LIQUID PHASE METHANOL UPDATE

by

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ABSTRACT

The U.S. DOE and Air Products and Chemicals, Inc. are now somewhat over halfway through a 42-month R&D program to prove the feasibility of the Liquid Phase Methanol (LPMeOH) technology. The program began in September 1981. Chem Systems Inc., inventor of the LPMeOH technology, is performing as a key subcontractor in the program. Cost sharing participants are DOE, Air Products, Fluor Engineers, Inc. and the Electric Power Research Institute. LPMeOH technology has the potential to be a lower-cost conversion route to methanol-from-coal than current gas-phase processes. Laboratory work to date shows LPMeOH technology particularly suited to coal-derived synthesis gas rich in carbon monoxide because: it is capable of processing feed gas of varying CO and H_2 contents; it can achieve high CO conversion per pass; and it permits effective recovery of heat liberated during reaction. In this program, a DOE-owned skid mounted process development unit was transferred from Chicago, refurbished, expanded for service as the LPMeOH Process Development Unit (PDU), and has been relocated to Air Products' LaPorte, TX facility. Synthesis feed gas from the facility will be used to test the unit beginning late this year. A liquid-fluidized (ebullated bed) mode and a liquid-entrained (slurry) mode will be tested. The PDU operation is supported by an extensive 42-month laboratory program, conducted principally at Chem Systems' labs, with a complementary research effort at Air Products. Chem Systems is providing technical management for the project. Air Products is providing overall program management and is responsible for engineering design, construction, and operation.

In the bench scale effort of the laboratory support program, new baseline data was established for gas phase and liquid phase methanol synthesis. CO conversion and methanol specific productivity in the liquid phase are comparable to the gas phase at matching conditions. Optimum in-situ reduction conditions for slurry powders have been identified which give performance very similar to gas phase reduction. Several commercial catalyst powders achieve acceptable liquid phase performance. Of the 28 new slurry catalysts prepared in this program, 3 have recently advanced from gas phase to liquid phase screening. Autoclave life tests were initially affected by the trace contaminants iron carbonyl and organic chloride; these are strong poisons of methanol synthesis catalysts. Tests in support of the LaPorte PDU design demonstrated that hot (350°C) alpha-alumina provided an effective guard bed against iron carbonyl. In the laboratory systems, ambient activated carbon has been effective. With strong guard measures in place, liquid phase life data from the autoclaves has been encouraging. CO-rich gas was run in the autoclave in excess of 1500 hours, and balanced gas in excess of 1000 hours. Activities were

stable with a very slow rate of decline. The slow liquid phase deactivation is less than expected for gas phase synthesis with dilute balanced gas.

In the Lab PDU effort, modifications to the Fairfield unit to allow either ebullated or slurry operation were completed. A second ebullated test was performed with an improved catalyst and with CO-rich gas. Catalyst activity maintenance over the 500 hour run was excellent but there is still an apparent catalyst attrition problem. Another catalyst candidate is presently under test. The first Lab PDU slurry run was recently accomplished with an 18 wt% loading. The early interpretation of the data suggests PDU performance similar to the autoclave (i.e., good mass transfer, mixing). With balanced gas at 1000 psig, 250°C, very high methanol specific productivities were achieved, up to 55 g mole/hr-kg = 1.8 kg/hr-kg at a space velocity of 22,000 l/kg-hr. Gas holdup at superficial gas velocities up to 0.23 ft/sec. appears to be lower than expected from cold flow tests.

In the fundamental modeling effort, the slurry reactor has been described as a back flow cell model. Intrinsic rate constants were back calculated from autoclave data. Mass transfer is calculated from the k_La correlation of Akita and Yoshida, using the gas holdup determined in cold flow tests. When applied to the recent Lab PDU slurry run, the model provides a remarkably good fit of the balanced gas data at both 1000 psig and 500 psig.

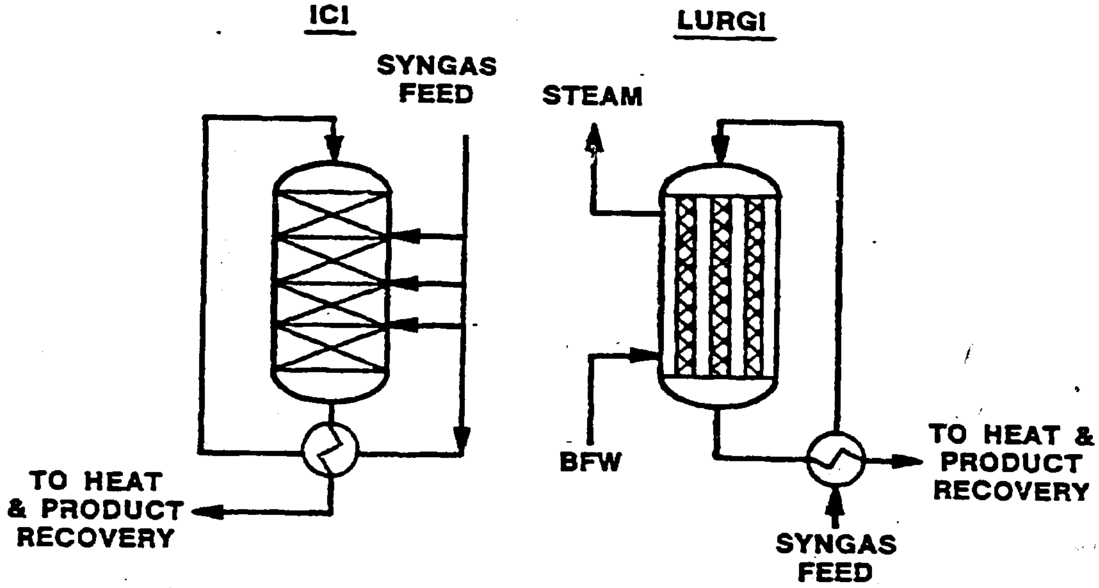
The LaPorte PDU engineering is now complete and intense activity is underway at the site. Mechanical work is 95% complete and instrument/electrical work is 60% along. Integrated shakedown will begin in November. The ebullated operating campaign will start in December, with the slurry mode to follow in the spring of 1984.

LIQUID PHASE METHANOL UPDATE

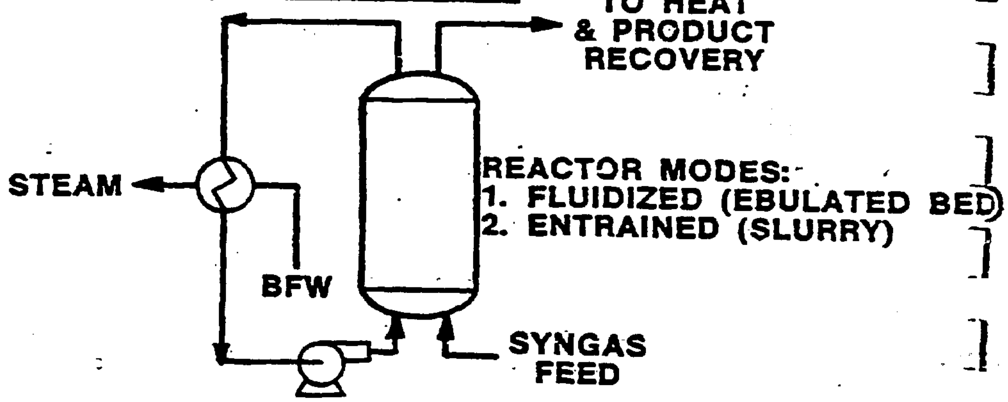
- INTRODUCTION
- TECHNICAL CHALLENGES
  - BENCH SCALE - RESULTS AND INTERPRETATION
  - LAB PDU - RESULTS AND INTERPRETATION
  - FUNDAMENTAL MODELING PROGRESS
- SUMMARY AND PERSPECTIVE
- LAPORTE PDU ENGINEERING STATUS

REACTOR SCHEMATICS

CONVENTIONAL MeOH REACTORS:



LPMeOH REACTOR:



LPMeOH TECHNICAL MOTIVATION

LIQUID, AGITATED MEDIUM

1. LARGE HEAT SINK TO CONTROL REACTION TEMPERATURE
2. POTENTIAL FOR BROADER CATALYST COMPOSITIONS (SLURRY)

- LOW TEMPERATURE RISE
- HIGH CONVERSION PER PASS
- LOW RECYCLE RATE
- POTENTIAL TO ACCEPT LOW H_2/CO FEED

APPLICATIONS

1. METHANOL + FUEL GAS (COAL GASIF. COMBINED CYCLE)
2. ALL-METHANOL

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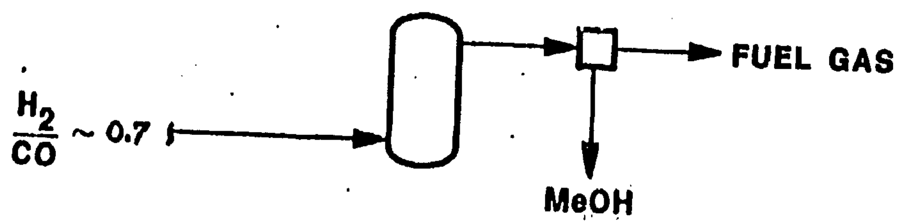
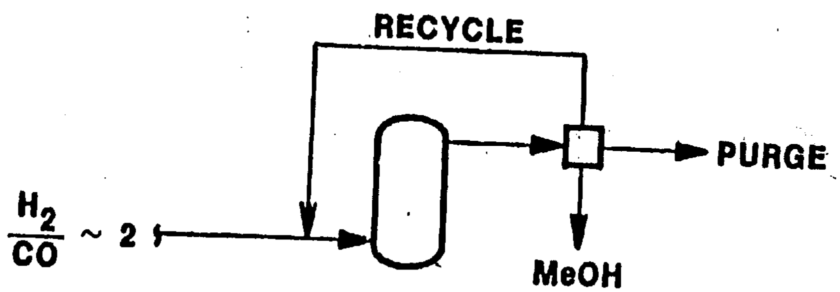
2. ALL-METHANOL



1. SINGLE PASS LPMeOH W. CGCC POWER
   - NO SHIFT
   - NO CO_2 REMOV.



2. CONVENTIONAL MeOH SYNTHESIS

LPMeOH PROJECT DESCRIPTION

OBJECTIVE

- DEMONSTRATE TECHNICAL FEASIBILITY OF LPMeOH PROCESS AT PDU SCALE

  ~ 1 MM SCFD
  ~ 5 TPD MeOH

STRATEGY

- UTILIZE EXISTING CHICAGO LPM PDU (LIQUID-FLUIDIZED)
- RELOCATE, REFURBISH, INSTALL AT LAPORTE SYNGAS FACILITY
- OPERATE LIQUID-FLUIDIZED (EBULLATED BED) MODE
- CONCURRENT WITH ABOVE, DEVELOP NEW CATALYSTS/ DATA BASE FOR LIQUID-ENTRAINED (SLURRY) MODE
- MODIFY PDU FOR LIQUID-ENTRAINED OPERATION
- OPERATE LIQUID-ENTRAINED (SLURRY) MODE

LPMeOH PROJECT DESCRIPTION (CONT.)

DURATION

- 42 MONTHS (1 OCTOBER 1981 – 1 APRIL 1985)

PARTICIPANTS

- DOE
- AIR PRODUCTS
- CHEM SYSTEMS
- EPRI
- FLUOR

LAPORTE LPMeOH PDU PRINCIPAL FEED GAS COMPOSITIONS

(TEXACO GASIFIER)

METHANOL + FUEL GAS COPRODUCTS

	UNBALANCED TYPE REACTOR FEED
H_2	34.8 MOLE %
CO	51.2
CO_2	13.1
CH_4, C_2H_6	0.1
N_2, Ar, INERTS	0.8
TOTAL	100.0
H_2/CO	0.68
$\frac{H_2}{(CO+1.5CO_2)}$	0.49
$\frac{(H_2-CO_2)}{(CO+CO_2)}$	0.34

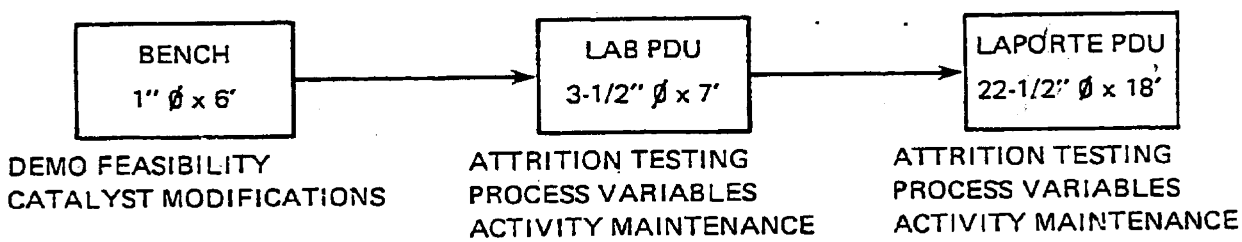
LAPORTE LPMeOH PDU PRINCIPAL FEED GAS COMPOSITIONS (CONT.)

ALL-METHANOL PRODUCTS

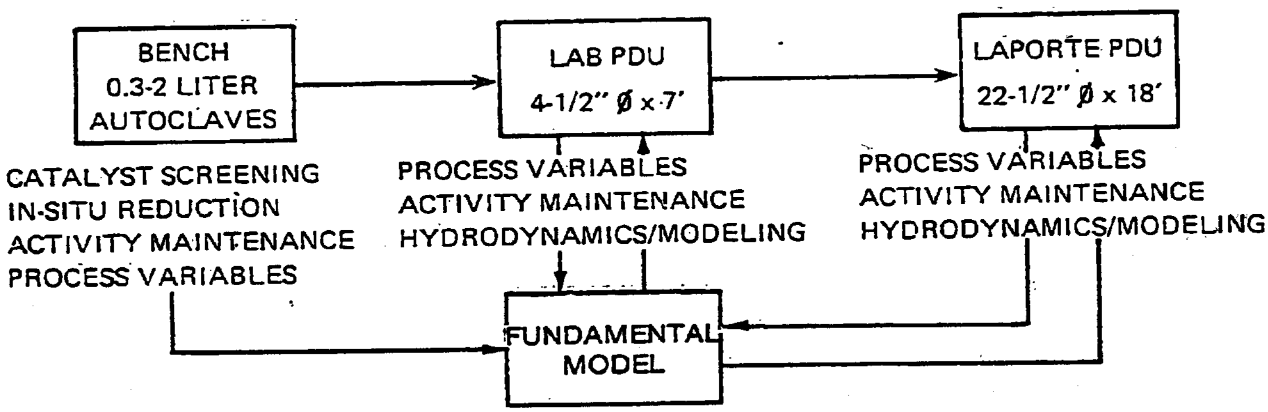
	SHIFTED FRESH FEED	BALANCED TYPE REACTOR FEED
H_2	66.4 MOLE %	54.9 MOLE %
CO	30.7	18.8
CO_2	2.0	4.9
CH_4,C_2H_6	0.1	2.1
N_2, Ar, INERTS	0.8	19.3
TOTAL	100.0	100.0
H_2/CO	2.16	2.92
$\frac{H_2}{(CO+1.5CO_2)}$	1. 97	2.10
$\frac{(H_2-CO_2)}{(CO+CO_2)}$	1.97	2.11

LPMeOH TECHNOLOGY DEVELOPMENT

LIQUID-FLUIDIZED (EBULLATED BED) REACTOR 1975-1983



LIQUID-ENTRAINED (SLURRY) REACTOR 1979-1983



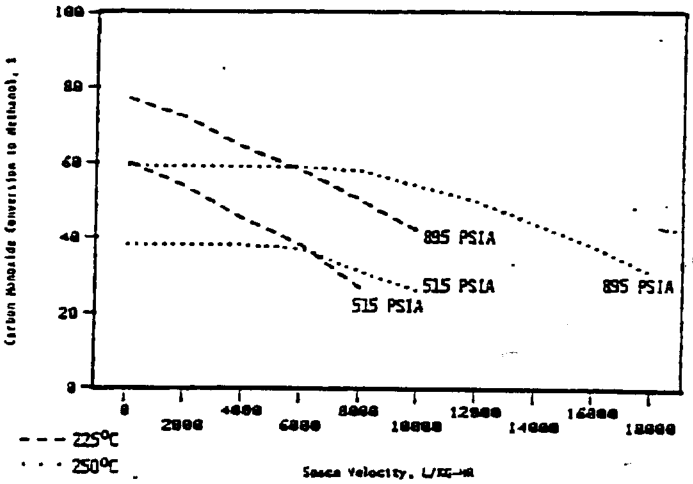
LABORATORY AUTOCLAVE PROGRAM

OBJECTIVE:

- EXPLOIT SLURRY SYSTEM ON CATALYST ACTIVITY, SELECTIVITY, LIFE ISSUES
- COMPARE GAS PHASE TO LIQUID PHASE OPERATION
- SCREEN COMMERCIAL CATALYSTS
- SCREEN NEW EXPLORATORY CATALYSTS
- OPTIMIZE REDUCTION TECHNIQUES
- CONDUCT PROCESS VARIABLE SCANS AND LIFE TESTS
- USE DATA TO MODEL PROCESS

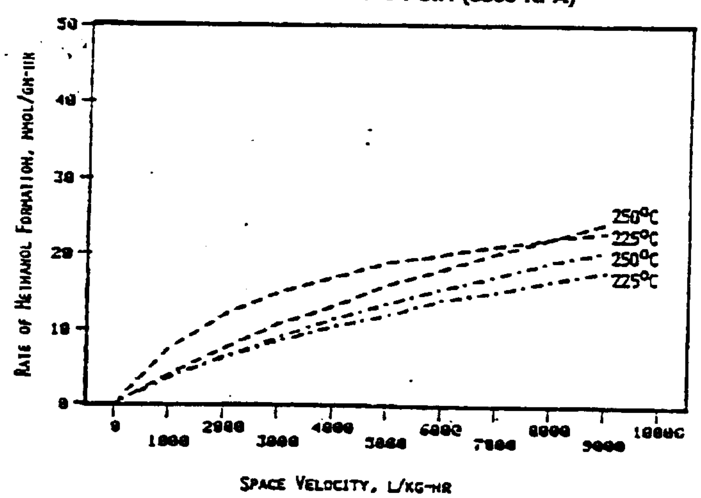
CATALYST ACTIVITY IN APCI GAS PHASE SCREENING REACTOR

FEED GAS = 55% H_2/19% CO/5% CO_2/N_2
CATALYST = F50/4E75-01
REACTOR LOAD = 3 gm (AS OXIDE)

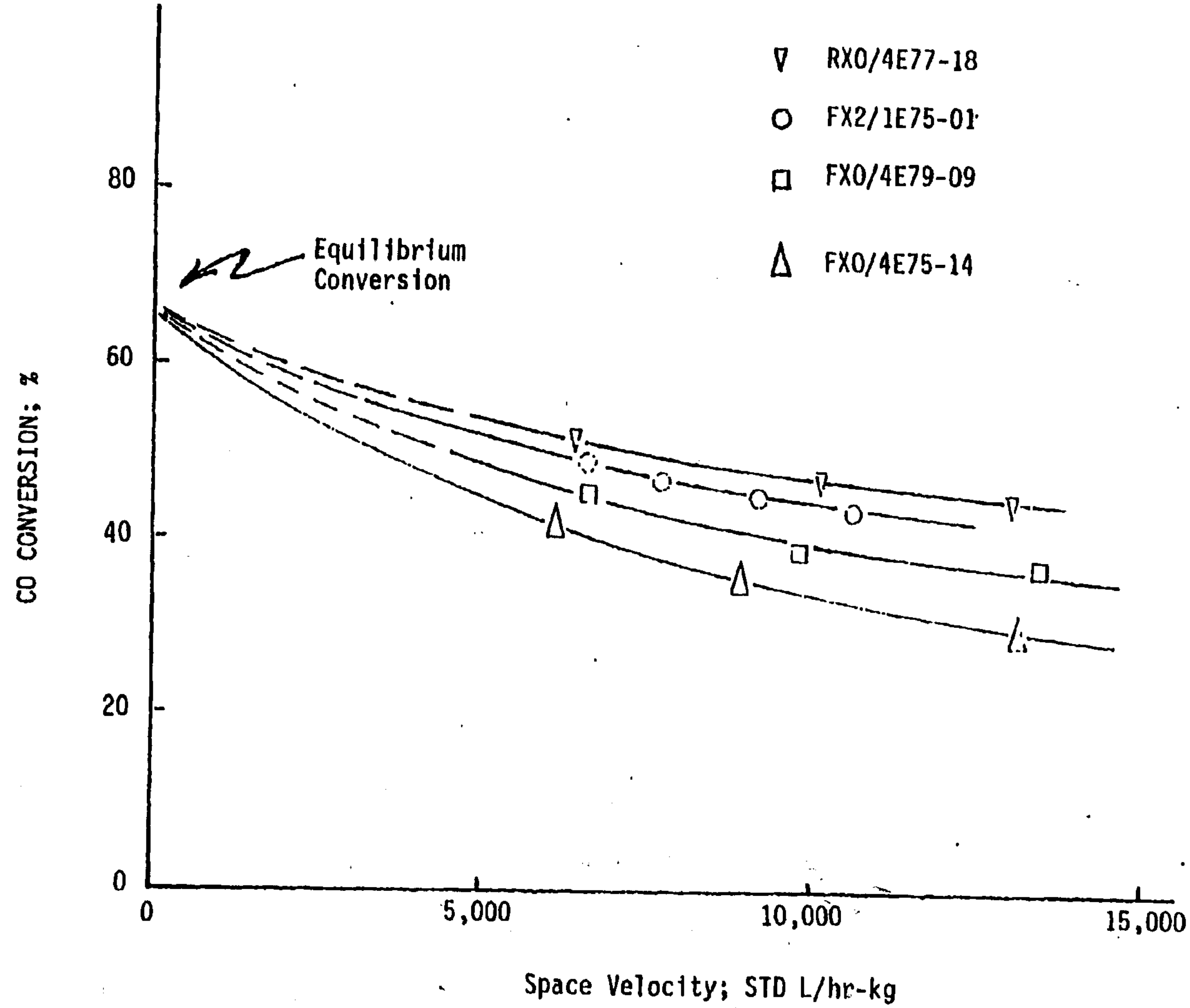


EFFECT OF GAS COMPOSITION APCI GAS PHASE SCREENING REACTOR

——FEED GAS = 55% H_2/19% CO/5% CO_2/N_2
-·-—FEED GAS = 35% H_2/50% CO/13% CO_2/N_2
CATALYST = F50/4E75-01
PRESSURE = 515 PSIA (3500 KPA)



CO CONVERSION VS. S. ACE VELOCITY – BALANCED GAS AT 250°C; 7000 kPa IN FREEZENE-100



SOME NEW APCI LPMeOH CATALYST POWDERS

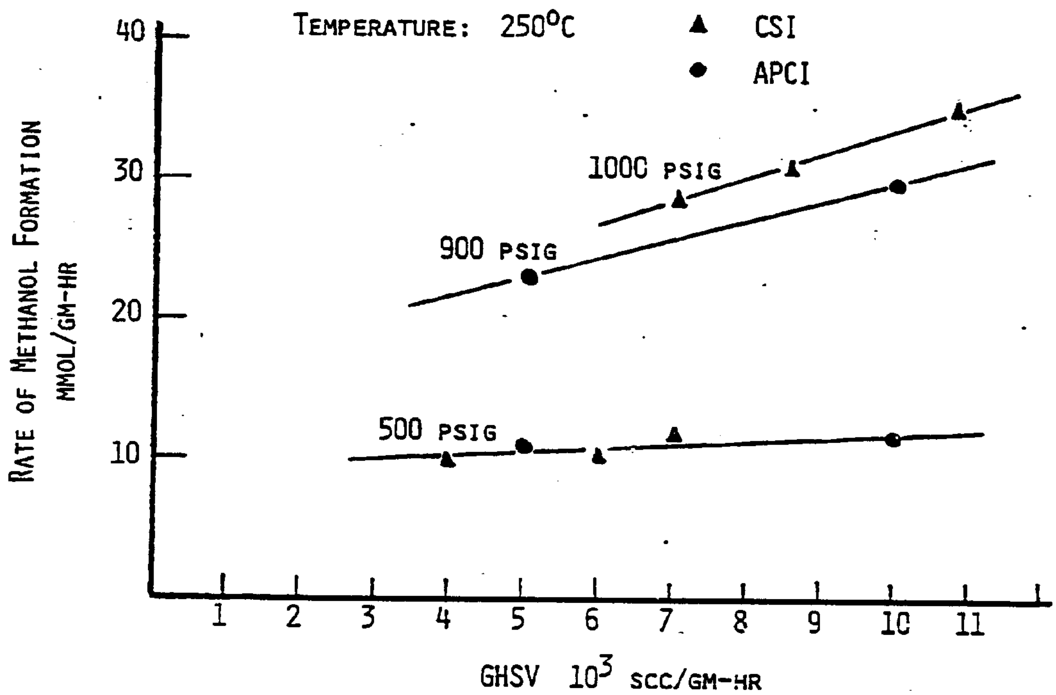
CATALYST PREP NO.	COMPOSITION	MeOH YIELD*, m.mol/gm-hr
ICI Commercial	$Cu/Zn/Al_2O_3$	18.6
66	$Cu/Zn/Al_2O_3$ (Stiles)	14.6
56	$Cu/Zn/Cr_2O_3$	Nil
50	Cu/Zn (Binary)	0.7
60	Cu/Zn/Boron	7.8
63	Cu-Zn-Al Raney (stored)	1.0
75	Cu-Zn/Al Raney (fresh)	6.0
70	Ni-Boride	0.05 (25.8 CH_4)

*Gas-Phase Screening @ 500 psig, 225°C, 5000 l/hr-kg,
Balanced Gas: 55% H_2, 19% CO, 5% CO_2, 21% N_2

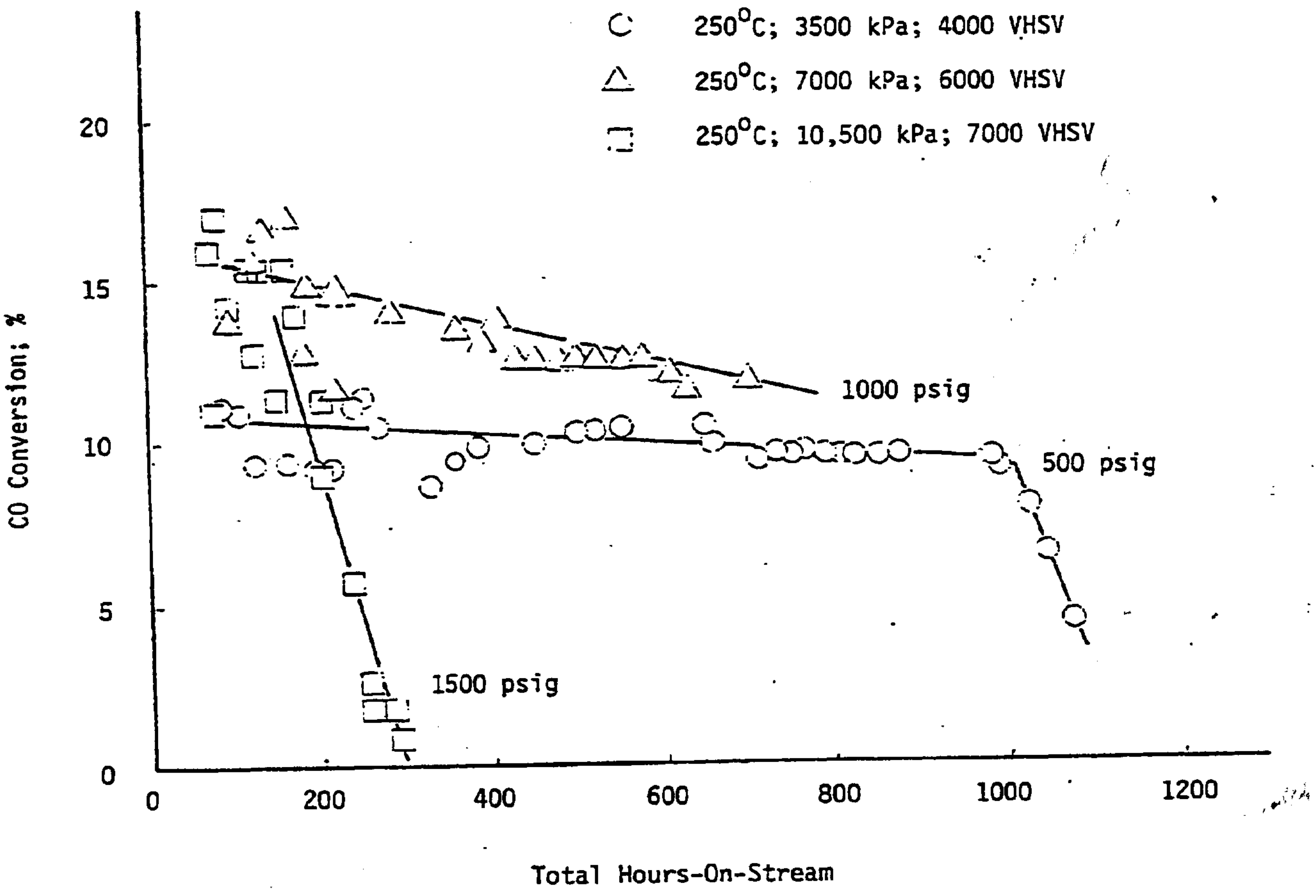
APCI STIRRED AUTOCLAVE

CROSS-CHECK WITH CSI AUTOCLAVE:

- SAME BASELINE COMMERCIAL CATALYST (F50/4E75)
- GAS PHASE REDUCTION
- BALANCED GAS, 55% H_2/ 19% CO/5% CO_2/21% N_2
- 15 WT% SOLIDS
- 30 DAYS OPERATION



CO Conversion Vs. Total Hours on Stream for Catalyst F50/4E75-01; In-Situ Reduction in Freezene-100



CARBONYLS AT LAPORTE

- CONCERN WITH CO RICH GAS (UNBALANCED CASE)

  $Fe + 5CO \rightleftarrows Fe(CO)_5$

  $Ni + 4CO \rightleftarrows Ni(CO)_4$

- POTENTIAL IMPACT
  - LINE CORROSION
  - CATALYST POISONING

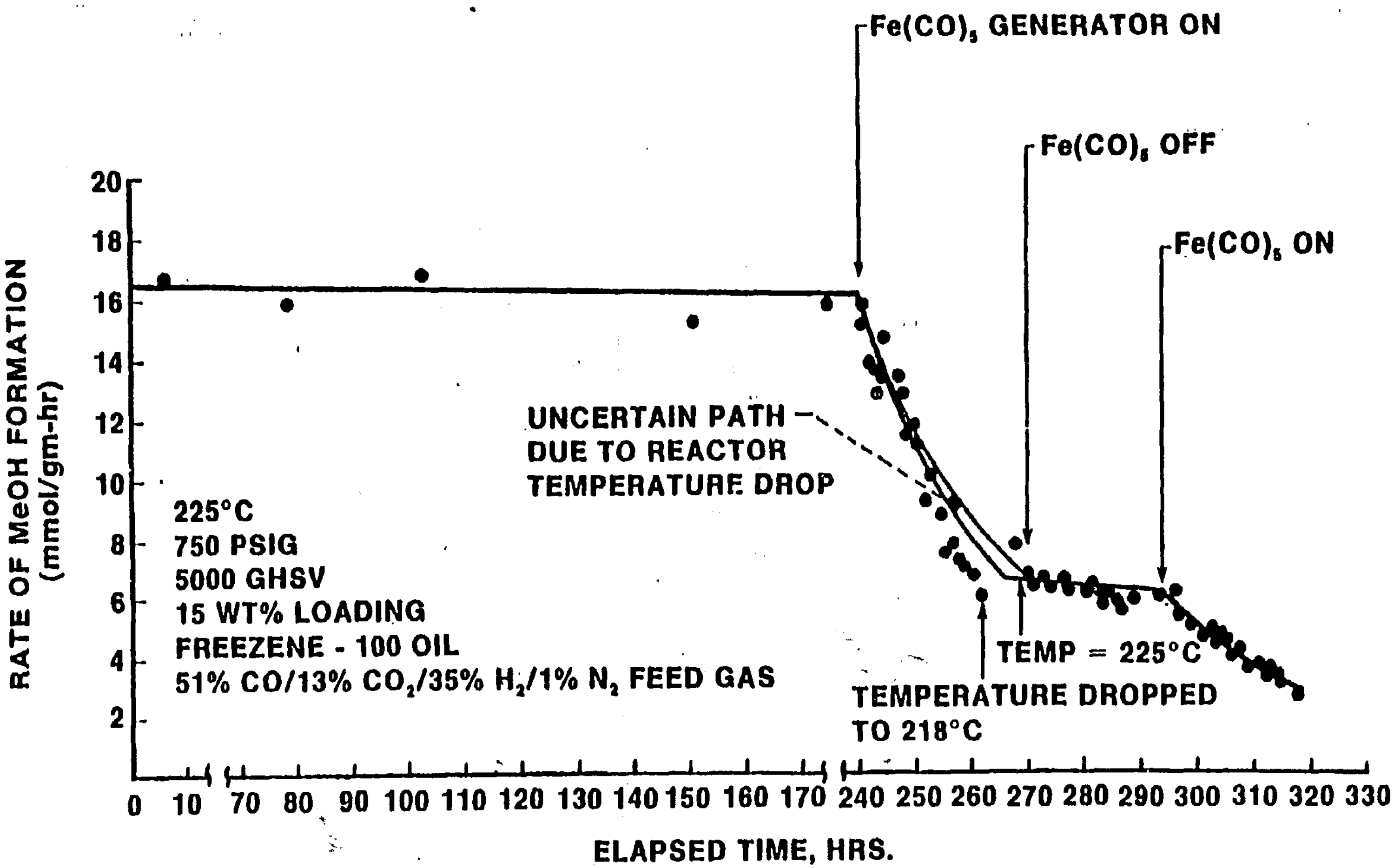
<u>INDUSTRIAL EXPERIENCE</u>

LIMITED TO GAS PHASE SYNTHESIS

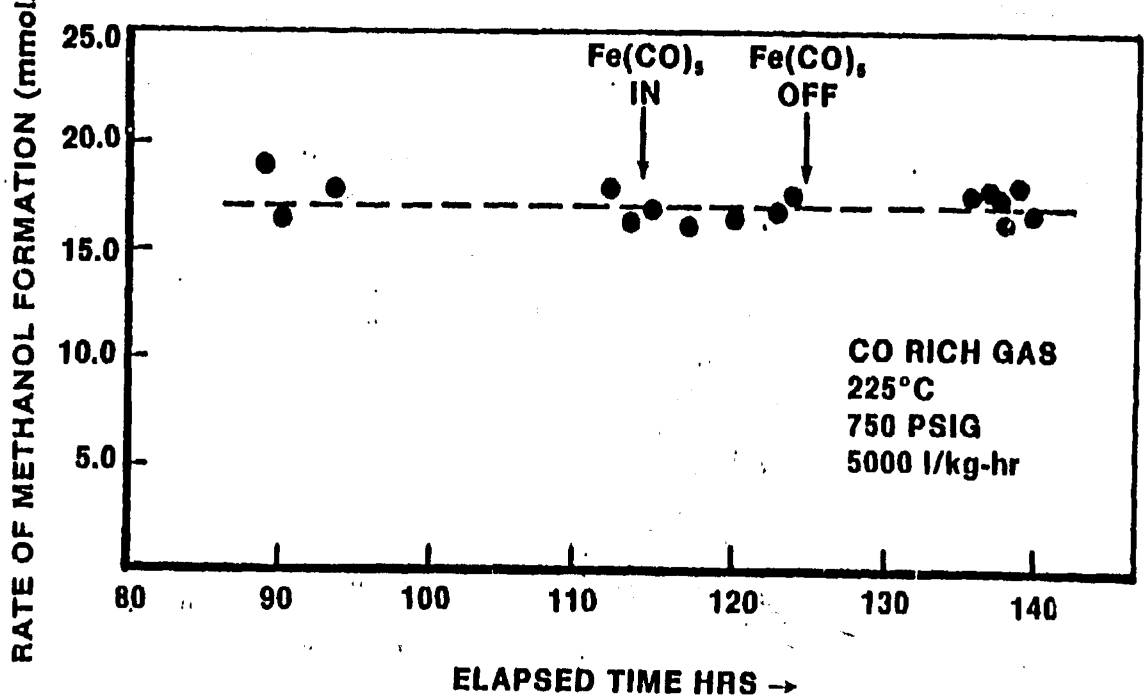
SIGNIFICANT IN HIGH PRESSURE MeOH
- CATALYST DEACTIVATION
- METHANATION

CORRECTIVE ACTION
- IMPROVED STEELS/COPPER LINING
- ACTIVATED CARBON
- MAINTAIN HIGH CO STREAMS AT T°F WHERE 200° > T > 600°

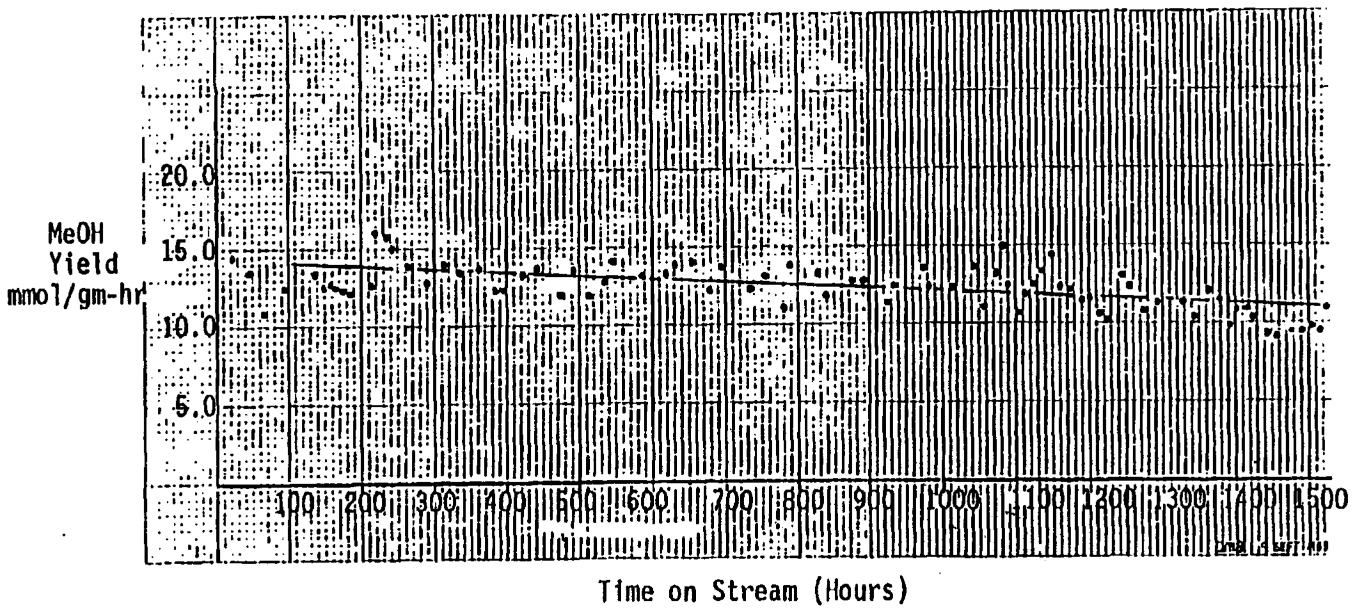
CATALYST POISONING STUDIES: EFFECT OF $Fe(CO)_5$ COMMERCIAL CATALYST



CATALYST POISONING BY Fe $(CO)_5$: EFFECT OF α– ALUMINA GUARD BED



MeOH PRODUCTIVITY WITH TIME
CSI AUTOCLAVE: CO-RICH, 250°C, 750 PSIG, 15 WT% ___ CATALYST

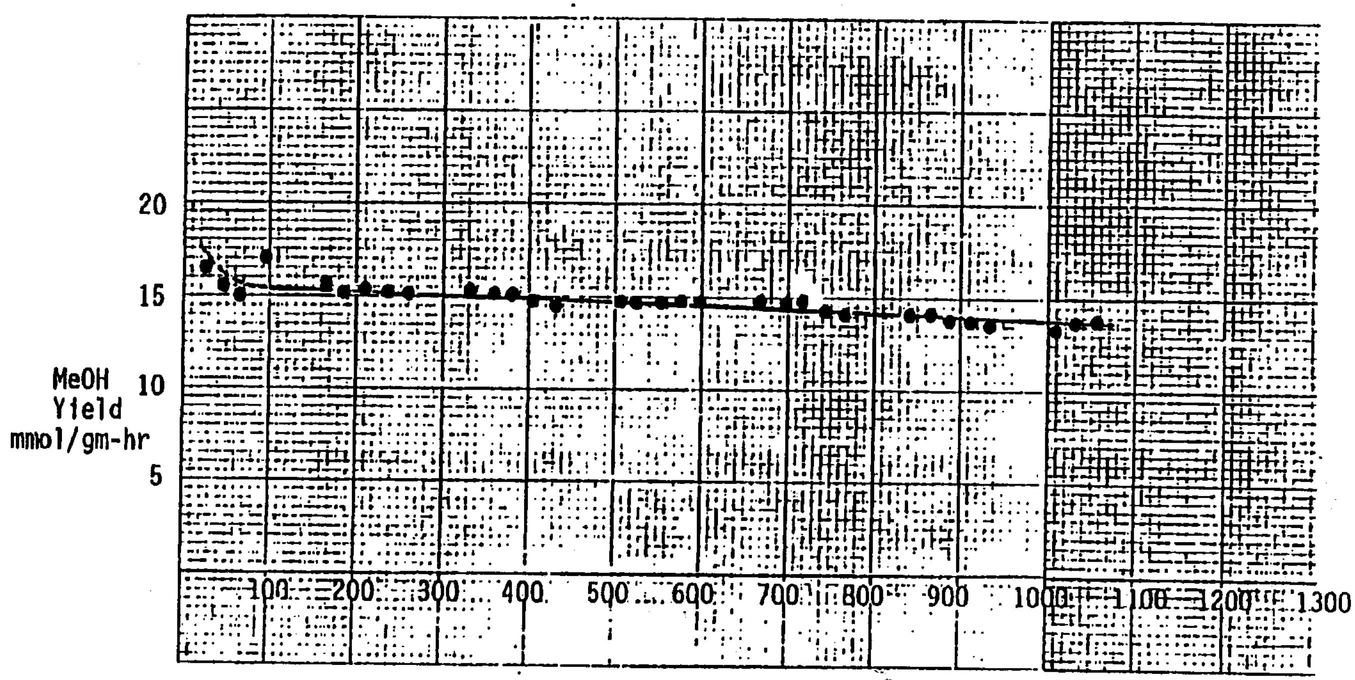


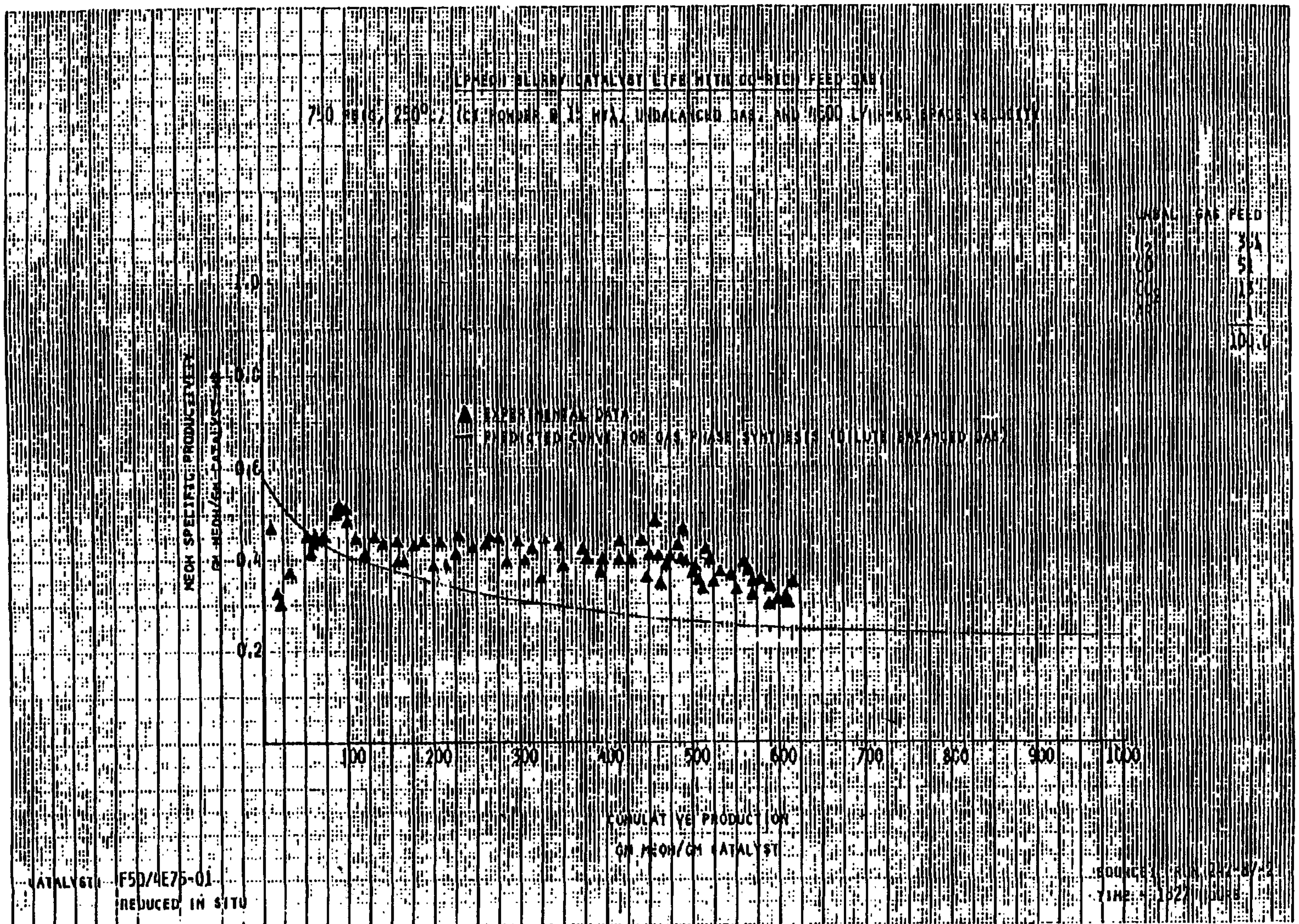
LIQUID PHASE

Balanced Gas: 15 wt% F50/4E75-01

$250^{o}C$, 750 psig, 5000 GHSV

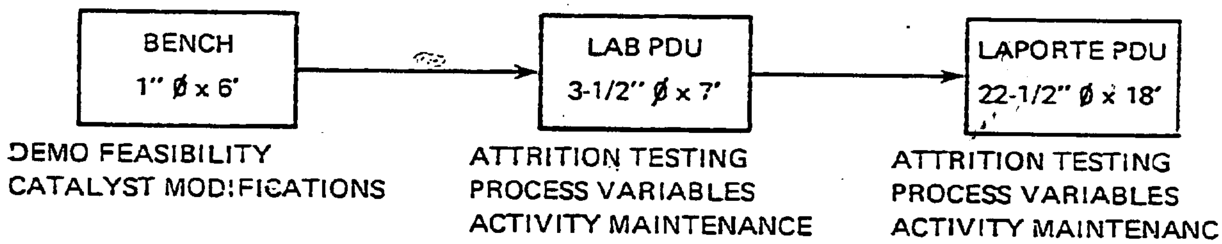
Methanol Productivity with Time



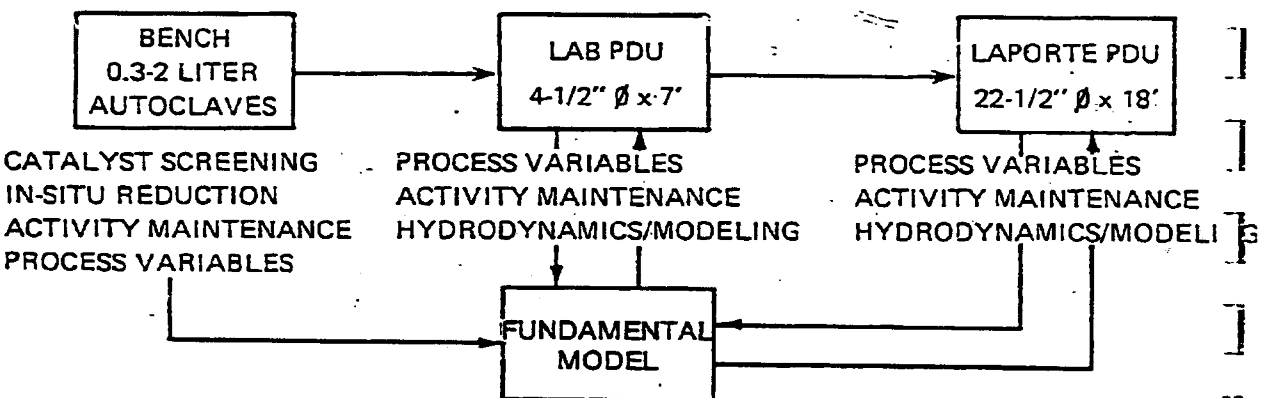

UNBALANCED GAS
EXPERIMENTAL DATA
PREDICTED CURVE FOR GAS PHASE SYNTHESIS (DILUTE BALANCED GAS)
MEOH SPECIFIC PRODUCTIVITY
1.0
0.8
0.6
0.4
0.2
100
200
300
400
500
600
700
800
900
1000
CUMULATIVE PRODUCTION
GM MEOH/GM CATALYST
GAS FEED
100.0
CATALYST: F50/4E75-01
REDUCED IN SITU
PSU

LPMeOH TECHNOLOGY DEVELOPMENT

LIQUID-FLUIDIZED (EBULLATED BED) REACTOR 1975-1983



LIQUID-ENTRAINED (SLURRY) REACTOR 1979-1983

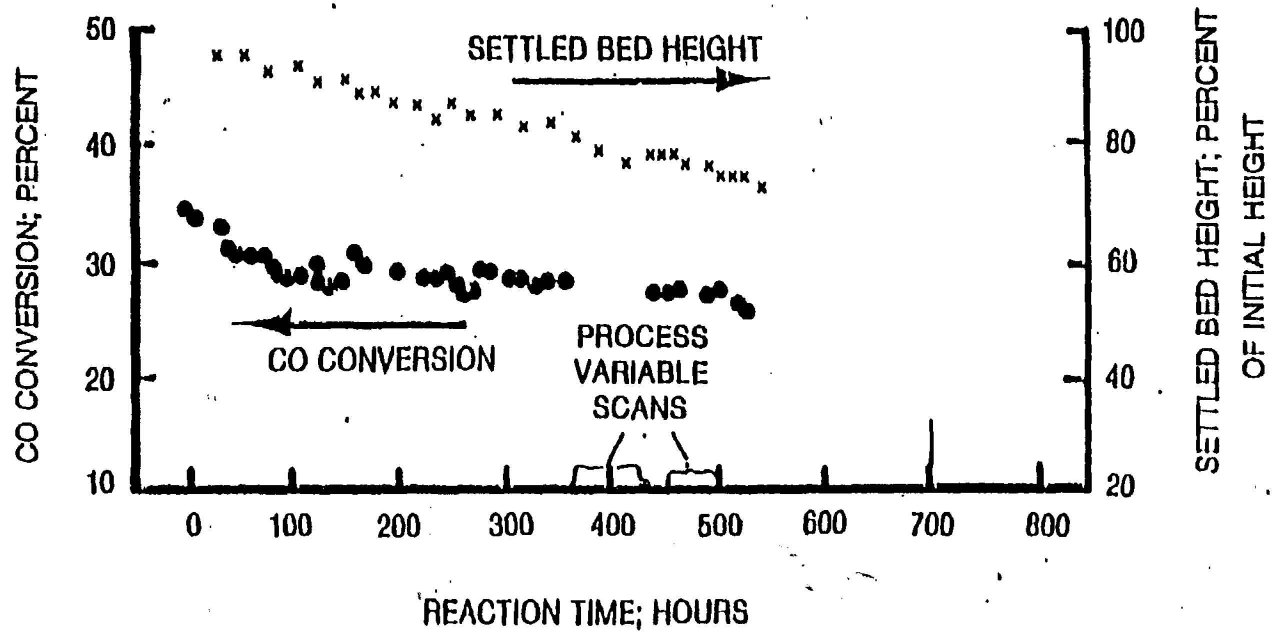


OBJECTIVES OF LAB PDU PROGRAM

- DEMONSTRATE EBULLATED AND SLURRY MODES AT A SCALE INTERMEDIATE TO LAPORTE
  - EBULLATED FACES CATALYST ATTRITION AND ACTIVITY ISSUES
  - SLURRY FACES CATALYST LOADING AND ACTIVITY ISSUES

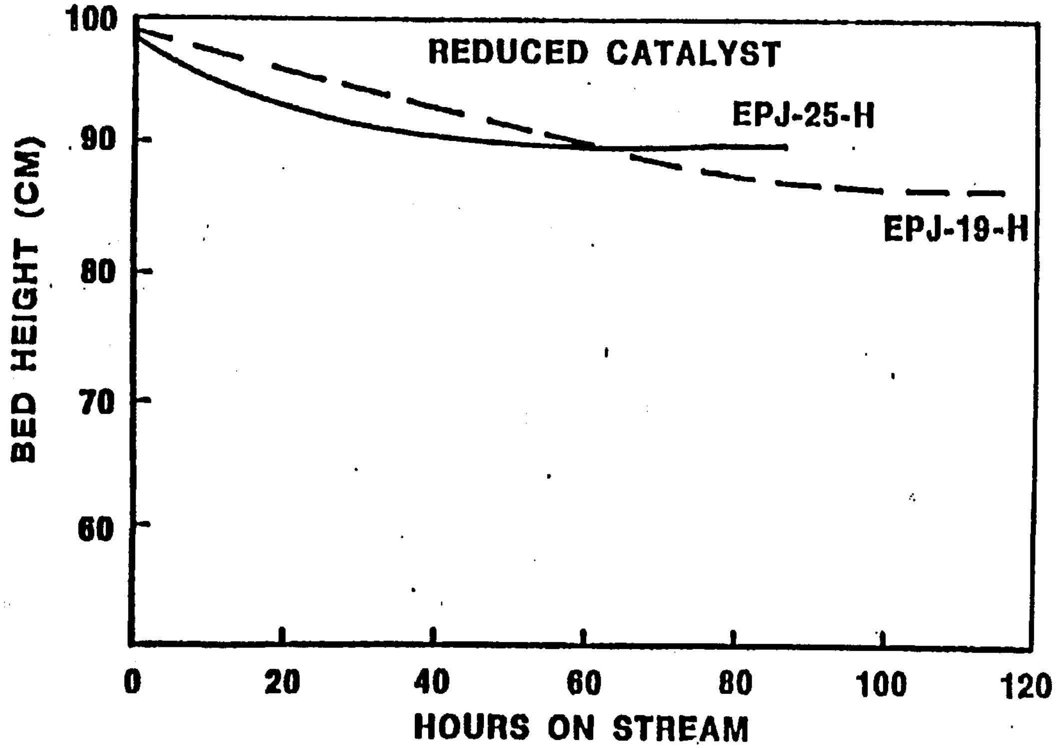
CATALYST ACTIVITY AND ATTRITION IN CSI LIQUID-FLUIDIZED LAB PDU

2/1 H_2/CO FEED GAS WITH 10% CO_2
250°C, 7000 kPa
3000 L/HR. - Kg CAT APPARENT SPACE VELOCITY
3.8 CM/SEC. SUPERFICIAL LIQUID VELOCITY



HRI COLD-FLOW TESTS

WET SETTLED BED HEIGHT COMPARISON

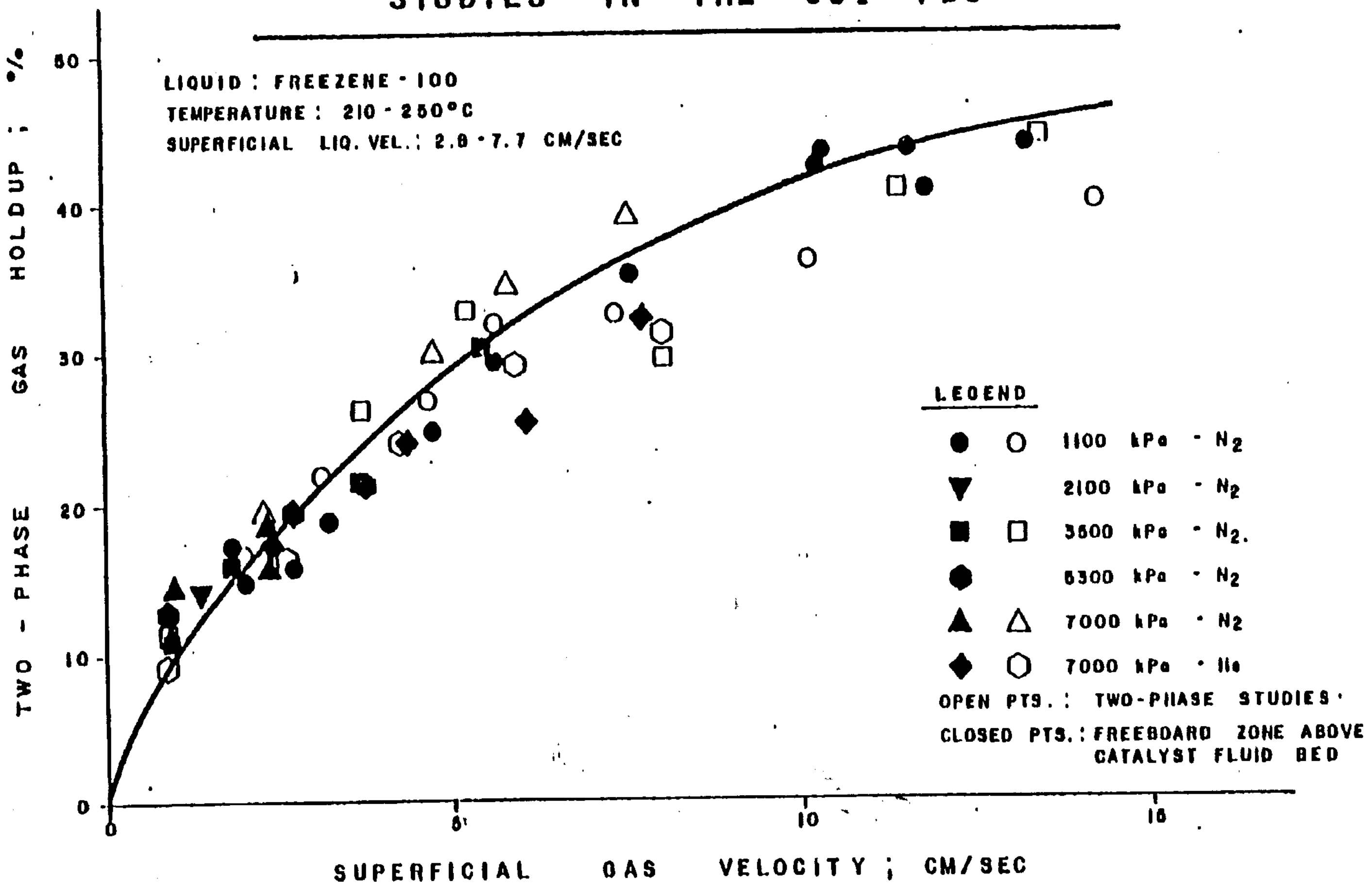


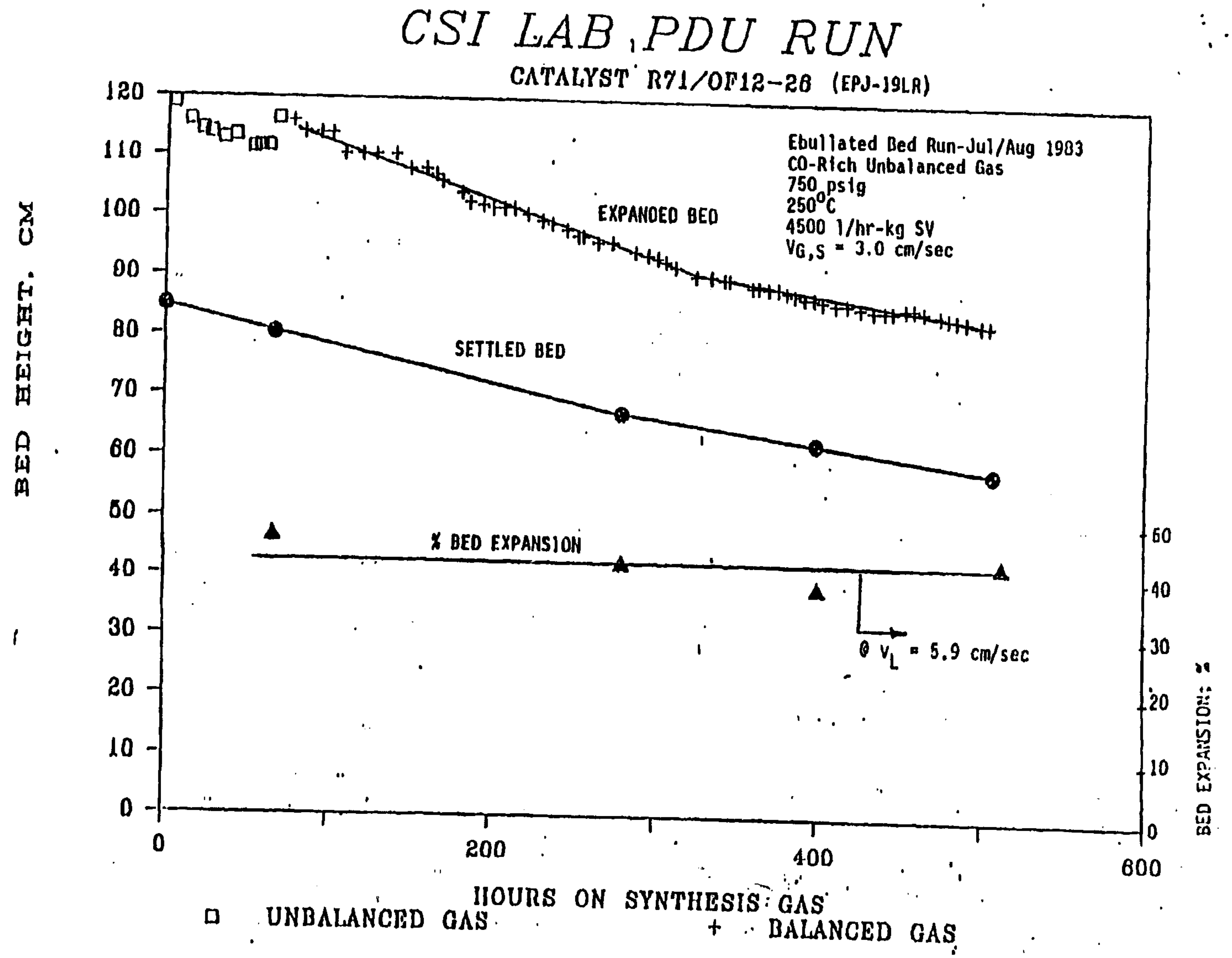
HRI COLD-FLOW TESTS ON EBULLATED CATALYST CANDIDATES

CONCLUSIONS : EPJ 19-H AND EPJ 25-H

- COMPARABLE AND ACCEPTABLE ATTRITION RATES
  0.5 WT% PER DAY
- FINES GENERATION PREDOMINATE
  LOW STEADY STATE CARRYOVER RATE
- UNIFORM BED DENSITY FOR 19-H
  SLIGHT DENSITY GRADIENT FOR 25-H
- DECREASE IN CATALYST LENGTH SEEN
  NO CHANGE IN DIAMETER

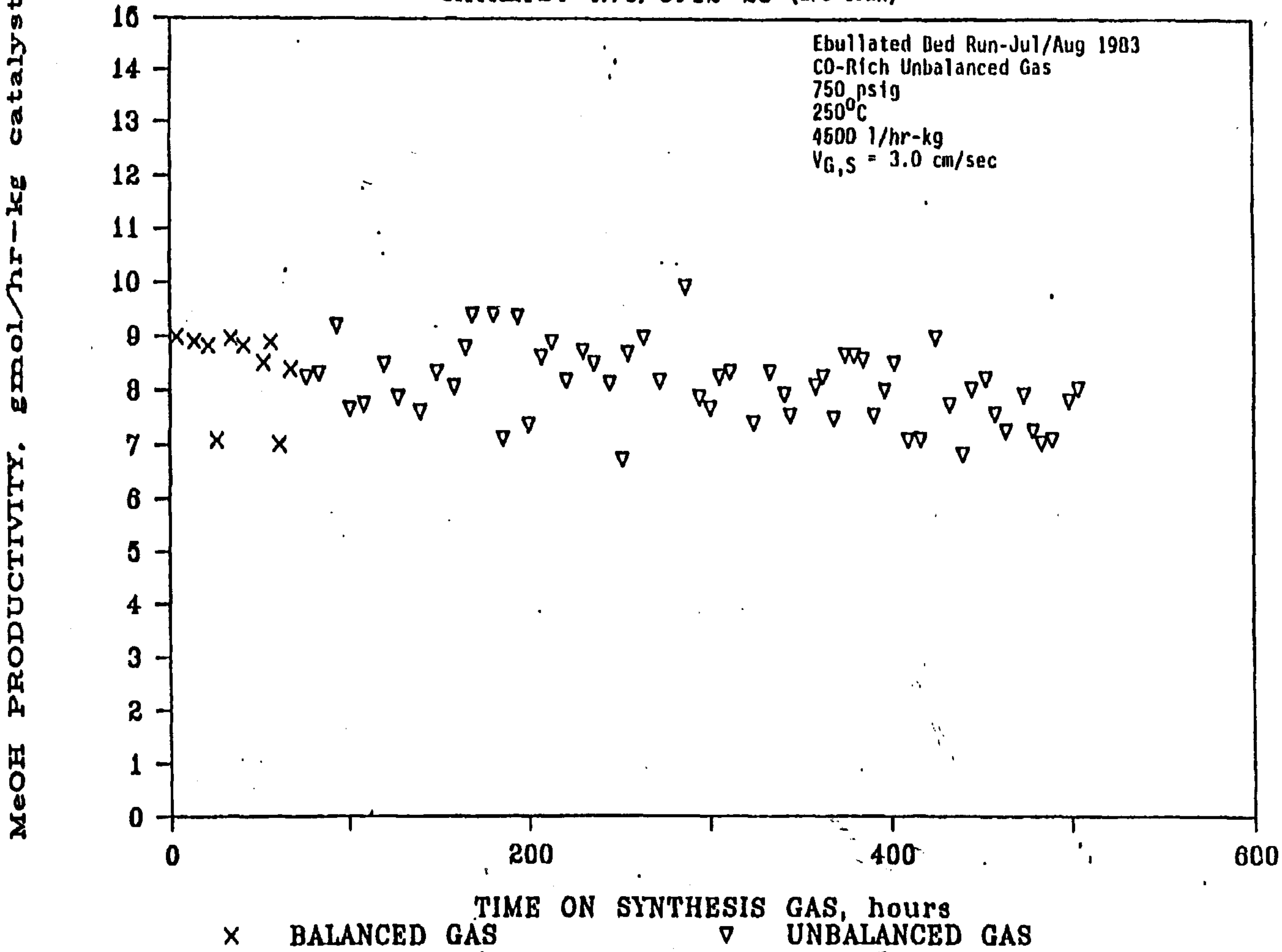
GAS HOLDUP DATA DURING EXPANSION STUDIES IN THE CSI PDU

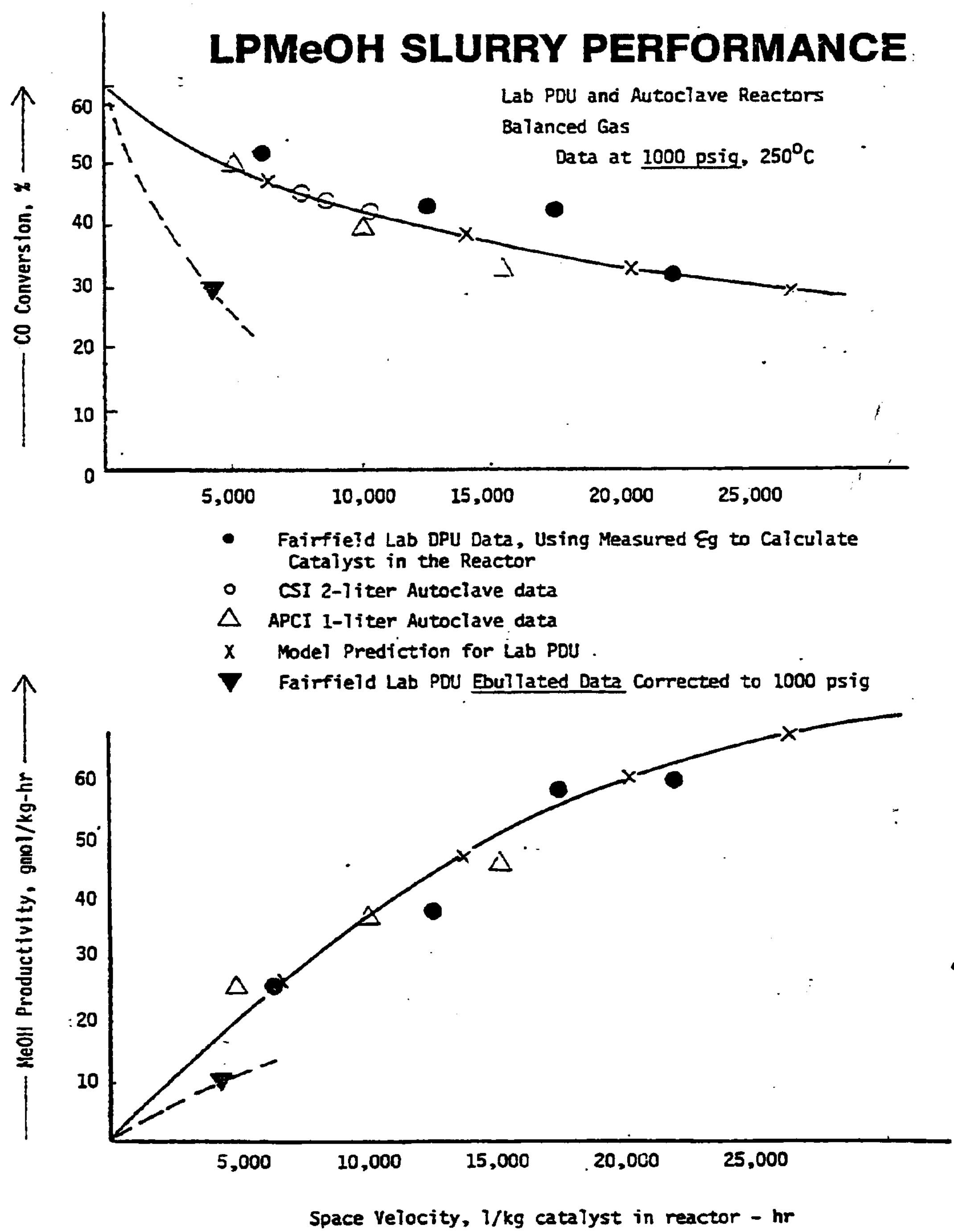



CSI LAB PDU RUN
CATALYST R71/OF12-26 (EPJ-19LR)
Ebullated Bed Run-Jul/Aug 1983
CO-Rich Unbalanced Gas
750 psig
250°C
4500 l/hr-kg SV
VG,S = 3.0 cm/sec
EXPANDED BED
SETTLED BED
% BED EXPANSION
@ VL = 5.9 cm/sec
BED HEIGHT, CM
BED EXPANSION, %
HOURS ON SYNTHESIS GAS
□ UNBALANCED GAS
+ BALANCED GAS
0
200
400
600
0
10
20
30
40
50
60
70
80
90
100
110
120

LAPORTE BATCH CHECK IN CSI LAB PDU

CATALYST R71/OF12-26 (EPJ-19LR)





LPMeOH SLURRY PERFORMANCE
Lab PDU and Autoclave Reactors
Balanced Gas
Data at 1000 psig, 250°C
CO Conversion, %
60
50
40
30
20
10
0
5,000
10,000
15,000
20,000
25,000
● Fairfield Lab DPU Data, Using Measured Єg to Calculate Catalyst in the Reactor
○ CSI 2-liter Autoclave data
△ APCI 1-liter Autoclave data
X Model Prediction for Lab PDU
▼ Fairfield Lab PDU Ebullated Data Corrected to 1000 psig
MeOH Productivity, gmol/kg-hr
60
50
40
30
20
10
5,000
10,000
15,000
20,000
25,000
Space Velocity, l/kg catalyst in reactor - hr

LAB PDU - PRELIMINARY CONCLUSIONS

- EBULLATED STILL HAS CATALYST ATTRITION QUESTION
- ACTIVITY MAINTENANCE IN EBULLATED LOOKS GOOD
- NO EVIDENCE OF MASS TRANSFER EFFECTS IN PDU

FURTHER LAB PDU

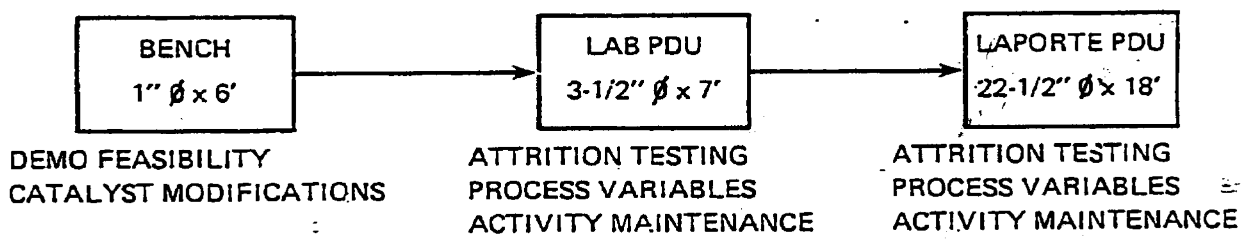
TEST OTHER EBULLATED CATALYST CANDIDATE

COMPLETE FURTHER SLURRY WORK

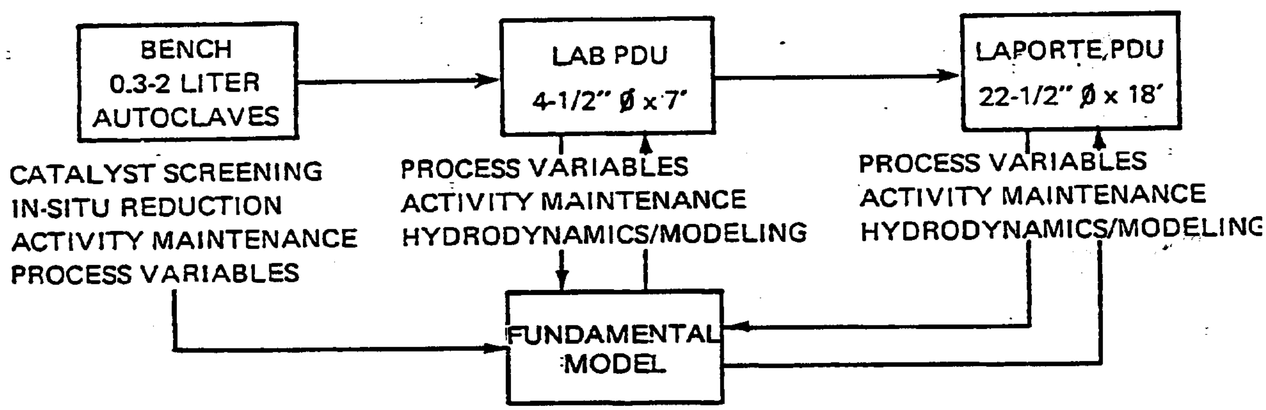
> MAXIMIZE THROUGHPUT
> MAXIMIZE SLURRY LOADING

LPMeOH TECHNOLOGY DEVELOPMENT

LIQUID-FLUIDIZED (EBULLATED BED) REACTOR 1975-1983



LIQUID-ENTRAINED (SLURRY) REACTOR 1979-1983



MODELING PROGRAM

GOAL:

CONSTRUCT A REALISTIC MATHEMATICAL MODEL WHICH ALLOWS PREDICTION OF REACTANT CONVERSION AND PRODUCT YIELD FOR A RANGE OF OPERATING CONDITIONS

APPLICATIONS:

- RECALCULATION OF PROCESS HEAT AND MATERIAL BALANCES
- ASSIST IN DEFINING OPERATING CONDITIONS FOR LAPORTE
- USE IN COMMERCIAL LP MeOH DESIGN STUDIES AND ONGOING ECONOMIC EVALUATIONS

SLURRY REACTOR MODEL

THREE PHASES, MIXING BETWEEN PLUG FLOW AND PERFECTLY MIXED

- DISPERSION MODEL – CLOSER TO PLUG FLOW
- TANKS IN SERIES MODEL – CLOSER TO PERFECT MIXING

LAPORTE REACTOR PROBABLY CLOSER TO PERFECT MIXING

REACTOR VOLUME V DIVIDED INTO N EQUAL TANKS WHERE

$$\frac{1}{N} = 2\left(\frac{D}{VL}\right) - 2\left(\frac{D}{VL}\right)^2 (1 - e^{-VL/D})$$

WHICH FOR LARGE DISPERSIONS $N \rightarrow VL/2D$

V = SUPERFICIAL VELOCITY

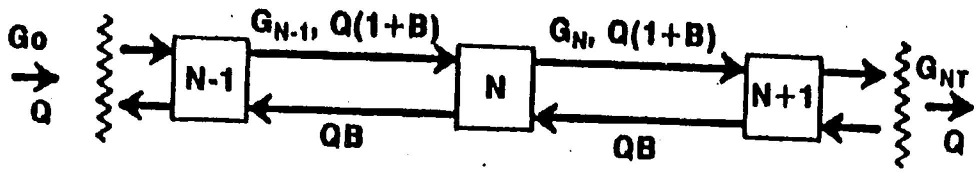
L = REACTOR LENGTH

D = DISPERSION COEFFICIENT

FOR MULTI-PHASE, NEED N FOR EACH PHASE

INTRODUCE BACKFLOW MODIFICATION

- USES A SINGLE NUMBER OF TANKS IN SERIES WITH N BASED ON THE LEAST DISPERSED PHASE
- MIXING OF OTHER PHASES DESCRIBED BY DIFFERENT DEGREES OF BACKFLOW, B

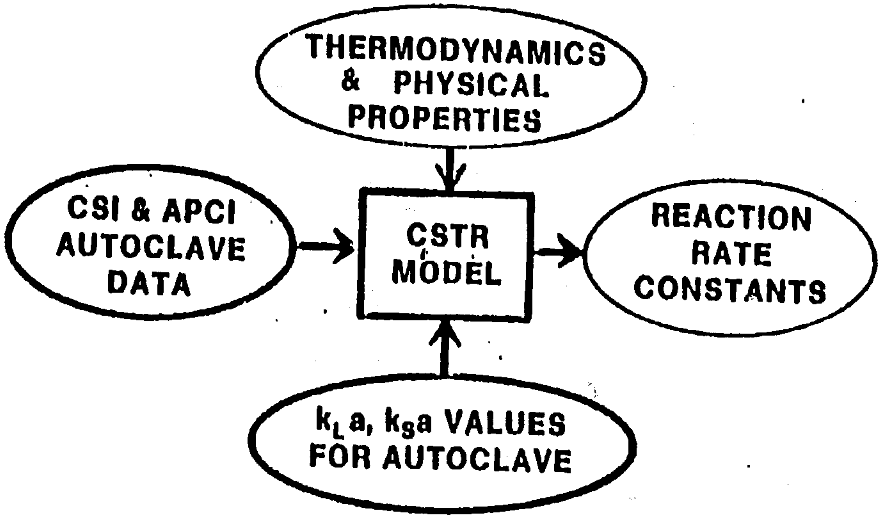


- CAN HAVE B FOR MORE THAN ONE PHASE, HENCE DESCRIBING DEGREES OF MIXING FOR ALL PHASES
- CURRENT MODEL DESCRIBES 7 TANKS IN SERIES WITH BACKFLOW RATIOS UP TO 10 AVAILABLE

REACTION RATE DATA

CSI & APCI AUTOCLAVES: ADVANCE FUNDED WORK, CURRENT DOE CONTRACT

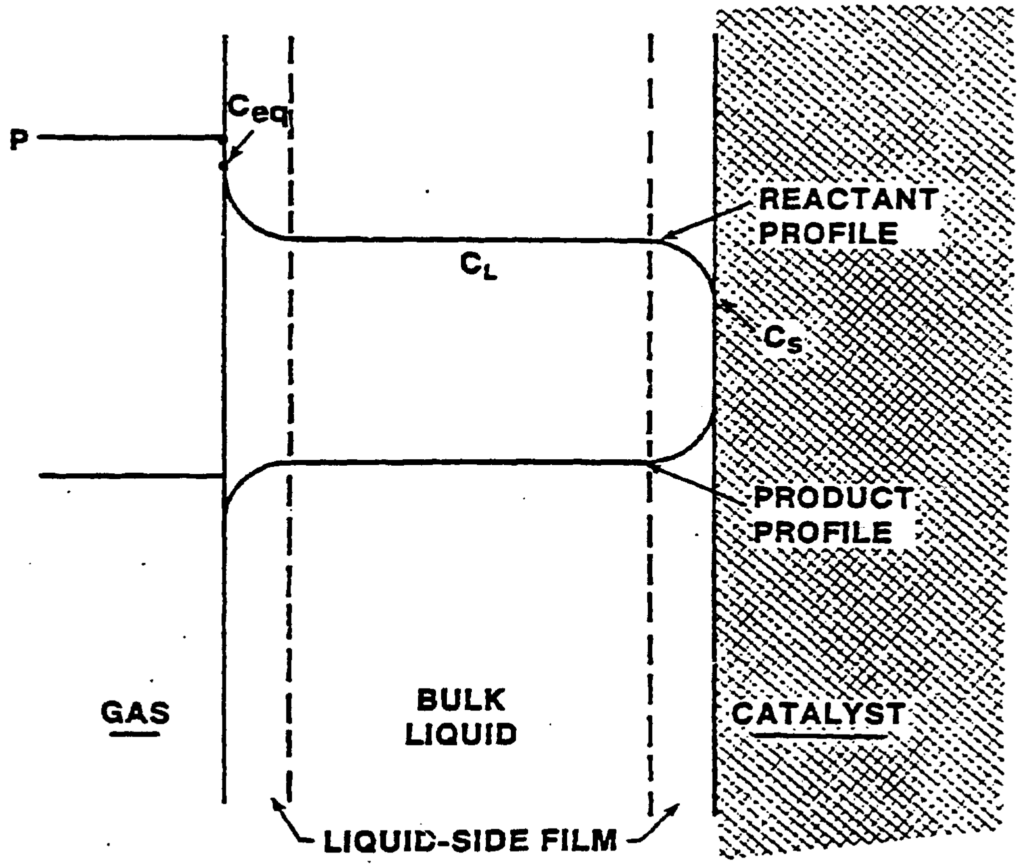
USE A CSTR MODEL TO DESCRIBE AUTOCLAVE OPERATION



ASSUMPTIONS

- WELL MIXED REACTOR
- NO INTRA PARTICLE DIFFUSION

CONCENTRATION PROFILES IN STIRRED AUTOCLAVE REACTOR



C_{eq} – LIQUID CONCENTRATION IN EQUILIBRIUM WITH GAS

C_L – BULK LIQUID CONCENTRATION

C_S = LIQUID CONCENTRATION AT CATALYST SURFACE

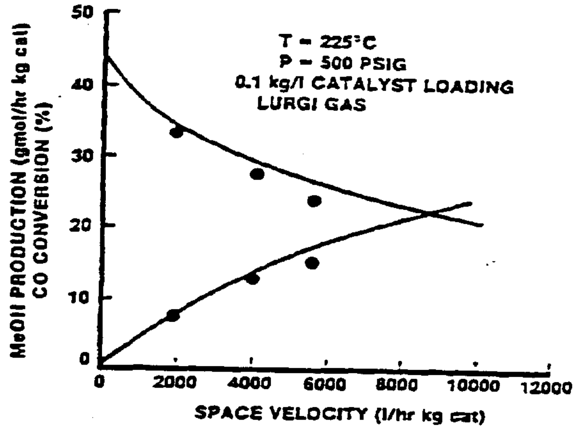
CALCULATION OF RATE CONSTANT

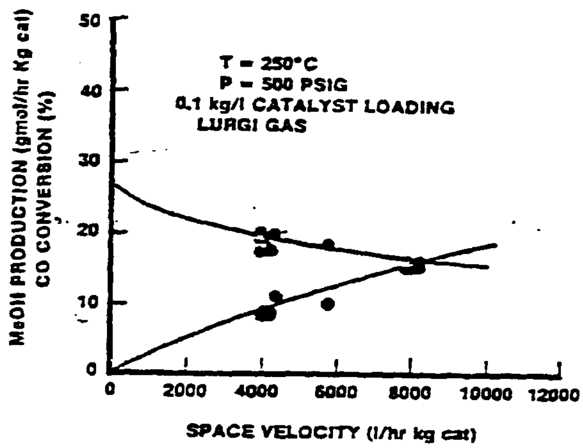
UNDER REACTION RATE CONTROL,

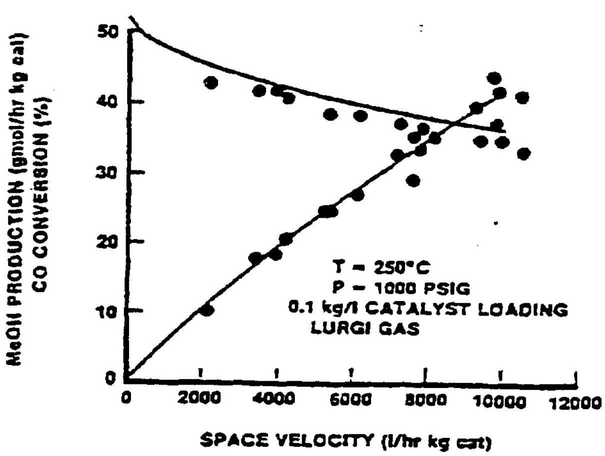
$$\text{RATE (MEASURED)} = k_L a\,(C_{eq} - C_L)$$
$$= k_S a\,(C_L - C_S)$$
$$= k_r W_C\,(C_S - C_{S_{eq}})$$

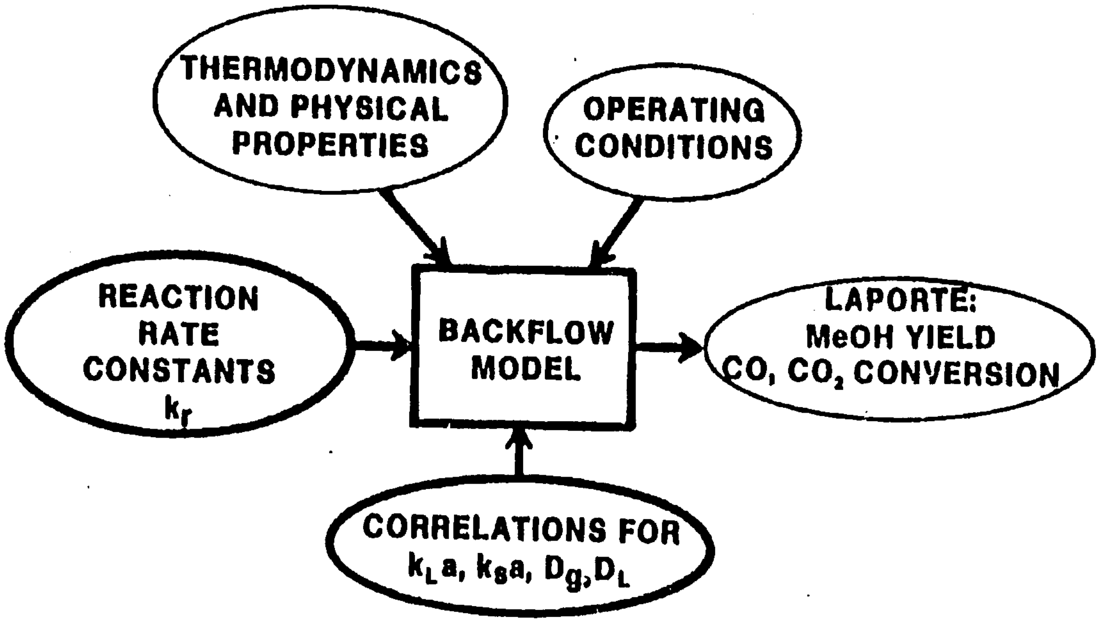
KNOWING $k_L a$, $k_S a$, A STEPWISE CALCULATION GIVES k_r

$k_S a$ CORRELATIONS AVAILABLE: NEED $k_L a$ DETERMINATION


T = 225°C
P = 500 PSIG
0.1 kg/l CATALYST LOADING
LURGI GAS
MeOH PRODUCTION (gmol/hr kg cat)
CO CONVERSION (%)
SPACE VELOCITY (l/hr kg cat)
0
10
20
30
40
50
2000
4000
6000
8000
10000
12000


T = 250°C
P = 500 PSIG
0.1 kg/l CATALYST LOADING
LURGI GAS
MeOH PRODUCTION (gmol/hr kg cat)
CO CONVERSION (%)
SPACE VELOCITY (l/hr kg cat)
0
10
20
30
40
50
2000
4000
6000
8000
10000
12000


T = 250°C
P = 1000 PSIG
0.1 kg/l CATALYST LOADING
LURGI GAS
MeOH PRODUCTION (gmol/hr kg cat)
CO CONVERSION (%)
SPACE VELOCITY (l/hr kg cat)
0
10
20
30
40
50
2000
4000
6000
8000
10000
12000



NEED

- REACTION RATE CONSTANTS
- MASS TRANSFER COEFFICIENTS

LAPORTE PDU : k_La DETERMINATION

CORRELATIONS USED:

- AKITA AND YOSHIDA (1973) FOR k_la:

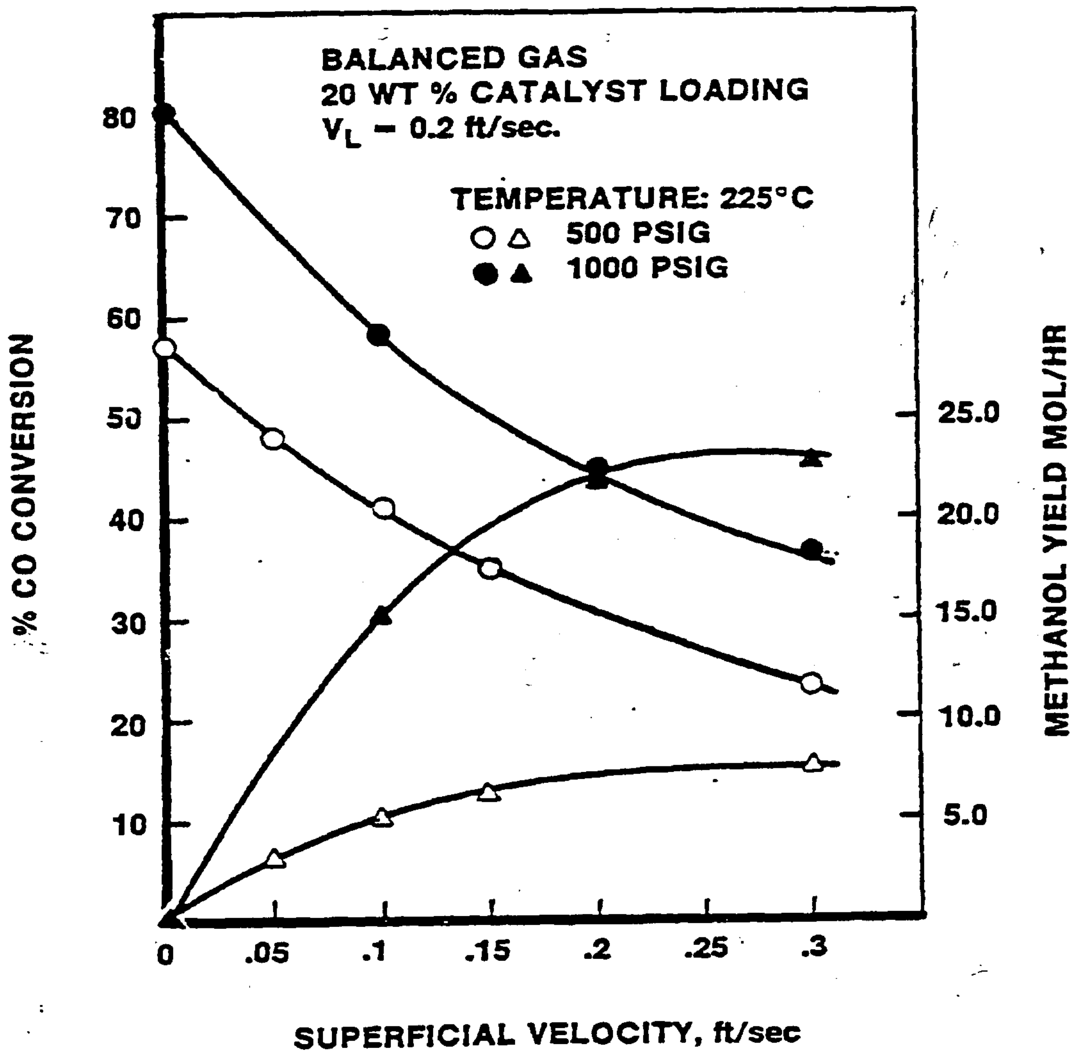
$$\frac{k_L a \cdot D_c^2}{D_i} = 0.6\left(\frac{\nu_L}{D_i}\right)^{0.5} \cdot \left(\frac{g\, D_c^2\, \rho_L}{\sigma}\right)^{0.62} \cdot \left(\frac{g\, D_c^3}{\nu_L^2}\right)^{0.31} \cdot (E_g)^{1.1}$$

- SANGER AND DECKWER (1981) FOR k_sa:

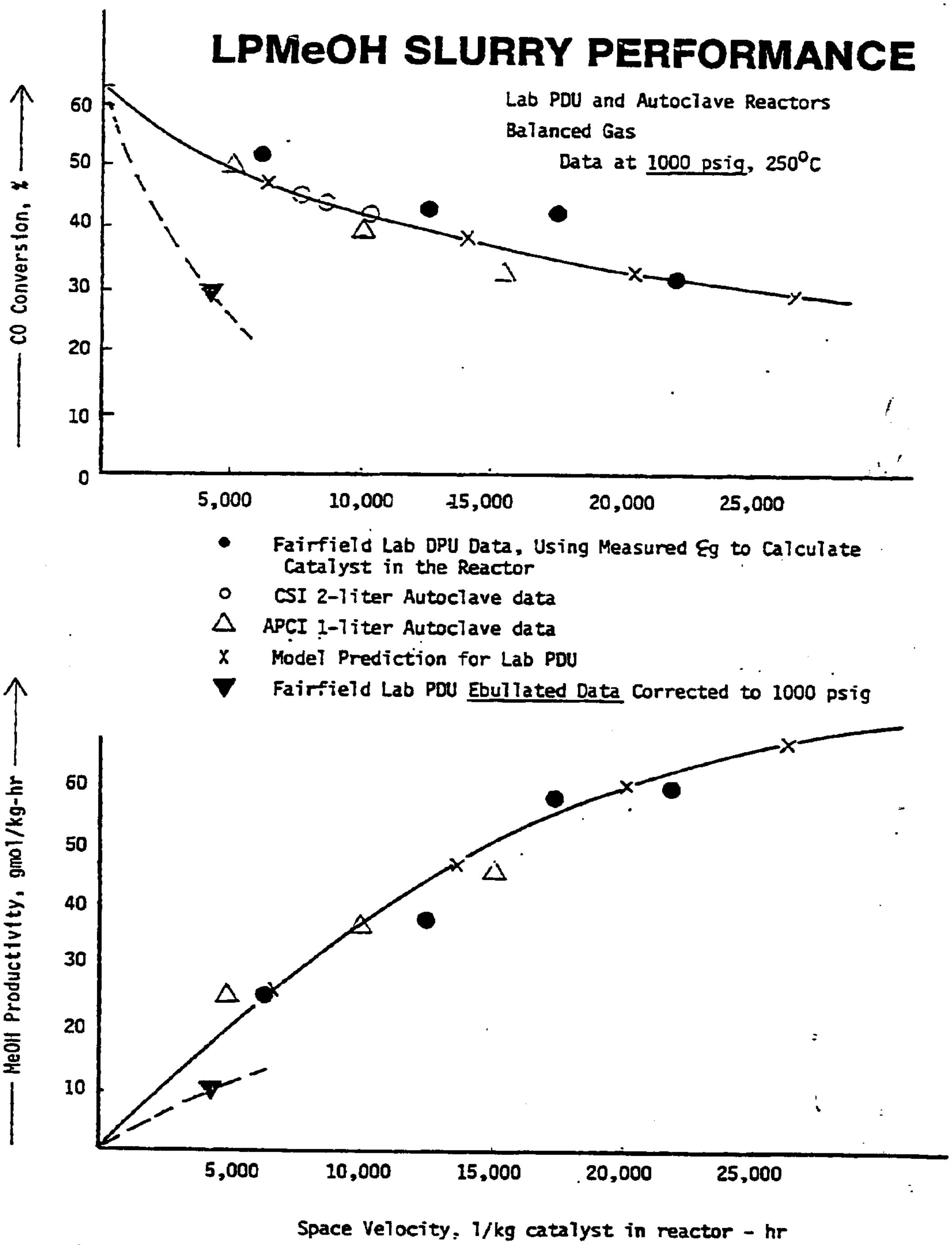
$$\frac{k_s d_p}{D_i} = 2 + 0.545\left(\frac{\mu_L}{\rho_L\, D_i}\right)^{0.33} \cdot \left(\frac{g\, V_g\, d_p^4}{\nu_L^3}\right)^{0.264}$$

- THE GAS HOLD-UP, E_g, IS CALCULATED FROM CSI'S PDU RESULTS,

$$E_g = 0.5\,(1 - \exp(-0.1735\, V_g))$$



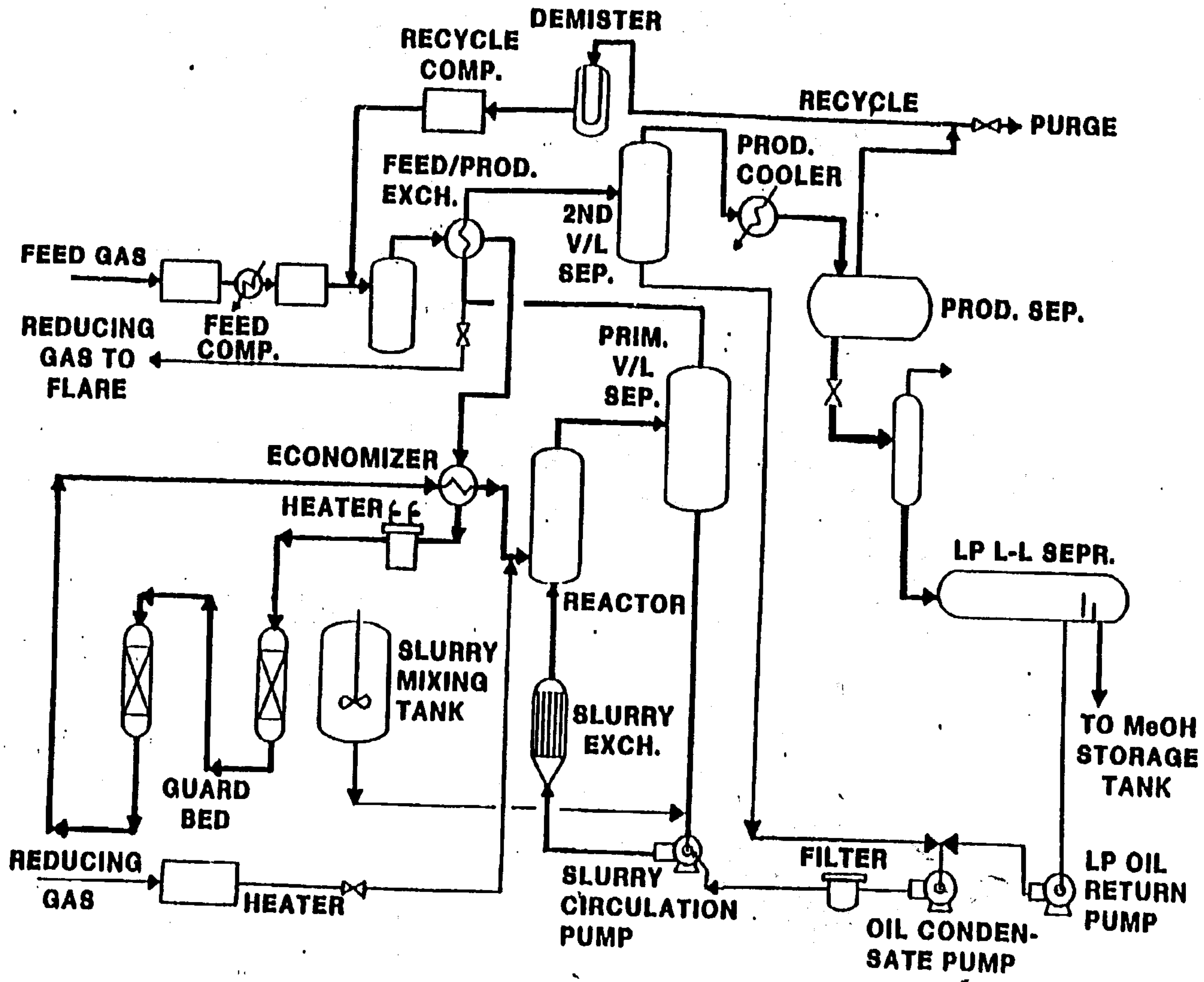
BALANCED GAS
20 WT % CATALYST LOADING
VL = 0.2 ft/sec.
TEMPERATURE: 225°C
500 PSIG
1000 PSIG
% CO CONVERSION
METHANOL YIELD MOL/HR
80
70
60
50
40
30
20
10
25.0
20.0
15.0
10.0
5.0
0
.05
.1
.15
.2
.25
.3
SUPERFICIAL VELOCITY, ft/sec

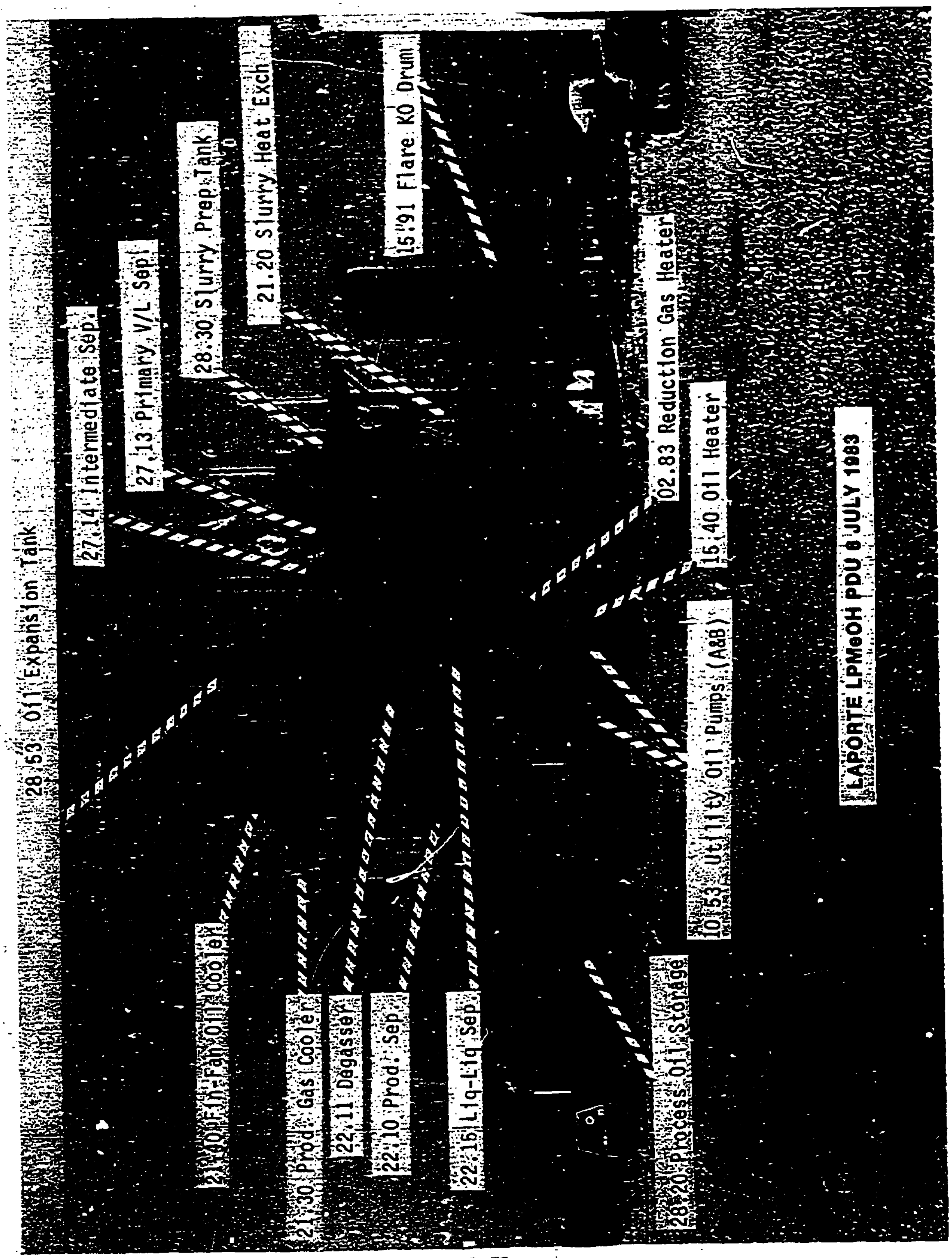

LPMeOH SLURRY PERFORMANCE
Lab PDU and Autoclave Reactors
Balanced Gas
Data at 1000 psig, 250°C
CO Conversion, %
0
10
20
30
40
50
60
5,000
10,000
15,000
20,000
25,000
● Fairfield Lab DPU Data, Using Measured Eg to Calculate Catalyst in the Reactor
○ CSI 2-liter Autoclave data
△ APCI 1-liter Autoclave data
X Model Prediction for Lab PDU
▼ Fairfield Lab PDU Ebullated Data Corrected to 1000 psig
MeOH Productivity, gmol/kg-hr
10
20
30
40
50
60
5,000
10,000
15,000
20,000
25,000
Space Velocity, l/kg catalyst in reactor - hr

LAPORTE LPMeOH PDU ENGINEERING STATUS

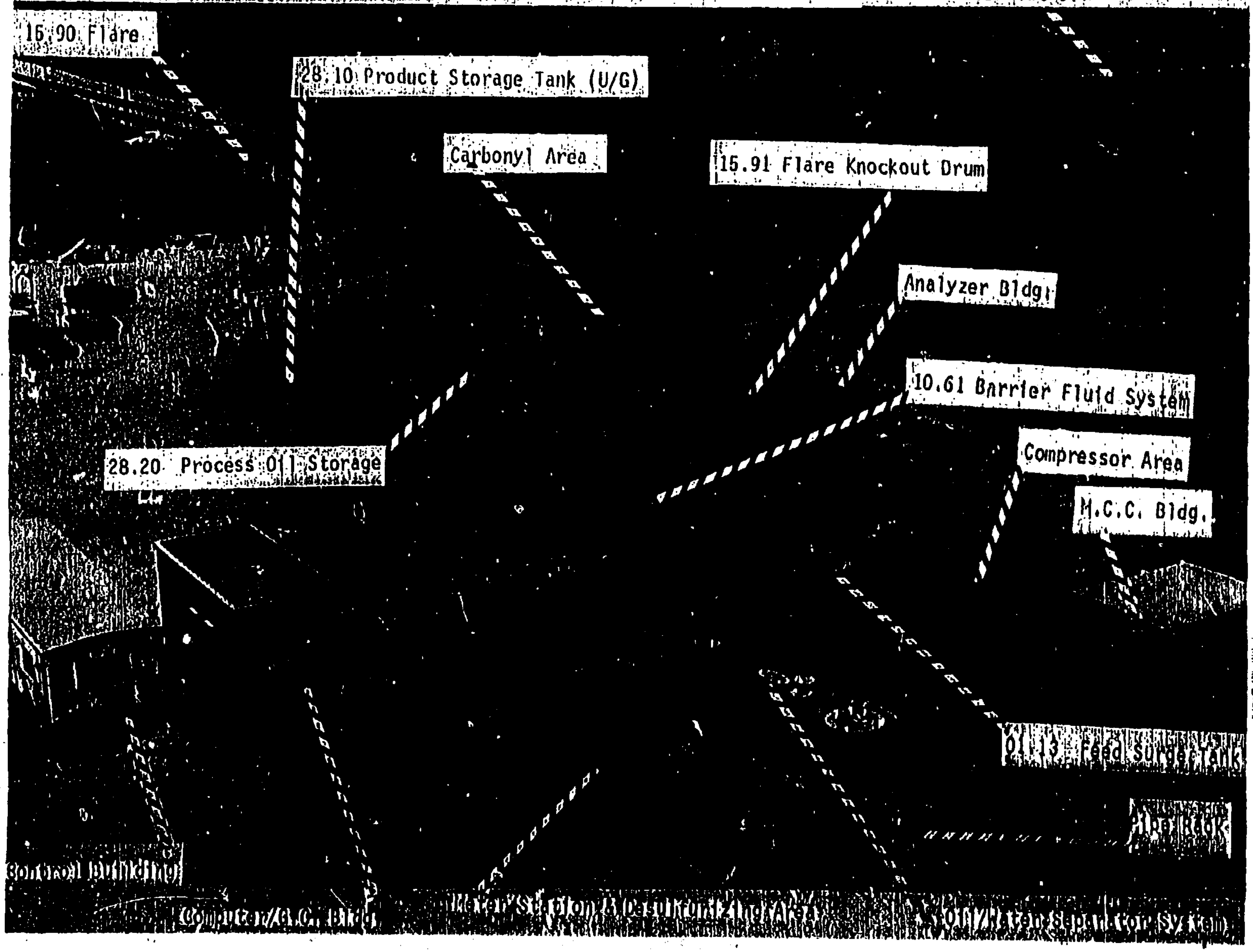
• LPM UNIT RELOCATION/ INSPECTION	COMPLETE
• PROCESS	COMPLETE
• EQUIPMENT	COMPLETE
• MECHANICAL	95% COMPLETE
• INSTRUMENTATION/ELECTRICAL	60% COMPLETE

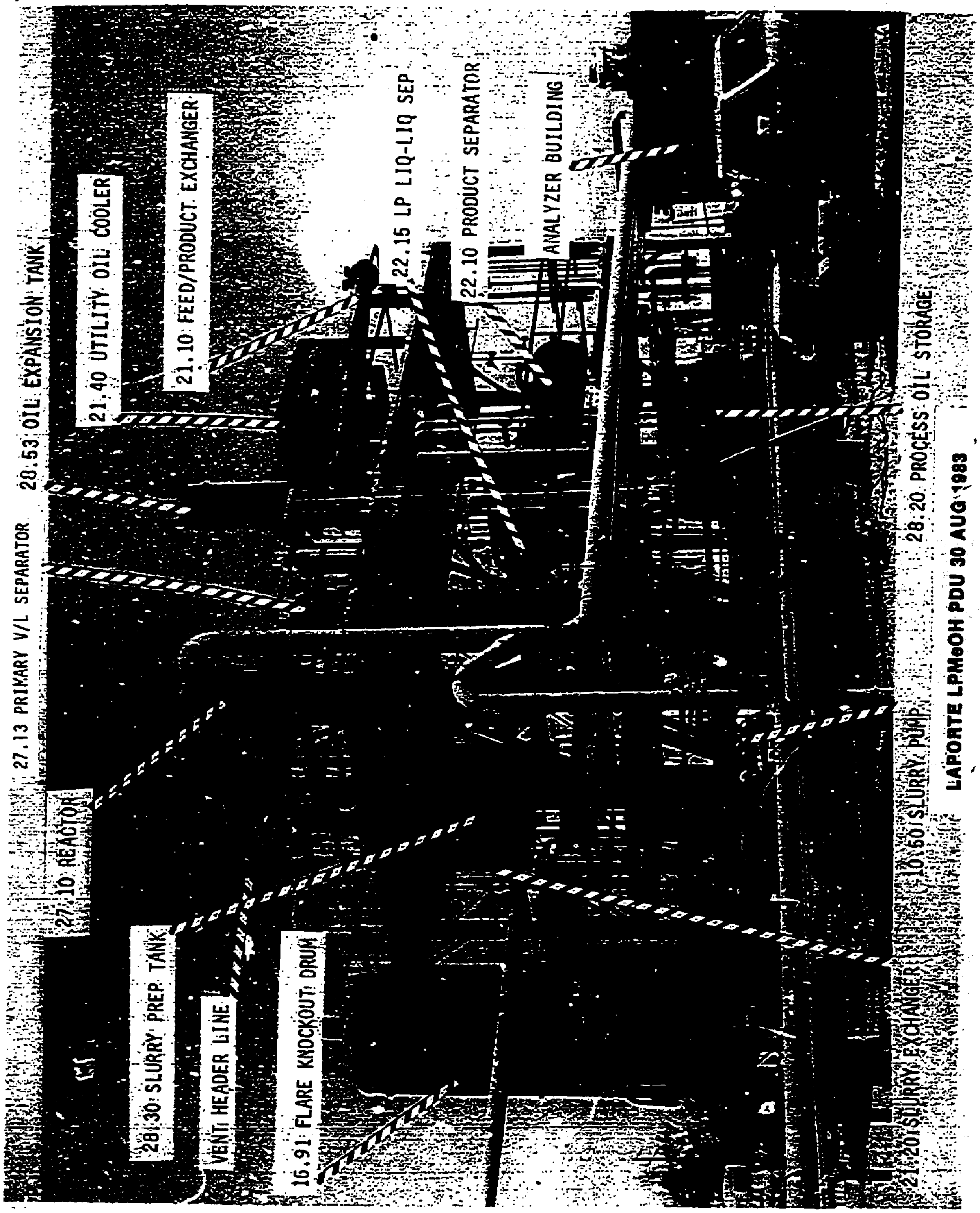
SIMPLIFIED PROCESS FLOWSHEET FOR LAPORTE LP MeOH PDU




28.53 Oil Expansion Tank
27.14 Intermediate Sep.
27.13 Primary V/L Sep.
28.30 Slurry Prep Tank
21.20 Slurry Heat Exch
15.91 Flare KO Drum
02.83 Reduction Gas Heater
15.40 Oil Heater
10.53 Utility Oil Pumps (A&B)
28.20 Process Oil Storage
21.40 Fin-Fan Oil Cooler
21.30 Prod. Gas Cooler
22.11 Degasser
22.10 Prod. Sep.
22.16 Liq-Liq Sep.
LAPORTE LPMeOH PDU 8 JULY 1983

LAPORTE LPMeOH PDU ... AUG 1983 Miller Cut-off




27.10 REACTOR
27.13 PRIMARY V/L SEPARATOR
28.53 OIL EXPANSION TANK
21.40 UTILITY OIL COOLER
21.10 FEED/PRODUCT EXCHANGER
22.15 LP LIQ-LIQ SEP
22.10 PRODUCT SEPARATOR
ANALYZER BUILDING
28.30 SLURRY PREP TANK
VENT HEADER LINE
16.91 FLARE KNOCKOUT DRUM
21.20 SLURRY EXCHANGER
10.60 SLURRY PUMP
28.20 PROCESS OIL STORAGE
LAPORTE LPMeOH PDU 30 AUG 1983