh oil can only be added to the process at an average of 0.1 - 0.2 gallons per minute to match the rate of oil loss with the methanol product; entrained slurry can be supplied at the rate of liquid traffic in the secondary oil knock-out drum and cyclone (1.5 to 2.0 gallons per minute).



### Catalyst Life ( $\eta$ )

The activity of the methanol synthesis catalyst can be expressed in terms of a dimensionless variable  $\eta$  ( $\eta$ ), which is defined as the ratio of the rate constant at any point in time to the rate constant for a freshly reduced catalyst (as determined in the laboratory autoclave). Appendix I, Figure 2 contains the plot for  $\eta$  versus days onstream since the start-up in April of 1997; shutdowns of the LPMEOH™ Demonstration Unit are indicated and match the longer interruptions in operation from Appendix I, Table 1. During the April/May 1997 operating period, the evidence was unclear whether the decline in  $\eta$  was a result of a decline in catalyst activity or hydrodynamic effects related to the increase in resistance coefficient for the gas sparger. Upon restarting the LPMEOH™ Demonstration Unit in June of 1997, the value of  $\eta$  was determined to be unaffected by the magnitude of the sparger resistance coefficient. It appears that catalyst activity is declining more rapidly than expected.

A catalyst slurry sample was taken during the May/June 1997 complex outage. Due to a change in procedures for handling reduced catalyst in the laboratory, analysis of this sample for copper crystallite size, surface area, and the presence of catalyst poisons will not be performed until July of 1997.

Overall, the LPMEOH™ Demonstration Unit operated well during the initial campaign. The availability of the LPMEOH™ Demonstration Unit was 94.9% during the reporting period. All methanol produced (a total of 2,900,692 gallons) was used by Eastman in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. The start-up was successfully completed in a safe and environmentally sound manner.

### Methods of Calculation

As described in Section 6.2 of the Demonstration Test Plan, a comprehensive set of the formulas used to calculate key performance parameters of the LPMEOH™ Process was to be included in the first Technical Progress Report for Task 3.2.1 - Methanol Operation. These calculations are provided in Appendix L.

#### ***Task 3.2.2 DME Design, Modification and Operation***

No activities occurred in this Task during the reporting period.

#### ***Task 3.3 On-Site Testing (Product-Use Demonstration)***

No activities occurred in this Task during the reporting period.

#### ***Task 3.4 Off-Site Testing (Product-Use Demonstration)***

No activities occurred in this Task during the reporting period.

### ***Task 3.5 Data Analysis and Reports***

The results of the data analysis for the operation of the LPMEOH™ Demonstration Unit are reported under Task 3.2.1 (Methanol Operation).

### ***Task 3.6 Planning and Administration***

An interim project review meeting was held on 29 and 30 April 1997 in Allentown. Attendees from Air Products and DOE participated. An update on the performance of the demonstration unit was provided. The catalyst targets and corresponding economics for a commercially successful LPDME catalyst were reviewed; these and other comments from DOE were incorporated into the DME recommendation (issued 30 June 1997). The status of the updated product-use test plan was also discussed. The meeting agenda, extracts from the meeting handouts, and the meeting notes are included in Appendix M.

The Milestone Schedule Status Report and the Cost Management Report, through the period ending 30 June 1997, are included in Appendix N. 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 was mechanically complete on 31 January 1997. Ninety-eight percent (98%) 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 June 1997. Five percent (5%) of the \$158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1997.

Start-up activities were completed during the reporting period, and the initial methanol production from the demonstration unit occurred on 02 April 1997. The first extended stable operation at the nameplate capacity of 80,000 gallons per day (260 TPD) took place on 06 April 1997. The demonstration unit was shut down on 08 May 1997 as part of a scheduled complex outage for the Kingsport site. After completion of maintenance activities, the demonstration unit was restarted on 17 June 1997, and maintained stable operation through the remainder of the reporting period. Details of the operating activities are provided under Task 3.2 of this report.

Preparations for the plant dedication ceremony, scheduled for 25 July 1997, began in earnest. Participants are expected to include senior management from Air Products, Eastman, and DOE.

A press release on the start-up of the LPMEOH™ Demonstration Facility was issued on 21 May 1997. A copy of the press release, as well as a sample of other publications which reported on the start-up of the demonstration unit, are included in Appendix O.

An update of the Project Management Plan was submitted to DOE on 30 June 1997. This version summarizes the reporting structure during Tasks 1 and 2, and lists the current team members for Air Products, Eastman, and Acurex.

The monthly reports for April, May, and June were submitted. These reports include the Milestone Schedule Status Report, the Project Summary Report, and the Cost Management Report. All Quarterly Technical Progress Reports through 31 March 1997 have been approved by DOE. DOE and Air Products agreed to delay the publication of the Demonstration Technology Start-up Report until issues related to the oil make-up pump and the reactor sparger have been resolved (refer to Task 3.2 for the status of these items).

#### **E. Planned Activities for the Next Quarter**

- Resolve any issues associated with the gas sparger in the reactor and with the oil make-up pumps. Upon resolution of these items, write and submit the Demonstration Technology Start-up Report to DOE.
- Analyze catalyst slurry sample taken during May/June 1997 complex outage to determine causes for deactivation of methanol synthesis catalyst.
- Continue executing Phase 3, Task 2.1 Methanol Operation per the Demonstration Test Plan.
- Receive concurrence from DOE on the DVT Recommendation for a DME proof-of-concept test run at the LaPorte AFDU.
- Receive concurrence from DOE on the Off-Site, Product-Use Test Plan (Phase 1, Task 1.4).
- Hold a Project Review Meeting in Kingsport in July, in conjunction with the 25 July dedication ceremony.
- Incorporate DOE comments into the Topical Report on Process Economic Studies.

#### **F. Conclusion**

During this quarter, comments from the DOE on the Topical Report "Economic Analysis - LPMEOH™ Process as an Add-on to IGCC for Coproduction" were received. The study concludes that methanol coproduction, with IGCC electric power utilizing the LPMEOH™ process technology, will be competitive in serving local market needs.

A recommendation to continue with DME design verification testing was made. DME design verification testing studies show the liquid phase DME (LPDME) process will have a significant economic advantage for the coproduction of DME for local markets. The market applications for DME are large. An LPDME catalyst system with reasonable long-term activity and stability is being developed. Planning for a proof-of-concept test run at the LaPorte Alternative Fuels Development Unit (AFDU) was recommended. A recommendation document summarizing catalyst targets, experimental results, and the corresponding economics for a commercially successful LPDME catalyst was issued on 30 June 1997.

The off-site, product-use test plan was updated in June of 1997. During this quarter, Acurex and Air Products screened proposals for this task by the likelihood of the projects to proceed and the timing for the initial methanol requirement. Eight sites from the list have met these criteria. The formal submission of the eight projects for review and concurrence by the DOE will be made during the next reporting period.

An interim project review meeting was held in Allentown in late April of 1997. An update on the performance of the demonstration unit was provided, and the status of the DME recommendation and the off-site product-use test plan were discussed.

The site paving and final painting were completed in May of 1997. Start-up activities were completed during the reporting period, and the initial methanol production from the demonstration unit occurred on 02 April 1997. The first extended stable operation at the nameplate capacity of 80,000 gallons per day (260 TPD) took place on 06 April 1997. Pressure drop and resistance coefficient across the gas sparger at the bottom of the reactor increased over this initial operating period. The demonstration unit was shut down on 08 May 1997 as part of a scheduled complex outage for the Kingsport site. During this outage, the gas sparger was removed, cleaned, and reinstalled. After completion of other maintenance activities, the demonstration unit was restarted on 17 June 1997, and maintained stable operation through the remainder of the reporting period. Again, the gas sparger showed an increase in pressure drop and resistance since the restart, although not as rapidly as during the April-May operation. Fresh oil was introduced for the first time to a new flush connection on the vapor inlet line to the reactor; the flush lowered the pressure drop by 1 psi. However, the effects were temporary, and the sparger resistance coefficient continued to increase. Additional flushing with both fresh oil and entrained slurry will be attempted in order to stabilize the sparger resistance coefficient.

Catalyst activity, as defined by the ratio of the rate constant at any point in time to the rate constant for a freshly reduced catalyst (as determined in the laboratory autoclave), declined more rapidly than expected. A catalyst slurry sample was taken during the May/June 1997 complex outage for analysis.

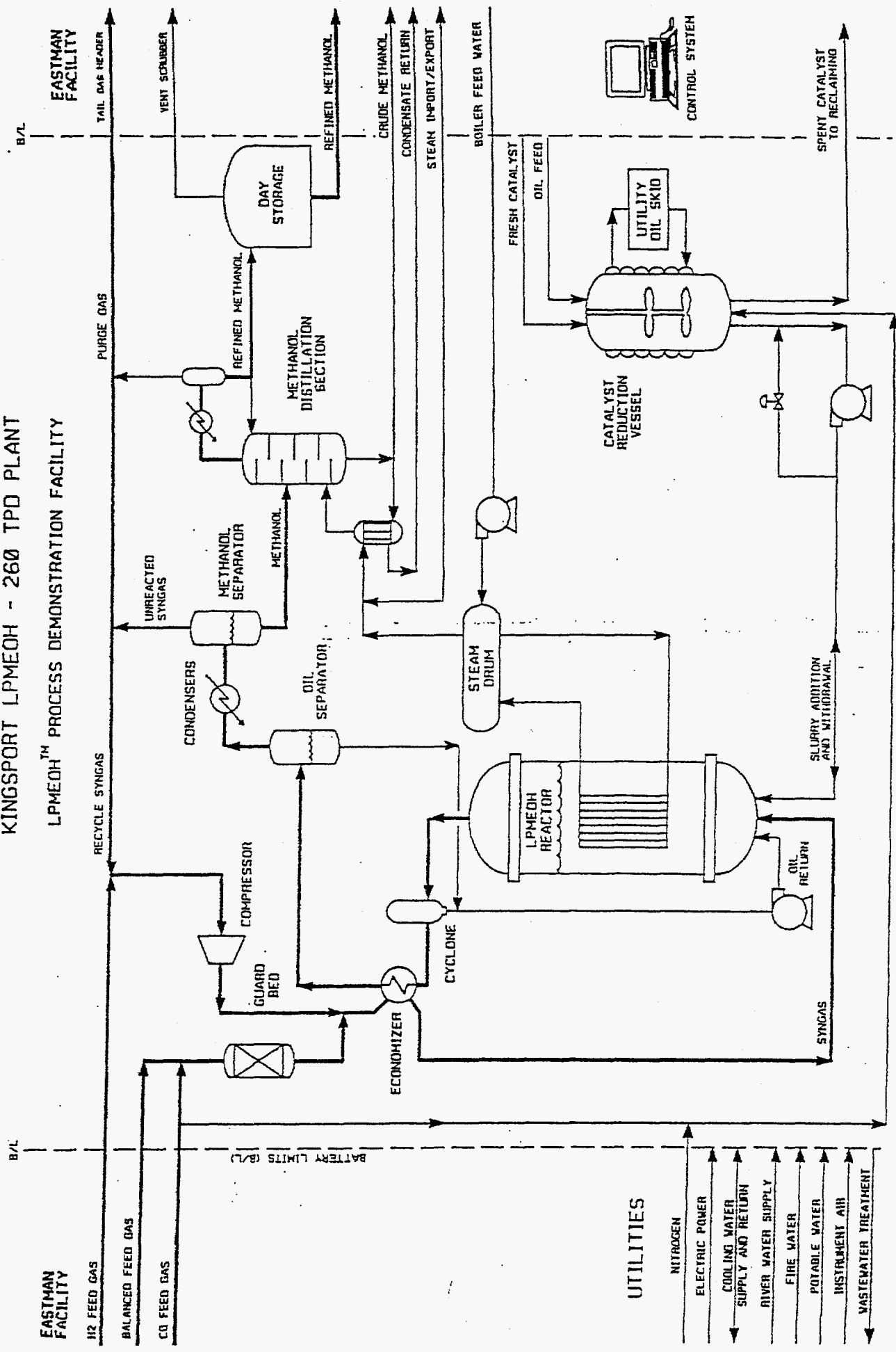
Overall, the LPMEOH™ Demonstration Unit operated well during the initial campaign. The availability of the LPMEOH™ Demonstration Unit was 94.9% during the reporting period. All methanol produced (a total of 2,900,692 gallons) was used by Eastman in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. The start-up was successfully completed in a safe and environmentally sound manner.

Ninety-eight percent (98%) 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 June 1997. Five percent (5%) of the \$158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1997.

**APPENDICES**

**APPENDIX A - SIMPLIFIED PROCESS FLOW DIAGRAM**

# SIMPLIFIED PROCESS DIAGRAM KINGSPORT LPMEOH - 260 TPD PLANT LPMEOH™ PROCESS DEMONSTRATION FACILITY



B/L

B/L

EASTMAN FACILITY

EASTMAN FACILITY

H<sub>2</sub> FEED GAS

BALANCED FEED GAS

CO FEED GAS

RECYCLE SYNGAS

PURGE GAS

EASTMAN FACILITY

TAIL GAS HEADER

VENT SCRUBBER

BATTERY LIMITS (B/L)

UNREACTED SYNGAS

CONDENSERS

GUARD BED

COMPRESSOR

ECONOMIZER

CYCLONE

OIL SEPARATOR

METHANOL SEPARATOR

METHANOL DISTILLATION SECTION

DAY STORAGE

REFINED METHANOL

CRUDE METHANOL

CONDENSATE RETURN

STEAM IMPORT/EXPORT

BOILER FEED WATER

FRESH CATALYST

OIL FEED

CATALYST REDUCTION VESSEL

UTILITY OIL SKID

CONTROL SYSTEM

UTILITIES

NITROGEN

ELECTRIC POWER

COOLING WATER SUPPLY AND RETURN

RIVER WATER SUPPLY

FIRE WATER

POTABLE WATER

INSTRUMENT AIR

WASTEWATER TREATMENT

SLURRY ADDITION AND WITHDRAWAL

SPENT CATALYST TO RECLAIMING

**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.

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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.

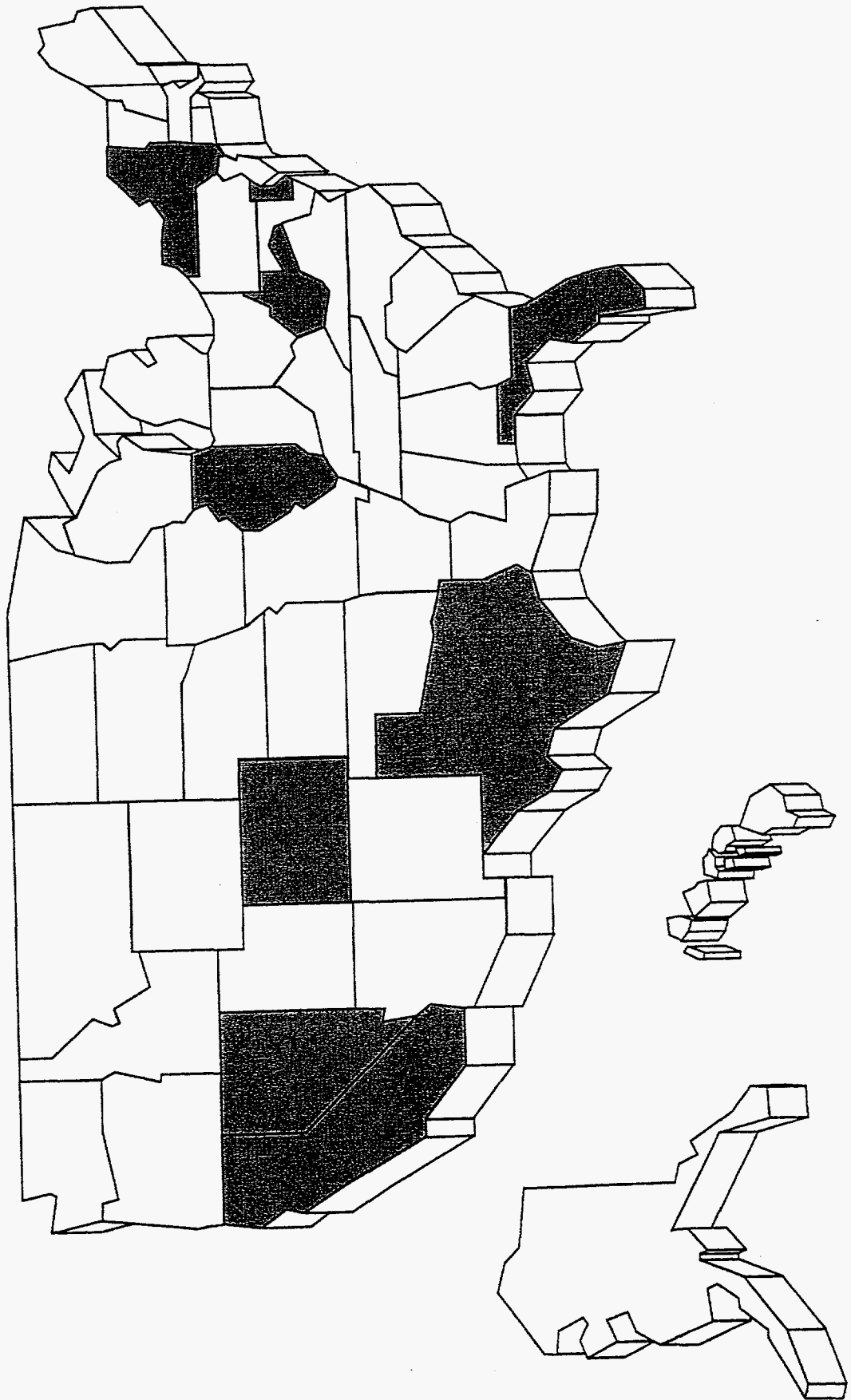
WRB/jjs/Proeva.

**APPENDIX C - TASK 1.4 - OFF-SITE TESTING (DEFINITION AND DESIGN)**

**Synopsis of All Proposals (twenty pages)**

**and**

**Summary Table of Eight Candidates (one page)**



# Acurex Environmental

C O R P O R A T I O N

A Geraghty & Miller Company

April 25, 1997

Peter Tijm  
Manager, Syngas Conversion Systems  
Air Products and Chemicals, Inc.  
7201 Hamilton Boulevard  
Allentown, PA 18195-1501

Reference: Acurex Subcontract under DOE Cooperative Agreement No. DE-FC22-92PC90543; Acurex Project 8438

Subject: Revised Fuel Test Plan

Dear Peter:

Glad we could meet this past April 18. I believe the meeting was quite fruitful in firming up our lines of communication and in making progress toward a final list of field test demonstration opportunities. I have enclosed a revised fuel test plan that includes the changes we agreed to at the meeting and via follow-up conversations I have held with Bob Senn. Please, call if you have any additional input. I look forward to get these quick start projects underway.

Sincerely,



Carlo Castaldini  
Manager, Process Engineering

encl.

cc: John O'Sullivan (EPRI)



Fuel Test Plan - Project Opportunities for Demonstration of LPMEOH for Power Generation and Pollution Control in Stationary and Mobile Sources

PROJECT NAME	TOTAL COST (\$k)	AP FUNDS (\$k)	COST SHARE (%)	PRIORITY	MEOH USE START DATE	LOCATION	MEOH QUANTITY (gallons)	QUICK START**	STATUS
<b>COMPLETED PROJECTS &amp; ADMIN.</b>									
LPMEOH/Dimethyl Ether Buses	694	274	420						
Port of Long Beach									
Heavy-Duty Truck									
Environmental Impact Volume									
<b>TEST PLAN PROJECTS</b>									
<b>Light Duty Vehicles</b>									
Acurex FFV	55	30	25	HIGH***	2Q 97	CA	220	yes	Ready for project initiation
Direct Injection Stratified Charge Engines	0	0	0	LOW	?	CO	55	no	None
<b>Hydrogen Production</b>									
Methanol to Hydrogen Reformer*	475	328	147	HIGH	1Q 99	CA	2,000	no	Examine hydrogen safety concern and repropose
Fuel Cell Powered Vehicles w/On Board H2 Supply	0	0	0	LOW	?	CA	0	no	None
<b>Distributed Power</b>									
Stationary Turbine for VOC Control: Phase 1	122	122	0	HIGH	4Q 97	CA, NY	1,200	yes	Ready for project initiation. EPRI will pursue utilities, identify sites
Stationary Turbine for VOC Control: Phase 2*	198	48	150	HIGH	2Q 98	CA, NY	3,000	no	Acurex will pursue cofunding opportunities (EPRI, AB 1890)
West Virginia Stationary Turbine	114	89	25	HIGH	3Q 97	WV	5,000	yes	Proposal received. Ready for project initiation
<b>Emulsion Fuels</b>									
Water/Naphtha/MeOH Bus	273	23	250	HIGH	3Q 97	CA	55	yes	Ready for project initiation. Secure A-55 project commitment
Aircraft Ground Equipment Emulsion	227	227	0	HIGH	3Q 97	FL, TX	220	yes	Ready for project initiation. Coordinate with AFBs
Sierra Power Peak Load Power Generation	180	80	80	HIGH	?	NV	330	no	EPRI will pursue with Sierra to solicit interest
<b>Fuel Cells</b>									
Florida Lab Fuji Fuel Cell	90	70	20	HIGH	3Q 97	FL	500	yes	Proposal received. Ready for project initiation
Fuel Cell Bus w/POX Reformer	500	200	300	HIGH	1Q 98	***	1,000	no	Acurex will track prototype progress
Fuel Cell Bus w/Steam Reformer	1	1	0	MED	?	DC, IL	1,000	no	Acurex will maintain contacts with bus researchers
Stationary Fuel Cell Power Generation*	907	300	607	LOW	?	CA	0	no	None
<b>Heavy Duty Buses</b>									
Triborough Coach	75	75	0	HIGH	3Q 97	NY	3,000	yes	Proposal received. Ready for project initiation
Gas Turbine Hybrid Bus*	950	250	700	HIGH	1Q 99	***	2,000	no	Acurex will pursue other possible sources of cofunding
Florida Institute of Technology Bus	149	99	50	MED	3Q 97	FL	4,000	no	Proposal received.
Methanol School Bus	200	30	170	LOW	3Q 97	CA	27,000	no	None
Methanol Transit Buses	0	0	0	LOW	?	CA	0	no	None
Heavy-Duty Methanol Engine	0	0	0	LOW	?	***	0	no	None
<b>Power Production</b>									
Advanced Power Generation	25	25	0	HIGH	1Q 98	CA	200	no	AP/EPRI will provide Westinghouse contact
Collie of Coal-Fired Boiler*	115	45	70	HIGH	3Q 98	IL	2,500	no	Acurex will pursue bid process with Illinois
<b>QUICK START PROJECTS</b>									
HIGH & MEDIUM PRIORITY PROJECTS	956	636	320				10,195		
ALL TEST PLAN PROJECTS	3,529	1,712	1,817				26,225		
ALL PRIOR + TEST PLAN PROJECTS	4,636	2,042	2,594				53,280		
	5,330	2,316	3,014				53,280		

\* - Projects require funding from other sources. Action items target bidding opportunities with CEC, ARB or FTA to receive cofunding.

\*\* - Quick Start: "yes" indicates project ready to kickoff

\*\*\* - All projects designated as high priority are recommended.

\*\*\*\* - Host site not yet identified

**PRIORITY: HIGH**  
**AVAILABILITY: HIGH**

**Project Name: Demonstration of LPMEOH™ in Light-Duty Flexible Fueled Vehicle (Acurex-owned)**

**Objective/Purpose**

- Demonstrate LPMEOH™ in a light-duty flexible fueled vehicle.
- Provide cost-effective demonstration with already proven hardware.

**Scope of Work**

- Operate Acurex-owned Ford Taurus FFV with LPMEOH™ M85 and regular M85 for 2 months on each fuel.
- Ship, locate fuel drum at Acurex for blending LPMEOH™-M85.
- Secure permitting and containment vessels for storage.
- Install fuel pump and dispenser.
- Track fuel economy during test periods for both fuels.
- Perform emissions testing on LPMEOH™ and M85 at CAVTC.
- Write short report containing emissions results and fuel economy comparison.

**Status**

- High-visibility, cost-effective project.
- Can be performed immediately.
- Possible synergy with NREL DISC engine and methanol formulations projects.

**Further Actions**

- Await go ahead from Air Products.
- Call NREL and identify methanol formulation interests.

**Costs**

<b>Total Funds:</b>	<b>\$55k</b>
<b>AP Funds:</b>	<b>\$30k</b>
<b>Cost Share:</b>	<b>\$25k</b>



**PRIORITY:**           LOW  
**AVAILABILITY:**    LOW

**Project Name:**       **Demonstration of LPMEOH<sup>TM</sup> in DISC Engines**

**Objective/Purpose**

- To demonstrate LPMEOH<sup>TM</sup> in new light-duty methanol Direct Injection Stratified Charge (DISC) engines under development by DOE-sponsored research companies in the United States.

**Scope of Work**

- Undefined.
- Demonstration would likely test LPMEOH<sup>TM</sup> versus standard M100 in a test-bench prototype engine.
- Perform bench emissions testing.
- Provide fuel for demonstration.

**Status**

- DISC engine currently being introduced for gasoline light-duty vehicles.
- Early development work undertaken on methanol DISC engines.
- Uncertain participation by engine developers.
- DOE already funding these sources.

**Further Actions**

- None. Project likelihood remote given timeframe of implementation and coordination problems with DOE and developers.

**PRIORITY:**           LOW  
**AVAILABILITY:**    LOW

**Project Name:**       **Demonstration of Hydrogen Production from LPMEOH™ for Use in Hydrogen Powered Vehicles**

**Objective/Purpose**

- To demonstrate local hydrogen generation for vehicle fueling and commercial hydrogen production
- To determine emissions from hydrogen production and verify low fuel cycle emissions for fuel cell powered zero emission vehicle candidates
- Verify suitability of LPMEOH™ as a feed for partial oxidation hydrogen generation systems

**Scope of Work**

- Review facility siting options at the UC Riverside College of Engineering Center for Environmental Research and Technology (CE-CERT).
- Purchase partial oxidation reformer configured for methanol operation
- Design system for hydrogen compression
- Obtain permits
- Prepare site
  - Electrical, controls, and equipment footings
  - Methanol and back up natural gas plumbing
- Install a methanol to hydrogen generation system
- Start up facility
  - Coordinate LPMEOH™ supply
  - Perform shake down testing
- Measure emissions from hydrogen generation system to support hydrogen as an equivalent to electric vehicles.
  - Evaluate emissions in terms of g/100scf, g/mi for fuel cell vehicle
- Install hydrogen compression equipment
  - Purchase compressor and gas storage
  - Operate facility for vehicle fueling and commercial hydrogen generation
- Prepare Final Report

**Status**

- Project team includes CE-CERT and Hydrogen Burner Technology
- Methanol storage tank is available at CE-CERT.
- An IC engine truck, research fuel cell vehicle, as well as commercial hydrogen are end use options
- Hydrogen compression experience with CE-CERT solar hydrogen facility.

**Further Actions**

- Determine cofunding opportunities from SCAQMD to fund compressor system integration.
- Review site options and hydrogen distribution options
- Certify safety of hydrogen tanks

**Costs**

**Total Funds:**           \$475k  
**AP Funds:**               \$328k  
**Cost Share:**             \$147k

**PRIORITY:**           LOW  
**AVAILABILITY:**    LOW

**Project Name:**       **Demonstration of LPMEOH™ in PEM Fuel-Cell Powered Vehicles  
with On-Board Hydrogen Supply**

**Objective/Purpose**

- Potential application of hydrogen production from methanol

**Scope of Work**

- Undefined.
- Operate fuel cell transit bus on LPMEOH™ and M100 in revenue service for 2 months for each fuel.
- Ship LPMEOH™ fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Write report containing emissions results and fuel economy comparison.

**Status**

- A fleet of hydrogen powered fuel cell golf carts is operating in the city of Palm Desert (east of Los Angeles). Hydrogen is provided from solar energy. Praxair may be providing hydrogen also.

**Further Actions**

- None. Funding uncertainties and the large number of project participants do not make this the best opportunity to demonstrate hydrogen production from methanol.

**PRIORITY:** HIGH  
**AVAILABILITY:** HIGH

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Stationary Gas Turbine with VOC Control for Distributed Power- Phase I

**Objective/Purpose**

- To demonstrate VOC destruction and low NOx emissions using a 25 kW stationary gas turbine fired with LPMEOH<sup>TM</sup>. Phase I of a two-phased project

**Scope of Work**

- Select and secure a local host facility (bakery) for VOC-control demonstration
- Perform a site visit a make presentation of project
- Procure and arrange for delivery of a 25 kW Capstone turbine
- Perform engineering analysis and installation review
- Select method for VOC destruction (eg high temperature in combustor or low temperature in recuperator)
- Coordinate catalyst and other turbine modification equipment retrofit
- Install Capstone turbine at bakery demonstration host site.
- Arrange for short-term methanol storage tank.
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Operate for 2 weeks running VOC laden gas through turbine for destruction.
- Perform source emissions testing.
- Write emission test result report

**Status**

- Small VOC industrial sources have few VOC-destruction cost effective solutions
- California SIP has targeted bakery, and other small VOC sources, for VOC control.
- Acurex has made preliminary contact with some bakeries that are willing to explore the VOC destruction with electric power generation
- California AB1890 funds would provide cofunding for project for Phase II power generation demo.

**Further Actions**

- Track progress of AB1890 and bid opportunities
- Find potential host site (John O'Sullivan of EPRI will assist with finding utility)
- Explore permit issues with local air district
- Make preliminary inquiries with Capstone Turbines regarding cost and methanol conversion
- Initiate look at VOC consumption rates

**Costs (PHASE I only)**

**Total Funds:** \$122k  
**AP Funds:** \$122k  
**Cost Share:** \$0

**PRIORITY:** HIGH  
**AVAILABILITY:** MEDIUM

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Stationary Gas Turbine with VOC Control - Phase II

**Objective/Purpose**

- To demonstrate the long-term performance and economic validity of distributed power generation in connection with VOC destruction using a 25 kW stationary gas turbine fired with LPMEOH<sup>TM</sup>. Phase II of a two-phased project
- Project builds on Phase I installation to perform long-term power generation and economic analysis demonstration of the GT-VOC control concept

**Scope of Work**

- Obtain long-term operating permit from local district
- Secure Phase I host facility (bakery) for long-term distributed power & VOC-control demonstration
- Perform a site visit a make presentation of project
- Modify fuel storage for long-term demonstration
- Retrofit turbine for multiple approach to VOC destruction
- Arrange for connection to power grid and electricity sale contract
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Operate for 2 months with LPMEOH and natural gas running VOC laden gas through turbine for destruction during process operation and ambient air at all other times.
- Perform source emissions testing.
- Record power generation, fuel use, operating cycle, power sales and power usage
- Write performance and emissions test result report
- Write economic analysis and commercialization feasibility report

**Status**

- California AB1890 funds would provide cofunding for project for Phase II power generation demo.
- California AB 1890 promotes the use of distributed power in connection with VOC control
- Proposal preparation expected in February 1998.

**Further Actions**

- The execution of this project depends on the successful completion of Phase I
- Track progress of AB1890 and bid opportunities
- Find potential host site
- Explore permit issues with local air district

**Costs (PHASE II only)**

**Total Funds:** \$198k  
**AP Funds:** \$48k  
**Cost Share:** \$150k

**PRIORITY: HIGH**  
**AVAILABILITY: HIGH**

**Project Name: Demonstration of LPMEOH™ in a Water-Naphtha-Methanol Fueled Bus**

**Objective/Purpose**

- To demonstrate viability of LPMEOH™ in a water-naphtha emulsion (A-55) containing 3% methanol.

**Scope of Work**

- Operate a 22 foot paratransit bus in revenue service using LPMEOH™ and M100 as an emulsion ingredient for 2 months on each fuel.
  - Daily pickup and transport for disabled persons in Sacramento
- Ship LPMEOH™ fuel to emulsion-producer for mixing.
- Coordinate logistics of tracking fuel use at host site.
- Track fuel economy during test period for both fuels.
  - Develop a fuel tracking plan
  - Coordinate with host site
- Provide vehicle troubleshooting and repair.
- Write short report containing fuel economy comparison between fuels and with control vehicles.

**Status**

- Acurex managed bus project already exists and revenue service will begin in late spring.
- Emulsion-producer is interested in potential sources of cheaper methanol.

**Further Actions**

- Call A-55 to confirm participation and coordinate details of emulsification process.

**Costs**

**Total Funds: \$273k**  
**AP Funds: \$23k**  
**Cost Share: \$250k**

**PRIORITY: HIGH**  
**AVAILABILITY: HIGH**

**Project Name: Demonstration of LPMEOH™ in a Diesel/Methanol Emulsion Fuel for Aircraft Ground Support and Stationary Power Generation Equipment**

**Objective/Purpose**

- To demonstrate diesel/LPMEOH™ emulsion in AGE equipment at Air Force Bases
- To monitor the emission and performance of the emulsion fuel in comparison with conventional diesel

**Scope of Work**

- Secure a host facility at a US AFB
- Perform a site visit to finalize scope and site support
- Select emulsion fuel supplier (e.g. A-55)
- Identify/engineer engine modifications needed
- Select fuel storage option and arrange for fuel tank installation
- Prepare a test plan
- Perform field test consisting of emissions and performance evaluation
- Analyze data
- Prepare test report

**Status**

- USAFB at Tyndall has expressed significant interest
- AGE and power generation equipment is high on priority list for NOx reduction
- Completed preliminary contact with Tyndall AFB in Florida
- Obtained agreement from the Air Force to in principle participate in the demonstration
- Expression of interest from Environics Directorate
- Preliminary contact with emulsified fuel supplier completed
- Defined an initial scope of work pending approval

**Further Actions**

- Explore with US AFB at Tyndall (FL) and Brooks (TX) on AF support
- Formulate a preliminary level of effort and present it to Tyndall personnel for agreement
- Make preliminary arrangements

**Costs**

**Total Funds: \$227k**  
**AP Funds: \$227k**  
**Cost Share: \$0k**

**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Fuel-Cell Powered Bus with POX Reformer

**Objective/Purpose**

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for fuel cell powered buses operating with multifuel POX reformers.

**Scope of Work**

- Coordinate methanol operation with demonstration site and vehicle developers.
- Install above ground fueling station
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Coordinate logistics of tracking fuel use.
- Operate fuel cell transit bus on LPMEOH<sup>TM</sup> and M100 in revenue service for 2 months for each fuel.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Perform chassis emissions testing on diesel, LPMEOH<sup>TM</sup>, and M100.
- Write report containing emissions results and fuel economy comparison.

**Status**

- Very high visibility project with excellent potential for vehicle use of methanol.
- Currently, DARPA-funded project for development of fuel cell/reformer technology is underway. Program for testing PEM fuel cell bus has not been finalized.
- Though project appears to have initial support from fuel cell developer, they will not operate on-road bus until late 1998. The bus is designed for multifuel operation; however, modifications to the fuel system would be necessary for methanol operation.

**Further Actions**

- While project has high visibility value, current hardware development plans will not allow demonstration to start until 1999. Excellent project for follow-on funds.
- Monitor project development and inquire regarding the possibilities for methanol operation

**Costs**

**Total Funds:** \$500k  
**AP Funds:** \$200k  
**Cost Share:** \$300k (Contingent)



**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> Fuel-Cell Powered Bus with Steam Reformer

**Objective/Purpose**

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for fuel cell powered buses operating with steam reformers
- Demonstrate LPMEOH<sup>TM</sup> use in breadboard and bus operation

**Scope of Work**

- Follow-on to Florida Lab 25kW Fuel Cell project.
- Operate fuel cell transit bus on LPMEOH<sup>TM</sup> and M100 in revenue service for 2 months for each fuel.
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Write report containing emissions results and fuel economy comparison.
- Provide fuel for Phase IV developments.

**Status**

- Very high visibility project with excellent potential for vehicle use of methanol.
- IFC and Ballard are developing methanol steam reforming fuel cell powered buses for Georgetown University. The IFC system uses a high temperature (1500F, Ni Catalyst) reformer and the Ballard system uses a low temperature (500F, Cu/Zn Catalyst) reformer. The high temperature system should be able to reform all types of alcohols while the low temperature system may not convert hydrocarbons and other alcohols.
- The project steps include system design, breadboard development, vehicle integration, and field demonstration. Actual operation on methanol in buses is several years away.
- Demonstration sites have not been identified at this time

**Further Actions**

- Provide input to IFC and Ballard on LPMEOH<sup>TM</sup> specifications and availability. Inquire if the fuel is feasible for vehicle operation. Provide samples for laboratory testing.

**PRIORITY:** LOW  
**AVAILABILITY:** MEDIUM (Contingent)

**Project Name:** Demonstration of LPMEOH™ in Stationary Fuel Cell Power Generation Applications

**Objective/Purpose**

- To demonstrate the viability of LPMEOH™ for stationary fuel cell distributed power generation

**Scope of Work**

- Identify demonstration site and cost sharing
- Design modifications for methanol operation
- Procure fuel cell
- Procure and install above ground fuel tank and fuel supply system
- Prepare site and electrical generation interface
- Install fuel cell
- Perform emission testing on methanol and natural gas
- Collect operating data
- Prepare final report

**Status**

- IFC/ONSI fuel cells (PC25) operate on natural gas and LPG. There are about 60 installations around the world. The IFC system uses a high temperature (1500°F) steam reformer to produce hydrogen. This catalyst system could operate well on any grade of methanol.
- The IFC fuel cell system has not been configured to operate on methanol for stationary applications.
- DOE is supporting R&D for PEM fuel cells for vehicles and building cogeneration. The hydrogen generation will most likely be with a partial oxidation system that can operate on gasoline, natural gas, diesel, ethanol, and methanol.
- PEM fuel cell power generation system will not be available from the DOE program for 3 years.

**Further Actions**

- Monitor developments with stationary fuel cell projects. Make contact with EPRI, IFC, and project participants and explore opportunities for LPMEOH™ demonstration.
- Seek funding under AB1890 to fund a project
- Discuss requirements for methanol operation with IFC

**Costs**

**Total Funds:** \$907k  
**AP Funds:** \$300k  
**Cost Share:** \$607k (contingent upon AB1890 and other funding)

**PRIORITY:** HIGH  
**AVAILABILITY:** MEDIUM (Contingent on funding and participation)

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Gas Turbine Powered Hybrid Bus

**Objective/Purpose**

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for turbine powered hybrid buses.

**Scope of Work**

- Install Capstone turbines in an Orion Bus Industries hybrid-electric bus.
- Install methanol fuel system on bus.
  - Determine appropriate design considerations
  - Identify, purchase, and install parts
- Reconfigure electronic control for operation with gas turbine.
  - Develop software modifications
  - Create hardware for interface between master controller and turbine
- Operate bus in revenue service using LPMEOH<sup>TM</sup> for 12 months.
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period.
  - Develop field, performance, and emissions test plan
  - Implement data collection procedures
- Provide vehicle troubleshooting and repair.
- Write report containing vehicle development description, vehicle demonstration results, emissions results and fuel economy comparison to control vehicles.

**Status**

- Extremely visible, high-potential project.
- Initial response from Capstone, OBI, and CE-CERT is very positive.
- Requires commitment of several participants and extra funding from local, state or federal agencies. Funding could come from FTA or ARB. Requires development of partnership with involved parties.

**Further Actions**

- Clarify interest of partners for project plan.
- Identify additional funding from other agencies, such as ARB or FTA.

**Costs**

**Total Funds:** \$950k  
**AP Funds:** \$250k  
**Cost Share:** \$700k (Contingent)

**PRIORITY:**           LOW  
**AVAILABILITY:**   HIGH

**Project Name:**       **Demonstration of LPMEOH™ in Methanol Fueled School Bus**

**Objective/Purpose**

- To determine viability of LPMEOH™ as a fuel for school buses.

**Scope of Work**

- Operate school buses in revenue service using LPMEOH™ and M100 for 2 months on each fuel.
- Ship LPMEOH™ fuel to host site.
- Collect data from on-board data acquisition systems and operating records:
  - Vehicle speed/mileage
  - Fuel consumption
  - Engine speed
  - Foot brake activation
  - Percent engine load
  - Percent throttle
  - Idle time
- Provide vehicle troubleshooting and repair.
- Interview drivers with evaluation questionnaire.
- Track fuel economy during test period for both fuels.
- Write short report containing fuel economy comparison between fuels and with control vehicles.

**Status**

- Host site Antelope Valley Schools Transportation Agency (AVSTA) reacted positively to idea.
- 15 MeOH buses are part of CEC demonstration -- fuel source change requires CEC approval.
- Approval of bus manufacturer (Carpenter) required to protect warranty
- 12,000 gal MEOH tank onsite for school bus fueling

**Further Actions**

- Get fuel specification sheet and MSDS for AVSTA, CEC, Carpenter, DDC, and OSHA needs
- Verify fuel compatibility for Carpenter M100 schoolbuses
- Contact CEC
- Contact Carpenter and estimate fuel quantity needs

**Costs**

**Total Funds:**           \$200k  
**AP Funds:**               \$30k  
**Cost Share:**             \$170k

**PRIORITY:**           LOW  
**AVAILABILITY:**    LOW

**Project Name:**       **Demonstration of LPMEOH™ in Transit Buses with DDC 6V-92TA Engines**

**Objective/Purpose**

- Demonstrate LPMEOH™ use at transit agencies operating DDC 6V-92TA engines.
- Prove viability of LPMEOH™ in heavy-duty transit bus applications.

**Scope of Work**

- Operate methanol transit buses on LPMEOH™ and M100 for period of two weeks.
- Ship fuel to transit agency methanol storage tank.
- Coordinate refueling efforts.
- Track fuel economy during test periods for both fuels.
- Perform emissions testing on LPMEOH™ and M100 at LACMTA chassis dynamometer.
- Write short report containing emissions results and fuel economy comparison.

**Status**

- Already measured emissions from an MTA bus operating on M100, LPMEOH™ and LPMEOH™ with DME mixtures (December 1994) in cooperation with Air Products.
- LACMTA's fleet of methanol buses is making a transition to ethanol operation. MTA's organization is complex and the logistics of integrating LPMEOH use with a large fleet of buses would be costly.
- Kenawah Valley (KVRTA) was a planned site for methanol bus operation but they are no longer operating buses on methanol.

**Further Actions**

- None. Extensive efforts with transit bus operation are not warranted given the availability of methanol engines and the logistics of fueling and data collection at transit agencies.

**PRIORITY:**           LOW  
**AVAILABILITY:**    LOW

**Project Name:**       **Demonstrate of LPMEOH™ in Caterpillar Heavy-Duty Methanol Engine**

**Objective/Purpose**

- To demonstrate LPMEOH™ in a new M100 heavy-duty engine currently under development by Caterpillar.
- Prove viability of neat-LPMEOH™ in heavy-duty methanol engines.

**Scope of Work**

- Undefined.
- Test LPMEOH™ versus standard M100 in a test-bench prototype engine.
- Perform bench emissions testing.

**Status**

- Caterpillar bench prototype engine will not be available within a year's time.
- Not certain if Caterpillar would be interested in demonstration of LPMEOH™ in their new engine.

**Further Actions**

- None.

**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMeOH<sup>TM</sup> for Advanced Power Generation Equipment

Objective/Purpose

- To test LPMeOH<sup>TM</sup> in the fuel cell reformer and gas turbine in advanced power cycle equipment being developed under DOE program
- To compare the performance and cost of the power plant with more conventional combined cycle fuels

Scope of Work

- Re-contact Solar R&D group later this year regarding progress and schedule
- Obtain agreement and firmup schedule
- Visit the site and secure final agreement
- Develop test plan and get it approved
- Arrange for delivery of LPMeOH<sup>TM</sup> and storage
- Monitor the testing and data gathering effort
- Obtain data from the site
- Analyze data
- Write a test report

Status

- Acurex will take advantage of an ongoing project sponsored by DOE and performed by Solar Turbines Division of Caterpillar and Westinghouse where an advanced power generation cycle consisting of GT and fuel cell combination will be used to generate electricity with overall efficiency exceeding 65 percent. The equipment and technology is currently being assembled at Solar Turbines and is scheduled for multifuel testing later this year and in 1998
- Solar will consider methanol firing, including LPMeOH<sup>TM</sup>
- Preliminary contact made with Solar Turbines. Agreement in principle. Further negotiations are necessary

Further Actions

- Acurex will confirm the feasibility of the project later this year
- If deemed feasible to pursue, Acurex will continue contact to coordinate the scope of work and schedule

Costs

**Total Funds:** \$25k  
**AP Funds:** \$25k  
**Cost Share:** \$0

**PRIORITY:** HIGH  
**AVAILABILITY:** MEDIUM

**Project Name:** Demonstration of LPMeOH<sup>TM</sup> Cofire/Startup for Coal-Fired Boiler

**Objective/Purpose**

- To demonstrate the use of LPMeOH<sup>TM</sup> as a cofire or startup fuel for existing coal-fired industrial and small-scale power generation boilers in the Midwest. The LPMeOH<sup>TM</sup> fuel will be used in minimal amounts to support improved boiler operation, minimize emissions, and in general improve the reliability and performance of the boiler continuing its viability as a coal-fired boiler. The boiler that will be selected will be among the population of boilers recently retrofitted under the GRI gas cofire program. This will ensure that the boiler is already equipment ready for installation and firing of methanol fuel with minor modification of existing burner equipment

**Scope of Work**

- Define site selection criteria
- Survey boiler population for site selection
- Undertake phone search for site selection and securing preliminary agreement
- Make site visit and secure host facility for the demonstration
- Prepare a retrofit, equipment modification and test plan
- Subcontract the burner vendor to make modifications to the burner for methanol ready firing
- Arrange for delivery, storage, and hookup of fuel
- Perform startup and initial diagnostic tests
- Perform emission and performance tests in line with the test plan
- Arrange for site equipment to return to normal
- Analyze test data
- Write report

**Status**

- Acurex has made preliminary contacts with the Illinois Clean Coal Institute (ICCI) to explore the interest in this demonstration. Heman Feldmann. Preliminary interest pending on the economic viability of LPMeOH<sup>TM</sup> as a cofire fuel compared with alternatives.

**Further Actions**

- Acurex will further explore interest in this demonstration following approval from all project stakeholders. The viability of the project will also hinge on securing cofunding using the open submittal of project ideas under the current ICCI open solicitation mechanism. Stakeholder approval and award of contract from ICCI following submittal of Acurex proposal will be followed up with the proposed scope of work described above. Level of ICCI cofunding is limited to \$250,000 per project.

**Costs**

**Total Funds:** \$115k  
**AP Funds:** \$45k  
**Cost Share:** \$70k



**Off-Site Product-Use Testing  
Proposals Under Consideration**

<u>Demonstration Project</u>	<u>Site</u>
Acurex FFV	California
Stationary Turbine for VOC Control	Site to be determined in cooperation with EPRI
West Virginia Univ. Stationary Gas Turbine	West Virginia
Water/Naphtha/MeOH Bus,	California
Aircraft Ground Equipment Emulsion	Tyndall AFB, Florida Brooks AFB, Texas
University of Florida Fuel Cell Fuel Cell, Florida	Florida
West Virginia Univ. Tri-Boro Bus	New York
Florida Inst. of Tech. Bus & Light Vehicle	Florida

**APPENDIX D - TASK 1.5.2 - PROCESS ECONOMIC STUDY**

**Process Economics Study - Outline  
(Draft - 3/31/97 - four pages)**

**and**

**LPMEOH™ Process Economics - for IGCC Coproduction  
(Memo - 31 March 1997 - two pages)**

# Process Economics Study - Outline

## LPMEOH™ Process, as an add-on to IGCC for Coproduction

**Part One - Coproduction of Methanol** Note - 2nd Draft was dated 10/01/96; comments received 11/25/96, 3d Draft released ~03/31/97.

### 1. Introduction

#### 1.1. 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 design and costs. 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.

# Process Economics Study - Outline

## LPMEOH™ Process, as an add-on to IGCC for Coproduction

### 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

Note - Portions of Part Two, Section 3.1; was included in the Tampa CCT Conference's Paper, 1/9/97.

### 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  $1735 \times 10^6$  Btu(HHV)/hr. output each ( $1626 \times 10^6$  LHV)

#### **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.

<u>Syngas Conversion</u>	<u>Power Plant Size</u>	<u>Methanol Plant Size</u>	<u>Methanol to Power Ratio</u>	<u>Gasification Plant Size</u>
0.0 %	500 MW	0 T/D	0 T/D per MW	Base
13.8%	426 MW	500 T/D	1.2 T/D per MW	Base
20.0%	394 MW	691 T/D	1.8 T/D per MW	Base
30.0%	342 MW	1085 T/D	3.2 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  $1735 \times 10^6$  Btu(HHV)/hr. gasifiers), the methanol to power coproduction ratio's could be:

<u>Syngas Conversion</u>	<u>Power Plant Size</u>	<u>Methanol Plant Size</u>	<u>Methanol to Power Ratio</u>	<u>Gasification Plant Size</u>
0.0 %	500 MW	0 T/D	0 T/D per MW	1.00 x Base
16.7 %	500 MW	736 T/D	1.5 T/D per MW	1.20 x Base
25.0 %	500 MW	1227 T/D	2.5 T/D per MW	1.33 x Base
33.3 %	500 MW	1825 T/D	3.7 T/D per MW	1.50 x Base

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

### End of Part Two.

**Process Economics Study - Outline**  
**LPMEOH™ Process, as an add-on to IGCC for Coproduction**  
**Part Three - Coproduction for Intermediate Electric Load Following.**

**4. Intermediate Load Coproduction**

Note - Part Three, Section 4.2: is being developed as a paper for the June 1997 Power-Gen Europe Conference.

**4.1. Syngas Value as a function of (time of day) Power Value.**

Earlier electric power daily load following studies indicate that LPMEOH™ coproduction optimizes for daily or seasonal power peaks in the 500 to 2500 hr./yr. range. This means the methanol plant operates, during daily or seasonal "off-peak" power periods, in the 8260 to 6260 hr./yr. range, with stop/start operations for these on/off power peaks. This is the "intermediate load" area of a typical power grid system. (8760 hr./yr. = 100%; all exclude gasifier/plant outages)

**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 intermediate load coproduction cases, redundant investment to utilize syngas 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 several intermediate load coproduction power plant design choices; a) a CC power plant turned down, or b) a baseload CC power plant with other CC or CT power plant(s) for peak. These may be combined with methanol plant design choices such as size/% syngas conversion. To evaluate the system properly, time of day power values (also called Lambda Curves) are needed. The Lambda Curve examples from published EPRI studies can be used for initial evaluations. The Section 2.(above) Methanol Plant design choices can then be combined with power plant design options, to optimize the system.

**4.3. Intermediate Load Coproduction, for Methanol Sales and for Dispersed Power.**

- Dispersed power can provide electricity and heat locally, at the use point, eliminating the need for new power distribution lines in congested areas. The world wide package (0.2 MW to 10 MW) power plant market is large, and growing. A variety of technologies (combustion turbine, internal combustion engine, fuel cell) are being packaged. Methanol produced at a nearby IGCC power plant during off-peak power periods could provide clean local (peak) power; bypassing the local electric power distribution system.

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

- When other peaking fuels are not available, or are too expensive, then methanol may also be used as a peaking fuel. 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. A study option would be to compare ourselves (IGCC/OTM) to the various published EPRI (IG-Cash, et. al.) studies, which provide Lambda Curve examples for energy storage. However, selling methanol and using distillate fuel for peaking, is the economic choice at currently forecasted world oil and methanol prices. Therefore, this study should have low priority, until a site specific need is identified.
- *Methanol could be transported to remote existing, or to new peaking power plants, to unload grid systems.*
- 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.)

**End of Part Three.**

# Process Economics Study - Outline

## LPMEOH™ Process, as an add-on to IGCC for Coproduction

### 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; \$27/bbl diesel = \$4.50 /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-à-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 arrange fuel tests to confirm the dispersed energy environmental advantage.*

#### **5.1. 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 H<sub>2</sub>. For small H<sub>2</sub> 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 liquid H<sub>2</sub>.

##### **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 can provide power and heat locally, at the use point, eliminating the need for new power distribution lines in congested city areas. The world wide package (0.2 MW to 10 MW) power plant market is large, and growing. A variety of technologies (combustion turbine, internal combustion engine, fuel cell) are being packaged. Methanol produced at a nearby IGCC power plant during off-peak power periods could provide clean local power; bypassing the local electric power distribution system.

#### **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.

# Memorandum



To: Distribution Dept./Loc.:

From: W. R. Brown Dept./Ext.: PSED, X17584

Date: 31 March 1997

Subject: LPMEOH™ Process Economics - for IGCC Coproduction

Distribution:

c: D. M. Brown - APE (Hersham)  
R. J. Allam - APE (Hersham)

APCI

E. C. Heydorn  
J. Klosek/E. R. Osterstock  
R. B. Moore/D. P. Drown  
V. E. Stein  
P. J. A. Tijm

R. M. Kornosky - DOE-FETC  
W. J. O'Dowd - DOE-FETC  
W. C. Jones - Eastman

The third draft of the DOE Topical Report on LPMEOH™ Process Economics (Part One) is attached for your use (review, comment). This Topical Report develops plant design options for our LPMEOH™ process, as an add-on to IGCC power plants for the coproduction of methanol and power. Part One also compares our LPMEOH™ (LP) methanol process with the gas phase (GP) methanol process.

LP's advantage over GP is about 10 cents per gallon; when the syngas conversion is low (less than 34%), and when the feed gas pressure is high (greater the 750 psig), and when the methanol plant size is relatively small (400 to 1200 TPD). Surprisingly, even at these small plant sizes, the LP technology can coproduce methanol at less than 50 cents per gallon (good). The GP technology is over 50 cents per gallon (not good). Therefore, when baseload IGCC power is viable, the LP Technology makes coproduction viable.

The DOE Topical Report (Part One) looks specifically at:

- Determining and optimizing **conversion costs** for our LP technology as a function of feed gas pressure and % syngas conversion. (See graphs on pages A - 5, 6, 7, 9, 10).
- Determining **purification (distillation) costs** for "Fuel", "MTBE", and "Chemical" grade methanol. (See graph, page A - 15). *Distillation savings are a significant part of LP's advantage.*

- Comparing LP with GP technology. (See the above graphs, plus Summary Table on page 16).
- Listing of future LP design improvements, expected from actual operation, or that are recommended for further engineering study (see pages 17,18).

Parts Two, Three and Four of the DOE Topical Report are planned for the future (the outline is attached). Part Two will examine the impact of baseload coproduction on electric power costs. Part Two, Section 3.1 was included in the Tampa CCT Conference's Paper; "Fuel and Power Coproduction" (1/9/97). Part Three will look at time-of-day energy values: a) intermediate load coproduction (e.g.- off-peak methanol production), and b) methanol as stored energy for peaking and/or dispersed electric power. Part Four of the Topical Report plans to look at Methanol Fuel Applications, where locally produced (non-inflationary) methanol, at less than 50 cents per gallon, could be a viable source of hydrogen for industrial or fuel (cells) power applications. Serving (initially) small local fuel markets builds on LP's strengths; good economics at small plant sizes, fuel grade product distillation savings, and a freight advantage in local markets vis-a-vis large off-shore remote gas methanol.

Your comments on this third draft of the Topical Report (Part One) would be appreciated. After your further comments are received; we will formally release this as the final (draft) of a Topical Report.

Bill



**APPENDIX E - TASK 1.5.3 - DME DESIGN VERIFICATION TESTING**

**Air Products and Chemicals, Inc.**  
7201 Hamilton Boulevard  
Allentown, PA 18195-1501  
Telephone (610) 481-4911



30 June 1997

Mr. Robert M. Kornosky  
Technical Project Manager  
Mail Stop 920-L  
U. S. Department of Energy  
Federal Energy Technology Center  
P. O. Box 10940  
Pittsburgh, PA 15236-0940

**Subject: Cooperative Agreement DE-FC22-92PC90543  
Liquid Phase Methanol Demonstration Project  
Liquid Phase Dimethyl Ether Design Verification Testing -  
Recommendation**

Dear Bob:

The updated version of the Recommendation to proceed with Design Verification Testing of the Liquid Phase Dimethyl Ether Process is attached. This document will be used during the Project Review Meeting on 24-25 July, at which time final approval by DOE and the Partnership will be requested.

Very truly yours,

A handwritten signature in black ink, appearing to read "Edward C. Heydorn".

Edward C. Heydorn  
Program Manager  
LPMEOH™ Demonstration Project

Enclosure

cc: Mr. William C. Jones - Eastman Chemical Co.  
Mr. William J. O'Dowd - DOE-FETC  
Mr. Edward Schmetz - DOE-FE-HQ  
Dr. John Shen - DOE-FE-HQ  
Mr. Barry T. Street - Eastman Chemical Co.  
Mr. Peter Tijm - Air Products & Chemicals, Inc.

# LPDME Recommendation

## Summary

From the Statement of Work, "Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process," selected under Round 3 of the U.S. Department of Energy's (DOE's) Clean Coal Technology (CCT) Program: "Subject to Design Verification Testing (DVT), the Partnership proposes to enhance the Project by including the demonstration of the slurry reactor's capability to produce DME (*dimethyl ether*) as a mixed co-product with methanol." The first DVT step (Phase 1, Task 5), to address issues such as catalyst activity and stability, to provide data for engineering design, and to verify the market through engine tests and through market and economic study, is now complete. The market potential for DME is large, and progress in the laboratory toward developing a catalyst system whose performance meets the economic targets of a methanol equivalent productivity of 14 mol/kg catalyst-hr after 6 months of operation, producing at least 75% (by heating value) DME and 25% methanol.

A test of the Liquid Phase Dimethyl Ether (LPDME) at the LaPorte Alternative Fuels Development Unit (AFDU), in conjunction with the DOE's Liquid Fuels Program, would be appropriate if the catalyst system development can be completed successfully. An implementation decision, made mutually by the DOE's Clean Coal Technology LPMEOH™ project participants, and by the DOE's Liquid Fuels Program participants, should be made (by July of 1997) to implement testing at LaPorte in early 1998. (*Final dates should be recommended by the DOE's Liquid Fuels Program, based on progress in developing the LPDME catalyst system.*)

## Liquid Phase Dimethyl Ether (LPDME) Design Verification Testing (DVT)

From the Statement of Work, DOE's CCT LPMEOH™ project (Cooperative Agreement No. DE-FC22-92PC90543): "Subject to Design Verification Testing (DVT), the Partnership proposes to enhance the Project by including the demonstration of the slurry reactor's capability to produce DME as a mixed co-product with methanol. The production of DME from synthesis gas is a natural extension of the LPMEOH™ process in that three reactions occur concurrently in a single liquid phase reactor, methanol synthesis, methanol dehydration and water-gas shift. This process enhancement can significantly improve the overall conversion of coal derived synthesis gas to a storable blend of methanol and DME. -- -- -- the enhanced (DME production demonstration is complementary to ongoing studies being sponsored by DOE's Liquid Fuels Program --) -- . -- At the conclusion of each of the DVT steps, a joint Partnership/DOE decision will be made regarding continuation of methanol/DME demonstration.."

The first DVT step (Phase 1, Task 5), to address issues such as catalyst activity and stability, to provide data for engineering design, and to verify the market through engine tests and through market and economic study, is now complete.

## LPDME Recommendation

### The LPDME Process Concept: - Three Concurrent Reactions:

- $2 \text{ CO} + 4 \text{ H}_2 = 2 \text{ CH}_3\text{OH}$  (Methanol Synthesis).
- $2 \text{ CH}_3\text{OH} = 1 \text{ CH}_3\text{-O-CH}_3 + 1 \text{ H}_2\text{O}$  (Methanol Dehydration).
- $1 \text{ CO} + 1 \text{ H}_2\text{O} = 1 \text{ CO}_2 + 1 \text{ H}_2$  (Water-gas Shift).

The overall reaction, with carbon monoxide (CO)-rich synthesis gas (syngas), in a single liquid phase (slurry) reactor:

- $3 \text{ CO} + 3 \text{ H}_2 = 1 \text{ CH}_3\text{-O-CH}_3 + 1 \text{ CO}_2$  (DME from CO-rich syngas)

This is the "once-through" CO-rich syngas concept for the LPDME process utilizing a single slurry reactor. Conversion per pass, with CO-rich syngas, can be higher than for the LPMEOH<sup>TM</sup> process. Methanol may also be produced, as a mixed co-product with the DME, and can easily be separated and recovered. The separation of DME from carbon dioxide (CO<sub>2</sub>) will be necessary for certain market applications.

### Status of the LPDME DVT Work

The status of a) the LPDME process economics/market study work, and of b) the LPDME catalyst system R&D work, follows:

**A-1. The market applications** for DME are extensive. DME is, or may be, used as:

- Aerosol - Small, but established market. High purity DME is required.
- Cooking Fuel - Potentially a large market, to replace imported liquefied petroleum gas (LPG). There is a lot of interest in China, and DME is on the agenda for DOE's Pittsburgh Coal Conference in China (Sept. of 1997). Purity, of about >95% DME, with <2% methanol, < 3% CO<sub>2</sub> is estimated. An unresolved application issue is CO emissions during cooking. How does DME purity impact this? Use testing is needed. Our contacts with representatives from the Institute of Coal Chemistry of the Chinese Academy of Sciences in Shanxi has provided the following assessment of the potential market for DME as a cooking fuel:  
Of the 1.2 billion people in China, 0.3 billion live in cities. Of these, 1/3 currently use natural gas or LPG. Assuming 4 people per family, the 0.2 billion people who do not use gas or LPG converts to 50 million families. If DME captures 20-30% of the market share for these new applications, and the DME consumption is 200 kg per family per year, the demand for DME would be 2.4-3.0 million tons per year.
- Diesel Replacement Fuel. DME is an ultra clean (high Cetane) diesel fuel; and an 80% DME mixture with methanol and water is now being engine-tested by others (Amoco, et. al.). Market development (at least in the U.S.) faces a fuel distribution infrastructure problem. DME might

## LPDME Recommendation

more easily replace LPG in countries where LPG is already an engine fuel. Diesel use in the U.S. is projected to increase by 1.5 percent a year, assuming an economic growth of 1.9 percent a year. This will raise consumption from over 4 quadrillion BTU to approaching 6 quadrillion BTU (Reference 1). This corresponds to an annual increase of almost 1.4 million gallons per year of diesel consumption.

- DME Derivatives, as a Diesel Fuel Additive. Quotes from the DOE Liquid Fuels Program (Contract No. DE-FC22-95PC93052) quarterly report for April-June 1996: "Initial Cetane number (CN) testing of a three-component composition of 1,2-dimethoxy ethane, 1,1-dimethoxy methane and methanol blended with diesel fuel showed a 40% increase in the CN of the diesel fuel when the blend was 50/50." "The concept of adding a blend of oxygenated compounds to diesel fuel in order to enhance the Cetane value and cold start properties is being investigated. The blend of oxygenated compounds is derived from dimethyl ether chemistry, and builds on work conducted earlier --." The testing of this DME feedstock chemistry is in its early days, but it is possible that CO<sub>2</sub> may not need to be separated from the DME prior to the production of DME derivatives. The 50/50 blend referenced above would therefore provide a large market opportunity for the projected U.S. market growth (Reference 1), let alone for the present consumption.
- DME Derivatives, as Chemicals/Other Fuels. DME is a key intermediate in a commercial synthesis gas-to-gasoline process, and is being developed as an intermediate for other chemicals and fuels as part of the DOE's Liquid Fuels Program. The fit for DME here is long-term.

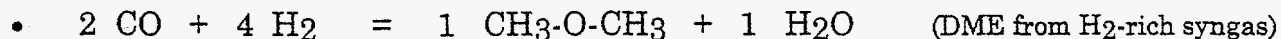
A-2. The economics studies, for once-through coproduction (with an integrated gasification combined cycle (IGCC) power plant, for example) on synthesis gas rich in carbon oxides, show that the LPDME process will have an economic advantage greater than the LPMEOH™ process. A once-through LPDME reactor is able to convert greater than 50% of such a syngas, whereas a once-through LPMEOH™ reactor can convert only about 30%. The economics, of course, depend upon the end-use (purity) of the DME and upon the gasification plant's coproduct mix (amount of power, methanol, DME, etc.). The same liquid phase reactor design options to increase syngas conversion (Reference 2); such as feed gas compression and/or CO-rich gas recycle; are also be applicable for LPDME. So, the LPDME technology has the potential to improve on the 5-10 cents per gallon (methanol equivalent) advantage over the LPMEOH™ process for the coproduction of DME to serve local markets.

As with the LPMEOH™ process, gas phase process technology must be considered as the economic competitor. The gas phase DME process (Reference 3) must run with hydrogen (H<sub>2</sub>)-rich syngas. In the IGCC coproduction flow sheet (shown in Figure 1), gas phase technology is at an economic disadvantage, since separate shift and CO<sub>2</sub> removal are required. As is the case for methanol, inexpensive remote natural gas would therefore be the economic plant site choice for gas phase technology. A comparison, of IGCC/LPDME coproduction with DME imported from remote gas facilities, shows an advantage of 20-30% for locally produced DME relative to

## LPDME Recommendation

imported DME. The transportation cost to import DME is much higher than for methanol, and the LPDME coproduction advantage is even greater than that for LPMEOH™ (vs. methanol import) (Reference 2). Dehydration of imported methanol to make DME is not competitive either. Therefore, for DME in local markets, LPDME coproduction should be a winner!

With H<sub>2</sub>-rich syngas, the LPDME process loses its (once-through, high conversion per pass) economic advantage. The overall reaction, with (> 2:1) H<sub>2</sub>-rich syngas is:



Since water inhibits the methanol dehydration reaction, the slurry reactor must be staged, with water removal between stages. Staging could be by high ratio gas recycle, and/or with multiple reactors; but the once-through simplicity is lost. Therefore, it is unlikely that the LPDME process would be developed for use in H<sub>2</sub>-rich syngas applications.

A cost estimate of commercial-scale LPDME plants has been performed. This work has helped quantify the targets for the laboratory R&D program (summarized in Part B). From these studies, a commercially successful LPDME system is defined for a Texaco-type synthesis gas (35 mol% H<sub>2</sub>, 51 mol% CO, 13 mol% CO<sub>2</sub>) available at 500 PSIG. At a reactor operating pressure of 950 PSIG and a space velocity of 4,000 liters/hr-kg catalyst, the LPDME catalyst system must have a methanol equivalent productivity of 14 mol/kg catalyst-hr after 6 months of operation, producing at least 75% (by heating value) DME and 25% methanol. Figure 2 shows the effect of plant size on DME cost. These costs are competitive with LPG in China (Section A-1).

### B. Laboratory R&D Results

Summary of work through end of funding by CCT LPMEOH™ Project (9/96): An LPDME catalyst system, with reasonable long-term activity (57% of initial activity after 1000 hours), productivity (equivalent methanol productivity of 29 mol/kg catalyst-hr), and selectivity (79% carbon selectivity to DME, CO<sub>2</sub>-free basis), was identified and tested. The system exhibits best activity under CO-rich syngas conditions, i.e. those most likely for (IGCC) coproduction. Accelerated aging of the catalyst system is a remaining issue. Water concentrations in the liquid phase reactor are higher with syngases richer in H<sub>2</sub>, and its effect needs to be evaluated.

Laboratory work has continued under the DOE's Liquid Fuels Program. The issues, to be addressed in the lab before a decision on a test run at the DOE's AFDU in LaPorte, are:

- 1) Understanding the LPDME catalyst system's accelerated aging; and modifying the catalyst and/or the system operating conditions; and
- 2) Manufacturing scale-up of catalyst for a LaPorte AFDU run.

## LPDME Recommendation

Progress has been made in the laboratory effort. Figure 3 shows the performance for the first DME catalyst which was tested; goals from the Liquid Fuels Program are provided for reference. After further study, an improved DME catalyst (AB-05) was tested with two LPMEOH™ catalysts (S3-86 and MK-101); the results of a 700 hour life study are presented in Figure 4. When compared with the program goals (summarized in Figure 5), the catalyst performance of the newer catalyst is approaching the commercial targets defined in Section A. The status of the laboratory program is summarized in the following table:

	Liquid Fuels Program Goals	Commercial Targets	Laboratory Results
Catalyst Productivity, mol/kg catalyst-hr (MeOH-equivalent)	> 28 (Initial Productivity)	> 14 (productivity for aged catalyst)	28 (Initial Productivity)
Catalyst Selectivity	DME Selectivity > 80% (% Carbon, CO <sub>2</sub> -free)	DME = 75%, Methanol = 25% (heating value basis)	DME Selectivity = 79% (% Carbon, CO <sub>2</sub> -free)
Catalyst Life	> 50% Remaining Activity after 1000 hours	Target Productivity after 6 months of operation	57% Remaining Activity after 1000 hours

Initial discussions with catalyst manufacturers have been held. Once a manufacturer is selected, a laboratory-scale catalyst batch will be produced and tested in the autoclave to verify the production technique developed at Air Products. An interim 1 lb batch will then be produced and tested. Once the catalyst production techniques have been verified at this scale, the 200 lb LaPorte batch will be produced using the same methodology as for a full commercial batch. An autoclave check of this material will be performed prior to the start of the LaPorte AFDU run.

### Recommendations

The catalyst system and the market applications/opportunities are sufficiently promising that proof-of-concept testing at the LaPorte AFDU is recommended. Kingsport is an unlikely site for the commercial size demonstration of LPDME, since there are limited times for CO-rich syngas testing; and H<sub>2</sub>-rich syngas would create water buildup. Therefore, the basis for commercializing LPDME must come from:

- 1) catalyst performance (productivity, selectivity, and life) for the LPDME catalyst system under CO-rich syngas from the proof-of-concept testing at the LaPorte AFDU;

## LPDME Recommendation

- 2) continuing work in hydrodynamics of slurry reactors (other ongoing DOE programs); and
- 3) reactor performance (methanol catalyst activity and life, hydrodynamics, and heat transfer) from the LPMEOH™ Process Demonstration Unit.

The tie-in between the laboratory and the LaPorte AFDU is important. Historically, the rate of deactivation of methanol synthesis catalyst has been greater in the autoclave than at the AFDU; this may be a result of loss of catalyst from the autoclave, or due to greater carbonyl poisoning as a result of the higher surface-to-volume ratio at the laboratory scale. Testing at the engineering scale of the LaPorte AFDU can eliminate this variable. Operation of the LPMEOH™ Process Demonstration Unit will provide data on catalyst life under coal-derived syngas and at the larger engineering scale (the tie-in to the LaPorte AFDU for commercialization).

The recommendations for proceeding with DVT of the LPDME catalyst system are:

- An LPDME test run at the LaPorte AFDU, in conjunction with the DOE's Liquid Fuels Program, would be appropriate if the LPDME catalyst system development can be completed successfully. Up to \$875,000 of CCT LPMEOH™ Project budget support, from the Cost Plan (22 October 1996), should be made available to support a suitable LPDME test run at LaPorte.
- An implementation decision, made mutually by the DOE's CCT (DE-FC22-92PC90543) LPMEOH™ Project participants, and by the DOE's Liquid Fuels (DE-FC22-95PC93052) Program participants, should be made (by *July of 1997*) in time to implement testing at LaPorte in *early 1998*. (*Final dates should be recommended by the DOE's Liquid Fuels Program, based on progress in developing the LPDME catalyst system*). The CCT LPMEOH™ Project participants shall be kept informed (via review meetings and status reports) by Air Products of the development by the DOE Liquid Fuels Program participants of the LaPorte AFDU LPDME test-run plans, so that a timely final approval can be made
- In the interim, some DME product-use testing may be appropriate for the LPMEOH™ Demonstration Project's off-site product-use testing.

The schedule for the proposed LPDME testing at the LaPorte AFDU and possible implementation at the Kingsport LPMEOH™ Process Demonstration Facility is summarized below:

DME DVT Decision Made	July 1997
Commercial-Scale DME Catalyst Produced/Tested	
in Laboratory Autoclave	January 1998
LaPorte AFDU Test	February/March 1998
Kingsport Decision Made	March/April 1998
Kingsport Implementation (Provisional) Plan	July 1998 - March 2001



## LPDME Recommendation

### Impact on CCT Project

Technical: The commercialization of the LPDME Process can be successfully achieved by the combination of the activities at the LaPorte AFDU and the LPMEOH™ Process Demonstration Unit described previously.

Cost: Up to \$875,000 of Project funds would be available to support a suitable LPDME run. An update of the CCT Project's Cost Plan (22 October 1996), based upon the DVT Recommendation, will be performed following the joint Partnership/DOE decision.

Schedule: If the DVT Recommendation is approved by the Partnership and DOE, the operating schedule for the LPMEOH™ Process Demonstration Unit will remain unchanged from the current Demonstration Test Plan (September 1996). The DVT would proceed according to the September 1996 DME Milestone Plan (included in the Demonstration Test Plan) and the schedule of the Liquid Fuels Program.

### References

1. Transportation energy consumption by fuel, 1975, 1995 and 2015: History: Energy Information Administration, *Short-Term Energy Outlook*, DOE/EIA-0202(96/4Q) (Washington, DC, October 1996), and *State Energy Data Report 1994*, DOE/EIA-0214(93). Projections: Table A2. Internet access at <http://www/eia.doe.gov/oiaf/aec97/figure.html#fig46>.
2. "Fuel and Power Coproduction - The Liquid Phase Methanol™ Process Demonstration at Kingsport", paper presented at Fifth Annual DOE Clean Coal Technology Conference, Tampa, FL, January 7-9, 1997.
3. Haldor Topsoe AS, "Preparation of Fuel Grade Dimethyl Ether", International Publication Number WO9623755, World International Property Organization, 08 August 1996.

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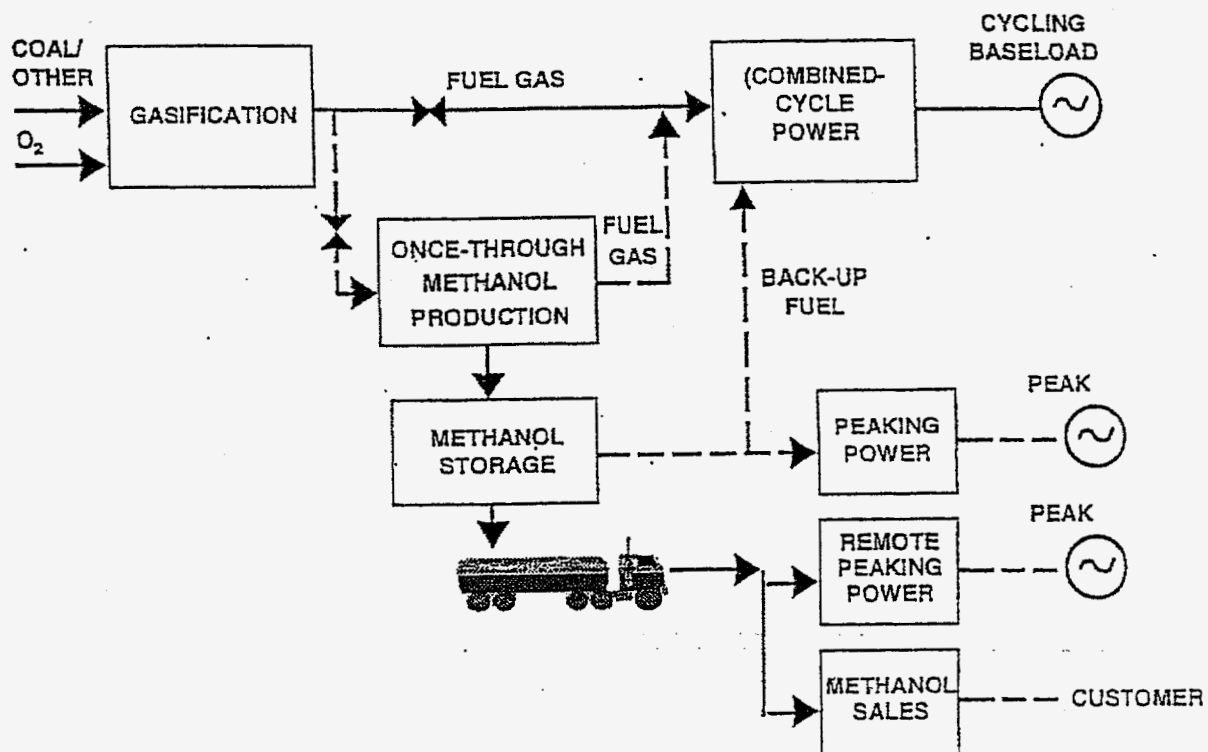
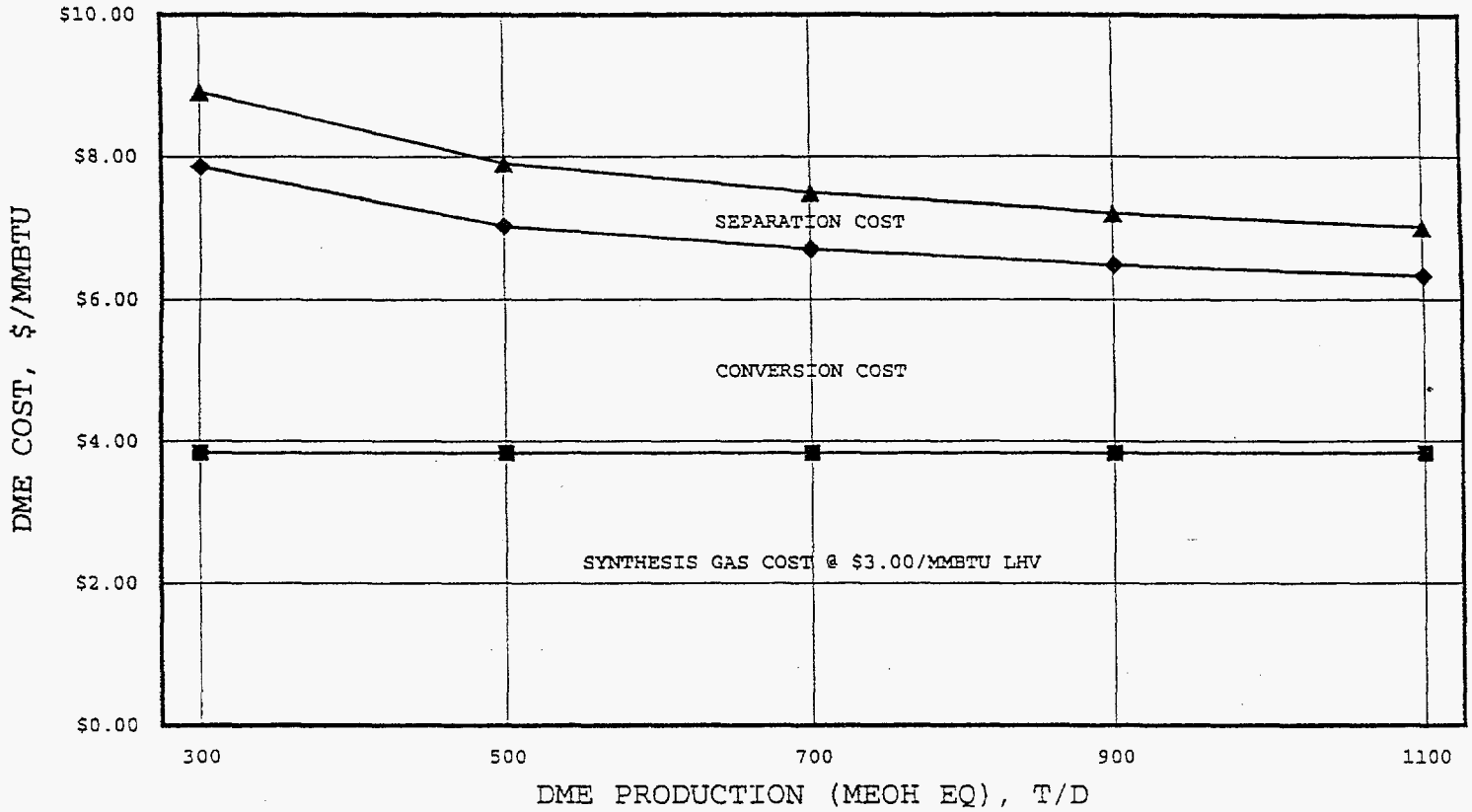


Figure 1. Once-through Methanol Coproduction with IGCC Electric Power

Figure 2

# DME COST VERSUS SIZE

TEXACO-TYPE SYNTHESIS GAS, 1:1 FEED:RECYCLE



■ SYNTHESIS GAS ONLY

◆ SYNTHESIS GAS PLUS CONVERSION

▲ TOTAL DME COST

# GOALS

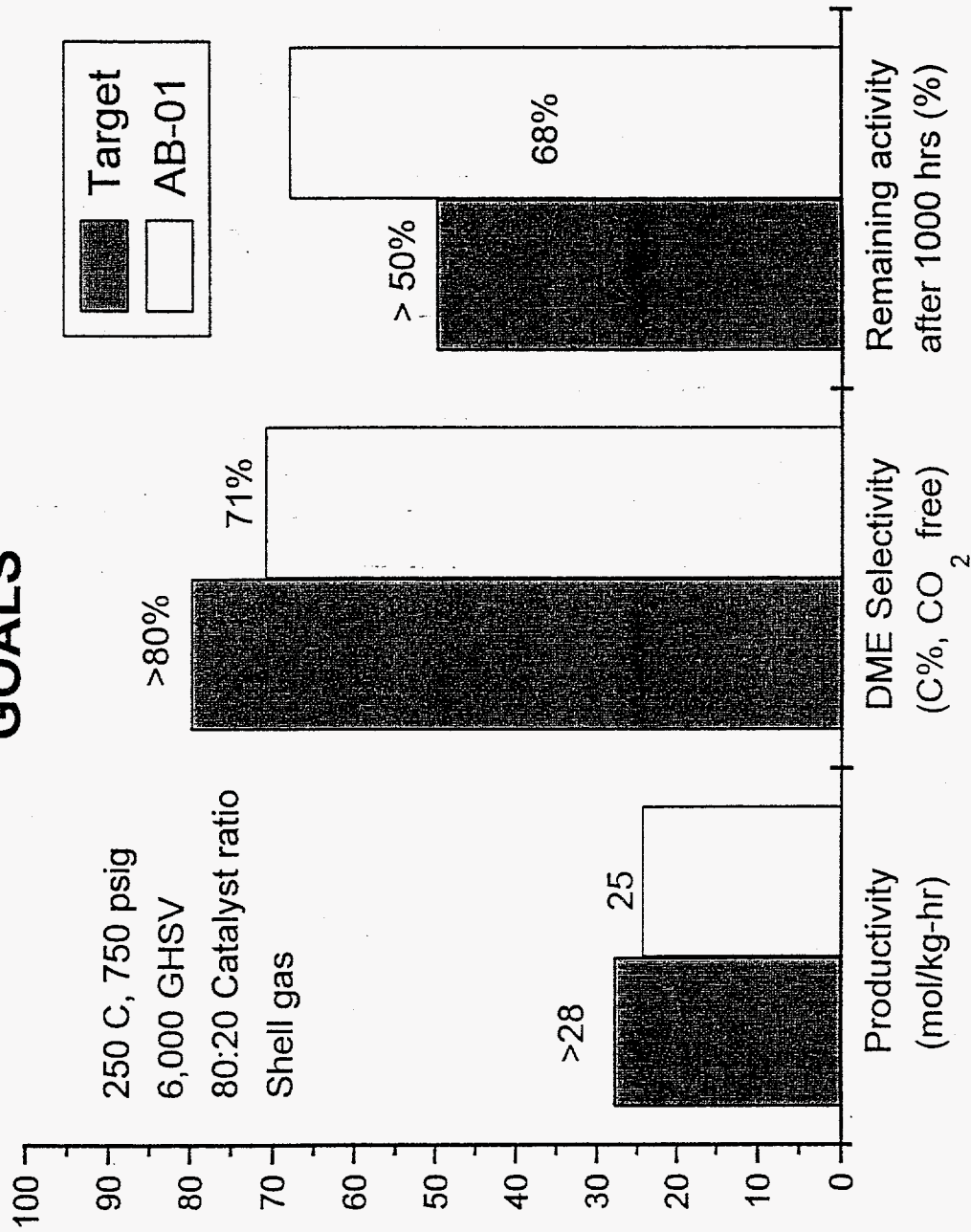
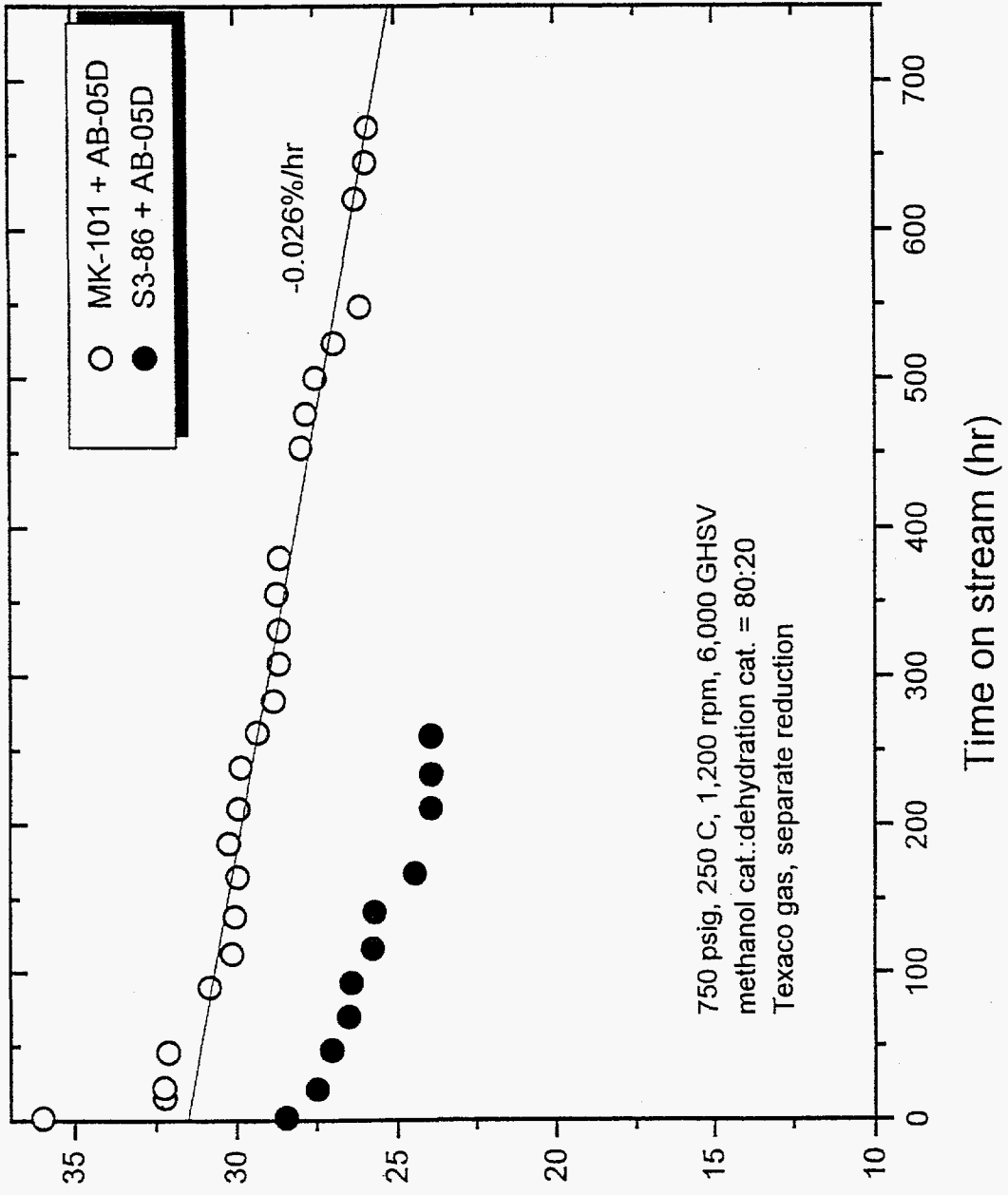


FIGURE 3

MEOH Equiv. Prod. (mol/kg-hr) **FIGURE 4**



- Six catalyst samples (#1 - #6) were developed with good stability and decent activity.

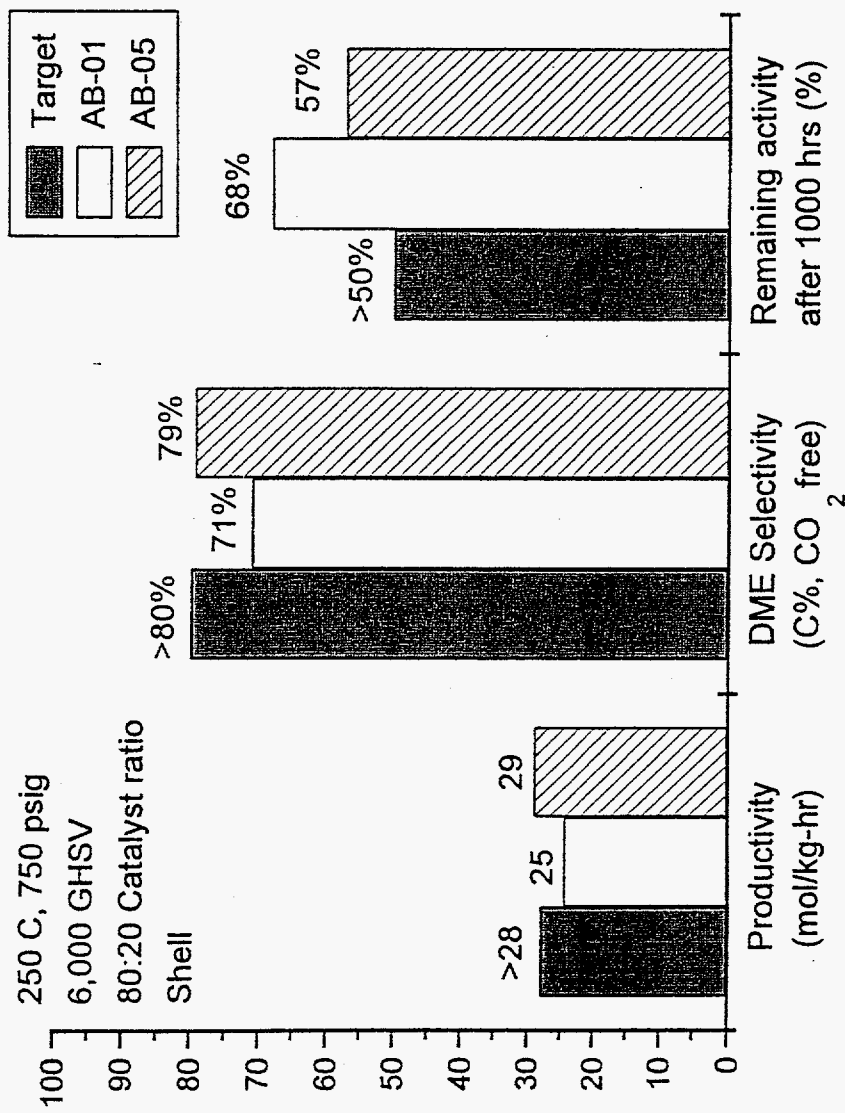


FIGURE 5

**APPENDIX F - TASK 1.5.4 - APPROVAL FOR BUDGET PERIOD THREE**



Department of Energy  
Washington, DC 20585

OCT 03 1996

MEMORANDUM

To: Sun Chou  
Director, Pittsburgh Energy Technology Center

From: Patricia Fry Godley *Patricia Fry Godley*  
Assistant Secretary for Fossil Energy

Subject: Approval of Request for Transition to the Final Budget Period Three for the  
Liquid Phase Methanol Process Demonstration Project Cooperative Agreement  
No. DE-FC22-92PC90543

You are authorized to transition from Budget Period Two (Design and Construction) to the final Budget Period Three (Commissioning, Startup, and Operation) on the demonstration project, "Commercial Demonstration of the Liquid Phase Methanol Process," Cooperative Agreement No. DE-FC22-92PC90543 in accordance with the Continuation Application Request of August 2, 1996, and supporting documentation. You are authorized to provide \$67,138,458 of funding as the Department of Energy's (DOE) share of the cost of the final Budget Period. The total estimated cost of the project remains at \$213,700,000 with a DOE cost share of \$92,708,370.

cc:  
C. L. Miller ✓  
G. Kight  
G. Lynch  
D. Archer  
J. Strakey, PETC  
R. Komosky, PETC



**APPENDIX G - TASK 2.5 - PARTNERSHIP ANNUAL PLAN  
(For FY - 97)**

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To: Distribution Dept./Loc.:

From: W. R. Brown Dept./Ext.: PSED/A31E9, X17584

Date: 11 November 1996

Subject: Partnership Annual Operating Plan for FY-97

---

Distribution:

cc: R. M. Kornosky/DOE/PETC

D. P. Drown/APCI                      L. B. Paulonis/EMN  
E. C. Heydorn/APCI                    V. E. Stein/APCI  
W. C. Jones/EMN                      P. J. A. Tijm/APCI  
R. B. Moore/APCI

Background

The Partnership Agreement requires that an Annual Operating Plan be prepared each Fiscal Year for the approval of the Partners. Article 5.2 of the Partnership Agreement sets forth the requirements. This memo constitutes the Partnership's Annual Operating Plan for FY-'97.

Goals and Objectives for FY- '97

The goals and objectives for FY-'97 are to initiate Phase 3 operation of the LPMEOH™ demonstration plant in accordance with the Statement of Work. The Milestone Schedule (Attachment A), the Demonstration Test Plan (Attachment B), the FY-97 Cost Plan (Attachment C) and the Project Success Factors (Attachment D) are attached for reference. These attachments summarize the Phase 3, Operation activities, and the schedule for their performance. The Partnership's major FY-'97 objectives are:

- the LPMEOH™ demonstration plant will have successfully completed Test Runs #1 through #5 (by May-'97), and will have achieved 30 plus weeks of Task 2.1.1 operation (by Sept-'97).

- the decision to continue DME design verification testing, at the LaPorte AFDU in conjunction with the DOE Alternative Fuels R & D program, will have been made (by Dec.'96); and plans will have been made (by Apr '97) for completion of the operational proof of concept testing at LaPorte by December of 1997.

- the updated plan for Off-site Product-use Testing will have been completed (by May '97).

- the project Success Factors will continue to have been achieved during FY-97.



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W. R. Brown

Approved:



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Air Products/W.R. Brown



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Eastman/W.C. Jones

# MILESTONE SCHEDULE STATUS REPORT LIQUID PHASE METHANOL DEMONSTRATION DE-FC22-92PC90543

Attachment A

Task Name	Duration	Start	End	Years													
				93	94	95	96	97	98	99	0	1	2				
<b>PHASE 1: DESIGN</b>																	
PROJECT DEFINITION(TASK 1)	51.20 m	Oct/01/93	Dec/30/97														
CONTINUATION APPLICATION PERMITTING(TASK 2)	12.04 m	Oct/01/93	Sep/30/94														
NEPA FONSI APPROVAL	9.00 d	Aug/02/94	Aug/10/94														
DESIGN ENGINEERING(TASK 3)	33.09 m	Nov/17/93	Aug/15/96														
VENDOR ENGINEERING	0.00 d	Jun/30/95	Jun/30/95														
OFF-SITE TESTING(TASK 4)	27.71 m	Apr/15/94	Aug/01/96														
UPDATED FUEL TEST PLAN APPROVAL	23.79 m	Aug/10/94	Jul/30/96														
DECISION TO CONTINUE DME TESTING	46.35 m	Feb/25/94	Dec/30/97														
PLANNING, ADMIN & DME DVT(TASK 5)	0.00 d	Apr/30/97	Apr/30/97														
<b>PHASE 2: CONSTRUCTION</b>																	
PROCUREMENT(TASK 1)	39.16 m	Dec/01/96	Dec/01/96														
CONSTRUCTION(TASK 2)	42.66 m	Oct/17/94	May/01/98														
TRAINING & COMMISSIONING(TASK 3)	21.54 m	Oct/17/94	Jul/30/96														
OFF-SITE TESTING(TASK 4)	15.08 m	Oct/02/95	Dec/31/96														
PLANNING & ADMINISTRATION(TASK 5)	16.53 m	Sep/05/95	Jan/17/97														
CONTINUATION APPLICATION(B.P. #3)	9.01 m	Aug/02/97	May/01/98														
<b>PHASE 3: OPERATION</b>																	
START-UP(TASK 1)	35.17 m	Jun/01/95	May/01/98														
METHANOL OPERATION(TASK 2.1)	77.00 d	May/31/96	Aug/15/96														
DISMANTLE PLANT(TASK 2.3)	59.51 m	Jan/20/97	Dec/28/01														
ON-SITE PRODUCT USE DEMO(TASK 3)	1.22 m	Jan/20/97	Feb/25/97														
OFF-SITE PRODUCT USE DEMO(TASK 4)	49.02 m	Feb/17/97	Mar/13/01														
DATA ANALYSIS/REPORTS(TASK 5)	6.96 m	Jun/01/01	Dec/28/01														
PLANNING & ADMINISTRATIVE(TASK 6)	2.08 m	Aug/01/97	Oct/02/97														
<b>PROVISIONAL DME IMPLEMENTATION</b>	20.00 m	May/15/98	Jan/11/00														
DME DVT(PDU TESTS)(TASK 3.6)	56.35 m	Jan/20/97	Sep/23/01														
DECISION TO IMPLEMENT	59.51 m	Jan/20/97	Dec/28/01														
DESIGN, MODIFY & OPERATE(TASK 3.2.2)	49.02 m	Apr/01/97	Apr/25/01														
	9.57 m	Apr/01/97	Jan/15/98														
	0.00 d	Mar/01/98	Mar/01/98														
	33.98 m	Jul/01/98	Apr/25/01														

Milestone Δ Summary □

Attachment 1

TABLE 5-1 - DEMONSTRATION TEST PLAN

Test Run #	Test Run Description	Temp (Deg C)	Wt% Cat	H2/CO Ratio at Inlet	Space Velocity (SI/hr-kg)	MeOH (lpd)	Fresh Feed		Recycle Gas (KSCFH)	Inlet Sup. Velocity (ft/sec)	Time Period (weeks)	Elapsed Time (incl. outages) (weeks)	Start of Test
							Balanced (KSCFH)	CO Gas (KSCFH)					
<b>Task 2.1.1 - Process Shakedown and Catalyst Aging:</b>													
1.	Initial Shakedown; and Design Production Tests	250	28	2.42	8,000	260	900	50	1,800	0.64	6	6	Feb-97
							(varies, to maintain syngas utilization.)						
2.	Gassed Slurry Level	Part of other tests											
3.	Reactor Feed: Texaco-Type Syngas	250	28	0.67	9,240	202	650	95 (*)	2,612 (*)	0.77	2	9	Mar-97
4.	Early Testing @ High Superficial Velocity	250	28	2.54	10,300	TBD	1,200 (**)	50	2,520 (*)	0.88	2	12	Apr-97
5.	Check @ Test 1 Conditions	250	28	2.42	8,000	< 260	900	50	1,800	0.64	2	15	May-97
6.	Catalyst Addition and Aging	250 or less	28 - 40	2.51	Dec. from 8,000	237	765	40	Max (2,700)	0.79	18	41	May-97 to Nov-97
<i>(Note: Kingsport Complex Outage during this test)</i>													
7.	Free-Drain Entrained/ Condensed Oil to Reactor	250 or less	28 - 40	2.51	Dec. from 8,000	237	765	40	Max	0.79	During Test 6		
8.	Operation @ Design Feed Gas Rates	250	40	2.42	4,000	260	900	50	1,800	0.64	2	43	Nov-97
9.	Check for Limitation on Catalyst Slurry Concentration	250	> 40	2.51	Varies	TBD	765	40	Max (2,700)	0.79	6	50	Dec-97
10.	Catalyst Addition to Reach Max Productivity	250 or less	Target 45	2.49	3,320	256	765	40	2,605	0.79	12	68	Jan-98
				2.29	3,500	293	900	50	2,520	0.81	2		
				TBD	TBD	TBD	1,110 (**)	50	2,520	0.86	2		

Attachment C

U.S. DEPARTMENT OF ENERGY  
COST PLAN

OMB Control No.  
1910-1400

DOE F 1332.7  
(12-85)

1. TITLE	2. IDENTIFICATION NUMBER		4. COST PLAN DATE		CURRENT FISCAL YEAR (FY97)												12. FUTURE FISCAL YEARS		13. Subsequent Fiscal Years	
	DE-FC22-92PC90543		October 22, 1996														98 99		00	
	5. START DATE January 1, 1990		6. COMPLETION DATE December 30, 2001		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total	98	99	00
2. PARTICIPANT NAME AND ADDRESS	Liquid Phase Methanol Demonstration																			
	Air Products and Chemicals, Inc.																			
	7201 Humhoul Boulevard																			
	Allentown, PA 18195-4911																			
8. Reporting Element	9. Plan Prior Fiscal Years	10. Act. Prior Fiscal Years	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Total	12. FUTURE FISCAL YEARS		13. Subsequent Fiscal Years		
Prior to Mod 2	16,289	16,304	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16,304
1.1.1 Project Definition	1,021	1,051	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,051
1.1.2 Permitting	246	238	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	238
1.1.3 Design Engr.	9,677	10,034	200	200	160	160	160	160	21	0	0	0	0	0	1,301	0	0	0	0	11,335
1.1.4 Off-Site Testing	74	12	0	5	10	10	15	15	15	20	20	30	30	30	175	89	0	0	0	276
1.1.5 Plan, Admin, DME Verif Test	1,892	2,707	40	40	13	0	0	0	0	0	0	0	0	0	163	0	0	0	0	2,870
1.2.1 Procurement	8,655	9,220	150	100	33	0	0	0	0	0	0	0	0	0	483	0	0	0	0	9,703
1.2.2 Construction	9,598	7,444	1,200	1,000	800	600	400	30	30	46	0	0	0	0	4,106	0	0	0	0	11,550
1.2.3 Training & Commissioning	1,163	117	200	250	98	0	0	0	0	0	0	0	0	0	998	0	0	0	0	1,115
1.2.4 Off-Site Test-Proc.&Constr	0	0	0	0	0	0	0	0	0	0	0	20	50	50	120	136	0	0	0	256
1.2.5 Planning & Admin	613	721	45	45	10	10	10	10	15	15	15	15	15	15	285	9	0	0	0	1,015
1.3.1 Startup	0	0	0	0	0	680	0	0	0	0	0	0	0	0	680	0	0	0	0	680
1.3.2 Operations	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3.2.1 Methanol Operation	0	0	0	0	2,524	2,524	2,545	2,546	2,546	2,546	2,545	2,545	2,545	2,546	20,321	34,240	38,689	40,061	13,174	146,485
1.3.2.2 DME Design, Mod., Oper.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	567	1,223	0	1,790
1.3.2.3 LPMEOH Dismanment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1.3.3 On-Site Testing	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	2	0	0	0	4
1.3.4 Off-Site Testing	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,213	1,972	246	3,451
1.3.5 Data Analysis & Reports	0	0	0	0	13	13	61	61	61	61	61	61	61	61	390	520	500	553	707	2,670
1.3.6 Plan., Adm., & DME La Pt.	0	0	0	0	20	20	20	20	50	50	80	100	100	100	520	800	280	282	510	2,392
15. TOTAL	49,228	47,848	1,835	1,640	1,440	1,865	3,283	2,772	2,871	2,754	2,721	2,761	2,801	2,801	29,544	42,008	42,365	14,906	213,700	
16. DOLLARS EXPRESSED IN:	Thousands																			
17. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE	[Signature]																			
18. SIGNATURE OF PARTICIPANT'S AUTHORIZED FINANCIAL REPRESENTATIVE AND DATE	Susan Kasner 10/22/96																			



**DOE/Air Products/Eastman  
SUCCESS FACTORS  
LPMEOH™ DEMONSTRATION PROJECT**



The three participants will judge the project success on the following factors:

- SAFE AND ENVIRONMENTALLY SOUND OPERATION
- DEMONSTRATE THE NEW TECHNOLOGY:
  - RESOLVE ALL TECHNICAL ISSUES
  - ACQUIRE SUFFICIENT ENGINEERING DATA FOR COMMERCIAL DESIGNS
  - OBTAIN INDUSTRY ACCEPTANCE
- FOR EASTMAN OPERATION AT KINGSPORT:
  - NO ADVERSE IMPACT DURING DEMONSTRATION
  - VALUABLE PLANT ASSET AT END
- MEET BUDGET AND SCHEDULE EXPECTATIONS
- POSITIVE WORKING RELATIONSHIPS BETWEEN THE PARTICIPANTS

Bob Komarsky

Bill Brown

Bill Jones

**APPENDIX H - TEST AUTHORIZATION #K1 - INITIAL SHAKEDOWN AND  
DESIGN PRODUCTION TESTS**



**TEST AUTHORIZATION # K1**  
Kingsport LPMEOH™ Plant

Sheet: 1 of 3  
Date : 03/31/97  
By: VES

RUN NUMBER: K1 (also incorporating K7)  
APPROX. START DATE: 1 April, 1997

TITLE: METHANOL SYNTHESIS WITH BASELINE CATALYST:  
INITIAL SHAKEDOWN AND DESIGN PRODUCTION TESTS

**OBJECTIVE:**

To start-up the LPMEOH™ facility, test the design methanol production rate, and shakedown various systems critical to successful long-term operation of the plant.

**SUMMARY:**

After activation of the initial catalyst charge (approximately 20,000 lbs of catalyst oxide, or about 1/2 of the design catalyst loading in the reactor), the start-up of methanol operations will initiate a total system shakedown and test of the design methanol production rate of 260 TPD. This 6-week operating period prior to Eastman's complex outage will facilitate testing of systems which must operate on a continuous basis (e.g. recycle compression, carbonyl guard bed, reactor/steam system, oil collection and return, methanol collection and distillation, data acquisition, analytical, etc.). The process control strategy will be validated and tuned, and material balance calculations will be performed. During this test, catalyst activity will decrease slowly due to normal catalyst aging. Fresh Feed flowrates will be adjusted to maintain Syngas Utilization at its initial value.

TEST DETAILS: See pages 2 to 3 for details.

ANALYTICAL COMMENTS: See page 3.

**SAFETY IMPLICATIONS:**

Air Products personnel will be required to wear Nomex in the plant when syngas is present. Otherwise, Eastman safety rules (including M.O.C.) are in effect. All visitors to the facility must follow the Visitor Safety Guidelines issued by the Joint Venture.

**ENVIRONMENTAL IMPLICATIONS:**


Minimal. The plant syngas purge will go to the Eastman boilers as designed.

**SPECIAL REMARKS:**

Because of ongoing problems with the 29G-03 Oil Make-up Pumps, which provide high pressure seal flush to the 29G-01 Condensed Oil Circulation Pumps and batch make-up oil into the reactor loop, Test #K1 will also incorporate Test #K7. The objective of Test #K7 is to test the capability of the system to free-drain condensed and entrained oil/catalyst from the 29C-06 Cyclone and 29C-05 Secondary Oil K.O. Separator back to the reactor. During this period the 29G-30 Slurry Transfer Pump will provide make-up oil to the process in batches as necessary. It requires only low pressure packing flush oil, which the 29G-03 can provide.

**AUTHORIZATIONS:**

  
\_\_\_\_\_  
E. C. Heydorn - Program Manager

  
\_\_\_\_\_  
V. E. Stein - Lead Process Engineer

**TEST AUTHORIZATION # K1**  
Kingsport LPMEOH™ Plant

Sheet: 2 of 3  
Date : 03/31/97  
By: VES

TEST DETAILS:

1. Set up N2 purges to the vent header at 100 SCFH on each of the rotameters by the 29E-01 (FI-1970) and 29C-02 (FI-1115).
2. Follow the Reactor Area Start-Up Procedure S.O.P. Section II A 3. After the start-up preparation steps (A-C), continue with Step D.
  - D. Charge fresh oil from 29D-30 to 29C-05 secondary oil K.O. vessel and 29C-06 cyclone.
  - E. Place 29K-01 syngas recycle compressor in service.
  - F. Transfer reduced catalyst slurry from 29D-02 slurry tank to the reactor (via 29G-02) per Section IV A 9 Steps K, L, M, and N. **The slurry temperature must not exceed ambient temperature by more than 165 °C.**
  - G. Start N2 Flow from 29K-01 to reactor.
  - H. Start BFW to 29C-02 steam drum and reactor tubes.
  - I. Start CW flow to 29E-04 MeOH product CW condenser.
  - J. Start fans on 29E-03 MeOH product air-cooled condenser.
  - K. Heat reactor to 204 °C at <30 °C/hr. **Initially BFW / steam temperature should not exceed slurry temperature by more than 150 °C. Once the slurry temperature exceeds 125 °C, BFW / steam temperature should not exceed slurry temperature by more than 40 °C.**
3. Because condensed and entrained oil/catalyst will free-drain back to the reactor, omit Steps L-O. Instead, ensure that automatic valves HV-184 and HV-185 are both shut.
4. Continue with Step P.
  - P. Start fresh feed syngas to plant.
  - Q. Establish level control for 29C-03 high pressure MeOH separator.
5. At Step R, raise the reactor pressure (PIC-150) and temperature (TIC-109) to the design operating conditions: 735 psig and 250 °C. Set the syngas flow rate (FIC-009) at 990 KSCFH, and skip Steps S and T until Plant 19 lines out at reduced rates and the H2 Makeup composition reaches its new steady state. Eventually, new feed setpoints will be calculated for the CO and H2 Makeup streams. Then, FIC-009 will be reduced by that combined flow rate to maintain total fresh feed at 990 KSCFH. Set the compressor flow (FIC-008) at 1,760 KSCFH.
6. During the first 24 hours, the syngas conversion across the reactor may decrease as the catalyst loses its initial hyperactivity. As a result, the purge flow (FI-157) may increase. Eventually, the purge rate should be about 160 KSCFH.
7. To free-drain condensed and entrained oil/catalyst from 29C-05 and 29C-06 to the reactor, open HV-185 and the necessary manual valves. Monitor levels in the 29C-05 (LI-102) and 29C-06 (LI-152), as well as the reactor NDG.

TEST AUTHORIZATION # K1  
Kingsport LPMEOH™ Plant

Sheet: 3 of 3  
Date : 03/31/97  
By: VES

8. Until the 29G-03 pumps are repaired, oil will be batch transferred into the system as needed by the 29G-30 pump per S.O.P. Section II C 3 Step P.
9. The shakedown period will likely conclude with the Eastman complex outage in mid-May. In that event, purge, cool, and drain the reactor system according to the Reactor Area Extended Shutdown Procedure (S.O.P. Section II A 8).

TEST AUTHORIZATION #K1 is complete.

ANALYTICAL REQUIREMENTS:

1. Process GC sampling requirements:
  - SP-1: syngas feed;
  - SP-4: K-01 outlet;
  - SP-5: reactor feed (highest frequency);
  - SP-6: C-05 outlet (highest frequency);
  - SP-7: main purge;
  - SP-8: distillation purge;
  
  - SP-2 and SP-3 can remain valved out until required.
2. Carbonyl GC sampling requirements:
  - SP-12: 29C-40 guard bed inlet;
  - SP-13: 29C-40 guard bed intermediate #1;
  - SP-14: 29C-40 guard bed intermediate #2;
  - SP-15: 29C-40 guard bed outlet.
3. Liquid sampling requirements:
  - all identified liquid sampling points per standard Eastman routine.

**APPENDIX I - TASK 3.2.1 - RESULTS OF DEMONSTRATION PLANT  
OPERATION**

**Table 1 - Summary of LPMEOH™ Demonstration Unit Outages -  
April/June 1997**

**Figure 1 - Sparger Resistance Coefficient vs. Days Onstream -  
April/June 1997 Operating Period**

**Figure 2 - Catalyst Life ( $\eta$ ) vs. Days Onstream**

Table 1 - Summary of LPMEOH™ Demonstration Unit Outages - April/June 1997

Operation Start	Operation End	Operating Hours	Shutdown Hours	Reason for Shutdown
4/2/97 09:00	4/2/97 16:15	7.3	4.8	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/2/97 21:05	4/2/97 21:25	0.3	23.3	Liquids to K-01
4/3/97 20:40	4/4/97 11:00	14.3	24.8	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/5/97 11:45	4/6/97 01:45	13.0	5.8	C-03 Outlet Plugged
4/6/97 07:30	4/7/97 13:05	29.6	2.1	C-03 Outlet Plugged
4/7/97 15:10	4/8/97 06:30	15.3	21.5	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/9/97 04:00	4/9/97 05:30	1.5	4.0	ESD on C-02 Level
4/9/97 09:30	4/9/97 14:20	4.8	9.7	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/10/97 00:00	4/11/97 08:25	32.4	14.8	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/11/97 23:15	4/18/97 18:05	162.8	0.7	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/18/97 18:45	4/19/97 07:50	13.1	0.7	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/19/97 08:30	4/23/97 00:20	87.8	20.7	Syngas Unavailable to LPMEOH™ Demonstration Unit
4/23/97 21:00	4/23/97 21:00	0.0	12.0	Replace TV-101 Trim
4/24/97 09:00	5/8/97 23:59	351.0	950.1	* Syngas Unavailable to LPMEOH™ Demonstration Unit
6/17/97 14:05	6/30/97 23:59	321.9		** Syngas Unavailable to LPMEOH™ Demonstration Unit
				End of Reporting Period
			1055.2	
			1112.0	
			94.9	

Total Operating Hours  
 Syngas Available Hours  
 Plant Availability, %

\* Plant was ready to startup, but Eastman waited 12 hours to give the day crew training on startup procedures.

\*\* Eastman complex outage.

Figure 1 - Sparger Resistance Coefficient vs. Days On-stream  
April/June 1997 Operating Period

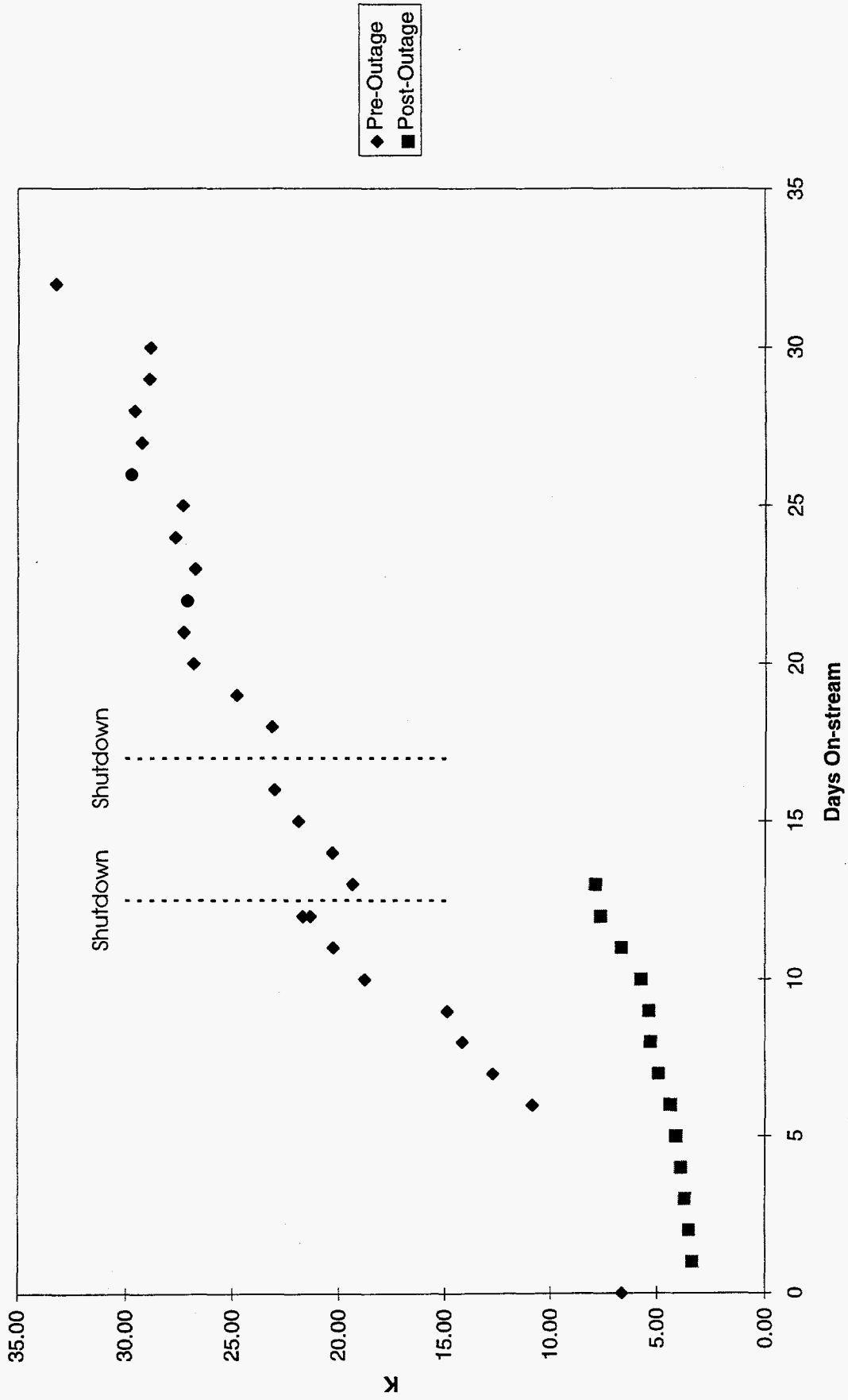
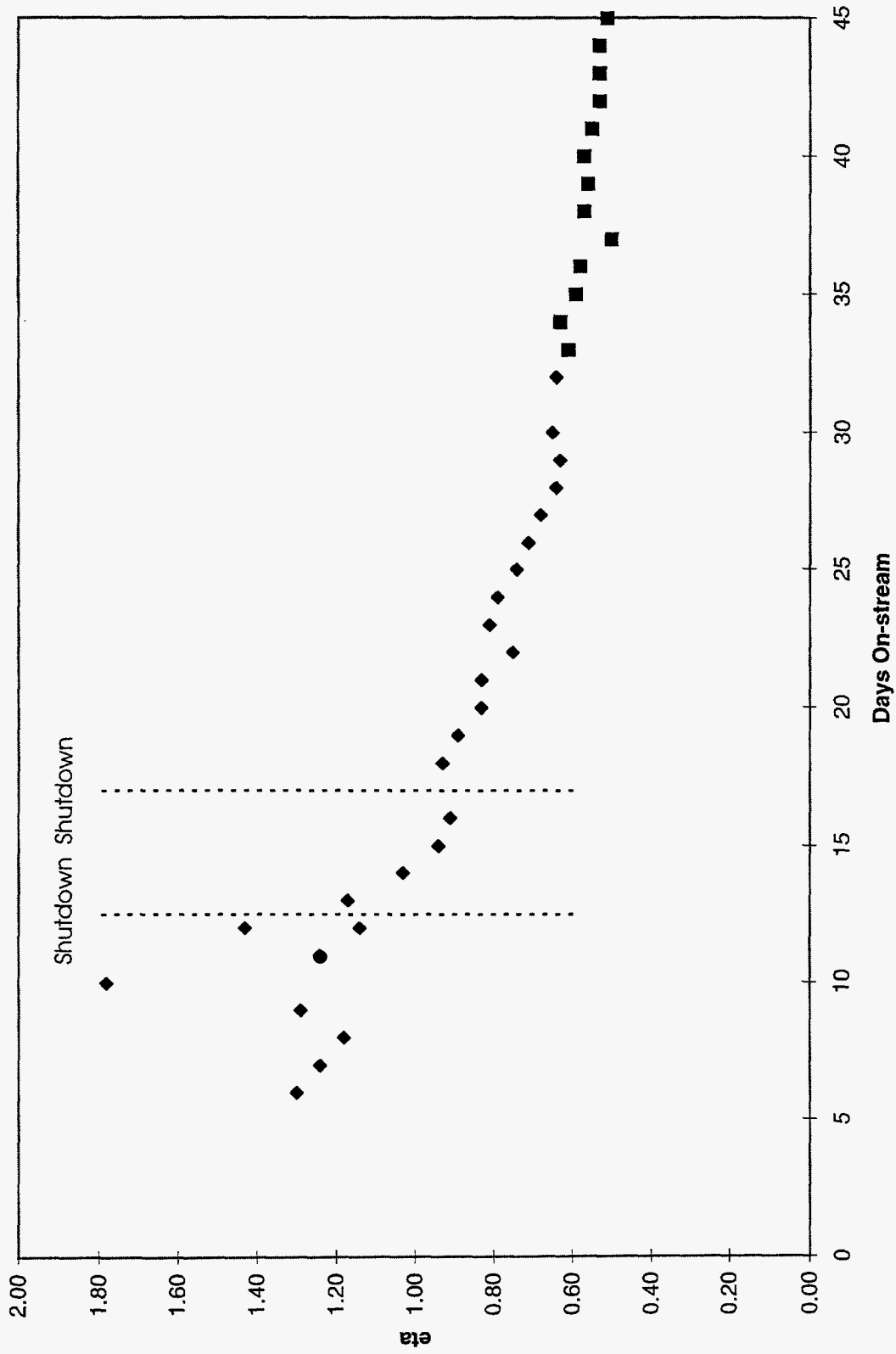


Figure 2 - Catalyst Life vs. Days On-Stream  
April/June 1997 Operating Period



**APPENDIX J - TASK 3.2.1 - SAMPLES OF DETAILED MATERIAL BALANCE  
REPORTS**



RUN NO:

K1-412

TITLE: Shakedown & Design Production Tests

Balance Period:

Start Date  
End Date

12apr97 7:00:00  
13apr97 7:00:00

Time From Start of Run (days)

Start  
End

5.7  
6.7

Reaction Conditions

Temperature (°F)  
Pressure (psig)  
Space Velocity (sL/kg-hr)  
Vg (inlet)

478  
719  
6203  
0.50

Slurry Data

Catalyst Weight (lb oxide)  
Slurry Concentration (wt %)  
Slurry Level (ft)  
Gas Holdup (vol %)  
Gassed Slurry Volume (ft3)

20,300  
30.5  
54.9  
50.2  
2306

Performance Results

Raw MeOH Production (ton/day)  
Raw MeOH Production (ton/day)  
Syngas Utilization (SCF/lb MeOH)

242.3 (gas measurements)  
242.3 (liquid measurements)  
37.6

Energy Balance

Steam Production (lb/hr)  
Steam Drum Pressure (psig)  
Steam Import/Export (lb/hr)  
Reactor O-T-M Conversion (% LHV)  
Wetted Tube Length (ft)  
Heat Transfer Area (ft2)

17955  
308  
1185  
33.1  
51.1  
1981

CO Conversion (total) (%)  
CO Conversion to MeOH (%)  
CO Conversion to H2 (%)  
Theoretical Conversion % (1 CSTR)  
Syngas Conversion (% LHV)  
Syngas Usage (BTU/gallon MeOH)  
Recycle Ratio  
MeOH Productivity (gmo/kg-hr)  
Rxt Volumetric Productivity (ton/day-ft3)

53.3  
54.8  
-1.60  
53.9  
85.5  
66,959  
1.81  
30.74  
0.105

Atom/Mass Balance Closure (% of reactor inlet)

C  
H  
O  
N  
Total Mass

100.15  
104.17  
100.95  
86.37  
101.12

Liquid Product Analysis (wt%)

REFINED PRODUCT

CRUDE PRODUCT

4/12 4/13  
13:00 1:00  
99.98 99.99  
0.01 0.01  
0.02 0.01  
0.00 0.00  
100.01 100.00

4/12 4/13  
13:00 1:00  
90.19 89.00  
0.25 0.25  
9.18 10.52  
0.15 0.15  
99.77 99.92

Methanol  
Ethanol  
Water  
Oil  
Total

RUN NO: K1-4/12 TITLE: Shakedown & Design Production Tests

	FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
T	70	61	61	95	306	246	80	53	227	74
P	744	857	719	742	739	714	708	6	185	142
Comp (mol %)										
H2	66.44	1.93	77.66	70.23	68.63	59.66	68.84	59.05	0.00	0.00
CO	31.35	97.05	9.12	14.25	20.27	12.27	13.86	8.11	0.00	0.00
N2	0.43	0.97	6.50	6.54	4.38	5.67	6.44	7.14	0.00	0.00
CH4	0.05	0.05	0.92	0.80	0.53	0.69	0.78	0.77	0.00	0.00
CO2	1.73	0.00	3.76	6.14	4.53	5.45	6.10	7.69	0.00	0.00
DME	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00
MeOH	0.00	0.00	0.06	0.25	0.32	14.81	1.87	5.15	83.50	99.98
EtOH	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.16	0.01
H2O	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.00	16.33	0.02
others	0.00	0.00	1.97	1.78	1.33	1.02	2.10	12.09	0.02	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mole Wt	11.013	27.501	7.770	10.693	10.874	13.746	11.119	17.882	29.822	32.038
LHV	214.3	0.0	0.0	339.9	554.3	530.6	8.6	2.2	50.4	132.9
Enthalpy	-35.75	0.00	0.00	-64.64	-91.74	-120.88	-1.72	-0.61	-21.32	-47.08
Flow										
SCFH	758,227	0	0	1,374,926	2,131,233	1,645,533	33,657	9,362	78,566	173,502
lbmol/hr	1,998.8	0.0	0.0	3,624.5	5,618.2	4,337.8	88.7	24.7	207.1	457.4
lb/hr	22,012	0	0	38,756	61,091	59,628	987	441	6,176	14,653

RUN NO: K1-4/19

TITLE: Shakedown & Design Production Tests

**Balance Period:**

Start Date 19apr97 10:00:00  
 End Date 20apr97 07:00:00

**Time From Start of Run (days)**

Start 12.8  
 End 13.7

**Reaction Conditions**

Temperature (°F) 480  
 Pressure (psig) 709  
 Space Velocity (sL/kg-hr) 8562  
 Vg (inlet) 0.70

**Slurry Data**

Catalyst Weight (lb oxide) 20,300  
 Slurry Concentration (wt %) 32.2  
 Slurry Level (ft) 52.4  
 Gas Holdup (vol %) 51.5  
 Gassed Slurry Volume (ft3) 2202

**Performance Results**

Raw MeOH Production (ton/day) 292.2 (gas measurements)  
 Raw MeOH Production (ton/day) 292.2 (liquid measurements)  
 Syngas Utilization (SCF/lb MeOH) 39.4  
 CO Conversion (total) (%) 47.5  
 CO Conversion to MeOH (%) 48.3  
 CO Conversion to H2 (%) -0.90  
 Theoretical Conversion % (1 CSTR) 48.0

**Energy Balance**

Steam Production (lb/hr) 21530  
 Steam Drum Pressure (psig) 256  
 Steam Import/Export (lb/hr) 1171  
 Reactor O-T-M Conversion (% LHV) 29.2  
 Wetted Tube Length (ft) 48.6  
 Heat Transfer Area (ft2) 1886

**Atom/Mass Balance Closure (% of reactor inlet)**

C 100.03  
 H 102.41  
 O 98.65  
 N 91.46  
 Total Mass 99.92

**Liquid Product Analysis (wt%)**

**REFINED PRODUCT**

4/19  
 13:00  
 99.97  
 0.01  
 0.03  
 0.00  
 100.01

**CRUDE PRODUCT**

4/19  
 19:00  
 91.30  
 0.25  
 8.44  
 0.15  
 100.14



RUN NO:

K5-6/30

TITLE: Recheck Test 1 Conditions

**Balance Period:**

Start Date  
End Date

30jun97 07:00:00  
01jul97 03:00:00

**Time From Start of Run (days)**

Start  
End

84.7  
85.5

**Reaction Conditions**

Temperature (°F)  
Pressure (psig)  
Space Velocity (s/L/kg-hr)  
Vg (inlet)

481  
706  
9019  
0.72

**Slurry Data**

Catalyst Weight (lb oxide)  
Slurry Concentration (wt %)  
Slurry Level (ft)  
Gas Holdup (vol %)  
Gassed Slurry Volume (ft3)

19,500  
28.1  
52.5  
43.9  
2206

**Performance Results**

Raw MeOH Production (ton/day)  
Raw MeOH Production (ton/day)  
Syngas Utilization (SCF/lb MeOH)  
Catalyst Life (eta)

198.4  
198.4  
43.0  
0.51

(gas measurements)  
(liquid measurements)

**Energy Balance**

Steam Production (lb/hr)  
Steam Drum Pressure (psig)  
Steam Import/Export (lb/hr)  
Reactor O-T-M Conversion (% LHV)  
Wetted Tube Length (ft)  
Heat Transfer Area (ft2)  
Reactor Overall U (BTU/hr-ft2-F)

12043  
360  
1377  
19.1  
48.7  
1890  
168

CO Conversion (total) (%)  
CO Conversion to MeOH (%)  
CO Conversion to H2 (%)

28.2  
29.9  
-1.84

Syngas Conversion (% LHV)  
Syngas Usage (BTU/gallon MeOH)  
Recycle Ratio  
MeOH Productivity (gmol/kg-hr)  
Fixr Volumetric Productivity (ton/day-ft3)  
Sparger "K"-value

75.5  
69,712  
3.18  
25.77  
0.090  
7.90

**Atom/Mass Balance Closure (% of reactor inlet)**

C  
H  
O  
N  
Total Mass

99.05  
99.31  
100.84  
94.65  
100.70

**Liquid Product Analysis (wt%)**

**REFINED PRODUCT**

**CRUDE PRODUCT**

Methanol  
Ethanol  
Water  
Off  
Total

6/30 7/1  
19:00 7:00  
99.94 99.97  
0.01 0.01  
0.06 0.03  
0.00 0.00  
100.00 100.01

6/30 7/1  
19:00 7:00  
85.84 85.59  
0.25 0.25  
13.76 14.05  
0.15 0.15  
100.00 100.04

RUN NO: K5-6/30 TITLE: Recheck Test 1 Conditions

T	F	FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
P	psig	89 752	77 868	79 496	114 738	328 729	247 697	97 685	71 8	222 185	81 139
Comp (mol %)		67.20 29.80 0.45 0.04 2.51	1.93 97.05 0.97 0.05 0.00	77.66 9.12 6.50 0.92 3.76	69.89 18.97 3.12 0.31 5.01	68.86 21.39 2.50 0.25 4.42	63.74 17.60 2.86 0.28 4.61	69.89 18.97 3.12 0.31 5.01	8.00 7.00 2.00 0.00 62.00	0.00 0.00 0.00 0.00 0.00	0.00 0.00 0.00 0.00 0.00
	DME	0.00	0.00	0.01	0.00	0.00	0.01	0.00	4.00	0.00	0.00
	MeOH	0.00	0.00	0.06	0.48	0.58	8.01	0.48	10.00	77.47	99.91
	EtOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.01
	H2O	0.00	0.00	0.00	0.00	0.00	0.47	0.00	0.00	22.35	0.08
	others	0.00	0.00	1.97	2.22	2.01	2.41	2.22	7.00	0.01	0.00
	TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Mole Wt	lb/lbmol	10.940	27.501	7.770	10.674	10.855	12.185	10.674	39.217	28.974	32.030
LHV	MMBTU/hr	198.8	0.0	0.0	585.1	784.9	766.0	23.7	1.6	33.6	116.5
Enthalpy	MMBTU/hr	-34.33	0.00	0.00	-108.23	-131.62	-157.68	-4.41	-3.01	-15.48	-41.26
Flow	SCFH	710,737	0	0	2,262,559	2,976,850	2,596,550	91,517	8,828	56,318	152,209
	lbmol/hr	1,873.6	0.0	0.0	5,964.4	7,847.3	6,844.8	241.3	23.3	148.5	401.2
	lb/hr	20,498	0	0	63,661	85,180	83,403	2,575	913	4,302	12,852

**APPENDIX K - TEST AUTHORIZATION K22 - METHANOL SYNTHESIS WITH  
BGL-TYPE SYNGAS**

**TEST AUTHORIZATION # K22**

Kingsport LPMEOH™ Plant

Sheet: 1 of 2  
Date : 05/07/97  
By: VES

RUN NUMBER: K22  
APPROX. START DATE: 7 May, 1997

TITLE: METHANOL SYNTHESIS WITH BGL-TYPE SYNGAS

**OBJECTIVE:**

To evaluate the performance of the LPMEOH™ facility when fed with BGL-type (CO-rich) syngas per a typical IGCC application.

**SUMMARY:**

At a time when approximately 200 KSCFH of CO is available for use in Plant 29 over a multi-week period, the reactor feed composition will be adjusted to match the typical syngas composition exiting a BGL gasifier. The performance data from this test will be more directly comparable to the extensive database from the LaPorte pilot plant and more indicative of LPMEOH™'s expected market in IGCC facilities. The test will best be accomplished by maintaining essentially constant feed gas composition (SP-5), and the operators may adjust the Balanced Gas, CO Gas, and Recycle flow rates to achieve that. Liquid samples from the 29C-10 underflow should be collected periodically to test the stabilized product's suitability for fuel-grade applications.

TEST DETAILS: See page 2.

ANALYTICAL COMMENTS: See page 2.

**SAFETY IMPLICATIONS:**

Air Products personnel will be required to wear Nomex in the plant when syngas is present. Otherwise, Eastman safety rules (including M.O.C.) are in effect. All visitors to the facility must follow the Visitor Safety Guidelines issued by the Joint Venture.

**ENVIRONMENTAL IMPLICATIONS:**

Minimal. The plant syngas purge will go to the Eastman boilers as designed.

**SPECIAL REMARKS:**

Because of ongoing problems with plugging in the free-draining oil return line to the reactor, the current off-design operating mode will be continued. Condensed oil will be batch transferred from 29C-05 to 29C-30 and then returned to the reactor with the 29G-30 pump.

**AUTHORIZATIONS:**

  
\_\_\_\_\_  
E. C. Heydorn - Program Manager

  
\_\_\_\_\_  
V. E. Stein - Lead Process Engineer



## TEST AUTHORIZATION # K22

Kingsport LPMEOH™ Plant

Sheet: 2 of 2  
Date : 05/07/97  
By: VES

### TEST DETAILS:

1. Call the PIA's and have them set up SP-2 (CO Makeup) and add it to the analysis sequence.
2. Follow the Reactor Area Start-Up Procedure S.O.P. Section II A 3 Step T - start CO makeup feed.
3. Line up CO flow through FE-010B (open valve 2025) and shut off flow through FE-010A (close valve 2026). Make sure the Honeywell DCS is set up to recognize FE-010B.
4. Slowly increase the flow on FC-010 to approximately 200 KSCFH while decreasing the flow on FC-009 to approximately 485 KSCFH. As the MW of the recycle stream begins to rise, the compressor flow will increase. Adjust it to maintain approximately 1570 KSCFH on FI-100.
5. The target feed gas composition (SP-5) in mol% (Honeywell schematic AnalD or AnalB) is: 32% H<sub>2</sub>, 61% CO, 5% CO<sub>2</sub>, 1% N<sub>2</sub>. In wt% (Honeywell schematic Anal\_D or Anal\_B), this corresponds to 3% H<sub>2</sub>, 83% CO, 11% CO<sub>2</sub>, 2% N<sub>2</sub>. Be patient when adjusting flows to match the target composition; Air Products personnel will advise.

TEST AUTHORIZATION #K22 is complete.

### ANALYTICAL REQUIREMENTS:

1. Process GC sampling requirements:
  - SP-1: syngas feed;
  - SP-2: CO makeup
  - SP-4: K-01 outlet;
  - SP-5: reactor feed (highest frequency);
  - SP-6: C-05 outlet (highest frequency);
  - SP-7: main purge;
  - SP-8: distillation purge;
  
  - SP-3 can remain valved out.
2. Carbonyl GC sampling requirements:
  - SP-12: 29C-40 guard bed inlet;
  - SP-13: 29C-40 guard bed intermediate #1;
  - SP-14: 29C-40 guard bed intermediate #2;
  - SP-15: 29C-40 guard bed outlet.
3. Liquid sampling requirements:
  - all identified liquid sampling points per standard Eastman routine;
  - 29C-10 underflow samples may be shipped to Allentown for by-product analysis.

**APPENDIX L - METHODS OF CALCULATION FOR KEY PROCESS  
PARAMETERS**

$$\text{Catalyst Age } (\eta) = k_0/k_0(t=0)$$

where:

$k_0$  = the pre-exponential kinetic rate constant for the methanol synthesis reaction at any time

$k_0(t=0)$  = the pre-exponential kinetic rate constant for the methanol synthesis reaction for fresh catalyst

The rate constants are determined using a proprietary model which computes the kinetic rate constant for the methanol synthesis reaction.

$$\text{CO Conversion to Methanol [\%]} =$$

$$\frac{(\text{Raw Methanol Flow} + \text{Methanol in Main Plant Purge} + \text{Methanol in Distillation Purge [all lbmol/hr]})}{\text{Carbon Monoxide in Reactor Feed [lbmol/hr]} * 0.01}$$

where:

$$\text{Methanol in Main Plant Purge [lbmol/hr]} = \text{Main Plant Purge Flow [lbmol/hr]} * \text{Methanol Concentration in Main Plant Purge [mol\%]}$$

$$\text{Methanol in Distillation Purge [lbmol/hr]} = \text{Distillation Purge Flow [lbmol/hr]} * \text{Methanol Concentration in Distillation Purge [mol\%]}$$

$$\text{Carbon Monoxide in Reactor Feed [lbmol/hr]} = \text{Reactor Feed Flow [lbmol/hr]} * \text{Carbon Monoxide Concentration in Reactor Feed [mol\%]}$$

$$\text{Gas Holdup (vol\%)} = \frac{(\text{Liquid-Solid Density [lb/ft}^3\text{]} - \text{3-Phase Density [lb/ft}^3\text{]}) * 100}{(\text{Liquid-Solid Density [lb/ft}^3\text{]} - \text{Vapor Density [lb/ft}^3\text{]})}$$

where:

Vapor Density [lb/ft<sup>3</sup>] is calculated using the composition at the Reactor Effluent, and at the measured temperature and pressure of the Reactor

$$\text{3-Phase Density [lb/ft}^3\text{]} = \frac{\text{Pressure Drop [psi]} * 144 \text{ [in}^2\text{/ft}^2\text{]}}{\text{Span between Taps of Pressure Drop Measurement [ft]}}$$

Liquid-Solid Phase Density [lb/ft<sup>3</sup>] is a function of the catalyst concentration [wt%], which is iterated until the calculated weight of catalyst matches the catalyst weight in the Reactor.

Notes:

1. All terms in *Italics* refer to measured variables, either by field instruments or gas chromatographs.

$$\text{Gassed Slurry Volume [ft}^3\text{]} = \text{Reactor Cylindrical Volume [ft}^3\text{]} + \text{Reactor Head Volume [ft}^3\text{]}$$

where:      Reactor Cylindrical Volume [ft<sup>3</sup>] = A [ft<sup>2</sup>] \* Cylindrical Height [ft]

$$A \text{ [ft}^2\text{]} = \frac{\pi}{4} * (\text{Reactor ID [ft]})^2 * (\text{Fraction Open Area})$$

$$\text{Reactor ID} = \text{Reactor Inside Diameter} = 7.5 \text{ ft}$$

Fraction Open Area = 0.9652 (3.48% of the cross-sectional area of the Reactor is occupied by the tubes of the internal heat exchanger)

$$\text{Cylindrical Height [ft]} = \text{Gassed Slurry Height [ft]} - \frac{(\text{Reactor ID [ft]})}{4}$$

Note: The term “(Reactor ID)/4” is the depth of the bottom head of the Reactor.

$$\text{Reactor Head Volume [ft}^3\text{]} = \frac{\pi * (\text{Reactor ID [ft]})^3}{24} - 8 \text{ [ft}^3\text{]}$$

Note: 8 cubic feet is subtracted from the Reactor Head Volume to account for the displacement of the gas sparger and the header piping for the internal heat exchanger.

$$\text{Inlet Superficial Velocity [ft/s]} = \frac{\text{Reactor Feed Flow [lbmol/hr]} * V \text{ [ft}^3\text{/lbmol]}}{3,600 \text{ [s/hr]} * A \text{ [ft}^2\text{]}}$$

where:       $V \text{ [ft}^3\text{/lbmol]} = \frac{10.73 * (\text{Reactor Temperature [}^\circ\text{F]} + 459.67)}{(\text{Reactor Pressure [psig]} + 14.1)}$

$$A \text{ [ft}^2\text{]} = \frac{\pi}{4} * (\text{Reactor ID [ft]})^2 * (\text{Fraction Open Area})$$

$$\text{Reactor ID} = \text{Reactor Inside Diameter} = 7.5 \text{ ft}$$

Fraction Open Area = 0.9652 (3.48% of the cross-sectional area of the Reactor is occupied by the tubes of the internal heat exchanger)

Notes:

1. All terms in *Italics* refer to measured variables, either by field instruments or gas chromatographs.

$$\text{Methanol Productivity [gmol/kg-hr]} = \frac{(\text{Methanol in Reactor Effluent [lbmol/hr]} - \text{Methanol in Reactor Feed [lbmol/hr]}) * 1,000 \text{ [g/kg]}}{\text{Catalyst Weight (lb oxide)}}$$

where:

$$\text{Methanol in Reactor Effluent [lbmol/hr]} = \text{Reactor Effluent Flow [lbmol/hr]} * \text{Methanol Concentration in Reactor Effluent Stream [mol\%]}$$

$$\text{Methanol in Reactor Feed [lbmol/hr]} = \text{Reactor Feed Flow [lbmol/hr]} * \text{Methanol Concentration in Reactor Feed Stream [mol\%]}$$

$$\text{Reactor O-T-M Conversion [\%]} = \frac{\text{Lower Heating Value of Raw Methanol} * 100}{\text{Lower Heating Value of Reactor Feed}}$$

Note: Lower heating values for Raw Methanol and Reactor Feed are calculated from compositions of each stream, in units of million Btu per hour.

$$\text{Reactor Volumetric Productivity [TPD/ft}^3\text{]} = \frac{\text{Raw Methanol Flow [TPD]}}{\text{Gassed Slurry Volume [ft}^3\text{]}}$$

$$\text{Space Velocity [sL/kg-hr]} = \frac{\text{Reactor Feed Flow [lbmol/hr]} * 10,175 \text{ [sL/lbmol @ 0}^\circ\text{C]}}{\text{Catalyst Weight [lb oxide]} * 0.454 \text{ [kg/lb]}}$$

$$\text{Sparger Resistance Coefficient "K"} = \frac{\text{Sparger Pressure Drop [psi]} * \text{Reactor Feed Density [lb/ft}^3\text{]} * 10^9}{(\text{Reactor Feed Flow [KSCFH]} * \text{Reactor Feed Molecular Weight [lb/lbmol]})^2}$$

where:  $10^9$  is an arbitrary factor.

$$\text{Syngas Usage [Btu/gallon Methanol]} = \frac{\text{Syngas LHV to Methanol [Btu/hr]} * 24 \text{ [hr/day]} * 6.642 \text{ [lb/gallon Methanol]}}{\text{Raw Methanol Flow [TPD]} * 2,000 \text{ [lb/ton]}}$$

where:

Syngas LHV to Methanol [Btu/hr] = the difference between the Lower Heating Value of the three feed gas streams (Balanced Gas, CO Gas, H<sub>2</sub> Gas) and the two purge gas streams (Main Plant Purge, Distillation Purge). Lower heating values are calculated from the compositions of each stream.

Notes:

1. All terms in *Italics* refer to measured variables, either by field instruments or gas chromatographs.

$$\text{Syngas Utilization [SCF/lb Methanol]} = \frac{(\text{Balanced Gas Flow [SCFH]} + \text{CO Gas Flow [SCFH]}) * 24 \text{ [hr/day]}}{\text{Raw Methanol Flow [TPD]} * 2,000 \text{ [lb/ton]}}$$

**Notes:**

1. All terms in *Italics* refer to measured variables, either by field instruments or gas chromatographs.

**APPENDIX M - TASK 3.6 - INTERIM PROJECT REVIEW MEETING  
(29 & 30 April 1997)**

NOTES FROM MEETING

DISTRIBUTION (NAME/ORGANIZATION) *Unable to attend. **Chairman		COPIED FOR INFORMATION ONLY	
Jo Ann Franks - APCI	Bob Senn - APCI	Bharat Bhatt - APCI	
Frank Frenduto - APCI	John Shen - DOE FE-HQ	Dave Drown - APCI	
Bob Kornosky - DOE - FETC	Van Eric Stein - APCI	Barry Halper - APCI	
Bob Moore - APCI	Peter Tijn - APCI	Bill Jones - EMN	
Bill O'Dowd - DOE - FETC	Bernie Toseland - APCI	Barry Street - EMN	
X. D. Peng - APCI			

FROM Edward C. Heydorn <i>ESH</i>	ORGANIZATION APCI - Program Manager	EXTENSION 17099	TODAY'S DATE 20 May, 1997
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DATE OF MEETING April 29 & 30, 1997	WEEKDAY Tues. & Wed.	TIME STARTED 1:30 PM	ENDED 11:15 AM	LOCATION Tues. - in A3CR112K Wed. - in LNG CR A31E4
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SUBJECT AND/OR PURPOSE  
**• Project Review Meeting - DOE and Air Products**

ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
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1.	ECH	Updated 5/19/97	<p><b><u>DME Design Verification Testing - Status - Review</u></b></p> <p>The definition of the productivity of a commercially successful DME catalyst were reviewed. An 80%/20% methanol/DME catalyst productivity of 14 g-moles of methanol product equivalent per Kg of catalyst per hour of operation after six months of aging was defined as commercially successful for coproduction in an IGCC situation using Texaco-type of synthesis gas. Further definition includes an operating pressure of 1000 psig, a catalyst space velocity of 4000 sL/kg-hr and at 1:1 recycle:fresh feed gas ratio. The memo from R. Moore on LPDME economics is included (Attachment 1).</p> <p>Progress has been made in the laboratory effort. The latest results are included in the updated (5/19/97) DME Design Verification memo (Attachment 2). Figure 2 shows the performance for the first DME catalyst which was tested; goals from the Liquid Fuels Program are provided for reference. After further study, an improved DME catalyst (AB-05) was tested with two LPMEOH™ catalysts (S3-86 and MK-101); the results of a 700 hour life study are presented in Figure 3. When compared with the program goals (Figure 4), the catalyst performance of the newer catalyst is approaching the commercial targets.</p> <p>Large scale testing at the LaPorte AFDU will be required to confirm this productivity. Slides which provide a preliminary run plan at LaPorte and an analysis of catalyst life from the LaPorte LPMEOH™ life run are provided in Attachment 3.</p>
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NOTES FROM MEETING  
CONTINUATION

ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
2.	RMK/WJO	6/20/97	<p><u>Reports</u></p> <p><u>Preliminary Public Design Report</u>: A draft version was distributed. Comments should be directed to F. Frenduto.</p>
	WJO	6/2/97	<p><u>Topical Report - LPMEOH™ Process Economics</u>: W. O'Dowd will complete his review and forward comments to R. Moore.</p>
	DPD/ECH	6/30/97	<p><u>Topical Report - LPMEOH™ Reactor Design</u>: An updated version will be sent to DOE for review.</p>
	RMK ECH	Done 6/2/97	<p><u>Topical Report - Peroxide Formation</u>: R. Kornosky will send his latest comments for incorporation into a final version.</p>
	RMK/ECH	6/20/97	<p><u>Topical Report - Catalyst Poisons</u>: A draft report under the Liquid Fuels Program was issued in March. An agreement between the Liquid Fuels and CCT Programs on the possibility of publishing under two DOE contracts is forthcoming. Any separation of publically available data must be agreed upon between the partners.</p>
	ECH/BTS	6/20/97	<p><u>Topical Report - DME</u>: In progress.</p>
		Review Status 7/24/97	<p><u>Technical Progress Reports 1 &amp; 2</u>: F. Frenduto and R. Kornosky will work together to complete.</p>
	ECH	6/2/97	<p>An updated Project Management Plan will be issued.</p>
	ECH/VES	Done 5/19/97	<p>Upcoming reports include: - Technical Progress Report #11 - draft due mid-May.</p>
	ECH/VES	6/6/97	<p>- Demonstration Teechnology Start-up Report - report is issued without revision.</p>
	ECH/BTS	8/15/97	<p>- Environmental Monitoring Report #1 - first reporting period is April - June 1997.</p>

**NOTES FROM MEETING  
CONTINUATION**



ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
3.			<p><b><u>Updated Fuel-Use Demo Plan - Status/Schedule</u></b></p> <p>A review meeting between Air Products, DOE, and Acurex was held on 18 April. Attachment 4 is the summary of prospective methanol fuel test sites, testing programs, and costs. An update of the summary table will be provided to clarify the costs to the CCT program and the outside cost-sharing. A brief review of Air Products' corporate involvement with Penn State on R&amp;D was presented. The possibility of methanol testing using some of these facilities is being investigated.</p> <p><b>PJAT</b>      <b>5/28/97</b></p> <p><b>ECH</b>      <b>5/31/97</b>      The draft plan will be issued to DOE.</p> <p>Task 3.3 of the Statement of Work, On-Site Testing, states that Eastman will perform fitness-for-use tests on the methanol product for use as a chemical feedstock and provide a summary of the results. Further definition and timing for these tests is required.</p> <p><b>BTS</b>      <b>7/24/97</b>      <i>Timing for these tests is 4Q FY'97; an update will be presented at the next DOE Review Meeting.</i></p>

NOTES FROM MEETING  
CONTINUATION

ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
4.			<p><b><u>Task 2.1 - Methanol Operation Task - Status</u></b></p> <ul style="list-style-type: none"> <li>• Daily average production over the first two weeks of steady operation has been 242 - 292 tons per day (TPD), depending upon gas availability. There have been shorter time periods during which production exceeded 12.5 tons per hour, or 300 TPD. Attachment 5 contains the draft summary table and a sample of the detailed report for a particular operating day.</li> <li>• Gas holdup in the reactor has been about 50 vol% at 30 wt% slurry concentration. Maximum gas superficial velocity has been 0.72 ft/sec.</li> <li>• We are still awaiting price and delivery for repairs to the 29G-03 oil makeup pumps.</li> <li>• Free-draining of condensed oil and entrained oil/catalyst back to the reactor had been operating successfully until 4/25. It is unclear whether the blockage is due to catalyst or to a vapor pocket in the piping (something that has been observed in earlier operation). Eastman is currently draining oil from the 29C-05 oil separator back to the 29C-30 catalyst reduction vessel and pumping this oil back via the 29G-30 slurry pump to the reactor. Eastman is exploring options for providing a clean oil flush to the free-drain line.</li> <li>• The pressure drop across the gas sparger on the reactor has continued to increase over the last 2 weeks, either from catalyst migration from the reactor or construction debris from the gas inlet piping. The weakest component over the sparger design are endcaps (33 psi differential); this limitation prevents Eastman from trying to use gas pressure to pulse the sparger in an attempt to unplug it. We now expect to examine the sparger during the upcoming complex outage to determine the cause of the high pressure drop and reinforce the endcaps. The outage is scheduled to begin on 11 May and will last 2-3 weeks.</li> <li>• APCI personnel have been off-site since 25 April, and have been using the data link between Allentown and Kingsport to monitor plant performance and download historical data for heat and material balance calculations.</li> </ul>

NOTES FROM MEETING  
CONTINUATION

ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
5.			<p><b><u>Report Card - Project Success Factors</u></b></p> <p>The Project "Success Factors" were reviewed. The DOE/Air Products/<u>Eastman Participant Relationships continue to be excellent.</u> On the performance during <u>Phases 1 and 2</u>, performance was <u>very good in absolute terms</u>, and <u>excellent when compared to other CCT programs.</u></p>

**NOTES FROM MEETING  
CONTINUATION**

ITEM NO.	RESPONSIBLE PERSON (INITIALS)	TARGET DATE	DISCUSSION
6.			<p><b><u>Next Project Meeting, Dedication</u></b></p> <p>The next project review meeting is scheduled for the afternoon of 24 July and the morning of 25 July at the JV Trailer at Kingsport. R. Kornosky will advise if any earlier meetings to cover DME or the fuel-use program will be necessary.</p> <p>The Dedication Ceremony is scheduled for 25 July at Kingsport. Those guests travelling that day will arrive for lunch at 11:30 AM. Final details will be arranged with all parties. <i>The current agenda is included (Attachment 6).</i></p> <p>Specific questions/action items:</p> <ul style="list-style-type: none"> <li>• Several DOE visitors have requested a tour of the gasification control room (similar to the tour at the groundbreaking ceremony).</li> <li>• Check the timing of the aerial photograph for the plant to see if it will be available for the ceremony.</li> <li>• Update JV sign from groundbreaking to remove reference to funding.</li> <li>• Provide list of invitees.</li> <li>• Coordinate the preparation of a press release so that it is ready on 25 July.</li> <li>• Update DOE Fact Sheet on program.</li> <li>• Update project "poster" by adding photographs of Wabash and Tampa, a photo of the LPMEOH™ demonstration unit, and the map which depicts the potential sites for fuel-use testing.</li> </ul>
	<b>BTS</b>		
	<b>BTS/ECH</b>		
	<b>BTS/ECH</b>		
	<b>RMK</b>	<i>Ongoing</i>	
	<b>ECH/RMK/ BTS</b>		
	<b>ECH</b>	<b>Done 5/8/97</b>	
	<b>RMK/JAF/ ECH</b>		

**MEETING NOTICE**

(April 29 & 30, 1997)



PLEASE NOTE: Security badges required for visitors in all buildings and employees in R&D buildings.

DISTRIBUTION (NAME/ORGANIZATION) <i>(If unable to attend, contact originator)</i>		COPIED FOR INFORMATION ONLY	
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Bill O'Dowd - DOE - FETC	X. D. Peng - APCI	Bill Jones - EMN	
John Shen - DOE FE-HQ	Bob Senn - APCI		

FROM	ORGANIZATION	EXTENSION	TODAY'S DATE
William R. Brown <i>WRB</i> 4/23	APCI - Program Manager	17584	23 April 1997

DATE OF MEETING	WEEKDAY	TIME		LOCATION
April 29 & 30, 1997	Tues. & Weds.	FROM 1:30 PM	TO 10:45 AM	Tues. - in A3CR112K Weds. - in LNG CR A31E4

SUBJECT AND/OR PURPOSE

- **Project Review Meeting, DOE and Air Products**

DESIRED RESULTS/OUTCOMES

- **Review Project DME "go" decision, Fuel-use test plan, reports.**

REFERENCE MATERIAL/OTHER

- 

**AGENDA LPMEOH™ Project Review Meeting - Agenda\***

**Project Review - Part One      1:30 PM Tues. - April 29th**  
(In Conference Room 112K, Building Admin. 3, Air Products Trexlertown)

**1. DME Design Verification Testing - Status - Review**

- |  |              |
|--|--------------|
| A. Process Economics, Goal for Catalyst System Productivity/Life | 1A - RBM/WRB |
| B. Lab R & D results, status                                     | 1B. BAT/XDP  |
| C. Recommendation for LaPorte test run - Status/Timing           | 1C. PJAT     |

**2. Reports**

- |   |               |
|---|---------------|
| 2A <u>Public Design Report</u> (Review initial draft)   | 2A. FSF/RMK   |
| 2B <u>Topical Report - LPMEOH Process Economics Draft #3</u><br>(Review and comment on 3/31/97 Third Draft) | 2B WJO/RBM    |
| 2C <u>Other Reports</u>   | 2C RMK/et.al. |

**End of (work) Day One      -      4:30 PM**

**Project Review - Part Two      9:00 AM Weds. - April 30th**  
(In LNG Conference Room, Building Admin. 3, Air Products Trexlertown)

**3. Updated Fuel-use demo plan - Status/Schedule**      3. RJS/PJAT

- |  |            |
|--|------------|
| 4. <b>Task 2.1 - Methanol Operation Task - Status</b>        | 4. ECH/VES |
| 5. <b>Report Card - Project Success Factors</b>              | 5. All     |
| 6. <b>Plans for: Next Project Meeting, Dedication, Other</b> | 6. All     |

**End and Lunch ~ 11:15 AM .**

\* Agenda Questions/Additions/Deletions to Bill Brown please.



Memorandum

To: R. M. Kornosky Dept./Loc.: PETC Project Manager  
 From: Robert B. Moore Dept./Ext.: Program Development Engineering  
 Date: 22 April 1997  
 Subject: DME Catalyst Productivity

Distribution:

- ~~W. R. Brown - Eqpt & Bus Development~~ A31E9
- E. C. Heydorn - Eqpt & Bus Development
- P. J. A. Tijm - Eqpt & Bus Development
- B. A. Toseland/X. D. Peng - GEG Reaction Tech

DOE has asked APCI to define the productivity of a commercially successful DME catalyst. There are of course many variables which effect the answer which might be given. The composition, pressure and value of the feed have major effects as well as the value and composition of the product. DME is expected to have a commercial niche in about the same applications that LPMEOH™ has for coproduction of methanol in an IGCC process. With this in mind a commercially successful catalyst might be one which can economically produce DME from a typical Texaco-type synthesis gas, consuming at least one half of the synthesis gas with the balance going to a gas turbine. This analysis compares methanol and DME/methanol production from Texaco-type synthesis gas available at 500 psig. The gas is compressed to 1000 psig and fed to a reactor along with 1:1 recycle: fresh feed gas with a catalyst space velocity of 4000 sL/kg-hr and an ETA of 0.5 (50% of new catalyst activity), to produce 500 sT/D of methanol equivalent. In the "all methanol" case the catalyst contains 100% methanol catalyst. In the "DME/methanol" case the catalyst slurry contains 80% methanol catalyst and 20% dehydration catalyst. With a feed gas cost of \$3.00/MMBTU the crude product from the "all methanol" case would cost about \$7.63/MMBTU as a liquid. The crude DME/methanol from the alternate case will be produced at about \$7.02/MMBTU, modestly less expensive than "all methanol". However, the separation and purification of the crude DME/methanol into a cooking grade DME product and into a crude methanol product will add about \$0.89/MMBTU to this cost, giving a total product cost of \$7.91/MMBTU. About 23% of this product is a separated crude methanol stream which is assumed to have the same value as DME. The 77% balance is a cooking grade DME product. To achieve these economics it was assumed that the "all methanol" catalyst productivity was 11 g-mole/kg-hr after six months of operation. The 80%/20% methanol/DME catalyst productivity was assumed to be 14 g-moles of methanol product equivalent per kg of catalyst per hour of operation (g-mole/kg-hr), after six months of operation.

In the USA where natural gas and LPG are inexpensive, typically less than \$4.00/MMBTU, DME from coal is not likely to be competitive. However, in coal based countries of the world such as inland China, the fuel value for DME is competitive with that of propane/butane at \$7 to \$8/MMBTU. This is the area where the first DME facilities might be built. With future improvements in catalyst activity and improvements in the equipment technology co-produced DME should achieve an improved market position.

The following is a summary of the two cases being compared.

### 500 PSIG TEXACO-TYPE SYNTHESIS GAS TO ALL METHANOL OR DME/METHANOL

	All Methanol	DME/ Methanol
Production		
Methanol, T/D	500	106
DME, T/D	0	283
Synthesis Gas Conversion, %	43	55
Catalyst Productivity, g-mole/kg-hr	11	14
Synthesis Gas Used, MMBTU/Hr (LHV)	437	443
Product, MMBTU/Hr (LHV as liquid)		
Methanol	358	76
DME	<u>0</u>	<u>272</u>
Total Product, MMBTU/Hr (LHV as liquid)	365	380
Conversion Cost, MM\$/Yr	\$21.5	\$19.2
Crude Product Cost, \$/MMBTU (LHV as liquid)	\$7.63	\$7.02
DME Purification, \$/MMBTU (LHV as liquid)		<u>\$0.89</u>
Product Cost, \$/MMBTU (LHV as liquid)		<u>\$7.91</u>

A graph showing the effect of size of a DME facility is attached. For Production between 300 and 1100 sT/D methanol equivalent the product cost falls in the range of \$6.40 to \$8.10/MMBTU which should be competitive with LPG. About \$3.50/MMBTU of the cost is from the Texaco-type synthesis gas which is assumed to have a value of \$3.00/MMBTU.



Summary:

A commercially successful DME Catalyst is defined as one that has a productivity of 14 g-moles/kg-hr after six months of operation, producing at least 75% (by heating value) DME and 25% methanol with the following reactor inlet composition and when operating with a pressure exit the reactor of 950 psig and a SV of 4000:

H2	25.1%
CO	52.6%
CO2	20.8%
Inerts	1.4%
CH3OCH3	0.1%

Sensitivity:

Should the catalyst productivity decline twice as fast as assumed above, twice as frequent catalyst change out would add about \$0.36/MMBTU(LHV as a liquid) to the cost of DME produced. This would likely make small facilities, less than 700 T/D methanol equivalent, not competitive with LPG.

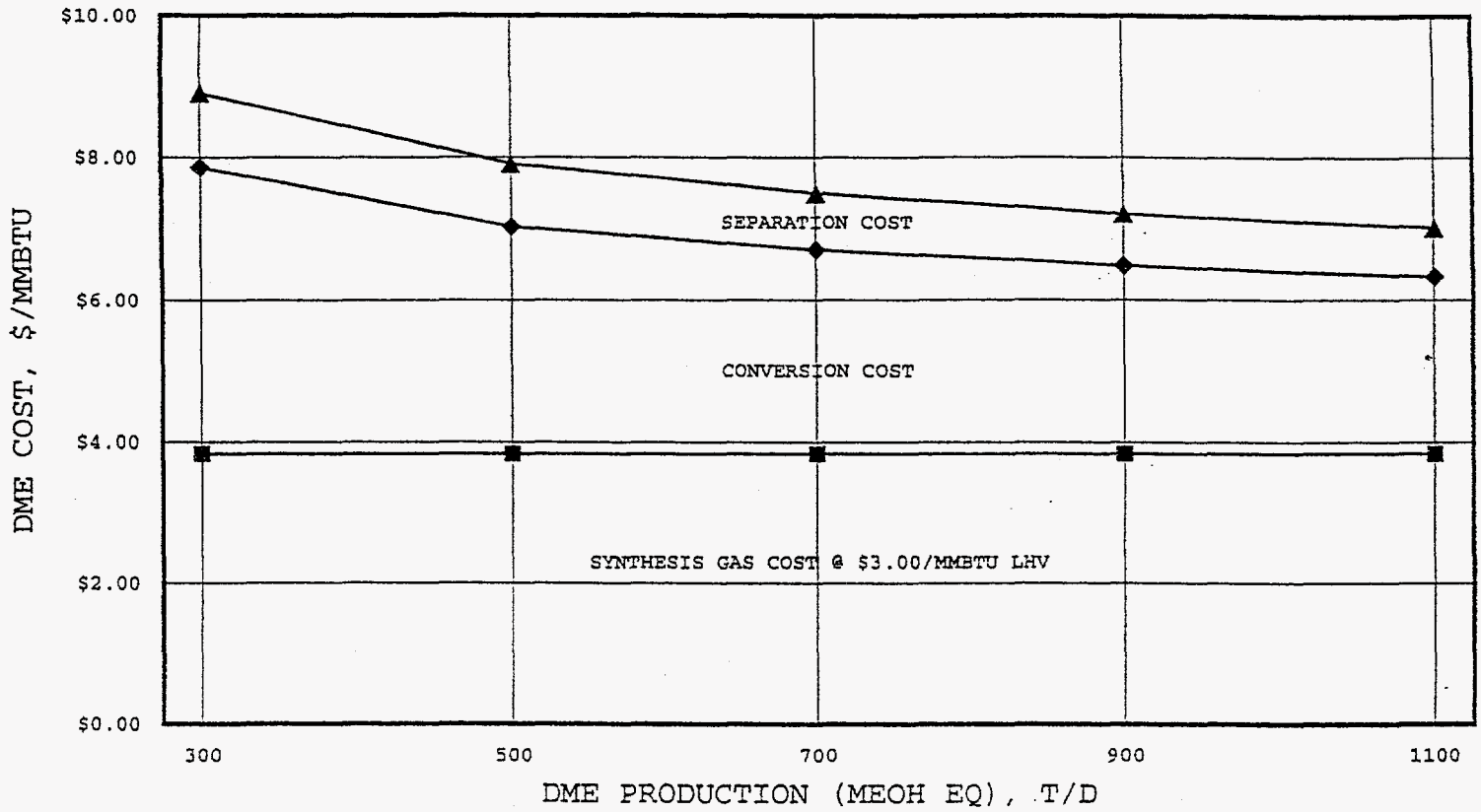
*Bob*  


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R. B. Moore

# DME COST VERSUS SIZE

TEXACO-TYPE SYNTHESIS GAS, 1:1 FEED:RECYCLE



■ SYNTHESIS GAS ONLY

◆ SYNTHESIS GAS PLUS CONVERSION

▲ TOTAL DME COST

LPDME RecommendationLPDME Design Verification Testing

From the Statement of Work : "Subject to Design Verification Testing (DVT), the Partnership proposes to enhance the Project by including the demonstration of the slurry reactor's capability to produce DME as a mixed co-product with methanol. The production of DME from synthesis gas is a natural extension of the LPMEOH™ process in that three reactions occur concurrently in a single liquid phase reactor, methanol synthesis, methanol dehydration and water-gas shift. This process enhancement can significantly improve the overall conversion of coal derived synthesis gas to a storable blend of methanol and DME. --- the enhanced (DME production demonstration is complementary to ongoing studies being sponsored by DOE's Liquid Fuels Program --) -- . -- At the conclusion of each of the DVT steps, a joint Partnership/DOE decision will be made regarding continuation of methanol/DME demonstration.."

The first DVT step (Phase 1, Task 5), to address issues such as catalyst activity and stability, to provide data for engineering design, and to verify the market through engine tests and through market and economic study, is now complete.

The LPDME Process Concept: - Three Concurrent Reactions:

- $2 \text{ CO} + 4 \text{ H}_2 = 2 \text{ CH}_3\text{OH}$  (Methanol Synthesis).
- $2 \text{ CH}_3\text{OH} = 1 \text{ CH}_3\text{-O-CH}_3 + 1 \text{ H}_2\text{O}$  (Methanol Dehydration).
- $1 \text{ CO} + 1 \text{ H}_2\text{O} = 1 \text{ CO}_2 + 1 \text{ H}_2$  (Water-gas Shift).

The overall reaction, with CO-rich Syngas, in a single liquid phase (slurry) reactor:

- $3 \text{ CO} + 3 \text{ H}_2 = 1 \text{ CH}_3\text{-O-CH}_3 + 1 \text{ CO}_2$  (DME from CO-rich syngas)

This is the "once-through" CO-rich syngas concept for the LPDME process utilizing a single slurry reactor. Conversion per pass, with CO-rich syngas, can be higher than for the LPMEOH™ process. Methanol may also be produced, as a mixed co-product with the DME, and can easily be separated and recovered. The separation of DME from CO<sub>2</sub> will be necessary for certain market applications.

Status of the LPDME DVT Work

The status of a) the LPDME process economics/market study work, and of b) the LPDME catalyst system R&D work, follows:

A. The market applications for DME are extensive. DME is, or may be, used as:

- Aerosol - Small, but established market. High purity DME is required.
- Cooking Fuel. Potentially a large market, to replace imported LPG. There is a lot of interest in China, and DME is on the DOE's CCT/FE China meeting (Sept. of 1997) agenda. Purity, of

about >95% DME, with <2% methanol, < 3% CO<sub>2</sub> is estimated. An unresolved application issue is CO emissions during cooking. How does DME purity impact this? Use testing is needed.

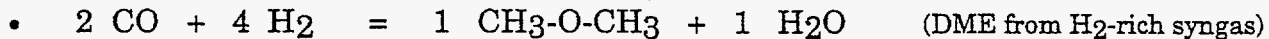
- Diesel Replacement Fuel. DME is an ultra clean (high Cetane) diesel fuel; and an 80% DME mixture with methanol and water is now being engine-tested by others (Amoco, et. al.). Market development (at least in the U.S.) faces a fuel distribution infrastructure problem. DME might more easily replace LPG in countries where LPG is already an engine fuel.
- DME Derivatives, as a Diesel Fuel Additive. Quotes from the DOE (Alt. Fuels R&D) Program quarterly report for April-June 1996: "Initial Cetane number (CN) testing of a three-component composition of 1,2-dimethoxy ethane, 1,1-dimethoxy methane and methanol blended with diesel fuel showed a 40% increase in the CN of the diesel fuel when the blend was 50/50." "The concept of adding a blend of oxygenated compounds to diesel fuel in order to enhance the Cetane value and cold start properties is being investigated. The blend of oxygenated compounds is derived from dimethyl ether chemistry, and builds on work conducted earlier --." It is early days for this DME feedstock chemistry, but CO<sub>2</sub> may not need to be separated from the DME.
- DME Derivatives, as Chemicals/Other Fuels. . DME is a key intermediate in a commercial synthesis gas-to-gasoline process, and is being developed as an intermediate for other chemicals and fuels as part of the DOE's Liquid Fuels (Alt. Fuels R&D) Program.

A. The economics studies, for once-through coproduction (with an IGCC power plant for example) on synthesis gas rich in carbon oxides, show that the LPDME process will have an advantage greater than the LPMEOH™ process. A once-through LPDME reactor is able to convert greater than 50% of such a syngas, whereas a once-through LPMEOH™ reactor can convert only about 30%. The economics, of course, depend upon the end-use (purity) of the DME and upon the gasification plant's coproduct mix (amount of power, methanol, DME, etc.). The same liquid phase reactor design options to increase syngas conversion (see the CCT Tampa Conference Paper); such as feed gas compression and/or CO-rich gas recycle; are also be applicable for LPDME. So, the LPDME technology should have a significant advantage for the coproduction of DME to serve local markets.

As with the LPMEOH™ process, gas phase process technology must be considered as the economic competitor. The gas phase DME process (see Haldor's patent) must run with H<sub>2</sub>-rich syngas. In the IGCC coproduction flow sheet, gas phase technology is at an economic disadvantage, since separate shift and CO<sub>2</sub> removal are required. As is the case for methanol, inexpensive remote natural gas would therefore be the economic plant site choice for gas phase technology. A comparison, of IGCC/LPDME coproduction with DME imported from remote gas facilities, shows an advantage for locally produced DME relative to imported DME. The transportation cost to import DME is much higher than for methanol, and the LPDME coproduction advantage is even greater than that for LPMEOH™ (vs. methanol import; see the CCT Tampa Conference Paper). Dehydration of imported methanol to make DME is not competitive either. Therefore, for DME in local markets, LPDME coproduction should be a winner!

LPDME Recommendation

With H<sub>2</sub>-rich syngas, the LPDME process loses its (once-through, high conversion per pass) economic advantage. The overall reaction, with (> 2:1) H<sub>2</sub>-rich syngas is:



Since water inhibits the methanol dehydration reaction, the slurry reactor must be staged, with water removal between stages. Staging could be by high ratio gas recycle, and/or with multiple reactors; but the once-through simplicity is lost. Therefore, it is unlikely that the LPDME process would be developed for use in H<sub>2</sub>-rich syngas applications.

A cost estimate of commercial-scale LPDME plants has been performed. This work has helped quantify the targets for the laboratory R&D program (summarized below). From these studies, a commercially successful LPDME system is defined for a Texaco-type synthesis gas (35 mol% H<sub>2</sub>, 51 mol% CO, 13 mol% CO<sub>2</sub>) available at 500 PSIG. At a reactor operating pressure of 950 PSIG and a space velocity of 4,000 liters/hr-kg catalyst, the LPDME catalyst system must have a methanol equivalent productivity of 14 mol/kg catalyst-hr after 6 months of operation, producing at least 75% (by heating value) DME and 25% methanol. Figure 1 shows the effect of plant size on DME cost.

B. Laboratory R&D Results (CCT Project - ended 9/96)

An LPDME catalyst system, with reasonable long-term activity, was identified and tested. The system exhibits best activity under CO-rich syngas conditions, i.e. those most likely for (IGCC) coproduction. Accelerated aging of the catalyst system is a remaining issue. Water concentrations in the LP reactor are higher with syngases richer in H<sub>2</sub>, and its effect needs to be evaluated.

Lab work has continued under the DOE's Liquid Fuels Program. The issues, to be addressed in the lab before a LaPorte test-run decision, are:

- 1) Understanding the LPDME catalyst system's accelerated aging; and modifying the catalyst and/or the system operating conditions; and
- 2) Manufacturing scale-up of catalyst for a LaPorte run.

Progress has been made in the laboratory effort. Figure 2 shows the performance for the first DME catalyst which was tested; goals from the Liquid Fuels Program are provided for reference. After further study, an improved DME catalyst (AB-05) was tested with two LPMEOH™ catalysts (S3-86 and MK-101); the results of a 700 hour life study are presented in Figure 3. When compared with the program goals (Figure 4), the catalyst performance of the newer catalyst is approaching the commercial targets defined in Section A.

LPDME Recommendation

Initial discussions with catalyst manufacturers have been held. Once a manufacturer is selected, a laboratory-scale catalyst batch will be produced and tested in the autoclave to verify the production technique developed at Air Products. An interim 1 lb batch will then be produced and tested. Once the catalyst production techniques have been verified at this scale, the 200 lb LaPorte batch will be produced using the same methodology as for a full commercial batch. An autoclave check of this material will be performed prior to the start of the LaPorte run.

Recommendations

The catalyst system and the market applications/opportunities are sufficiently promising that proof-of-concept testing at the LaPorte AFDU is recommended. Kingsport is an unlikely site for the commercial size demonstration of LPDME, since there are limited times for CO-rich syngas testing; and H<sub>2</sub>-rich syngas would create water buildup. Therefore, the basis for commercializing LPDME must come from:

- 1) catalyst performance (productivity, selectivity, and life) for the LPDME catalyst system under CO-rich syngas from the proof-of-concept testing at the LaPorte AFDU;
- 2) continuing work in hydrodynamics of slurry reactors (other ongoing DOE programs); and
- 3) reactor performance (methanol catalyst activity and life, hydrodynamics, and heat transfer) from the LPMEOH™ Process Demonstration Unit.

The tie-in between the laboratory and the LaPorte AFDU is important. Historically, the rate of deactivation of methanol synthesis catalyst has been greater in the autoclave than at the AFDU; this may be a result of loss of catalyst from the autoclave, or due to greater carbonyl poisoning as a result of the higher surface-to-volume ratio at the laboratory scale. Testing at the engineering scale of the LaPorte AFDU can eliminate this variable.

Recommendations:

- An LPDME test run at the LaPorte AFDU, in conjunction with the DOE's Liquid Fuels Program, would be appropriate if the LPDME catalyst system development can be completed successfully. Appendix A provides background for combining the funding from the CCT and Liquid Fuels Programs to support the LaPorte run. Up to \$875,000 of CCT Program budget support, from the LPMEOH™ Project's FY-97 Cost Plan (budget), should be made available to support a suitable LPDME test run at LaPorte.
- An implementation decision, made mutually by the DOE's CCT (DE-FC22-92PC90543) LPMEOH™ project participants, and by the DOE's Liquid Fuels (DE-FC22-95PC93052) program participants, should be made (by July of 1997) in time to implement testing at LaPorte in early 1998. (*Final dates should be recommended by the DOE's Liquid Fuels program, based on progress in developing the LPDME catalyst system*). The DOE LPMEOH™ project participants should be kept informed of the LaPorte AFDU LPDME test-run plans, so that a timely final approval can be made.

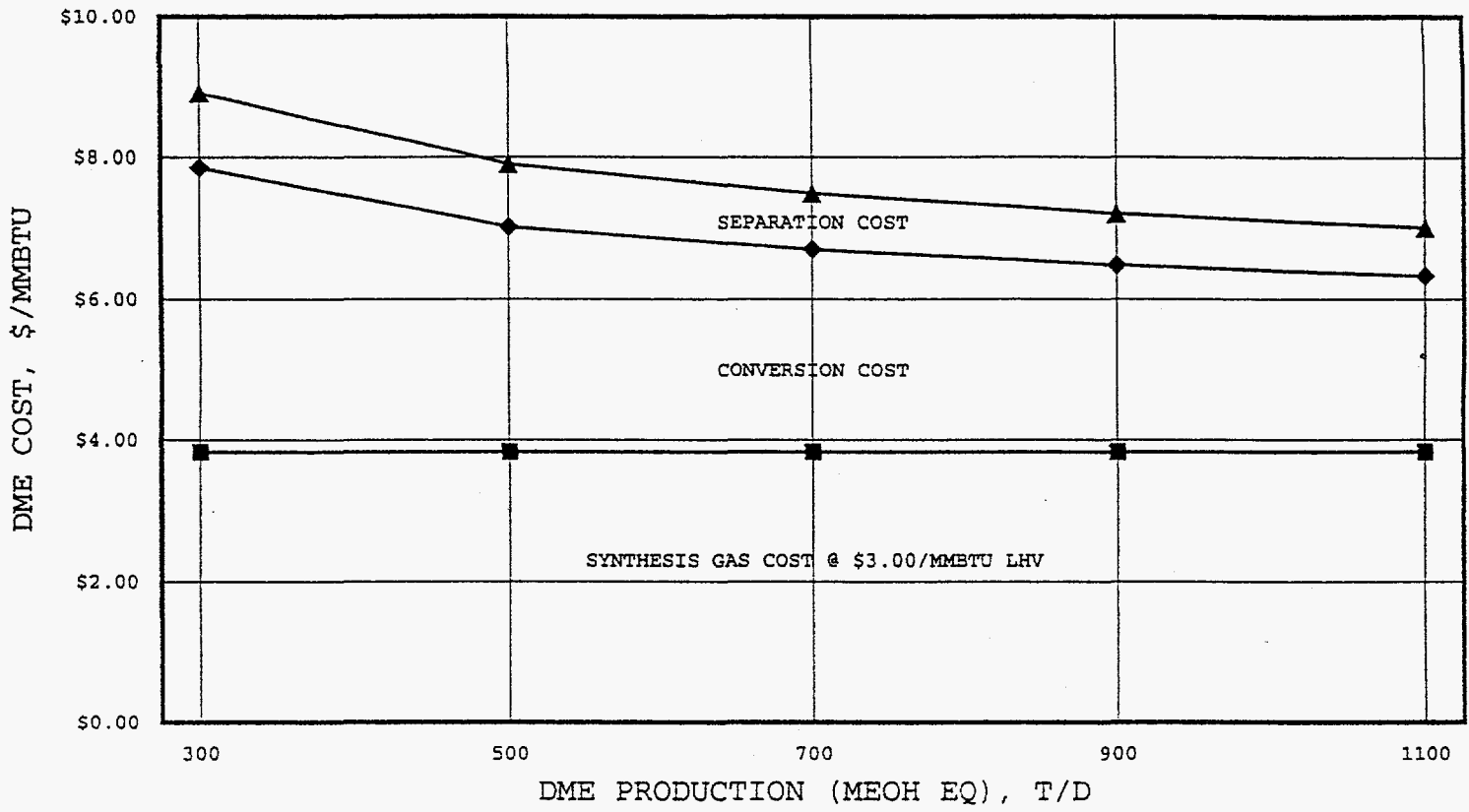
LPDME Recommendation

- In the interim, some DME product-use testing may be appropriate for the LPMEOH™ Project's Off-site Product testing.

(end).

# DME COST VERSUS SIZE

TEXACO-TYPE SYNTHESIS GAS, 1:1 FEED:RECYCLE



- SYNTHESIS GAS ONLY
- ◆ SYNTHESIS GAS PLUS CONVERSION
- ▲ TOTAL DME COST

FIGURE 1



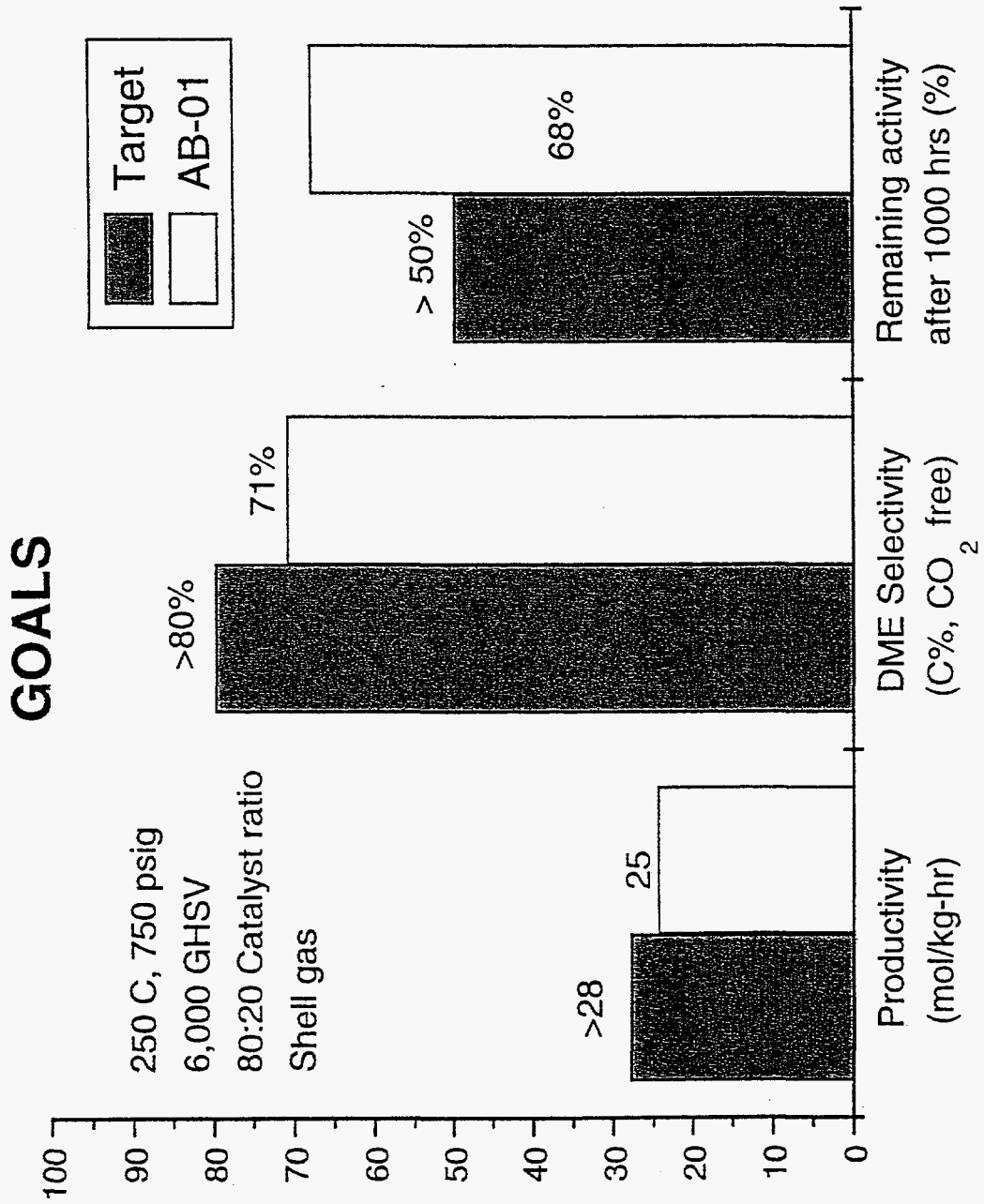
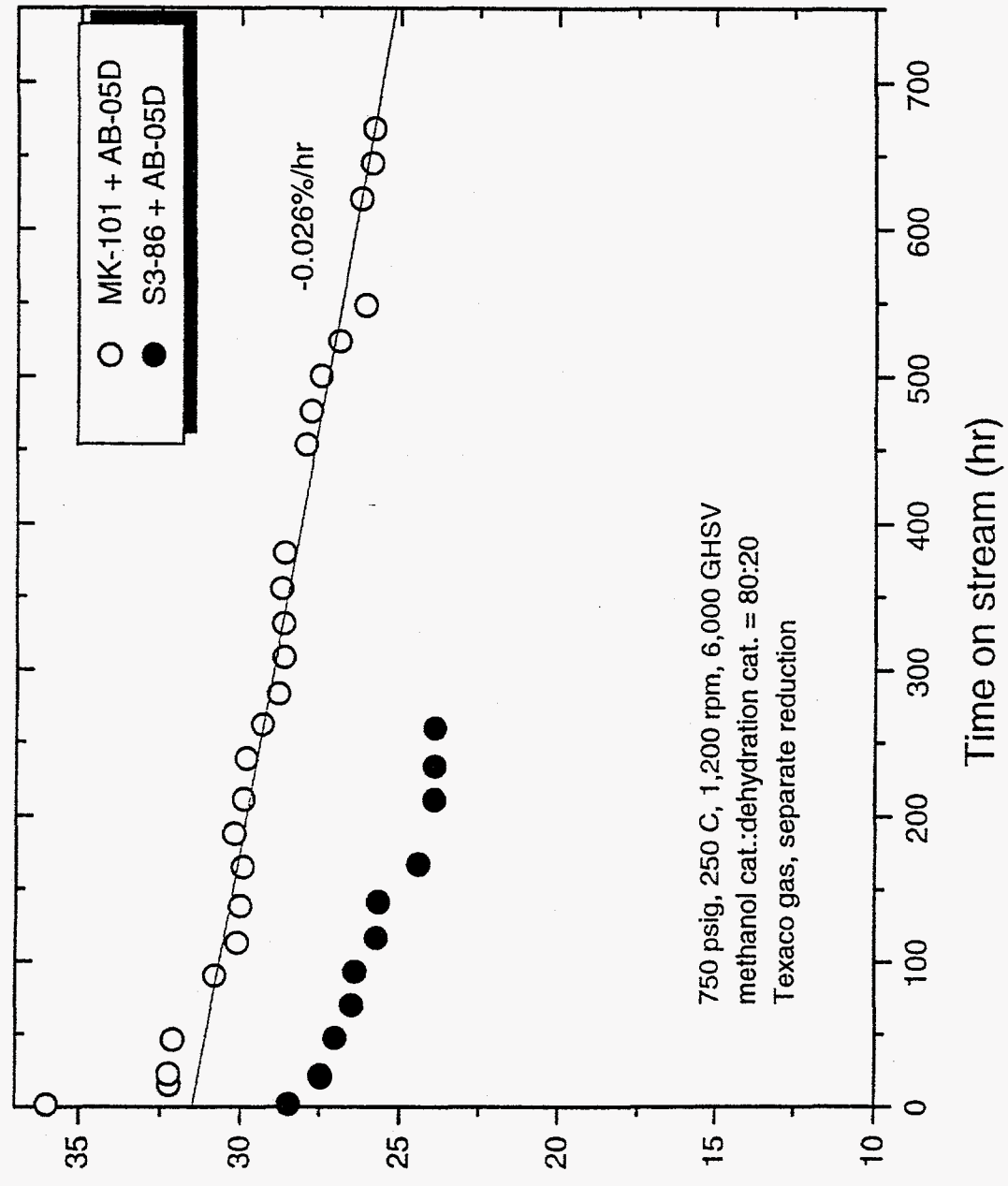


FIGURE 2

MEOH Equiv. Prod. (mol/kg-hr) **FIGURE 3**



- Six catalyst samples (#1 - #6) were developed with good stability and decent activity.

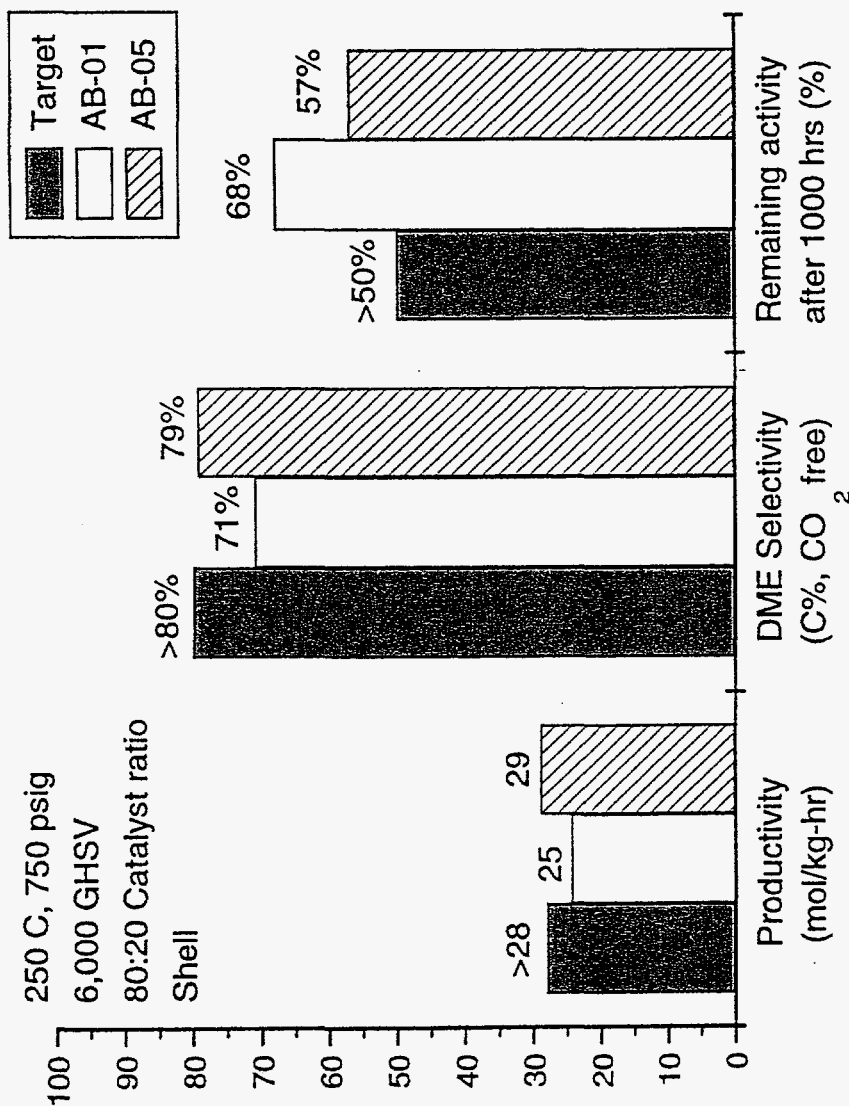


FIGURE 4

Appendix A.

Why combine the CCT and Liquid Fuels Programs for an LPDME test-run at the LaPorte AFDU?

**The programs are related.** The DOE Liquid Fuels Program has as one of its objectives: to investigate potential technologies for the conversion of syngas to oxygenated and hydrocarbon fuels and industrial chemicals; and to demonstrate the most promising at the LaPorte AFDU. Three slurry reactor programs are at the LaPorte AFDU demonstration stage:

1. Syngas to Fischer-Tropsch (F-T) liquids. A test-run at LaPorte in October of 1996 was partially successful, but terminated early. Analysis is underway, and a recommendation for an additional test run at LaPorte has been made. Air Products and Shell are participants.

2. Syngas to DME. An earlier (Liquid Fuels Program) LPDME test run at LaPorte showed good promise. DME is an important intermediate chemical building block for many of the Liquid Fuels Program's promising ideas. Development of a stable and active LPDME catalyst system is therefore an important part of this program.

3. Slurry Reactor Hydrodynamics. The LaPorte AFDU is the ultimate test unit to confirm laboratory (University, National Labs, Other) hydrodynamic studies. A test, planned for October of 1996 at LaPorte, was only partially executed due to the early termination of the F-T run. This needs to be rescheduled.

**Budgets are limited.** The DOE Liquid Fuels Program budget is limited. By combining the Liquid Fuels and the CCT Program budgets, the LPDME test-run at LaPorte can be made more extensive, and the CCT Program participants can provide experience from the Kingsport scaleup/demonstration to help in developing test-run plans.

PRELIMINARY RUN PLAN FOR A DME DEMONSTRATION RUN AT LAPORTE

Attachment 3

OBJECTIVE	CATALYST	FFED GAS	DURATION, DAYS
METHANOL WATER INJECTION STUDY	MEOH	TEXACO	7
DME LIFE STUDY	MEOH + X% DEHY.	SHELL	15
DME PROCESS VARIABLE STUDY: - HIGHER PRESSURE - HIGHER SUPERFICIAL VELOCITY - WATER INJECTION	MEOH + X% DEHY.	SHELL	7
DIFFERENT FEED GAS COMPOSITIONS	MEOH + X% DEHY.	TEXACO KINGSPORT	4
TRACER STUDY	MEOH + X% DEHY.	SHELL	3
HIGHER PROPORTION OF DEHY. CATALYST	MEOH + Y% DEHY.	SHELL	4
<b>TOTAL</b>			<b>40</b>

②

Analysis of 4-month LPMeOH Life Run at LaPorte

Days On-stream	Deact. Rate (a) of k <sub>0</sub> , %/day	2*Std Error of (a)	2*% Std Error of (a)
113	-0.38	0.01	3
60	-0.36	0.04	11
45	-0.29	0.06	21
30	-0.44	0.10	24
22	-0.52	0.18	34
15	-0.25	0.26	106
7	0.44	0.59	132

113

0.05%

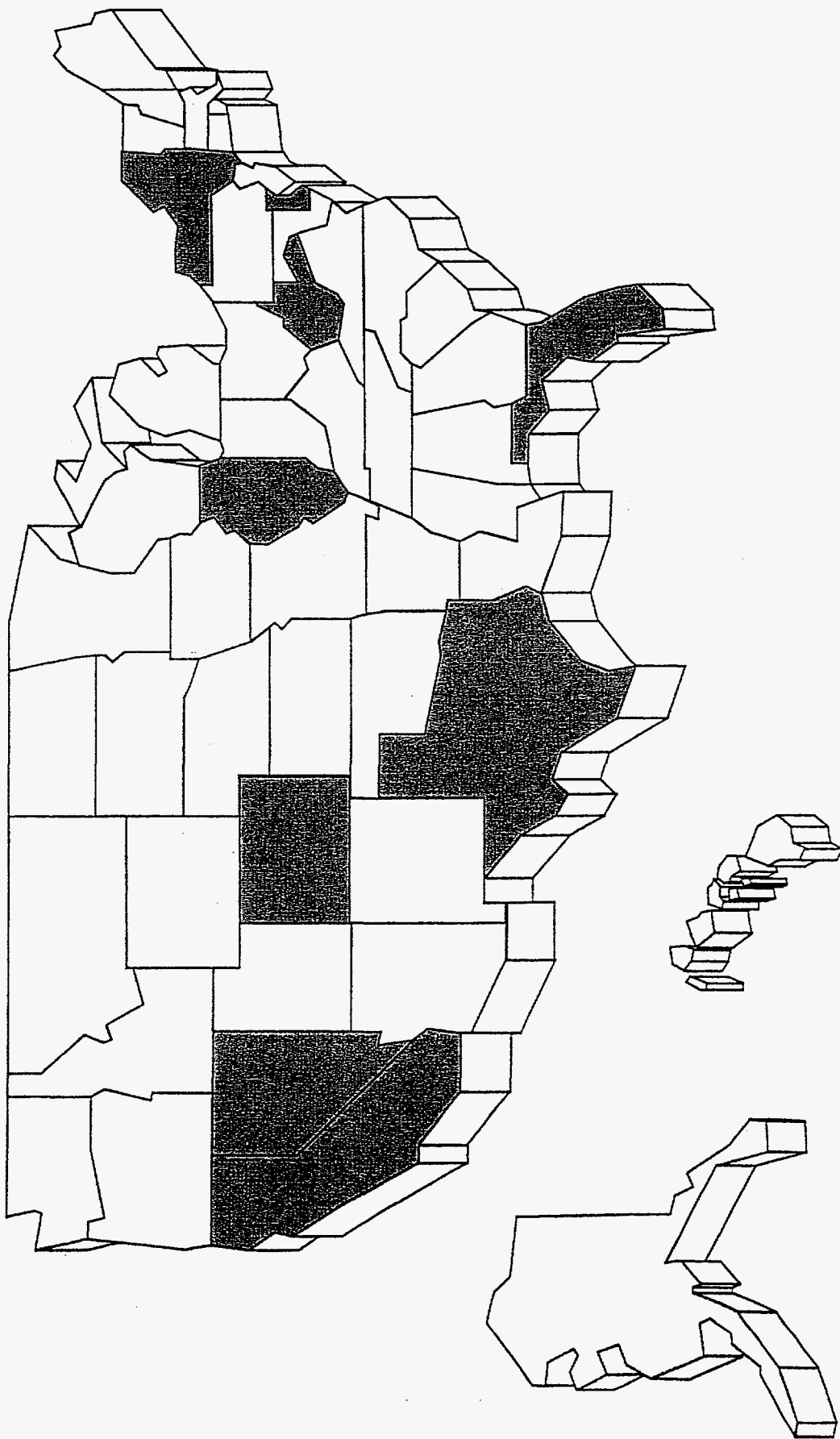
stable

Days On-stream	Deact. Rate (b) of Productivity, %/day	# of Days needed to see a 2% drop
113	-0.17	12

- \* Need minimum data for 15 days on-stream to check stability if catalyst is as stable as LPMeOH
- \* Need data for more than 3 weeks on-stream to quantify deactivation rate.
- \* Data for 60 days on-stream are enough to get fairly accurate deactivation rate.
- \* Kingsport LPMeOH Life Data will be available before the LaPorte DME run

Attachment

(2)



# Acurex Environmental

C O R P O R A T I O N

A Geraghty & Miller Company

April 25, 1997

Peter Tijm  
Manager, Syngas Conversion Systems  
Air Products and Chemicals, Inc.  
7201 Hamilton Boulevard  
Allentown, PA 18195-1501

Reference: Acurex Subcontract under DOE Cooperative Agreement No. DE-FC22-92PC90543; Acurex Project 8438

Subject: Revised Fuel Test Plan

Dear Peter:

Glad we could meet this past April 18. I believe the meeting was quite fruitful in firming up our lines of communication and in making progress toward a final list of field test demonstration opportunities. I have enclosed a revised fuel test plan that includes the changes we agreed to at the meeting and via follow-up conversations I have held with Bob Senn. Please, call if you have any additional input. I look forward to get these quick start projects underway.

Sincerely,



Carlo Castaldini  
Manager, Process Engineering

encl.

cc: John O'Sullivan (EPRI)





Fuel Test Plan - Project Opportunities for Demonstration of LPMEOH for Power Generation and Pollution Control in Stationary and Mobile Sources

PROJECT NAME	TOTAL COST (\$k)	AP FUNDS (\$k)	COST SHARE (%)	PRIORITY	MEOH USE START DATE	LOCATION	MEOH QUANTITY (gallons)	QUICK START**	STATUS
<b>COMPLETED PROJECTS &amp; ADMIN.</b>									
LPMEOH/Dimethyl Ether Buses	694	274	420						
Port of Long Beach									
Heavy-Duty Truck									
Environmental Impact Volume									
<b>TEST PLAN PROJECTS</b>									
<b>Light Duty Vehicles</b>									
Acurex FFV	55	30	25	HIGH***	2Q 97	CA	220	yes	Ready for project initiation
Direct Injection Stratified Charge Engines	0	0	0	LOW	?	CO	55	no	None
<b>Hydrogen Production</b>									
Methanol to Hydrogen Reformer*	475	328	147	HIGH	1Q 99	CA	2,000	no	Examine hydrogen safety concern and repropose
Fuel Cell Powered Vehicles w/On Board H2 Supply	0	0	0	LOW	?	CA	0	no	None
<b>Distributed Power</b>									
Stationary Turbine for VOC Control; Phase 1	122	122	0	HIGH	4Q 97	CA, NY	1,200	yes	Ready for project initiation. EPRI will pursue utilities. Identify sites
Stationary Turbine for VOC Control; Phase 2*	198	48	150	HIGH	2Q 98	CA, NY	3,000	no	Acurex will pursue cofunding opportunities (EPRI, AB 1890)
West Virginia Stationary Turbine	114	89	25	HIGH	3Q 97	WV	5,000	yes	Proposal received. Ready for project initiation
<b>Emission Fuels</b>									
Water/Napthal/MeOH Bus	273	23	250	HIGH	3Q 97	CA	55	yes	Ready for project initiation. Secure A-55 project commitment
Aircraft Ground Equipment Emission	227	227	0	HIGH	3Q 97	FL, TX	220	yes	Ready for project initiation. Coordinate with AFBs
Sierra Power Peak Load Power Generation	160	80	80	HIGH	?	NV	330	no	EPRI will pursue with Sierra to solicit interest
<b>Fuel Cells</b>									
Florida Lab Fujii Fuel Cell	90	70	20	HIGH	3Q 97	FL	500	yes	Proposal received. Ready for project initiation
Fuel Cell Bus w/POX Reformer	500	200	300	HIGH	1Q 98	***	1,000	no	Acurex will track prototype progress
Fuel Cell Bus w/Steam Reformer	1	1	0	MED	?	DC, IL	1,000	no	Acurex will maintain contacts with bus researchers
Stationary Fuel Cell Power Generation*	907	300	607	LOW	?	CA	0	no	None
<b>Heavy Duty Buses</b>									
Triborough Coach	75	75	0	HIGH	3Q 97	NY	3,000	yes	Proposal received. Ready for project initiation
Gas Turbine Hybrid Bus*	950	250	700	HIGH	1Q 99	***	2,000	no	Acurex will pursue other possible sources of cofunding
Florida Institute of Technology Bus	149	99	50	MED	3Q 97	FL	4,000	no	Proposal received.
Methanol School Bus	200	30	170	LOW	3Q 97	CA	27,000	no	None
Methanol Transit Buses	0	0	0	LOW	?	CA	0	no	None
Heavy-Duty Methanol Engine	0	0	0	LOW	?	***	0	no	None
<b>Power Production</b>									
Advanced Power Generation	25	25	0	HIGH	1Q 98	CA	200	no	AP/EPRI will provide Westinghouse contact
Colfire of Coal-Fired Boiler*	115	45	70	HIGH	3Q 98	IL	2,500	no	Acurex will pursue bid process with Illinois
<b>QUICK START PROJECTS</b>									
	956	636	320				10,195		
<b>HIGH &amp; MEDIUM PRIORITY PROJECTS</b>									
	3,529	1,712	1,817				26,225		
<b>ALL TEST PLAN PROJECTS</b>									
	4,636	2,042	2,594				53,280		
<b>ALL PRIOR + TEST PLAN PROJECTS</b>									
	5,330	2,316	3,014				63,280		

\* - Projects require funding from other sources. Action items target bidding opportunities with CEC, ARB or FTA to receive cofunding.

\*\* - Quick Start: "yes" indicates project ready to kickoff

\*\*\* - All projects designated as high priority are recommended.

\*\*\*\* - Host site not yet identified

**PRIORITY: HIGH**  
**AVAILABILITY: HIGH**

**Project Name: Demonstration of LPMEOH™ in Light-Duty Flexible Fueled Vehicle (Acurex-owned)**

**Objective/Purpose**

- Demonstrate LPMEOH™ in a light-duty flexible fueled vehicle.
- Provide cost-effective demonstration with already proven hardware.

**Scope of Work**

- Operate Acurex-owned Ford Taurus FFV with LPMEOH™ M85 and regular M85 for 2 months on each fuel.
- Ship, locate fuel drum at Acurex for blending LPMEOH™-M85.
- Secure permitting and containment vessels for storage.
- Install fuel pump and dispenser.
- Track fuel economy during test periods for both fuels.
- Perform emissions testing on LPMEOH™ and M85 at CAVTC.
- Write short report containing emissions results and fuel economy comparison.

**Status**

- High-visibility, cost-effective project.
- Can be performed immediately.
- Possible synergy with NREL DISC engine and methanol formulations projects.

**Further Actions**

- Await go ahead from Air Products.
- Call NREL and identify methanol formulation interests.

**Costs**

<b>Total Funds:</b>	<b>\$55k</b>
<b>AP Funds:</b>	<b>\$30k</b>
<b>Cost Share:</b>	<b>\$25k</b>

PRIORITY:           LOW  
AVAILABILITY:      LOW

Project Name:        Demonstration of LPMEOH™ in DISC Engines

Objective/Purpose

- To demonstrate LPMEOH™ in new light-duty methanol Direct Injection Stratified Charge (DISC) engines under development by DOE-sponsored research companies in the United States.

Scope of Work

- Undefined.
- Demonstration would likely test LPMEOH™ versus standard M100 in a test-bench prototype engine.
- Perform bench emissions testing.
- Provide fuel for demonstration.

Status

- DISC engine currently being introduced for gasoline light-duty vehicles.
- Early development work undertaken on methanol DISC engines.
- Uncertain participation by engine developers.
- DOE already funding these sources.

Further Actions

- None. Project likelihood remote given timeframe of implementation and coordination problems with DOE and developers.

PRIORITY: LOW  
AVAILABILITY: LOW

Project Name: Demonstration of Hydrogen Production from LPMEOH™ for Use in Hydrogen Powered Vehicles

Objective/Purpose

- To demonstrate local hydrogen generation for vehicle fueling and commercial hydrogen production
- To determine emissions from hydrogen production and verify low fuel cycle emissions for fuel cell powered zero emission vehicle candidates
- Verify suitability of LPMEOH™ as a feed for partial oxidation hydrogen generation systems

Scope of Work

- Review facility siting options at the UC Riverside College of Engineering Center for Environmental Research and Technology (CE-CERT).
- Purchase partial oxidation reformer configured for methanol operation
- Design system for hydrogen compression
- Obtain permits
- Prepare site
  - Electrical, controls, and equipment footings
  - Methanol and back up natural gas plumbing
- Install a methanol to hydrogen generation system
- Start up facility
  - Coordinate LPMEOH™ supply
  - Perform shake down testing
- Measure emissions from hydrogen generation system to support hydrogen as an equivalent to electric vehicles.
  - Evaluate emissions in terms of g/100scf, g/mi for fuel cell vehicle
- Install hydrogen compression equipment
  - Purchase compressor and gas storage
  - Operate facility for vehicle fueling and commercial hydrogen generation
- Prepare Final Report

Status

- Project team includes CE-CERT and Hydrogen Burner Technology
- Methanol storage tank is available at CE-CERT.
- An IC engine truck, research fuel cell vehicle, as well as commercial hydrogen are end use options
- Hydrogen compression experience with CE-CERT solar hydrogen facility.

Further Actions

- Determine cofunding opportunities from SCAQMD to fund compressor system integration.
- Review site options and hydrogen distribution options
- Certify safety of hydrogen tanks

Costs

Total Funds: \$475k  
AP Funds: \$328k  
Cost Share: \$147k

PRIORITY: LOW  
AVAILABILITY: LOW

Project Name: Demonstration of LPMEOH™ in PEM Fuel-Cell Powered Vehicles with On-Board Hydrogen Supply

Objective/Purpose

- Potential application of hydrogen production from methanol

Scope of Work

- Undefined.
- Operate fuel cell transit bus on LPMEOH™ and M100 in revenue service for 2 months for each fuel.
- Ship LPMEOH™ fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Write report containing emissions results and fuel economy comparison.

Status

- A fleet of hydrogen powered fuel cell golf carts is operating in the city of Palm Desert (east of Los Angeles). Hydrogen is provided from solar energy. Praxair may be providing hydrogen also.

Further Actions

- None. Funding uncertainties and the large number of project participants do not make this the best opportunity to demonstrate hydrogen production from methanol.

**PRIORITY:** HIGH  
**AVAILABILITY:** HIGH

**Project Name:** Demonstration of LPMEOH™ in Stationary Gas Turbine with VOC Control for Distributed Power- Phase I

Objective/Purpose

- To demonstrate VOC destruction and low NOx emissions using a 25 kW stationary gas turbine fired with LPMEOH™. Phase I of a two-phased project

Scope of Work

- Select and secure a local host facility (bakery) for VOC-control demonstration
- Perform a site visit a make presentation of project
- Procure and arrange for delivery of a 25 kW Capstone turbine
- Perform engineering analysis and installation review
- Select method for VOC destruction (eg high temperature in combustor or low temperature in recuperator)
- Coordinate catalyst and other turbine modification equipment retrofit
- Install Capstone turbine at bakery demonstration host site.
- Arrange for short-term methanol storage tank.
- Ship LPMEOH™ fuel to host site.
- Operate for 2 weeks running VOC laden gas through turbine for destruction.
- Perform source emissions testing.
- Write emission test result report

Status

- Small VOC industrial sources have few VOC-destruction cost effective solutions
- California SIP has targeted bakery, and other small VOC sources, for VOC control.
- Acurex has made preliminary contact with some bakeries that are willing to explore the VOC destruction with electric power generation
- California AB1890 funds would provide cofunding for project for Phase II power generation demo.

Further Actions

- Track progress of AB1890 and bid opportunities
- Find potential host site (John O'Sullivan of EPRI will assist with finding utility)
- Explore permit issues with local air district
- Make preliminary inquiries with Capstone Turbines regarding cost and methanol conversion
- Initiate look at VOC consumption rates

Costs (PHASE I only)

<b>Total Funds:</b>	\$122k
<b>AP Funds:</b>	\$122k
<b>Cost Share:</b>	\$0

PRIORITY: HIGH  
AVAILABILITY: MEDIUM

Project Name: Demonstration of LPMEOH™ in Stationary Gas Turbine with VOC Control - Phase II

Objective/Purpose

- To demonstrate the long-term performance and economic validity of distributed power generation in connection with VOC destruction using a 25 kW stationary gas turbine fired with LPMEOH™. Phase II of a two-phased project
- Project builds on Phase I installation to perform long-term power generation and economic analysis demonstration of the GT-VOC control concept

Scope of Work

- Obtain long-term operating permit from local district
- Secure Phase I host facility (bakery) for long-term distributed power & VOC-control demonstration
- Perform a site visit a make presentation of project
- Modify fuel storage for long-term demonstration
- Retrofit turbine for multiple approach to VOC destruction
- Arrange for connection to power grid and electricity sale contract
- Ship LPMEOH™ fuel to host site.
- Operate for 2 months with LPMEOH and natural gas running VOC laden gas through turbine for destruction during process operation and ambient air at all other times.
- Perform source emissions testing.
- Record power generation, fuel use, operating cycle, power sales and power usage
- Write performance and emissions test result report
- Write economic analysis and commercialization feasibility report

Status

- California AB1890 funds would provide cofunding for project for Phase II power generation demo.
- California AB 1890 promotes the use of distributed power in connection with VOC control
- Proposal preparation expected in February 1998.

Further Actions

- The execution of this project depends on the successful completion of Phase I
- Track progress of AB1890 and bid opportunities
- Find potential host site
- Explore permit issues with local air district

Costs (PHASE II only)

Total Funds: \$198k  
 AP Funds: \$48k  
 Cost Share: \$150k

PRIORITY: HIGH  
AVAILABILITY: HIGH

Project Name: Demonstration of LPMEOH<sup>TM</sup> in a Water-Naphtha-Methanol Fueled Bus

Objective/Purpose

- To demonstrate viability of LPMEOH<sup>TM</sup> in a water-naphtha emulsion (A-55) containing 3% methanol.

Scope of Work

- Operate a 22 foot paratransit bus in revenue service using LPMEOH<sup>TM</sup> and M100 as an emulsion ingredient for 2 months on each fuel.
  - Daily pickup and transport for disabled persons in Sacramento
- Ship LPMEOH<sup>TM</sup> fuel to emulsion-producer for mixing.
- Coordinate logistics of tracking fuel use at host site.
- Track fuel economy during test period for both fuels.
  - Develop a fuel tracking plan
  - Coordinate with host site
- Provide vehicle troubleshooting and repair.
- Write short report containing fuel economy comparison between fuels and with control vehicles.

Status

- Acurex managed bus project already exists and revenue service will begin in late spring.
- Emulsion-producer is interested in potential sources of cheaper methanol.

Further Actions

- Call A-55 to confirm participation and coordinate details of emulsification process.

Costs

Total Funds:	\$273k
AP Funds:	\$23k
Cost Share:	\$250k



**PRIORITY:** HIGH  
**AVAILABILITY:** HIGH

**Project Name:** Demonstration of LPMEOH™ in a Diesel/Methanol Emulsion Fuel for Aircraft Ground Support and Stationary Power Generation Equipment

Objective/Purpose

- To demonstrate diesel/LPMEOH™ emulsion in AGE equipment at Air Force Bases
- To monitor the emission and performance of the emulsion fuel in comparison with conventional diesel

Scope of Work

- Secure a host facility at a US AFB
- Perform a site visit to finalize scope and site support
- Select emulsion fuel supplier (e.g. A-55)
- Identify/engineer engine modifications needed
- Select fuel storage option and arrange for fuel tank installation
- Prepare a test plan
- Perform field test consisting of emissions and performance evaluation
- Analyze data
- Prepare test report

Status

- USAFB at Tyndall has expressed significant interest
- AGE and power generation equipment is high on priority list for NOx reduction
- Completed preliminary contact with Tyndall AFB in Florida
- Obtained agreement from the Air Force to in principle participate in the demonstration
- Expression of interest from Environics Directorate
- Preliminary contact with emulsified fuel supplier completed
- Defined an initial scope of work pending approval

Further Actions

- Explore with US AFB at Tyndall (FL) and Brooks (TX) on AF support
- Formulate a preliminary level of effort and present it to Tyndall personnel for agreement
- Make preliminary arrangements

Costs

**Total Funds:** \$227k  
**AP Funds:** \$227k  
**Cost Share:** \$0k

**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Fuel-Cell Powered Bus with POX Reformer

Objective/Purpose

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for fuel cell powered buses operating with multifuel POX reformers.

Scope of Work

- Coordinate methanol operation with demonstration site and vehicle developers.
- Install above ground fueling station
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Coordinate logistics of tracking fuel use.
- Operate fuel cell transit bus on LPMEOH<sup>TM</sup> and M100 in revenue service for 2 months for each fuel.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Perform chassis emissions testing on diesel, LPMEOH<sup>TM</sup>, and M100.
- Write report containing emissions results and fuel economy comparison.

Status

- Very high visibility project with excellent potential for vehicle use of methanol.
- Currently, DARPA-funded project for development of fuel cell/reformer technology is underway. Program for testing PEM fuel cell bus has not been finalized.
- Though project appears to have initial support from fuel cell developer, they will not operate on-road bus until late 1998. The bus is designed for multifuel operation; however, modifications to the fuel system would be necessary for methanol operation.

Further Actions

- While project has high visibility value, current hardware development plans will not allow demonstration to start until 1999. Excellent project for follow-on funds.
- Monitor project development and inquire regarding the possibilities for methanol operation

Costs

**Total Funds:** \$500k  
**AP Funds:** \$200k  
**Cost Share:** \$300k (Contingent)

**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> Fuel-Cell Powered Bus with Steam Reformer

Objective/Purpose

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for fuel cell powered buses operating with steam reformers
- Demonstrate LPMEOH<sup>TM</sup> use in breadboard and bus operation

Scope of Work

- Follow-on to Florida Lab 25kW Fuel Cell project.
- Operate fuel cell transit bus on LPMEOH<sup>TM</sup> and M100 in revenue service for 2 months for each fuel.
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period for both fuels.
- Provide vehicle troubleshooting and repair.
- Write report containing emissions results and fuel economy comparison.
- Provide fuel for Phase IV developments.

Status

- Very high visibility project with excellent potential for vehicle use of methanol.
- IFC and Ballard are developing methanol steam reforming fuel cell powered buses for Georgetown University. The IFC system uses a high temperature (1500F, Ni Catalyst) reformer and the Ballard system uses a low temperature (500F, Cu/Zn Catalyst) reformer. The high temperature system should be able to reform all types of alcohols while the low temperature system may not convert hydrocarbons and other alcohols.
- The project steps include system design, breadboard development, vehicle integration, and field demonstration. Actual operation on methanol in buses is several years away.
- Demonstration sites have not been identified at this time

Further Actions

- Provide input to IFC and Ballard on LPMEOH<sup>TM</sup> specifications and availability. Inquire if the fuel is feasible for vehicle operation. Provide samples for laboratory testing.

**PRIORITY:** LOW  
**AVAILABILITY:** MEDIUM (Contingent)

**Project Name:** Demonstration of LPMEOH™ in Stationary Fuel Cell Power Generation Applications

Objective/Purpose

- To demonstrate the viability of LPMEOH™ for stationary fuel cell distributed power generation

Scope of Work

- Identify demonstration site and cost sharing
- Design modifications for methanol operation
- Procure fuel cell
- Procure and install above ground fuel tank and fuel supply system
- Prepare site and electrical generation interface
- Install fuel cell
- Perform emission testing on methanol and natural gas
- Collect operating data
- Prepare final report

Status

- IFC/ONSI fuel cells (PC25) operate on natural gas and LPG. There are about 60 installations around the world. The IFC system uses a high temperature (1500°F) steam reformer to produce hydrogen. This catalyst system could operate well on any grade of methanol.
- The IFC fuel cell system has not been configured to operate on methanol for stationary applications.
- DOE is supporting R&D for PEM fuel cells for vehicles and building cogeneration. The hydrogen generation will most likely be with a partial oxidation system that can operate on gasoline, natural gas, diesel, ethanol, and methanol.
- PEM fuel cell power generation system will not be available from the DOE program for 3 years.

Further Actions

- Monitor developments with stationary fuel cell projects. Make contact with EPRI, IFC, and project participants and explore opportunities for LPMEOH™ demonstration.
- Seek funding under AB1890 to fund a project
- Discuss requirements for methanol operation with IFC

Costs

**Total Funds:** \$907k  
**AP Funds:** \$300k  
**Cost Share:** \$607k (contingent upon AB1890 and other funding)

**PRIORITY:** HIGH  
**AVAILABILITY:** MEDIUM (Contingent on funding and participation)

**Project Name:** Demonstration of LPMEOH™ in Gas Turbine Powered Hybrid Bus

Objective/Purpose

- To determine viability of LPMEOH™ as a fuel for turbine powered hybrid buses.

Scope of Work

- Install Capstone turbines in an Orion Bus Industries hybrid-electric bus.
- Install methanol fuel system on bus.
  - Determine appropriate design considerations
  - Identify, purchase, and install parts
- Reconfigure electronic control for operation with gas turbine.
  - Develop software modifications
  - Create hardware for interface between master controller and turbine
- Operate bus in revenue service using LPMEOH™ for 12 months.
- Ship LPMEOH™ fuel to host site.
- Coordinate logistics of tracking fuel use.
- Track fuel economy during test period.
  - Develop field, performance, and emissions test plan
  - Implement data collection procedures
- Provide vehicle troubleshooting and repair.
- Write report containing vehicle development description, vehicle demonstration results, emissions results and fuel economy comparison to control vehicles.

Status

- Extremely visible, high-potential project.
- Initial response from Capstone, OBI, and CE-CERT is very positive.
- Requires commitment of several participants and extra funding from local, state or federal agencies. Funding could come from FTA or ARB. Requires development of partnership with involved parties.

Further Actions

- Clarify interest of partners for project plan.
- Identify additional funding from other agencies, such as ARB or FTA.

Costs

**Total Funds:** \$950k  
**AP Funds:** \$250k  
**Cost Share:** \$700k (Contingent)

PRIORITY: LOW  
AVAILABILITY: HIGH

Project Name: Demonstration of LPMEOH<sup>TM</sup> in Methanol Fueled School Bus

Objective/Purpose

- To determine viability of LPMEOH<sup>TM</sup> as a fuel for school buses.

Scope of Work

- Operate school buses in revenue service using LPMEOH<sup>TM</sup> and M100 for 2 months on each fuel.
- Ship LPMEOH<sup>TM</sup> fuel to host site.
- Collect data from on-board data acquisition systems and operating records:
  - Vehicle speed/mileage
  - Fuel consumption
  - Engine speed
  - Foot brake activation
  - Percent engine load
  - Percent throttle
  - Idle time
- Provide vehicle troubleshooting and repair.
- Interview drivers with evaluation questionnaire.
- Track fuel economy during test period for both fuels.
- Write short report containing fuel economy comparison between fuels and with control vehicles.

Status

- Host site Antelope Valley Schools Transportation Agency (AVSTA) reacted positively to idea.
- 15 MeOH buses are part of CEC demonstration -- fuel source change requires CEC approval.
- Approval of bus manufacturer (Carpenter) required to protect warranty
- 12,000 gal MEOH tank onsite for school bus fueling

Further Actions

- Get fuel specification sheet and MSDS for AVSTA, CEC, Carpenter, DDC, and OSHA needs
- Verify fuel compatibility for Carpenter M100 schoolbuses
- Contact CEC
- Contact Carpenter and estimate fuel quantity needs

Costs

Total Funds: \$200k  
AP Funds: \$30k  
Cost Share: \$170k

**PRIORITY:** LOW  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMEOH<sup>TM</sup> in Transit Buses with DDC 6V-92TA Engines

Objective/Purpose

- Demonstrate LPMEOH<sup>TM</sup> use at transit agencies operating DDC 6V-92TA engines.
- Prove viability of LPMEOH<sup>TM</sup> in heavy-duty transit bus applications.

Scope of Work

- Operate methanol transit buses on LPMEOH<sup>TM</sup> and M100 for period of two weeks.
- Ship fuel to transit agency methanol storage tank.
- Coordinate refueling efforts.
- Track fuel economy during test periods for both fuels.
- Perform emissions testing on LPMEOH<sup>TM</sup> and M100 at LACMTA chassis dynamometer.
- Write short report containing emissions results and fuel economy comparison.

Status

- Already measured emissions from an MTA bus operating on M100, LPMEOH<sup>TM</sup> and LPMEOH<sup>TM</sup> with DME mixtures (December 1994) in cooperation with Air Products.
- LACMTA's fleet of methanol buses is making a transition to ethanol operation. MTA's organization is complex and the logistics of integrating LPMEOH use with a large fleet of buses would be costly.
- Kenawah Valley (KVRTA) was a planned site for methanol bus operation but they are no longer operating buses on methanol.

Further Actions

- None. Extensive efforts with transit bus operation are not warranted given the availability of methanol engines and the logistics of fueling and data collection at transit agencies.

PRIORITY: LOW  
AVAILABILITY: LOW

Project Name: Demonstrate of LPMEOH™ in Caterpillar Heavy-Duty Methanol Engine

Objective/Purpose

- To demonstrate LPMEOH™ in a new M100 heavy-duty engine currently under development by Caterpillar.
- Prove viability of neat-LPMEOH™ in heavy-duty methanol engines.

Scope of Work

- Undefined.
- Test LPMEOH™ versus standard M100 in a test-bench prototype engine.
- Perform bench emissions testing.

Status

- Caterpillar bench prototype engine will not be available within a year's time.
- Not certain if Caterpillar would be interested in demonstration of LPMEOH™ in their new engine.

Further Actions

- None.



**PRIORITY:** HIGH  
**AVAILABILITY:** LOW

**Project Name:** Demonstration of LPMeOH<sup>TM</sup> for Advanced Power Generation Equipment

Objective/Purpose

- To test LPMeOH<sup>TM</sup> in the fuel cell reformer and gas turbine in advanced power cycle equipment being developed under DOE program
- To compare the performance and cost of the power plant with more conventional combined cycle fuels

Scope of Work

- Re-contact Solar R&D group later this year regarding progress and schedule
- Obtain agreement and firmup schedule
- Visit the site and secure final agreement
- Develop test plan and get it approved
- Arrange for delivery of LPMeOH<sup>TM</sup> and storage
- Monitor the testing and data gathering effort
- Obtain data from the site
- Analyze data
- Write a test report

Status

- Acurex will take advantage of an ongoing project sponsored by DOE and performed by Solar Turbines Division of Caterpillar and Westinghouse where an advanced power generation cycle consisting of GT and fuel cell combination will be used to generate electricity with overall efficiency exceeding 65 percent. The equipment and technology is currently being assembled at Solar Turbines and is scheduled for multifuel testing later this year and in 1998
- Solar will consider methanol firing, including LPMeOH<sup>TM</sup>
- Preliminary contact made with Solar Turbines. Agreement in principle. Further negotiations are necessary

Further Actions

- Acurex will confirm the feasibility of the project later this year
- If deemed feasible to pursue, Acurex will continue contact to coordinate the scope of work and schedule

Costs

**Total Funds:** \$25k  
**AP Funds:** \$25k  
**Cost Share:** \$0

**PRIORITY:** HIGH  
**AVAILABILITY:** MEDIUM

**Project Name:** Demonstration of LPMeOH<sup>TM</sup> Cofire/Startup for Coal-Fired Boiler

Objective/Purpose

- To demonstrate the use of LPMeOH<sup>TM</sup> as a cofire or startup fuel for existing coal-fired industrial and small-scale power generation boilers in the Midwest. The LPMeOH<sup>TM</sup> fuel will be used in minimal amounts to support improved boiler operation, minimize emissions, and in general improve the reliability and performance of the boiler continuing its viability as a coal-fired boiler. The boiler that will be selected will be among the population of boilers recently retrofitted under the GRI gas cofire program. This will ensure that the boiler is already equipment ready for installation and firing of methanol fuel with minor modification of existing burner equipment

Scope of Work

- Define site selection criteria
- Survey boiler population for site selection
- Undertake phone search for site selection and securing preliminary agreement
- Make site visit and secure host facility for the demonstration
- Prepare a retrofit, equipment modification and test plan
- Subcontract the burner vendor to make modifications to the burner for methanol ready firing
- Arrange for delivery, storage, and hookup of fuel
- Perform startup and initial diagnostic tests
- Perform emission and performance tests in line with the test plan
- Arrange for site equipment to return to normal
- Analyze test data
- Write report

Status

- Acurex has made preliminary contacts with the Illinois Clean Coal Institute (ICCI) to explore the interest in this demonstration. Heman Feldmann. Preliminary interest pending on the economic viability of LPMeOH<sup>TM</sup> as a cofire fuel compared with alternatives.

Further Actions

- Acurex will further explore interest in this demonstration following approval from all project stakeholders. The viability of the project will also hinge on securing cofunding using the open submittal of project ideas under the current ICCI open solicitation mechanism. Stakeholder approval and award of contract from ICCI following submittal of Acurex proposal will be followed up with the proposed scope of work described above. Level of ICCI cofunding is limited to \$250,000 per project.

Costs

**Total Funds:** \$115k  
**AP Funds:** \$45k  
**Cost Share:** \$70k

DATA SUMMARY FOR LPMEOH DEMONSTRATION UNIT

Case	Date	Gas Type	Temp (Deg C)	Pres. (psig)	Balanced				Recycle Gas (KSCFH)	Inlet Sup. Velocity (ft/sec)	Space Velocity (1/hr-kg)	Slurry Conc. (wt% ox)	Gas Holdup (vol%)	Gassed Slurry Hgt (ft)	Catalyst Inventory (lb)	CO Conv. (%)	Reactor O-T-M Conv. (%)	Syngas Util. (SCF/lb)	Raw MeOH Production (TPD)	Catalyst MeOH Prod. (gmol/hr-kg)	Reactor Vol. Prod. (TPD/Cu ft)
					Gas (KSCFH)	CO Gas (KSCFH)	H2 Gas (KSCFH)	Gas (KSCFH)													
1	12-Apr-97	Balanced	248	719	758	0	0	1,375	0.50	6,203	30.5	50.2	54.9	20,300	54.8	33.1	37.6	242.3	30.74	0.105	
1	13-Apr-97	Balanced	249	716	792	0	0	1,536	0.55	6,783	30.8	50.6	54.9	20,300	52.5	31.7	37.5	253.8	32.19	0.110	
1	14-Apr-97	Balanced	249	705	789	0	0	1,619	0.58	7,014	30.9	52.0	56.1	20,300	50.5	30.5	37.5	252.4	32.00	0.107	
1	15-Apr-97	Balanced	249	705	818	0	0	1,601	0.58	7,019	30.8	50.9	55.1	20,300	51.7	31.2	37.9	258.9	32.84	0.112	
1	16-Apr-97	Balanced	248	705	904	0	0	1,527	0.59	7,094	30.9	50.7	54.5	20,300	55.8	33.6	38.5	281.9	35.82	0.123	
1	17-Apr-97	Balanced	249	704	887	0	0	1,746	0.63	7,629	32.1	53.0	54.3	20,300	49.8	30.0	39.4	270.5	34.35	0.119	
1	18-Apr-97	Balanced	249	705	841	0	0	1,843	0.64	7,762	32.0	51.9	53.4	20,300	48.2	29.1	37.8	267.0	33.86	0.119	
1	19-Apr-97	Balanced	249	703	964	0	0	1,779	0.66	7,970	32.0	52.2	53.8	20,300	51.1	30.7	40.0	288.8	36.80	0.128	
1	20-Apr-97	Balanced	249	709	958	0	0	1,994	0.70	8,562	32.2	51.5	52.4	20,300	48.3	29.2	39.4	292.2	36.60	0.133	
1	21-Apr-97	Balanced	249	708	913	0	0	2,114	0.72	8,771	30.3	50.5	55.8	20,300	47.1	26.4	39.8	275.5	34.77	0.117	
1	22-Apr-97	Balanced	249	709	859	0	0	2,122	0.71	8,635	29.4	50.4	58.0	20,300	47.5	25.6	39.5	261.1	32.84	0.107	
1	24-Apr-97	Balanced	249	709	793	0	0	2,106	0.69	8,376	29.3	49.0	56.7	20,300	49.0	24.6	39.2	242.7	30.66	0.102	
1	25-Apr-97	Balanced	249	702	865	0	0	2,024	0.70	8,419	29.9	50.7	57.0	20,300	44.6	26.2	39.8	261.0	33.17	0.109	
1	26-Apr-97	Balanced	248	700	835	0	0	1,921	0.67	8,019	31.8	45.6	47.5	20,300	44.6	26.2	40.4	248.2	31.58	0.125	
1	26-Apr-97	Balanced	246	694	864	0	0	1,877	0.67	7,980	32.8	46.0	45.8	20,300	41.6	26.0	41.9	247.8	31.38	0.129	

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Attachment (5)

RUN NO: K1-4/25 TITLE: Shakedown & Design Production Tests

T	F	FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
P	psig	72 748	57 857	59 635	103 743	303 737	250 693	84 683	51 9	226 185	75 151
Comp (mol %)	H2	66.94	1.93	77.66	71.19	69.63	63.20	68.25	32.94	0.00	0.00
	CO	30.16	97.05	9.12	15.41	19.78	13.43	14.93	8.53	0.00	0.00
	N2	0.42	0.97	6.50	4.38	3.17	3.86	4.15	30.36	0.00	0.00
	CH4	0.04	0.05	0.92	0.53	0.38	0.46	0.50	0.72	0.00	0.00
	CO2	2.43	0.00	3.76	6.57	5.26	6.31	6.32	23.84	0.00	0.00
	DME	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00
	MeOH	0.00	0.00	0.06	0.29	0.39	11.23	4.22	3.62	82.65	99.98
	EtOH	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.16	0.01
	H2O	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	17.18	0.02
	others	0.00	0.00	1.97	1.64	1.39	1.40	1.62	0.00	0.01	0.00
	TOTAL	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Mole Wt	lb/lbmol
LHV	10.997
Enthalpy	234.0
	-40.73
Flow	835.142
	2,201.5
	24,211

MMBTU/hr	SCFH	lbmol/hr	lb/hr
10.753	2,755.353	2,261.917	73,896
717.5	7,263.4	5,962.7	194.8
-126.27	78,102	76,569	5,786
12.841	2,261.917	21,842	73,896
692.9	5,962.7	57.6	194.8
-155.95	76,569	1,343	5,786
23.324	65,707	21,842	73,896
3.3	173.2	57.6	194.8
-2.76	1,979	1,343	5,786
29.703	2,755.353	21,842	73,896
47.0	7,263.4	57.6	194.8
-49.88	78,102	76,569	5,786
32.039	2,261.917	21,842	73,896
140.8	5,962.7	57.6	194.8
-49.88	76,569	1,343	5,786

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3

**PLANNING DETAILS  
LIQUID PHASE METHANOL DEDICATION CEREMONY  
25 JULY 1997 - KINGSPORT, TENNESSEE**

**SCHEDULE OF EVENT: (Approximately 50 People)**

11:30 A.M. - 12:30 P.M. - Arrive/Lunch\*

\*Lunch time to be slightly extended due to key contact individuals seated together at lunch tables to allow for discussion.

(Peter, Stan, Ed), (Peter, Sarkus, Jones), etc.

ECH & B. Kornosky (FETC) - JAF/Jean Kendrick

12:40 P.M. - 1:10 P.M. - Remarks - 10 minutes each: Eastman, Air Products, DOE

1:15 P.M. - 1:35 P.M. - Dedication Ceremony (Ribbon cutting, 3 scissors)

Photo Opportunity

1:40 P.M. - Finish Dedication/Photos

1:45 P.M. - 2:45 P.M. - Tours\*\* - Trailer/Control Room/Walk Around

(Split into groups of 10 people maximum

\*\* 20 minutes (subject to change depending on key contact meetings and Eastman's ideas

Tour Guides: ECH/Van Eric Stein/Frank Frenduto/Barry Street

3:00 P.M. - Conclusion/Leave if want

- APCI to show DOE gasifier - if requested. (Not to be part of written agenda)

**ACTION ITEMS:**

Eastman: (Jean Kendrick)

- Find location for dedication ceremony, prefer outside at site. Need to have rain option.
- Food - Plan catered lunch (Air Products sponsored)
- Transportation to & from airport (Air Products sponsored)
- Other ideas/suggestions - awaiting to hear from Jean Kendrick (literature, etc.)
- Safety items - hard hats, safety glasses. For APCI: nomex suits, however ECH checking on waive option.

Air Products:

- APCI invitee list to be reviewed and finalized - (2 weeks) - PJAT/ECH - JAF keeping updated listing. ECH to receive DOE's finalized invitee listing on 5/9 from B. Kornosky (FETC).
- Invitations - Distribution date: Early June (6 weeks prior to event)

Semi formal: JAF to draft: suggested first page photo: completed plant snapshot -need negative from Barry Street (Eastman).

Any theme? Gary Stiegel suggested to BJH: "Industry Partnering with Government".

To be approved by PJAT/ECH/BJH Rsvp name in invitation: Rochelle Oswald  
Invitations to be sent/monitored by Rochelle.

Formal to Pat Godley - BJH/JAF to draft. ECH to send to Godley.

- Corporate jet reserved (done) - JAF  
JAF to check with A. Katsaros regarding number of executives to fly together on corp. jet.
- Plan Dedication Ceremony - Ribbon with 3 scissors - JAF ordered thru Shirley Miller
  - Remarks/speeches - ECH to prepare & work up for v.p.'s
  - Obtain Jean Kendrick's thinking/timing for speeches at ribbon cutting.
- Update APCI/DOE poster - PJAT/ECH/JAF- APCI & Bob Kornosky- DOE/Eastman
  - Draft changes: #2 photo: include aerial close-up photo - ECH
  - #3 photo: slight changes to technology deploy
  - #4 photo: change photo to Destec & Tampa per B. Kornosky
  - #5 photo: change bus photo, want message to portray various types of technology usage through schematics for chemistry, transportation, stationary power, fuel bus, etc (B. Kornosky)
  - Poster to be displayed (location? on easel? qty of copies?)
  - Need glossy sheets made (to be available in trailer/folder)- qty?
  - Is this one poster enough? Any more needed elsewhere?
- DOE fact sheet - ECH to update Clean Coal sheet with B. Kornosky (FETC)
- Name tags, additional info., etc. - Eastman & Air Products - Jean/JAF
- News Release/Photographer needed - Greta Campbell
- Literature packet/folder - Jean/JAF  
Elements/items: - 1-Agenda/2-Press Release/3-Updated DOE Fact Sheet on Clean Coal/  
4-Eastman's newsletter for startup (April edition)/5-Glossy copy of updated poster/  
(no biographies needed)
- Completed plant stickers for front page of literature packets - JAF
- Update ground sign at facility by removing dollar figures - ECH
- Giveaways: Acrylic block with LPMEOH flask & liquid methanol - JAF ordered thru Shirley Miller, Shirley checking, will advise.
- Make new vinyl banner to hang on fence near trailer (can copy from groundbreaking event) - JAF
- 14 photographs representing each month's progress to be displayed in trailer - ECH
- Order megaphone rather than phone walkie talkies for plant tours - ECH

**APPENDIX N - TASK 3.6 - MILESTONE SCHEDULE STATUS AND COST  
MANAGEMENT REPORTS**

# MILESTONE SCHEDULE STATUS REPORT

## LIQUID PHASE METHANOL DEMONSTRATION

### DE-FC22-92PC90543

Task Name	Duration	Start	End	% Comp	% Sched	Years											
						93	94	95	96	97	98	99	0	1			
<b>PHASE 1: DESIGN</b>																	
PROJECT DEFINITION(TASK 1)	51.20 m	Oct/01/93	Dec/30/97	98	95												
CONTINUATION APPLICATION(B.P.#2)	12.04 m	Oct/01/93	Sep/30/94	100	100												
PERMITTING(TASK 2)	9.00 d	Aug/02/94	Aug/10/94	100	100												
NEPA FONSI APPROVAL	33.95 m	Nov/17/93	Sep/10/96	100	100												
DESIGN ENGINEERING(TASK 3)	0.00 d	Jun/30/95	Jun/30/96	100	100												
VENDOR ENGINEERING	27.71 m	Apr/15/94	Aug/01/96	100	100												
OFF-SITE TESTING(TASK 4)	23.79 m	Aug/10/94	Jul/30/96	100	100												
UPDATED FUEL TEST PLAN APPROVAL	46.35 m	Feb/25/94	Dec/30/97	27	82												
DECISION TO CONTINUE DME TESTING	0.00 d	Jun/30/97	Jun/30/97	0	0												
PLANNING, ADMIN & DME DVT(TASK 5)	0.00 d	Dec/04/96	Dec/04/96	100	100												
<b>PHASE 2: CONSTRUCTION</b>																	
PROCUREMENT(TASK 1)	39.85 m	Oct/01/93	Jan/20/97	100	100												
CONSTRUCTION(TASK 2)	42.66 m	Oct/17/94	May/01/98	97	79												
TRAINING & COMMISSIONING(TASK 3)	21.54 m	Oct/17/94	Jul/30/96	100	100												
OFF-SITE TESTING(TASK 4)	16.10 m	Oct/02/95	Jan/31/97	100	100												
PLANNING & ADMINISTRATION(TASK 5)	17.88 m	Sep/05/95	Feb/27/97	100	100												
CONTINUATION APPLICATION(B.P.#3)	9.00 m	Aug/02/97	May/01/98	0	0												
<b>PHASE 3: OPERATION</b>																	
METHANOL OPERATION(TASK 2.1)	35.17 m	Jun/01/95	May/01/98	93	66												
DISMANTLE PLANT(TASK 2.3)	3.20 m	May/31/96	Sep/04/96	100	100												
ON-SITE PRODUCT USE DEMO(TASK 3)	59.51 m	Jan/20/97	Dec/28/01	0	4												
OFF-SITE PRODUCT USE DEMO(TASK 4)	2.31 m	Jan/23/97	Apr/02/97	100	100												
DATA ANALYSIS/REPORTS(TASK 5)	48.07 m	Apr/02/97	Mar/28/01	4	4												
PLANNING & ADMINISTRATIVE(TASK 6)	6.96 m	Jun/01/01	Dec/28/01	0	0												
<b>PROVISIONAL DME IMPLEMENTATION</b>																	
DME DVT(PDU TESTS)(TASK 3.6)	2.08 m	Aug/01/97	Oct/02/97	0	0												
DECISION TO IMPLEMENT	20.00 m	May/15/98	Jan/11/00	0	0												
DESIGN, MODIFY & OPERATE(TASK 3.2.2)	56.35 m	Jan/20/97	Sep/23/01	0	0												
	59.51 m	Jan/20/97	Dec/28/01	7	7												
	61.36 m	Apr/01/97	Jul/05/01	0	0												
	12.54 m	Apr/01/97	Apr/15/98	0	0												
	123.00 d	Mar/01/98	Jul/01/98	0	0												
	36.32 m	Jul/01/98	Jul/05/01	0	0												

Milestone  
 Summary  
 Fixed Delay



LIQUID PHASE METHANOL DEMONSTRATION - PHASE III

Task Name	Start Date	Duration In Weeks	End Date	Percent Complete	1997			1998			1999			2000						
					Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4					
<b>Task 2.1.1 - Process Shutdown and Catalyst Aging</b>																				
Test 1 - Initial Shutdown, and Design Production Tests	4/2/97	68.00w	7/22/98	100%																
Test 2 - Gassed Slurry Level	4/2/97	5.43w	5/10/97	100%																
Test 3 - Reactor Feed: Texaco-Type Syngas	9/10/97	24.00w	9/17/97	0%																
Test 4 - Early Testing @ High Superficial Velocity	10/1/97	3.00w	10/1/97	0%																
Test 5 - Check @ Test 1 Conditions	10/1/97	3.00w	10/22/97	0%																
Test 6 - Check @ Test 1 Conditions	6/10/97	4.20w	7/10/97	15%																
Test 6 - Catalyst Addition and Aging	7/10/97	31.71w	2/17/98	0%																
Test 7 - Free-Drain Entrained/ Condensed Oil to Reactor	4/2/97	53.00w	4/8/98	17%																
Test 8 - Operation @ Design Feed Gas Rates	2/17/98	2.00w	3/3/98	0%																
Test 9 - Check for Limitation on Catalyst Slurry Concentration	3/3/98	7.00w	4/21/98	0%																
Test 10 - Catalyst Addition to Reach Max Productivity	4/21/98	13.14w	7/22/98	0%																
<b>Task 2.1.2 - Process Operational Test Phase</b>																				
Test 11 - Catalyst Addition/Withdrawal Test	7/22/98	105.00w	7/26/00	0%																
Test 12 - Test 11 Conditions with No CO Make-up	9/2/98	6.00w	9/2/98	0%																
Test 13 - Test 11 Conditions with No H2 Make-up	9/16/98	2.00w	9/16/98	0%																
Test 14 - Test 11 Conditions with No H2 or CO Make-up	10/7/98	3.00w	10/7/98	0%																
Test 15 - Repeat of Test 11 Conditions	10/21/98	2.00w	10/21/98	0%																
Test 16 - Repeat of Test 11 Conditions	11/4/98	2.00w	11/4/98	0%																
Test 17 - Design Fresh Feed Operation Test	11/14/98	3.00w	11/25/98	0%																
Test 17 - Testing @ High Superficial Velocity	11/25/98	2.00w	12/8/98	0%																
Test 18 - Shutdown and Ramping	12/8/98	4.00w	1/6/99	0%																
Test 19 - Load-Following, Cyclone, & On/Off Tests	1/6/99	7.00w	2/24/99	0%																
Test 20 - Reactor Feed: Texaco-Type Syngas	2/24/99	4.00w	3/24/99	0%																
Test 21 - Reactor Feed: Destec-Type Syngas	3/24/99	3.00w	4/14/99	0%																
Test 22 - Reactor Feed: BGL-Type Syngas	4/14/99	3.00w	5/5/99	0%																
Test 23 - Repeat of Test 15 Conditions	5/5/99	3.00w	5/26/99	0%																
Test 24 - Reactor Feed: Nat. Gas Reforming-Type Syngas	5/26/99	3.00w	6/16/99	0%																
Test 25 - Reactor Feed: Shell-Type Syngas with Steam Injection and 1:1 Recycle	6/16/99	3.00w	7/7/99	10%																
Test 26 - Repeat of Test 15 Conditions	7/7/99	3.00w	7/28/99	0%																
Test 27 - Repeat of Test 18 Conditions	7/28/99	2.00w	8/11/99	0%																
Test 28 - Reactor Operation @ 280 deg C	8/11/99	2.00w	8/25/99	0%																
Test 29 - Repeat of Test 26 Conditions	8/25/99	2.00w	9/8/99	0%																
Test 30 - Reactor Inspection - Then, Continue with Alternative Catalyst	9/8/99	4.00w	10/6/99	0%																
Test 31 - Plant Shutdown	10/6/99	6.00w	11/17/99	0%																
Test 32 - Reactor Feed: Texaco-Type Syngas	11/17/99	3.00w	12/8/99	0%																
Test 33 - Catalyst Aging	12/8/99	22.00w	6/10/00	0%																
Test 34 - Catalyst Addition/Withdrawal to Achieve Target Slurry Concentration	6/10/00	6.00w	6/21/00	0%																
Test 35 - Reactor Feed: Texaco-Type Syngas	6/21/00	6.00w	7/28/00	0%																
<b>Task 2.1.3 - Extended Optimum Operation</b>																				
Test 36 - Stable Operation	7/28/00	35.00w	3/28/01	0%																
Test 37 - Commercial Test Run	1/31/01	27.00w	1/31/01	0%																
		8.00w	3/28/01	0%																

**COPY**

8. ELEMENT	9. REPORTING ELEMENT		10. ACCRUED COSTS				11. ESTIMATED ACCRUED COSTS				12. Total Contract Value		13. Variance	
	1. TITLE		Cumulative to Date		a. Subsequent Reporting Period	b. Balance of Fiscal Year	c. FY 1998 (1)	FY 1999 (2)	FY 2000 (3)	d. Subsequent FY's (4)	e. Total	Total		
	a. Actual	b. Plan	c. Actual	d. Plan										Contract Value
		Prior to Mod 2	0	16,304	0	0					16,304	16,289	1	
1.1.1		Project Definition	0	0	0	1,021	0	0	0	0	1,039	1,021	1	
1.1.2		Permitting	0	0	0	246	0	0	0	0	253	246		
1.1.3		Design Engr.	36	0	10,896	10,865	0	0	0	0	10,979	9,960	1,011	
1.1.4		Off-site Testing	1	20	36	169	65	0	0	0	276	320	(4)	
1.1.5		Planning, Admin, & DMB Verif. Testing	0	0	2,984	2,055	0	0	0	0	2,984	1,892	1,092	
1.2.1		Procurement	4	0	10,173	9,000	0	0	0	0	10,326	9,783	543	
1.2.2		Construction	72	0	11,629	13,519	0	0	0	0	11,629	11,200	429	
1.2.3		Train. & Commissioning	0	0	588	2,162	0	0	0	0	588	1,197	(609)	
1.2.4		Off-Site Test - Proc. & Constr.	0	0	0	0	20	136	0	0	256	261	(5)	
1.2.5		Planning & Admin	0	15	966	853	15	90	0	0	1,071	681	390	
1.3.1		Startup	1	0	1,445	680	0	0	0	0	1,445	3,435	(1,990)	
1.3.2		Operations												
1.3.2.1		Methanol Operation	2,058	2,546	6,503	12,685	2,545	14,993	34,240	38,689	40,061	145,730	147,287	(1,557)
1.3.2.2		DMB Design, Mod., Oper.	0	0	0	0	0	0	0	0	0	1,790	2,340	(550)
1.3.2.3		LP/BOH Dismantlement	0	0	0	0	0	0	0	0	0	515	425	90
1.3.3		On-Site Product Use Demo	0	0	0	0	0	2	2	0	0	4	4	0
1.3.4		Off-Site Product Use Demo	0	0	0	0	0	0	1,233	1,972	246	3,451	3,840	(389)
1.3.5		Data Analysis & Reports	15	60	18	208	61	310	520	500	553	2,670	1,926	744
1.3.6		Planning & Admin.	49	80	346	220	100	74	800	280	282	2,392	1,593	799
14. TOTAL			2,236	2,721	63,180	69,974	2,788	15,933	36,996	42,008	42,365	213,700	213,700	0

15. DOLLARS EXPRESSED IN: Thousands

16. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE: *[Signature]* 7/21/97

17. SIGNATURE OF PARTICIPANT'S AUTHORIZED FINANCIAL REPRESENTATIVE AND DATE: *[Signature]* 7/21/97

**APPENDIX O - PRESS RELEASE (21 MAY 1997) AND PRESS COVERAGE**

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97089

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## CLEAN COAL DEMONSTRATION PROJECT IN KINGSPORT, TENN. NOW PRODUCING COMMERCIAL QUANTITIES OF METHANOL

Novel Process Offers Power Generation Flexibility  
In Integrated Gasification, Combined-Cycle Facilities

LEHIGH VALLEY, Pa. (May 21, 1997) -- A first-of-a-kind demonstration facility is now producing methanol from coal-derived synthesis gas on a commercial scale at Eastman Chemical Company, using Air Products and Chemicals, Inc.'s patented liquid phase technology.

The demonstration facility, which started up in early April at Eastman's Kingsport, Tenn. site, quickly achieved one of its initial performance targets by producing methanol at an 80,000 gallon-per-day rate, confirming the 25 to 1 size scale-up of the liquid phase reactor. The reactor's stability and flexibility have also been confirmed during more than 700 hours of stable operation at varying feed rates. The methanol has met all purity specifications and is being used directly as chemical feedstock.

The liquid phase methanol project is a cooperative effort between the Air Products Liquid Phase Conversion Company — a limited partnership formed by Air Products whose technology is being tested and the Eastman Chemical Company whose integrated coal-gasification facility in Kingsport is the host site for the demonstration — and the U. S. Department of Energy, who is funding 43 percent of the project's total cost under its Clean Coal Technology Demonstration Program.

The liquid phase methanol technology is designed to lower electricity costs and improve the flexibility of electric power generation in integrated gasification, combined-cycle (IGCC)

-more-

facilities. It accomplishes this by allowing the manufacture and sale of two products: electricity and methanol. The liquid phase methanol process can take advantage of periods of low electricity power demand by producing and storing methanol. This methanol is immediately available to generate electricity when the utility faces its next period of high power demand. This step will increase the utilization of gasifier capacity and lower the utility's costs. Several potential domestic and international customers are currently studying the possibility of incorporating the technology in their gasification systems.

The demonstration facility has met all of its early operational expectations. The next operational goal is to maximize the methanol production rate beyond 80,000 gallons per day and to demonstrate long-term catalyst life while operating on coal-derived synthesis gas. A carefully developed test plan that will be implemented over the next four years will assure that the technology is tested over a wide range of operating conditions and synthesis gas compositions to demonstrate its commercial advantages. Test operations will simulate electricity demand load-following by demonstrating the reliable off/on operation that the enhanced stability and heat dissipation of the liquid phase reactor provides.

The liquid phase methanol process differs significantly from commercial methanol processes because of its integrated reactor and heat removal system. Typically, methanol is made by passing synthesis gas mixtures with a very specific composition of hydrogen and carbon monoxide through a fixed bed of dry catalyst pellets. In the "liquid phase" process, fine particles of the temperature-sensitive methanol catalyst are suspended in an inert liquid. The liquid dissipates the heat of the chemical reaction away from the catalyst surface, protecting it and allowing the gas-to-methanol reaction to proceed at higher rates.

Because of its superior heat management, the process is able to directly handle the synthesis gas typically produced from the gasification of coal, petroleum coke, residual oil, wastes, or other hydrocarbon feedstocks. The liquid phase process readily converts a portion of the synthesis gas produced by the gasifier to methanol, allowing the remainder of the unconverted gas to be used to make other chemicals, for hydrogen recovery, or as a fuel for a gas turbine combined-cycle electric power plant.

Air Products expects to market the liquid phase methanol technology and its other liquid phase technologies through licensing, "own and operate" or tolling arrangements. As a world leader in the design, construction and operation of high-pressure oxygen plants for gasification applications, the company also can serve other commercial roles in IGCC projects, including the supply of equipment or on-site oxygen, and the clean-up and recovery of hydrogen and other gases.

Eastman Chemical Company manufactures and markets chemicals, fibers and plastics. Eastman employs 17,500 people in more than 30 countries and had 1996 sales of \$4.8 billion. Corporate headquarters are in Kingsport, Tennessee.

Air Products and Chemicals, Inc. is a \$4 billion global company with leading market positions in industrial gases and selected chemicals. Through innovative engineering, technology and marketing, the company provides products and services that help its customers win in markets around the world.

- # # #

To: DISTRIBUTION

Dept/Loc:

From: G. Campbell

Dept/Ext: Corp. Comm./ x14986

Date: 6 June 1997

Subject: LIQUID PHASE METHANOL PUBLICITY

- cc: B. M. Arndt  
D. M. Brown  
H. G. Dimopoulos  
A. G. Dolan  
B. J. Halper  
E. C. Heydorn *ABIEG*  
M. F. Hilton/K. M. Walck  
J. J. Holliday  
E. L. Kelly/J. R. Dodds  
S. A. Morth  
F. R. Schepis  
J. C. Sorensen  
J. F. Strecansky  
P. B. Sullivan  
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VES ✓  
DPD ✓  
BAT ✓  
FJW ✓  
B. J. Street (EMW) ✓  
R. M. Kornowky (DOE) ✓

*10 June 97*

Attached is the initial coverage we have received on the start-up of the liquid phase methanol demonstration plant in Kingsport, Tenn. As we receive additional coverage of this project over the next several weeks, I'll pass the clippings on to you.

Attach.

*See C.*

# A hive of activity



**PROCESS**

**T**he drive for greater energy efficiency, environmental friendliness, reduced downtime and improved profit margins sets ever increasing challenges to the methanol technology suppliers – and increasingly new plants have to be tailored to the specific project case.

While methanol is one of the most basic petrochemical products with some 25m tonne produced each year, there appears to be an upturn in methanol project activity worldwide. At least three large-scale projects are being progressed in the Middle East (Al Jubail, Saudi Arabia; Kharg Island, Iran; Umm Said, Qatar), two in Trinidad and one each in Indonesia and Chile, all with a feedstock cost advantage. Here in Europe there are new project proposals on both sides of the North Sea. In Norway a second plant is under consideration by Statoil, while in the UK project development company International Offshore Chemicals is pursuing a world-scale integrated methanol and ammonia plant – although the choice of location remains contentious. Many other smaller projects and revamps are underway. All will undoubtedly incorporate some new technological aspects.

Leading methanol synthesis licensor Lurgi has widely touted its developments in methanol reactor design in recent months, while Kvaerner John Brown, a leading approved contractor for ICI Katalco methanol catalyst and systems technology, is understood to be working quietly on new process enhancements following the recent signing of an agreement on reformer technology with BP. An announcement on the new process is expected towards the end of the year.

At the same time, other technology developers strive to commercialise alternative novel routes – the first commercial-scale demonstration plant to produce methanol from coal-derived synthesis gas came onstream at Eastman Chemical's Kingsport site in March, while Lurgi and catalyst partner Süd-Chemie have developed a reactor and catalyst system to produce methanol from carbon dioxide and hydrogen. Others strive to improve the conversion rates of more conventional processes – Twente University of

Contractors and producers are looking at improved ways of making methanol. Susan Royse takes a look at the many innovations currently taking place in the methanol industry.

Technology in the Netherlands has developed a pilot-scale process which obviates the need for a recycle loop and could achieve a conversion of over 97% (ECN 5 May), while the idea of floating methanol plants continues to be pursued by, amongst others, ICI Katalco despite the apparent indefinite postponement of previously announced major projects planned for Oman, Argentina and Indonesia.

Methanol is conventionally manufactured from synthesis gas (a mixture of carbon monoxide and hydrogen), produced from steam-reformed natural gas (or oil associated gas) and carbon dioxide. The methanol is synthesised in a catalytic process and the crude product is purified by distillation. While the synthesis reac-

tor and catalyst system are clearly at the heart of the process, and where much of the recent development effort has been focused, the whole process scheme provides numerous opportunities for design improvements. For example, optimum utilisation of the reaction heat offers cost advantages and energy savings for the overall plant.

Two types of reactor dominate the industrial methanol market: gas-cooled (quench reactors or gas-cooled tubular reactors) and steam-raising reactors, where the reaction heat is transferred to boiling water.

Lurgi, a leading proponent of the steam-raising type, notes a trend towards steam-raising reactors of various design. Such reactors are also now offered by Linde, Toyo Engineering, Mitsubishi Gas Chemical and ICI-approved contractors.

Lurgi's Herman Goehna explains the trend in terms of a growing focus on the control of the methanol-producing reaction in light of the development of more active, temperature-resistant catalysts. 'To achieve the same overall conversion efficiencies, modern catalysts

require smaller recycle ratios than catalysts of the first generation, he explains. 'This results in higher partial pressures of the reaction components at the reactor inlet so that the rapid removal of the reaction heat from the methanol reactor is becoming all the more important.'

While conceding that steam-raising reactors are more expensive than gas-cooled, Goehna argues that gas-cooled reactors suffer the disadvantages of poor utilisation of the reaction heat, low catalyst yield, high byproduct generation in the case of carbon monoxide rich synthesis gas, high pressure loss due to quench gas control and the potential risk of catalyst superheating.

Europe's latest methanol plant, the 2400 tonne/day Statoil/Conoco joint venture at Tjeldbergodden, Norway, commissioned last month, incorporates Haldor Topsøe's two-stage reforming technology together with Lurgi's methanol synthesis technology based on steam-raising reactors. The plant incorporates several new features. One is a new type of burner (for the oxygen-fired secondary reformer) supplied by Haldor Topsøe. 'There have been severe problems with burners in the

## PRODUCTION COST ESTIMATE FOR CO-PRODUCED METHANOL USING THE AIR PRODUCTS' LIQUID-PHASE CONVERSION PROCESS (PLANT CAPACITY 152 000 GAL/DAY; CAPITAL INVESTMENT, \$29 M)

Base load	
Methanol plant operation (hours/year)	7884
Methanol production (m gal/year)	49.9
Methanol production cost	
Syngas cost	
Feed gas @ fuel value (\$4.00/mBtu)	98.7
Unreacted (CO-rich) gas @ fuel value (\$4.00/mBtu)	(68.4)
Sub-total; net cost of syngas converted:	30.3
Operating cost:	
Catalyst and chemicals	2.6
Export steam	(2.9)
Utilities	0.9
Other (fixed) costs	4.0
Sub-total; operating costs	4.6
Capital charge:	
@ 20% of investment/year	11.6
<b>Total methanol production cost</b>	<b>46.5</b>

SOURCE: AIR PRODUCTS AND CHEMICALS



past. With flame temperatures of around 2000°C, even metal tends to vaporise. Flames can enter the refractory lining, even causing open fires,' says Peter Sogaard-Andersen, manager of Topsøe's refinery technology group.

The key to the new burner design is in controlling the flames – no backflow of hot gas towards the burner parts, a flame core located along the centre axis and an efficient recirculation in the combustion chamber zone. One such burner has operated for four years without problems at a Grande Paroisse ammonia plant in Waziers, northern France, Sogaard-Andersen claims. This compares with a typical burner life of around eight to nine months, he says, and as such should lead to significant improvements through reduced plant downtime.

A second key feature in the new plant is the back-end distillation (to purify the crude methanol), again designed and supplied by Topsøe. Here – with limits placed on carbon dioxide emissions – the focus has been on energy efficiency, with a split column design to allow use of the energy twice.

Of course, not all development relates to new plants. Modernising an existing reactor can prove a simple and effective means of upgrading production and improving performance. Methanol Casale specialises in such revamps and has recently implemented its Advanced Reactor Concept (ARC) in six projects.

The ARC is an adiabatic quench-cooled single-vessel converter which the company claims offers an improved quench mixing. It has been introduced as a revamp option for ICI's quench lozenge converter, but is equally applicable to other designs. The ARC is based on a typical peripheral mixer. A gas sparger introduces the quench gas in such a way as to generate the turbulence required for good mixing, while a deflector induces further local mixing and smooths out any temperature differences.

The \$213.7m Eastman demonstration project is a joint venture with technology supplier Air Products, supported with \$92.7m from the US Department of Energy's Clean Coal Technology Program. The aim is to produce methanol cost competitively from coal-derived synthesis gas, which tends to be rich in carbon monoxide.

Currently, less than 2% of world methanol is derived from coal. The key is in the use of a liquid-phase process employing a slurry bubble column reactor with powdered copper catalyst slurried in an inert mineral oil. This allows more controlled heat removal than conventional fixed-bed reactors operating in the gas-phase, and hence the synthesis process does not require a balanced carbon monoxide/hydrogen ratio. The slurry reactor is expected to achieve double the synthesis gas conversion rates per pass than a conventional reactor.

The process should be equally applicable to gasification of petroleum coke, residual oil or other hydrocarbon feedstocks. When added to an integrated gasification combined cycle power plant, the process converts a portion of the CO-rich synthesis gas to methanol, and the

remainder of the unconverted gas is used to fuel the gas turbine combined cycle power plant. Co-production of power and methanol via integrated gasification combined cycle could provide opportunities for energy storage for electrical demand, clean fuel for export and/or chemical methanol sales.

The 240 tonne/day demonstration plant achieved design production rates smoothly during the last week of March, according to Bill Brown, programme manager for the demonstration project. During a planned four-year operational phase, the plant will be subjected to a wide variety of test conditions. Most of the product methanol will be refined to chemical-grade quality and used by Eastman as replacement chemical feedstock. Eastman uses methanol in the manufacture of both acetic acid and dimethyl terephthalate (DMT). Use of the methanol as a feedstock for producing MTBE will also be investigated and, in the last six months of the project, the production of dimethyl ether (DME) as a co-product will also be assessed.

A commercialisation programme is set to run in parallel. 'Many refineries are looking at

"Small-scale units should prove competitive in local US markets with new world-scale overseas methanol plants"

gasification and are interested in seeing the process demonstrated,' says Brown. In any future technology licensing deal, Air Products would be interested in being involved as the gas supplier, he says.

Plants producing around 1200 tonne/day methanol with co-production of power and/or hydrogen are envisaged. These relatively small-scale units should prove competitive in local US markets with new world-scale overseas methanol plants. Brown estimates co-production costs for the liquid phase process of less than 50 cent/gal, which compares favourably with today's total delivered US Gulf Coast methanol cost (chemical grade) of some 55-60 cent/gal (see table, left).

A second alternative methanol feedstock under investigation is the combination of carbon dioxide and hydrogen, interest in such a process has heightened, not least because of the urgent need to find ways of reducing carbon dioxide emissions into the atmosphere as concerns mount over the role of the gas in global warming. Lurgi believes that small-scale methanol production could be economically justified at locations where both byproduct hydrogen and carbon dioxide are available.

In a joint development programme with Süd-Chemie, Lurgi has developed a catalyst and reactor system to convert a mixture of carbon dioxide and hydrogen to methanol in two parallel reactions. One, exothermic, to give methanol and water, the second, endothermic, to give carbon monoxide and water. The conversion rate and methanol selectivity depend on the pressure and temperature, with methanol formation favoured at high pressure and low temperature. To optimise the process, the partners have developed a copper-bearing, low-pressure catalyst, with which the highest methanol yield is obtained at 260-270°C.

A novel synthesis configuration has been devised in which the greater part of the reaction heat is used for generating high pressure steam. The configuration differs from the conventional in that, instead of adding the makeup gas to the recycle gas, it is directly passed through the catalyst-filled tubes of an adiabatic fixed-bed reactor in the once-through mode. This can be done at full synthesis pressure without risking catalyst superheating.

The product gas is then fed to a synthesis loop equipped with a second reactor which operates under quasi-isothermal conditions. The exothermic reaction (to give methanol and water) clearly predominates and the heat liberated is used to generate high-pressure steam at up to 70bar. By controlling the steam pressure, the narrow temperature range in which optimum thermodynamic and kinetic conditions occur can be reliably adjusted. Closed-circuit operation of the isothermal reactor suppresses the formation of unwanted carbon monoxide, resulting in high conversion rates. Development work at Lurgi continues, but the process has yet to be taken up commercially.

ICI Katalco continues to remain upbeat about the potential of floating methanol plants. The idea – to make use of associated gas from offshore oilfields – has been around since the 1970s, but commercialisation has proved more difficult than originally imagined.

Essentially, difficulties have been encountered in the design of a sufficiently robust, compact, wave-insensitive steam-reforming furnace. ICI Katalco believes it may have the answer in its compact gas-heated reformer, tested as part of its LCM methanol technology at BHP Petroleum's facility at Laverton, Australia. Test results on the furnace, the oxygen burner and distillation column look favourable, and work with BHP Petroleum continues. The dream, if realised, could transform the economics of the methanol industry in the 21st century. ■

Animal Health

# Mallinckrodt Sells Veterinary Unit to Schering-Plough

**C**ONTINUING ITS RESTRUCTURING DRIVE, Mallinckrodt has sold its \$456-million/year animal health business to Schering-Plough (Madison, NJ) for \$405 million. Ray Holman, Mallinckrodt's chairman and CEO, says the company plans to use the proceeds from the deal—along with \$550 million from the recent sale of its stake in Tastemaker—to buy back stock and make acquisitions in the health care segment.

The move reduces Mallinckrodt to seven health care and specialty chemicals divisions. The company says it is looking at acquisitions in medical products and pharmaceuticals and that it can spend \$1.3 billion-\$1.5 billion in a combination of cash and debt. Mallinckrodt says it does not plan to make more specialty chemicals acquisitions.

Jeffrey Cianci, an analyst at Bear Stearns, says, "If Mallinckrodt acquires, it will significantly dilute its earnings per share. The company should use the proceeds for more buybacks because of the high price of health care acquisitions."

The deal catapults Schering-Plough from the 20th-largest animal health company to ninth (*table*), says Matthew Phillips of Wood Mackenzie (Edinburgh). "The acquisition will expand Schering-Plough's exposure in vaccines, building on its poultry products business and the North American pet product lines acquired from American Home Products earlier this year," he says. "The move will also considerably expand Schering-Plough's international presence, reducing its depen-

dence on the U.S. market."

The deal continues a consolidation trend in the animal health market. Since the

## ANIMAL HEALTH LEADERS\*

(in millions of dollars)	
COMPANY	SALES
Roche	\$1,464
Merial <sup>1</sup>	1,415
Pfizer	1,222
Bayer	888
Rhône-Poulenc	763
BASF	730
American Home Products	710
Novartis	680
Schering-Plough	666
DowElanco	547

\* 1996; all acquisitions consolidated. 1) Joint venture between Rhône-Poulenc and Merck. Source: Wood Mackenzie Animal Health Service (Edinburgh).

beginning of this year, Merck and Rhône-Poulenc have merged their animal health, and poultry genetics businesses; American Home Products has acquired Solvay Animal Health; Bayer has acquired Pharmacia & Upjohn's vaccines business; and Boehringer Ingelheim (St. Joseph, MI) has purchased vaccines maker NOBL Laboratories.

—KERRI A. WALSH

Resins

# Borden Buys Indspec Unit

**B**ORDEN CHEMICAL HAS PURCHASED the phenol-resorcinol wood adhesive and reinforced plastic resins businesses of Indspec Chemical (Pittsburgh), a subsidiary of OxyChem. Borden will produce the adhesives and resins using phenol-resorcinol supplied by Indspec.

Borden says the acquisition will enhance its position in the rapidly expanding radiation curing segment of the wood adhesives business. The acquisition includes Indspec's patented phenol-resorcinol radiation-cured wood adhesives.

The business will be merged with Borden's

forest products unit, and Borden will manufacture the acquired product lines at its facilities in Springfield, OR and Demopolis, AL. Borden will also obtain Indspec's line of phenol-resorcinol resins used in reinforced plastic composites, which will become part of Borden's foundry and industrial products business.

Indspec is the world's largest producer of resorcinol and the only U.S. producer, with capacity for 58 million lbs/year in Petrolia, PA. OxyChem bought a 65% stake in Indspec in 1995 from New York merchant bank Castle Harlan.

—STEVEN VAMES

## COMPANIES

### REXENE-HUNTSMAN TALKS GET MORE FRIENDLY

Rexene has rescheduled a May 22 stockholders meeting that was to evaluate Huntsman Corp.'s \$16/share bid for Rexene. The meeting will be held June 12 to accommodate negotiations that are under way between the companies.

Rexene management scheduled the May 22 meeting after Huntsman signed a secrecy agreement in late April to gain access to confidential company information for its due diligence review.

Huntsman has since completed due diligence, and a Rexene spokesperson says both companies are proceeding with acquisition discussions in a "cooperative" manner. However, he adds, there is no guarantee that a definitive agreement will be reached. Huntsman launched its bid for the plastic resins and films maker last August.

—ROBERT WESTERVELT

## TECHNOLOGY

### AIR PRODUCTS, EASTMAN START COAL-TO-METHANOL UNIT

Air Products and Chemicals and Eastman Chemical have started up a demonstration plant at Kingsport, TN using novel coal-to-methanol technology. The companies say the unit is producing 80,000 gal/day of methanol.

The plant is based on Air Products' liquid-phase technology for converting coal-derived synthesis gas (syngas) into methanol (*CW*, Oct. 25, 1995, p. 41). The technology is being developed in a joint effort between Air Products, Eastman Chemical, and the Department of Energy, which is funding about 43% of the project's total cost under the agency's Clean Coal technology program.

The group says it plans to test the process during the next four years to optimize operating conditions and to demonstrate the technology's commercial advantages. If the tests are successful, Air Products expects to market the coal-to-methanol technology to other producers. Eastman plans to use the methanol produced at the plant as a chemical feedstock.

—DAVID ROTMAN

# CHEMICAL MARKET

Volume 251 No. 21

REPORTING THE BUSINESS OF CHEMICALS SINCE 1911

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## THIS WEEK

**EASTMAN CHEMICAL** has opened a demonstration plant at its Kingsport, Tenn., complex that is producing methanol from coal-derived synthesis gas on a commercial scale using Air Products and Chemicals Inc.'s liquid phase technology [page 3].

**IN RESPONSE** to a market with tight supply and high operating rates, two chlorine producers are pushing for a \$25-per-ton price increase. If other producers follow, this would mark the third price hike this year, bringing the total increase for the product in 1997 up to \$80 [page 5].

**VEBA IS ACQUIRING** a 36.4 percent stake in Degussa in a move which could lead to the creation of a large new German specialty chemicals operation [page 7].

**THE INTERNET** has made fundamental changes in the delivery of news and information. Within the last two years, printed newspapers have made the transition from print to the interactive World Wide Web [page 18].



Hercules' production site at Brunswick, Ga., is one of the company's primary rosin resin plants.

## Hercules Declares Commitment To Both Sides of Resins Unit

Capital spending, though, is focused on hydrocarbons.

By Michael McCoy

"WE ARE HERE TO STAY. Hercules is not getting out of the resins business," says R. Michael Alberts, division vice-president and general manager of Hercules Incorporated's resins division, in response to competitors who question his company's commitment to the business.

Hercules Resins is a \$500 million busi-

ness question where loyalties lie for a company that sells competing rosin and hydrocarbon resins.

Mr. Alberts and other Hercules Resins executives acknowledge these points but don't consider them negatives. Hercules sees itself as equal to its integrated competitors in feedstock sourcing, due to its wide range of options. The dual-product lines is a

## Acrylic Acid For Massiv Capacity I

BASF is latest end-use-driven c Markets remain

By John Hoff

**ACRYLIC ACID PRODUCERS** massive new capacity, but market to stay relatively to strong demand in all m

BASF Corporation has est manufacturer to joi boom. A week and a half started up its new 160 crude acrylic acid plant Freeport, Tex., raising th plate of 300,000 metric t ny opened an identical ac Antwerp, Belgium, early l

BASF's action comes o announcement at the Elf Atochem and Nippon formed a 50-50 joint v 120,000-metric-ton acty the Gulf Coast. The comj project to cost \$200 mill butyl acrylate unit (CMR 1). They plan to start bu duction in 1999 and begi acrylic acid by late 2003.



ions. The other products, Evatec, brought an expansion on line in January.

## Sovereign Buys Laporte Unit

Sovereign Specialty Chemicals LP has agreed to purchase Laporte PLC's North American adhesives, sealants and coatings division for about £77 million (\$123 million). The Laporte unit, with sales of £77 million last year, includes Ohio Sealants Inc., Darworth Company, Mercer Products Company and Evode-Tanner Industries Inc.

The Laporte purchase is Sovereign's third within the past year. It acquired Goodrich's adhesives systems division in April 1996 and Pierce & Williams from Sherwin-Williams in August 1996. Total revenues for the combined operations will exceed \$200 million.

Laporte sold most of its European adhesives unit to Elf Atochem earlier this year for £110 million. Laporte said last week that its Italian unit will be sold to Lafarge SA for £10 million.

## PQ to Enter Molecular Sieves

PQ CORPORATION is expanding its Kansas City, Kan., facility and will manufacture molecular sieves for the adsorbent and desiccant markets. The new plant will start up in late 1997 and have a capacity of 40 million pounds of formed product. The multimillion-dollar unit will supply molecular sieves for numerous end uses, including insulated glass, natural gas drying and purification, medical oxygen concentration, air purification and chemical processing. The company plans to market the products throughout the world.

Early last year, PQ restarted a zeolite plant in Kansas City, Kan., that was idled in 1994 because of lack of demand. The company is using the Kansas City site to manufacture sodium silicate, detergent zeolites, zeolite catalysts and silica gel, and says it is the preferred location for launching new products.

## Borden Buys Indspec Resins

BORDEN CHEMICAL Inc. has bought the phenol resin sorcinol wood adhesive and reinforced plastic resins business of Indspec Chemical Corporation. The acquisition includes new, enhanced technology for radio-frequency curing resins systems.

Borden will merge the Indspec business with its forest products business unit and manufacture the acquired product lines at its facilities in Springfield, Ore., and Demopolis, Ala. The purchase also includes phenol resorcinol resins used in reinforced plastic composites, primarily in pultrusion, resin transfer molding and wet lay-up applications. These products will become part of Borden's foundry and industrial products business.

from a more proper view since that year or so, according to one of the leaders in the \$10 billion worldwide animal health market.

Schering says the purchase will enable it to compete

## Process Technology

# Eastman Features Novel Methanol Route Using Liquid-Phase Reactor

By John Hoffman

EASTMAN CHEMICAL Company has opened a demonstration plant at its Kingsport, Tenn., complex that is producing methanol from coal-derived synthesis gas on a commercial scale using Air Products and Chemicals Inc.'s liquid phase technology.

Eastman's plant started up in early April and is already producing methanol at a rate of 80,000 gallons per day, a 25-to-1 scale-up from its initial operations. The liquid-phase reactor has run for more than 700 hours at varying feed rates, and the methanol has met all purity requirements and is being used directly as a chemical feedstock. The liquid-phase methanol plant is a cooperative effort between Air Products Liquid Phase Conversion Company—a limited partnership between Air Products and Eastman—and US Department of Energy, which is funding 43 percent of the project's cost under its clean coal technology program.

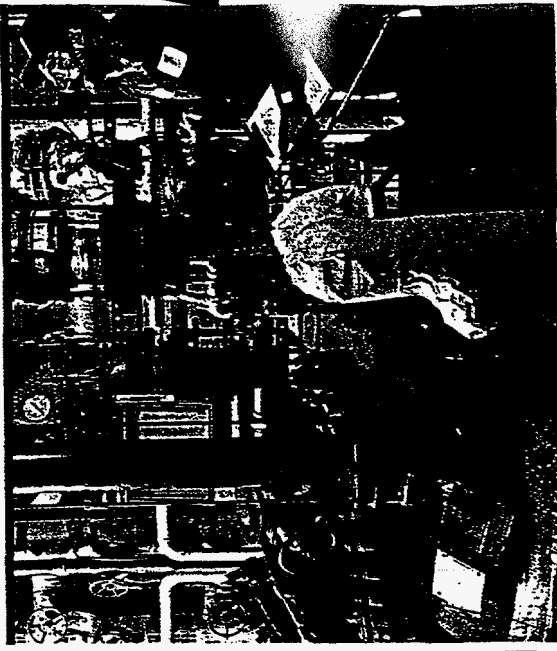
DOE expects the technology to lower electricity costs and improve the flexibility of power plants. The liquid-phase methanol process can take advantage of periods of low power demand by producing and storing methanol for consumption when electrical demand is high.

The companies say the demonstration unit has met all of its initial requirements. The next goals are to raise methanol production beyond 80,000 gallons per day and show that its catalyst can operate over the long term while running on coal-derived synthesis gas. During the next four years, the technology will be tested over a range of operating conditions and synthesis gas compositions.

The liquid-phase methanol process differs from commercial methanol processes because of its integrated reactor and heat removal systems.

Methanol is traditionally made by passing synthesis gas mixtures, with a very specific composition of hydrogen and carbon monoxide, through a fixed bed of dry catalyst pellets. In the liquid-phase process, fine particles of the temperature-sensitive methanol catalyst are suspended in an inert liquid.

Health, says MVI's research capabilities in viral vectors, gene deletion and controlled release technology hold considerable promise.



Pressure Chemical Company, Pittsburgh, Pa., has a newly available facility to benefit custom process research and pilot development programs. The plant's specialized design allows for a wide range of synthetic capabilities, the company says. Pressure Chemical specializes in high pressure chemistry and controlled polymer synthesis.

## Air Products Buys ICI Alkyl Amines Business

AIR PRODUCTS AND CHEMICALS Inc. will acquire ICI Chemicals and Polymers Ltd.'s worldwide ethyl and higher amines business. Air Products says the purchase will "significantly increase" the company's global position in the alkyl amines market.

ICI's methyldamine and derivatives businesses are not included in the sale. Financial details of the transaction were not disclosed, but the business has annual sales of around £10 million (\$16 million).

ICI will continue to produce ethyl and higher amines for Air Products at its Billingham, UK, facility. The products are used primarily as intermediates for agrochemicals, water treatment, catalysis and pharmaceutical applications.

The sale comes in the wake of ICI's intent to buy Unilever NV's specialties chemical business. Insiders have said that ICI would sell other non-core businesses in addition to putting Tioxide and its ICI Australia subsidiary on the block.

MAY 4, 1997



**Bacon's**

## 11/9 New plant generates excitement for methanol created from coal

**KINGSPORT** — An experimental plant to make methanol from coal-derived synthesis gas has come on line. If successful, the technology could help reduce the country's dependence on imported oil.

The plant is a joint venture of the Department of Energy's Clean Coal Technology Program, Eastman Chemical Co. and Air Products and Chemicals Inc.

Eastman and Air Products provided \$121 million toward the \$213.7 million project; the DOE made up the remainder.

Construction began in late 1995 at Air Products' local complex.

The plant began operating in April and is producing 260 tons of methanol a day.

Over the next four years, the DOE will study samples of the methanol produced at the plant.

Methanol is a clean-burning liquid that can be used to power electricity-generating turbines or as a fuel for automobiles and other vehicles.

It also is used as a feedstock for a variety of chemicals.

Eastman was invited to participate in the project because of its expertise in chemicals-from-coal technology.

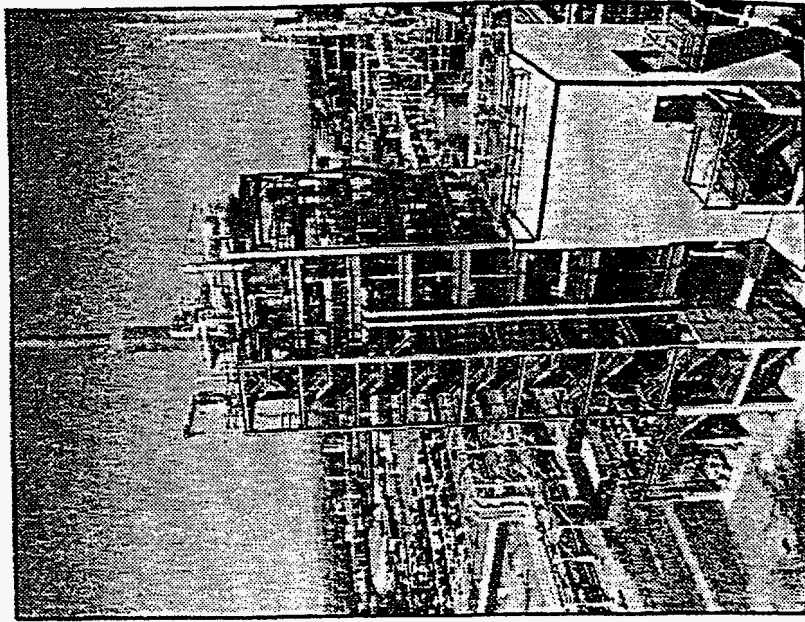
Although most methanol is produced from natural gas, Eastman pioneered at its local facility the commercial technology for producing methanol from coal.

Eastman will use a portion of the methanol produced here as a chemical feedstock in the products that eventually go into certain plastics and chemicals.

The Clean Coal Technology program is designed to demonstrate a new, more cost-effective way to make methanol. The synthesis process being used at the plant is the result of more than a decade of federally sponsored research.

If successful, the technology could significantly enhance the prospects for the use of coal-based methanol to generate electricity.

For example, it could be used to supplement fuel for gas turbines during peak energy demands or it could be sold to commercial fuel and chemical companies.



Experimental plant produces methanol //