

FURTHER PROCESS IMPROVEMENTS
AT THE
LAPORTE LIQUID PHASE METHANOL FACILITY

J. H. FREY
D. W. STUDER
J. L. HENDERSON
R. F. WEIMER

AIR PRODUCTS AND CHEMICALS, INC.
ALLENTOWN, PA 18195

PRESENTED AT THE
DOE INDIRECT LIQUEFACTION CONTRACTORS'
REVIEW MEETING

PITTSBURGH, PA

NOVEMBER 15-17, 1988

Date: November 15, 1988

TITLE: Further Process Improvements at the LaPorte Liquid Phase Methanol Facility

PIs (Authors): J. H. Frey, D. W. Studer, J. L. Henderson, R. F. Weimer,

INSTITUTION/ORGANIZATION: Air Products and Chemicals, Inc.
Allentown, PA 18195

CONTRACT NO: DE-AC22-87PC90005

PERIOD OF PERFORMANCE: April 9, 1987 - August 9, 1989

OBJECTIVE: Complete the concluding phase of work in the existing LaPorte PDU to support the design and future operation of a larger scale LPMEOH plant. Current objective is to demonstrate process simplifications.

TECHNICAL APPROACH: The work under this contract will be to implement and test certain process improvements identified through engineering studies completed under DOE contract DE-AC22-85PC80007 and to demonstrate the capacity of long-term catalyst activity maintenance and to perform process and design engineering work that is generic to a scaled-up LPMEOH facility. A parallel research program will be conducted to enhance the LPMEOH technical data base to improve the likelihood of commercialization of the LPMEOH process. Current technical approach is to perform a series of PDU runs to evaluate the process improvements.

SIGNIFICANT ACCOMPLISHMENTS: Subtasks with significant progress include identifying alternate liquid media, identifying alternate catalysts, optimization of the in situ reduction, catalyst poison studies and installation of new equipment items at LaPorte. The current accomplishments include LPMEOH process productivity near or above lab scale autoclave productivity, the successful operation of a 45 wt% slurry, and a production rate of 10 tons per day.

PUBLICATIONS: "Liquid Phase Methanol Process Development Unit: Installation, Operation and Support Studies, Final Report" DOE Contract No. DE-AC22-81PC30019, by Air Products and Chemicals, Inc. and Chem Systems Inc. (1987).

"Liquid Phase Methanol Process Development Unit: LaPorte PDU Research and Engineering Support Studies, Draft Final Report" DOE Contract No. DE-AC22-85PC80007, by Air Products and Chemicals, Inc. and Chem Systems, Inc. (1987).

ABSTRACT

The Liquid Phase Methanol Process is a viable alternative to traditional gas phase methanol processes and is well suited to coal-derived synthesis gas which is rich in carbon monoxide. This paper describes the progress that has been made at the LaPorte LPMEOH process facility during the summer of 1988.

The primary purpose of the Process Development Unit (PDU) operating program is to obtain sufficient data to evaluate the LPMEOH technology and allow for a confident move to the next scale of operation. Several process improvements, including elimination of the liquid circulation loop and operating at high slurry concentrations, have simplified and improved the economics of the process. These modifications were evaluated in the summer of 1988.

The productivity of the modified LaPorte PDU was near or above the productivity predicted by a laboratory scale autoclave, and record production rates of 10 tons per day were achieved. This was achieved using a CO-rich (35% H₂, 51% CO, 13% CO₂, 1% N₂) feed gas with a H₂/CO ratio of 0.7 at catalyst deactivation rates of 0.2 %/day. Slurry concentrations of 45 wt% were successful and gave higher productivities than previous attempts. This progress represents another step towards commercialization of the LPMEOH process.

INTRODUCTION

Methanol is a versatile commodity chemical with applications ranging from synthetic fuels to feedstocks for higher valued chemicals such as methyl methacrylate and methyl t-butyl ether (MTBE—an octane booster). Many applications have evolved for methanol as a fuel including methanol as a gasoline extender, the methanol to gasoline process, and integrated gasification-combined cycle (IGCC) technology for the coproduction of methanol and electricity.

The Liquid Phase Methanol (LPMEOH*) process represents a major departure from traditional gas-phase routes to methanol in the method of removing the heat of reaction. The reactions of hydrogen and carbon oxides to form methanol are highly exothermic (Figure 1). One of the most difficult design problems of the methanol synthesis process is removing the heat of reaction while maintaining close temperature control to achieve optimum catalyst life and reaction rate. Catalyst life is seriously reduced by excessive temperatures. In conventional gas-phase reactors, either cool unreacted gas, injected at stages in the catalyst bed, or internal cooling surfaces are used to provide temperature control. These schemes, however, were developed for diluted syngas which yields low conversion per pass. The Liquid Phase Methanol process uses a solid catalyst entrained in an inert hydrocarbon liquid, usually a mineral oil. The presence of this liquid adsorbs the reaction heat, effectively controlling the reaction temperature, thereby allowing a higher conversion per pass than in

* LPMEOH is a trademark of Chem Systems Inc.

gas-phase processes. In addition, LPMEOH process technology is particularly well suited to coal-derived synthesis gas which is rich in carbon monoxide. These capabilities make the LPMEOH process a potentially lower-cost conversion route to methanol, especially when methanol coproduction is added to a coal-based IGCC power plant. For a modest increase in complexity of an IGCC plant, the methanol coproduction scheme produces a storable liquid fuel in parallel with electric power production, providing a significant turndown and peak-load capability for the IGCC plant.

Beginning in April 1987, engineering design and subsequent construction modifications began on the LaPorte Liquid Phase Methanol Process Development Unit (PDU). In July 1988, the first results were obtained on the modified and simplified PDU and currently a long term catalyst evaluation is in progress. Prior to the current program, a total of five major PDU synthesis runs and numerous hydrodynamic and analytical tests have been conducted at LaPorte since commissioning of the PDU in March 1984.

The work reported here is funded by a contract entitled "Liquid Phase Methanol LaPorte PDU: Modification, Operation, and Support Studies" and was awarded to Air Products and Chemicals, Inc. (Air Products) by the United States Department of Energy (DOE) (DE-AC22-B7PC90005). Air Products is the prime contractor providing overall program management, engineering design, procurement, construction and operation of the PDU and provides support through laboratory research and development. Chem Systems Inc., inventor of the Liquid Phase Methanol process, acts as the key subcontractor in the program. Cost-sharing is provided by Air Products and the Electric Power Research Institute (EPRI).

LaPorte PDU History

The primary function of the LaPorte PDU is to acquire data using a representative engineering scale for testing the feasibility of the LPNEOH process. Thus, the PDU was designed with the capability of generating and collecting plant data over a wide range of operating conditions and was originally designed to produce 5 tons of methanol per day.

The principal reactor feed gas compositions considered during design were:

- Balanced Type (Table 1), in which the hydrogen and carbon oxide concentrations are approximately stoichiometrically balanced in order to achieve an "all-methanol" product.
- CO-rich Type (Table 1), in which the hydrogen and carbon oxide concentrations are not stoichiometrically balanced, is representative of synthesis gases from modern coal gasifiers. These gases are suitable for once-through methanol synthesis in an IGCC plant configured to make electric power and coproduct methanol.

The different reactor feed gas compositions are blended from H_2 , CO, N_2 , and CH_4 supplied by Air Products' adjacent syngas facility. Carbon dioxide is trucked into the plant as a liquid and stored on-site. Since only a portion

of the reactor feed is converted per pass, the unconverted synthesis gas is recycled and mixed with fresh makeup gas. The makeup gas is blended so that the reactor feed (makeup plus recycle) simulates either the balanced or CO-rich gas type. Recycling the unconverted synthesis gas reduces gas consumption by 70 percent for cost-effective operation at LaPorte.

A simplified process flowsheet for the original LaPorte PDU is shown in Figure 2. The makeup synthesis gas is compressed to the reactor pressure (3,500-6,300 kPa, 500-900 psig) by the feed compressor. The compressed makeup and recycle gases are mixed and preheated in the feed/product exchanger before being fed into the methanol reactor. The inert hydrocarbon liquid or slurry that circulates through the reactor is separated from the unconverted synthesis gas and methanol product vapor in the primary V/L separator, and recirculated to the reactor through the slurry heat exchanger. The circulating liquid and slurry can be heated or cooled in the slurry exchanger to maintain a constant reactor temperature, depending upon the level of conversion, system heat losses, and the rate of cold seal flush required by the slurry pump. A utility oil system provides the heating or cooling duty to the slurry exchanger.

The unconverted synthesis gas/product methanol stream leaving the primary V/L separator is cooled against incoming feed gas and the condensed oil is separated in the secondary V/L separator. The uncondensed vapor is further cooled in the product cooler. Condensed methanol is then separated from the synthesis gas before being piped to product storage. A small purge stream is sent to flare. The bulk of the unconverted synthesis gas is compressed and returned to the front end of the PDU. Additional systems are present to

activate the catalyst, provide seal flush to the slurry pump, and mix catalyst slurry for the liquid-entrained mode of operation.

Previous LaPorte PDU operations, conducted during five major synthesis runs, successfully demonstrated LPMEDH process technology at a representative engineering scale. The PDU accumulated over 2,500 hours of methanol synthesis operation (over 2200 hours with CO-rich gas) with an on-stream factor of 95-100 percent. Identification of catalyst poisons (iron and nickel carbonyl) and subsequent application of new metallurgy contributed to superior performance. Low catalyst deactivation while operating the liquid-entrained system with a 25 wt% catalyst slurry for 40 days on CO-rich synthesis gas and matching laboratory predictions for catalyst life and activity was a notable achievement. Methanol production levels as high as 8 TPD for balanced gas feed and 7 TPD for CO-rich gas feed were achieved; the purity of the methanol product from CO-rich gas was consistently higher than 96 wt%, a good quality for use as a fuel.

Previous operation at 45 wt% slurry concentration was also successful. The ability to activate methanol synthesis catalyst powders in an inert liquid at high concentrations was noteworthy. High operability was maintained during the 45 wt% slurry run for 10 days and the reactor performance was close to 7 tons per day; however, the catalyst productivity was lower than the laboratory predictions. This deficiency was attributed to a mass transfer limitation and/or inadequate gas/slurry mixing at the high solids loading.

The PDU operations, laboratory activities, and commercial studies conducted under the two previous DOE contracts helped to prove the viability of the LPMEOH process. The results of the LaPorte runs and the laboratory research have been reported at the 1982-1987 annual contractors' meetings (1-6). Further requirements must be met to scale to a larger demonstration plant or a small commercial unit; these requirements and results will be presented in the following sections.

Current Objectives

The primary focus of the new PDU operating program is to allow for a confident move to the next scale of operation with an optimized and simplified process. Although the PDU had been very reliable in prior campaigns, several new design options of merit were identified. These options were thoroughly evaluated in a subsequent process engineering study which became the basis for the new PDU modification/operating program.

Simplifying the process can greatly improve the process economics by reducing the capital costs and the amount of down time due to equipment failure. The proposed process simplifications focus on the slurry loop, which consists of the reactor, the vapor/liquid separator, the slurry heat exchanger, and the slurry circulation pump. The desired process simplification is the elimination of the entire loop outside the reactor (Figure 3). This can be achieved if vapor/slurry separation and heat exchange are performed in the reactor vessel. This modification would be a significant process improvement since it eliminates two large high-pressure vessels (the vapor/slurry separator and the

heat exchanger shell) and the slurry circulation pump. The 250 gpm centrifugal slurry pump proved to be a highly reliable but a high preventive maintenance piece of equipment at LaPorte.

Three key conclusions were reached as a result of the detailed process engineering evaluation: first, there should be sufficient liquid circulation and turbulence induced by the high synthesis gas velocities to suspend the catalyst particles homogeneously within the slurry; second, the required internal heat transfer surface should be relatively small, so that it can be installed with little effect on reactor bubble column hydrodynamics; and third, adequate vapor/liquid disengagement can potentially be achieved by incorporating a reactor freeboard section with a small internal or external demisting device.

While eliminating all three of these equipment items (external separator, pump, heat exchanger) is a valuable goal, eliminating any of the three would be a worthwhile accomplishment. A new process design capable of operating with one or all of the process simplifications was therefore developed and is schematically shown in Figure 4. The ranges of operating variables are listed in Table 2.

Fortunately, the process flowsheet modifications were achieved without major reconstruction of existing piping. The PDU is able to run in one of the following modes:

- an external circulation mode similar to the original mode
- a completely internal mode
- with external heat exchange but internal separation
- with internal heat exchange and a small external separator
- in other possible combinations.

Vapor/liquid disengagement is accomplished in a new, longer, all-stainless steel reactor by incorporating a freeboard section followed by a demisting mesh pad. If desired, the demisting pad can be bypassed to use a small-diameter external cyclone to knock out small slurry droplets. Recovered slurry droplets are returned to the reactor via a positive displacement pump.

The internal heat exchanger consists of parallel 1-inch-diameter tubes manifolded at each end by a 16-inch-diameter header ring. The heat exchanger occupies only 3.5% of the reactor cross-sectional area and is not expected to interfere with the reactor hydrodynamics.

Feed synthesis gas will be introduced to the reactor using a circular gas sparger. The estimated slurry circulation rate resulting from the feed gas flow is an order of magnitude higher than the superficial velocity resulting from the slurry pump and should be sufficient to suspend the catalyst particles.

Process economics are also improved by increasing the reactor productivity as a result of a higher catalyst loading. The newly designed gas sparger was

developed to suspend a high concentration catalyst slurry while providing intimate gas/slurry mixing and suitable mass transfer.

PDU performance evaluation was undertaken in several stages. First, each new equipment item (i.e., internal heat exchanger, sparger, demister and cyclone) was examined under normal operating conditions at high slurry concentrations. The evaluation began with a 2 phase gas/liquid study to compare reactor gas holdup with previous runs and to identify the presence of metal carbonyl catalyst poisons. Three phase evaluation began after catalyst addition at 45 wt% and in situ reduction. The three phase tests, run at normal operating conditions and with simulated and real process failures, provide a comparison of the performance of the new system with the predicted performance and with the past performance of the unit. The results were used to establish the optimum process configuration for the remaining stages of the PDU performance evaluation which include an alternate catalyst study, a 120 day catalyst life study and a process variable study.

PDU RESULTS

Two-phase tests began at LaPorte in June 1988 with nitrogen/oil and CO-rich gas/oil systems. The purpose of these tests was to study the hydrodynamics of the reactor, detect metal carbonyl catalyst poisons, and train operating personnel. Any effect of the new gas sparger and the internal heat exchanger would be revealed by comparing the hydrodynamic data with previous PDU hydrodynamic data. Hydrodynamic information was measured with a nuclear density gauge. The density gauge is mounted on a track which allows

measurements along the axis of the reactor. Gas and liquid holdup are calculated from the absorbance of gamma radiation using Beer's law and absorption coefficients based on calibration experiments.

Gas holdups for CO-rich gas flowing through oil in the old and new reactors are shown in Figure 5. Under external slurry loop circulation process conditions, the presence of the new gas sparger and internal heat exchanger provides essentially equivalent gas holdup in the reactor. However, the liquid circulation that is present for the cases depicted in Figure 5 suppresses the gas holdup. When external liquid circulation is eliminated, gas holdup is higher. The effect of liquid circulation on gas holdup is shown in Figure 6. In addition, gas holdup profiles are uniform over the height of the reactor as shown in Figure 7.

Two-phase CO-rich gas studies also served to monitor the production of catalyst poisons such as iron and nickel carbonyls. Initial levels of carbonyls, determined by gas chromatography and atomic adsorption, were below 70 ppbv. After replacing the reactor oil with fresh oil, carbonyl levels dropped to 19 ppbv of $\text{Fe}(\text{CO})_5$ and 4 ppbv of $\text{Ni}(\text{CO})_4$. The low carbonyl levels found justified the use of a stainless steel reactor system.

Catalyst was added to the system and reduced in situ. Methanol production runs began on 16 July 1988 from CO-rich gas. The cases shown in Table 3 were run in a systematic order to test each new equipment item. Evaluation of the sparger, internal heat exchanger, and internal separation were conducted in runs E-5A,

E-5B and E-5D, respectively. In runs E-5E and E-5F lower catalyst loadings and a deliberate 24 hour shutdown were studied.

Production of methanol was stable in run E-5A after only 18 hours on-stream with syngas. The oil phase seen in previous runs was eliminated due to the repiping of the feed/product heat exchanger and the weight percent oil in the methanol was reduced from 1.3 to 0.6%. The methanol productivity, as illustrated in Figure 8, and the gas holdup were higher than previous runs (Run E-4) at high catalyst loadings. This demonstrates improvement attributable to the new gas sparger; however, the methanol productivity was still slightly below the autoclave curve for high loadings and mass transfer limitations may still have been present.

The new internal heat exchanger was evaluated in runs E-5B and E-5C. Again, the reactor was performing closer to the autoclave results (Figure 8). The overall heat transfer coefficient of the heat exchanger was 98 Btu/hr-ft²-°F, close to the design value of 105 Btu/hr-ft²-°F. Operation at high space velocities was not possible with the internal heat exchanger only because its area was conscientiously underdesigned in order to achieve measurable temperature differences with a 35 wt% catalyst slurry where a lower temperature differential between slurry and heat transfer oil exists. There was a concern that the high ΔT at 45 wt% slurry and high gas velocities could produce excessive thermal stresses. Therefore, both internal and external heat exchangers were used in run E-5C to remove the heat of reaction. Daily methanol production ranged from 8 to 9 tons per day for the 45 wt% runs

(Table 3), which exceeded the previous production rates of 5 to 7 tons per day at 47 wt% slurry.

Run E-5D was the first test of the LaPorte reactor without external circulation. A higher methanol productivity results in run E-5D compared to run E-5B, as illustrated in Figure 8 and Table 3. The increased productivity could be due to higher gas/liquid interfacial area or reduced backmixing in the absence of liquid circulation. Clearly, the catalyst in the external loop was not contributing significantly to the methanol production. The internal slurry/gas separators performed well. The cyclone had a pressure drop of 7.6 psid and the demister pad cycled between 2 and 5 psid between backflushings.

Runs E-5E and E-5F were completed at the end of July with 34 wt% slurry. Methanol productivity was greater than autoclave performance, indicating that the design of the new system must have eliminated most of any mixing and mass transfer limitations. The heat transfer coefficient for the 34 wt% slurry was 124 Btu/hr-ft²-°F. Productivity levels achieved in run E-5F demonstrated the resilience of the process to one hour and 24 hour deliberate shutdowns, performed prior to run E-5F. Four unplanned power outages during the month of July also demonstrated the reliability of this process after unscheduled shutdowns.

A post run inspection of the process equipment after run E-5 showed no evidence of catalyst plugging and no catalyst buildup near the new gas sparger. The demister, however, was damaged and required replacement. During this

inspection period, the internal heat exchanger was equipped with an expansion loop to relieve thermal stresses so operation at high catalyst loadings and high gas velocities would be possible.

Run E-6 was started in late August for the purpose of studying an alternate commercial catalyst. If the alternate catalyst performed better than the catalyst used in previous runs, the alternate catalyst run would be continued for 120 days to evaluate deactivation. Run E-6 consisted of a series of process variable scans (Table 4) to determine the performance of the catalyst slurry under various operating conditions.

The initial condition of 5,700 l/hr-kg cat space velocity at a catalyst loading of 39 wt% achieved only 80% of the predicted autoclave performance. The catalyst productivity improved, however, both with time and with dilution of the catalyst concentration in the slurry (Figure 9 and Table 4). During 7 days of Run E-6, the catalyst concentration was lowered from 39 to 35 wt% and the catalyst productivity increased from 80 to 105% of autoclave performance. The cause of the changing reactor performance during Run E-6 is being investigated. An additional demister, installed in the intermediate V/L separator prior to run E-6, reduced the oil impurity in the methanol product from 0.6 wt% to 0.2 wt%.

A comparison of the catalysts at equal feed rates and reactor volumes showed that the alternate catalyst will produce 9% more methanol at 35 wt% than the previous catalyst at 40 wt%. The alternate catalyst run was continued as run E-7 for a 120 day deactivation study at nominal conditions of 10,000 sl/kg-hr.

250°C, 750 psi and 35 wt% oxide catalyst. The PDU produced a record 10.1 tons per day of methanol during the first 2 weeks of Run E-7.

Operation of Run E-7 was suspended for three days beginning on 15 September for safety reasons due to the threat of hurricane Gilbert. The reactor was isolated for 33 hours without gas flow or heat control. The flow of feed gas to the reactor was resumed after a 68 hour outage. Methanol production was 10 TPD for the 10 hour period prior to shutdown and was restarted without difficulty after the hurricane passed. The methanol production rate for the 12 hour period after start-up was 10.1 TPD, demonstrating again the resilience of the LPMEOH process to upsets. After 26 days of operation, the methanol production rate was still 9.9 TPD, indicating a deactivation rate of no more than 0.2%/day compared to 0.35%/day in run E-3 in 1985. Run E-7 will be continued until early January 1989.

SUMMARY

The results reported here are the preliminary findings of runs that will last into 1989. Current and future runs include continuation of the catalyst life run and a process variables study. These results will be reported in future papers.

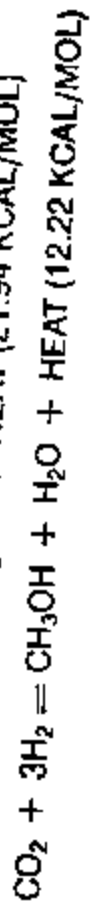
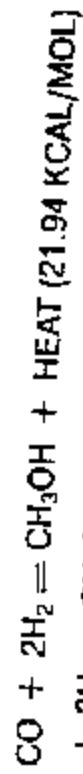
Operations performed during the summer of 1988 fulfilled our goal of developing a more scalable process. Increasing productivity with higher catalyst loadings and simplifying the process through elimination of the external liquid circulation loop have also resulted in a more economical process. The success of the current LPMEOH process campaign represents another step towards making LPMEOH a reliable and economical commercial process.

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FIGURE 1

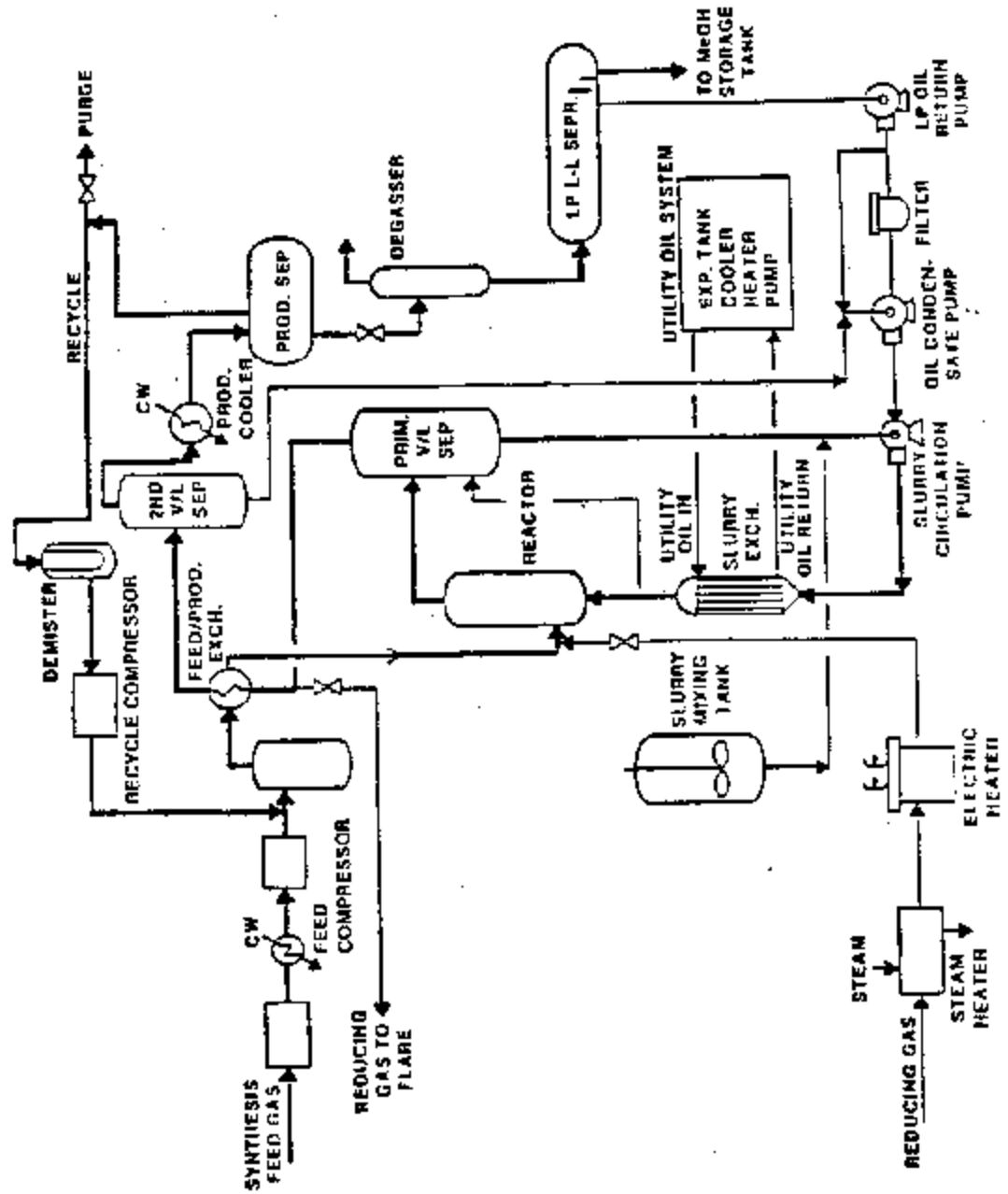
METHANOL SYNTHESIS



TYPICAL REACTION CONDITIONS:

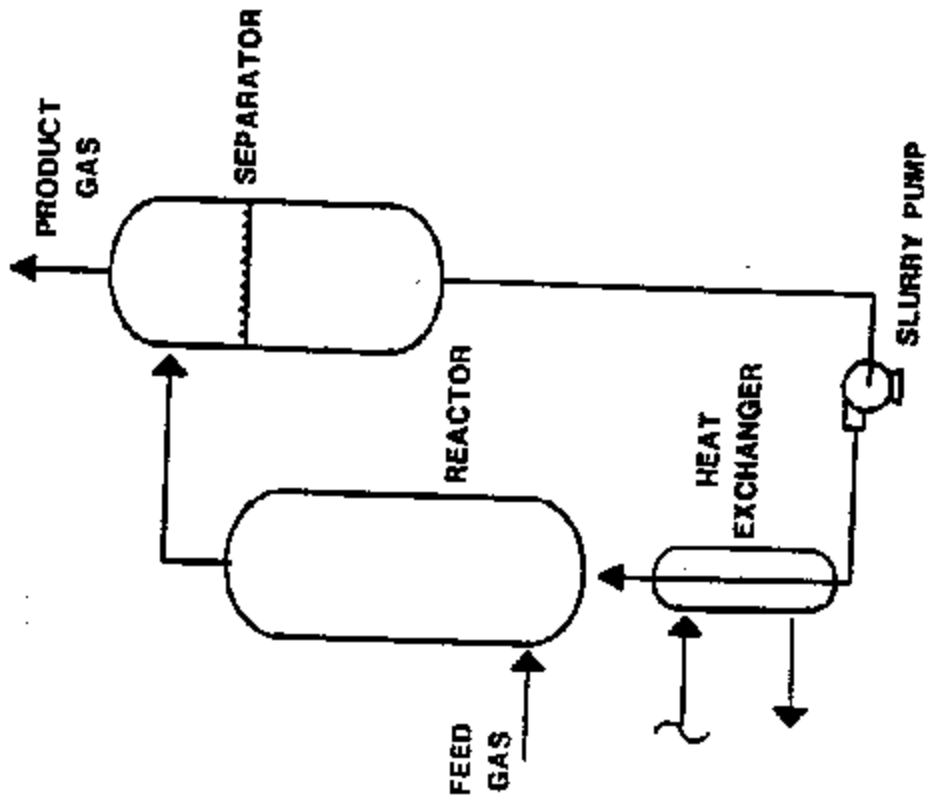
250°C, 5300 kPa

FIGURE 2
Simplified Process Flowsheet for Original LaPorte PDU



LPMEOH REACTOR/SLURRY LOOP SIMPLIFICATION

LP I, II CONTRACTS
OLD, PROVEN CONFIGURATION



LP III CONTRACT
NEW TEST CONFIGURATION

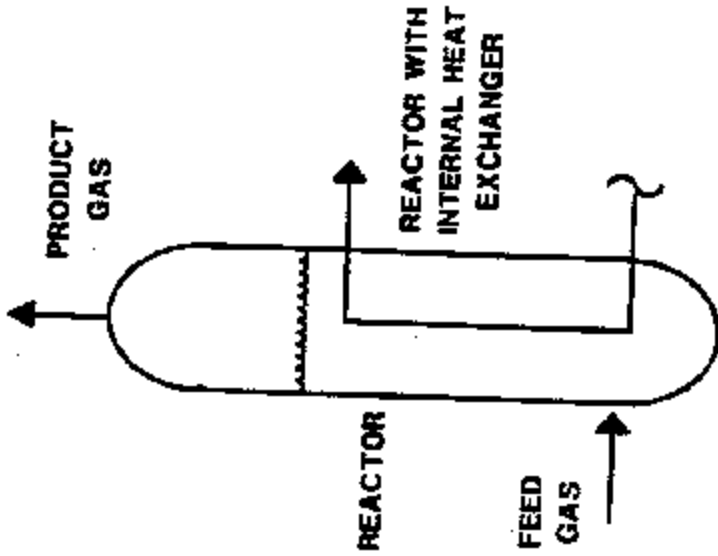


FIGURE 5

LAPORTE LPMEOH PDU 2-PHASE GAS HOLDUP
CO RICH GAS, 750 PSIG, 250°C

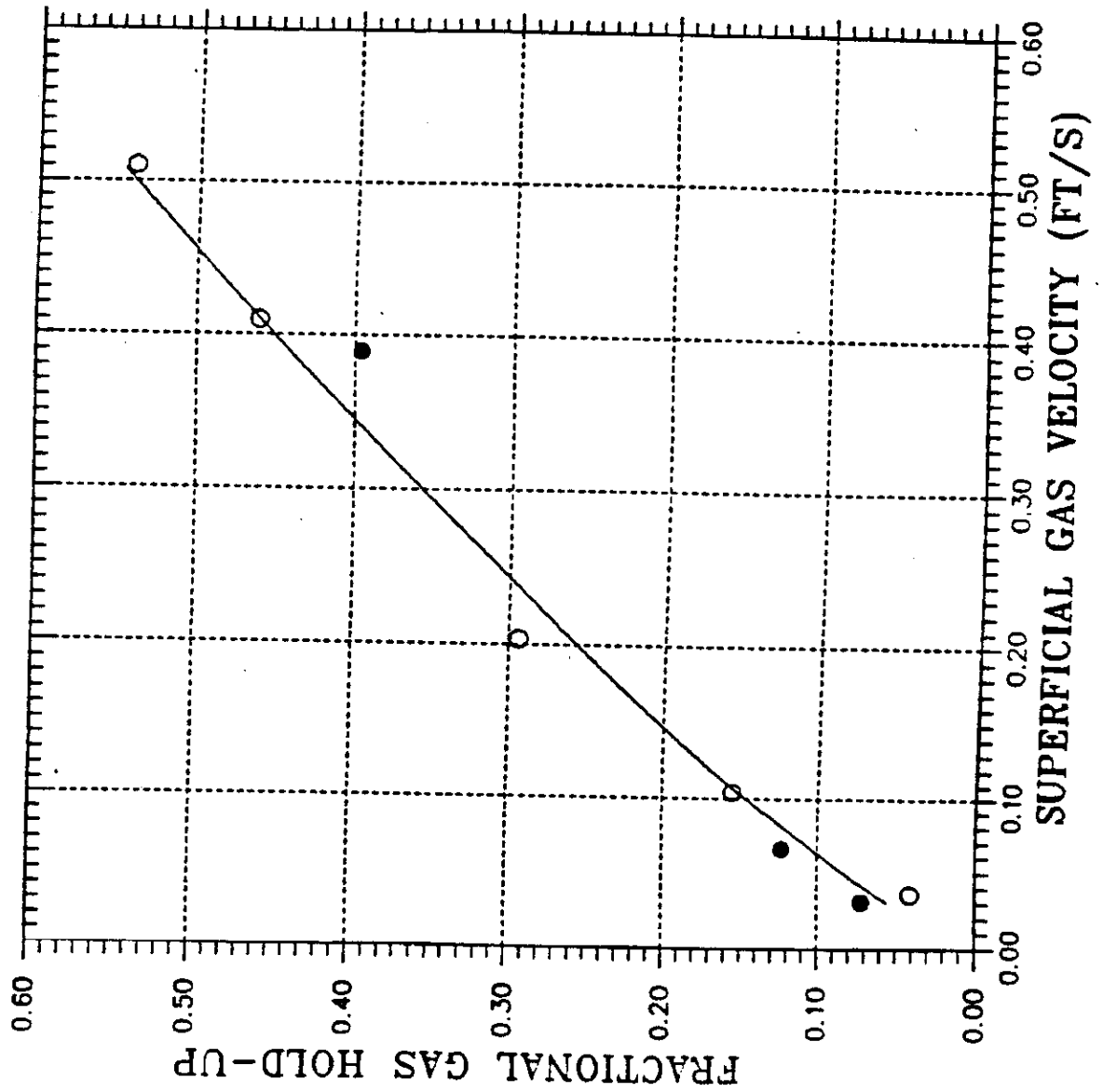
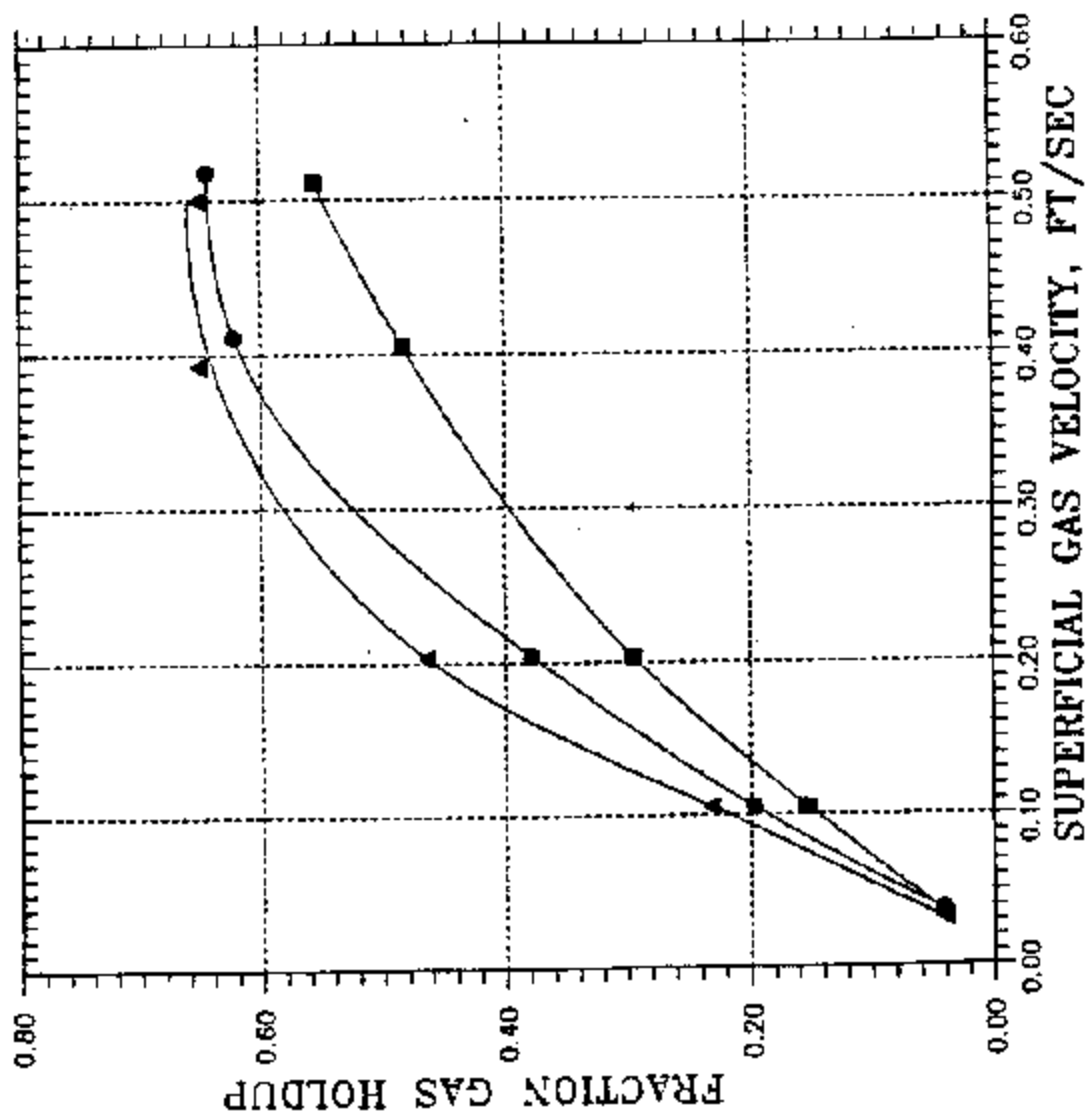


FIGURE 6

LAPORTE LPMEOH PDU 2-PHASE GAS HOLD-UP
CO-RICH GAS, 750 PSIG, 250°C



LEGEND

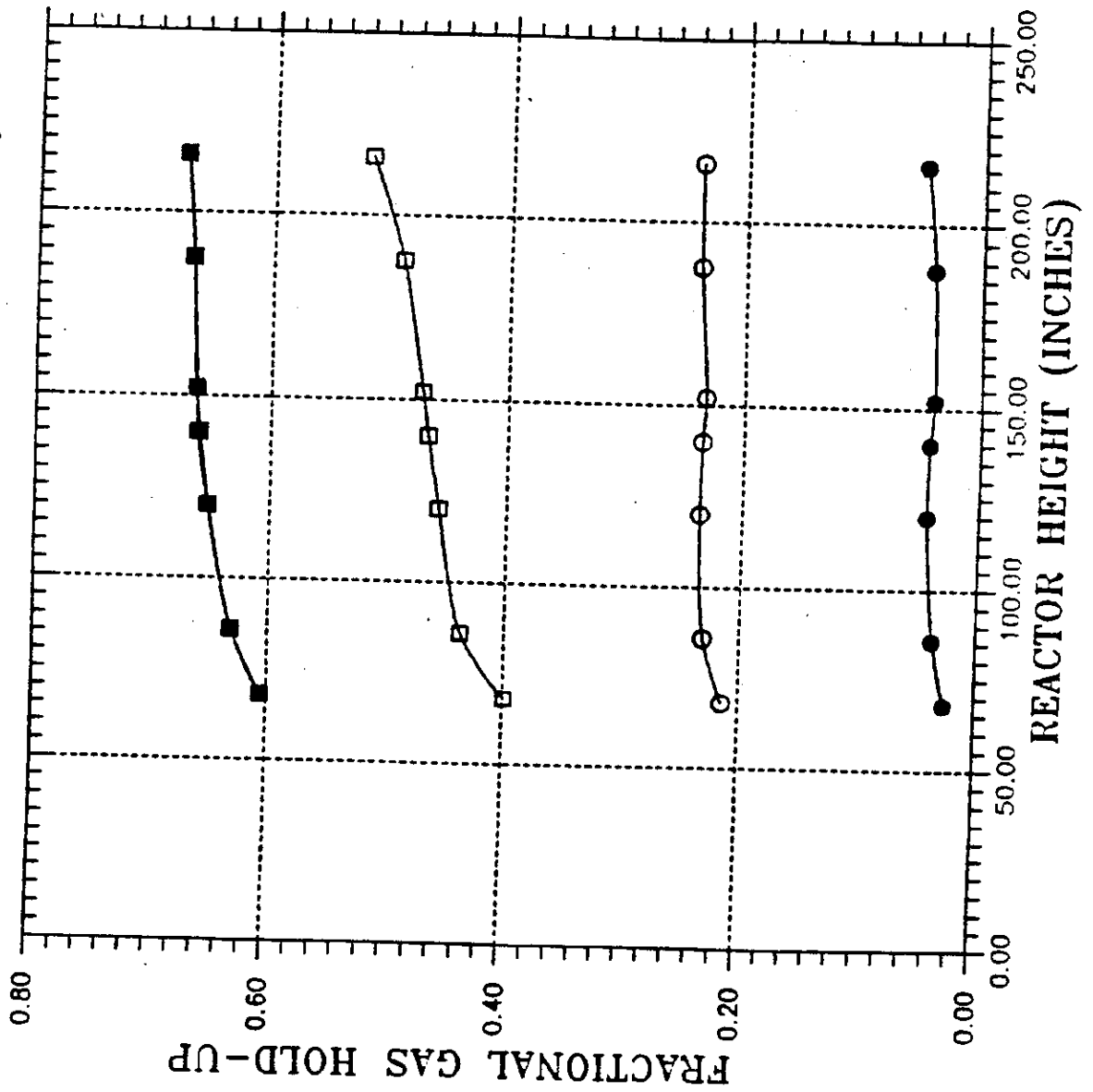
▲ $v_g = 0.00$ FT/S

● $v_g = 0.06$ FT/S

□ $v_g = 0.16$ FT/S

FIGURE 7

LAPORTE LPMEOH PDU 2-PHASE GAS HOLD-UP
 CO RICH GAS, 750 PSIG, 250°C, $V_L=0$ FT/S



LEGEND

● $V_g = .032$ ft/s

○ $V_g = .108$ ft/s

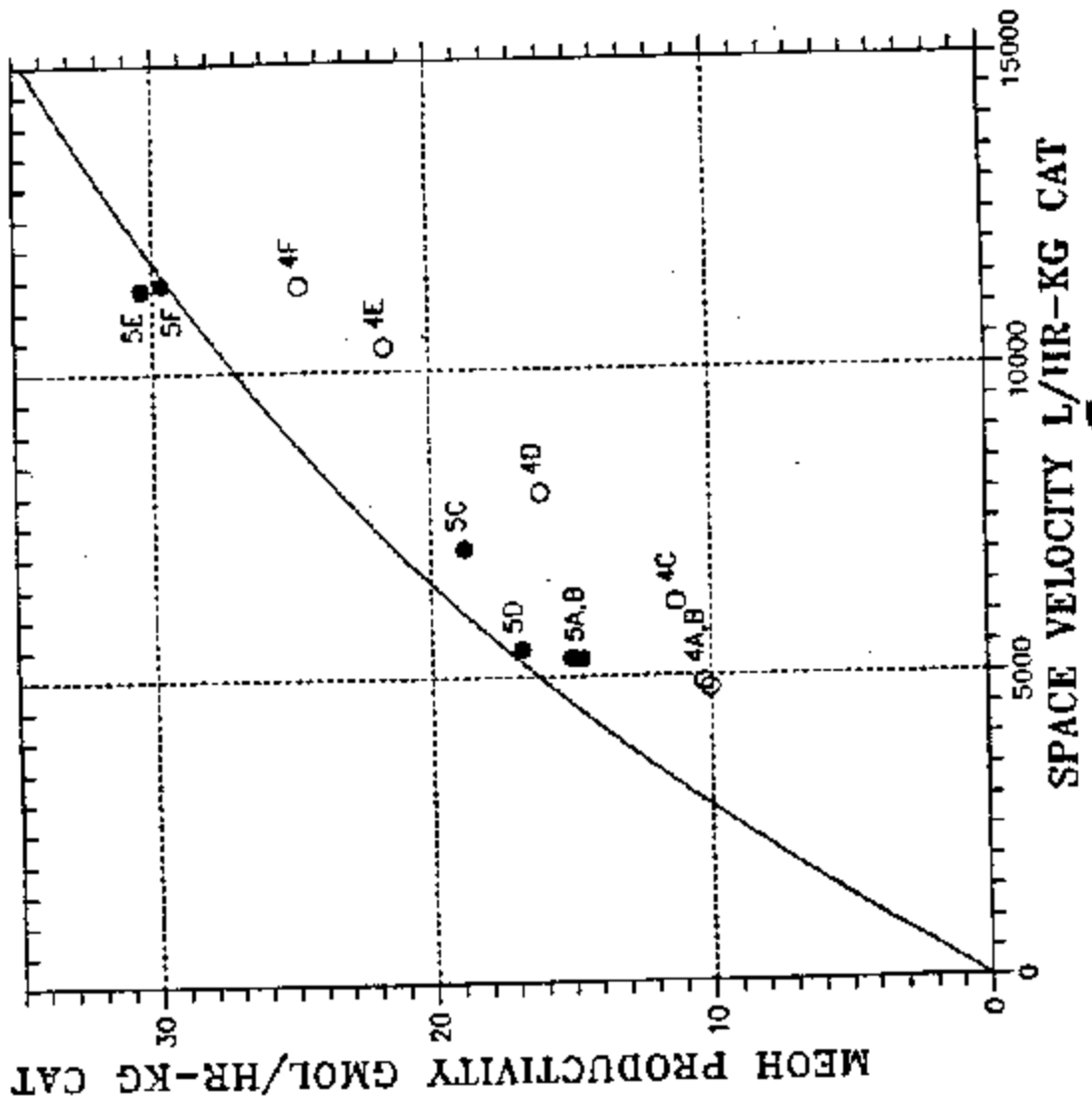
□ $V_g = .204$ ft/s

△ $V_g = .393$ ft/s

▲ $V_g = .500$ ft/s

FIGURE 8

LAPORTE LPMEOH PDU REACTOR PERFORMANCE
 CO RICH GAS, 750 PSIG, 250°C

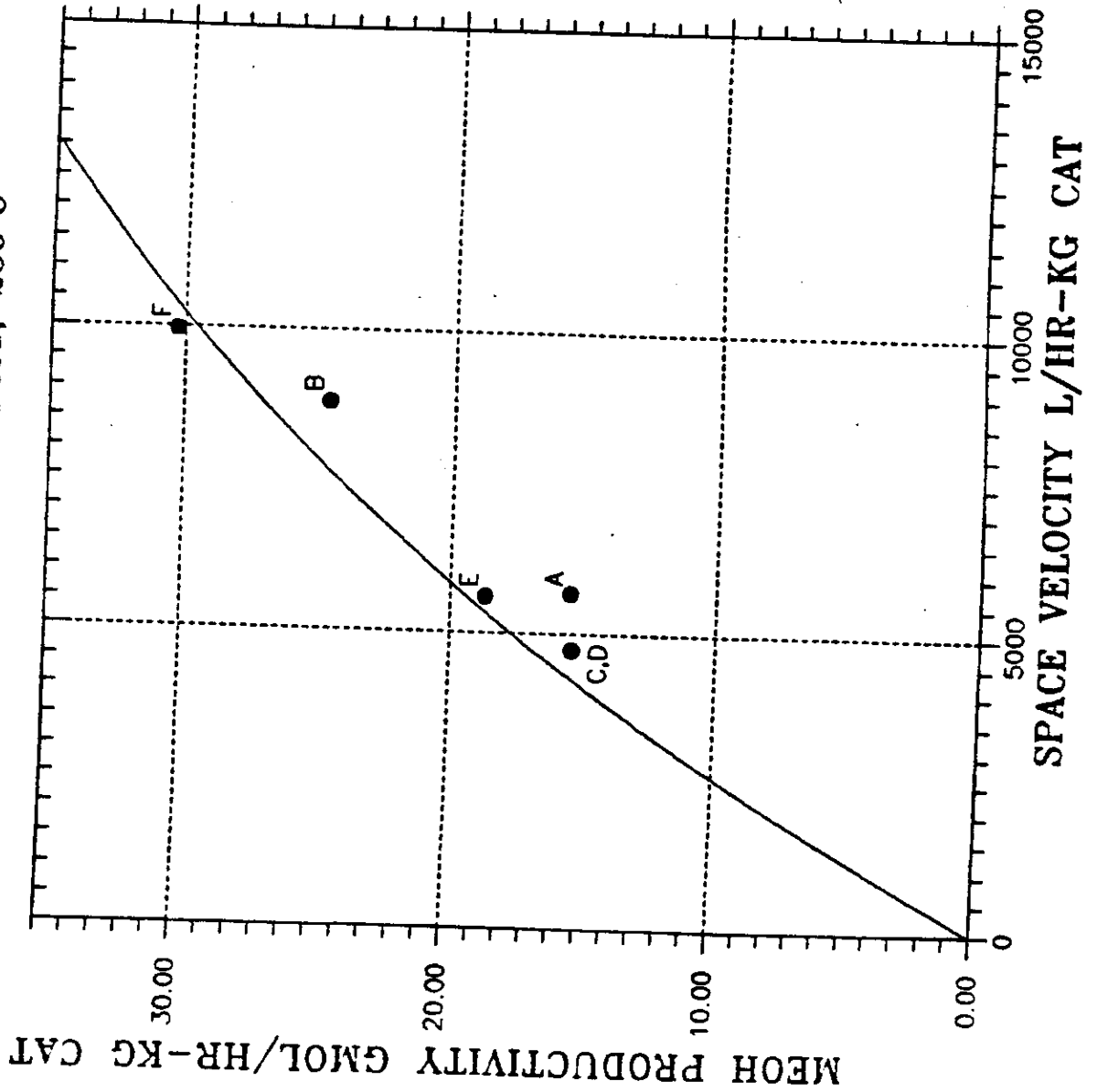


LEGEND

- RUN E-4
 4A, B, C 47 wts
 4D 40 wts
 4E, F 34 wts
- RUN E-5
 5A, B, C, D 45 wts
 5E, F 34 wts
- AUTOCLAVE

FIGURE 9

LAPORTE LPMEOH PDU REACTOR PERFORMANCE
 CO RICH GAS, 750 PSIG, 250°C



LEGEND

- RUN E-6
 - 8A, B, C 39wts
 - 8D 37wts
 - 8E 33wts
 - 8F 35wts
-
- AUTOCLAVE

TABLE 1

LAPORTE PDU PRINCIPAL FEED GAS COMPOSITIONS

	BALANCED TYPE REACTOR FEED	CO-RICH TYPE REACTOR FEED
H ₂	54.9 MOLE %	34.8
CO	18.8	51.2
CO ₂	4.9	13.1
CH ₄ , C ₂ H ₆	2.1	0.1
N ₂ , Ar, INERTS	19.3	0.8
TOTAL	100.0	100.0
H ₂ /CO	2.92	.68

TABLE 2

TYPICAL RANGE OF OPERATING VARIABLES FOR LAPORTE PDU

	MINIMUM	"NORMAL"	MAXIMUM
REACTOR PRESSURE, kPA	3,500	5,300	6,300
REACTOR TEMPERATURE, °C	220	250	270
SPACE VELOCITY, LITER/HR-KG CAT.	2,000	5,000/ 10,000	15,000
CATALYST LOADING, WT. %	25	35	45

NOTE: SPACE VELOCITY BASED ON STANDARD LITERS (0°C, 14.7 PSIA), KG OF OXIDE CATALYST.

TABLE 3
Conditions and Preliminary Results for Equipment Evaluation
 (Run E-5)

T = 250°C, P = 750 psig

CASE:	<u>A.</u>	<u>B.</u>	<u>C.</u>	<u>D.</u>	<u>E.</u>	<u>F.</u>
Catalyst wt%	45.0	44.9	45.9	45.0	34.1	33.9
Space Velocity (1/hr-kg)	5,297	5,313	7,107	5,445	11,356	11,444
Heat Exchanger	Ext.	Int.	Ext./ Int.	Int.	Int.	Int.
Slurry Loop	Ext.	Ext.	Ext.	None	None	None
Production (Tons/Day)	7.8	7.8	9.2	8.3	8.9	8.6
% Methanol in Effluent	8.12	8.04	6.79	8.79	7.70	7.37
Methanol Productivity (gmol/hr-kg cat)	14.6	15.0	18.8	16.8	30.4	29.7
Productivity as % of Autoclave Productivity	86	89	88	97	104	101

TABLE 4
Conditions and Preliminary Results for Alternate Catalyst
(Run E-6)

T = 250°C, P = 750 psig

CASE:	<u>A</u>	<u>B</u>	<u>C</u>	<u>D</u>	<u>E</u>	<u>F</u>
Catalyst wt%	38.7	39.6	38.5	37.2	33.3	35.0
Space Velocity (1/hr-kg)	5,675	8,797	4,746	4,733	5,612	9,969
Heat Exchanger	Int.	Int.	Int.	Int.	Int.	Int.
Slurry Loop	None	None	None	None	None	None
Production (Tons/Day)	7.1	10.3	6.4	6.4	6.2	10.0
% Methanol in Effluent	7.79	8.21	9.17	9.17	9.90	8.92
Methanol Productivity (gmol/hr-kg cat)	15.5	24.6	15.4	15.4	18.7	30.3
Productivity as % of Autoclave	79	91	91	91	96	103