SECTION 9
LITERATURE CITED

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APPENDIX A
EVALUATION PROCEDURES AND RANKINGS

APPENDIX A

EVALUATION PROCEDURES AND RANKINGS

A.1 INTRODUCTION

This appendix presents preliminary rankings of the commercial potentials for candiate processes and the procedures used to develop these rankings.

The scope of the study summarized in this report was broad, incorporating the total field of coal liquefaction. The resource application, defined by contract period and level of funding, required a direct approach to define highest potential processes early in the study in order to permit maximum time/effort to develop preferred product slate, processing procedures, projected economics, and opinions regarding expected performance. To aid in the high potential process selection program, procedures were defined to develop numerical ratings of the separate process characteristics, to weight the ratings, and then, to add these weighted ratings to produce projected rankings of the processes.

The number of processes considered, 33, precluded detailed and quantitative analyses of all characteristics of each process at the ranking stage of this study. What was done was to develop defined techniques to compare 15 different characteristics of each candidate process and apply best engineering and economic assessment judgement to the data and information known for each candidate. The goal was to be objective; in a practical sense, because of resource limitations, certain elements had to be judgementally subjective.

The results of this ranking effort may be viewed as the opinions of a particular group at a given point in time based on nonproprietary information available to them at that time. A significant amount of analytical information is presented which represents a contribution to the coal liquefaction development program.

The rankings developed represent one input to the high potential process selection decision. The rankings were viewed against the perspective gained during work consisting of approximately 130 manyears of work in the field prior to recommending a list of high potential processes for more detailed study.

The ranking techniques and weighting factors used were independently developed for use in this study. They used the experience of similar studies for other fields[21] as background.

A.2 PROCEDURES

Two separate ranking categories were used; they were:

- Development Status
- Commercial Potential

A total of fifteen separate process characteristics, as listed in Table A-1, were defined and evaluated under these two ranking headings. The weighted rating of each of these characteristics were added to obtain sums used as a guide to process ranking.

Details of the ranking procedures used are presented in the following paragraphs.

A.2.1 DEVELOPMENT STATUS

The Development Status Ranking was composed of three factors with weighting as follows:

FACTORS	WEIGHT
D1; Technology Status	3 1/3
D2; Equipment Development Requirements	3 1/3
D3; Process Development Status	3 1/3
Total Weight	10.0

The numerical values assigned to the individual ratings and weighting factors were based on analysis and judgement. Rating values selected ranged from 0 to 10 and weighting factors from 0 to 10, adjusted so that the maximum possible weighted ranking score was 100.

Items comprising each of the three factors and guidelines for establishing the ratings were:

A.2.1.1 D1; Technology Status (weight 3 1/3)

Rating	Status
1	Laboratory work not begun
2	Bench scale/laboratory
3	PDU work underway
5	Pilot plant data available
7	Demonstration plant engineering complete
10	Commercial plant in operation

Where the following definitions were applied:

Operation Type	Coal Feed
Bench scale/laboratory	less than 1 TPD
PDU	1 to 5 TPD
Pilot Plant	6 to 100 TPD
Demonstration plant	101 to 3000 TPD
Commercial size plant	more than 3000 TPD

A.2.1.2 D2; Equipment Development Requirements (weight 3 1/3)

Equipment development is defined as the summation of twice the number of new and complete items of equipment that are not presently available, plus the number of items of equipment that require extension of existing technology to new and more severe conditions.

Rating	Development Requirements
0	7
1	6
2	5
4	4
5	3
6	2
8	1
10	0

Examples of equipment not presently available:

- o Indirect slurry heaters
- o Centrifugal slurry pumps above 100 psig discharge pressure
- o Lock hoppers operating above 500 psig

- Coal extruders discharging above 500 psig

- Rotary filters operating above 300°F

Examples of equipment requiring an extension of existing technology:

- Rotating fluidized bed

A.2.1.3 D3; Process Development Status (weight 3 1/3)

Rating	Evaluation
1	Critical steps unproven at any scale, assumptions made.
2	Critical process steps unproven at any scale, but theoretically sound.
3	All process steps proven at bench scale.
5	Critical process steps proven at PDU scale; difficult but solvable problems exist.
7	Critical process steps proven at pilot plant scale; difficult but solvable problems exist.
10	All process steps proven in an integrated demonstration plant; none or only minor problems exist.

Examples of difficult but solvable problems:

- Flashing (one or more) in presence of solids
- Fractionation in presence of solids

A.2.2 COMMERCIAL POTENTIAL

The Liquefaction Potential Ranking is composed of twelve factors as listed below:

Ranking Factor	Weighting Factor
P1; Complexity	0.855
P2; Severity	0.945
P3; Industrial Capacity	0.450
P4; Feed Versatility	0.675
P5; Product Versatility	0.675
P6; Liquefaction Efficiency	0.900
P7; Sulfur Reduction Efficiency	1.575
P8; Conversion Efficiency	0.540
P9; Product Premium	1.260
P10; Product Compatibility	0.180
P11; Product Hazard	0.945
P12; Uncertainty Factor	1.000
Total Weight	10.000

The numerical values assigned to the individual ratings and weighting factors are based on analysis and judgement. Ratings have been selected to have values ranging from 0 to 10, with the weighting factors adjusted so that the maximum possible ranking score is 100.

The ratings used for the separate factors and the guidelines defined for the process assessors are summarized in the following paragraphs.

A.2.2.1 P1; Process Complexity (weight 0.855)

Complexity is the sum of Internal and External Factors which are defined as follows:

- Internal Factors

Internal Factors	Value
Number of independent reaction stages	1 each
Number of principle recycle streams	1 each

- External Factors

Number of process units that feed the liquefaction plant e.g.

Process Unit	Value
Coal drying	1
Hydrogen by coal oxidation	2
Methane steam reformer	1
Oxygen plant	0
Coal grinding	0
Steam generation	0

The Complexity Rating is the numerical sum of the above value items:

Complexity	Rating
10	0
9	1
8	2
7	3

6	4
5	5
4	6
3	7
2	8
1	9
0	10

A.2.2.2 P2; Process Severity (weight 0.945)

Operating pressures and temperatures were categorized as follows:

Category	Pressure (psia)	Temperature (°F)
High	>1000	>1000
Medium	501–1000	651–1000
Low	<500	<650

Each process was rated for severity according to the following:

Pressure	Temperature: High	Temperature: Medium	Temperature: Low
High	1	3	6
Medium	2	5	8
Low	4	7	10

[a]For pressures over 3000 psi, at any temperature, rating = 1.

A.2.2.3 P3; Industrial Capacity (weight 0.45)

Industrial capacity was defined to be a function of the maximum amount of liquid product, expressed in BPSD, that can be produced from one primary coal conversion reactor. The maximum practical reactor size for high pressure operation was defined as a vessel 12-foot ID with an internal volume not to exceed 8,000 feet.

The relationship between industrial capacity rating and reactor capacity as defined above is shown in Figure A-1.

A.2.2.4 P4; Feed Versatility (weight 0.675)

Each process is rated according to its ability to liquefy the following four basic types of coal, with a liquid yield variation of less than 25%.

1. Low-volatile bituminous coal
2. Med- and High-volatile bituminous coal
3. Sub-bituminous coal
4. Lignite

Types 1. and 2. are considered to be agglomerating coals.

Versatility	Rating
Process handles 1 coal	2.5
Process handles 2 coals	5.0
Process handles 3 coals	7.5
Process handles 4 coals	10.0

A.2.2.5 P5; Product Versatility (weight 0.675)

Product State Versatility	Rating
Only one liquid product, cannot be varied by operational or catalyst changes.	1
Either one of two liquid products can be produced.	2

A multi-liquid product slate is produced, and cannot be varied by operational or catalyst changes.	4
A multi-liquid product slate is produced. Preliminary product can be shifted to next higher or lower boiler range product.	6
A multi-liquid product slate is produced. Primary product can be shifted to next two higher or lower boilering range products.	8
Any primary product between heavy fuel oil and LPG can be produced.	10

A.2.2.6 <u>P6; Liquefaction Efficiency (weight 0.900)</u>

Liquefaction efficiency is defined as the percentage of the higher heating value of the coal feed plus added hydrogen coal equivalent recovered as liquid hydrocarbons, excluding liquified petroleum gases (LPGs).

$$E_L = \frac{\text{HHV (liquids with BP} \quad \text{LPG)}}{\text{HHV (Coal Feed} + H_{2\ CE})}$$

$$H_{2\ CE} = 0.7\ (\text{HHV}_{H_2}\ \text{consumed})$$

where: E_L = Liquefaction Efficiency

$H_{2\ CE}$ = Coal Equivalent of H_2 consumed

Liquefaction Efficiency	Rating
0%	0
50%	5
100%	10

A.2.2.7 P7; Sulfur Reduction Efficiency (weight 1.575)

Sulfur reduction efficiency is the difference between coal and product oil sulfur contents, measured as lbs. of sulfur per MM Btu, expressed as a percentage of the coal sulfur content.

$$E_{SR} = \frac{Sc - So}{Sc} \times 100$$

where: E_{SR} = Sulfur Reduction Efficiency

Sc = Lb. Sulfur in Coal per MM HHV

So = Lb. Sulfur in Product Oil per MM Btu HHV

Sulfur Reduction Efficiency	Rating
0%	0
50%	5
100%	10

A.2.2.8 P8; Conversion Efficiency (weight 0.540)

Conversion efficiency is a measure of the degree of coal liquefaction achieved; it is defined as 100 minus the percentage of C_5 + hydrocarbons (Btu basis) boiling above 850°F which fail to meet a Bunker Fuel Oil viscosity specification of 180 SSF at 122°F. This may be expressed as follows:

Conversion Efficiency = 100 - % C_5, + with BP 850°F, 180 SSF @ 122°F.

Conversion Efficiency	Rating
0%	0
50%	5
100%	10

A.2.2.9 P9; Product Market Value (weight 1.260)

Product market value is defined as the anticipated market value of the coal derived liquids, expressed as a percentage of the value of an equivalent petroleum based fuel, when due consideration is given to fuel octane or cetane number, volatility, heating value, pour point, and carbon to hydrogen ratio.

The overall product market values for each process were determined by dividing the wide boiling range coal liquid into cuts of equivalent petroleum based fuels, according to ASTM specifications. Product market values for each cut were then assessed and the overall market value obtained by weighing the individual values on a Btu basis.

Product Market Value as % of Petroleum Based Product	Rating
0%	0
50%	5
100%	10

A.2.2.10 P10; Product Compatibility (weight 0.180)

Product compatibility is a measure of the ability of the coal derived liquids to maintain satisfactory storage stability in the presence of equivalent petroleum based fuels. The significance of this factor is that if a coal oil fuel is not compatible with an equivalent petroleum fuel, then users would be required to dedicate tankage specifically for coal based fuels.

Product compatibility is defined as the percentage of coal oil products, on a Btu basis, that are fully compatible with the equivalent petroleum based product. Since compatibility information for many processes is inadequate, ratings have been made on the general assumption that only residual fuels, excluding those produced by reaction of synthesis gas, i.e., a mixture of $CO+H_2$, would be incompatible with a petroleum base fuel.

Compatibility	Rating
0%	0
50%	5
100%	10

A.2.2.11 P11; Product Hazard (weight 0.945)

The potential hazard of coal oil fuels to the safety and health of humans, when encountered under normal conditions of use, is related to toxic and carcinogenic properties of the fuel.

Several classification schemes were reviewed before establishing the rating guidelines. In one, Sax, I. N., Dangerous Properties of Industrial Materials, Van Nostrand Reinhold Co., 1975, the following system of toxicity rating has been used to indicate the relative hazard of these fuels as applied to human exposure.

U	=	Unknown
0	=	No toxicity
1	=	Slight toxicity
2	=	Moderate toxicity
3	=	Severe toxicity

The acute toxicity ratings, referring to a single exposure of durations up to several hours, have been used in this evaluation.

Another procedure reviewed for expressing toxic levels is the Threshold Limit Value (TLV), which is pertinent for industrial and occupational exposure restrictions, and refers to airborne concentrations, at which it is believed nearly all workers may be repeatedly exposed for an 8 hour day, 5 days a week. Substances carcinogenic for humans may be divided into those substances with an assigned TLV, and those without an assigned TLV.

Since toxicity data for most liquefaction products is meager, the hazard rating has been based upon published data for similar substances, e.g., coal tar fuels, pure aromatics, and petroleum fuels.

Product hazard ratings for the individual product cuts were weighted to obtain the overall product hazard rating.

The product hazard rating is determined according to the following guidelines:

Product Hazard	Rating
Extremely Toxic o carcinogenic with no TLV	0
Highly Toxic o carcinogenic with TLV 1 ppm V	2
Very Toxic o acute toxicity rating = 3 or U o carcinogenic with TLV 10 ppm	4
Moderately Toxic o acute toxicity rating = 2 o carcinogenic with TLV 200 ppm	6
Slightly Toxic o acute toxicity rating = 1 o carcinogenic with TLV 500 ppm	8
Harmless o acute toxicity rating = 0 o non carcinogenic	10

A.2.2.12 P12: Uncertainty Factor (weight 1.0)

This factor, which reflects the degree of confidence in the published data is taken to be proportional to the process Development Status Ranking, defined on Page 4-4.

Development Status Ranking	Rating
0%	0
50%	5
100%	10

A.3 NUMERICAL RANKINGS

A summary of the Development Status and Commercial Potential ratings for the thirty-three processes is shown in Table A-2. Table A-3 presents the unadjusted Development Status rankings for the processes while Table A-4 presents similar rankings for the Commercial Potential category.

Details of the ratings for the separate factors in the Development Status Rating are presented in Table A-5, and similar details for the Commercial Potential Rating is shown in Table A-6.

A.4 DISCUSSION OF RANKINGS

The ranking scheme used has been designed to focus attention on those coal liquefaction processes which appear most promising for future liquid fuels production.

Interpretation of the results of this type of analysis requires judgement since the additive system of rating used can give misleading results when extreme values of certain evaluation factors are encountered, e.g. the impact of inclusion of a small number of extreme values must be assessed.

A.4.1 DEVELOPMENT STATUS

The Development Status rating is a measure of how far a process has progressed towards full commercialization, given a cost-development time relationship similar to that found in the process industries. Accelerated funding of a particular process would have the effect of reducing the time required for commercial development.

In general, the following interpretations of the ratings are suggested:

- Development Status rating, 90

  Processes in this category are considered to be either commercial or at the commercial prototype stage.

- Development Status rating, 50 to 90

  Processes in this category are considered to be capable of demonstrating commercial operation by the year 1990 if due diligence is used in pursuing their development.

- Development Status rating, 40 to 50

  Processes in this category are considered to be able to demonstrate commercial operation later than 1990, but before the year 2000; again based on use of due diligence.

- Development Status rating, 40

  Processes in this category are considered to be able to demonstrate commercial operation only after the year 2000.

A.4.2 COMMERCIAL POTENTIAL

A review of the commercial potential ranking indicates that 12 coal conversion processes scored points 60 or better, and seven other processes received scores ranging from 55 up to 59 points; these are considered candidates.

The processes with scores of 60 or more consist of:

- o 8 indirect processes
- o 3 catalytic hydroliquefaction processes
- o 1 donor solvent process

The economics and potential of the indirect processes are heavily dependent on the gasification process used to produce syngas. Complete gasification of feed coal to syngas, in general, leads to relatively high unit production costs.

The catalytic hydroliquefaction processes offer good potential and should be capable of demonstrating commercial potential by 1990 if due diligence is used. Catalyst performance and cost per unit of production remain a question.

The seven processes in the group scoring 55 to 59 points are in varying stages of development. Three of the seven processes are not considered to be capable of commercial demonstration by the year 2000 while the SRC I, SRC II and Exxon Donor Solvent should, with due diligence, be capable of demonstrating commercial potential by 1990. One of these processes, 2.3.2 SRT Coal Hydropyrolysis, is a low yield high quality liquid producer and should therefore, probably be excluded from this evaluation.

The remaining processes received scores below 55, and are considered less attractive candidates for future commercial liquefaction application, although possibly having future application for coal gasification, or specialty chemicals production (e.g., metallurgical coke).

An overview of the potential rankings shows that the most promisisng processes for liquefaction are based upon hydroliquefaction (processes idenitfied by the prefix 1.0) and indirect (processes identified by the prefix 3.0) technology.

Table A-1 - Evaluation Criteria

Ranking Category	Characteristics	Description of Characteristics
Development Status	3	1. Technology status 2. Equipment development requirements 3. Process development status
Commercial Potential	12	1. Process complexity 2. Process severity 3. Industrial capacity 4. Feed versatility 5. Product versatility 6. Liquefaction efficiency 7. Sulfur reduction efficiency 8. Conversion efficiency 9. Product premium 10. Product compatibility 11. Product hazard 12. Uncertainty factor

Table A-2 - Summary of Development Status and Commercial Potential Ratings

Process Number	Process	Development Status Rating	Commercial Potential Rating
1.1.1	Solvent Refined Coal (SRC) I	53.3	55.1
1.1.1	Solvent Refined Coal (SRC) II	53.3	56.5
1.1.2	UOP Extraction Process	36.7	52.5
1.2.1	Gulf Catalytic Coal Liquids (CCL)	43.3	63.0
1.2.2	SYNTHOIL	43.3	64.3
1.2.3	H-Coal	50.0	62.6
1.2.4	Clean Fuel from Coal (CFC)	36.7	55.6
1.2.5	Conoco Zinc Halide Hydrocracking	30.0	57.6
1.3.1	Exxon Donor Solvent (EDS)	46.7	56.1
1.3.2	ADL Extractive Coking	43.3	53.5
1.3.3	Consol Synthetic Fuel (CSF)	53.3	63.6
2.1.1	Char-Oil-Energy-Development (COED), RMP	70.0	46.5
2.1.2	Char-Oil-Energy-Development (COED), FMC	73.3	42.9
2.1.3	Occidental Research Corp. Coal Flash Pyrolysis	60.0	46.3
2.1.4	TOSCOAL	73.3	52.6
2.1.5	Lurgi-Ruhrgas		52.5
2.2.1	U.S. Steel Clean Coke	40.0	48.3
2.2.2	Coalcon	53.3	55.6
2.3.1	BNL Rotating Fluidized Bed	13.3	56.4
2.3.2	Short Residence Time (SRT) Coal Hydropyrolysis	36.7	55.6
2.3.3	Intermediate Coal Hydrogenation	33.3	52.7
2.3.4	Schroeder's Rapid Hydrogenation	36.7	54.4
2.3.5	BNL Flash Hydropyrolysis	30.0	50.1
2.3.6	Rockwell International Direct Coal Hydrogenation	33.3	46.6
3.1.1	Flame Sprayed Catalyst (FSC)	50.0	74.3
3.1.2	ARGE (Arbeit Germeinschaft, Ruhrchemie/Lurgi)	100.0	78.2
3.1.3	SYNTHOIL	100.0	75.6
3.2.1	High Pressure Methanol Process	100.0	67.3
3.2.2	ICI LP/LT Methanol	100.0	68.6
3.2.3	Lurgi LP/LT Methanol Synthesis	100.0	69.5
3.2.4	Three-Phase Methanol Synthesis	50.0	62.7
3.3.1	M-Gasoline (Mobil)	50.0	67.7
4.1.1	Supercritical Gas Extraction (SCE)	36.7	37.5

Table A-3 - Development Status Process Rankings

Process Number	Process	Development Status Rating
3.1.2	ARGE (Arbeit Germeinschaft, Ruhrchemie/Lurgi	100.0
3.1.3	SYNTHOIL	100.0
3.2.1	High Pressure Methanol Process	100.0
3.2.2	ICI LP/LT Methanol	100.0
3.2.3	Lurgi LP/LT Methanol	100.0
2.1.5	Lurgi-Ruhrgas	96.7
2.1.2	Char-Oil-Energy-Development (COED), FMC	73.3
2.1.4	TOSCOAL	73.3
2.1.1	Char-Oil-Energy-Development (COED), RMP	70.0
2.1.3	Occidental Research Corp. Coal Flash Pyrolysis	60.0
1.1.1	Solvent Refined Coal (SRC) I	53.3
1.1.1	Solvent Refined Coal (SRC) II	53.3
1.3.3	Consol Synthetic Fuel (CSF)	53.3
2.2.2	Coalcon	53.3
1.2.3	H-Coal	50.0
3.1.1	Flame Sprayed Catalyst (FSC)	50.0
3.2.4	Three Phase Methanol Synthesis	50.0
3.3.1	M-Gasoline (Mobil)	50.0
1.3.1	Exxon Donor Solvent (EDS)	46.7
1.2.1	Gulf Catalytic Coal Liquids (CCL)	43.3
1.2.2	SYNTHOIL	43.3
1.3.2	ADL Extractive Coking	43.3
2.2.1	U.S. Steel Clean Coke	40.0
1.1.2	UOP Extraction Process	36.7
1.2.4	Clean Fuel from Coal (CFFC)	36.7
2.3.2	Short Residence Time SRT) Coal Hydropyrolysis	36.7
2.3.4	Schroeder's Rapid Hydrogenation	36.7
4.1.1	Supercritical Gas Extraction (SCE)	36.7
2.3.3	Intermediate Coal Hydrogenation	33.3
2.3.6	Rockwell International Direct Coal Hydrogenation	33.3
1.2.5	Conoco Zinc Halide Hydrocracking	30.0
2.3.5	BNL Flash Hydropyrolysis	30.0
2.3.1	BNL Rotating Fluidized Bed	13.3

Table A-4 - Commercial Potential Process Rankings

Rank	Process Number	Process	Commercial Potential Rating
1	3.1.2	ARGE (Arbeit Germeinschaft, Ruhrchemie/Lurgi)	78.2
2	3.1.3	SYNTHOL	75.6
3	3.1.1	Flame Sprayed Catalyst (FSC)	74.3
4	3.2.3	Lurgi LP/LT Methanol	69.5
5	3.2.2	ICI LP/LT Methanol	68.6
6	3.3.1	M-Gasoline (Mobil)	67.7
7	3.2.1	High Pressure Methanol Process	67.3
8	1.2.2	SYNTHOIL	64.3
9	1.3.3	Consol Synthetic Fuel (CSF)	63.6
10	1.2.1	Gulf Catalytic Coal Liquids (CCL)	63.0
11	3.2.4	Three-Phase Methanol Synthesis	62.7
12	1.2.3	H-Coal	62.6
13	1.2.5	Conoco Zinc Halide Hydrocracking	57.6
14	1.3.1	Exxon Donor Solvent (EDS)	56.8
15	1.1.1	Solvent Refined Coal (SRC) II	56.5
16	2.3.1	BNL Rotating Fluidized Bed	56.4
17	1.2.4	Clean Fuel from Coal (CFFC)	55.6
18	2.2.2	Coalcon	55.6
19	2.3.2	Short Residence Time (SRT) Coal Hydropyrolysis	55.6
20	1.1.1	Solvent Refined Coal (SRC) I	55.1
21	2.3.4	Schroeder's Rapid Hydrogenation	54.4
22	1.3.2	ADL Extractive Coking	53.5
23	2.3.3	Intermediate Coal Hydrogenation	52.7
24	2.1.4	TOSCOAL	52.6
25	1.1.2	UOP Extraction Process	52.5
26	2.1.5	Lurgi-Ruhrgas	52.5
27	2.3.5	BNL Flash Hydropyrolysis	50.1
28	2.2.1	U.S. Steel Clean Coke	48.3
29	2.3.6	Rockwell International Direct Coal Hydrogenation	46.6
30	2.1.1	Char-Oil-Energy-Development (COED), RMP	46.5
31	2.1.3	Occidental Research Corp. Coal Flash Pyrolysis	46.3
32	2.1.2	Char-Oil-Energy-Development (COED), FMC	42.9
33	4.1.1	Supercritical Gas Extraction (SCE)	37.3

Table A-5 - Development Status Rating

Process Number	Process	Technology Status D1[a]	Equipment Development Requiremtns D2[a]	Process Development Status D3[a]	Score (Max = 100)
1.1.1	Solvent Refined Coal (SRC) I	5	5	6	53.3
1.1.1	Solvent Refined Coal (SRC) II	5	5	6	53.3
1.1.2	UOP Extraction Process	3	5	3	36.7
1.2.1	Gulf Catalytic Coal Liquids	3	5	5	43.3
1.2.2	SYNTHOIL	3	5	5	43.3
1.2.3	H-Coal	5	4	6	50.0
1.2.4	Clean Fuel from Coal (CFFC)	2	6	3	36.7
1.2.5	Conoco Zinc Halide Hydrocracking	2	4	3	30.0
1.3.1	Exxon Donor Solvent (EDS)	3	6	5	46.7
1.3.2	ADL Extractive Coking	2	8	3	43.3
1.3.3	Consol Synthetic Fuel (CSF)	5	5	6	53.3
2.1.1	Char-Oil-Energy-Development (COED), RMP	5	10	6	70.0
2.1.2	Char-Oil-Energy-Development (COED), FMC	5	10	7	73.3
2.1.3	Occidental Research Corp. Flash Pyrolysis	3	10	5	60.0
2.1.4	TOSCOAL	5	10	7	73.3
2.1.5	Lurgi-Ruhrgas	10	10	9	96.7
2.2.1	U.S. Steel Clean Coke	3	5	4	40.0
2.2.2	Coalcon	5	6	5	53.3
2.3.1	BNL Rotating Fluidized Bed	1	2	1	13.3
2.3.2	Short Residence Time (SRT) Coal Hydro-pyrolysis	2	6	3	36.7
2.3.3	Intermediate Coal Hydrogenation	2	5	3	33.3
2.3.4	Schroeder's Rapid Hydrogenation	2	6	3	36.7
2.3.5	BNL Flash Hydropyrolysis	2	5	2	30.0
2.3.6	Rockwell International Direct Coal Hydrogenation	2	6	2	33.3
3.1.1	Flame Sprayed Catalyst (FSC)	2	6	7	50.0
3.1.2	ARGE (Arbeit Germeinschaft, Ruhrchemie/ Lurgi	10	10	10	100.0
3.1.3	SYNTHOIL	10	10	10	100.0
3.2.1	High Pressure Methanol Process	10	10	10	100.0
3.2.2	ICI LP/LT Methanol	10	10	10	100.0
3.2.3	Lurgi LP/LT Methanol	10	10	10	100.0
3.2.4	Three-Phase Methanol Synthesis	2	10	3	50.0
3.3.1	M-Gasoline (Mobil)	2	10	3	50.0
4.1.1	Supercritical Gas Extraction	2	6	3	36.7

[a]Weighting Factor: 3.33

Table A-6 - Commercial Potential Rating

Process Number	Process	Complexity P1 0.855[a]	Severity P2 0.945	Industrial Capacity P3 0.45	Feed Versatility P4 0.675	Product Versatility P5 0.675	Liquefaction Efficiency P6 0.90	Sulfur Reduction Efficiency P7 1.575	Conversion Efficiency P8 0.54	Product Premium P9 1.26	Product Compatibility P10 0.18	Product Hazard P11 0.945	Uncertainty Factor P12 1.0	Score (Maximum = 100)
1.1.1	Solvent Refined Coal (SRC) I	4	3	10.0	7.5	5	7.9	8.5	1.8	5.6	0.8	2.0	5.3	55.1
1.1.1	Solvent Refined Coal (SRC) II	4	3	4.1	10.0	5	7.7	9.3	4.6	5.6	2.4	2.0	5.3	56.5
1.1.2	UOP Extraction Process	4	5	0.7	10.0	5	7.8	8.3	1.7	5.6	1.6	2.0	3.7	52.5
1.2.1	Gulf Catalytic Coal Liquids	6	3	5.9	10.0	6	6.8	9.2	7.3	7.8	5.6	2.0	4.3	63.0
1.2.2	SYNTHOIL	5	3	10.0	10.0	6	7.4	9.3	7.0	7.7	5.2	2.0	4.3	64.3
1.2.3	H-Coal	3	3	4.1	10.0	6	7.2	9.7	8.4	8.0	7.1	2.0	5.0	62.6
1.2.4	Clean Fuel from Coal (CFFC)	3	3	4.1	10.0	6	5.8	9.4	4.8	7.0	3.1	2.0	3.7	55.6
1.2.5	Conoco Zinc Halide Hydrocracking	2	3	4.5	10.0	6	7.7	9.7	5.8	7.1	5.7	2.0	3.0	57.6
1.3.1	Exxon Donor Solvent (EDS)	5	3	5.9	10.0	5	6.1	9.3	4.6	5.6	3.3	2.0	4.7	56.8
1.3.2	ADL Extractive Coking	6	7	4.1	10.0	6	5.3	2.5	10.0	5.6	10.0	2.0	4.3	53.5
1.3.3	Consol Synthetic Fuel (CSF)	2	5	4.8	10.0	6	5.7	9.6	9.0	8.3	8.1	2.0	5.3	63.6
2.1.1	Char-Oil-Energy-Development (COED), RHP	3	4	4.3	6.0	4	2.6	5.7	5.6	5.9	4.2	2.0	7.0	46.5
2.1.2	Char-Oil-Energy-Development (COED), FMC	3	4	4.1	6.0	4	2.5	3.7	5.0	5.8	3.6	2.0	7.3	42.9
2.1.3	Occidental Research Flash Pyrolysis	5	4	10.0	6.0	4	3.7	3.3	5.0	5.8	3.4	2.0	6.0	46.3
2.1.4	TOSCOAL	7	7	1.4	6.0	4	1.8	6.4	6.7	5.8	4.4	2.0	7.3	52.6
2.1.5	Lurgi-Ruhrgas	6	4	1.7	6.0	4	1.9	5.0	10.0	6.1	10.0	2.0	9.7	52.5
2.2.1	U.S. Steel Clean Coke	2	4	1.7	7.5	4	1.2	9.1	5.2	7.7	2.4	2.0	4.0	48.3
2.2.2	Coalcon	4	4	10.0	5.0	4	3.0	9.0	10.0	5.9	5.0	2.0	5.3	55.6
2.3.1	BNL Rotating Fluidized Bed	5	1	10.0	5.0	3	6.0	8.7	10.0	8.0	10.0	3.8	1.3	56.4
2.3.2	Short Residence Time (SRT) Coal Hydropyrolysis	5	1	10.0	5.0	1	1.6	9.9	10.0	8.0	10.0	4.0	3.7	55.6
2.3.3	Intermediate Coal Hydrogenation	3	1	10.0	5.0	3	5.2	8.7	10.0	6.6	8.1	2.6	3.3	57.7
2.3.4	Schroeder's Rapid Hydrogenation	4	3	1.7	5.0	3	6.0	8.7	10.0	7.2	10.0	3.1	3.7	54.4
2.3.5	BNL Flash Hydropyrolysis	5	1	0.0	5.0	3	1.6	9.9	10.0	7.3	10.0	3.2	3.0	50.1
2.3.6	Rockwell International Direct Coal Hydrogenation	5	1	10.0	5.0	3	4.4	7.6	6.1	5.6	0.0	2.0	3.3	46.6
3.1.1	F-T Flame Sprayed Catalyst (FSC)	6	10	0.7	10.0	5	4.0	10.0	10.0	6.9	10.0	9.6	5.0	74.3
3.1.2	F-T ARGE (Arbeit Gemeinschaft, Ruhrchemie/Lurgi)	5	10	0.0	10.0	6	4.4	10.0	10.0	7.3	10.0	8.0	10.0	78.2
3.1.3	F-T SYNTHOL	5	10	1.4	10.0	6	3.4	10.0	10.0	6.7	10.0	6.3	10.0	75.6
3.2.1	High Pressure Methanol Process	6	1	10.0	10.0	1	6.0	10.0	10.0	7.1	0.0	4.0	10.0	67.3
3.2.2	ICI LP/LT Methanol	6	6	2.4	10.0	1	6.0	10.0	10.0	7.1	0.0	4.0	10.0	68.6
3.2.3	Lurgi LP/LT Methanol	6	6	4.5	10.0	1	6.0	10.0	10.0	7.1	0.0	4.0	10.0	69.5
3.2.4	Three-Phase Methanol Synthesis	5	6	2.4	10.0	1	6.0	10.0	10.0	7.1	0.0	4.0	5.0	62.7
3.3.1	M-Gasoline (Mobil)	3	7	0.3	10.0	1	5.3	10.0	10.0	10.0	10.0	6.0	5.0	67.7
4.1.1	Supercritical Gas Extraction (SGE)	7	3	2.4	10.0	1	3.7	4.2	0.0	3.7	0.0	2.0	3.7	37.5

[a] Weighting Factor

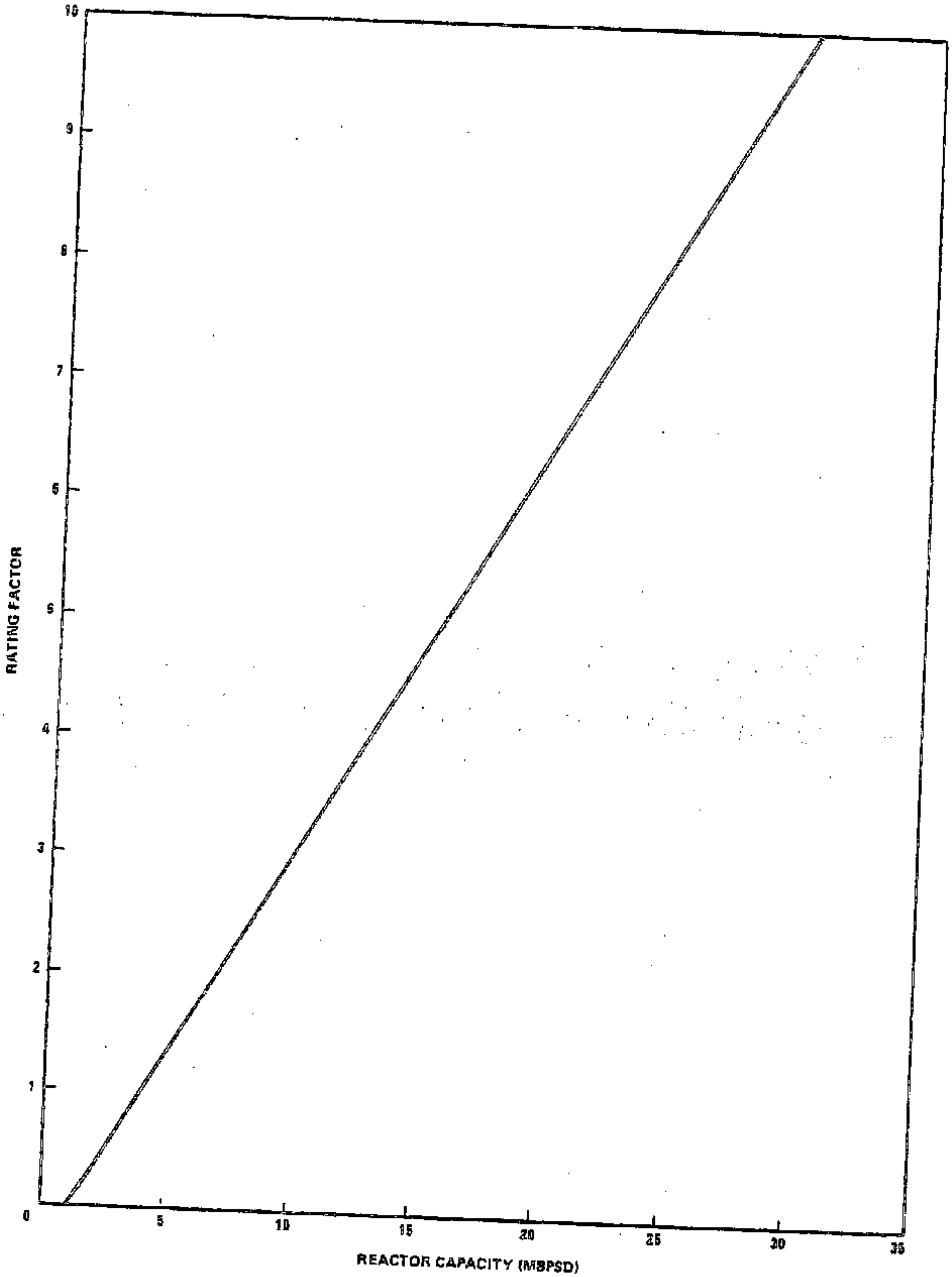

Figure A-1 - Industrial Capacity Rating (P3)