Appendix B-6

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

to

Mr. Robert Senn
consultant to

Air Products and Chemicals, Inc.

from

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Fleet Trails for Fuel Grade Methanol

under

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

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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 <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	5/20	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 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	5/22	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 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	6/5	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 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	6/19	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 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	6/26	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 <u>both</u> 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.*

FORM 1020 (REV. 6/89)
MEMO34

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

LPDME Recommendation

Summary

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

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

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

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

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

LPDME Recommendation

The LPDME Process Concept: - Three Concurrent Reactions:

- $2\ CO + 4\ H_2 = 2\ CH_3OH$ (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).

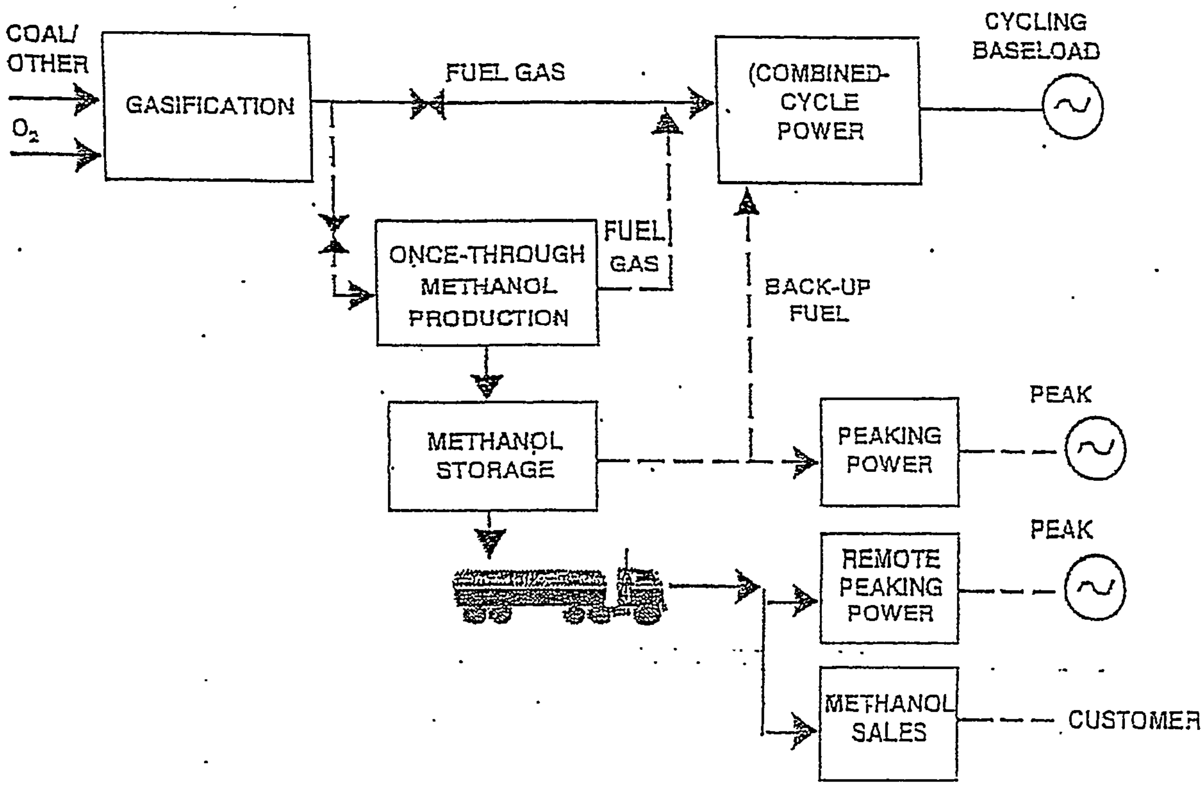
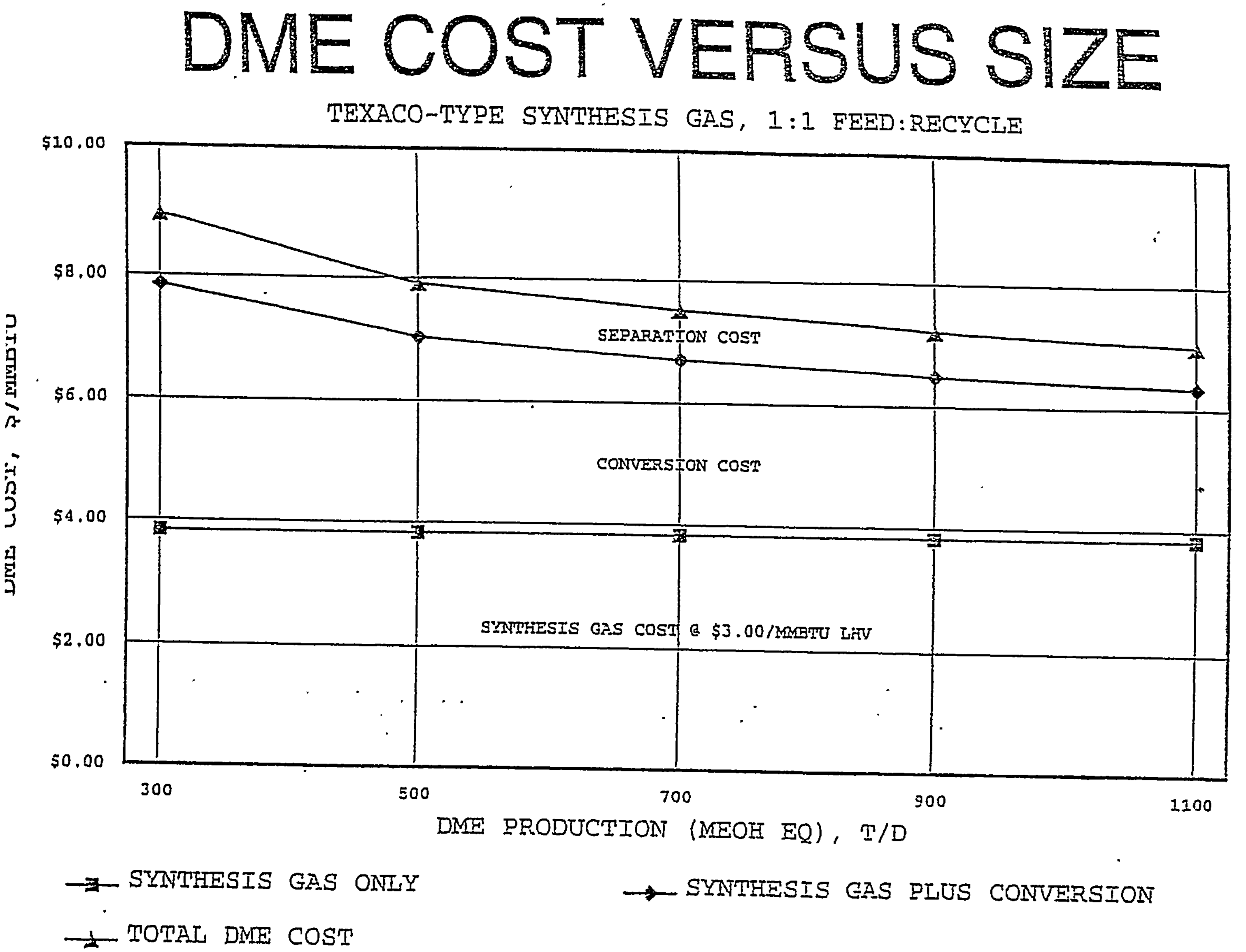


Figure 1. Once-through Methanol Coproduction with IGCC Electric Power

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
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

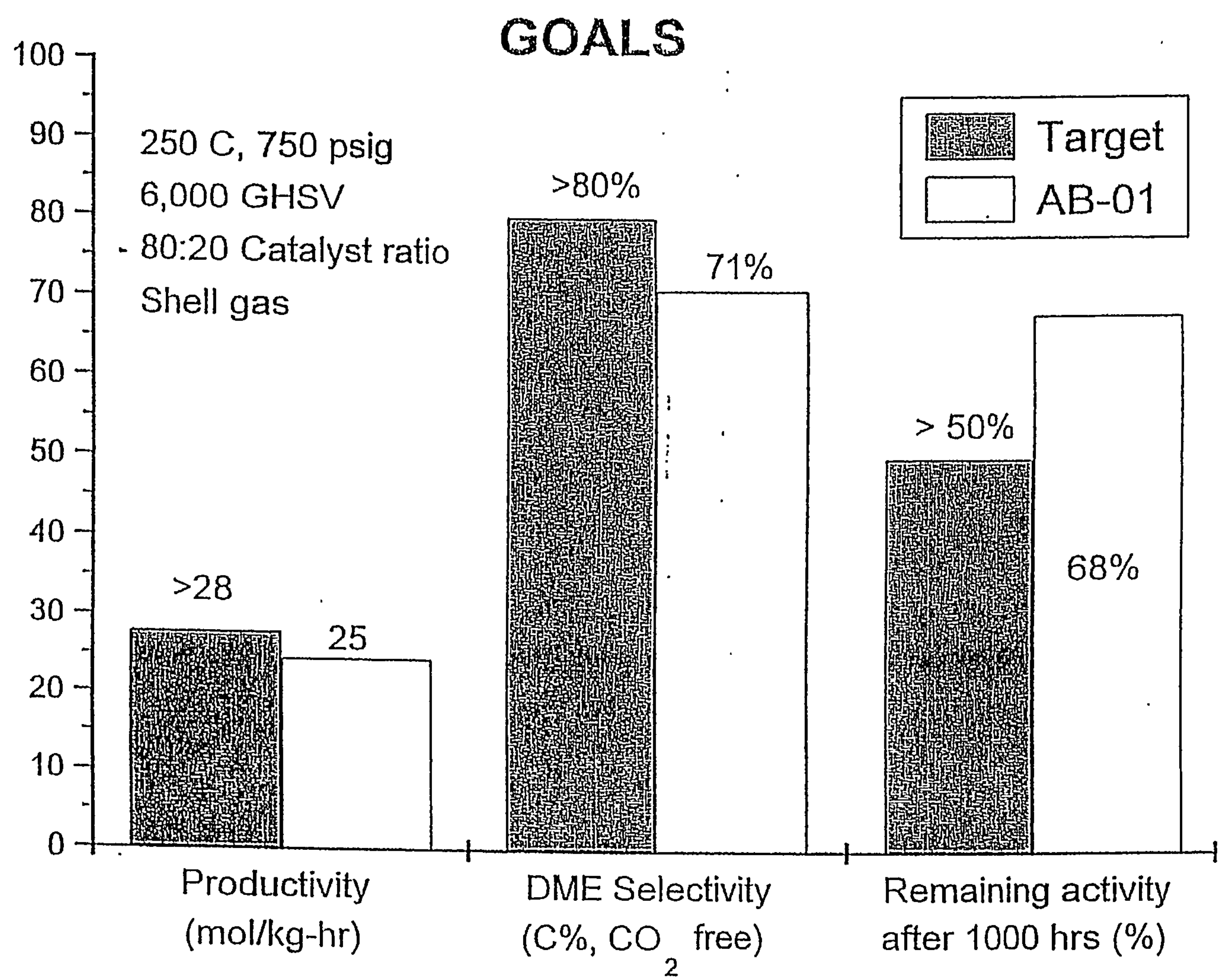
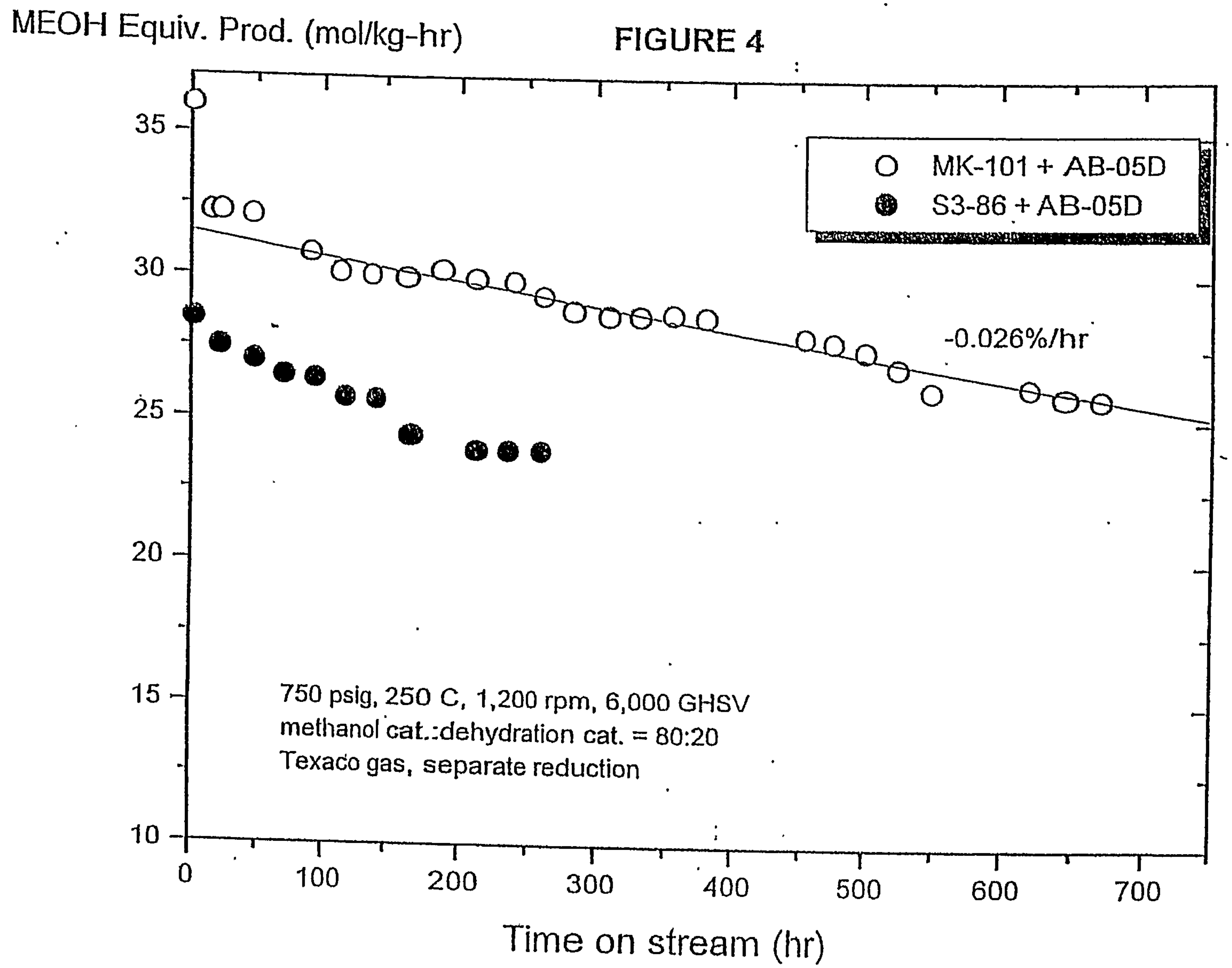

GOALS
100
90
80
70
60
50
40
30
20
10
0
250 C, 750 psig
6,000 GHSV
80:20 Catalyst ratio
Shell gas
Target
AB-01
>28
25
>80%
71%
> 50%
68%
Productivity
(mol/kg-hr)
DME Selectivity
(C%, CO 2 free)
Remaining activity
after 1000 hrs (%)

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.

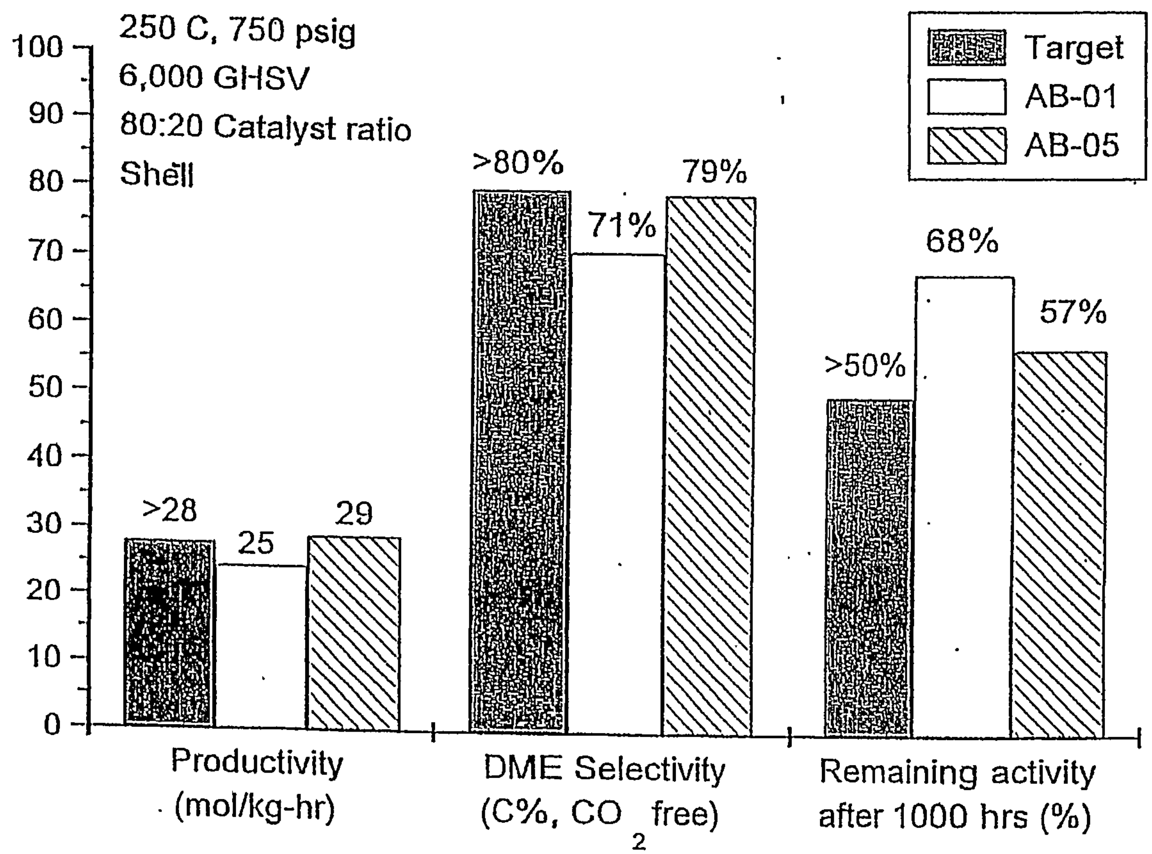


FIGURE 5

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		CRUDE PRODUCT	
	5/13 19:00	5/14 7:00	5/13 19:00	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™ Demonstration Unit Outages - April/June 1998
Table 2 - Summary of Catalyst Samples - Second Catalyst Batch

Figure 1 - Catalyst Age (η) vs. Days Onstream - Second Catalyst Batch
Figure 2 - Sparger Resistance Coefficient vs. Days Onstream (Post-19 December 1997 Restart)

Table 1 - Summary of LPMEOH™ 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

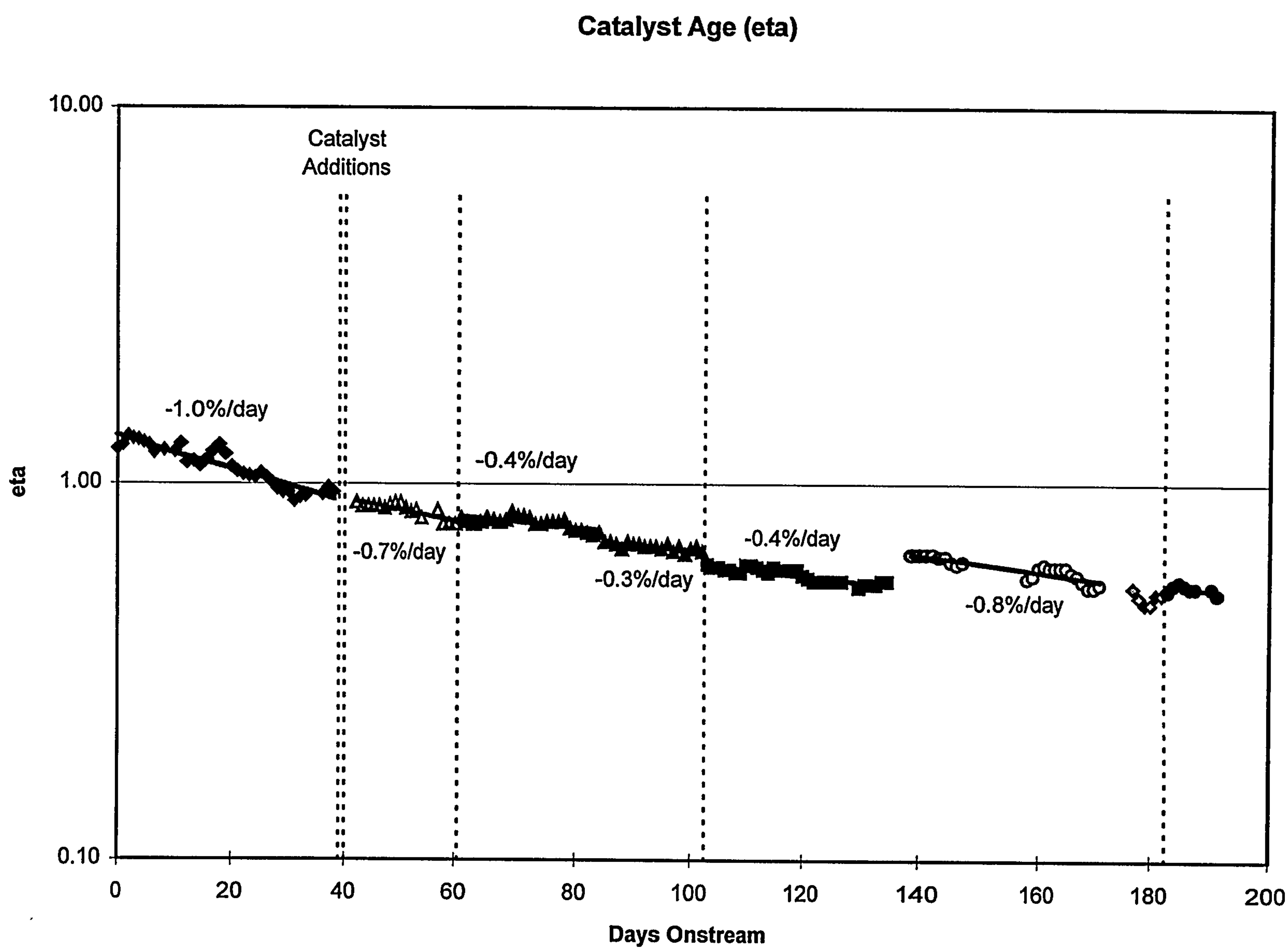
Table 2 - Summary of Catalyst Analyses - Second Catalyst Batch

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	

<u>Notes:</u>

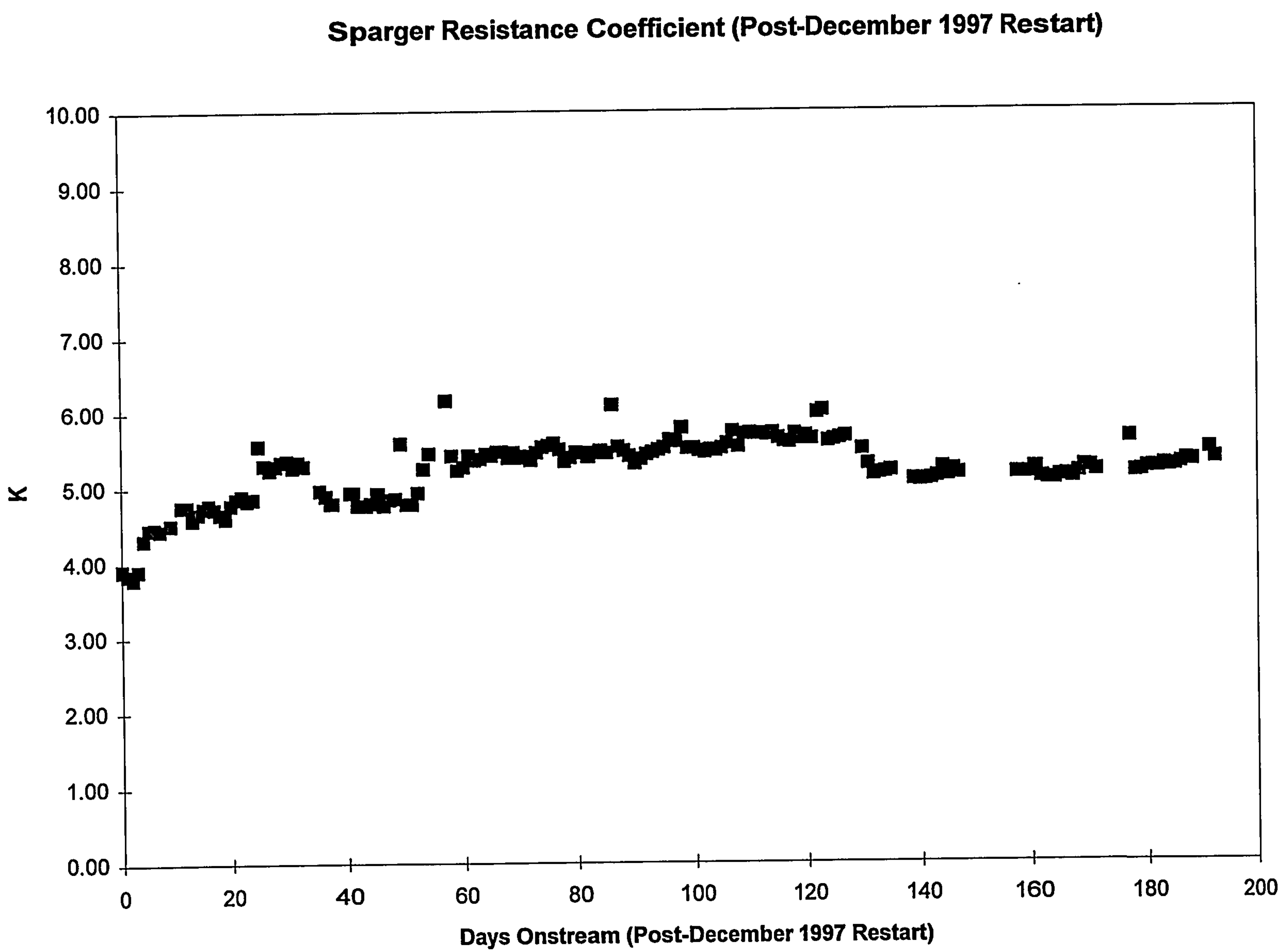
1) nd = none detected

Figure 1



Catalyst Age (eta)
eta
10.00
1.00
0.10
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

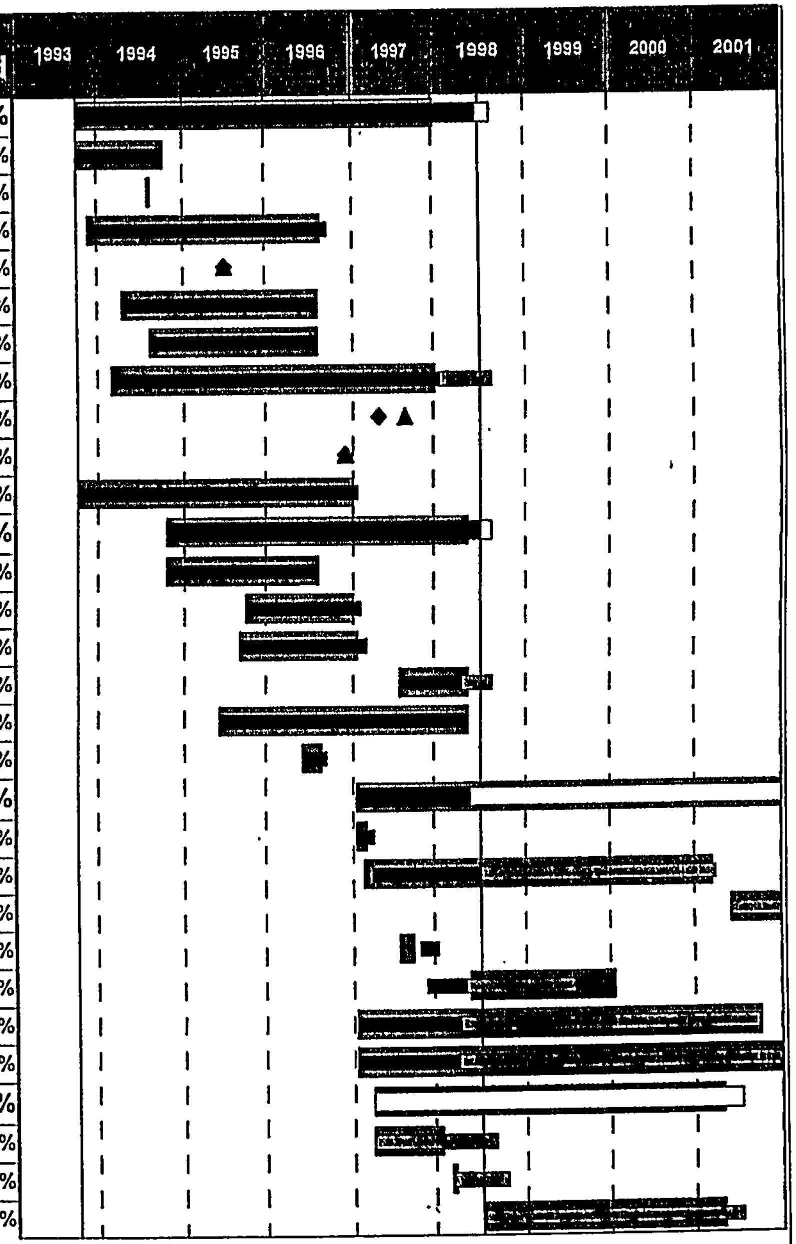
Figure 2


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

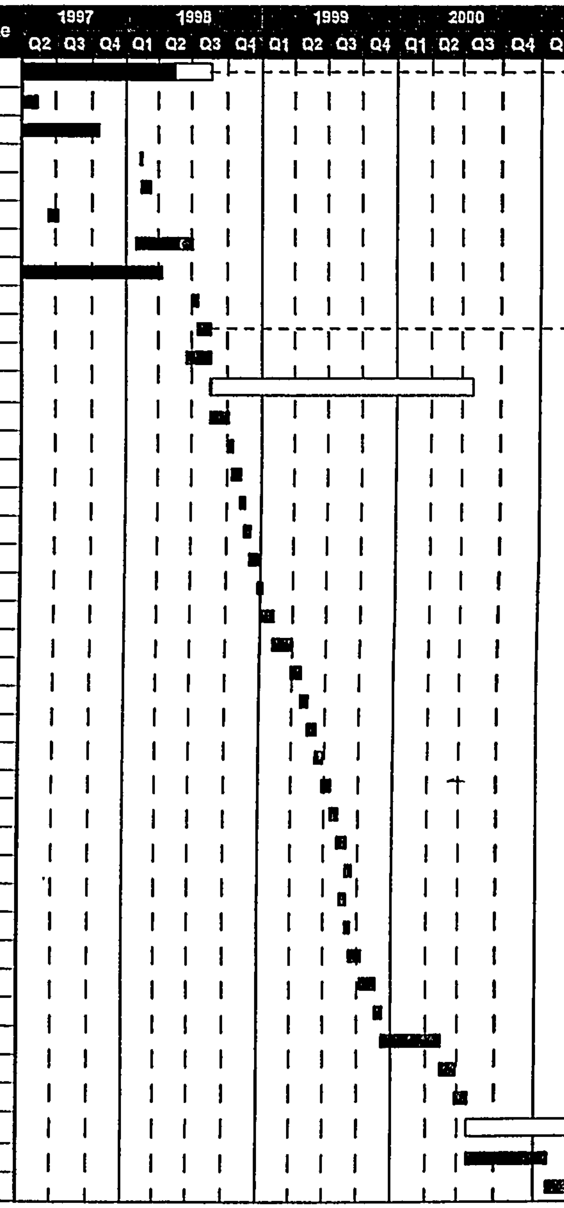
MILESTONE SCHEDULE STATUS REPORT
LIQUID PHASE METHANOL DEMONSTRATION
DE-FC22-92PC90543

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%



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				11. ESTIMATED ACCRUED COSTS							12.	13.
		Reporting Period		Cumulative to Date		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	Total Plan Value	Variance
		a. Actual	b. Plan	c. Actual	d. Plan									
	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 — 7/13/98
S. J. Kasinecz
DATE