Economics of Liquid-Phase Methanol Process

Alan J. Nizamoff

Chem Systems Inc.
303 South Broadway
Tarrytown, NY 10591

Indirect Liquefaction Contractors' Review Meeting
Pittsburgh Energy Technology Center
November 13-15, 1989
Pittsburgh, PA

Economics of Liquid-Phase Methanol Process

Abstract

The latest results from the Process Development Unit (PDU) in LaPorte, Texas, are incorporated into the base case IGCC/OTM design. The economics based on the latest design for an IGCC/OTM facility are compared for both the liquid-phase and conventional vapor-phase technologies.

The all-methanol design evaluations compare the liquid-phase methanol technology (nominally 5,000 MTPD of methanol production) for both natural gas and coal feeds. These, in turn, are compared with conventional vapor-phase technology for both natural gas and coal-fed facilities.

Introduction

The production and use of coal-produced methanol has been extensively studied. Methanol is a very versatile fuel with potential applications ranging from automobiles to gas turbines. Also, the coproduction of methanol and electricity is economically attractive when applied to integrated gasification-combined cycle (IGCC) technology.

The liquid-phase methanol (LPMEOH*) process invented by Chem Systems Inc. differs significantly from conventional gas-phase processes in the method of removing the heat of reaction. This process uses a catalyst powder entrained by a circulating 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 conventional vapor-phase processes. In addition, LPMEOH 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.

* LPMEOH is a trademark of Chem Systems Inc.

Economics for Methanol Coproduction

The LPMEOH process has the ability of being able to accept a carbon monoxide-rich synthesis gas. This lends itself to a highly efficient method of achieving partial conversion of the synthesis gas to methanol in a once-through manner, which is designated a Once-Through Methanol (OTM) process. Using the LPMEOH process in an OTM configuration is based on its capability of handling a gasifier product containing approximately 50 percent carbon monoxide, 35 percent hydrogen and 15 percent carbon dioxide without the need to shift this gas composition into a balanced gas as required by conventional vapor-phase methanol synthesis technologies.

EXHIBIT 1 shows a general diagram of an IGCC/OTM plant. The IGCC plant is composed of a Texaco gasifier and its waste heat recovery (WHR) unit, an acid gas removal (AGR) unit, and a combustion turbine with a heat recovery steam generation (HRSG) system including a steam turbine. An intermediate-sized IGCC facility based on a design developed by Fluor,(1) producing 658 megawatts of electricity at 20°F has been used as the basis for this work. The LPMEOH unit is placed between the AGR unit and the combustion turbine where most of the sulfur compounds have been removed to prevent poisoning the methanol catalyst.

The addition of OTM to an IGCC plant can reduce both capital costs and power costs over an IGCC-only facility that is designed for load-following cycling operation. The gasification section of the plant can be reduced by 25 percent while still maintaining combined cycle peaking capacity at 100 percent. Methanol produced during off-peak hours is stored and used for load-following and peak power generation.

The latest test results from the Process Development Unit (PDU) at LaPorte, Texas, have produced positive results which have been incorporated into a base case IGCC/OTM design and have led to the following modifications to previous designs (EXHIBIT 2):

- Elimination of guard-bed exchanger.
- Incorporation of vapor separation into the reactors.

- Elimination of slurry pumps.
- Reduction of catalyst makeup.
- Use of higher catalyst concentrations.
- Increased CO conversion.

The latest process flow diagram for the LPMEOH process is shown in EXHIBIT 3. The basic LPMEOH process has been described previously.[2,3] EXHIBIT 4 lists the LPMEOH unit design assumptions based on the latest PDU results.

EXHIBIT 5 is an update of Table 4 presented at last year's conference and summarizes the cost of production for an IGCC/OTM facility using the latest LPMEOH technology. Syngas production is handled as a separate cost item with return on capital investment included. The syngas cost plus return is used as a raw material price in methanol and electricity production. Thus, the capital investment in the gasification facility is recovered through the transfer of syngas to the methanol unit and the combined-cycle facility. All utilities are transferred internally among the three plant sections at their cash costs of production. The IGCC/OTM facility produces syngas at a cost plus return of $4.83 per MMBtu, fuel-grade methanol at 43.6 cents per gallon, and power at 4.64 cents per kWh.

In EXHIBIT 6 we can see just how the latest PDU test results have improved the economics for the once-through operation. This evaluation was made to take full advantage of the latest PDU results including maximizing the methanol production. The crude methanol section has been upgraded to 101.5 million gallons per year from the base case 91.85 million gallons per year at a total fixed investment of $33.3 million. This is a savings of almost 9 percent over the previous investment cost. The cash cost of production shows a savings of 0.8 cents per gallon while cost plus return shows a savings of 1.7 cents per gallon.

A conventional vapor-phase methanol design was configured to fit into a Texaco-based IGCC facility for comparison purposes. EXHIBIT 7 summarizes the economics for an IGCC/OTM facility using conventional technology. As in the case of the LPMEOH facility design, the economics of the vapor-phase process were analyzed in terms of its three facility segments. The methanol and power costs for the conventional vapor-phase methanol facility are 7.3 and 1.7 percent higher, respectively, than for the LPMEOH facility.

All-Methanol Evaluation

In order to assess the commercial potential for an all-methanol process two conceptual designs were developed. The first design is based on a natural gas feedstock using a single partial oxidation step as the synthesis gas generator and was described previously.(4) The second design uses a front-end based on Texaco coal gasification. A block flow diagram of the coal-fed process is given in EXHIBIT 8. Since an objective of this evaluation was to develop a conceptual design that would achieve all-methanol production with maximum thermal efficiency, the design includes both quench and convective trains. The quench train is needed to sufficiently saturate the gas stream with water to allow a CO shift reaction to be carried out. The shift reaction along with a carbon dioxide purge allows control of the syngas feed composition to the LPMEOH unit. The convective train allows maximum heat recovery.

A simplified flow diagram of the LPMEOH unit with an all-methanol configuration is shown in EXHIBIT 9. For all-methanol production the LPMEOH unit is designed as a two-stage operation. The first stage consists of a once-through reactor operating at 1550 pounds. The second stage consists of two reactors with the unconverted gases from the last reactor recycled back to the second reactor inlet after a small purge is taken to remove inerts. These reactors operate at slightly lower pressure.

Reaction conditions and conversions are summarized in EXHIBIT 10. The feed composition favors the conversion of carbon monoxide over carbon dioxide. This unit has the potential for approximately 5,000 MTPD of methanol produced from a single train and achieves a high overall carbon conversion of 90 percent.

EXHIBIT 11 compares the cost of production for an integrated gasification/all-methanol design for both natural gas feed and coal feed. The investment is significantly higher for the coal fed design. The overall effect of the higher capital investment and related factors is that the coal-fed design requires a selling price of over 30 cents higher at 10 percent DCF. Thus, a coal-to-methanol facility cannot compete cost effectively with a design based on natural gas at the current relative feedstock prices.

Another comparison that was made is between conventional vapor-phase(5) and liquid-phase all-methanol designs both using natural gas feed. The 5,000 MTPD LPMEOH design described above is compared to two 2,500 MTPD conventional plants using natural gas reforming to generate the syngas and conventional methanol synthesis (e.g., ICI or Lurgi). Economy of scale gives an advantage to the LPMEOH route. The LPMEOH also shows an advantage in raw material usage and utilities. The economics for these two cases are summarized in EXHIBIT 12. Thus, for a maximum size methanol production design, the LPMEOH design shows a clear advantage over the conventional vapor-phase design of over 3 cents per gallon at a DCF return of 10 percent.

A similar comparison was made for coal-to-methanol using both the LPMEOH configuration and a conventional vapor-phase design.(5) The economics for these cases are shown in EXHIBIT 13. In this comparison, the savings is not as significant when compared to the large investment in the front end of the plant. Again at a nominal production rate of 5,000 MTPD the LPMEOH design is more attractive than conventional coal-to-methanol by almost 3 cents per gallon.

Summary

In comparing world-scale methanol production, economy of scale gives the LPMEOH design a clear advantage over a conventional vapor-phase methanol synthesis plant. It is expected that the economics for plants designed for production less than 2,500 MTPD will show the conventional design to be competitive with the LPMEOH technology. For an integrated gasification-combined cycle facility, the once-through design using LPMEOH technology shows a marked advantage over conventional vapor-phase technology.

Literature Cited

1. "Cost and Performance for Commercial Applications of Texaco-Based Gasification Combined-Cycle Plants," EPRI AP-3486 (Vol. 1 and 2), by Fluor Engineers, Inc. (1984).

2. "Liquid-Phase Methanol Process Development Unit: Installation, Operation, and Support Studies," Final Report under DOE Contract No. DE-AC22-81PC30019, by Air Products and Chemicals, Inc. and Chem Systems Inc. (1985).

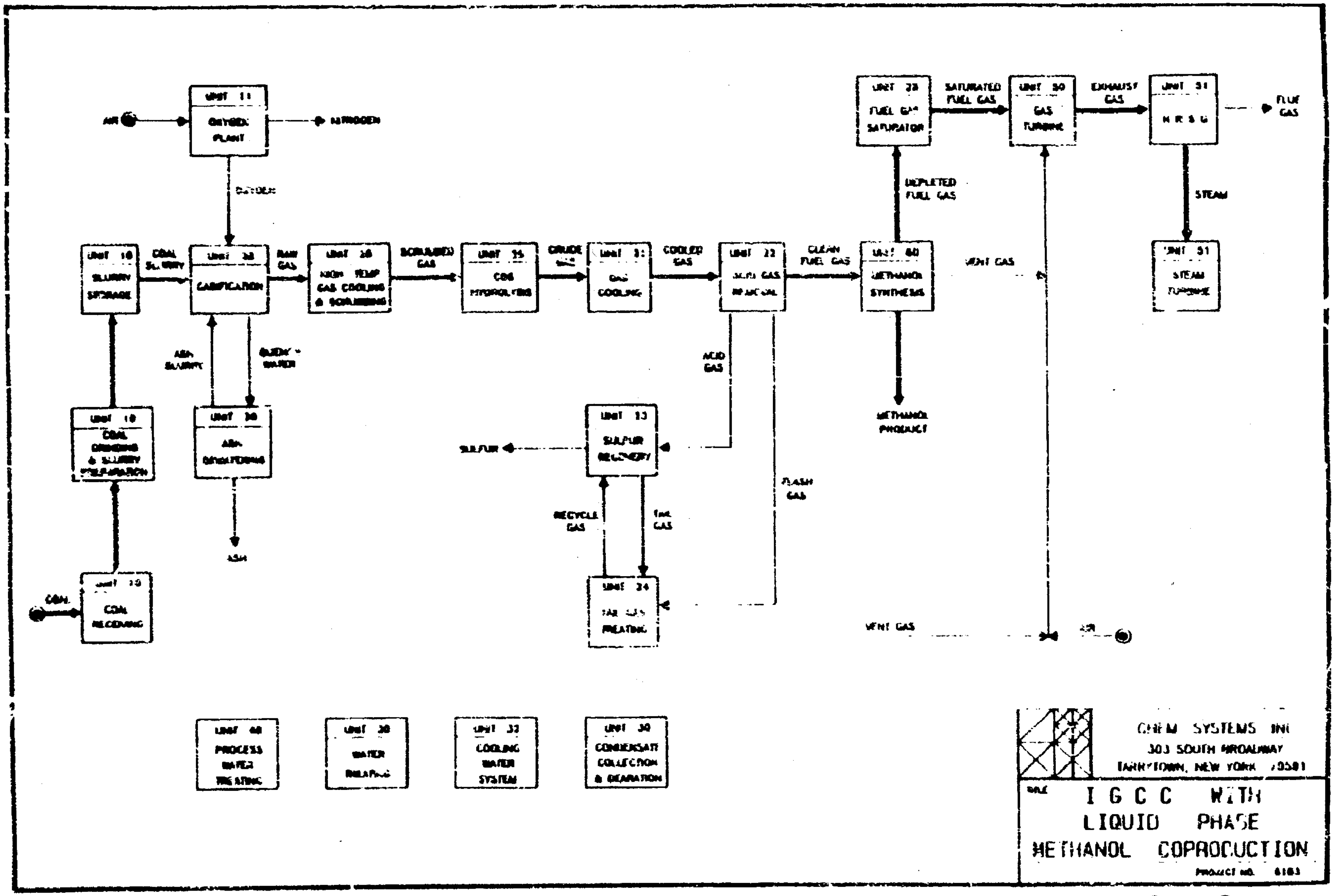
3. "Liquid Phase Methanol Process Development Unit: Installation, Operation, and Support Studies, Topical Report, Task 10: Liquid-Entrained Operations, in LaPorte LPMEOH PDU." DOE Contract No. DE-AC22-81PC3001119, by Air Products and Chemicals, Inc. and Chem Systems Inc. (1986).

4. "Optimization of LPMEOH Configurations of IGCC/OTM," EPRI RP-2771-1 Final Report by Chem Systems Inc., to be published.

5. "Assessment of Cost and Benefits of Flexible and Alternative Fuel Use in the U.S. Transportation Sector - Technical Report Three: Methanol Production and Transportation Costs," 21 July 1989 draft of future United States Department of Energy Report.

EXHIBIT 1

Block Flow Diagram for IGCC with Methanol Coproduction



6196aine 1

Chem Systems

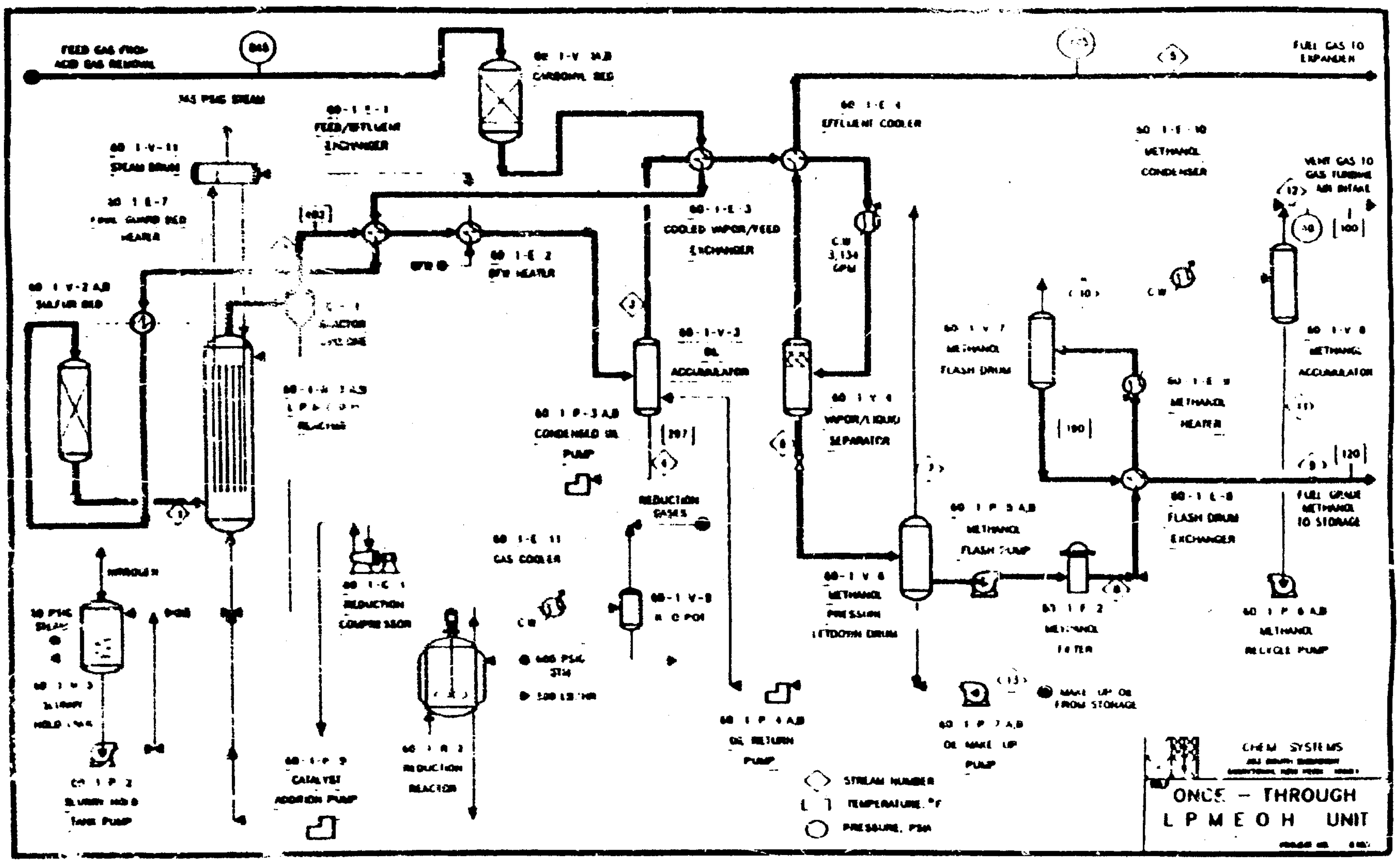
EXHIBIT 2

LPMEOH Enhancements

- Eliminate guard bed exchangers.
- Incorporate vapor separation with reactor.
- Eliminate slurry pumps.
- Reduce catalyst makeup.
- Use of higher catalyst concentrations
- Increase CO conversion.

EXHIBIT 3

OTM LPMEOH Flow Scheme



6192ajna.3

Chem Systems

EXHIBIT 4

LPMEOH Unit Design Assumptions Based on Latest PDU Results

Space velocity, L/hr-kg catalyst	7,000
Temperature, Deg F	482
Pressure, psia	765
CO conversion, %	14.7
CO_2 conversion, %	1.0
Selectivity to methanol, mol %	99.58
Catalyst concentration, wt %	35-40
Net fuel methanol production, TPD	1,080

EXHIBIT 5

Summary Economics for IGCC/OTM Facility Using LPMEOH Technology

	Texaco Gasification (Cents/MMBtu)	LPMEOH Unit (Cents/Gal)	Combined Cycle (Cents/kWh)
Raw Materials			
Coal @ $35/ST	205	-	-
Syngas @ $4.83/MMBtu	-	36.8	3.21
Catalysts/chemicals	3	2.3	0.02
Total raw materials	**208**	**39.1**	**3.23**
Utilities	2	(3.1)	0.06
Direct cash costs	55	2.1	0.20
Allocated cash costs	39	1.0	0.19
By-product credits			
Sulfur @ $75/ST	(15)	-	-
Ash disposal @ $10.50/ST	6	-	-
Total by-product credit	**(9)**	**-**	**-**
Cash cost of production	**295**	**39.1**	**3.68**
Cost plus return @ 7.5 percent DCF	**483**	**43.6**	**4.64**

Chem Systems

6195alne.5

EXHIBIT 6

Economic Comparison of Previous Design and Latest LaPorte Results for Once-Through Operation

	Previous Design	Latest LaPorte Results
Fuel methanol production, MM gal/yr	91.85	101.51
Capital investment, $ MM		
Battery limits	31.1	28.6
General facilities	5.4	4.7
Total fixed investment	**36.5**	**33.3**
Cost of production, cents/gal		
Raw materials		
Syngas @ $4.83 MMBtu	36.8	36.8
Catalyst/chemicals	2.5	2.3
Total raw materials	**39.3**	**39.1**
Utilities	(3.0)	(3.1)
Direct cash costs	2.4	2.1
Allocated cash costs	1.2	1.0
Cash cost of production	**39.9**	**39.1**

Chem Systems

EXHIBIT 7

Summary Economics for IGCC/OTM Facility Using Conventional Technology

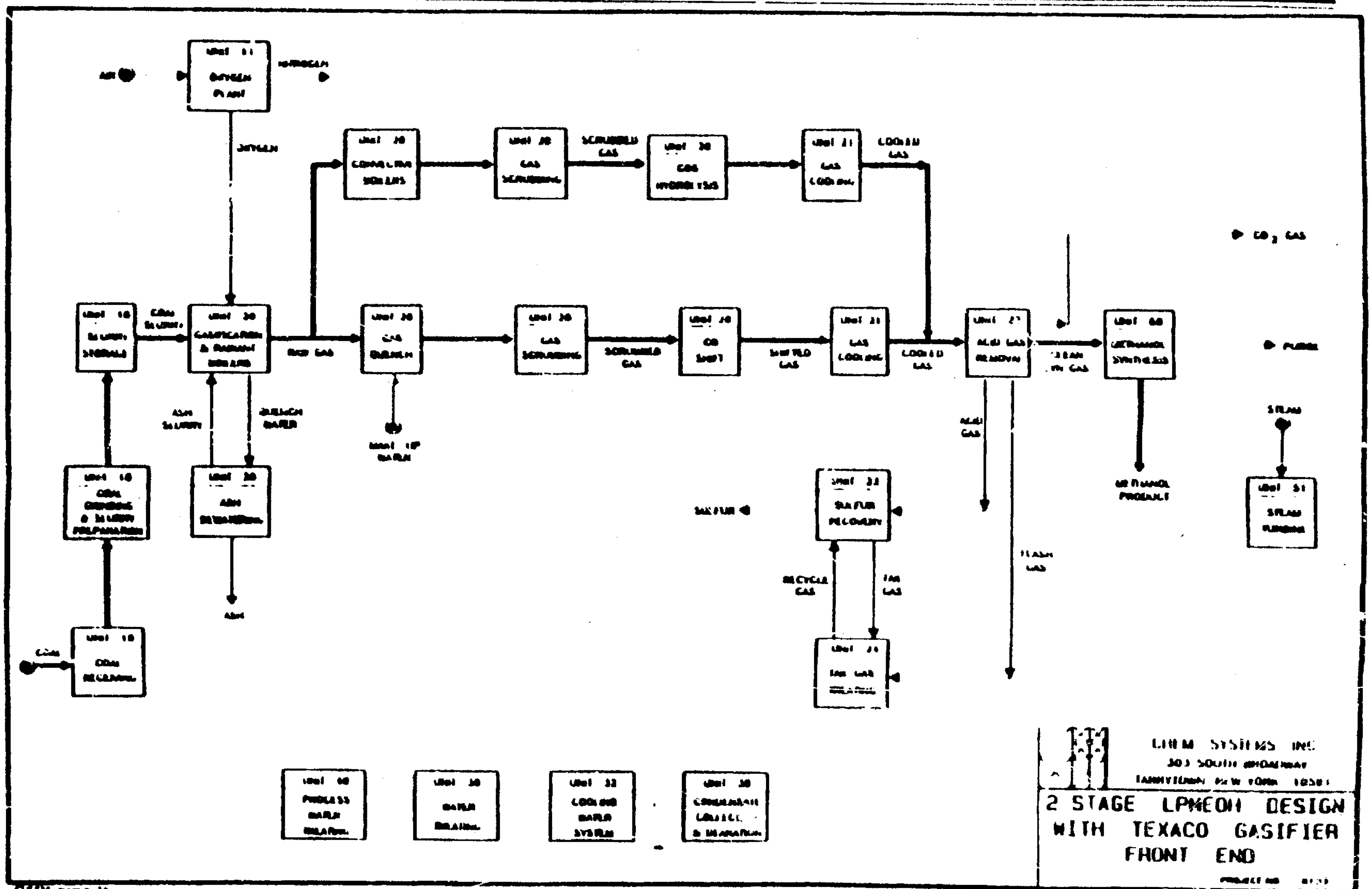
	Texaco Gasification (Cents/MMBtu)	CVPMEOH Unit (Cents/Gal)	Combined Cycle (Cents/kWh)
Raw Materials			
Coal @ $35/ST	204	-	-
Syngas @ $4.90/MMBtu	-	37.6	3.28
Catalysts/chemicals	3	0.6	0.03
Total raw materials	**207**	**38.1**	**3.31**
Utilities	1	(1.2)	0.03
Direct cash costs	56	2.5	0.20
Allocated cash costs	41	1.3	0.19
By-product credits			
Sulfur @ $75/ST	(15)	-	-
Ash disposal @ $10.50/ST	6	-	-
Total by-product credit	**(9)**	**-**	**-**
Cash cost of production	**295**	**40.8**	**3.73**
Cost plus return @ 7.5 percent DCF	**490**	**46.8**	**4.72**

6195alne.7

Chem Systems

EXHIBIT 8

Block Flow Diagram for All-Methanol Flow Scheme

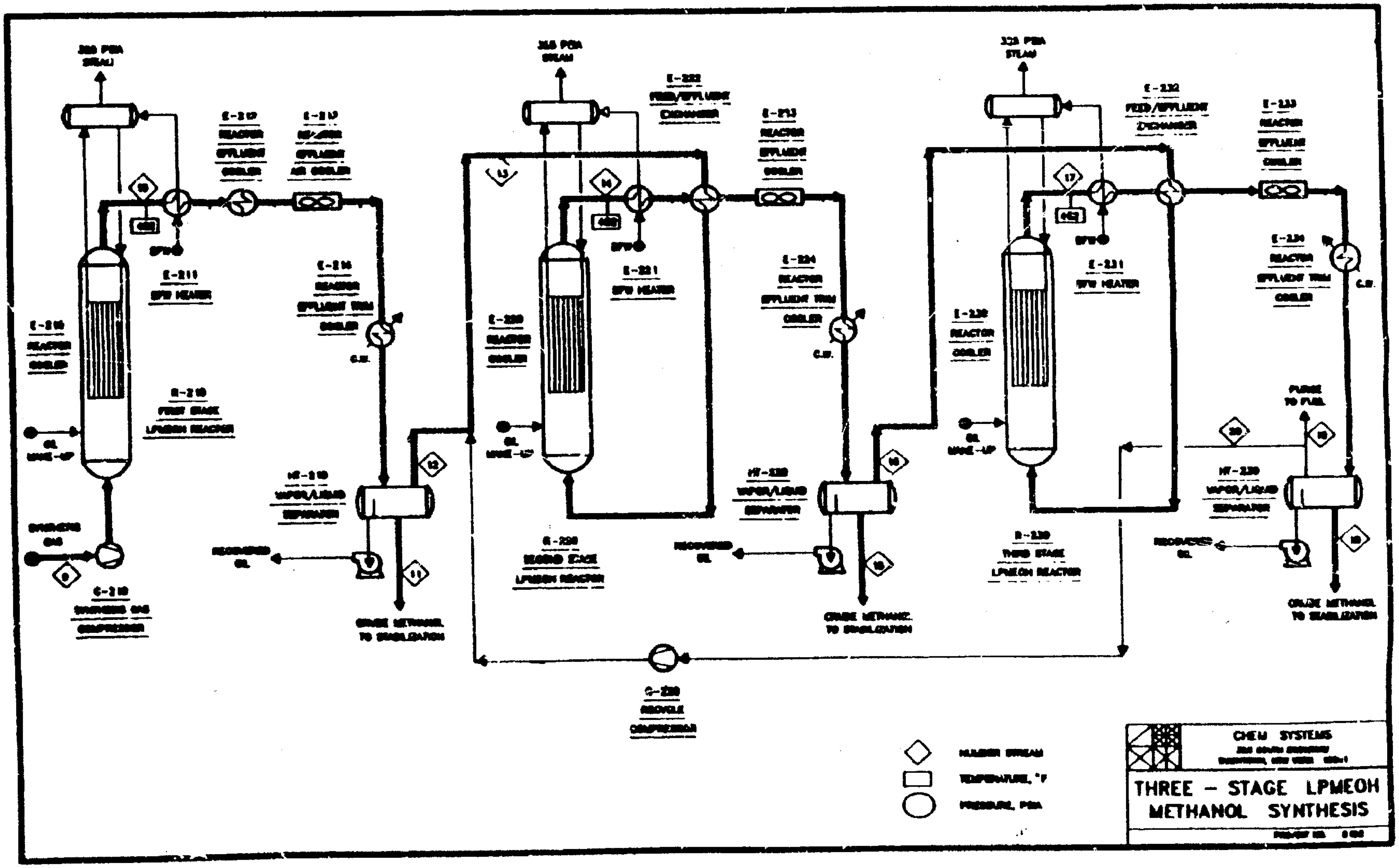


6195ajne.8

Chem Systems

EXHIBIT 9

Coal Based All-Methanol LPMEOH Flow Scheme



6195ajne 9

Chem Systems

EXHIBIT 10

Coal Based All-Methanol Operating Conditions and Conversions

	Reactor 1	Reactor 2	Reactor 3
Diameter, ft	14.8	12.5	10.1
L/D	4.5	5.2	5.9
Space velocity, L/hr-Kg cat	10,000	10,000	10,000
Operating Pressure, psia	1,550	1,490	1,400
Operating Temperature, Deg C	250	250	250
CO Conversion, %	63.9	61.6	53.9
CO_2 Conversion, %	0	4.76	8.70
Recycle	No	Yes	Yes
Percent of net methanol produced	60	28	12

EXHIBIT 11

Cost of Production for All-Methanol Design Using LPMEOH Technology

	Natural Gas Feed	Coal Feed
Fuel methanol production, MTPD	5,000	5,000
Capital Investment, $ MM		
ISBL	227.8	779.9
Offsites	102.3	270.1
Total fixed Investment	**330.1**	**1,050.0**
Cost of production, cents/gal		
Raw materials*	18.8	19.0
Utilities	(1.7)	0.7
Direct cash costs	2.8	5.3
Allocated cash costs	3.7	6.1
Full Cash cost of production	**23.7**	**31.1**
Cost plus 10 percent DCF return	**37.5**	**67.7**

* Coal at $35/ST; Natural Gas at $1.8/MMBtu

Chem Systems

EXHIBIT 12

All-Methanol Cost of Production Comparison for Natural Gas Feed

	LPMEOH	CVPMEOH
Fuel methanol production, MTPD	5,000	2x2,500
Capital investment, $ MM		
ISBL	227.8	297.6
Offsites	102.3	116.3
Total fixed investment	**330.1**	**413.9**
Cost of production, cents/gal		
Raw materials (NG @ $1.8/MMBtu)	18.8	19.0
Utilities	(1.7)	0.0
Direct cash costs	2.8	3.7
Allocated cash costs	3.7	3.4
Full Cash cost of production	**23.7**	**26.1**
Cost plus 10 percent DCF return	**37.5**	**41.0**

EXHIBIT 13

All-Methanol Cost of Production Comparison for Coal Feed

	LPMEOH	CVPMEOH
Fuel methanol production, MTPD	5,000	2x2,500*
Capital investment, $ MM		
ISBL	779.9	828.0
Offsites	270.1	270.1
Total fixed investment	**1,050.0**	**1,098.1**
Cost of production, cents/gal		
Raw materials (Coal @ $35/ST)	19.0	19.7
Utilities	0.7	0.7
Direct cash costs	5.3	5.6
Allocated cash costs	6.1	6.4
Full cash cost of production	**31.1**	**32.4**
Cost plus 10 percent DCF return	**67.7**	**70.7**

* Second generation coal gasification technology, improved acid gas removal system (e.g., Selexol).

Chem Systems