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

Topical Report
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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) to produce methanol from coal-derived synthesis gas (syngas). 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 coal-to-chemicals complex in Kingsport.

The LPMEOH™ Demonstration Facility completed its first year of operation on 02 April 1998. The LPMEOH™ Demonstration Facility also completed the longest continuous operating run (65 days) on 21 April 1998.

Catalyst activity, as defined by the ratio of the rate constant at any point in time to the rate constant for freshly reduced catalyst (as determined in the laboratory autoclave), was monitored throughout the reporting period. During a six-week test at a reactor temperature of 225°C and Balanced Gas flowrate of 700 KSCFH, the rate of decline in catalyst activity was steady at 0.29-0.36% per day. During a second one-month test at a reactor temperature of 220°C and a Balanced Gas flowrate of 550 - 600 KSCFH, the rate of decline in catalyst activity was 0.4% per day, which matched the performance at 225°C, as well as the 4-month proof-of-concept run at the LaPorte AFDU in 1988/89.

Beginning on 08 May 1998, the LPMEOH™ Reactor temperature was increased to 235°C, which was the operating temperature after the December 1997 restart with the fresh charge of catalyst (50% of design loading). The flowrate of the primary syngas feed stream (Balanced Gas) was also increased to 700 - 750 KSCFH. During two stable operating periods between 08 May and 09 June 1998, the average catalyst deactivation rate was 0.8% per day. Due to the scatter of the statistical analysis of the results, this test was extended to better quantify the catalyst aging behavior. During the reporting period, two batches of fresh catalyst were activated and transferred to the reactor (on 02 April and 20 June 1998). The weight of catalyst in the LPMEOH™ Reactor has reached 80% of the design value.

At the end of the reporting period, a step-change in the pressure-drop profile within the LPMEOH™ Reactor and an increase in the pressure of the steam system which provides cooling to the LPMEOH™ Reactor were observed. No change in the calculated activity of the catalyst was detected during either of these transients. These parameters will be monitored closely for any additional changes.

Catalyst slurry samples from the LPMEOH™ Reactor have been taken on a regular basis to correlate any change in plant performance with changes in the physical properties of the catalyst. Samples have continued to show an increase in arsenic loading, continuing the trend from the prior reporting period. Copper crystallite size measurements have shown a continuing slow growth,

consistent with expectations given the length of time on-stream. Levels of iron and nickel have remained steady since the restart in December of 1997.

The performance of the alternative gas sparger, which was designed by Air Products and installed into the LPMEOH™ Reactor prior to the restart of the LPMEOH™ Demonstration Unit in December of 1997, was monitored throughout the reporting period. Pressure drop through the gas sparger of the LPMEOH™ Reactor remained steady by maintaining a continuous flush of condensed oil and entrained slurry which was gravity-drained from the 29C-05 secondary oil knock-out drum and 29C-06 cyclone. These results provide a confirmation of the encouraging data collected during the prior reporting period. This parameter will continue to be closely monitored for any change in flow resistance.

During the reporting period, a total of 4,645,166 gallons of methanol was produced at the LPMEOH™ Demonstration Unit. Since startup, over 20.3 million gallons of methanol has been produced. Eastman accepted all of this methanol for use in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. No safety or environmental incidents were reported during this quarter. Availability has exceeded 99% since the restart of the LPMEOH™ Demonstration Unit on 19 December 1997.

During this quarter, initial planning, procurement, and test operations continued on the seven project sites which have been accepted for participation in the off-site, product-use test program. At the three projects which are testing transportation vehicles, over 4,000 miles of operation have been completed on chemical-grade methanol and on fuel-grade methanol provided by the Demonstration Project. In a stationary turbine test, a glow plug ignition system was added to a eliminate the flame-out which occurred when the turbine was switched from jet fuel to methanol at idle speed. The start of testing of fuel-grade methanol in a fuel cell is pending the completion of a system component analysis.

During the reporting period, planning for a proof-of-concept test run of the Liquid Phase Dimethyl Ether (LPDME™) Process at the Alternative Fuels Development Unit (AFDU) in LaPorte, TX continued. Production of the remaining dehydration catalyst by the commercial catalyst manufacturer (Engelhard, formerly Calsicat) is awaiting the completion of testing of a sample of the first production batch in the laboratory autoclave. The resulting delay in the scheduled delivery of the catalyst has not impacted the timing for the fall 1998 AFDU proof-of-concept test.

Ninety-nine percent (99%) 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 1998. Twenty-four percent (24%) of the $158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1998.

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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"
AFFTU	-	Alternative Fuels Field Trailer Unit
Balanced Gas	-	A syngas with a composition of hydrogen (H_2), carbon monoxide (CO), and carbon dioxide (CO_2) in stoichiometric balance for the production of methanol
Carbon Monoxide Gas	-	A syngas containing primarily carbon monoxide (CO); also called CO Gas
Catalyst Age (η -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
FFV	-	flexible fuel vehicle
Fresh Feed	-	sum of Balanced Gas, H_2 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_2) over the stoichiometric balance for the production of methanol; also called H_2 Gas
IGCC	-	Integrated Gasification Combined Cycle, a type of electric power generation plant
IGCC/OTM	-	An IGCC plant with a "Once-Thru Methanol" plant (the LPMEOH™ Process) added-on
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)
M85	-	a fuel blend of 85 volume percent methanol and 15 volume percent unleaded gasoline
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
ρ	-	density, pounds per cubic foot

ACRONYMS AND DEFINITIONS (cont'd)

Partnership	-	Air Products Liquid Phase Conversion Company, L.P.
PDU	-	Process Development Unit
PFD	-	Process Flow Diagram(s)
ppbv	-	parts per billion (volume basis)
ppmw	-	parts per million (weight 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_2) and carbon monoxide (CO), or mixtures of H_2 and CO; intended for "synthesis" in a reactor to form methanol and/or other hydrocarbons (synthesis gas may also contain CO_2, water, and other gases)
Tie-in(s)	-	the interconnection(s) between the LPMEOH™ Process Demonstration Facility and the Eastman Facility
TPD	-	Ton(s) per Day
V	-	volumetric flowrate, thousand standard cubic feet per hour
VOC	-	volatile organic compound
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) to produce methanol from coal-derived synthesis gas (syngas). 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 is in operation at a site located at the Eastman coal-to-chemicals 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 syngas, utilities, product storage, and other needed services.

The project involves the operation 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 the Alternative Fuels Development Unit (AFDU), 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 and off-site product-use test program will demonstrate the commercial viability of the LPMEOH™ process and allow utilities to evaluate the application of this technology in the coproduction of methanol with electricity. 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 (Modification No. 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.

The LPMEOH™ Demonstration Facility completed its first year of operation on 02 April 1998. The LPMEOH™ Demonstration Facility also completed the longest continuous operating run (65 days) on 21 April 1998; an outage was taken as the result of a failure in a reactor temperature measurement device which is tied into a plant emergency shutdown.

Catalyst activity, as defined by the ratio of the rate constant at any point in time to the rate constant for freshly reduced catalyst (as determined in the laboratory autoclave), was monitored throughout the reporting period. During a six-week test at a reactor temperature of 225°C and flowrate of the primary syngas feed (Balanced Gas) of 700 KSCFH, the rate of decline in catalyst activity was steady at 0.29-0.36% per day. On 02 April 1998, an additional catalyst batch of the alternate methanol synthesis catalyst was added to the LPMEOH™ Reactor. At the same time, reactor temperature was lowered to 220°C and Balanced Gas flowrate was reduced to 550 - 600 KSCFH. Over the next month, the rate of decline in catalyst activity was 0.4% per day, which matched the performance at 225°C, as well as the 4-month proof-of-concept run at the LaPorte AFDU in 1988/89.

Beginning on 08 May 1998, the LPMEOH™ Reactor temperature was increased to 235°C, which was the operating temperature after the December 1997 restart with the fresh charge of catalyst (50% of design loading). The Balanced Gas flowrate was also increased to 700 - 750 KSCFH. During two stable operating periods between 08 May and 09 June 1998, the average catalyst deactivation rate was 0.8% per day. In addition, the absolute value of the calculated rate constant in the kinetic model increased by 15% (relative), confirming earlier observations that the model tends to underpredict the rate constant at lower operating temperature. Due to the scatter of the statistical analysis of the results, the test was extended to better quantify the catalyst aging behavior at this condition. A fresh batch of catalyst was activated and transferred to the reactor on 20 June 1998 to maintain process viability for a minimum three-week test. The weight of catalyst in the LPMEOH™ Reactor has reached 80% of the design value.

At the end of the reporting period, a step-change in the pressure-drop profile within the LPMEOH™ Reactor and an increase in the pressure of the steam system which provides cooling to the LPMEOH™ Reactor were observed. No change in the calculated activity of the catalyst was detected during either of these transients. These parameters will be monitored closely for any additional changes.

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Ninety-nine percent (99%) 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 1998. Twenty-four percent (24%) of the $158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1998.

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 is operating 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 or H_2 Gas, carbon monoxide gas or CO Gas, and the primary syngas feed known as Balanced Gas) are 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, covering those areas in which activity took place during the reporting period. Major accomplishments during this period are as follows:

D.1 Off-Site Testing (Product-Use Demonstration)

Discussion

The product-use test program, developed in 1992 to support the demonstration at the original Cool Water Gasification Facility site, became outdated due in large part to changes within the power and chemical industries. This original product test program under-represented new utility dispersed electric power developments, and possibly new mobile transport engine developments. The updated product-use test program attempts for broader market applications and for commercial fuels comparisons. The objective of the product-use test program is 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 program has been 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. When compared to conventional methanol synthesis processes, cost savings (10 to 15%) of several cents per gallon of methanol can be achieved in coproduction facilities, if the suitability of the stabilized product as a fuel can be demonstrated. The applications (for example, 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. Chemical feedstock applications will also be tested as warranted.

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 were targeted for an approximate 18 to 30-month period, and commenced during the first year of demonstration operations. An initial inventory of approximately 12,000 gallons of stabilized methanol was produced at LPMEOH™ Demonstration Unit in February of 1998 to supply the needs of the product-use test program; due to the pre-1998 timing for certain tests, methanol was shipped from the inventory held at the AFDU in LaPorte, TX. Air Products, ARCADIS, Geraghty & Miller (formerly Acurex Environmental Corporation), and the DOE have worked together to select the projects to be included in the off-site, product-use test program.

Activity during this quarter

Eight sites involving a variety of product-use tests have been selected to participate in this task. The sites and project titles are listed in Appendix B-1. In a letter to the DOE dated 31 July 1997, Air Products formally recommended that seven of the eight projects had been defined in sufficient detail so that final planning and implementation should begin. DOE accepted Air Products' recommendation to proceed with the seven projects in August of 1997. The eighth project, involving the testing of a water/naphtha/methanol emulsion as a transportation fuel, is awaiting final project definition.

All of the remaining product-use test projects have begun planning and equipment procurement. Methanol produced from carbon monoxide (CO)-rich syngas at the LaPorte AFDU has been shipped to three of the project sites. Appendix B-2 through B-6 contain summary reports from the approved projects. Highlights from these reports include:

Acurex Flexible Fuel Vehicle (FFV) - The FFV has begun emission testing on both M85 made from chemical-grade methanol and on M85 made from methanol supplied from the inventory at the LaPorte AFDU. The FFV has accumulated 1,500 miles on the LPMEOH™ M85 fuel.

Stationary Turbine for Volatile Organic Carbon (VOC) Control - AlliedSignal has committed to serve as host site for this demonstration, and an outline of the demonstration tests was prepared.

West Virginia University (WVU) Stationary Gas Turbine - A glow plug ignition system was added to the gas turbine to eliminate the flame-out which occurred when the turbine was switched from jet fuel to methanol fuel at idle speed. Methanol from inventory at the LaPorte AFDU is being used in this program.

Aircraft Ground Equipment Emulsion - Scoping tests were delayed until August of 1998 pending the results of studies to determine the best emulsion composition.

University of Florida Fuel Cell - Based upon the results of analysis of the fuel-grade methanol from the LPMEOH™ Demonstration Project, an investigation is underway to determine the potential (if any) for degradation of the reformer or the stack components due to trace components in the methanol.

West Virginia University Tri-Boro Bus - Testing has been completed, and a draft final report was prepared. Results indicate that fuel-grade methanol is well suited to use in alcohol fuel compression ignition engines from the standpoint of emissions benefits (lower emissions of nitrogen oxides and particulate matter than chemical-grade methanol, but higher emissions of hydrocarbons for fuel-grade methanol).

Florida Institute of Technology Bus & Light Vehicle - Fuel-grade methanol from the LPMEOH™ Demonstration Project was used to operate both vehicles. The car has been operating for 6 months and over 2,000 miles, and the bus has completed 500 miles of testing. A preliminary car exhaust sample was submitted for analysis (methanol, nitrogen oxides, formaldehyde).

D.2 Commercialization Studies

Discussion

Several areas have been identified for 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 C. 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 program.

Recent Activities

- Part One of the Outline - "Coproduction 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" are the current basis for discussion. As part of reviewing this report, Air Products has submitted a recommendation that the cost breakdown by plant area matches the format to be used in the Final Report - Volume 1 - Public Design. A letter from DOE dated 07 April 1998 indicated that the Topical Report could be issued using a different cost breakdown than the Final Report - Volume 1 - Public Design. Air Products began incorporating this and other comments from DOE in anticipation of providing an updated Topical Report to DOE for further comment.

- Part Two of the Outline - "Baseload Power and Methanol Coproduction", has been incorporated into the paper, "Fuel and Power Coproduction - The Liquid Phase Methanol (LPMEOH™) Process Demonstration at Kingsport ", 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", was used as the basis to update the product-use test program (Task 1.4).

D.3 DME Design Verification Testing

Discussion

The first decision milestone, on whether to continue with dimethyl ether (DME) Design Verification Testing (DVT), was targeted for 01 December 1996. This milestone was relaxed to July of 1997 to allow time for further development of the Liquid Phase Dimethyl Ether (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 D.

Prior work in this task included a recommendation to continue with DME DVT and Market Economic Studies. Ongoing activity is focusing on Laboratory R&D.

DME DVT Recommendation

DOE issued a letter dated 31 July 1997 accepting Air Products' 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 D. 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.

Based upon the potential size of the markets and the promise of the LPDME™ catalyst system, proof-of-concept planning for the LaPorte AFDU was 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 Liquid Fuels Program (DE-FC22-95PC93052) project participants, will be made in time to meet the schedule for testing at LaPorte.

LPDME™ is not applicable to hydrogen (H_2)-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 at Kingsport.

The DME DVT recommendation summarizes the catalyst targets, experimental results, and the corresponding economics for a commercially successful LPDME™ catalyst.

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 China and the Pacific Rim regions. The results to date, are included in the DME recommendation in Appendix D.

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 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

- The commercial catalyst manufacturer (Engelhard) completed the preparation of the first batch of dehydration catalyst in larger-scale (500 gallon) equipment. Air Products began testing a sample of this material in the laboratory autoclave. This testing continued through the end of the reporting period, causing a delay in the production and shipment of the dehydration catalyst to the LaPorte AFDU (from the June of 1998 scheduled date). To date, this delay has not impacted the timing for the AFDU proof-of-concept test, which is scheduled for the fall of 1998.

D.4 LPMEOH™ Process Demonstration Facility - Methanol Operation

Table D.4-1 contains the summary table of performance data for the LPMEOH™ Demonstration Unit during the reporting period. These data represent daily averages, typically from a 24-hour material balance period, and those days with less than 12 hours of stable operation are omitted. Appendix E contains samples of the detailed material balance reports which are representative of the operation of the LPMEOH™ Demonstration Unit during the reporting period.

During the reporting period, a total of 4,645,166 gallons of methanol was produced at the LPMEOH™ Demonstration Unit. Eastman accepted all of this methanol for use in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. No safety or environmental incidents were reported during this quarter.

The LPMEOH™ Demonstration Unit completed its first year of operation on 02 April 1998, and the longest continuous operating run without a shutdown of any kind lasted until 21 April 1998 (65 days). That campaign ended when a reactor temperature transmitter failed, causing a false emergency shutdown on high temperature. Eastman operating personnel quickly identified the problem, and the plant was back onstream within 30 minutes. A second fault occurred in this same circuit two days later, prompting a review by Eastman to determine if a system of 2-out-of-3 voting can be applied to temperature measurements in the LPMEOH™ Reactor to limit the upsets resulting from instrumentation faults. On 27 April, a tubing leak on the syngas recycle compressor required a 10-hour shutdown for repair; a similar leak on 18 May required a 9-hour shutdown for repair. No other shutdowns during the reporting period were related to operation of the LPMEOH™ Demonstration Unit.

Despite this series of trips, the LPMEOH™ Demonstration Unit continues to operate at greater than 99% availability since being brought back onstream on 19 December 1997. The resulting extended operating periods provide an indication of the flexibility of the LPMEOH™ Process and the opportunity to collect sufficient steady-state data on the performance of the catalyst and the various components within the LPMEOH™

TABLE D.4-1

DATA SUMMARY FOR LPMEOH™ DEMONSTRATION UNIT

Case	Date	Days Onstream	Gas Type	Temp (Deg C)	Pres. (psig)	Fresh Feed (KSCFH)	Recycle Gas (KSCFH)	Reactor Feed (H2:CO)	Purge Gas (KSCFH)	Inlet Sup. Velocity (ft/sec)	Space Velocity (l/hr-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/hr-kg)	Reactor Vol. Prod. (TPD/Cu ft)	U Overall (BTU/hr ft2 F)	Sparger dP (psi)	Sparger Resistance (°K')
6	1-Apr-98	102	Balanced	224	709	682	2,247	3.46	71.9	0.66	6,268	39.2	42.9	44.0	27,450	0.66	33.9	19.7	40.5	202.1	19.20	0.110	152	5.44	5.46
6	2-Apr-98	103	Balanced	221	710	684	2,234	3.51	91.6	0.66	5,696	40.7	43.1	45.5	30,050	0.61	32.8	19.0	42.2	194.6	18.90	0.102	152	5.28	5.49
6	3-Apr-98	104	Balanced	220	710	641	2,240	3.51	82.1	0.65	5,615	39.2	41.6	47.0	30,050	0.60	31.9	18.4	41.6	185.0	18.07	0.094	145	5.19	5.48
6	4-Apr-98	105	Balanced	219	710	630	2,267	3.39	79.4	0.65	5,646	40.8	42.1	44.5	30,050	0.60	30.2	17.9	41.6	181.8	15.79	0.098	149	5.24	5.51
6	5-Apr-98	106	Balanced	219	709	630	2,261	3.33	85.8	0.64	5,620	41.2	40.9	43.0	30,050	0.59	29.5	17.8	42.0	179.9	15.63	0.100	148	5.25	5.57
6	6-Apr-98	107	Balanced	218	709	605	2,269	3.47	75.6	0.64	5,605	41.9	39.0	40.5	30,050	0.59	30.0	17.4	41.2	176.2	15.31	0.104	150	5.28	5.73
6	7-Apr-98	108	Balanced	218	710	593	2,252	3.44	65.3	0.64	5,578	42.2	37.3	39.0	30,050	0.58	29.8	17.3	40.9	173.8	15.10	0.107	147	5.19	5.53
6	8-Apr-98	109	Balanced	218	710	587	2,264	3.30	66.2	0.64	5,604	43.0	36.8	37.5	30,050	0.58	28.6	17.2	40.6	173.6	15.09	0.111	143	5.43	5.70
6	9-Apr-98	110	Balanced	219	709	583	2,227	3.61	50.2	0.63	5,519	37.6	42.1	50.5	30,050	0.61	32.1	17.9	39.7	176.4	15.31	0.083	143	5.26	5.71
6	10-Apr-98	111	Balanced	220	710	578	2,195	4.03	45.0	0.63	5,462	37.5	44.8	53.0	30,050	0.61	35.4	18.0	39.2	177.1	15.40	0.080	152	4.83	5.70
6	11-Apr-98	112	Balanced	220	710	582	2,185	4.05	50.0	0.63	5,447	37.9	43.9	51.5	30,050	0.60	35.2	17.9	39.7	176.0	15.28	0.081	151	4.75	5.70
6	12-Apr-98	113	Balanced	220	711	582	2,192	3.80	52.0	0.63	5,451	38.1	42.7	50.0	30,050	0.59	33.5	17.9	39.7	176.0	15.28	0.084	150	4.91	5.69
6	13-Apr-98	114	Balanced	219	710	576	2,208	3.61	49.3	0.63	5,468	37.4	41.8	50.5	30,050	0.58	31.8	17.8	39.6	174.4	15.14	0.082	146	5.07	5.71
6	14-Apr-98	115	Balanced	220	710	580	2,189	3.68	46.4	0.62	5,436	36.9	43.9	53.5	30,050	0.60	33.1	18.3	39.4	176.9	15.36	0.079	152	5.02	5.64
6	15-Apr-98	116	Balanced	220	710	578	2,183	3.65	46.5	0.62	5,426	36.3	44.5	55.5	30,050	0.59	32.7	18.2	39.5	175.5	15.24	0.075	146	5.01	5.60
6	16-Apr-98	117	Balanced	219	709	578	2,227	3.57	48.1	0.63	5,506	37.1	44.8	54.0	30,050	0.59	31.7	18.0	39.5	175.5	15.24	0.077	151	5.15	5.59
6	17-Apr-98	118	Balanced	220	710	573	2,258	3.58	46.5	0.64	5,570	37.2	45.0	54.0	30,050	0.59	31.4	17.7	39.2	175.7	15.25	0.077	151	5.30	5.70
6	18-Apr-98	119	Balanced	220	710	567	2,267	3.54	39.3	0.64	5,550	36.5	44.9	55.5	30,050	0.59	31.3	17.8	39.0	174.5	15.17	0.075	149	5.33	5.63
6	19-Apr-98	120	Balanced	220	710	577	2,229	3.57	50.4	0.63	5,505	37.6	44.4	52.5	30,050	0.57	31.3	17.7	40.0	173.0	15.06	0.078	148	5.19	5.67
6	20-Apr-98	121	Balanced	220	710	583	2,198	3.52	61.0	0.63	5,473	37.5	43.5	52.0	30,050	0.56	30.8	17.7	40.6	172.5	14.98	0.079	142	5.11	5.63
6	21-Apr-98	122	Balanced	219	710	583	2,240	3.35	65.0	0.64	5,543	38.4	41.0	48.0	30,050	0.55	28.7	17.2	41.0	170.9	14.84	0.085	144	5.60	5.98
6	22-Apr-98	123	Balanced	219	711	583	2,229	3.34	70.2	0.63	5,535	39.2	42.3	47.5	30,050	0.55	28.5	17.1	41.2	169.9	14.76	0.085	141	5.54	6.01
6	23-Apr-98	124	Balanced	220	710	583	2,230	3.38	63.3	0.63	5,517	36.7	43.5	53.5	30,050	0.55	29.4	17.5	40.7	172.1	14.94	0.077	146	5.23	5.60
6	24-Apr-98	125	Balanced	220	710	583	2,201	3.55	67.3	0.63	5,473	37.1	42.0	51.5	30,050	0.55	30.3	17.4	41.2	170.0	14.76	0.079	145	5.00	5.62
6	25-Apr-98	126	Balanced	219	709	583	2,193	3.53	69.7	0.63	5,459	37.4	41.7	50.5	30,050	0.55	30.0	17.3	41.4	168.9	14.68	0.080	144	4.96	5.64
6	26-Apr-98	127	Balanced	219	708	583	2,182	3.47	70.2	0.63	5,440	37.7	40.7	49.0	30,050	0.55	29.7	17.3	41.3	169.4	14.72	0.082	149	4.94	5.66
6	29-Apr-98	130	Balanced	220	709	554	2,292	3.80	63.3	0.64	5,555	37.2	43.5	52.5	30,050	0.53	30.0	16.0	41.0	162.0	14.08	0.073	145	4.87	5.49
6	30-Apr-98	131	Balanced	220	709	552	2,259	3.98	63.1	0.63	5,487	36.7	41.1	51.5	30,050	0.54	31.1	16.0	41.4	159.9	13.89	0.074	147	4.53	5.29
6	1-May-98	132	Balanced	219	710	549	2,249	3.96	62.7	0.63	5,481	37.4	41.2	50.0	30,050	0.54	30.8	15.9	41.6	158.2	13.74	0.075	149	4.46	5.15
6	2-May-98	133	Balanced	219	710	554	2,233	3.93	67.3	0.63	5,455	38.4	39.7	47.0	30,050	0.54	30.5	15.9	42.2	157.7	13.70	0.080	150	4.40	5.17
6	3-May-98	134	Balanced	219	709	554	2,206	4.15	67.9	0.62	5,413	37.1	40.5	50.0	30,050	0.55	32.2	16.1	42.1	158.0	13.73	0.075	151	4.25	5.18
6	4-May-98	135	Balanced	220	710	555	2,289	4.16	59.8	0.64	5,554	37.7	41.2	49.5	30,050	0.55	31.8	15.9	41.7	159.9	13.89	0.077	150	4.41	5.20
6	8-May-98	139	Balanced	234	709	735	2,145	4.45	54.8	0.67	5,619	37.3	41.7	51.5	30,050	0.65	47.3	22.4	40.2	219.5	19.05	0.101	147	5.01	5.08
6	9-May-98	140	Balanced	235	707	738	2,176	4.20	49.5	0.67	5,683	36.9	42.0	52.5	30,050	0.65	45.7	22.6	39.5	224.1	19.45	0.102	148	5.24	5.07
6	10-May-98	141	Balanced	234	707	738	2,130	4.41	55.2	0.66	5,601	37.6	41.4	50.5	30,050	0.65	47.1	22.6	40.1	221.1	19.19	0.104	149	4.90	5.08
6	11-May-98	142	Balanced	235	710	729	2,139	4.48	52.0	0.66	5,615	36.8	42.4	53.0	30,050	0.65	47.6	22.5	39.7	220.0	19.09	0.099	148	4.94	5.09
6	12-May-98	143	Balanced	235	710	738	2,139	4.55	60.1	0.67	5,625	36.5	42.1	53.5	30,050	0.64	47.7	22.5	40.4	219.4	19.05	0.098	147	4.89	5.12
6	13-May-98	144	Balanced	234	710	733	2,096	4.73	67.2	0.65	5,537	37.1	40.2	50.5	30,050	0.64	48.9	22.3	40.5	216.8	18.83	0.102	148	4.64	5.24
6	14-May-98	145	Balanced	234	710	713	2,138	4.40	53.2	0.66	5,584	37.4	40.2	50.0	30,050	0.62	46.2	22.1	39.6	215.9	18.75	0.103	145	4.97	5.14
6	15-May-98	146	Balanced	235	710	732	2,107	4.13	54.6	0.66	5,577	35.9	41.4	54.0	30,050	0.61	44.6	22.4	40.1	218.8	19.00	0.096	143	5.19	5.21
6	16-May-98	147	Balanced	235	710	732	2,087	4.34	59.3	0.65	5,516	36.5	40.5	52.0	30,050	0.62	48.5	22.6	40.0	219.6	19.07	0.101	144	4.78	5.16
6	27-May-98	158	Balanced	234	710	733	2,115	3.99	80.4	0.66	5,584	37.2	40.4	50.5	30,050	0.56	41.7	21.6	41.2	213.5	18.54	0.101	144	5.07	5.16
6	28-May-98	159	Balanced	235	710	731	2,078	4.01	71.5	0.65	5,507	37.1	40.3	50.5	30,050	0.57	42.5	21.9	40.6	216.1	18.77	0.102	142	4.76	5.16
6	29-May-98	160	Balanced	234	710	731	2,050	4.08	63.6	0.65	5,456	36.5	40.4	52.0	30,050	0.60	44.3	22.6	39.9	219.5	19.06	0.100	144	4.63	5.16
6	30-May-98	161	Balanced	234	710	732	2,023	4.25	68.8	0.64	5,412	37.1	39.5	50.0	30,050	0.61	45.6	22.7	40.3	217.8	18.91	0.104	144	4.53	5.23
6	31-May-98	162	Balanced	234	710	726	2,054	3.88	57.3	0.65	5,469	37.7	39.8	49.0	30,050	0.60	42.9	22.9	39.6	219.9	19.09	0.107	144	4.83	5.10
6	1-Jun-98	163	Balanced	235	710	721	2,085	3.88	56.1	0.65	5,498	38.3	39.9	48.0	30,050	0.60	42.8	22.7	39.4	219.6	19.06	0.109	144	4.88	5.08
6	2-Jun-98	164	Balanced	234	710	705	2,064	3.94	49.3	0.64	5,442	37.4	37.9	48.0	30,050	0.60	43.3	22.6	39.2	215.8	18.73	0.107	148	4.82	5.08
6	3-Jun-98	165	Balanced	235	710	730	2,013	4.13	66.4	0.64	5,388	37.2	39.7	50.0	30,050	0.60	45.2	22.9	40.1	218.6	18.98	0.104	144	4.51	5.12
6	4-Jun-98	166	Balanced	234	710	725	2,029	4.28	75.2	0.64	5,412	37.8	39.4	48.5	30,050	0.58	45.1	22.4	40.8	213.4	18.52	0.105	145	4.51	5.13
6	5-Jun-98	167	Balanced	234	709	736	2,050	3.97	79.9	0.65	5,460	37.5	39.9	49.5	30,050	0.57	42.5	22.4	41.0	215.4	18.70	0.104	145	4.75	5.10
6	6-Jun-98	168	Balanced	235	710	735	2,072	3.98	81.3	0.65	5,504	37.5	40.4	50.0	30,050	0.55	41.9	22.0	41.1	214.4	18.61	0.102	146	4.72	5.17
6	7-Jun-98	169	Balanced	234	710	719	2,064	4.05	79.8	0.65	5,461	38.0	39.9	48.5	30,050	0.53	41.4	21.4	41.5	207.8	18.04	0.102	144	4.61	5.25
6	8-Jun-98	170	Balanced	234	710	734	2,047	3.94	89.1	0.64	5,447	37.4	40.3	50.0	30,050	0.53	41.0	21.7	41.8	210.9	18.32	0.100	143	4.61	5.24

TABLE D.4-1

DATA SUMMARY FOR LPMEOH^{TM} DEMONSTRATION UNIT

Case	Date	Days Onstream	Gas Type	Temp (Deg C)	Pres. (psig)	Fresh Feed (KSCFH)	Recycle Gas (KSCFH)	Reactor Feed (H2:CO)	Purge Gas (KSCFH)	Inlet Sup. Velocity (ft/sec)	Space Velocity (l/hr-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/hr-kg)	Reactor Vol. Prod. (TPD/Cu ft)	U Overall (BTU/hr ft2 F)	Sparger dP (psi)	Sparger Resistance ("K")
6	9-Jun-98	171	Balanced	234	709	733	2,058	3.76	80.5	0.64	5,444	38.3	41.2	53.0	30,050	0.54	40.1	21.9	41.4	212.4	18.44	0.095	144	4.78	5.19
6	15-Jun-98	177	Balanced	234	709	732	2,032	4.58	112.2	0.64	5,420	38.7	42.7	49.5	30,050	0.53	44.3	20.8	43.6	201.4	17.51	0.097	146	4.70	5.63
6	16-Jun-98	178	Balanced	230	711	497	2,212	5.24	27.6	0.62	5,304	37.4	41.1	50.5	30,050	0.50	40.4	16.7	39.3	151.7	13.18	0.072	142	4.32	5.17
6	17-Jun-98	179	Balanced	230	710	497	2,246	4.94	26.2	0.63	5,359	36.7	39.0	50.0	30,050	0.48	38.5	16.7	39.1	152.5	13.24	0.073	140	4.56	5.18
6	18-Jun-98	180	Balanced	230	707	487	2,178	5.08	26.6	0.62	5,229	37.6	38.6	48.0	30,050	0.48	39.6	16.7	39.1	149.7	13.01	0.074	143	4.38	5.22
6	19-Jun-98	181	Balanced	235	709	733	2,084	3.74	96.2	0.65	5,482	38.1	40.2	48.5	30,050	0.51	38.4	21.1	42.4	207.2	18.01	0.102	141	4.81	5.23
6	20-Jun-98	182	Balanced	235	709	732	2,080	3.83	100.5	0.65	5,470	38.2	38.5	47.0	30,050	0.51	39.2	21.2	42.5	206.7	17.98	0.105	142	4.81	5.23
6	21-Jun-98	183	Balanced	235	709	732	2,062	4.00	69.5	0.65	5,003	38.4	41.2	53.0	32,700	0.52	43.3	22.5	40.8	215.4	17.20	0.097	137	4.91	5.26
6	22-Jun-98	184	Balanced	235	709	734	2,061	4.05	59.8	0.65	5,013	37.9	41.2	54.0	32,700	0.54	44.3	22.8	40.2	219.0	17.48	0.096	135	4.85	5.24
6	23-Jun-98	185	Balanced	235	709	733	2,035	4.17	62.4	0.64	4,953	37.9	39.4	52.5	32,700	0.55	45.6	22.9	40.2	218.5	17.44	0.099	137	4.63	5.25
6	24-Jun-98	186	Balanced	235	709	721	2,031	4.29	64.8	0.64	4,942	39.4	40.7	50.5	32,700	0.54	45.7	22.5	40.5	213.6	17.04	0.101	137	4.59	5.28
6	25-Jun-98	187	Balanced	235	709	739	1,982	4.30	84.0	0.63	4,882	39.3	38.6	49.0	32,700	0.53	45.6	22.5	41.8	212.3	16.95	0.103	134	4.44	5.32
6	26-Jun-98	188	Balanced	234	709	740	1,949	4.36	87.2	0.62	4,826	38.0	38.0	51.0	32,700	0.53	46.4	22.6	42.2	210.7	16.84	0.098	133	4.34	5.31
6	29-Jun-98	191	Balanced	234	710	722	1,927	4.43	77.8	0.62	4,780	38.0	33.9	52.0	32,700	0.53	46.9	22.6	41.3	210.1	16.77	0.096	179	4.20	5.47
6	30-Jun-98	192	Balanced	235	710	631	1,978	4.72	41.5	0.61	4,707	34.7	28.7	51.0	32,700	0.51	47.2	21.3	39.6	191.6	15.28	0.089	190	4.18	5.34

Demonstration Unit. Appendix F, Table 1 contains the summary of outages for the LPMEOH™ Demonstration Unit during this quarter.

At the very end of the reporting period, rapid changes occurred in the pressure-drop profile within the LPMEOH™ Reactor, as well as in the pressure of the steam system which provides cooling to the LPMEOH™ Reactor. Over a 12-hour period, the liquid level in the LPMEOH™ Reactor dropped about six feet with little appreciable change in overall pressure drop, indicating a decrease in the gas holdup. Shortly thereafter, the steam pressure (as measured by two independent transmitters and confirmed by a temperature measurement device) ramped up over a 4-hour period. Since the productivity of the catalyst did not change during either of these transients, the increased steam pressure caused the calculated heat transfer coefficient for the internal heat exchanger to increase. However, the new value of the heat transfer coefficient at the end of the event exceeded even the original startup value for the clean system. The pressure drop across the gas sparger remained steady during the changes in the other measurements. Since these events are as yet unexplained, these parameters will be monitored closely for any additional changes.

Operations focused on resolution of key issues identified during prior operating periods.

Catalyst Life (eta) - December of 1997 - June 1998

The "age" of the methanol synthesis catalyst can be expressed in terms of a dimensionless variable eta (η), which is defined as the ratio of the rate constant at any time to the rate constant for freshly reduced catalyst (as determined in the laboratory autoclave). Appendix F, Figure 1 plots log η versus days onstream from the restart in December of 1997 through the end of the reporting period. Since catalyst activity typically follows a pattern of exponential decay, the plot of log η is fit to a series of straight lines, with step-changes whenever fresh catalyst was added to the reactor.

An extended operating test at a reactor temperature of 225°C and Balanced Gas flowrate of 700 KSCFH was completed on 02 April 1998. During this six-week test, the rate of decline in catalyst activity was steady at 0.29-0.36% per day, exclusive of a small negative step change apparently related to a gasifier switch. This activity decline was a measurable improvement over the 1% per day rate seen at 235°C in January and met the original target from the 4-month proof-of-concept run at the LaPorte AFDU in 1988/89. On 02 April 1998, a batch of an alternate methanol synthesis catalyst was activated and transferred to the LPMEOH™ Reactor. At the same time, reactor temperature was reduced again to 220°C and Balanced Gas flowrate was reduced to 550 - 600 KSCFH to maintain overall efficiency. Over the next month, the average catalyst deactivation rate was 0.4% per day, matching the performance at 225°C.

Beginning on 08 May 1998, the LPMEOH™ Reactor temperature was increased back to 235°C, which was the original operating temperature after the restart in December of 1997 with the fresh charge of catalyst (50% of design loading). The Balanced Gas flowrate was also increased to 700 - 750 KSCFH. Notably, the calculated rate constant from the kinetic model increased by 18% (relative) immediately after the transition, confirming earlier observations that the model tends to underpredict the rate constant at lower operating temperature. During the first nine days at this condition, the average catalyst deactivation rate was 0.8% per day. This result approaches the 1% per day rate seen in January of 1998, although the confidence limits on the data were still rather broad. Unfortunately, a one-week curtailment in syngas availability interrupted the test after ten days, necessitating an additional two to three weeks to better quantify the catalyst aging behavior at this condition.

During a second stable operating period, the rate of decline in catalyst activity was again 0.8% per day at this condition; however, on 09 June 1998 another one-week interruption in syngas supply cut short the test after two weeks, while the confidence limits on the data were still rather broad. The plant restarted on June 15, but remained at reduced rates until June 19. A fresh batch of catalyst was activated and transferred to the reactor on 20 June 1998 to maintain process viability for a minimum three-week test to better quantify the catalyst aging behavior at this condition.

Analyses of catalyst samples for changes in physical characteristics and levels of poisons have begun. Appendix F, Table 2 summarizes the results to date. Samples have continued to show an increase in arsenic loading, although not nearly to the levels seen in the summer of 1997. Copper crystallite size measurements have shown a continuing slow growth, consistent with expectations given the length of time on-stream. Levels of iron and nickel have remained steady since the restart in December of 1997.

Sparger Resistance

As reported in earlier Technical Progress Reports, flow resistance through the gas sparger of the LPMEOH™ Reactor had been stabilized using a continuous flush of condensed oil and entrained slurry from the 29C-05 secondary oil knock-out drum and 29C-06 cyclone. These streams are gravity-drained back to the reactor through a flush connection at the gas inlet line to the reactor, thus eliminating a batch-transfer operation which had been used during prior operation. The flow rate of the flush is equivalent to the average rate of liquid traffic in the reactor loop (1 to 2 gallons per minute).

This technique was first applied to a clean sparger at the restart of operations on 19 December 1997. Appendix F, Figure 2 plots the average daily sparger resistance coefficient since then, and provides continued confirmation of the earlier encouraging results. The various shutdowns caused no negative effects. The data for this plot, along with the corresponding average pressure drop, are included in Table D.4-1. This parameter will continue to be closely monitored for any change in flow resistance.

D.5 Planning and Administration

The Milestone Schedule Status Report and the Cost Management Report, through the period ending 30 June 1998, are included in Appendix G. These two reports show the current schedule, the percentage completion and the latest cost forecast for each of the Work Breakdown Structure (WBS) tasks. Ninety-nine percent (99%) 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 1998. Twenty-four percent (24%) of the $158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1998.

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.

A paper entitled "Commercial-Scale Demonstration of the Liquid Phase Methanol (LPMEOH™) Process: Initial Operating Experience" was presented at the Clean Coal Technology Conference in Reno, Nevada on April 29, 1998.

A draft topical report entitled "Design and Fabrication of the First Commercial-Scale LPMEOH™ Reactor" was submitted to DOE for review.

A draft of the Demonstration Technology Start-up Report was issued internally for review.

E. Planned Activities for the Next Quarter

- Write and submit the Demonstration Technology Start-up Report to DOE.
- Continue to analyze catalyst slurry samples and gas samples to determine causes for deactivation of methanol synthesis catalyst.
- Continue executing Phase 3, Task 2.1 Methanol Operation per the Demonstration Test Plan. Focus activities on increasing catalyst concentration in the LPMEOH™ Reactor to determine the maximum slurry concentration (Test 9 of Test Plan).
- Continue preparations for a DME proof-of-concept test run at the LaPorte AFDU pending the completion of the production of the dehydration catalyst.
- Continue execution of the Off-Site, Product-Use Test Program (Phase 1, Task 1.4).
- Continue to incorporate DOE comments into the Topical Report on Process Economic Studies.
- Reach agreement with DOE on the equipment breakdown and operating cost summary for use in the Final Technical Report, Volume 1, Public Design Report.
- Reissue the Topical Report on Liquid Phase Reactor Design to DOE for review and comment.

F. Conclusion

The LPMEOH™ Demonstration Facility completed its first year of operation on 02 April 1998. The LPMEOH™ Demonstration Facility also completed the longest continuous operating run (65 days) on 21 April 1998; an outage was taken as the result of a failure in a reactor temperature measurement device which is tied into a plant emergency shutdown.

Catalyst activity, as defined by the ratio of the rate constant at any point in time to the rate constant for freshly reduced catalyst (as determined in the laboratory autoclave), was monitored throughout the reporting period. During a six-week test at a reactor temperature of 225°C and Balanced Gas flowrate of 700 KSCFH, the rate of decline in catalyst activity was steady at 0.29-0.36% per day. On 02 April 1998, an additional catalyst batch of the alternate methanol synthesis catalyst was added to the LPMEOH™ Reactor. At the same time, reactor temperature was lowered to 220°C and Balanced Gas flowrate was reduced to 550 - 600 KSCFH. Over the next month, the rate of decline in catalyst activity was 0.4% per day, which matched the performance at 225°C, as well as the 4-month proof-of-concept run at the LaPorte AFDU in 1988/89.

Beginning on 08 May 1998, the LPMEOH™ Reactor temperature was increased to 235°C, which was the operating temperature after the December 1997 restart with the fresh charge of catalyst (50% of design loading). The Balanced Gas flowrate was also increased to 700 - 750 KSCFH. During two stable operating periods between 08 May and 09 June 1998, the average catalyst deactivation rate was 0.8% per day. In addition, the absolute value of the calculated rate constant in the kinetic model increased by 15% (relative), confirming earlier observations that the model tends to underpredict the rate constant at lower operating temperature. Due to the scatter of the statistical analysis of the results, the test was extended to better quantify the catalyst aging behavior at this condition. A fresh batch of catalyst was activated and transferred to the reactor on 20 June 1998 to maintain process viability for a minimum three-week test. The weight of catalyst in the LPMEOH™ Reactor has reached 80% of the design value.

At the end of the reporting period, a step-change in the pressure-drop profile within the LPMEOH™ Reactor and an increase in the pressure of the steam system which provides cooling to the LPMEOH™ Reactor were observed. No change in the calculated activity of the catalyst was detected during either of these transients. These parameters will be monitored closely for any additional changes.

Catalyst slurry samples from the LPMEOH™ Reactor have been taken on a regular basis to correlate any change in plant performance with changes in the physical properties of the catalyst. Samples have continued to show an increase in arsenic loading, continuing the trend from the prior reporting period. Copper crystallite size measurements have shown a continuing slow growth, consistent with expectations given the length of time on-stream. Levels of iron and nickel have remained steady since the restart in December of 1997.

The performance of the alternative gas sparger, which was designed by Air Products and installed into the LPMEOH™ Reactor prior to the restart of the LPMEOH™ Demonstration Unit in December of 1997, was monitored throughout the reporting period. Pressure drop through the gas sparger of the LPMEOH™ Reactor remained steady by maintaining a continuous flush of condensed oil and entrained slurry which was gravity-drained from the 29C-05 secondary oil knock-out drum and 29C-06 cyclone. These results provide a confirmation of the encouraging data collected during the prior reporting period. This parameter will continue to be closely monitored for any change in flow resistance.

During the reporting period, a total of 4,645,166 gallons of methanol was produced at the LPMEOH™ Demonstration Unit. Since startup, over 20.3 million gallons of methanol has been produced. Eastman accepted all of this methanol for use in the production of methyl acetate, and ultimately cellulose acetate and acetic acid. No safety or environmental incidents were reported during this quarter. Availability has exceeded 99% since the restart of the LPMEOH™ Demonstration Unit on 19 December 1997.

During this quarter, initial planning, procurement, and test operations continued on the seven project sites which have been accepted for participation in the off-site, product-use test program. At the three projects which are testing transportation vehicles, over 4,000 miles of operation have been completed on chemical-grade methanol and on fuel-grade methanol from either the LPMEOH™ Demonstration Unit or from inventory at the LaPorte AFDU. In a stationary turbine test, a glow plug ignition system was added to a eliminate the flame-out which occurred when the turbine was switched from jet fuel to methanol at idle speed. The start of testing of fuel-grade methanol in a fuel cell is pending the completion of the analysis of the effect of trace components in the methanol on components in the fuel cell system.

During the reporting period, planning for a proof-of-concept test run of the Liquid Phase Dimethyl Ether (LPDME™) Process at the LaPorte AFDU continued. The commercial catalyst manufacturer (Engelhard) has prepared the first batch of dehydration catalyst in large-scale equipment. Production of the remaining catalyst is awaiting the completion of testing of a sample of this material in the laboratory autoclave. The resulting delay in the scheduled delivery of the catalyst has not impacted the timing for the AFDU proof-of-concept test, which is scheduled for the fall of 1998.

Ninety-nine percent (99%) 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 1998. Twenty-four percent (24%) of the $158 million of funds for the Phase 3 tasks have been expended (as invoiced), as of 30 June 1998.

APPENDICES

APPENDIX A - SIMPLIFIED PROCESS FLOW DIAGRAM

Appendix B-1

Off-Site Product-Use Testing
Proposals Under Consideration

Demonstration Project	Site
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

ARCADIS Appendix B-2

ARCADIS Geraghty & Miller, Inc.
555 Clyde Avenue
Mountain View
California 94043
Tel 650 961 5700
Fax 650 254 2497

MEMO

To:
Peter Tijm
Bob Senn

Copies:
D. Coleman
P. Hill
M. Cruz

ENGINEERING SYSTEMS

From:
Larry Waterland

Date:
7 July 1998

Subject:
Project update report LPMEOH™ Demonstration Project

Reference:
DOE Cooperative Agreement DE-FC22-92PC90543
ARCADIS Geraghty & Miller Project SJ008438

The following discusses recent progress on each of the three active projects under the referenced contract. If you need anything further, please don't hesitate to give me a call at (650) 254-2440

Flexible fuel vehicle

The FFV demonstration has seen considerable progress in the last quarter. The FFV has been emission tested on both regular M85 and LPMEOH™ M85. We are awaiting the results of the latter test and will compare the results from the two tests when the latter is received Unfortunately, for the LPMEOH test sequence, evaporative testing had to be canceled A small amount of fuel had leaked out of two auxiliary fuel cans that were stored in the trunk (which were required for the tests). Hydrocarbons emitted from the trunk then caused an extremely high evaporative emissions rate and invalidated the tests We are not planning to redo this portion of the tests, as exhaust emissions are considered more important.

Meanwhile, the FFV has accumulated 1500 miles on LPMEOH™ M85, almost half of the mileage expected to be recorded on this fuel We are into the third drum of LPMEOH™ shipped for this project. Once we have finished this portion of the in-field demonstration, we will resume with regular M85 and finish the remaining miles on that fuel.

Our ref.:
l:\airprods\progrpt3 doc

Aircraft ground support equipment

Preliminary scoping tests on this project were scheduled for April and May These tests would allow finalizing the formulation of the emulsion fuel for the long term testing and to tune the engines for operation on the emulsion fuel. These tests have been postponed until August while the ARA lead scientist determines the most appropriate ratios of water, methanol, and their proprietary additives to diesel in the emulsion fuel to be tested. The current formulation is 5 percent methanol, 20 to 30 percent water, 1 percent additives and the balance diesel The specific -86 engine generator sets have been selected, and it has been decided not to change the fuel injectors.

During the next reporting period, ARCADIS Geraghty & Miller will write the test plan, specify a high shear pump for blending the fuel, and participate in the scoping tests scheduled for August

Stationary gas turbine for VOC control

A meeting was held at the AlliedSignal facility in Phoenix on May 14 to discuss AlliedSignal participation in a demonstration program. Messrs. C. Castaldini and M. Chan of ARCADIS Geraghty & Miller met with P. Dodge, J. Zimmerman, and R. Pardini of AlliedSignal. AlliedSignal committed to serving as host site for the demonstration, as their interest in pursuing the VOC control market is high, as is their interest in investigating the performance characteristics of their turbines with methanol fuel

An outline of the demonstration tests in terms of VOC contaminants to include, number of tests, test variables, sampling points, and sampling and analysis protocols was discussed at the meeting. With concurrence on the test plan outline, AlliedSignal will prepare a project statement of work, with their estimate of support needed and the level of cost share they will provide, and submit this to ARCADIS Geraghty & Miller in early July.

Appendix B-3

WVU Progress Report

July 1, 1998

for

Air Products and Chemical Inc.

Methanol Utilization Demonstration Project

WVU Emission Studies on a
Dual-Fuel, Methanol/Jet Fuel
Stationary Gas Turbine.
350 HP Type GTC-85
Manufactured by Allied Signals Inc.

Report Prepared for

Robert J. Senn
Air Products and Chemical Inc.
7201 Hamilton Blvd.
Allentown, AP 18195-1501

by

John L. Loth and Nigel N. Clark

Department of Mechanical and Aerospace Engineering
West Virginia University

P.O. Box 6106, Morgantown, WV 26506-6106

Status Summary

Three attempts have been made to successfully complete fuel type change over from jet A to methanol on a GTC gas turbine. The procedure used for these attempts was operate the turbine for a minimum of 5 minutes to adequately warm the system before initiating the change over. The change over attempt was made at engine idle by progressively changing from jet A to a mixture of methanol/jet A and finally to pure methanol. All three of these attempts resulted engine shutdown as a result of flame-out.

While none of the change over attempts were successful, these tests allowed our research team to compile some possible reasons for these flame outs. The following are the suspected problems and the appropriate procedure or equipment change that has been implemented.

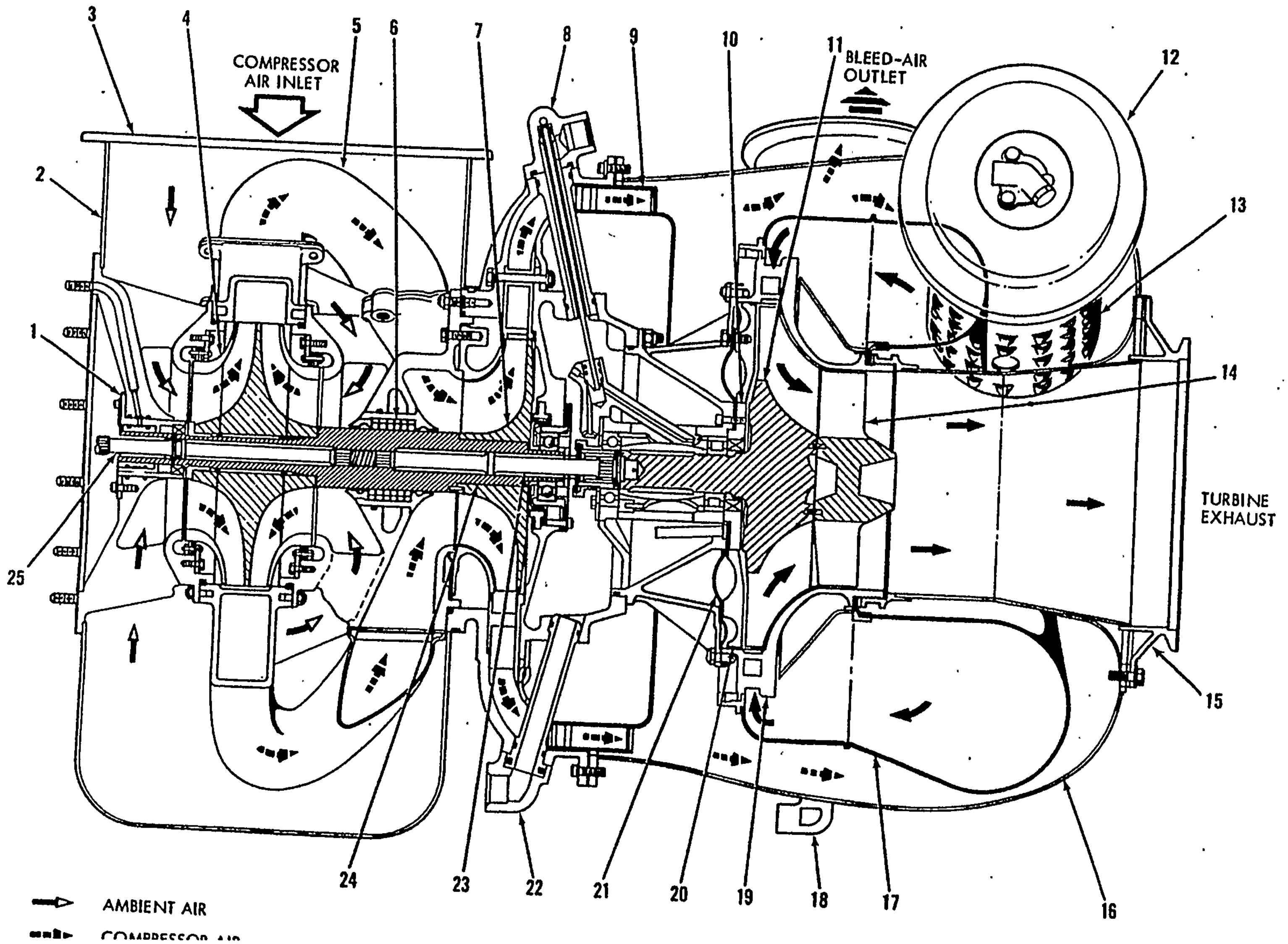
- It is possible that the procedure used for fuel change over simply has not allowed enough heat for successful ignition of the methanol. To remedy this problem, two changes have been made. The first is simply a fuel switch at high power and exhaust gas temperature (EGT≈1,000°F) instead of at idle with low EGT. This will greatly increase the temperature of the combustion chamber and facilitate Methanol ignition. The second change was the addition of a standard Pratt and Whitney PT 6 dual glow plug ignition system. These glow plugs will be operated continuously during the fuel change over to insure sufficient ignition sources to permit steady combustion.

- It was noted that during the change over from jet to methanol that the combination of these two fuels produced very poor mixing. Due to this nonhomogeneous mixture, the fuel injector was supplied with small bursts of pure methanol instead of the desired diluted mixture. To provide gradual jet fuel/methanol mixture ratio change over, a mixing chamber and recirculating fuel pump were added. Preliminary tests of this system showed greatly improved mixing of the fuels when the pump is in use.

- A final improvement was made to the fuel system to reduce the pressure pulses that were generated by the air driven fuel pumps. This modification was made by simply installing a small chamber containing a flexible pressure absorber in the fuel line. Preliminary tests show that this system is successful in reducing the large pressure pulses noted before installation.

All of these changes have been made, and I am pleased to inform you that the turbine assembly is nearing completion. We expect to have completed successful fuel change overs in the very near future. Due to these unforseen delays, please allow us a no-cost extension till November 1, 1998.

Enclosed, please find two schematics showing the GTC-85 gas turbine and a photograph of the experimental set-up including fuel drums, engine controls and battery powered start-cart.



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BLEED-AIR OUTLET
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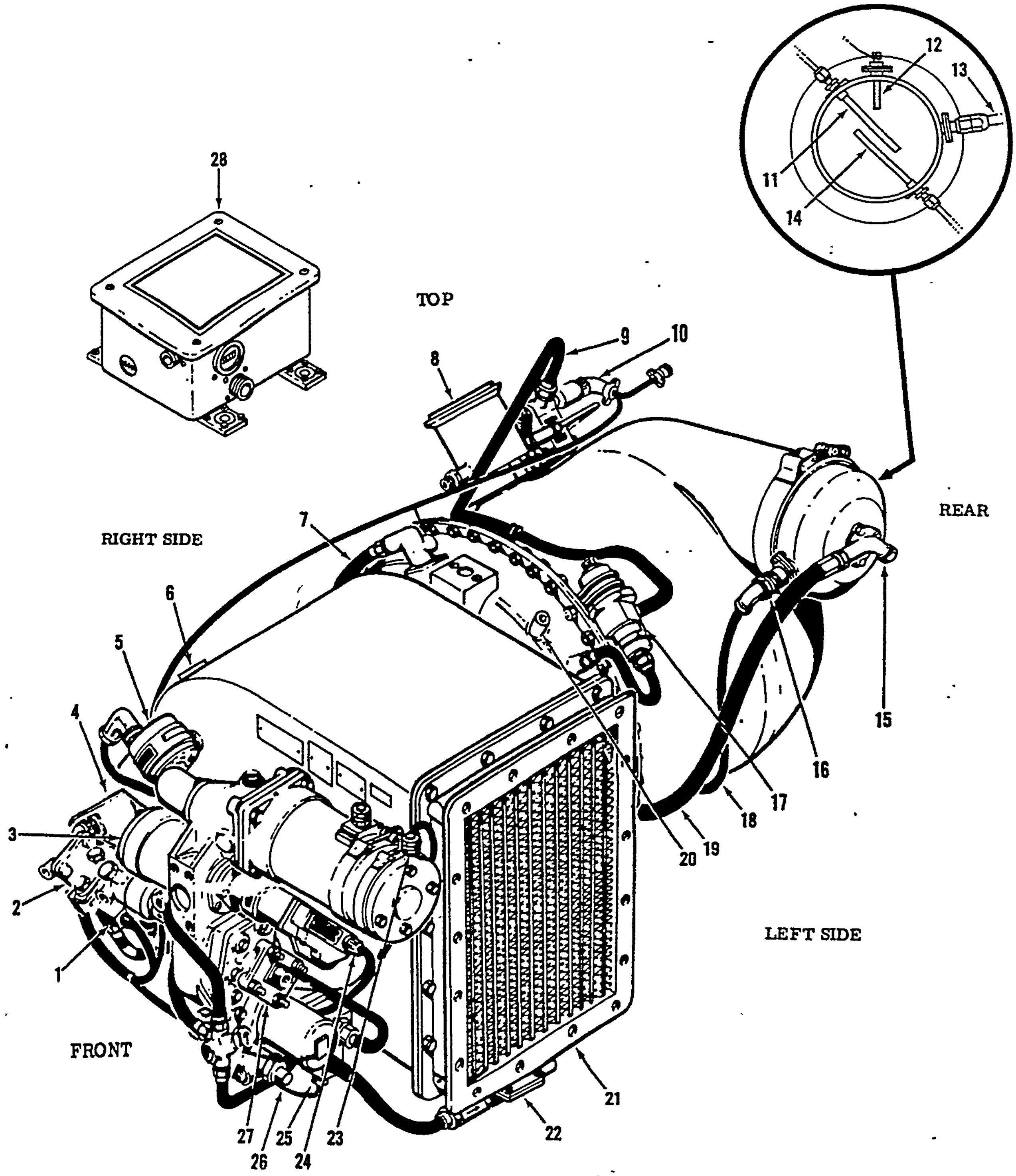
AMBIENT AIR



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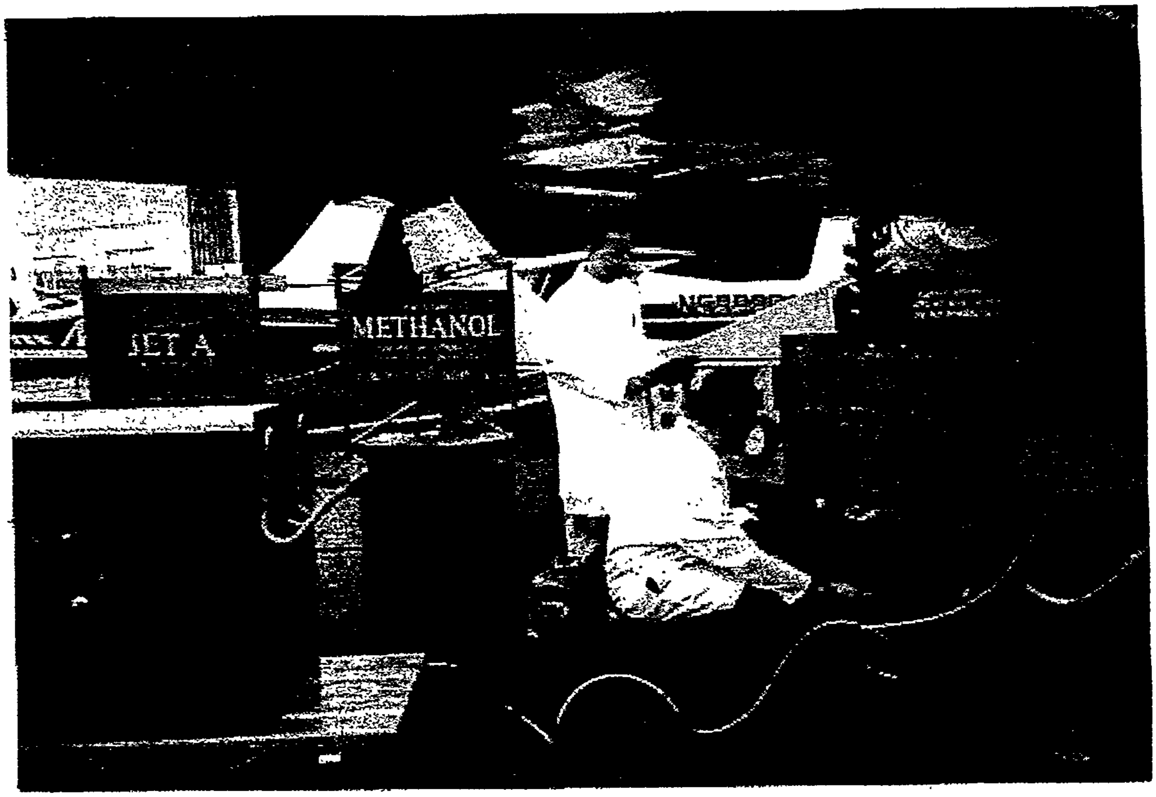
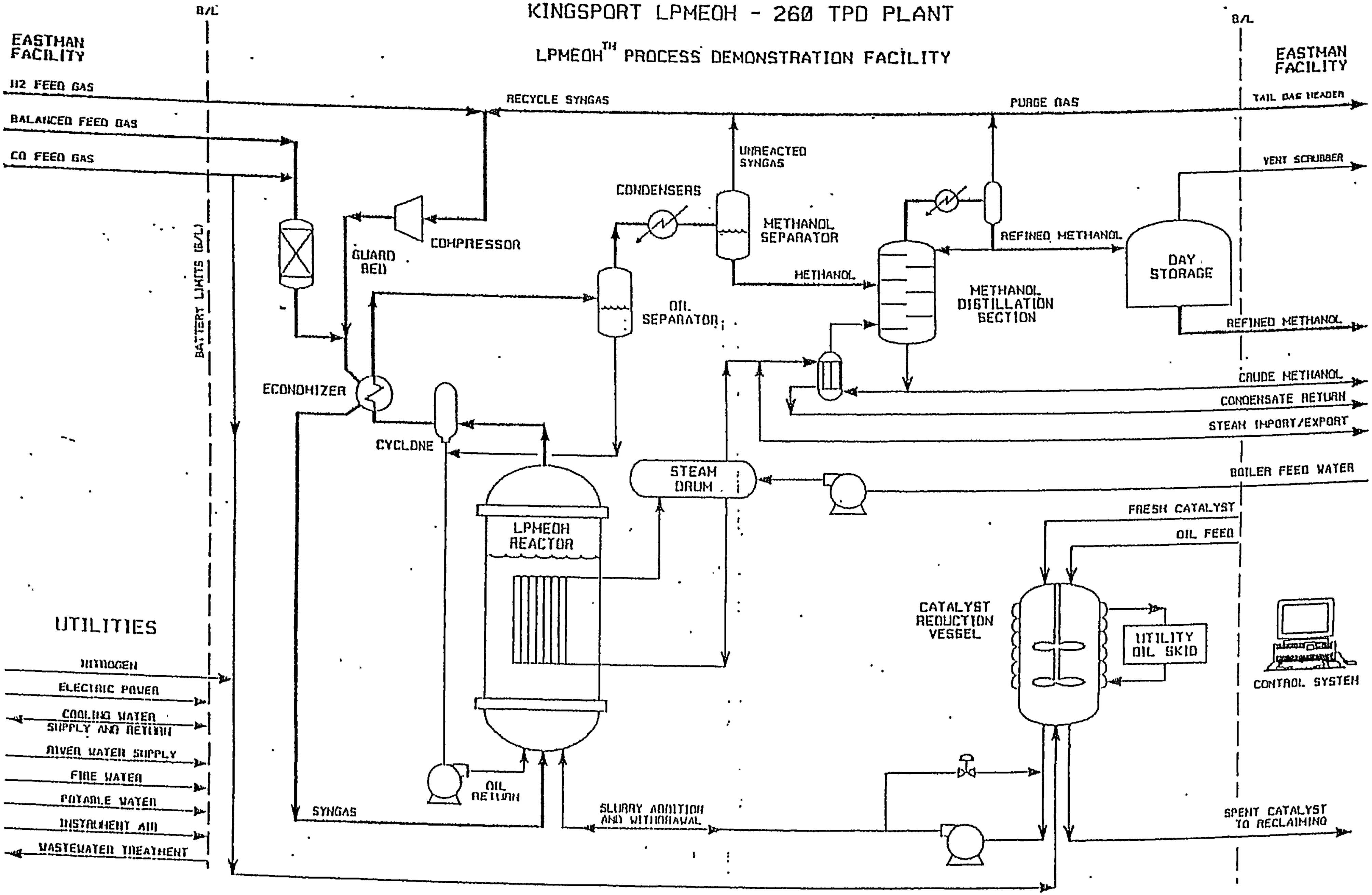

METHANOL


N3

SIMPLIFIED PROCESS DIAGRAM
KINGSPORT LPMEOH - 260 TPD PLANT

LPMEOH™ PROCESS DEMONSTRATION FACILITY



APPENDIX B - OFF-SITE TESTING (DEFINITION AND DESIGN)

Appendix B-1 - Summary Table of Eight Candidates (one page)

Quarterly Reports:

Appendix B-2 - ARCADIS Projects (two pages):
- **Acurex FFV**
- **Stationary Turbine for VOC Control**
- **Aircraft Ground Equipment Emulsion**

Appendix B-3 - West Virginia University Stationary Gas Turbine (five pages)
Appendix B-4 - University of Florida Fuel Cell (three pages)
Appendix B-5 - West Virginia University Tri-Boro Bus (twenty-six pages)
Appendix B-6 - Florida Institute of Technology Bus & Light Vehicle (twenty-six pages)

UNIVERSITY OF FLORIDA

CENTER FOR ADVANCED STUDIES IN ENGINEERING

3950 RCA Boulevard, Suite 5003 ● Palm Beach Gardens, Florida 33410 ● Office: (407) 624-4111 ● Fax: (407) 624-4117

Appendix B-4

July 28, 1998

TO: Bob Senn, Air Products **VIA FAX:** ~~610~~ 706-7299 (3 pages)

FROM: V.P. Roan, Principal Investigator
Jim Fletcher, Research Assistant

SUBJECT: Air Products "Coal-based Methanol" Contract Progress Report for Quarter Ending May through June 1998

Samples were taken from both the Air Products coal-based and conventional fuel grade (natural gas-based) methanol. The required shipping paperwork was completed and the samples shipped to Intertek Testing Services (ITS) in Seabrook, Texas. ITS has performed similar methanol analysis for the Georgetown University Fuel Cell Bus project. First sample results have been received and are attached to this progress report.

An in-house investigation is presently underway to determine potential for degradation to either the reformer or the stack components due to the various chemical specie in the coal based methanol. Based on the results of the investigation, alternatives for experimental evaluation of degradation severity may be considered.

It was determined that another testing laboratory which had been selected to provide another independent analysis would not be able to perform the required testing. A third possible laboratory, Atlantic Analytical Laboratory, has been identified and tentatively selected to do sample analyses.. The required paperwork has been started, and it is expected that samples will be delivered for the laboratory within the next few weeks.

The upgrading of the data acquisition system has continued with the full integration and calibration of the fuel flow meter and air flow meter into the fuel cell. Work has continued to upgrade the Labview software program primarily in the area of providing the operator better access to the data in real time. Preliminary baseline testing utilizing the fuel grade methanol is continuing.

The gas chromatograph which will be used for in-house analyses is operational. Sample gases have been analyzed and calibration files for the known fuel cell gases have been developed. The gas collection equipment has been received and installation of the sampling interface on the fuel cell system bas begun. It is expected that full gas analysis capability will be achieved in the near future.

The equipment for the new fuel management system has been delivered and installed. The system allows the choice between fuel grade methanol in the existing fuel tank or the mixture of fuel grade methanol and coal-based methanol stored in a 55 gallon drum. In addition, it is possible to utilize both type of fuels at the same time in certain arrangements, such as fuel grade methanol as the primary fuel and the fuel mixture as fuel for the burners.

No major problems have been encountered and work is expected to continue as planned.

Attachment

Intertek Testing Services
Caleb Brett

Bayport Petrochemical Facility
11727 Port Road
Seabrook, Tx 77586
Telephone: (281) 291-9889
Fax: (281) 291-9984

REPORT OF ANALYSIS

LABORATORY REPORT NUMBER: BP/98-01777

July 2, 1998

UNIVERSITY OF FLORIDA

Your Reference: P.O.#347871

Customer Product Description: METHANOL

SAMPLE ID: BP/98-01777-01
SAMPLE DESCRIPTION: Submitted Sample #1 AIR PRODUCTS

ANALYSIS:	METHOD:	RESULT:	
Sulfur Content	D-4045	<0.02	mg/kg
Chloride Content	D-5808	<1	mg/kg
Mineral Oil as Non-Volatile Matter	D-1353	2208	mg/kg
Water Content	E-1064	4286	mg/kg
Identification of Mineral Oil	FT-IR	N/A	
Purity (Anhydrous)	GC	99.90	Wt. %
Ethanol		1433	mg/kg
Dimethyl Ether		<10	mg/kg
n-Propanol		499	mg/kg
sec-Butanol		10	mg/kg
iso-Butanol		49	mg/kg
n-Butanol		300	mg/kg
iso-Pentanol		13	mg/kg
n-Pentanol		159	mg/kg
Methyl Acetate		<10	mg/kg
Methyl Ethyl Ketone		114	mg/kg
n-Hexanol		87	mg/kg
Other Impurities		0.73	Wt. %

SAMPLE ID: BP/98-01777-02
SAMPLE DESCRIPTION: Submitted Sample #2 AIR PRODUCTS

ANALYSIS:	METHOD:	RESULT:	
Sulfur Content	D-4045	<0.02	mg/kg
Chloride Content	D-5808	<1	mg/kg

Continued on next page.

Appendix B-5

Exhaust Emissions Testing Performed for Air Products Corporation on Transit Buses Fueled by Air Products Brand Methanol Fuel

Draft Report

Nigel N. Clark and James A. Boyce

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August 21, 1998

Contents

1 Introduction

Figure 1 -- Laboratory #1

1.1 Overview

The emissions testing reviewed in this report was performed for Air Products Corporation who are currently developing a "fuel grade" methanol (FGM) product for use in heavy duty vehicles. The subject vehicles, transit buses, were equipped with Detroit Diesel Corporation 6V92 compression ignition engines designed to operate on alcohol fuels. At the time of this research, the only fuel commonly used in methanol vehicles is a high purity chemical grade methanol (CGM). The FGM is being developed as a replacement for the CGM which is expensive when compared to diesel fuel.

West Virginia University (WVU), through funding from Air Products Corporation, performed emissions measurements on a sample of three Methanol fueled transit busses in New York City in April, 1998. The vehicles were tested on both FGM and CGM. The vehicles were operated through commonly used, pre-determined vehicle speed vs. time schedules while vehicle emission, torque and speed were monitored and recorded. Emissions monitored during the testing included hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO2), oxides of nitrogen (NOx), particulate matter (PM), methanol (CH3OH), and formaldehyde (HCHO).

1.2 Emissions Laboratory Description and General Approach

The WVU Transportable Heavy Duty Emissions Testing Laboratory (Figure 1) evaluates emissions from alternatively fueled vehicles across North America. The usual objective of the research performed is to build an emissions database that can be used to ascertain emissions performance and fuel efficiency of alternatively fueled vehicles. West Virginia University designed, constructed and now operates two Transportable Heavy Duty Vehicle Emissions Testing Laboratories which travel to transit agencies and trucking facilities where the laboratory is stationed to test vehicle emissions.

Several technical papers (SAE 961082, SAE 951016, and SAE 952746) have been presented on the design of the two laboratories and on emissions data collected from both conventional and alternatively fueled vehicles.

The transportable laboratory used in this research consisted of a dynamometer test bed, instrumentation trailer and support trailer. The test bed (Figure 2 and Figure 3) was designed to be transported to the test site by a tractor truck where it is then lowered to the ground. Once lowered, subject vehicles were then driven on to the test bed where the outer drive wheels of the vehicle are removed and replaced by special adapters (Figure 4), which provided a connection between the drive axle of the vehicle and the inertial flywheels and power absorbers of the dynamometer. Speed-increasing gearboxes transmitted the bus drive axle power to flywheel sets. The flywheel sets consisted of a series of selectable discs used to simulate vehicle inertia. During the test cycle, torque cells and speed transducers at the vehicle hubs monitored wheel torque and hub speed.

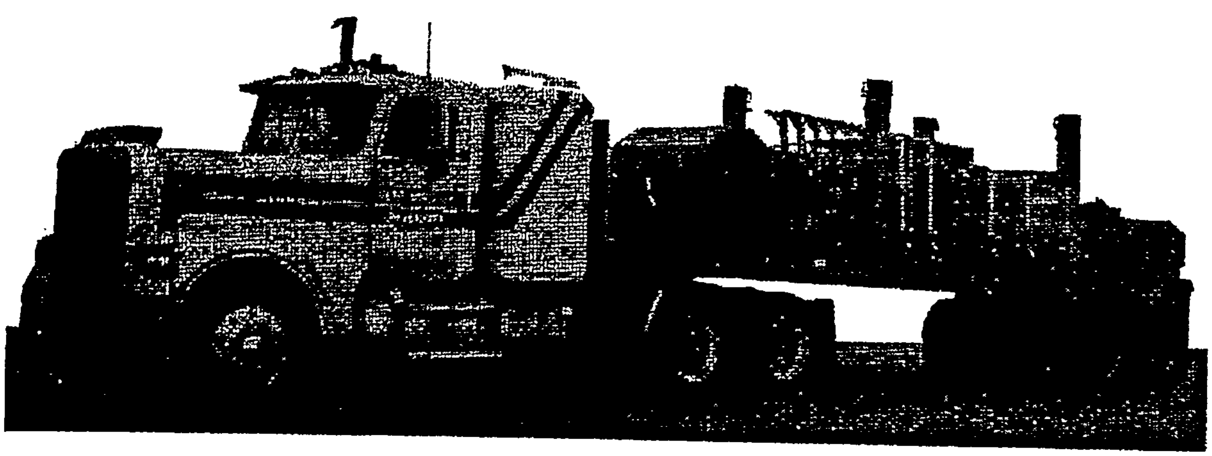

Figure 2 -- Dynamometer test bed packed for transport

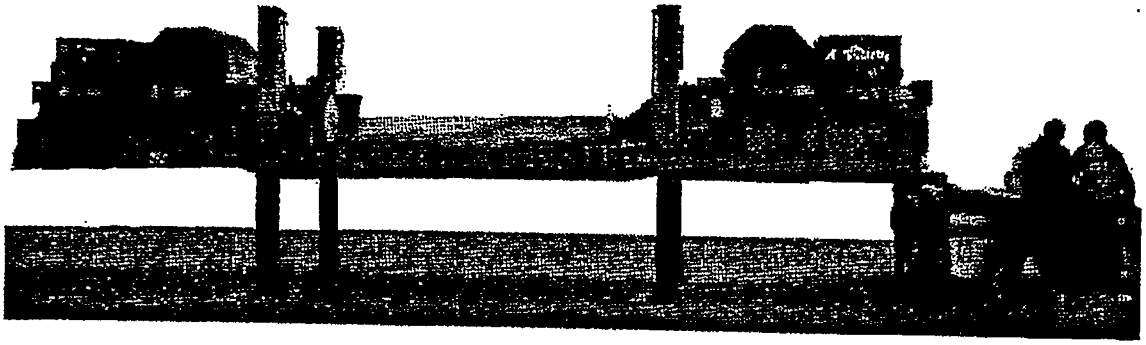

Figure 3 – Test bed ready for lowering in preparation for testing

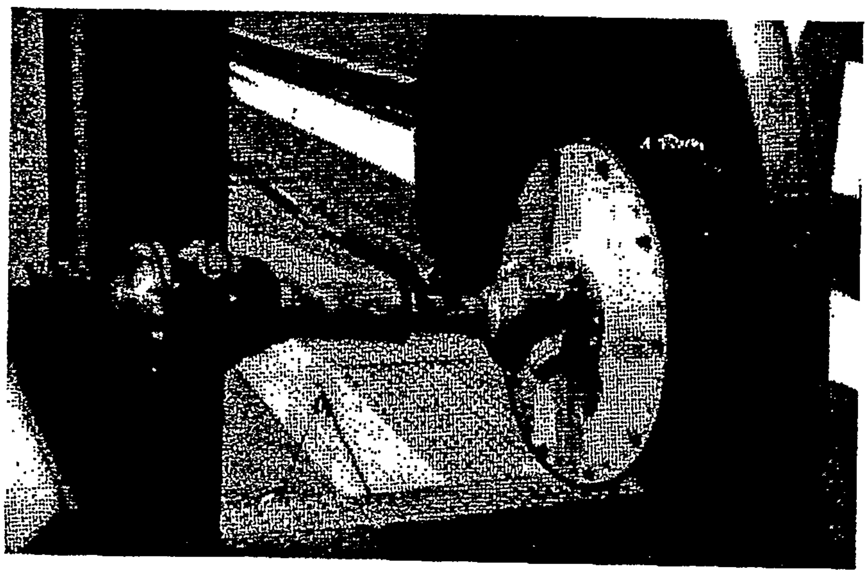

Figure 4 – Close-up of adapter connecting the vehicle

hub to the dynamometer drivetrain

The instrumentation trailer (Figure 5) held both the emissions measurement system for the laboratory and the data acquisition and control hardware necessary for the operation of the test bed. Exhaust emissions from the bus were piped to a 45cm dilution tunnel at the instrumentation trailer. The tunnel mixed the exhaust with ambient air which both cooled and diluted the exhaust. The use of dilution tunnels has been discussed in detail by Kittelson and Johnson (1991). Dilution tunnel flow control was realized using a critical flow venturi system (CVS). A two-stage blower system maintained critical flow through the venturi throat restrictions to maintain a known, and nearly constant mass flow of dilute exhaust during testing flow of dilute exhaust during testing. The flow used in the research was approximately 1000 scfm, including both vehicle exhaust and dilution air.

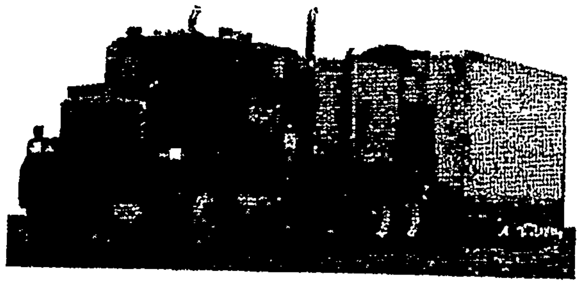

Figure 5 -- Instrumentation trailer and transport vehicle

Dilute exhaust samples were drawn from sample probes located 15 feet from the mouth of the dilution tunnel. The samples were routed to the respective analyzers using heated sampling lines. Levels of carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x) and hydrocarbons (HC) were measured continuously, then integrated over the complete test cycle. A sample of the ambient (dilution) air was collected in a Tedlar bag and analyzed at the end of each test. These measurements were then subtracted from the continuous measurements. Detail of the analyzers used in this research are given in Table 1

Hydrocarbons	Flame ionization detector	Rosemount Analytical Model 402
Carbon Monoxide	Non-dispersive infrared	Rosemount Analytical Model 880A
Carbon Dioxide	Non-dispersive infrared	Rosemount Analytical Model 880A
Oxides of Nitrogen	Chemiluminescent	Rosemount Analytical Model 955

Table 1-- Analyzers used for emissions measurement

A gravimetric measurement of particulate matter (PM) was obtained using 70mm filters, weighed before and after testing. The filters were conditioned for temperature and humidity in an environmental chamber before each weighing to reduce error due to variation in water content. It was known from prior research that the PM levels from methanol fueled buses were likely to be low.

The researchers also measured the amount of formaldehyde and methanol present in the engine exhaust. Formaldehyde measurement was accomplished using DNPH coated silica beads in sample cartridges prepared by Atmospheric Analysis & Consulting (AA&C). During the test, a continuous exhaust sample from the dilution tunnel was passed through the cartridge where any formaldehyde present depleted a quantity of DNPH from the cartridge proportional to the amount of formaldehyde in the sample. The amount of methanol in the exhaust was determined by passing a continuous sample through a series of two impingers containing 25 ml of distilled water. Any methanol present in the sample was dissolved in the water, which was then analyzed using gas chromatography with a Varian 3600 gas chromatograph. The continuous reading from the hydrocarbon analyzer was known to be affected by the level of methanol in the exhaust because the flame ionization detector's response to the methanol, as compared to its calibration gas (propane), is slightly lower.

2 Specific Test Procedures

2.1 Pre-Test

Prior to testing each methanol bus, a visual inspection was performed to locate lift points, look for damage, and examine exhaust connections. Also vehicle information was gathered such as mileage, identification numbers (chassis and engine), type of muffler and catalyst, and seating capacity.

To minimize variation in emissions due to air-cleaner quality, a clean air filter was used for all the vehicles tested. The original air cleaner was reinstalled in each bus before it was returned to the owner.

Proper operation of the gas sampling system, associated analyzers, and test bed instrumentation was checked following a comprehensive calibration schedule after setup of the laboratory. In particular, the gas analysis instrumentation was calibrated and checked using "zero" air (air free of any contaminants) and "span" gas (air containing a known quantity of the gas under consideration) as well as evenly spaced concentration levels of the gas. The integrity of the dilution tunnel and associated plumbing was verified using a propane injection. This procedure involved introducing a known amount of propane into the dilution tunnel using a critical flow orifice injection rig. The hydrocarbon concentration measured using the hydrocarbon analyzer was then compared to that calculated from the injection rig to verify propane mass recovery. A difference of less than 2% indicated that there were no leaks and that the analysis system was operating satisfactorily. The 2% valve is customarily used because it follows the requirements for emissions testing presented in the Code of Federal Regulations Title 40, Part 86, Subpart N.

Since this emissions research involved vehicles (buses) with a single rear axles, additional load on the inner rear tires was introduced when the outside tires were removed. This additional load was removed by placing jacks on calibrated scales beneath the bus. The vehicle was lifted until each scale read one quarter of the vehicle's rear curb weight.

Prior to performing a test, the vehicle was operated on the dynamometer to bring the vehicle's engine and transmission as well as associated dynamometer equipment up to operating temperature. This provided a uniform starting point for all testing when considering the vehicle/dynamometer drivetrain and associated transmission losses in each component.

At least one practice test cycle was then performed to allow the driver to become familiar with vehicle characteristics, and to help the instrument operator determine proper analyzer settings. Prior to taking the first data set, the vehicle transmission was set to neutral and the engine was allowed to idle for a period of 17 minutes. The vehicle was then driven though a set of practice ramps to expel constituents that may have collected in the exhaust system during idling. Twenty seconds after completion of the final practice ramp, data collection was initiated.

2.2 Emissions Measurement

During an emissions test, the driver was provided with a visual speed trace displaying both the actual and the desired vehicle speed. The driver was instructed to follow the prescribed speed trace as closely as possible. While the driver operated the vehicle through the speed cycle, continuous dilute exhaust samples from the dilution tunnel were monitored and recorded in the instrumentation trailer. At the completion of the test cycle, integrated bag samples were analyzed and recorded and particulate filters were changed. Data from each test were recorded and preparations for the next test were initiated. Particulate data were not available until the filters could be appropriately conditioned after the test. This involved placing the filters in an environmental chamber where they were left for at least 4 hours prior to weighing.

Test to test variation was monitored to assure quality of the research conclusions. Testing was considered to be complete when a minimum of 4 complete test were performed and the test to test variation showed acceptable repeatability.

3 Vehicles, Fuels and Tests Performed

3.1 Test Vehicles

Resistance to auto-ignition and high heat of vaporization make alcohol fuels difficult for compression ignition application. In addition, the low heating value of alcohol fuels demands that a greater volume of fuel must be injected into the cylinder than for diesel. Other problems that must be addressed are related to poor fuel lubricity, the changed heat release rates relative to diesel and the presence of corrosive products of combustion in the cylinder. Despite these obstacles, Detroit Diesel Corporation (DDC) has manufactured a methanol compression ignition engine based on the 6V92 diesel engine. The design uses the two stroke cycle, with exhaust valves in the head and is supercharged and turbocharged. Injection is managed electronically. After treatment catalytic converters are used to oxidize emissions.

Three Transit Motor Corp. methanol fueled transit buses (1993 T80206 model) were tested on both CGM and FGM in 1998. They were equipped with Detroit Diesel 6V92 engines. These vehicles were selected from Triboro Coach Company's in-service fleet in Brooklyn, NY. Details on the engine and vehicles are contained in Table 2.

Vehicle Number	2145	2139	2143
Model Year	1994	1993	1993
Seating Capacity	43	43	43
Frontal Area (ft^2)	80.5	80.5	80.5
Tire Diameter (in.)	41.8	41.8	41.8
GVW (lb.)	39500	39500	39500
Curb Weight (lb.)	28500	28500	28500
Test Weight (lb.)	34500	34500	34500
Odometer Reading (miles)	10000	69020	88772
Engine Type	DD6V92TA	DD6V92TA	DD6V92LH
Engine Displacement (liters)	9.0	9.0	9.0
Engine Rated Power (hp)	253	253	253

Table 2-- Data from vehicles tested in this study

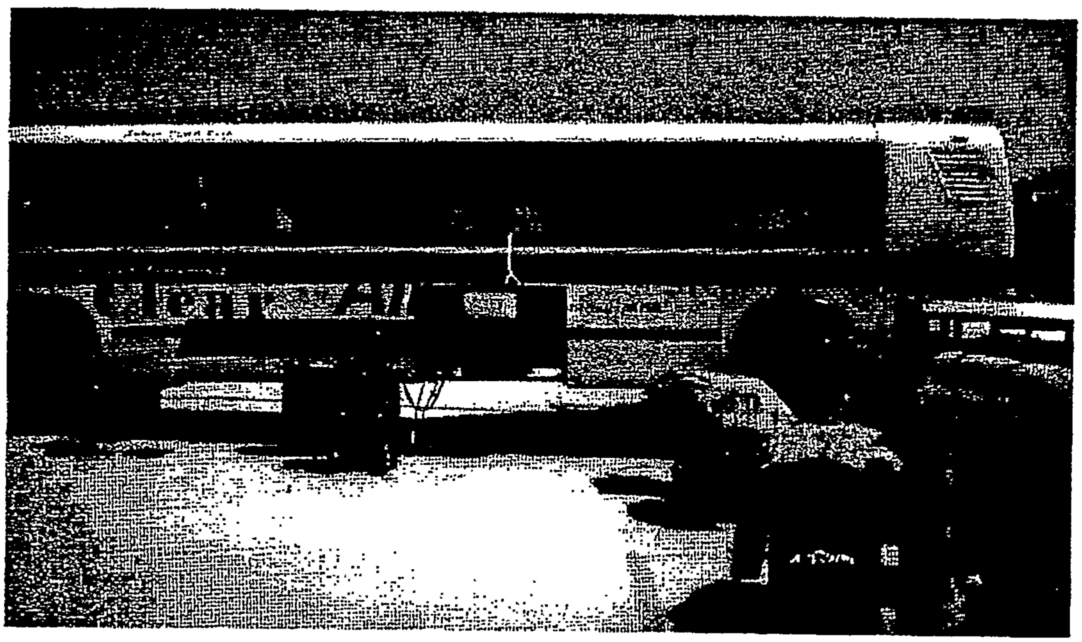

Figure 6 --Triboro Methanol bus running on Air Products methanol

3.2 Fuels

The fuels used in this research program were the fuel grade methanol (FGM) supplied by Air Products from their plant in Laporte, TX, and the chemical grade methanol (CGM) in current use by Triboro coach. The CGM, supplied by Rad Energy Corp., was essentially pure and its specifications are given in

Table 3.

Table 3—Chemical grade methanol fuel specifications

PURITY	99.85 minimum *wt%*
APPEARANCE	bright & clear, free of suspended matter
COLOR	5 maximum *Platinum cobalt scale*
SPECIFIC GRAVITY	0.7928 maximum *at 20 degrees/20 degrees C*
WATER	0.10 maximum *wt%*
ACIDITY	0.003 maximum *as acetic acid wt%*
ALKALINITY	0.003 maximum *as ammonia wt%*
PERMANGANATE TEST	60 minimum *at 15 degrees C, minutes*
ACETONE	0.003 maximum *wt%*
DISTILLATION RANGE	not more than 1 degrees including 64.6 degrees C *at 760mm Hg*
CARBONIZABLE SUBSTANCE	30 maximum *platinum cobalt scale*
WATER MISCIBILITY	No turbidity after 1 hour at 25degreesC *when 1 volume is distilled with 3 volumes of distilled water*
NON-VOLATILES	0.001 maximum *gram/100ml*

Received: July 8, 1998 (by Boyce)
From: Rad Energy Corp.
287 Bowman Ave.
Purchase, NY 10577-2540
914-701-2710

An additive, manufactured by Lubrizol, was customarily used by Triboro to treat the chemical grade fuel. The same additive was used to doctor the FGM before the comparative emissions research commenced. The additive was mixed 0.06 percent by volume.

3.3 Tests Perfomed

The vehicles were tested on fuel grade methanol (FGM) that was developed by Air Products (Figure 6). They were also tested using the regularly used fuel, which was chemical grade methanol (CGM). All three vehicles were tested using the Central Business District (CBD) cycle (Figure 7), and one vehicle was tested using both the CBD and the 5 mile route (Figure 8).

The Central Business District Cycle is a fixed speed-versus-time trace that the driver must follow. It is intended to simulate the use of a transit bus in city service and is also used to ratify the performance of new models of transit bus. Details of the CBD are given in SAE Recommended Practice J1376. The CBD is two miles long, and is customarily followed without difficulty by transit buses in current service. All cruise sections are at 20 mph.

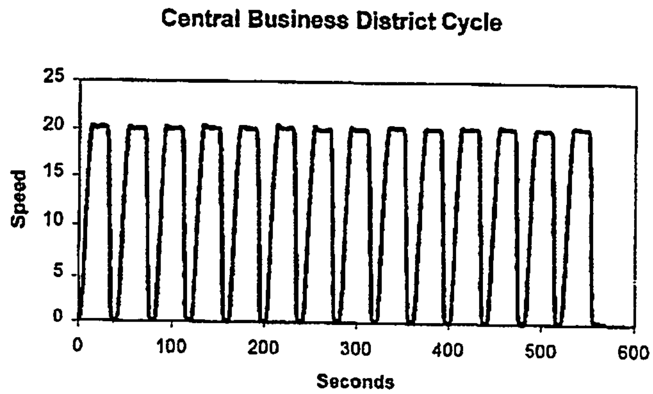

Figure 7 – Vehicle speed from a CBD cycle

The 5 mile route is less energy intensive than the CBD cycle, having longer cruise sections. It consists of five acceleration, cruise and deceleration segments, at 20, 25, 30, 35 and 40 mph. The accelerations are designed to be free accelerations at maximum axle power, so that a more powerful vehicle will complete a 5 mile route in less time. Therefore, completion time for the route may vary from vehicle to vehicle. This route was originally designed for heavy over-the-road trucks and has been discussed in more detail by Clark and Lyons (ASAE 986082).

WVU 5-mile Cycle

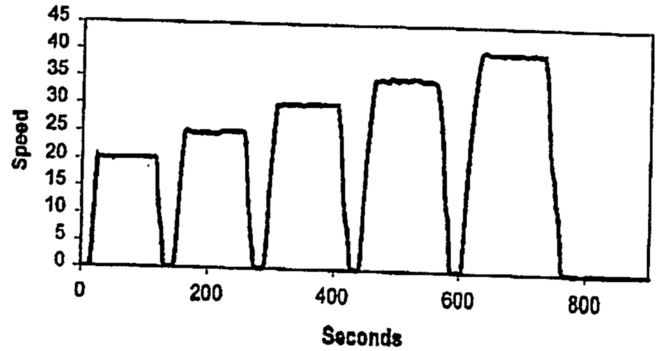

Figure 8 – Vehicle speed from a 5 mile route.

When testing on the FGM, a 55-gallon drum was used to replace the fuel tank as shown in Figure 9. Braided Stainless Teflon line was used to replace the fuel line. The line from the fuel tank was disconnected and capped, and an identical line was attached in its place, which came from the Air Products methanol drum. The return line to the fuel tank was also replaced (Figure 10).

Initial attempts to operate the engine using the fueling system described above failed. The reason for these failures was found to have been caused by low pressure in the substitute fuel return line. Without the backpressure normally created by an orifice in the origional line, the engine would not operate properly. To remedy this, a restriction to increase backpressure was created by installing a stainless steel ball valve in the return line. A mechanic from the transit agency adjusted the backpressure to the same level as when the original return line was in use.

To minimize contamination of the test fuels, the return line was directed into a waste drum and the fuel pump was operated until approximately 10 gallons had cycled through the system. The return line was then directed back into the drum of test fuel. This insured that the FGM was not contaminated with CGM during a test run.

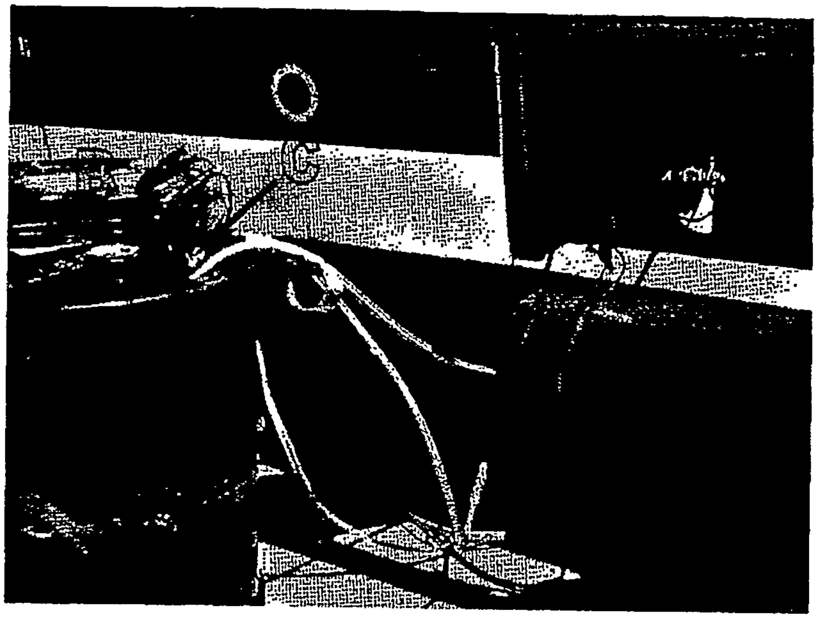

Figure 9 -- Fuel tank replacement

A. Air Products methanol 55-gal drum
B. Waste fuel 55-gal drum
C. Valve on return line used as restriction to increase fuel system pressure

Figure 10 -- Fuel line replacement

A. Intake from 55-gal drum
B. Capped line from fuel tank
C. One of two fuel filters
D. Fuel pump
E. Return line to 55-gal drum

4 Emissions Data

4.1 Fuel and Chemical Grade Methanol

This section discusses emissions measured from the methanol fueled transit buses with Detroit Diesel DD6V92 engines, and the contrast between the results obtained using Air Products FGM and the currently used CGM. Table 4 shows the emissions results, in g/mile, for all three buses operated through the CBD cycle, and one bus operated through the 5-mile test. Each entry in these tables is the average of several test runs. The data from individual runs appears in **6.1 Short Reports** on page 18 of this report. An explanation of terms can be found in Section **6, Reading the Short Report**

Table 4—Methanol Emissions Summary

Vehicle #2145 using the CBD test cycle

Seq #	Fuel	CO	NOx	FIDHC	PM	CO2	MPG	BTU/mile	CH3OH	HCHO	OMHCE
1097	CGM	5.83	4.62	2.17	0.09	2382	1.72	33131	2.66	1.35	0.79
1099	FGM	4.01	3.47	4.10	0.11	2489	1.65	34578	4.16	2.03	3.08
	% diff. *	***-31%***	***-25%***	***89%***	***24%***	***4%***	***-4%***	***4%***	***56%***	***50%***	***290%***

Vehicle #2139 using the CBD test cycle

Seq #	Fuel	CO	NOx	FIDHC	PM	CO2	MPG	BTU/mile	CH3OH	HCHO	OMHCE
1101	CGM	12.90	6.61	5.28	0.10	3013	1.36	42035	6.17	1.17	3.34
1103	FGM	11.80	6.24	5.55	0.12	2953	1.38	41171	6.05	1.41	3.59
	% diff. *	***-9%***	***-6%***	***5%***	***25%***	***-2%***	***1%***	***-2%***	***-2%***	***21%***	***7%***

Vehicle #2143 using the CBD test cycle

Seq #	Fuel	CO	NOx	FIDHC	PM	CO2	MPG	BTU/mile	CH3OH	HCHO	OMHCE
1106	CGM	12.50	5.56	8.71	0.44	2923	1.40	40778	9.84	1.35	5.16
1105	FGM	13.00	5.63	11.00	0.49	2992	1.37	41748	13.99	1.44	6.64
	% diff. *	***4%***	***1%***	***26%***	***11%***	***2%***	***-2%***	***2%***	***42%***	***7%***	***29%***

Vehicle Average using the CBD test cycle

Seq #	Fuel	CO	NOx	FIDHC	PM	CO2	MPG	BTU/mile	CH3OH	HCHO	OMHCE
Average	CGM	10.41	5.60	5.39	0.21	2772.67	1.49	38648	6.22	1.29	3.10
Average	FGM	9.60	5.11	6.88	0.24	2811.33	1.47	39166	8.07	1.63	4.44
	% diff. *	***-8%***	***-9%***	***28%***	***15%***	***1%***	***-2%***	***1%***	***30%***	***26%***	***43%***

Vehicle #2143 using the 5-mile test cycle

Seq #	Fuel	CO	NOx	FIDHC	PM	CO2	MPG	BTU/mile	CH3OH	HCHO	OMHCE
1107	CGM	11.80	3.47	51.10	0.39	1962	2.08	27447	71.19	2.54	29.53
1109	FGM	15.70	3.53	54.80	0.52	1965	2.07	27575	71.85	2.40	31.78
	% diff. *	***33%***	***2%***	***7%***	***33%***	***0%***	***0%***	***0%***	***1%***	***-6%***	***8%***

***** % diff.***–*The percent difference of FGM emissions versus CGM emissions using: %diff=(FGM-CGM)/CGM)*

Carbon Monoxide (CO): For the CBD cycle, the average level of CO for the three vehicles when tested on CGM was 10.4 g/mile. The average level for the three vehicles when tested on Air Products FGM was comparable at 9.6 g/mile. This represented an 8% decrease.

Oxides of Nitrogen (NOx): For the CBD cycle, the average level of NOx for the three vehicles when tested on CGM was 5.6 g/mile. The average level for the three vehicles when tested on Air Products FGM was comparable at 5.1 g/mile. This represented a 9% decrease.

Hydrocarbons (HC): For the CBD cycle, the average level of HC when tested on CGM was 5.4 g/mile. The average level for the three vehicles when tested on Air Products FGM was 6.9 g/mile, representing a 28% increase.

Particulate Matter (PM): For the CBD cycle, low levels of PM were experienced from both fuels. However, PM was 15% higher on average when using the FGM.

Carbon Dioxide (CO2) and Fuel Consumption: For the CBD cycle, CO2 levels were about 2800 g/mi. and energy equivalent fuel consumption was approximately 1.5 mpg and for both fuels.

Raw Methanol (CH3OH): The average level for the three vehicles when tested on CGM was 6.22 g/mile and average level for the three vehicles when tested on Air Products FGM was 8.07 g/mile. This indicates a 30% increase using FGM. This comparison assumes 100% recovery by the methanol (water impinger) sampling system.

Formaldehyde (HCHO): The average level for the three vehicles when tested on CGM was 1.29 g/mile and average level for the three vehicles when tested on Air Products FGM was 1.63 g/mile. This indicates a 26% increase using FGM. This comparison assumes 100% recovery by the aldehyde (DNPH cartridge) sampling system.

Organic Material HC Equivalent (OMHCE): OMHC is the designation used by the EPA to denote the total HC mass emitted from the engine as unburned and partially burned fuel. OMHC was calculated by adding the residual hydrocarbons (RHC) mass to the contributions of methanol (CH3OH) and formaldehyde (HCHO). The masses were each multiplied by the ratio of the molecular weight of gasoline associated with each carbon atom (13.8756) to their respective molecular weight per carbon atom.

4.2 Fuel Grade Methanol (FGM) and Diesel (D2)

Although no diesel bus emission characterization was performed in this research effort, existing data were previously acquired by West Virginia University through funding from the Department of Energy, Office of Transportation Technologies. Two sets of diesel bus data were selected for comparison with the FGM bus emission. The first set of buses, in use in Peoria, Ill., in 1996, employed Detroit Diesel 2 stroke 6V92 diesel engines (277HP DDC6V-92TA DDECII), and represent the same era of technology as the methanol buses that are the subject of the present study. The second set of buses, tested in Flint, MI, in 1997, had newer technology four stroke cycle Detroit Diesel Series 50 engines. Although these buses were not identical in weight and transmission configuration, they represented closely the same 40ft transit bus class as the methanol buses under investigation. All data discussed below were acquired using the CBD cycle.

Table 5—Triboro FGM vs. Peoria D2

	Fuel	CO	NOx	FIDHC	PM	CO2
Peoria	D2	5.3	22.9	2.8	0.9	3115
Triboro	FGM	9.6	5.1	6.9	0.24	2811

Table 5 compares the emissions from the Peoria diesel buses with the Triboro buses operated on FGM. It is evident that the methanol buses offer advantages in reducing NOx and PM, but that HC and CO emissions are higher for the methanol buses.

Table 6—Triboro FGM vs. Flint D2

	Fuel	CO	NOx	FIDHC	PM	CO2
Flint	D2	4.9	30.1	0.13	0.28	2611
Triboro	FGM	9.6	5.1	6.9	0.24	2811

Table 6 shows the comparison of the Triboro buses on FGM with the newer Flint diesel buses tested in 1997. Notice that the series 50 (275HP) buses enjoy very low hydrocarbon and PM emissions. The Methanol buses showed lower NOx emission and similar PM emission, but higher HC and CO.

5 Conclusions

Fuel grade methanol, containing small quantities of organic compounds besides the methanol, can be more economically produced than can the chemical grade methanol currently in use as a heavy-duty automotive fuel. Forty-foot transit buses, powered by Detroit Diesel 6V92 methanol fueled compression ignition engines, were subjected to emission characterization using both fuel and chemical grade methanol. Data gathered using the Central Business District test revealed that the FGM offered a slight reduction in oxides of nitrogen (NOx) produced, but an increase in hydrocarbon emissions. It is difficult to argue the cause of such changes, but the NOx emission variation might be influenced by cetane rating change and a consequent shift in the premix/diffusion burn ration. Exhaust catalyst selectivity might influence the hydrocarbon emissions. No difficulties were experienced in operating the buses on the FGM. Emission using FGM were also compared with existing data from diesel buses with Detroit Diesel 6V92 engines. The benefit of the methanol fuel in yielding particulate matter (PM) and NOx emission below those of the diesel engine was evident, but hydrocarbon emission were higher. It is concluded that the Air Products fuel grade methanol is well suited to use in alcohol fuel compression ignition engine from the standpoint of emissions benefit.

6 Reading the Short Report

The short report shows the vehicle information, vehicle engine information, emissions data in grams/mile, and fuel economy for each test run, average emissions over all test runs, and brief comments for each test in a compact format on one page. The odometer mileage reading or hub mileage reading in the short reports is rounded to the nearest 100 miles.

Symbols used in Short Report Emissions data result table:

- **a** A value was measured and identified as an apparent outlier, and therefore is not reported and not used to compute other parameters or the average values.
- **b** The residual hydrocarbon emissions (RHC) is calculated from the difference between the methanol (CH_3OH) and the FID-HC concentrations. For 100% alcohol fuels, the value of RHC is small and due to experimental variations, it may be measured as positive or negative but can best be assumed to be zero.
- **c** A value cannot be calculated because the parameters required for calculation are not available.
- **d** A value of coefficient variance (CV%) is not meaningful because the average value is too small or not available. A significant coefficient of variance may exist for PM from CNG vehicles, where the PM is at very low levels. Note that CNG PM is more than an order of magnitude less than PM usually measured from diesel vehicles. Similarly some modern diesel vehicles will yield very low hydrocarbon emissions.

Component codes used in the short report data table:

CO: Carbon monoxide in grams/mile

CO_2: Carbon dioxide in grams/mile

NO_x: Oxides of nitrogen in grams/mile

FIDHC: Total hydrocarbon measured by HFID in grams/mile. For CNG and LNG vehicle test, unburned methane is included and no HFID response factor was corrected.

PM: Particulate matter in grams/mile

CH_4: Unburned methane emissions in grams/mile

mile/gal: Calculated fuel economy in mile/gallon. For NG fueled vehicles, MPG means miles per equivalent gallon diesel. In this table, 137 cubic feet CNG at standard temperature and pressure (STP) is equivalent to 1 gallon of #1 diesel.

BTU/mile: Calculated fuel energy used by the vehicle, in BTU/mile.

Miles: Total actual driving distance for a test run

CH3OH Raw unburned methanol

HCHO Formaldehyde

OMHCE Organic Material HC Equivalent

6.1 Short Reports

Copies of the short reports from the tests conducted follow. They are organized in chronological order.

Test Sequence Number: 1097
WVU Test Reference Number: TCC-2145-M100

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA6PR829624
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1994
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	10000
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92TA
Engine ID Number	06VF204716
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/24/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) — **Fuel Economy** (mile/gal, BTU/mile, Miles)

Run Seq. No.	CO	NO_x	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
1097-1	5.70	4.69	2.16	0.125	2429	1.69	33789	2.02
1097-2	5.53	4.55	2.04	0.094	2367	1.73	32916	1.99
1097-3	6.15	4.63	2.25	0.075	2381	1.72	33127	2.00
1097-4	5.93	4.59	2.22	0.063	2350	1.74	32693	1.98
1097 Average	5.83	4.62	2.17	0.089	2382	1.72	33131	2.00
Std. Dev.	0.27	0.06	0.09	0.027	34	0.02	473	0.02
CV%	4.6	1.2	4.3	30.4	1.4	1.4	1.4	0.8

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1097-1	2.84	1.38	0.00	b	0.43
1097-2	2.46	1.34	0.00	b	0.38
1097-3	2.68	1.36	0.00	b	0.54
1097-4	2.64	1.31	0.00	b	1.80
1097 Average	2.66	1.35	0.00	c	0.79
Std. Dev.	0.16	0.03	0.00	c	0.68
CV%	6.0	2.2	d	d	85.8

Test Purpose:

Testing vehicle on chemical grade (currently used) of methanol for comparison to fuel grade methanol.

Test Sequence Number: 1099
WVU Test Reference Number: TCC-2145-M100-FGM

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA6PR829624
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1994
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	10000
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92TA
Engine ID Number	06VF204716
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/27/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile)

						Fuel Economy		
Run Seq. No.	CO	NO_x	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
1099-1	4.87	3.50	3.93	0.12	2510	1.63	34883	1.99
1099-2	3.77	3.46	3.96	0.11	2484	1.65	34496	2.00
1099-3	3.78	3.48	4.48	0.12	2497	1.64	34685	1.99
1099-4	3.64	3.44	4.04	0.11	2466	1.66	34248	1.99
1099 Average	4.01	3.47	4.10	0.11	2489	1.65	34578	1.99
Std. Dev.	0.57	0.03	0.25	0.01	19	0.01	271	0.00
CV%	14.3	0.7	6.2	4.9	0.8	0.8	0.8	0.2

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1099-1	3.86	2.00	0.01	b	2.97
1099-2	3.74	1.89	0.01	b	2.92
1099-3	4.81	2.16	0.01	b	3.36
1099-4	4.24	2.06	0.01	b	3.08
1099 Average	4.16	2.03	0.01	c	3.08
Std. Dev.	0.48	0.11	0.00	c	0.20
CV%	11.6	5.6	d	d	6.4

Test Purpose:
testing of fuel grade methanol to compare with chemical grade methanol

Special Procedures:
Pumping fuel from 55 gal drum in place of 175 gal fuel tank. Restriction made from stainless whitey valve. Fuel pressure set at 80 psi at idle

Test Sequence Number: 1101
WVU Test Reference Number: TCC-2139-M100

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA0PR829618
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	69000
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92TA
Engine ID Number	06VF204716
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/28/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) / **Fuel Economy**

Run Seq. No.	CO	NO_x	FID HC	PM	CO_2	mile/gal	BTU/mile	Miles
1101-1	12.7	6.64	4.93	0.082	3056	1.34	42617	2.04
1101-2	13.0	6.56	5.48	0.088	3013	1.36	42038	2.05
1101-3	13.1	6.57	5.31	0.105	3050	1.34	42545	2.02
1101-4	12.9	6.57	5.30	0.101	2977	1.37	41532	2.04
1101-5	12.9	6.71	5.38	0.104	2971	1.38	41444	2.02
1101 Average	12.9	6.61	5.28	0.096	3013	1.36	42035	2.03
Std. Dev.	0.1	0.06	0.21	0.010	40	0.02	548	0.01
CV%	1.1	1.0	3.9	10.9	1.3	1.3	1.3	0.5

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1101-1	5.48	0.93	0.01	b	3.05
1101-2	6.48	a	0.01	b	C
1101-3	6.25	1.23	0.00	b	3.42
1101-4	6.30	1.23	0.01	b	3.42
1101-5	6.35	1.28	0.01	b	3.48
1101 Average	6.17	1.17	0.00	c	3.34
Std. Dev.	0.40	0.16	0.00	c	0.20
CV%	6.4	13.6	d	d	5.9

Test Purpose:
Testing vehicle on chemical grade (currently used) of methanol for comparison to fuel grade methanol.

Test Sequence Number: 1103
WVU Test Reference Number: TCC-2139-M100-FGM

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA0PR829618
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	69000
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92TA
Engine ID Number	06VF204716
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/29/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
1103-1	11.5	6.12	5.81	0.12	3019	1.35	42080	2.02
1103-2	12.7	6.40	5.69	0.12	3014	1.36	42041	2.02
1103-3	12.4	6.24	5.53	0.12	2908	1.41	40560	2.04
1103-4	11.3	6.21	5.43	0.13	2920	1.40	40714	2.03
1103-5	11.2	6.22	5.31	0.13	2902	1.41	40461	2.03
1103 Average	11.8	6.24	5.55	0.12	2953	1.38	41171	2.03
Std. Dev.	0.7	0.10	0.20	0.01	59	0.03	817	0.01
CV%	5.6	1.6	3.6	4.5	2.0	2.0	2.0	0.5

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1103-1	6.68	1.51	0.01	b	3.80
1103-2	6.33	1.49	0.01	b	3.71
1103-3	5.37	1.48	0.01	b	3.55
1103-4	5.82	1.36	0.01	b	3.49
1103-5	6.04	1.22	0.01	b	3.40
1103 Average	6.05	1.41	0.01	c	3.59
Std. Dev.	0.50	0.12	0.00	c	0.16
CV%	8.3	8.5	d	d	4.6

Test Purpose:

testing of fuel grade methanol to compare with chemical grade methanol

Special Procedures:

Pumping fuel from 55 gal drum in place of 175 gal fuel tank. Restriction made from stainless whitey valve. Fuel pressure set at 90 psi at idle

Test Sequence Number: 1105
WVU Test Reference Number: TCC-2143-M100-FGM

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA2PR829622
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	88800
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92LH
Engine ID Number	06VF204696
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/29/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) | **Fuel Economy**

Run Seq. No.	CO	NO_x	HC	PM	CO_2	mile/gal	BTU/mile	Miles
1105-1	12.9	5.63	9.9	0.51	2997	1.36	41810	2.00
1105-2	12.9	5.71	11.6	0.47	3009	1.36	41979	1.99
1105-3	13.1	5.58	11.8	0.46	3018	1.35	42099	1.98
1105-4	12.9	5.60	11.0	0.48	2962	1.38	41322	1.98
1105-5	13.2	5.63	10.5	0.51	2976	1.37	41530	2.00
1105 Average	13.0	5.63	11.0	0.49	2992	1.37	41748	1.99
Std. Dev.	0.1	0.05	0.8	0.02	23	0.01	320	0.01
CV%	0.9	0.9	7.1	4.8	0.8	0.8	0.8	0.5

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1105-1	10.11	1.19	0.02	b	5.74
1105-2	13.76	1.58	0.02	b	6.96
1105-3	14.26	1.47	0.02	b	7.04
1105-4	14.52	1.50	0.02	b	6.74
1105-5	17.30	1.42	0.02	b	6.71
1105 Average	13.99	1.44	0.02	c	6.64
Std. Dev.	2.57	0.15	0.00	c	0.52
CV%	18.4	10.2	7.0	d	7.9

Test Purpose:
testing of fuel grade methanol to compare with chemical grade methanol

Special Procedures:
Pumping fuel from 55 gal drum in place of 175 gal fuel tank. Restriction made from stainless whitey valve. Fuel pressure set at 90 psi at idle

Test Sequence Number: 1106
WVU Test Reference Number: TCC-2143-M100

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA2PR829622
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	88800
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92LH
Engine ID Number	06VF204696
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	CBD
Test Date	4/30/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) / **Fuel Economy**

Run Seq No	CO	NOx	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
1106-1	12.8	5.64	10.11	0.41	2997	1.36	41806	2.00
1106-2	12.9	5.61	9.53	0.39	2944	1.39	41080	1.99
1106-5	12.7	5.57	8.00	0.47	2904	1.41	40516	2.01
1106-6	11.9	5.41	7.95	0.47	2892	1.41	40330	2.01
1106-7	12.0	5.55	7.96	0.48	2879	1.42	40159	2.00
1106 Average	12.5	5.56	8.71	0.44	2923	1.40	40778	2.00
Std. Dev.	0.5	0.09	1.04	0.04	48	0.02	671	0.01
CV%	3.9	1.6	11.9	9.4	1.6	1.6	1.6	0.4

Run Seq No	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1106-1	11.98	1.53	0.01	b	6.14
1106-2	10.60	a	0.01	b	C
1106-5	9.02	1.30	0.02	b	4.86
1106-6	8.84	1.18	0.01	b	4.76
1106-7	8.76	1.38	0.01	b	4.86
1106 Average	9.84	1.35	0.01	c	5.16
Std. Dev.	1.41	0.15	0.00	c	0.66
CV%	14.4	11.0	d	d	12.8

Test Purpose:
Testing vehicle on chemical grade (currently used) of methanol for comparison to fuel grade methanol.

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Test Sequence Number: 1107
WVU Test Reference Number: TCC-2143-M100-5MILES

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA2PR829622
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	88800
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92LH
Engine ID Number	06VF204696
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	5 Mile Route
Test Date	4/30/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) / **Fuel Economy**

Run Seq. No.	CO	NO_x	FID HC	PM	CO_2	mile/gal	BTU/mile	Miles
1107-2	11.7	3.45	50.1	0.40	1962	2.08	27444	5.01
1107-3	11.8	3.49	50.4	0.39	1965	2.07	27492	5.01
1107-4	11.8	3.46	52.8	0.38	1959	2.08	27406	5.01
1107 Average	11.8	3.47	51.1	0.39	1962	2.08	27447	5.01
Std. Dev.	0.1	0.02	1.5	0.01	3	0.00	43	0.00
CV%	0.5	0.6	2.9	1.4	0.2	0.2	0.2	0.0

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1107-2	73.89	2.61	0.00	b	29.36
1107-3	65.23	2.52	0.00	b	28.70
1107-4	74.44	2.50	0.00	b	30.54
1107 Average	71.19	2.54	0.00	c	29.53
Std. Dev.	5.17	0.06	0.00	c	0.93
CV%	7.3	2.3	d	d	3.2

Test Purpose:

Testing vehicle on chemical grade (currently used) of methanol for comparison to fuel grade methanol.

Test Sequence Number: 1109
WVU Test Reference Number: TCC-2143-M100-5MILES-FGM

Fleet Owner Full Name	Triboro Coach Company
Fleet Address	85-01 24th Ave.
Fleet Address (City, State, Zip)	Jackson Heights, NY 11359
Vehicle Type	Transit Bus
Vehicle ID Number (VIN)	1TUMDTDA2PR829622
Vehicle Manufacturer	Transit Motor Corp.
Vehicle Model Year	1993
Gross Vehicle Weight (GVW) (lb.)	39500
Vehicle Total Curb Weight (lb.)	28500
Vehicle Tested Weight (lb.)	34500
Odometer Reading (mile)	88800
Transmission Type	Automatic
Transmission Configuration	3-Speed
Number of Axles	2
Engine Type	Detroit Diesel Corp. 6V-92LH
Engine ID Number	06VF204696
Engine Displacement (Liter)	9.05
Number of Cylinders	6
Engine Rated Power (hp)	253
Primary Fuel	M100
Test Cycle	5 Mile Route
Test Date	5/1/98
Engineer	J. Boyce
Driver	L. McGrath

Emissions Results (g/mile) **Fuel Economy**

Run Seq. No.	CO	NO_x	FIDHC	PM	CO_2	mile/gal	BTU/mile	Miles
1109-1	15.5	3.56	55.9	0.53	1994	2.04	27964	5.01
1109-2	16.5	3.57	57.0	0.54	1978	2.05	27762	5.01
1109-3	15.2	3.45	51.5	0.51	1925	2.11	27000	5.02
1109 Average	15.7	3.53	54.8	0.52	1965	2.07	27575	5.02
Std. Dev.	0.7	0.07	2.9	0.02	36	0.04	508	0.01
CV%	4.2	1.9	5.4	3.3	1.8	1.9	1.8	0.2

Run Seq. No.	CH_3OH	HCHO	CH_3CHO	RHC	OMHCE
1109-1	73.74	2.36	0.01	b	31.76
1109-2	67.97	2.43	0.01	b	31.80
1109-3	73.84	a	0.00	b	C
1109 Average	71.85	2.40	0.00	c	31.78
Std. Dev.	3.36	0.05	0.00	c	0.03
CV%	4.7	2.0	d	d	0.1

Test Purpose:
testing of fuel grade methanol to compare with chemical grade methanol

Special Procedures:
Pumping fuel from 55 gal drum in place of 175 gal fuel tank. Restriction made from stainless whitey valve. Fuel pressure set at 90 psi at idle

Appendix B-6

Quarterly Report
(March 12, 1998 - June 25, 1998)

to

Mr. Robert Senn
consultant to

Air Products and Chemicals, Inc.

from

Dr. John J. Thomas
Florida Tech
150 W. University Blvd.
Melbourne, FL 32901
Ph 407-674-7252
Fax 407-984-8461

Fleet Trails for Fuel Grade Methanol

under

USDOE Cooperative Agreement No. DE-FC22-92PC90543
Performance Period 8/11/97 - 10/10/98

Table of Contents

1. Introduction

During this period, Dr. John Thomas drove the car on a routine basis between 3325 W. New Haven Avenue and the Florida Tech main campus at 150 W. University Blvd. as well as other locations in and around Melbourne - Palm Bay (please see Appendix). Before and after these trips he recorded all the gauge readings. This allowed several MPG calculations. As the summer approached, it became very necessary to repair the air conditioning system. After several failed attempts, GM was contacted and they sent us a wiring diagram. Soon after, the AC was repaired. There was also trouble with the ECM which had to be replaced. The vehicle was also modified to allow on-board collection of emission data. Preliminary results concerning sampling techniques for emission testing were very encouraging.

After fixing the AC and ECM, the car ran better than ever. The MPG in traffic was 9.1 MPG. On the highway however, the MPG was 11.92.

Also, during this period, the bus was made completely operational and routine trips were started to the Harbor Branch Oceanographic Institute (HBOI) just south of Vero Beach; a distance of 50 miles. Any failures in bus performance to this point have been caused by bad injectors, bad solenoids, and bad vacuum lines. No problems have yet occurred that were caused by the methanol fuel or the Avocet additive.

2. Activities: Methanol Car

1. $110.51 was spent on a commercial cold start ether injection system. Cold start was installed and appears to have made a big difference in starting.

2. The ECM in car was found to be non-functional and was removed. ECM was modified from original so a new one needs to be installed. Adapter for emissions testing was placed on exhaust of bus. Decal contract pending.

3. Decals applied to vehicles.

4. New ECM installed and prom with standard equipment.

5. Trouble code 32 & 41 continuously popped. Installed 5 new coil packs, one ignition module, spark plugs and spark plug wires, new MAP sensor and a new crank sensor. Replacement of ECM eliminated code 32 but 41 prevailed. Code 41 still present.

6. Code 41 was Electronic Spark Timing (EST).

7. It was determined that wires going to the ECM were spliced and excessive corrosion built up on splice. Splice was cut out and resoldered properly which eliminates a "magic" black box which was removed because it was extraneous. Solved code 41. Car ran considerably better than ever.

8. Warm A/C complaint. Diagnosed bad cooling fan compression switch. A new one was bought from Rathmann's and installed. The system began working properly and approximately 1 lb. freon was added to optimize cooling.

9. A hole was cut in the bottom of the trunk of the car to allow room to install a coupling. Fred welded the coupling into the exhaust pipe and a plug was installed to seal up the hole until emissions testing was done. Rubber tubing was put all the way around the lip of the hole to seal it. A trap door was then pop riveted to the floor to close up the hole in the floor.

10. A modified brake line with brass fittings was made for taking samples. It was installed into exhaust and tightened down to the coupling welded into the pipe.

METHANOL BUS OPERATION DATA

Procedure for starting the methanol bus

The bus is first switched to the daytime running position prior to starting the engine. Upon activating this switch, the air pump turns on to fill the air brakes and door activator. Then, the engine can be turned over. This is accomplished by pulling a switch in the rear of the bus. However, due to the cold weather in the winter, the bus was equipped with a ether injection system to help turn the engine over. On average, it takes about 5-10 tries to successfully turn engine over with this injection system. However, with an addition of methanol additive (Avocet) to the fuel (3%), engine turn over is sometimes around 2-5 times. After the engine has been successfully started, the high idle switch is engaged to decrease the warm up time. The engine is warmed up to 180 degrees before trying to move the bus. The average warm up time is approximately 20-40 minutes. The bus will run very rough if the engine is not at 180 degrees. After this initial warm-up period the bus can be run all day without problems.

5/19/98 - 110 gals. of fuel in. Bus was driven to Biowest and back. 35 minute warm up time.

Special valve adaptation made for methanol drums. Small air leaks in front - fixed 5/21/98.

Start mileage - 14514 -
ending mileage - 14527
13 miles = (30 min. drive)
3 gal of additive put in

5/26/98 - Radio put in. Battery terminals cleaned and polished. Driven to Biowest to stay. Start temp - 170°. Start - 14527.
End - 14531
4 miles (15 minutes)

5/27/98 - MeOH was put in (50 gals). Tank filled. 1 gal of Avocet additive put in. Driven locally. N. Wickham - 95 S - Biowest. Start temp 180°.

Start mileage - 14531.2
Ending mileage - 14556.9
25.6 miles (1 hour drive)

5/29/98 - May need oil soon, pre-trip inspection found low oil on stick. New windshield wipers also needed. 2 gals of oil put in. Driven to FIT. Road driven: Babcock - Palm Bay (BTR lab) - 95N - Wickham Road - Biowest.

6/1/98 - Bus taken from Biowest to campus to investigate an engine problem. Problem unsolved due to lack of experience with this type of engine. It maybe a vacuum leak. Bus then driven back to Biowest.

Start mileage - 14599.3
Ending mileage - 14611.2
11.9 miles

6/16/98 - Engine problem fixed and ready to take to Harbor Branch Oceanographic Institute just south of Vero Beach.

6/17/98 - Bus taken on a test run to HBOI for experience, starting tomorrow (6/18) HBOI will be a daily trip.

Ending mileage - 14704.4
Starting mileage - 14611.5
92.9 miles

Babcock - US1 (S) - HBOI return
27.5 gals of MeOH put in.

6/19/98 - Bus driven to HBOI for work. This time it will be taken on I95 and back.

Ending miles - 14799.5
Starting mileage - 14704.4
95.1

Bus ran fine there and back - 23 minute warm-up.

6/22/98 - HBOI trip - 55 gals of fuel put in.

ending - 14895.6
starting - 14799.5
96.1

23 minute warm up. Bus ran terrible on way back.

6/23/98 - 55 gals put in with 3 gals of additive. 20 minute warm up.

6/25/98 - HBOI ending - 14995.6
starting - 14895.6
100.0

Noticed that the governor is not taking over anymore. But pick up later on. Bus ran very well 20 minute warm up. 55 gal of fuel put in and 2.0 gals of additive. 19 min. warm up.

6/29/98 - HBOI ending 15096.1
starting 14995.6
100.5

Bus started on 2nd try - very good. Ran well. 55 gals put in with 2 gals of additive.
25 minute warm up time.

6/30/98 - HBOI ending N/A
starting 15096.1

Bus broke down at HBOI. Bus started on third try - 20 minute warm up time.

7/3/98 - Bus towed back to Melbourne by Lee's Wrecking.

7/10/98 - Bus returned to operating condition. Cause of breakdown was a faulty fuel injector.

3. Results and Discussion

The methanol powered car continued operating routinely and the total miles traveled now since recommissioning is 2060 miles over approximately 6 months. The mileage ranged from a high of 11.92 mpg (highway) to a low of 9.0 mpg (city driving). All gauges are functioning well and no unusual readings were observed. The air-conditioning system was repaired and now functions very well. The cold-starting system still works very well. As of now the only repair requirement is for dash lighting which we expect will be completed soon. Installation of the on-board emission measuring systems have been completed for both the car and the bus.

The methanol powered bus was recommissioned and made several trips in the Melbourne area. It also made 5 trips (500 mi) to the Harbor Branch Oceanographic Institute (HBOI) just south of Vero Beach. The ethyl ether starting system still works well but is becoming unnecessary because of the use of fresh Avocet ignition enhancer (3%) and the hot weather. On the last trip the bus broke down at HBOI. The cause of the breakdown was a faulty injector which was quickly replaced. The bus is now operational once again.

A preliminary car exhaust sample was submitted for analysis. Methanol, NOx, and formaldehyde concentrations are being determined. Results are slow in coming due to a back-up in the analytical lab.

4. Work Schedule for Fourth Quarter

1. Determine the bus mileage for city and highway.
2. Determine emissions for the car and bus in the following speed ranges.

Bus	Car
0 - 10	0 - 10
10 -30	10 - 30
30 - 55	30 - 50
	50 +

3. Complete the dash lights repair for the car to enable night driving.

The work scheduled for the third quarter was completed except for gathering the analytical data. Results are slow in coming because of vacations for key personnel and a backed-up analytical laboratory.

5. Listing of Project Personnel

1. Dr. John Thomas, Principal Investigator
2. Steve Roth, New Driver
3. Greg Palubin, Research Assistant
4. Frank Aransky, Research Assistant
5. Richard MacKenzie, Director, Florida Tech Vehicle Maintenance
6. Greg Leonard, Diesel Mechanic (Consultant)
7. Jeff Reilly
8. David Cash
9. Bert Austin

6. Appendix

Road Data for the Methanol Car

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	3/23	5:08	8056.7	175	60	F+	13	S	Biowest	
			199.7							
JT	3/23	5:40	8070.2	198	35	F-	13	F	419B	
			213.3							
JT	3/24	7:59	"	100	60	F-	14	S	419B	Instant start
JT	3/24	8:25	8082.6	203	35	F-	13	F	Biowest	
			225.7							
JT	3/24	9:38	"	150	60	3/4+	14	S	Biowest	
JT	3/24	9:55	8087.0	203	40	3/4+	13	F	FIT	
			230.1							
JT	3/24	12:33	8091.5	170	60	3/4+	13	S	Rooney's	
			234.6							
JT	3/24	12:49	8101.5	195	35	3/4	13	F	Biowest	
			244.6							
JT	3/24	1:30	"	170	50	3/4	13	S	Biowest	
JT	3/24	1:44	8105.7	203	35	3/4-	13	F	FIT	
			248.8							
JT	3/24	2:40	"	165	60	3/4-	14	S	FIT	
JT	3/24	2:56	8110.4	203	35	1/2+	13	F	Biowest	
			256.7							
JT	3/24	4:35	"	150	60	1/2+	14	S	Biowest	
JT	3/24	4:58	8118.7	203	35	1/2+	13	F	Rooney's	
JT	3/24	5:27	"	180	50	1/2+	13	S	FIT	
			261.7							
JT	3/24	5:40	8122.7	195	35	1/2+	13	F	FIT	
			265.7							
JT	3/24	7:51	"	150	60	1/2+	14	S	FIT	

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	3/24	8:21P	8134.3	192	40	1/2	13	F	419B	
			277.4							
	3/25	8:04	"	100	60	1/2+	15	S	419B	Instant start, key, button, ignition order
	3/25	8:40	8146.7	205	35	1/2-	13	F	Biowest	
			289.8							

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	3/25	9:15	8146.7	170	50	1/2-	14	S	Biowest	
			289.8							
JT	3/25	9:29	8151.0	200	40	1/4	13	F	FIT	
			294.1							
JT	3/25	10:10	"	170	55	1/4	13	S	FIT	
JT	3/25	10:23	8155.8	199	35	red line	73	F	Biowest	Fill up with 11.0 gallons
			298.9							9.85 mpg
JT	3/25	2:07	"	110	60	F+	14	S	Biowest	
JT	3/25	2:20	8160.7	192	33	F+	13	F	FIT	
			306.7							
JT	3/25	3:25	306.7	150	60	F+	14	S	FIT	
JT	3/25	3:39	8165.1	200	35	F+	13	F	Biowest	
			308.2							
JT	3/25	4:50	"	160	60	F+	14	S	Biowest	
JT	3/25	5:20	8178.7	195	35	F	13	F	419B	Via Wickham Road
			321.8							
JT	3/27	8:21	"	100	70	F-	15	S	419B	Instant start with ETO
JT	3/27	8:51	8191.2	193	35	F-	13	F	Biowest	
			334.3							
JT	3/27	9:00	"	190	45	F-	13	S	Biowest	
JT	3/27	9:11	8195.5	193	40	3/4	13	F	FIT	
			338.6							
JT	3/27	11:31	"	120	60	3/4+	13	S	FIT	
JT	3/27	11:43	8199.4	195	35	3/4+	13	F	Rooney's	
			342.3							
JT	3/27	12:45	"	100	60	3/4+	13	S	Rooney's	
JT	3/27	1:06	8209.3	195	35	3/4	13	F	Biowest	
			352.4							

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	5/20	11:30	8236.7	150	60	3/4	14	S	Biowest	Last of old LPMeOH, NO AC
			379.8							
JT	5/20	11:58	8250.3	202	30	3/4	14	F	419B	Smooth ride
			393.4							
JT	5/20	12:53	"	170	60	3/4	14	S	419B	Easy start
JT	5/20	1:24	8262.7	222	20	3/4-	13	F	Biowest	High temp?
			405.8							
JT	5/20	1:33	"	215	30	3/4-	14	S	Biowest	easy start
JT	5/20	1:47	8267.4	210	30	1/2+	13	F	FIT	
			410.5							
JT	5/20	2:28	"	190	45	1/2+	14	S	FIT	
			8272.1	215	35	1/2+	13	F	Biowest	Smooth ride
JT	5/20	2:44	415.5							
JT	5/20	3:19	"	195	45	1/2+	14	S	Biowest	
JT	5/20	3:34	8276.5	203	30	1/2+	13	F	FIT	
			419.6							
JT	5/20	4:02	"	190	40	1/2+	14	S	FIT	Smooth ride
JT	5/20	4:17	8281.1	230	30	1/2	13	F	Biowest	
			424.2							
JT	5/20	4:21	"	220	30	1/2	13	S	Biowest	
JT	5/20	4:36	8285.2	220	30	1/2	13	F	FIT	Smooth ride
			428.6							
JT	5/21	9:58	"	100	70	1/2+	15	S	FIT	Easy start
JT	5/21	10:14	8290.4	200	35	1/2-	14	F	Biowest	
			433.5							
JT	5/21	10:35	"	185	50	1/2-	14	S	Biowest	
JT	5/21	10:50	8295.3	208	35	1/2-	13	F	FIT	
			438.4							

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	5/21	11:35	8295.5	180	60	1/2-	14	S	FIT	
			438.4							
JT	5/21	12:03	8307.5	205	35	1/2-	14	F	419B	
			450.6						419B	
JT	5/21	1:00P	"	180	50	1/2-	14	S	419B	Easy start
JT	5/21	1:28	8319.5	210	30	1/4	13	F	FIT	
			462.6							
JT	5/21	3:05	8328.5	205	35	F+	14	S	FIT	Filled with new MeOH
			471.6							
JT	5/21	3:15	8329.2	220	35	F+	13	S	FIT	
			472.5							
JT	5/21	3:43	8337.8	220	35	F+	13	S	BTR	
JT			480.9							
JT	5/21	4:05	8344.4	222	35	F-	13	F	FIT	
			487.5							
JT	5/22	10:08	"	100	70	F-	16	S	FIT	
JT	5/22	10:25	8350.1	200	40	F-	14	F	Biowest	
			493.2							
JT	5/22	11:01	"	170	70	F-	14	S	Biowest	
JT	5/22	11:10	8352.0	205	38	F-	14	F	1st Union	192
			495.1							
JT	5/22	11:20	"	203	42	F-	14	S	1st Union	192
JT	5/22	11:42	8358.8	220	38	3/4+	13	F	Rooney's	
			501.9							
JT	5/22	12:37	"	190	40	3/4+	13	S	Rooney's	

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	5/22	12:58	8368.6	210	38	3/4	14	F	Biowest	
			511.8							
JT	5/22	1:18	"	200	42	3/4	14	S	Biowest	
JT	5/22	1:32	8373.0	210	37	3/4	14	F	FIT	
			516.1							
JT	5/22	2:05	"	195	45	3/4	14	S	FIT	Filled up to overflow
JT	5/22	4:25	8388.0	200	35	F+	14	S	Biowest	
			531.1							
JT	5/22	4:40	8392.1	210	35	F+	13	F	FIT	
			535.1							
JT	6/1	11:30	"	100	70	F+	14	S	FIT	Easy start; no ether; hot day
JT	6/1	11:56	8404.0	208	35	F+	14	F	419B	
			547.1							
JT	6/1	1:03	"	170	60	F-	14	S	419B	
JT	6/1	1:28	8416.0	211	35	F-	13	F	FIT	
			559.1							
JT	6/1	4:13	"	150	70	F-	14	S	FIT	
JT	6/1	4:40	8427.9	215	35	F-	14	F	419B	
			571.0							
JT	6/1	6:50	"	150	60	F-	14	S	419B	Easy start
JT	6/1	7:17	8439.9	211	30	3/4	13	F	FIT	
			583.0							
JT	6/2	10:07	"	100	70	3/4+	14	S	FIT	Very easy start hot day
JT	6/2	10:23	8444.7	205	35	3/4-	14	F	Biowest	
			587.8							
JT	6/2	11:20	"	165	60	3/4-	14	S	Biowest	
JT	6/2	11:47	8458.3	210	30	1/2+	13	F	419B	
		601.4								

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/2	12:58	8458.3	170	70	1/2+	14	S	419B	
			601.4							
JT	6/2	1:28	8470.7	215	30	1/2+	13	F	Biowest	
			613.8							
JT	6/2	1:38	"	220	38	1/2+	14	S	Biowest	
JT	6/2	1:54	8475.0	220	20	1/2	13	F	FIT	
			618.1							
JT	6/3	2:28	8475.2	170	55	1/2-	13	S	FIT	AC fixed, Easy start
			618.3							
JT	6/3	2:40	8479.8	210	35	1/2	12	F	Biowest	Slight hesitation in low gear
			622.9							
JT	6/4	3:05	8490.2	140	60	F+	13	S	FIT	Filled with MeOH ~ 11+ gallons = 10.50 mpg
			653.7							to 192 to I95 to Malabar to Babcock to Palm Bay Rd
JT	6/4	3:50	8515.3	213	35	F+	12	F	Biowest	to I95 to 192 to Biowest
	6/4		658.4							Runs fine after filling
JT	6/4	4:36	"	195	40	F+	13	S	Biowest	
JT	6/4	5:08	8527.8	210	30	F-	12	F	419B	
			670.9							
JT	6/5	9:55	8539.8	180	60	F-	13	S	FIT	
			682.8							
JT	6/5	10:14	8546.7	208	35	3/4	12	F	BTR	
			689.9							
JT	6/5	10:23	"	195	40	3/4	12	S	BTR	
JT	6/5	10:40	8553.5	210	35	3/4-	12	F	FIT	
			696.6							
JT	6/5	11:47	"	172	50	3/4-	13	S	FIT	

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/5	12:00	8557.2	215	35	3/4-	13	F	Rooney's	
			700.3							
JT	6/5	12:55	"	190	42	3/4-	12	S	Rooney's	
JT	6/5	1:13	8567.1	210	35	1/2+	13	F	Biowest	
			710.2							
JT	6/5	1:25	"	200	38	1/2+	12	S	Biowest	
JT	6/5	1:42	8571.6	215	38	1/2+	12	F	FIT	
			714.7							
JT	6/8	2:38	8571.8	140	60	1/2+	13	S	FIT	
			714.9							
JT	6/8	2:53	8576.2	202	35	1/2+	12	F	Biowest	
			719.5							
JT	6/8	3:58	"	170	60	1/2+	13	S	Biowest	
JT	6/8	4:13	8580.8	202	35	1/2	12	F	FIT	
			723.9							
JT	6/10	9:14	"	100	70	1/2	13	S	FIT	
JT	6/10	9:29	8585.5	200	40	1/2-	13	F	Biowest	Engine? or fuel flow skips? low on fuel?
			728.6							
JT	6/10	9:48	"	185	45	1/2-	13	S	Biowest	
JT	6/10	10:00	8589.8	202	35	1/4	13	F	FIT	Less of above
			732.8							
JT	6/10	10:36	"	180	50	1/2-	13	S	FIT	
JT	6/10	10:53	8594.6	201	48	red line	12	F	Biowest	9.16 mpg Filled with MeOH 11.4 gallons
			737.7							All miles air conditioned
JT	6/10	2:35	"	130	70	F+	14	S	Biowest	
JT	6/10	2:50	8598.5	202	35	F+	12	F	FIT	Smooth ride
			742.9							

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/10	3:52	8598.5	172	55	F+	13	S	FIT	
			742.9							
JT	6/10	4:09	8603.0	215	35	F+	13	F	Biowest	
			746.0							
JT	6/10	4:33	"	195	40	F+	13	S	Biowest	
JT	6/10	4:54	8611.8	208	35	F+	12	F	Rooney's	
			754.9							
JT	6/12	10:37	8618.2	100	70	F+	14	S	FIT	to Babcock, to Malabar, to I-95, to Fiske, to I-95
			761.3							to Malabar, to Palm Bay Rd, to Rooney's
JT	6/12	11:45	8673.1	215	35	3/4-	13	F	Rooney's	
			816.0							
JT	6/12	12:30	"	190	45	3/4-	13	S	Rooney's	
JT	6/12	12:50	8682.0	210	35	1/2+	13	F	Biowest	
			826.1							
JT	6/12	1:03	"	200	38	1/2+	13	S	Biowest	
JT	6/12	1:22	8687.3	213	35	1/2+	12	F	FIT	
			830.4							
JT	6/12	2:03	"	190	42	1/2+	13	S	FIT	to Babcock, to Malabar, to I-95, to Fiske,
		3:10	8731.3			red mark		F	Dans Welding	to Wickham. Out of fuel at Dan's Welding.
			874.4							Filled with 5.0 gallons of MeOH and drove 1.4
JT	6/12	4:55	8732.7	170	60	F+	13	S	Biowest	miles to Biowest.
			875.8							Total till 11.89 gals 11.92 mpg!
JT	6/12	5:14	8737.4	208	35	F+	12	F	FIT	
			880.5							
JT	6/16	8:14	"	110	70	F+	14	S	FIT	
JT	6/16	8:27	8742.0	202	38	F+	13	F	Biowest	
			885.1							

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/16	9:08	8742.0	170	60	F+	14	S	Biowest	
			885.1							
JT	6/16	9:22	8747.0	208	38	F+	13	F	FIT	
			890.1							
JT	6/16	9:47	"	190	45	F+	13	S	FIT	
JT	6/16	10:00	8751.9	205	38	F+	13	F	Biowest	
			895.0							
JT	6/16	10:50	"	180	45	F+	13	S	Biowest	
JT	6/16	11:03	8756.1	210	38	F+	13	F	FIT	
			899.2							
JT	6/16	11:25	"	200	40	F+	13	S	FIT	Via 192 & CC Road
JT	6/16	11:39	8760.9	210	38	F-	13	F	Biowest	
			903.8							
JT	6/16	2:02	"	150	60	F+	13	S	Biowest	
JT	6/16	2:33	8771.1	211	33	F-	13	F	BTR	
			914.2							
JT	6/16	2:40	"	200	38	F-	12	S	BTR	
JT	6/16	3:05	8777.3	218	35	F	12	F	FIT	
			920.4							
JT	6/16	3:10	"	210	38	F-	12	S	FIT	
JT	6/16	2:24	8781.9	218	38	3/4+	12	F	Biowest	
			925.1							
JT	6/17	10:33	8782.1	110	70	3/4+	14	S	Biowest	
			925.3							
JT	6/17	10:45	8786.3	200	40	3/4-	13	F	FIT	
			929.4							
JT	6/17	11:43	"	170	60	3/4	13	S	FIT	

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/17	11:55	8790.4	215	38	3/4-	12	F	Rooney's	
			933.5							
JT	6/17	12:32	"	190	42	3/4-	13	S	Rooney's	
JT	6/17	12:53	8800.2	215	38	1/2+	13	F	FIT	
			943.3							
JT	6/17	1:03	"	210	38	1/2+	13	S	Biowest	
JT	6/17	1:20	8804.8	215	35	1/2+	12	F	FIT	
			947.9							
JT	6/17	1:38	"	202	39	1/2+	13	S	FIT	
JT	6/17	1:53	8810.4	215	38	1/2+	12	F	Biowest	
			953.2							
JT	6/17	2:15	"	202	39	1/2+	13	S	Biowest	
JT	6/17	2:28	8814.7	210	38	1/2+	13	F	FIT	
			957.4							
JT	6/17	3:51	"	170	60	1/2+	13	S	FIT	Starting to need filling
JT	6/17	4:08	8819.8	215	35	1/2-	12	F	Biowest	
			962.7							
JT	6/18	9:07	"	110	73	1/2-	14	S	Biowest	None bucking
JT	6/18	9:20	8823.9	202	40	1/2-	13	F	FIT	
			967.0							
JT	6/18	10:02	"	172	65	1/2-	13	S	FIT	
JT	6/18	10:18	8828.8		38	1/4		F	Biowest	Stalled 4 times. Filled with 10.68
			971.9							gallons = 9.0 mpg
JT	6/19	8:43	"	110	75	F+	15	S	Biowest	
JT	6/19	8:55	8833.2	205	40	F+	13	F	FIT	
			976.3							
JT	6/19	9:11	"	190	45	F+	14	S	FIT	

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/19	9:24	8839.2	208	38	F+	13	F	BTR lab	
			982.3							
JT	6/19	9:37	"	198	40	F+	13	S	BTR lab	
JT	6/19	9:54	8845.6	215	38	F+	12	F	FIT	
			988.7							
JT	6/19	11:25	"	170	60	F+	13	S	FIT	
JT	6/19	11:36	8849.6	215	38	F+	13	F	Rooney's	
			992.7							
JT	6/19	12:19	"	190	42	F+	13	S	Rooney's	
			8855.5							
JT	6/19	12:35	998.6	215	38	F+	12	F	BTR	
JT	6/19	12:38	"	212	38	F+	12	S	BTR	
JT	6/19	12:53	8861.7	218	38	F-	12	F	FIT	
			4.8							
JT	6/19	1:50	"	190	42	F-	12	S	FIT	
JT	6/19	2:04	8866.5	218	38	F-	12	F	Biowest	
			9.6							
JT	6/19	3:20	"	180	42	F-	13	S	Biowest	
JT	6/19	3:33	8870.7	210	30	F-	12	F	FIT	
			13.8							
JT	6/19	3:48	"	200	40	F-	12	S	FIT	
JT	6/19	4:05	8875.6	215	35	3/4+	12	F	Biowest	
			18.7							
JT	6/22	8:35	"	120	70	3/4+	15	S	Biowest	
JT	6/22	8:47	8879.9	200	40	3/4	13	F	FIT	Needed ether to start
			23.0							
JT	6/22	11:10	"	140	70	3/4	14	S	FIT	

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/22	11:34	8884.4	203	38	3/4	12	F	Biowest	
			27.5							
JT	6/22	1:48	"	150	60	3/4	13	S	Biowest	
JT	6/22	2:02	8888.6	210	38	3/4	12	F	FIT	
			31.7							
JT	6/22	2:38	"	188	50	3/4	13	S	FIT	
JT	6/22	2:53	8893.1	215	30	3/4-	12	F	Biowest	
			36.2							
JT	6/23	9:12	8893.2	110	70	3/4-	15	S	Biowest	
			36.3							
JT	6/23	9:38	8903.7	202	38	1/2+	13	F	BTR	
			46.8							
JT	6/23	9:57	"	193	40	1/2+	13	S	BTR	
JT	6/23	10:07	8907.6	210	38	1/2+	12	F	Barnett	
			50.7							
JT	6/23	10:13	"	205	38	1/2+	13	S	Barnett	
JT	6/23	10:21	8910.0	210	38	1/2	13	F	FIT	
			53.1							
JT	6/23	10:17	"	180	68	1/2+	13	S	FIT	
JT	6/23	11:30	8914.2	215	38	1/2	12	F	Biowest	Filled with 9.58 gallons =8.91 mpg
			57.3							
JT	6/23	3:00	"	150	60	F+	13	S	Biowest	
JT	6/23	3:12	8918.3	208	38	F+	12	F	Rialto	
			61.4							
JT	6/23	3:37	"	193	42	F+	13	S	Rialto	
			8922.6	218	38	F+	12	F	Biowest	
JT	6/23	3:52	65.7							

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/25	9:10	8922.7	100	70	F+	15	S	Biowest	
			65.8							
JT	6/25	9:20	8926.9	195	45	F+	13	F	FIT	
			70.0							
JT	6/25	10:58	"	150	70	F+	14	S	FIT	
JT	6/25	11:08	8930.1	200	40	F+	13	F	Travelmax	
			73.2							
JT	6/25	11:13	"	202	40	F+	13	S	Travelmax	
JT	6/25	11:21	8932.2	203	38	F+	12	F	Biowest	
			75.3							
JT	6/25	1:34	"	150	60	F+	13	S	Biowest	
			8936.5	204	40	F+	13	F	FIT	
JT	6/25	1:46	79.6							
JT	6/25	3:00	"	165	60	F+	13	S	FIT	
JT	6/25	3:14	8941.0	216	35	F+	12	F	Biowest	
			84.1							
JT	6/26	9:08	8941.1	100	70	F	14	S	Biowest	
			84.2							
JT	6/26	9:23	8945.6	40		F-		F	FIT	
			88.7							
JT	6/26	10:23	"	155	70	F-	14	S	FIT	
JT	6/26	10:36	8951.8	207	38	F-	13	F	BTR	
			94.9							
JT	6/26	10:53	"	198	40	F-	13	S	BTR	
JT	6/26	11:03	8955.7	210	38	F-	12	F	Barnett	
			98.7							
JT	6/26	11:09	"	203	38	F-	13	S	Barnett	

" means ditto for <u>both</u> mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/26	11:17	8958.1	213	38	F-	13	F	FIT	
			101.2							
JT	6/26	11:36	"	201	40	F-	13	S	FIT	
JT	6/26	11:48	8962.0	218	38	3/4+	12	F	Rooney's	
			105.1							
JT	6/26		"					S	Rooney's	
JT	6/26	1:19	8971.9	210	38	3/4	13	F	Biowest	
			115.0							
JT	6/26	1:32	"	201	38	3/4	13	S	Biowest	
JT	6/26	1:47	8973.7	210	38	3/4	12	F	Travelmax	
			118.8							
JT	6/26	1:52	"	208	38	3/4-	12	S	Travelmax	
			8979.1	203	38	3/4-	12	F	FIT	
JT	6/26	2:03	122.2							
JT	6/26	2:38	"	180	42	3/4-	13	S	FIT	
JT	6/26	2:51	8982.6	209	38	1/2+	12	F	Travelmax	
			125.7							
JT	6/26	3:04	"	199	39	1/2+	12	S	Travelmax	
JT	6/26	3:13	8984.8	212	38	1/2+	12	F	Biowest	
			127.9							
JT	6/29	9:00	8984.9	110	70	1/2+	14	S	Biowest	
			128.0							
JT	6/29	9:15	8989.5	208	38	1/2+	13	F	FIT	
			132.6							

" means ditto for both mileage 1 and mileage 2

Operator	1998 Date	Time	Mileage 1 Mileage 2	Temp (°F)	Oil (psi)	Fuel	Batt (V)	Start (S) Finish (F)	Place	Comments
JT	6/29	10:23	8989.5	170	50	1/2+	14	S	FIT	
			132.6							
JT	6/29	10:35	8993.2	210	38	1/2+	13	F	Travelmax	
			136.3							
JT	6/29	10:45	"	203	39	1/2+	13	S	Travelmax	
JT	6/29	10:53	8993.3	208	38	1/2+	12	F	Biowest	
			138.4							
JT	6/29	1:55	"	150	70	1/2+	14	S	Biowest	
JT	6/29	2:10	8999.6	208	38	1/2	12	F	FIT	
			142.7							
JT	6/29	2:53	"	170	50	1/2	13	S	FIT	
JT	6/29	3:14	9004.2	218	35	1/2-	12	F	Biowest	Filled with 9.97 gallon = 9.04 mpg
			147.5							
JT	6/30	9:13	9004.3	110	73	F+	15	S	Biowest	
			147.4							
JT	6/30	9:26	9008.3		40	F+		F	FIT	
JT	6/30	10:30	151.6	170	60	F+	14	S	FIT	
JT	6/30	10:45	9008.5	210	38	F+	12	F	FIT	
NO MORE TRIP RECORDS UNTIL NEXT FILL										
" means ditto for both mileage 1 and mileage 2										

APPENDIX C - 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.. 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.

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 x 10^6 Btu(HHV)/hr. output each (1626 x 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.

Syngas Conversion	Power Plant Size	Methanol Plant Size	Methanol to Power Ratio	Gasification Plant Size
0.0 %	500 MW	0 T/D	0 T/D per MW	Base
13.8%	426 MW	500 T/D	1.2 T/D per NW	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 x 10^6 Btu(HHV)/hr. gasifiers), the methanol to power coproduction ratio's could be:

Syngas Conversion	Power Plant Size	Methanol Plant Size	Methanol to Power Ratio	Gasification Plant Size
0.0 %	500 MW	0 T/D	0 T/D per MW	1.00 x Base
16.7 %	500 MW	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.

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.. Hydrogen Source for:

- Hydrogen fuel cells, being developed for transportation applications, can achieve 65% system efficiency, as compared to 45% for diesel IC engines and 32% for gasoline IC engines. Methanol is a storable, transportable liquid fuel which can be reformed under mild conditions to provide H2. For small H2 applications, *and at low utilization factors,* methanol reforming is a more economical source of hydrogen than : a) natural gas reforming, b) distillate (oil) reforming; and is cheaper than liquid H_2.

5.1.1. Fuel Cells for Transportation

5.1.2. Fuel Cells for Stationary Power

(See also dispersed power below).

5.1.3. Industrial Applications - Small Hydrogen Plants

Small pressurized methanol reformers for transportation applications may be suitable for adapting to meet the needs of small commercial hydrogen gas requirements.

5.2. Dispersed Power

- Dispersed power 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

AIR PRODUCTS

To: Distribution | Dept./Loc.:

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

Date: 31 March 1997

Subject: LPMEOH™ Process Economics - for IGCC Coproduction

<u>Distribution</u>:

<u>APCI</u>
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

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

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; <u>when</u> the syngas conversion is low (less than 34%), <u>and when</u> the feed gas pressure is high (greater the 750 psig), <u>and when</u> 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, **<u>the LP Technology makes coproduction viable</u>**.

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 D - DME DESIGN VERIFICATION TESTING

Air Products and Chemicals, Inc.
7201 Hamilton Boulevard
Allentown, PA 18195-1501

Telephone (610) 481-4911

AIR PRODUCTS

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,

Edward C. Heydorn
Program Manager
LPMEOH™ Demonstration Project

Enclosure

cc: Mr. William C. Jones - Eastman Chemical Co.
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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 <u>July of 1997</u>) to implement testing at LaPorte in <u>early 1998</u>. *(Final <u>dates</u> 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 <u>three reactions occur concurrently</u> 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:

- $2\ CO + 4\ H_2 = 2\ CH_3OH$ (Methanol Synthesis).
- $2\ CH_3OH = 1\ CH_3\text{-}O\text{-}CH_3 + 1\ H_2O$ (Methanol Dehydration).
- $1\ CO + 1\ H_2O = 1\ CO_2 + 1\ H_2$ (Water-gas Shift).

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

- $3\ CO + 3\ H_2 = 1\ CH_3\text{-}O\text{-}CH_3 + 1\ CO_2$ (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 carbon dioxide (CO_2) 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_2 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

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_2 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_2)-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_2 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 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_2-rich syngas, the LPDME process loses its (once-through, high conversion per pass) economic advantage. The overall reaction, with (> 2:1) H_2-rich syngas is:

- $2\ CO + 4\ H_2 = 1\ CH_3\text{-}O\text{-}CH_3 + 1\ H_2O$ (DME from H_2-rich syngas)

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_2-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_2, 51 mol% CO, 13 mol% CO_2) 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_2-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_2, 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_2-free)	DME = 75%, Methanol = 25% (heating value basis)	DME Selectivity = 79% (% Carbon, CO_2-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_2-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. 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/aeo97/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.

(end).

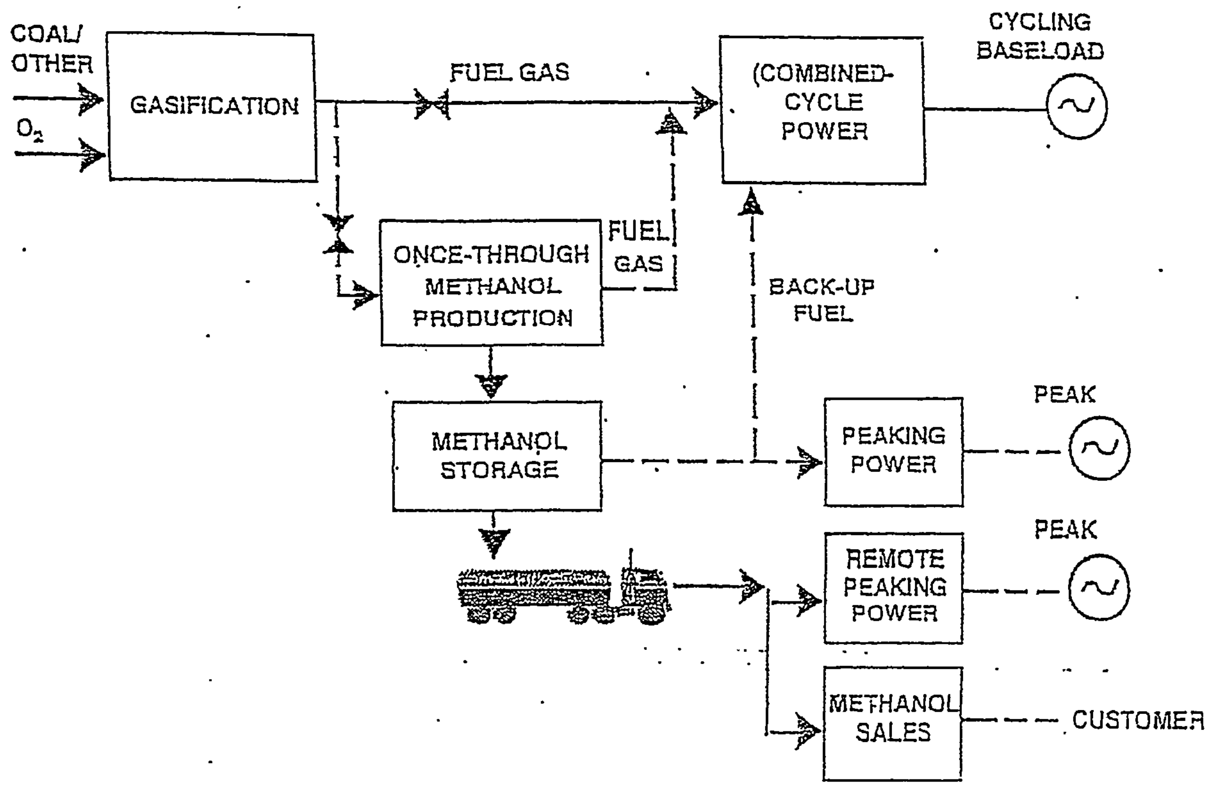
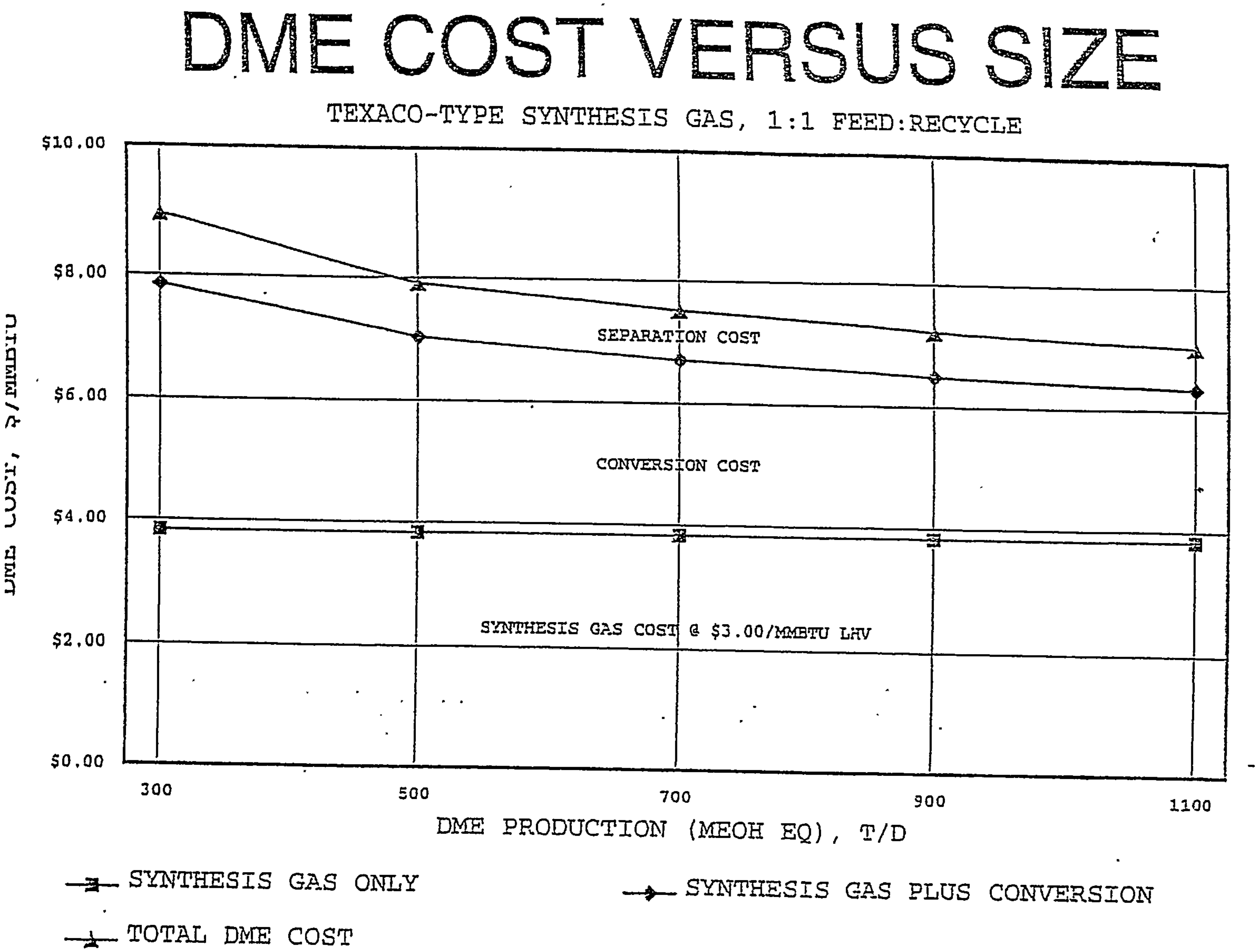


Figure 1. Once-through Methanol Coproduction with IGCC Electric Power

Figure 2



DME COST VERSUS SIZE
TEXACO-TYPE SYNTHESIS GAS, 1:1 FEED:RECYCLE
$10.00
$8.00
$6.00
$4.00
$2.00
$0.00
DME COST, $/MMBTU
SEPARATION COST
CONVERSION COST
SYNTHESIS GAS COST @ $3.00/MMBTU LHV
300
500
700
900
1100
DME PRODUCTION (MEOH EQ), T/D
SYNTHESIS GAS ONLY
SYNTHESIS GAS PLUS CONVERSION
TOTAL DME COST

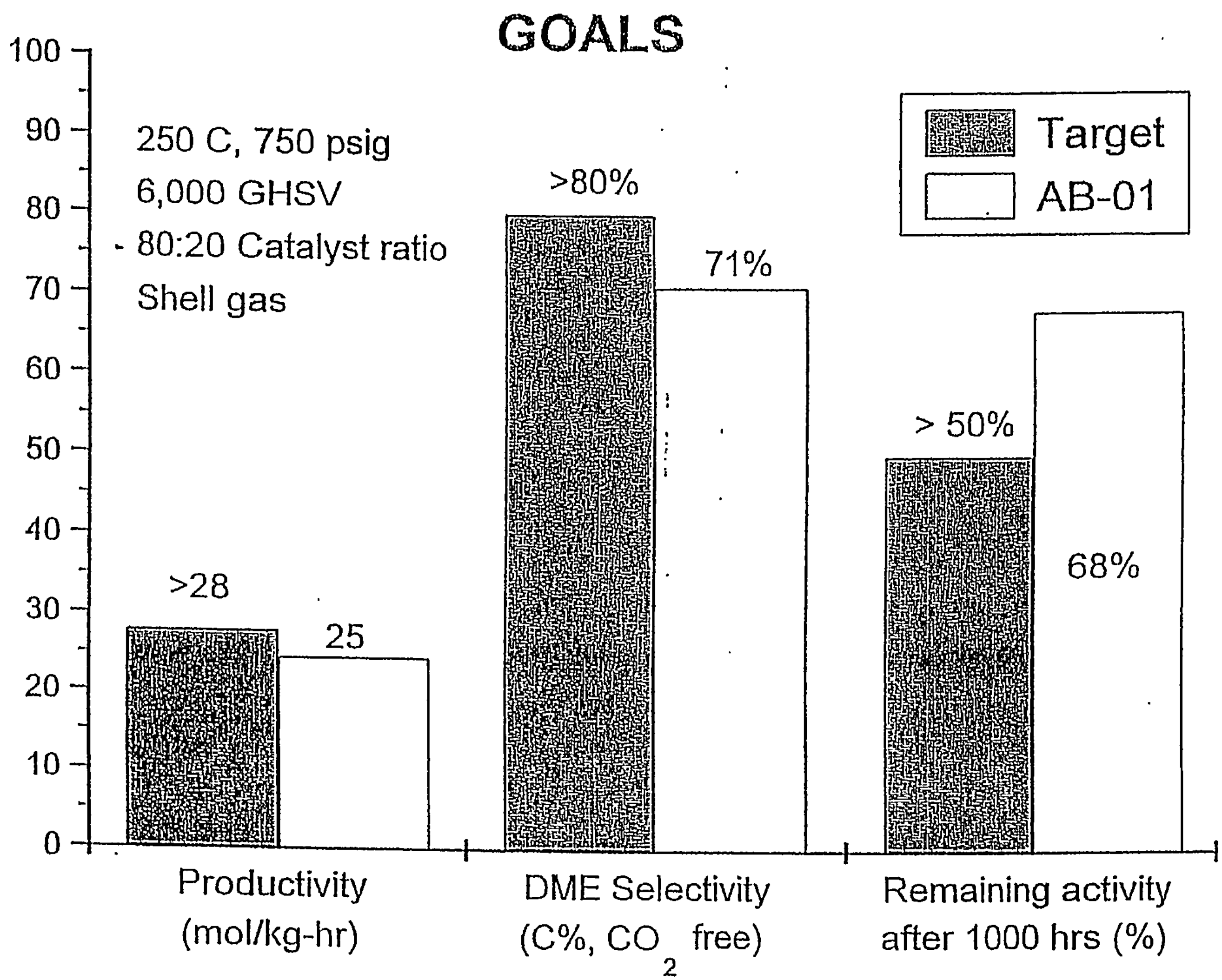
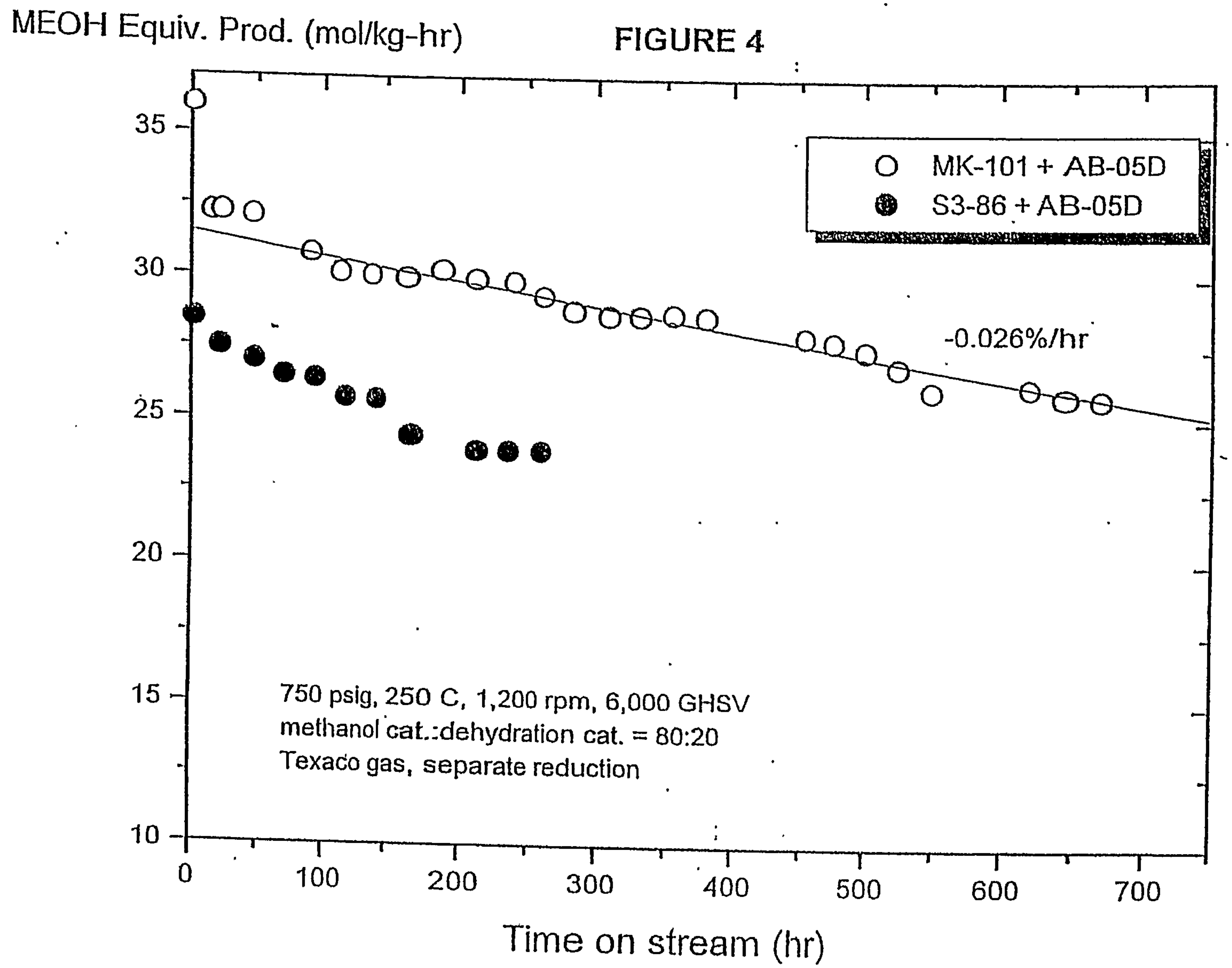

GOALS
100
90
80
70
60
50
40
30
20
10
0
250 C, 750 psig
6,000 GHSV
80:20 Catalyst ratio
Shell gas
Target
AB-01
>28
25
>80%
71%
> 50%
68%
Productivity (mol/kg-hr)
DME Selectivity (C%, CO2 free)
Remaining activity after 1000 hrs (%)

FIGURE 3

FIGURE 4



MEOH Equiv. Prod. (mol/kg-hr)
35
30
25
20
15
10
0
100
200
300
400
500
600
700
Time on stream (hr)
MK-101 + AB-05D
S3-86 + AB-05D
-0.026%/hr
750 psig, 250 C, 1,200 rpm, 6,000 GHSV
methanol cat.:dehydration cat. = 80:20
Texaco gas, separate reduction

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

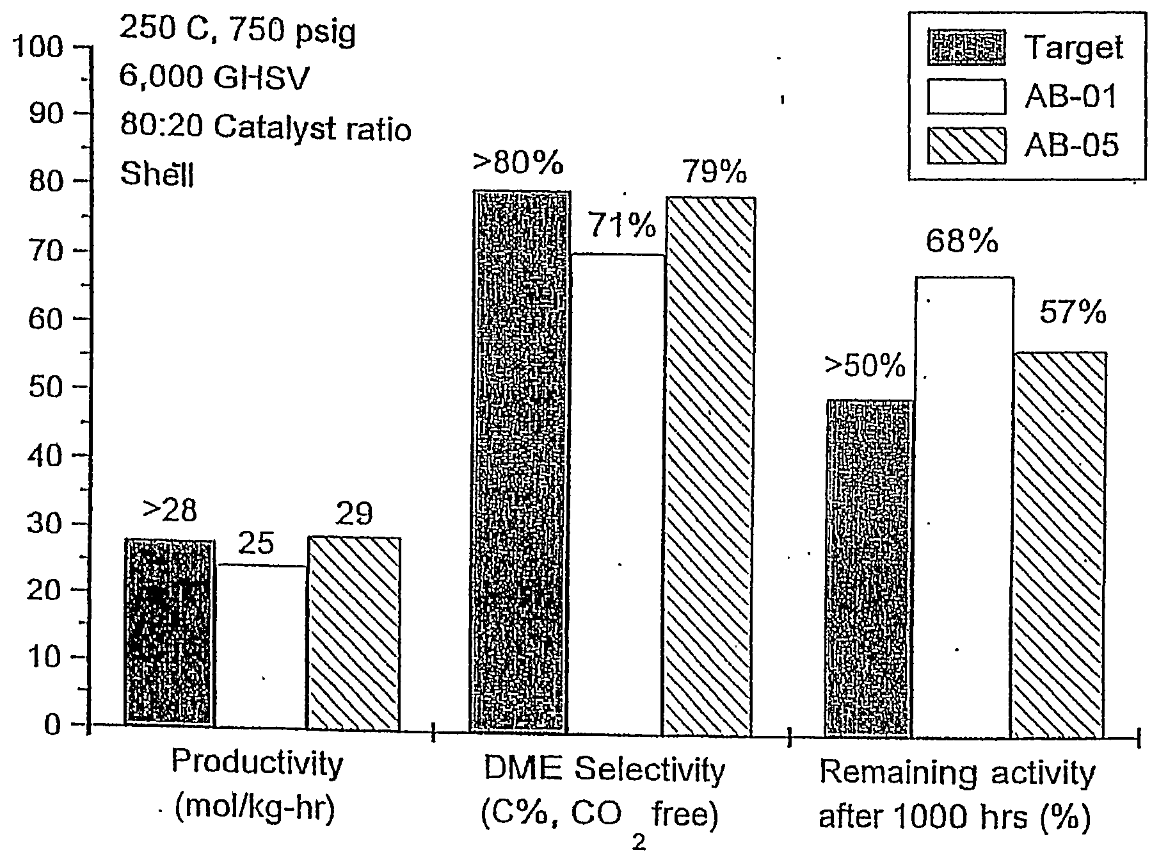


FIGURE 5

APPENDIX E - SAMPLES OF DETAILED MATERIAL BALANCE REPORTS

RUN NO: K6-04/04 **TITLE: Catalyst Addition and Aging**

Balance Period:		
Start Date	04apr98 07:00:00	
End Date	05apr98 07:00:00	
Reaction Conditions		
Temperature (°F)	426	
Pressure (psig)	710	
Space Velocity (sL/kg-hr)	5646	
Vg (inlet)	0.65	
Performance Results		
Raw MeOH Production (ton/day)	190.1	(gas measurements)
Raw MeOH Production (ton/day)	181.8	(liquid measurements)
Syngas Utilization (SCF/lb MeOH)	41.6	
Catalyst Life (eta)	0.60	
CO Conversion (total) (%)	28.4	
CO Conversion to MeOH (%)	30.2	
CO Conversion to H2 (%)	-1.90	
Syngas Conversion (% LHV)	78.5	
Syngas Usage (BTU/gallon MeOH)	67,345	
Recycle Ratio	3.60	
MeOH Productivity (gmol/kg-hr)	15.79	
Rxr Volumetric Productivity (ton/day-ft3)	0.098	
Sparger "K"-value	5.51	

Time From Start of Run (days)	
Start	105.3
End	106.3
Slurry Data	
Catalyst Weight (lb oxide)	30,050
Slurry Concentration (wt %)	40.8
Slurry Level (ft)	44.5
Gas Holdup (vol %)	42.1
Gassed Slurry Volume (ft3)	1865
Energy Balance	
Steam Production (lb/hr)	13025
Steam Drum Pressure (psig)	176
Steam Import/Export (lb/hr)	3490
Reactor O-T-M Conversion (% LHV)	17.9
Wetted Tube Length (ft)	40.7
Heat Transfer Area (ft2)	1579
Reactor Overall U (BTU/hr-ft2-F)	149
Atom/Mass Balance Closure (% of reactor Inlet)	
C	99.92
H	101.48
O	99.44
N	100.25
Total Mass	100.02

Liquid Product Analysis (wt%)	REFINED PRODUCT 4/4 19:00	REFINED PRODUCT 4/5 7:00	CRUDE PRODUCT 4/4 19:00	CRUDE PRODUCT 4/5 7:00
Methanol	99.98	99.99	87.59	87.76
Ethanol	0.01	0.01	0.09	0.09
Water	0.02	0.00	12.39	12.24
Oil	0.00	0.00	0.06	0.06
Total	100.01	100.00	100.13	100.15

RUN NO: K6-04/04 TITLE: Catalyst Addition and Aging

		FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
T	F	76	49	49	269	269	239	85	63	221	75
P	psig	755	863	688	736	729	701	689	7	185	142
Comp	H2	67.31	1.93	77.66	71.59	70.37	65.55	71.59	8.00	0.00	0.00
(mol %)	CO	29.09	97.05	9.12	18.53	20.74	16.96	18.53	7.00	0.00	0.00
	N2	0.43	0.97	6.50	3.33	2.68	3.06	3.33	2.00	0.00	0.00
	CH4	0.08	0.05	0.92	0.60	0.48	0.55	0.60	0.00	0.00	0.00
	CO2	3.09	0.00	3.76	5.23	4.99	5.25	5.23	62.00	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	0.21	0.45	7.67	0.21	10.00	79.96	99.98
	EtOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
	H2O	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	19.98	0.02
	others	0.00	0.00	1.97	0.51	0.28	0.49	0.51	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	11.000	27.501	7.770	10.187	10.485	11.962	10.187	39.217	29.265	32.039
LHV	MMBTU/hr	175.2	0.0	0.0	594.8	766.4	748.7	20.8	0.7	36.9	100.6
Enthalpy	MMBTU/hr	-31.69	0.00	0.00	-99.93	-132.51	-153.69	-3.78	-1.35	-16.47	-35.63
Flow	SCFH	630,109	0	0	2,266,909	2,871,813	2,515,414	79,431	3,944	60,178	131,329
	lbmol/hr	1,661.0	0.0	0.0	5,975.8	7,570.4	6,630.9	209.4	10.4	158.6	346.2
	lb/hr	18,271	0	0	60,876	79,374	79,322	2,133	408	4,642	11,092

RUN NO: K6-05/13 **TITLE: Catalyst Addition and Aging**

Balance Period:

Start Date	13may98 07:00:00	
End Date	14may98 07:00:00	

Reaction Conditions

Temperature (°F)	453	
Pressure (psig)	710	
Space Velocity (sL/kg-hr)	5537	
Vg (inlet)	0.65	

Performance Results

Raw MeOH Production (ton/day)	228.1	(gas measurements)
Raw MeOH Production (ton/day)	216.8	(liquid measurements)
Syngas Utilization (SCF/lb MeOH)	40.5	
Catalyst Life (eta)	0.64	
CO Conversion (total) (%)	45.9	
CO Conversion to MeOH (%)	48.9	
CO Conversion to H2 (%)	-3.09	
Syngas Conversion (% LHV)	80.3	
Syngas Usage (BTU/gallon MeOH)	68,498	
Recycle Ratio	2.86	
MeOH Productivity (gmol/kg-hr)	18.83	
Rxr Volumetric Productivity (ton/day-ft3)	0.102	
Sparger "K"-value	5.24	

Time From Start of Run (days)

Start	144.3
End	145.3

Slurry Data

Catalyst Weight (lb oxide)	30,050
Slurry Concentration (wt %)	37.1
Slurry Level (ft)	50.5
Gas Holdup (vol %)	40.2
Gassed Slurry Volume (ft3)	2121

Energy Balance

Steam Production (lb/hr)	17233
Steam Drum Pressure (psig)	216
Steam Import/Export (lb/hr)	5836
Reactor O-T-M Conversion (% LHV)	22.3
Wetted Tube Length (ft)	46.7
Heat Transfer Area (ft2)	1812
Reactor Overall U (BTU/hr-ft2-F)	148

Atom/Mass Balance Closure (% of reactor inlet)

C	100.78
H	99.12
O	100.89
N	99.07
Total Mass	100.92

Liquid Product Analysis (wt%)	REFINED PRODUCT 5/13 19:00	REFINED PRODUCT 5/14 7:00	CRUDE PRODUCT 5/13 19:00	CRUDE PRODUCT 5/14 7:00
Methanol	99.99	99.99	87.47	87.90
Ethanol	0.01	0.01	0.09	0.09
Water	0.01	0.01	12.41	11.98
Oil	0.00	0.00	0.06	0.06
Total	100.01	100.01	100.03	100.03

RUN NO: K6-05/13 TITLE: Catalyst Addition and Aging

		FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
T	F	108	74	77	269	304	239	92	73	222	82
P	psig	751	881	691	737	729	702	692	6	185	137
Comp	H2	68.40	1.93	77.66	76.30	73.83	68.62	76.30	8.00	0.00	0.00
(mol %)	CO	28.43	97.05	9.12	11.26	15.60	9.98	11.26	7.00	0.00	0.00
	N2	0.49	0.97	6.50	5.20	4.01	4.74	5.20	2.00	0.00	0.00
	CH4	0.04	0.05	0.92	0.54	0.41	0.49	0.54	0.00	0.00	0.00
	CO2	2.63	0.00	3.76	4.85	4.23	4.43	4.85	62.00	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	0.47	0.75	9.89	0.47	10.00	80.12	99.97
	EtOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
	H2O	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	19.82	0.02
	others	0.00	0.00	1.97	1.37	1.17	1.26	1.37	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	10.650	27.501	7.770	8.939	9.503	11.041	8.939	39.217	29.287	32.038
LHV	MMBTU/hr	204.1	0.0	0.0	531.3	736.6	715.4	17.0	0.7	44.3	119.7
Enthalpy	MMBTU/hr	-34.28	0.00	0.00	-71.49	-103.01	-129.68	-2.52	-1.36	-19.72	-42.33
Flow	SCFH	732,633	0	0	2,096,169	2,816,198	2,383,124	67,232	3,988	72,104	156,227
	lbmol/hr	1,931.3	0.0	0.0	5,525.8	7,423.8	6,282.2	177.2	10.5	190.1	411.8
	lb/hr	20,568	0	0	49,393	70,548	69,359	1,584	412	5,567	13,194

RUN NO: K6-06/24

TITLE: Catalyst Addition and Aging

Balance Period:		
Start Date	24jun98 07:00:00	
End Date	25jun98 07:00:00	
Reaction Conditions		
Temperature (°F)	454	
Pressure (psig)	709	
Space Velocity (sL/kg-hr)	4942	
Vg (inlet)	0.64	
Performance Results		
Raw MeOH Production (ton/day)	220.8	(gas measurements)
Raw MeOH Production (ton/day)	213.6	(liquid measurements)
Syngas Utilization (SCF/lb MeOH)	40.5	
Catalyst Life (eta)	0.54	
CO Conversion (total) (%)	42.8	
CO Conversion to MeOH (%)	45.7	
CO Conversion to H2 (%)	-2.99	
Syngas Conversion (% LHV)	80.5	
Syngas Usage (BTU/gallon MeOH)	68,390	
Recycle Ratio	2.82	
MeOH Productivity (gmol/kg-hr)	17.04	
Rxr Volumetric Productivity (ton/day-ft3)	0.101	
Sparger "K"-value	5.28	

Time From Start of Run (days)	
Start	186.3
End	187.3
Slurry Data	
Catalyst Weight (lb oxide)	32,700
Slurry Concentration (wt %)	39.4
Slurry Level (ft)	50.5
Gas Holdup (vol %)	40.7
Gassed Slurry Volume (ft3)	2121
Energy Balance	
Steam Production (lb/hr)	17452
Steam Drum Pressure (psig)	206
Steam Import/Export (lb/hr)	6726
Reactor O-T-M Conversion (% LHV)	22.5
Wetted Tube Length (ft)	46.7
Heat Transfer Area (ft2)	1812
Reactor Overall U (BTU/hr-ft2-F)	137
Atom/Mass Balance Closure (% of reactor inlet)	
C	100.07
H	99.56
O	99.87
N	102.53
Total Mass	100.10

Liquid Product Analysis (wt%)

	REFINED PRODUCT		CRUDE PRODUCT	
	6/24 19:00	6/25 7:00	6/24 19:00	6/25 7:00
Methanol	99.99	99.99	87.80	86.83
Ethanol	0.01	0.01	0.09	0.09
Water	0.01	0.01	12.09	12.91
Oil	0.00	0.00	0.06	0.16
Total	100.01	100.01	100.04	99.99

RUN NO: K6-06/24 TITLE: Catalyst Addition and Aging

		FRESH FEED	CO MAKEUP	H2 MAKEUP	K-01 OUTLET	REACTOR FEED	C-05 OUTLET	MAIN PURGE	DISTILL. PURGE	CRUDE PRODUCT	REFINED PRODUCT
T	F	102	76	78	269	309	239	96	74	222	84
P	psig	744	866	544	737	729	701	691	6	185	137
Comp	H2	67.96	1.93	77.66	74.57	72.56	66.94	74.57	8.00	0.00	0.00
(mol %)	CO	28.65	97.05	9.12	12.74	16.92	11.46	12.74	7.00	0.00	0.00
	N2	0.42	0.97	6.50	4.65	3.56	4.22	4.65	2.00	0.00	0.00
	CH4	0.05	0.05	0.92	0.70	0.53	0.63	0.70	0.00	0.00	0.00
	CO2	2.92	0.00	3.76	6.04	5.16	5.50	6.04	62.00	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	0.50	0.63	9.89	0.50	10.00	79.65	99.98
	EtOH	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06	0.01
	H2O	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	20.28	0.02
	others	0.00	0.00	1.97	0.80	0.63	0.73	0.80	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	10.808	27.501	7.770	9.546	9.950	11.682	9.546	39.217	29.238	32.038
LHV	MMBTU/hr	200.5	0.0	0.0	518.1	718.1	697.2	16.5	0.7	43.9	117.6
Enthalpy	MMBTU/hr	-34.94	0.00	0.00	-83.81	-114.67	-141.10	-2.89	-1.40	-19.69	-41.57
Flow	SCFH	720,770	0	0	2,030,584	2,735,544	2,311,517	64,756	4,101	71,909	153,459
	lbmol/hr	1,900.0	0.0	0.0	5,352.9	7,211.2	6,093.4	170.7	10.8	189.6	404.5
	lb/hr	20,536	0	0	51,101	71,753	71,183	1,630	424	5,542	12,961

APPENDIX F - RESULTS OF DEMONSTRATION PLANT OPERATION

Table 1 - Summary of LPMEOH^{TM} Demonstration Plant Outages - April/June 1998

Operation Start	Operation End	Operating Hours	Shutdown Hours	Reason for Shutdown
4/1/98 00:01	4/21/98 01:40	480.6	0.5	ESD on Bad Reactor TT
4/21/98 02:10	4/22/98 20:10	42.0	0.8	ESD on Bad Reactor TT
4/22/98 21:00	4/27/98 12:42	111.7	10.2	Tubing Leak on K-01
4/27/98 22:52	5/18/98 19:50	501.0	9.0	Fitting Leak on K-01
5/19/98 04:50	5/19/98 04:50	0.0	154.8	Syngas Outage
5/25/98 15:40	6/9/98 19:40	364.0	43.4	Syngas Outage
6/11/98 15:05	6/11/98 21:35	6.5	15.5	Syngas Outage
6/12/98 13:05	6/12/98 13:55	0.8	66.3	Syngas Outage
6/15/98 08:10	6/30/98 23:59	375.8		End of Reporting Period

Total Operating Hours	1882.5
Syngas Available Hours	1903.0
Plant Availability, %	98.92

Table 2 - Summary of Catalyst Analyses - Second Catalyst Batch

Sample	Identity	XRD		BET	Analytical (ppmw)				
		Cu	ZnO	m2/g	Fe	Ni	S	As	Cl
K9804-1	Reduction Sample 4/2/98 - Alternative Catalyst	72.5	84.9	105	23	11	<=110	<=12	
K9712-1	Transfer sample from 29D-02 to Reactor	95.3	74		362	47.2	66.7	10.2	nd
K9712-2	Reactor Sample Day 1	100	123.8	75	92.1	<=18	<=167	<50	nd
K9712-3	Reactor Sample Day 4	130.9	64						
K9712-4	Reactor Sample Day 10	126.8	73.3	73	126	<=22	<=127	<50	nd
K9801-2	Reactor Sample 1/26/98	132.05	98.3		63.5	39.5	42.7	29.2	<100
K9802-1	Reactor Sample 2/3/98	141.1	91.5						
K9802-2	Reactor Sample 2/9/98	158.1	113						
K9802-3	Reactor Sample 2/15/98	145.7	91		67.1	36	<=97	209	
K9802-4	Reactor Sample 2/23/98	176.8	114.5						
K9803-2	Reactor Sample 3/10/1998	154.3	95.8	44	61.4	35.8	<=94	408	
K9803-4	Reactor Sample 3/29/98	169.6	87.9						
K9804-2	Reactor Sample 4/14/98	152.4	89.3		81.7	30.8	<=170	615	
K9805-2	Reactor Sample 5/11/98	219.2	109.6		73.15	35.85	163	538	

Notes:

1) nd = none detected

Figure 1

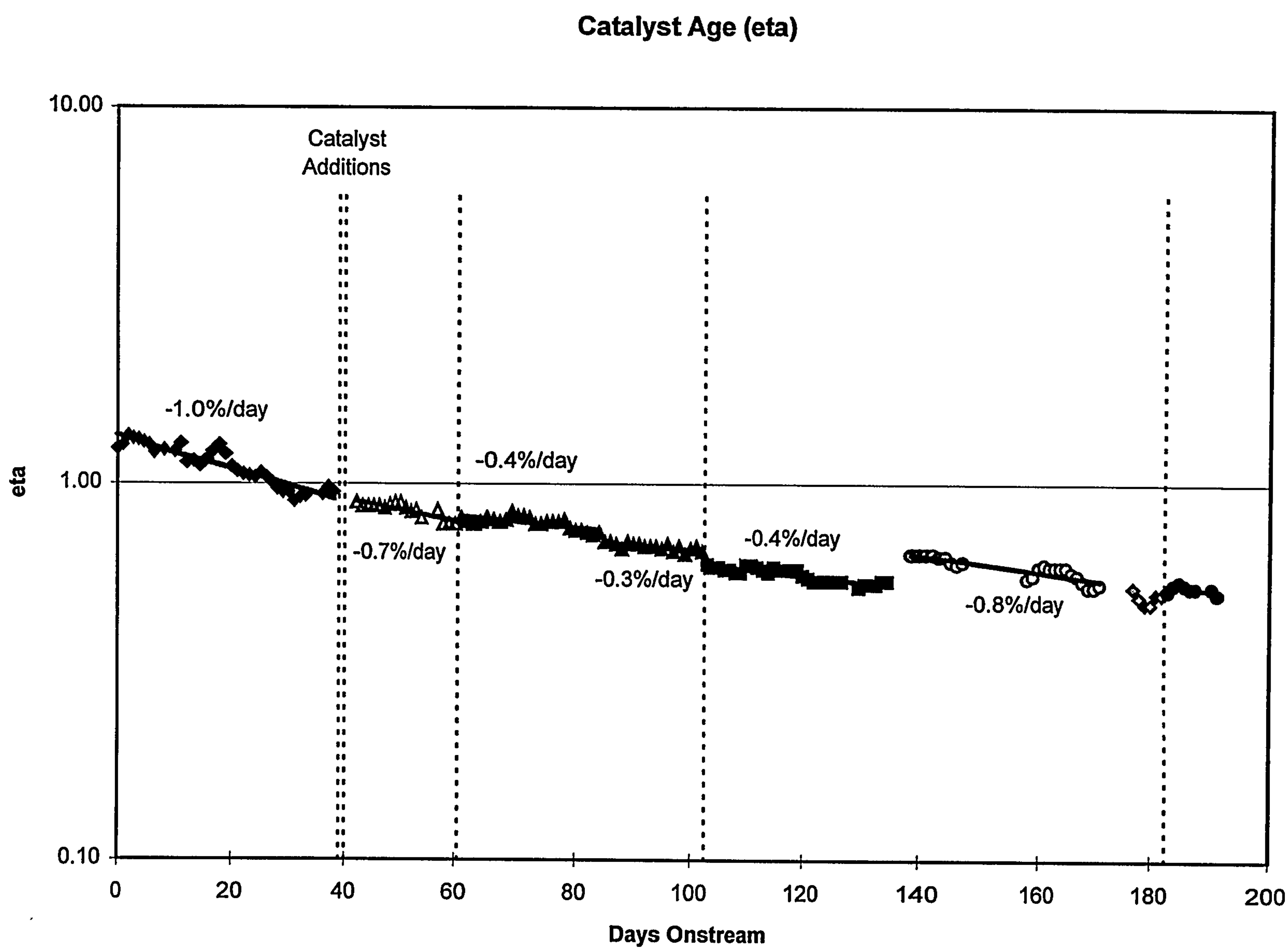
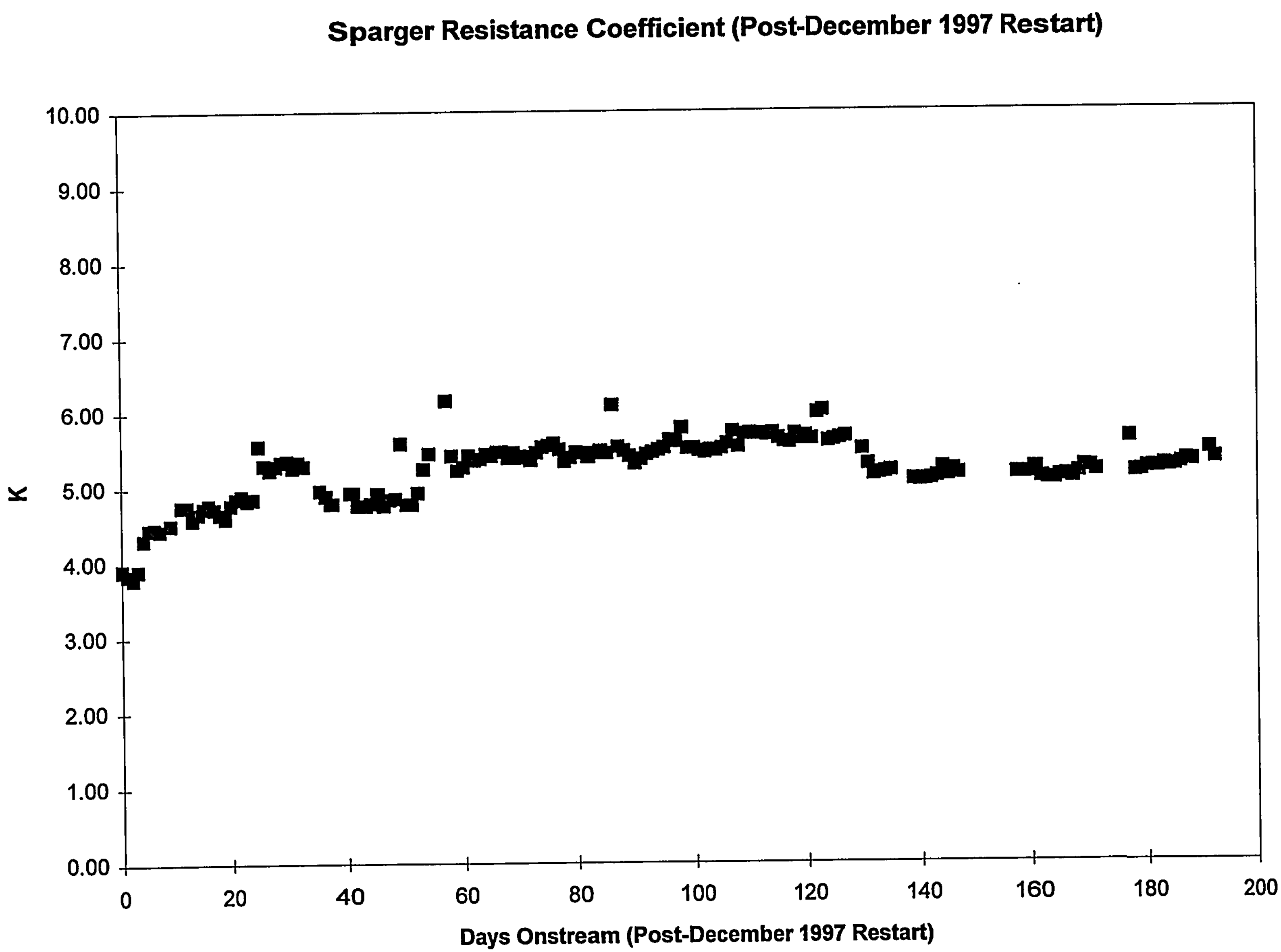

Catalyst Age (eta)
10.00
1.00
0.10
eta
Catalyst
Additions
-1.0%/day
-0.4%/day
-0.7%/day
-0.3%/day
-0.4%/day
-0.8%/day
0
20
40
60
80
100
120
140
160
180
200
Days Onstream

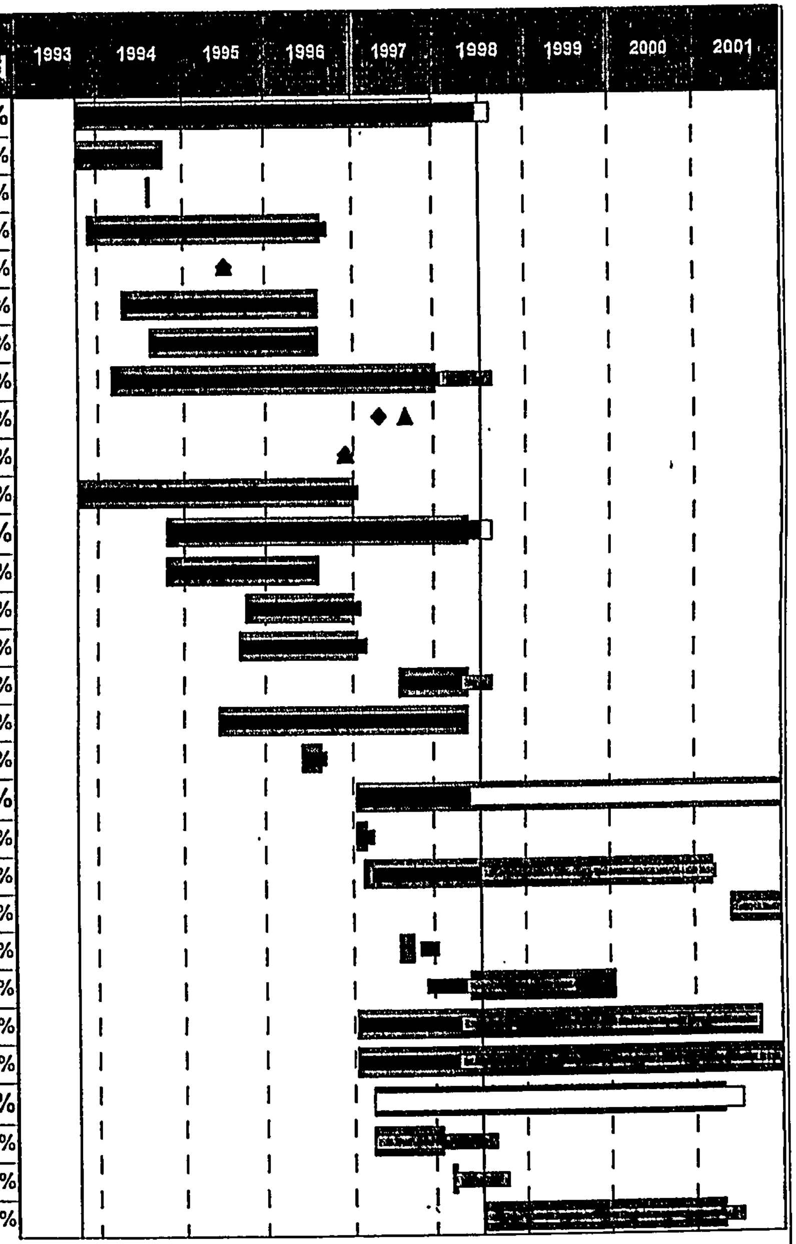
Figure 2


Sparger Resistance Coefficient (Post-December 1997 Restart)
K
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
0
20
40
60
80
100
120
140
160
180
200
Days Onstream (Post-December 1997 Restart)

APPENDIX G - MILESTONE SCHEDULE STATUS AND COST MANAGEMENT REPORTS

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

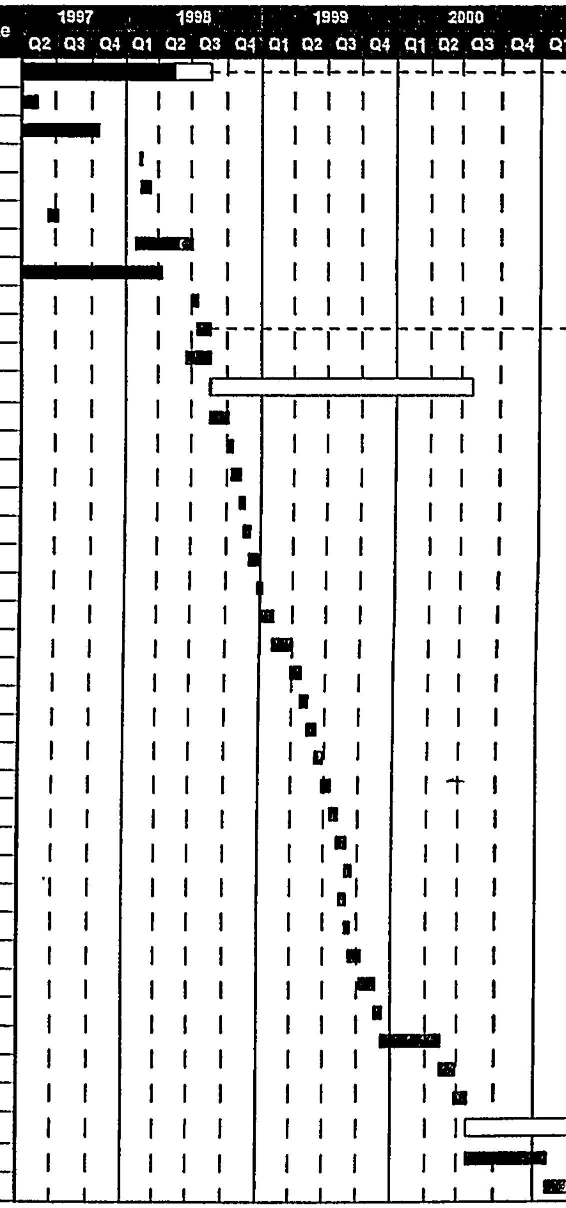
Task Name	Duration In Months	Start Date	End Date	% Com	% Sched
PHASE 1: DESIGN	**56.28mon**	**10/1/93**	**7/31/98**	**98**	**97%**
PROJECT DEFINITION (TASK1)	16.78mon	10/1/93	9/30/94	100	100%
CONTINUATION APPLICATION (B.P.#2)	0.41mon	8/2/94	8/10/94	100	100%
PERMITTING (TASK 2)	47.31mon	11/17/93	9/10/96	100	100%
NEPA FONSI APPROVAL		6/30/95	6/30/95	100	100%
DESIGN ENGINEERING (TASK 3)	38.62mon	4/15/94	8/1/96	100	100%
VENDOR ENGINEERING	33.15mon	8/10/94	7/30/96	100	100%
OFF-SITE TESTING (TASK 4)	51.63mon	2/25/94	7/31/98	88	88%
UPDATED FUEL TEST PLAN APPROVAL		8/29/97	8/29/97	100	100%
DECISION TO CONTINUE DME TESTING		12/4/96	12/4/96	100	100%
PLANNING, ADMIN & DME DVT (TASK 5)	55.54mon	10/1/93	1/20/97	100	100%
PHASE 2: CONSTRUCTION	**44.14mon**	**10/17/94**	**7/31/98**	**97**	**97%**
PROCUREMENT (TASK1)	30.02mon	10/17/94	7/30/96	100	100%
CONSTRUCTION (TASK 2)	22.44mon	10/2/95	1/31/97	100	100%
TRAINING & COMMISSIONING (TASK 3)	24.92mon	9/5/95	2/27/97	100	100%
OFF-SITE TESTING (TASK 4)	11.63mon	8/1/97	7/31/98	52	70%
PLANNING & ADMINISTRATION (TASK 5)	34.02mon	6/1/95	5/1/98	100	100%
CONTINUATION APPLICATION (B.P.#3)	4.46mon	5/31/96	9/4/96	100	100%
PHASE 3: OPERATION	**57.66mon**	**1/20/97**	**12/28/01**	**18**	**27%**
START-UP (TASK 1)	3.22mon	1/23/97	4/2/97	100	100%
METHANOL OPERATION (TASK 2.1)	46.48mon	4/2/97	3/28/01	31	31%
DISMANTLE PLANT (TASK 2.3)	6.76mon	6/1/01	12/28/01	0	0%
ON-SITE PRODUCT USE DEMO (TASK 3)	2.02mon	11/3/97	1/7/98	100	100%
OFF-SITE PRODUCT USE DEMO (TASK 4)	19.26mon	12/1/97	7/27/99	24	24%
DATA ANALYSIS/REPORTS (TASK 5)	54.53mon	1/20/97	9/21/01	26	26%
PLANNING & ADMINISTRATIVE (TASK 6)	57.66mon	1/20/97	12/28/01	24	24%
PROVISIONAL DME IMPLEMENTATION	**49.70mon**	**4/1/97**	**7/5/01**	**0**	**0%**
DME DVT (PDU TESTS) (TASK 3.6)	16.05mon	4/1/97	8/14/98	0	0%
DECISION TO IMPLEMENT	6.94mon	3/1/98	10/1/98	0	0%
DESIGN, MODIFY & OPERATE (TASK 3.2.2)	35.13mon	7/1/98	7/5/01	0	0%



Printed: 6/22/98

LIQUID PHASE METHANOL DEMONSTRATION - PHASE III

Task Name	Start Date	Duration in Weeks	End Date	Percent Complete
Task 2.1.1 - Process Shakedown and Catalyst Aging	**4/2/97**	**72.14w**	**8/20/98**	**81%**
Test 1 - Initial Shakedown; and Design Production Tests	4/2/97	5.43w	5/10/97	100%
Test 2 - Gassed Slurry Level	4/2/97	28.29w	10/17/97	100%
Test 3 - Reactor Feed: Texaco-Type Syngas	2/8/98	0.71w	2/13/98	100%
Test 4 - Early Testing @ High Superficial Velocity	2/13/98	3.00w	3/6/98	0%
Test 5 - Check @ Test 1 Conditions	6/10/97	3.43w	7/4/97	100%
Test 6 - Catalyst Addition and Aging	1/27/98	22.14w	7/1/98	78%
Test 7 - Free-Drain Entrained/ Condensed Oil to Reactor	4/2/97	53.00w	4/8/98	100%
Test 8 - Operation @ Design Feed Gas Rates	7/1/98	2.00w	7/15/98	0%
Test 9 - Check for Limitation on Catalyst Slurry Concentration	7/15/98	5.14w	8/20/98	0%
Test 10 - Catalyst Addition to Reach Max Productivity	6/13/98	9.71w	8/20/98	0%
Task 2.1.2 - Process Operational Test Phase	**8/20/98**	**100.86w**	**7/26/00**	**1%**
Test 11 - Catalyst Addition/ Withdrawal Test	8/20/98	6.00w	10/1/98	0%
Test 12 - Test 11 Conditions with No CO Make-up	10/1/98	2.00w	10/15/98	0%
Test 13 - Test 11 Conditions with No H2 Make-up	10/15/98	3.00w	11/5/98	0%
Test 14 - Test 11 Conditions with No H2 or CO Make-up	11/5/98	2.00w	11/19/98	0%
Test 15 - Repeat of Test 11 Conditions	11/19/98	2.00w	12/3/98	0%
Test 16 - Design Fresh Feed Operation Test	12/3/98	3.00w	12/24/98	0%
Test 17 - Testing @ High Superficial Velocity	12/24/98	2.00w	1/7/99	0%
Test 18 - Turndown and Ramping	1/7/99	4.00w	2/4/99	0%
Test 19 - Load-Following, Cyclone, & On/Off Tests	2/4/99	7.00w	3/25/99	0%
Test 20 - Reactor Feed: Texaco-Type Syngas	3/25/99	4.00w	4/22/99	0%
Test 21 - Reactor Feed: Destec-Type Syngas	4/22/99	3.00w	5/13/99	0%
Test 22 - Reactor Feed: BGL-Type Syngas	5/13/99	3.00w	6/3/99	10%
Test 23 - Repeat of Test 15 Conditions	6/3/99	3.00w	6/24/99	0%
Test 24 - Reactor Feed: Nat. Gas Reformer-Type Syngas	6/24/99	3.00w	7/15/99	0%
Test 25 - Reactor Feed: Shell-Type Syngas with Steam Injection and 1:1 Recycle	7/15/99	3.00w	8/5/99	0%
Test 26 - Repeat of Test 15 Conditions	8/5/99	3.00w	8/26/99	0%
Test 27 - Repeat of Test 16 Conditions	8/26/99	2.00w	9/9/99	0%
Test 28 - Reactor Operation @ 260 deg C	8/11/99	2.00w	8/25/99	25%
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 Shakedown	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	5/10/00	0%
Test 34 - Catalyst Addition/ Withdrawal to Achieve Target Slurry Concentration	5/10/00	6.00w	6/21/00	0%
Test 35 - Reactor Feed: Texaco-Type Syngas	6/21/00	5.00w	7/26/00	0%
Task 2.1.3 - Extended Optimum Operation	**7/26/00**	**35.00w**	**3/28/01**	**0%**
Test 36 - Stable Operation	7/26/00	27.00w	1/31/01	0%
Test 37 - Commercial Test Run	1/31/01	8.00w	3/28/01	0%



DOE F 1332.9
(11-84)

U.S. DEPARTMENT OF ENERGY
COST MANAGEMENT REPORT

FORM APPROVED
OMB 1910-1400

1. TITLE Liquid Phase Methanol Demonstration	2. REPORTING PERIOD June 01, 1998 through June 30, 1998	3. IDENTIFICATION NUMBER DE-FC22-92PC90543
2. PARTICIPANT NAME AND ADDRESS Air Products Liquid Phase Conversion Co., L.P. 7201 Hamilton Boulevard Allentown, PA 18195-4911	5. COST PLAN DATE October 29, 1997	6. START DATE January 1, 1990 7. COMPLETION DATE December 31, 2001

8. ELEMENT	9. REPORTING ELEMENT	10. ACCRUED COSTS Reporting Period a. Actual	b. Plan	Cumulative to Date c. Actual	d. Plan	11. ESTIMATED ACCRUED COSTS a. Subsequent Reporting Period	b. Balance of Fiscal Year	c. FY 1999 (1)	FY 2000 (2)	FY 2001 (3)	d. Subsequent FY's (4)	e. Total	12. Total Plan Value	13. Variance
	Prior to Mod 3	0	0	16,282	16,304	0	0					16,282	16,304	(22)
1.1.1	Project Definition	0	0	1,011	1,011	0	0	0	0	0	0	1,011	1,011	(0)
1.1.2	Permitting	0	0	248	248	0	0	0	0	0	0	248	248	0
1.1.3	Design Engr.	0	0	10,852	10,895	0	0	0	0	0	0	10,852	10,895	(43)
1.1.4	Off-site Testing	27	54	333	703	54	477	0	0	0	0	864	864	0
1.1.5	Planning, Admin, & DME Verif. Testing	0	2	2,988	3,024	2	27	0	0	0	0	3,017	3,030	(13)
1.2.1	Procurement	0	0	10,122	10,226	0	0	0	0	0	0	10,122	10,226	(104)
1.2.2	Construction	0	0	11,630	11,728	0	0	0	0	0	0	11,630	11,728	(98)
1.2.3	Train. & Commissioning	0	0	583	864	0	279	0	0	0	0	862	864	(2)
1.2.4	Off-Site Test - Proc. & Constr.	34	66	152	597	66	577	0	0	0	0	795	795	(0)
1.2.5	Planning & Admin	0	2	945	972	2	22	0	0	0	0	969	978	(9)
1.3.1	Startup	0	0	1,513	1,497	0	0	0	0	0	0	1,513	1,497	16
1.3.2	Operations													0
1.3.2.1	Methanol Operation	2,104	2,374	33,725	35,497	2,374	6,521	34,635	36,137	33,487	0	147,135	146,862	273
1.3.2.2	DME Design, Mod., Oper.	0	0	0	0	0	0	560	1,207	0	0	1,767	1,767	0
1.3.2.3	LPMEOH Dismantlement	0	0	0	0	0	0	0	0	472	0	472	472	0
1.3.3	On-Site Product Use Demo	0	0	0	0	0	0	0	5	0	0	5	5	0
1.3.4	Off-Site Product Use Demo	49	2	53	18	2	18	24	1,546	45	0	1,688	1,688	0
1.3.5	Data Analysis & Reports	20	3	193	96	4	9	27	49	14	0	296	296	0
1.3.6	Planning & Admin.	43	81	1,025	1,190	81	327	1,149	652	936	0	4,170	4,170	(0)
14. TOTAL		2,277	2,584	91,655	94,870	2,585	8,257	36,395	39,596	34,954	0	213,700	213,700	0

15. DOLLARS EXPRESSED IN: Thousands

16. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE
[signature] E. C. Heydorn — 13 July 98 (DATE)

17. SIGNATURE OF PARTICIPANT'S AUTHORIZED FINANCIAL REPRESENTATIVE AND DATE
Susan J. Kasinecz [signature] S. J. Kasinecz — 7/13/98 (DATE)