SECTION 4

MULTI-PROCESS DEMONSTRATION PLANT

A preliminary design and economic evaluation for a multi-process demonstration plant (MPDP) has been completed and a report describing the results published.[8] The concept included a low pressure entrained slagging gasifier to produce fuel gas (Plant 1), a medium pressure fluidized bed gasifier and an alternate medium pressure entrained slagging type gasifier to produce syngas plus a combined cycle power plant (Plant 2), and a Fischer-Tropsch indirect liquefaction unit (Plant 3); also the necessary ancillaries to support these operating units plus a plant population of 500-plus people.

The objectives for the MPDP were to:

- Develop a broad technological, engineering, environmental, safety and economics base for coal conversion processing.
- Demonstrate the reliability and safety of the MPDP performance and the types of equipment that perform best to achieve the program objectives.
- Produce gaseous and liquid products for testing in commercial scale equipment. The probability exists that future commercial use of these fuels will require some mutual accommodation of fuel characteristics and users equipment design/mode of operation.
- Demonstrate that the plants can be operated in an environmentally acceptable manner.
- Develop a breadth and depth of technological and engineering base for subsequent use in the commercialization programs.
- Provide a reliable basis for predicting the economics of the commercial plants.

The design was developed to achieve these objectives.

4.1 FACILITIES DESCRIPTION

Figure 4-1, a block flow diagram, shows the MPDP plants and their interrelationships. Figure 4-2 is a plot plant of the plants and units involved. An artist's conceptual drawing of the complex is shown in Figure 4-3.

The design consists of three principal process plants plus coal receiving, storage, and handling facilities plus the necessary ancillaries to service the plants and its plant population. The key elements of the three plants are:

Plant 1: A low pressure coal gasifier, which can be operated either in the air-blown or oxygen blown mode, with attendant heat and sulfur recovery auxiliaries. The products generated are, initially, low Btu fuel gas, steam and by-product sulfur.

Plant 2: Two oxygen blown intermediate pressure gasifiers, entrained and fluid bed types with oxygen plant, heat and sulfur recovery equipment and a combined cycle power plant. The design provides for one of the two gasifier types to be operated at any given time.

The combined cycle power plant will provide facilities for demonstrating the performance of close coupled generation of environmentally acceptable intermediate Btu fuel gases from coal followed by conversion to electricity in a high efficiency mode.

In addition to supply of fuel gas to the combined cycle power plant, the gasifiers will produce synthesis gas (syngas) for use in a Fischer-Tropsch indirect liquefaction plant; this syngas can later be used as feed to other indirect liquefaction units or as a source of reducing gases for tests on hydroliquefaction or donor solvent coal liquefaction plants. The information obtained from this syngas production unit could complement that obtained from other pilot plant and demonstration plant programs.

Plant 3: A Fischer-Tropsch plant complete with a carbon dioxide removal system, methanation and product recovery equipment. Products include salable substitute natural gas (SNG), Fischer-Tropsch liquid fuels (LPG, naphthas, diesel fuel, and heavy fuel oil) and alcohol mistures.

The design incorporates the use of flame sprayed catalyst reactors; this technology appears to have promise, based on the results of an earlier published conceptual commercial plant design and a development program underway at the Department of Energy's Pittsburgh Energy Research Center (DOE's PERC).

To summarize, the three plants will have the capability for demonstrating a number of basic coal conversion operations:

- Low pressure coal gasification to produce a clean, low sulfur fuel gas and steam.

- Intermediate pressure coal gasification to produce synthesis gas from two basic types of advanced design gasifiers.

- Electric power generation, in the combined cycle mode, integrated with intermediate Btu gasification and sulfur removal.
- Advanced Fischer-Tropsch synthesis and methanation to produce high quality, high value fuel products and steam by-products.
- Creditable overall thermal efficiencies for the plants achieved through heat recoveries producing usable steam.

The total land area requirement of the project is 100 acres; this should be made available as a single parcel at the beginning for the three plants and also a fourth plant should it be later desired. The demonstration plants will require approximately 17,000 acre-feet per year of water for process requirements and utility makeup.

Purchased coal will be delivered by rail and trucks, received and stored in open piles. Coal receiving, unloading, handling, storage and grinding takes place at a central location which serves all three plants modules.

4.1.1 PLANT CAPACITY

Coal feed rates are shown on the block flow diagram for the three plants. To provide flexibility and the ability to expand the scope of the program in the future, the Plant 2 gasifiers and sulfur plants are sized to supply synthesis gas to a potential future fourth plant. To illustrate, when supplying gas for Plant 2 operation only, the gasifier will be operating at approximately 60% of capacity. While supplying gas for Plant 2 and Plant 3 simultaneous operation, the gasifier will operate at 80% of capacity. Coal feed rates may be tabulated as follows:

Plant	Plants in Operation	Coal Feed Rates
1	1	1,800 TPD
2	2	2,250 TPD
2	2 and 3	3,000 TPD
2	2, 3 and 4	3,750 TPD

4.1.2 OPERATING SEQUENCE AND LIMITS

The following outlines the operating relationships and the interrelationships of the plants:

Plant 1:

(a) Operates alone.

(b) Can be shut down independently of Plants 2 and 3 except for Coal Receiving and Coal Grinding.

Plant 2:

(a) Can operate simultaneously with Plant 1.

(b) Can be operated independently of Plant 1 except for Coal Receiving and Coal Grinding.

(c) Operates at 60% of oxygen and gasification capacity when operating alone.

(d) Operates at 80% of oxygen and gasification capacity when Plant 3 is also in operation.

(e) Operates at 100% of oxygen and gasification capacity when Plant 3 and possible future plant 4 are also in operation.

Plant 3:

(a) Cannot operate by itself; Plant 2 must supply the syngas feed.

Plant 4:

(a) Cannot operate by itself; Plant 2 must supply the syngas feed.

(b) Can operate while Plant 3 is down.

The Fischer-Tropsch demonstration plant, designated as Plant 3, will provide date for design of a commercial scale plant. It will convert approximately 44 million scfd of syngas to SNG plus liquid products. It will use the processing procedures defined in a published Fischer-Tropsch conceptual Design/economic evaluation.[5]

Table 4-1 summarizes feed and product quantities for each plant as well as heating values for the separate streams. Overall thermal efficiencies, based on coal feed, of approximately 81%, 63% and 59% are indicated for Plants 1, 2 and 3, respectively.

Table 4-2 presents the overall thermal efficiencies for the Fischer-Tropsch plant only, based on the incremental coal feed to produce the syngas for the F-T operations and also based on the synthesis gas feed alone. These projected efficiencies are approximately 61% and 75%, respectively.

The thermal efficiencies for Plant 2 and Plant 3 operations reflect the efficiency loss attributable to the use of water slurried coal feed. The evaporation of the slurry water results in reduced thermal efficiencies relative to operation with dry coal feed as used in Plant 1. The slurry feed method for Plants 2 and 3 operation was selected because of expected reliability of performance based on experience with similar operations.

4.2 ECONOMICS

All economics are expressed as mid-1977 dollars. The projections were:

- The following fixed capital investment estimates were predicted:

Plant	Scope	FCI ($ Million)	Cumulative FCI ($ Million)
1	Gasify 1800 TPD of Coal at 40 psig	105	105
2	Two (2) oxygen blown gasifiers to gasify 3,750 TPD of coal at 400-600 psig plus a 200 negawatt combined cycle power plant	305	410
3	A Fischer-Tropsch plant to process 44 million SCFD of syn-gas	90	500

- The estimated annual operation costs for each of the three plants were:

Plant	Annual Operating Costs ($ Million)	Cumulative Annual Operating Costs ($ Million)
1	26	26
2	49	75
3	17	92

The operating cost estimates were based on a $1.00 per million Btu coal cost.

- The estimated plant population is 530 people.

- The plan uses a 10-year project schedule. Plants 1 and 2 would require 4 years to design, construct and start up, allowing 6 years operation. The Plant 3 operation would start 18 months after Plants 1 and 2, allowing 4.5 years operation.

- The cumulative expenditures, capital plus operations costs, over the project life were estimated to be about $1.15 billion; the fund requirement schedule is illustrated in Figure 4-4.

- The possible product market values and revenues when all units are operating at capacity was estimated to be about $60 million per year. For this estimate, the production rates were based on a operating rate of 330 stream days per year, equal to a 90.4 percent operating factor, except for the first 18 months of operation of each plant. Projected revenues were based on operation at 25 percent capacity the first 6 months, 50 percent the second 6 months, 75 percent the third six months, and 100 percent thereafter.

- The projected 10 year net project cost, after credit for revenues as described in the previous point, was estimated to be about $800 million. This is illustrated in Figure 4-5.

- Possible tax write-offs were considered. These are specific to the project structure.

- To illustrate, if the project were 100 percent funded with private capital such that the tax losses could be used to offset profits from other operations, and if the MPDP could be depreciated over the 7 year operating life, the possible net cost to the owner for the project could be as low as $350 million; see Figure 4-5.

4.3 EXPECTED ACCOMPLISHMENTS

The key result expected is that the MPDP should provide a major basis for industry decisions regarding investment in the coal conversion technologies tested.

To accomplish its objectives, the facility should be conservatively designed, using experience from all sources to reduce technical risks to an acceptable level and assure reliable, safe, environmentally acceptable operation. The design effort should continue to be supported by an active research and development program. In parallel with the design, procurement, construction and start-up of the MPDP, components should be tested and improved; this includes cooperative programs with equipment, process development and instrumentation firms.

The construction and operation of a MPDP would provide hands-on experience with the performance of essential plant components. It would provide data and experience on operation of large scale coal conversion plant units and the interaction of the plant units with its associated supporting facilities and environment. An improved understanding would be developed for the range of costs and other factors pertinent to development of this energy option. The construction and operation experience would also contribute to development of the necessary technical and engineering expertise in safety, reliability, economics and environmental factors for later use in commercial projects. It would also provide a core of experienced personnel in the design, construction and operation of this type synfuels plant; the personnel should be available for contributions on later projects.

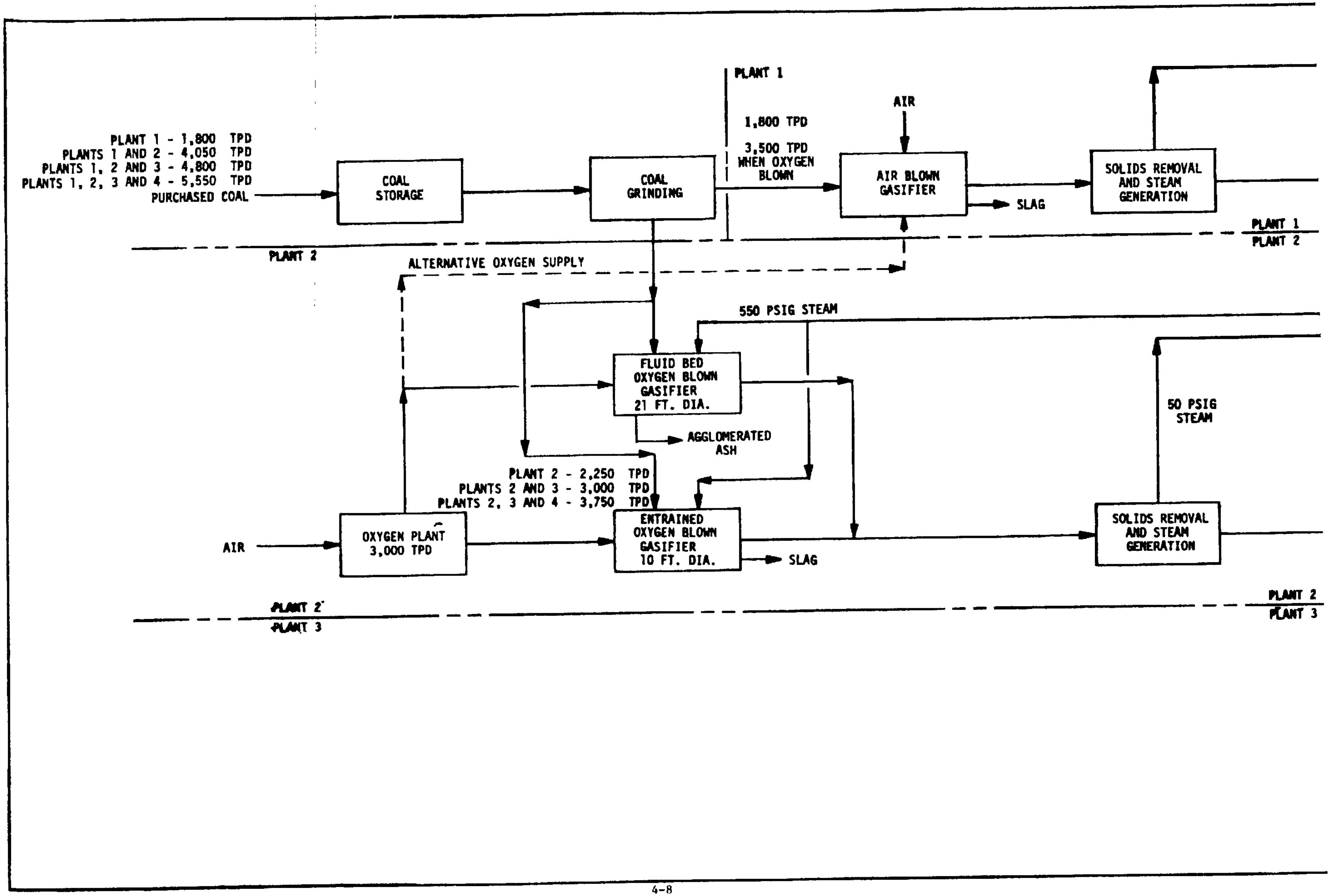
Specific results to be expected include:

- Successful development and testing of large components should lead to improvements in commercial plant planning, scheduling, and cost prediction.

- The availability of large components whose performance has been proven should reduce the risks in design of commercial scale plants and should, therefore, encourage industry to invest in the larger plants.

- Acceptance of the performance of the fuel products in consumer applications and establishing that they can be sold at competitive prices.

Importantly, the MPDP described here should provide the operational experience and records needed to evaluate the commercial viability of commercial scale coal conversion plants using the technologies tested.


PLANT 1
1,800 TPD
3,500 TPD WHEN OXYGEN BLOWN
AIR
PLANT 1 - 1,800 TPD
PLANTS 1 AND 2 - 4,050 TPD
PLANTS 1, 2 AND 3 - 4,800 TPD
PLANTS 1, 2, 3 AND 4 - 5,550 TPD
PURCHASED COAL
COAL STORAGE
COAL GRINDING
AIR BLOWN GASIFIER
SLAG
SOLIDS REMOVAL AND STEAM GENERATION
PLANT 1
PLANT 2
PLANT 2
ALTERNATIVE OXYGEN SUPPLY
550 PSIG STEAM
FLUID BED OXYGEN BLOWN GASIFIER 21 FT. DIA.
AGGLOMERATED ASH
50 PSIG STEAM
PLANT 2 - 2,250 TPD
PLANTS 2 AND 3 - 3,000 TPD
PLANTS 2, 3 AND 4 - 3,750 TPD
AIR
OXYGEN PLANT 3,000 TPD
ENTRAINED OXYGEN BLOWN GASIFIER 10 FT. DIA.
SLAG
SOLIDS REMOVAL AND STEAM GENERATION
PLANT 2
PLANT 3
PLANT 2
PLANT 3

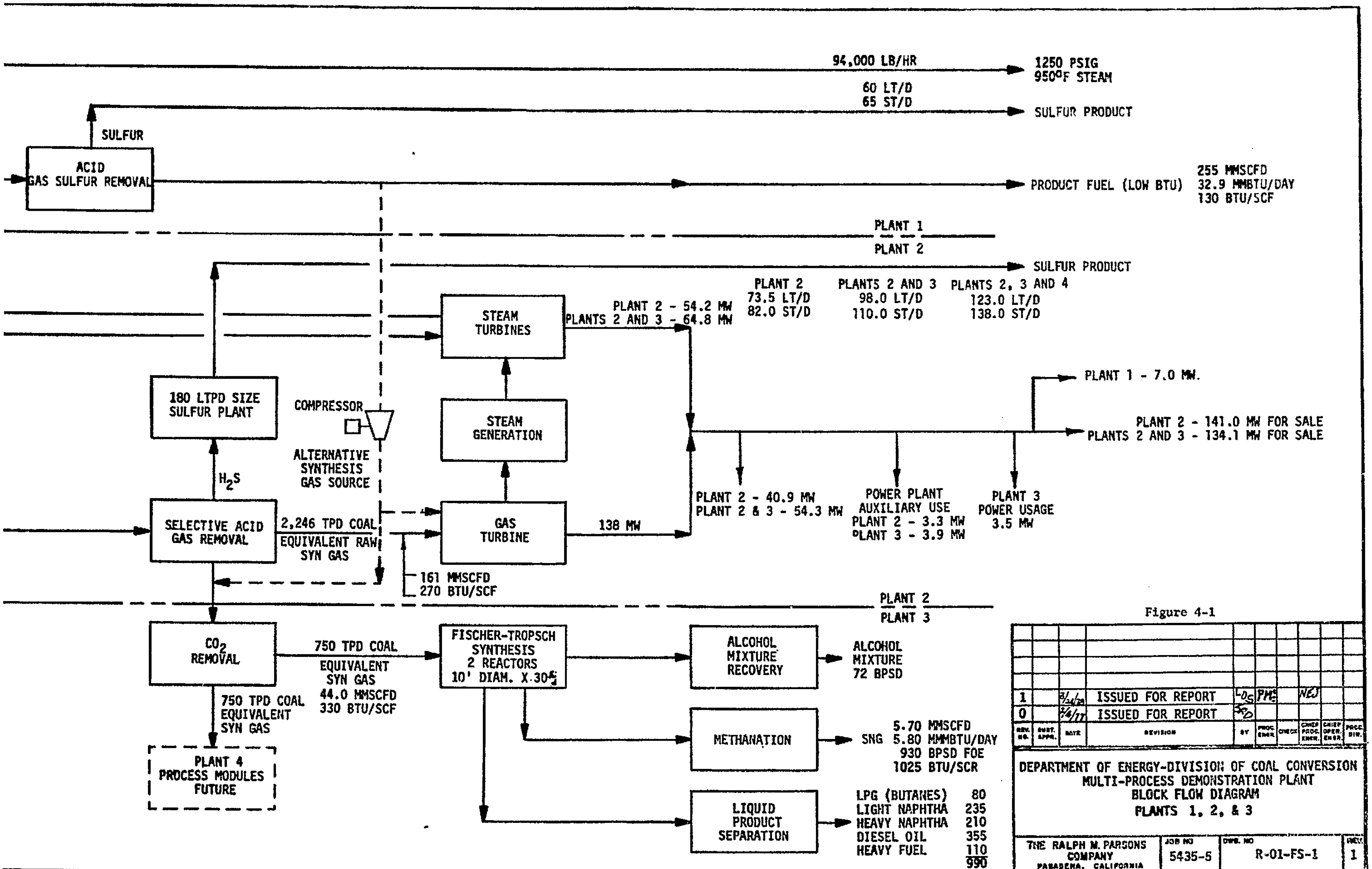
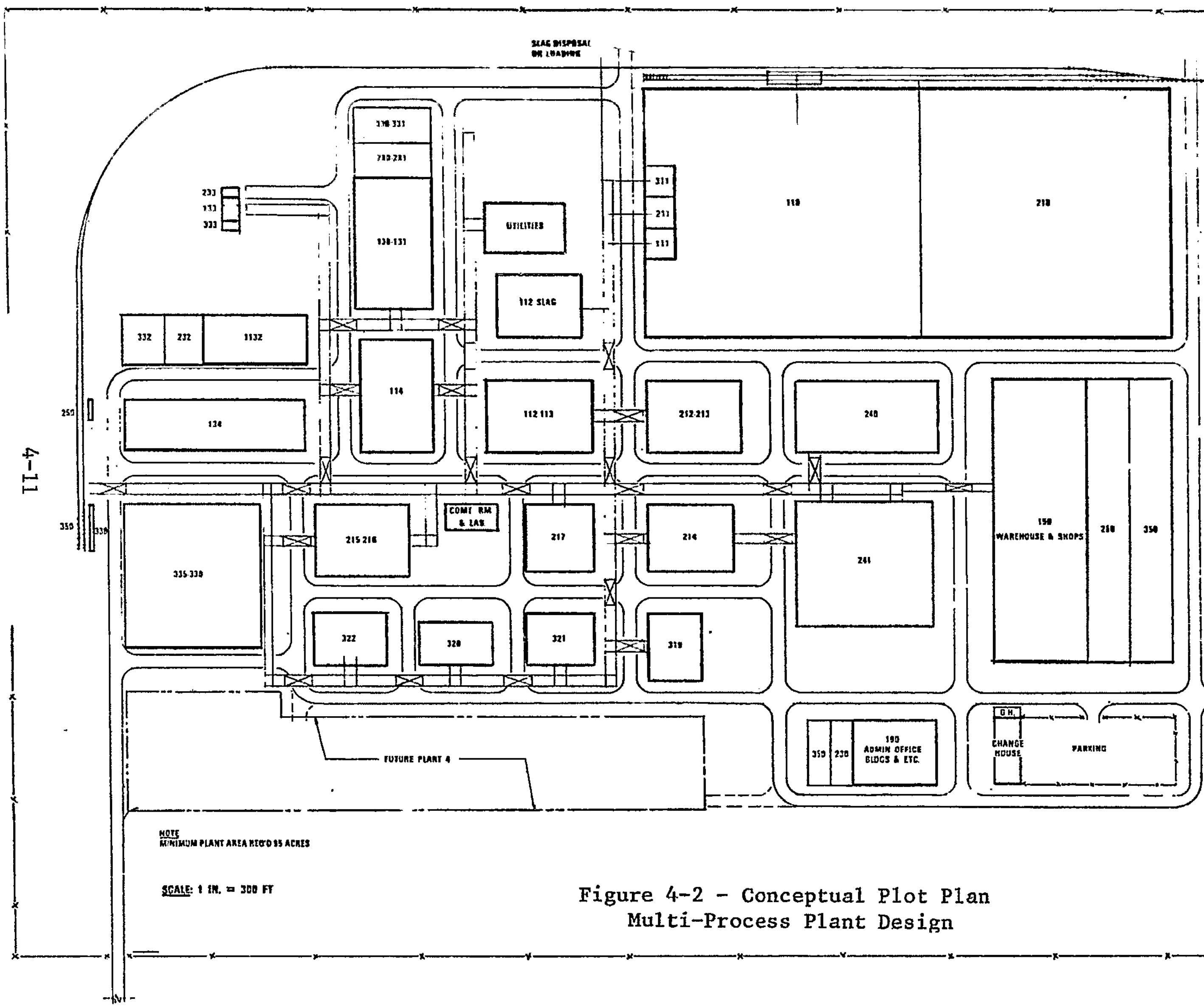

94,000 LB/HR
1250 PSIG
950°F STEAM
60 LT/D
65 ST/D
SULFUR PRODUCT
SULFUR
ACID GAS SULFUR REMOVAL
PRODUCT FUEL (LOW BTU)
255 MMSCFD
32.9 MMBTU/DAY
130 BTU/SCF
PLANT 1
PLANT 2
SULFUR PRODUCT
PLANT 2
73.5 LT/D
82.0 ST/D
PLANTS 2 AND 3
98.0 LT/D
110.0 ST/D
PLANTS 2, 3 AND 4
123.0 LT/D
138.0 ST/D
STEAM TURBINES
PLANT 2 - 54.2 MW
PLANTS 2 AND 3 - 64.8 MW
PLANT 1 - 7.0 MW.
PLANT 2 - 141.0 MW FOR SALE
PLANTS 2 AND 3 - 134.1 MW FOR SALE
180 LTPD SIZE SULFUR PLANT
COMPRESSOR
STEAM GENERATION
ALTERNATIVE SYNTHESIS GAS SOURCE
H2S
PLANT 2 - 40.9 MW
PLANT 2 & 3 - 54.3 MW
POWER PLANT AUXILIARY USE
PLANT 2 - 3.3 MW
PLANT 3 - 3.9 MW
PLANT 3 POWER USAGE
3.5 MW
SELECTIVE ACID GAS REMOVAL
2,246 TPD COAL
EQUIVALENT RAW SYN GAS
GAS TURBINE
138 MW
161 MMSCFD
270 BTU/SCF
PLANT 2
PLANT 3
CO2 REMOVAL
750 TPD COAL
EQUIVALENT SYN GAS
44.0 MMSCFD
330 BTU/SCF
FISCHER-TROPSCH SYNTHESIS
2 REACTORS
10' DIAM. X 30'
ALCOHOL MIXTURE RECOVERY
ALCOHOL MIXTURE
72 BPSD
750 TPD COAL
EQUIVALENT SYN GAS
METHANATION
SNG
5.70 MMSCFD
5.80 MMMBTU/DAY
930 BPSD FOE
1025 BTU/SCR
PLANT 4
PROCESS MODULES
FUTURE
LIQUID PRODUCT SEPARATION
LPG (BUTANES) 80
LIGHT NAPHTHA 235
HEAVY NAPHTHA 210
DIESEL OIL 355
HEAVY FUEL 110
990
1 ISSUED FOR REPORT
0 ISSUED FOR REPORT
DEPARTMENT OF ENERGY-DIVISION OF COAL CONVERSION
MULTI-PROCESS DEMONSTRATION PLANT
BLOCK FLOW DIAGRAM
PLANTS 1, 2, & 3
THE RALPH M. PARSONS COMPANY
PASADENA, CALIFORNIA
JOB NO 5435-5
DWG. NO R-01-FS-1
REV. 1

Figure 4-1



PLANT AND UNIT NO.	UNIT
PLANT 1	LOW-PRESSURE FUEL GAS GASIFICATION
110	COAL STORAGE
111	COAL GRINDING
112	LOW-PRESSURE GASIFIER
113	LOW-BTU GAS HEAT RECOVERY
114	LOW-BTU ACID GAS SULFUR REMOVAL
130	WATER TREATMENT
131.	COOLING WATER SYSTEM
132	EFFLUENT TREATMENT
133	FLARE
134	SULFUR STORAGE
150	BUILDINGS, RAILROAD, ROADS, GENERAL FACILITIES
PLANT 2	INTERMEDIATE PRESSURE GASIFICATION AND POWER GENERATION
210	ADDED COAL STORAGE
211	ADDED COAL GRINDING
212	MEDIUM PRESSURE GASIFIERS
213	MEDIUM BTU GAS HEAT RECOVERY
214	MEDIUM BTU ACID GAS REMOVAL
215	SULFUR PLANT
216	TAIL GAS TREATMENT
217	PROCESS WATER RECLAMATION
230	ADDED WATER TREATMENT
231	ADDED COOLING WATER SYSTEM
232	ADDED EFFLUENT TREATMENT
233	ADDED FLARE SYSTEM
240	OXYGEN PLANT
241	POWER PLANT
250	ADDED BUILDINGS, RAILROAD, ROADS, GENERAL FACILITIES
PLANT 3	INTERMEDIATE-PRESSURE GASIFICATION, POWER GENERATION, AND FISCHER-TROPSCH SYNTHESIS
311	ADDED COAL GRINDING
318	FISCHER-TROPSCH ACID GAS REMOVAL
319	FISCHER TROPSCH SYNTHESIS
320	FISCHER TROPSCH LIQUID PRODUCT RECOVERY
321	FISCHER TROPSCH GAS METHANATION
322	FISCHER TROPSCH ALCHOLOLS MIXTURE RECOVERY
330	ADDED WATER TREATMENT
331	ADDED COOLING WATER SYSTEM
332	ADDED EFFLUENT TREATMENT
335	INTERMEDIATE STORAGE
336	PRODUCT STORAGE AND SHIPPING FACILITIES
350	ADDED BUILDINGS, RAILROAD, ROADS, GENERAL FACILITIES

Figure 4-2 - Conceptual Plot Plan
Multi-Process Plant Design

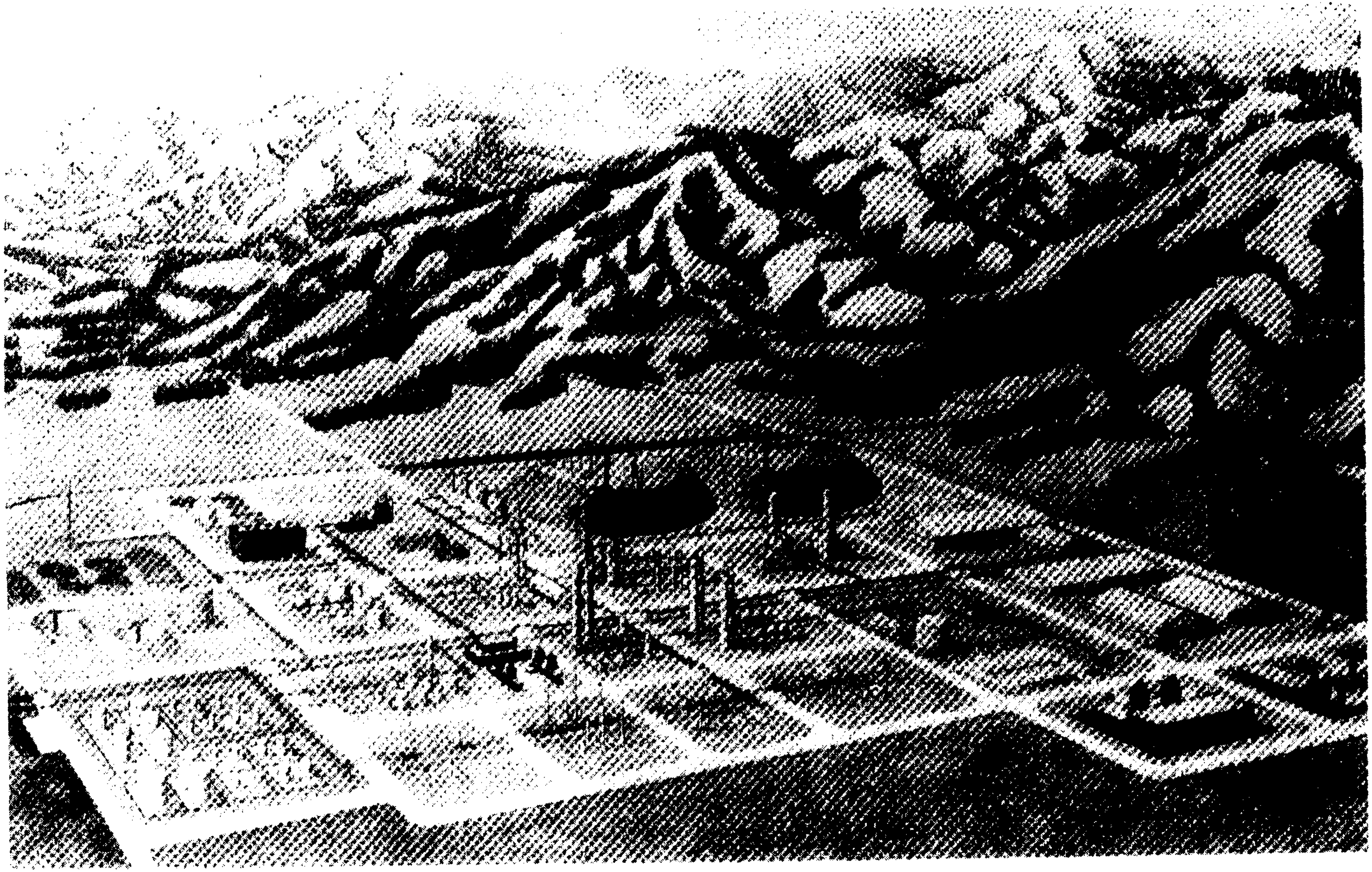


Figure 4-3 - Artist's Concept of Multi-Process Plant Design

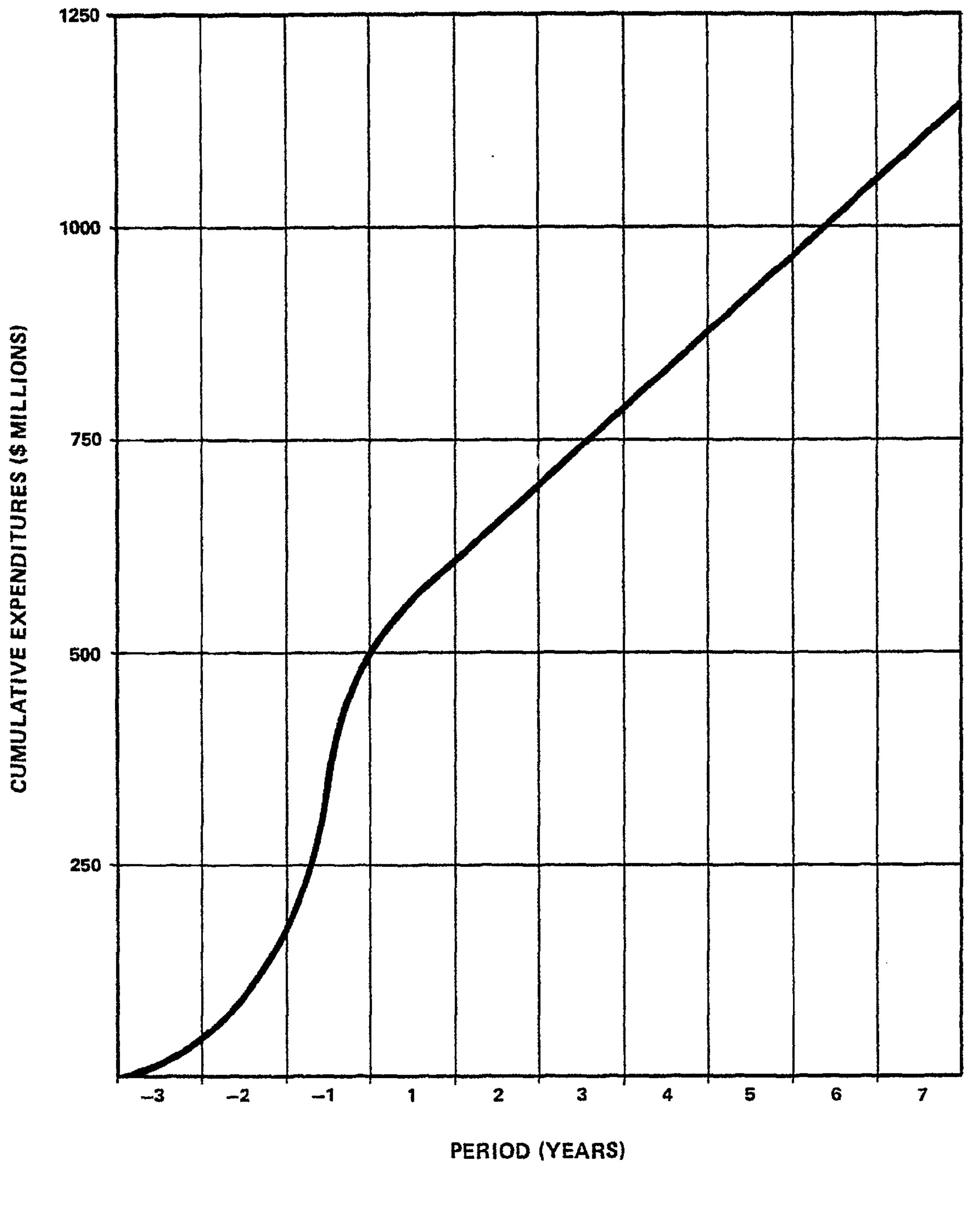


Figure 4-4 - Cumulative Project Expenditures
Multi-Process Plant Design

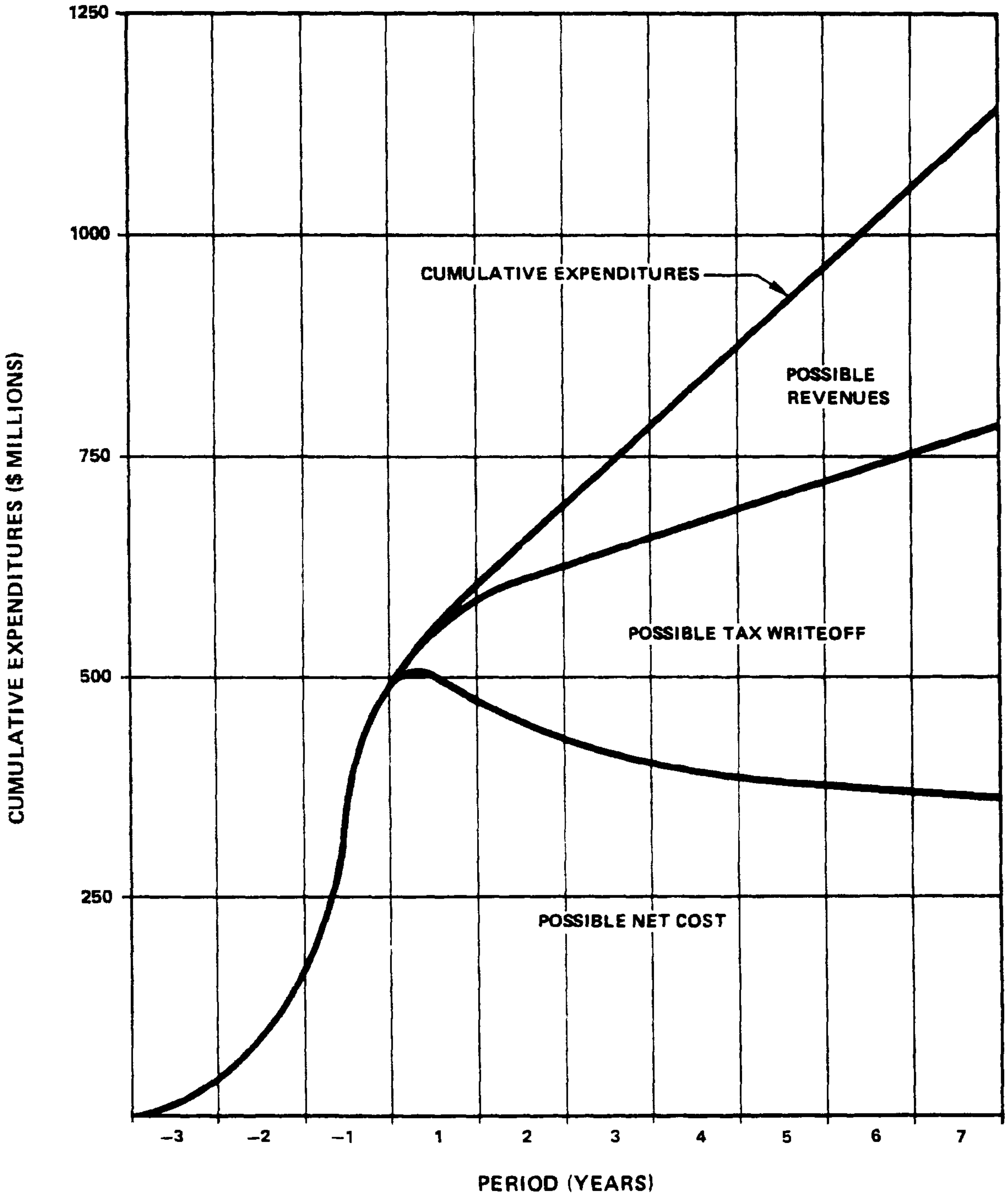


Figure 4-5 - Cumulative Project Expenditures with Credits
Multi-Process Plant Design

Table 4-1 - MPDP Products, Projected Quantities, Heating Values, and Process Thermal Efficiencies

Feed and Product	Stream Quantity: Quantity per Stream Day	Stream Quantity: Tons per Stream Day	Unit HHV	Total Heating Value (million Btu/d)	%
Plant 1 (Plant 2 in operation)					
Coal Feed		1800	12,125 Btu/lb	43,650	
Electric power (fuel basis)	5.27 MMscf/d		291.7 Btu/scf	1,537	
Energy in				45,187	
Fuel gas	253 MMscf/d		130 Btu/scf	32,890	
Steam	94,000 lb/hr		1,400 Btu/lb	3,158	
Sulfur		66.0	3,990 Btu/lb	527	
Total products' heating value				36,575	
Thermal efficiency					80.9
Plant 2					
Coal Feed		2246	12,125 Btu/lb	54,466	
Fuel gas to power plant	161 MMscf/d		270 Btu/scf	43,511	
less fuel gas equivalent of electric power used	-36 MMscf/d		270 Btu/scf	9.769	
	125 MMscf/d		270 Btu/scf	33,742	
Sulfur		82.4	3,990 Btu/lb	658	
Total products' heating value				34,400	
Thermal efficiency					63.2

Table 4-1 (Contd)

Feed and Product	Stream Quantity: Quantity per Stream Day	Stream Quantity: Tons per Stream Day	Unit HHV	Total Heating Value (million Btu/d)	%
Plant 3 (Including Plant 2)					
Coal feed		2996	12,125 Btu/lb	72,653	
Fuel gas (net)	114 MMscf/d		270 Btu/scf	30,791	
Oxygenates	72 BPD	9.97	12,505 Btu/lb	249	
SNG	5.69 MMscf/d		1,025 Btu/scf	5,832	
LPG, C_4's	78 BPD		21,035 Btu/lb	318	
Light naphtha	234 BPD	26.778	20,815 Btu/lb	1,115	
Heavy naphtha	211 BPD	25.773	20,430 Btu/lb	1,053	
Diesel Oil	356 BPD	46.618	20,255 Btu/lb	1,888	
Heavy fuel oil	112 BPD	16.095	19,855 Btu/lb	640	
Sulfur		109.9	3,990 Btu/lb	877	
Total products' heating value				42,763	
Thermal efficiency					58.9

Table 4-2 - MPDP Plant 3 Fischer-Tropsch Plant Products and Thermal Efficiencies

Feed and Product	Stream Quantity		Unit HHV	Total Heating Value (million Btu/d)	%
	Quantity per Stream Day	Tons per Stream Day			
Based on Incremental Coal Feed					
Feeds					
Coal feed		750	12,125 Btu/lb	18,188	
Add: fuel gas equivalent for electric power consumed	17,500 kW-h		*7,606 Btu/kW-h Heat Rate	3,195	
Total energy in				21,383	
Products					
Oxygenates	72 BPD	9.97	12,505 Btu/lb	249	
SNG	5.69 MMscf/d		1,025 Btu/scf	5,832	
LPG C_4's	78 BPD		21,035 Btu/lb	318	
Light naphtha	234 BPD	26.778	20,815 Btu/lb	1,115	
Heavy naphtha	211 BPD	25.773	20,430 Btu/lb	1,053	
Diesel oil	356 BPD	46.618	20,255 Btu/lb	1,888	
Heavy fuel oil	112 BPD	16.095	19,855 Btu/lb	640	
Sulfur		27.5	3,990 Btu/lb	219	
Excess steam produced	124,00 lb/hr		(avg) 620 Btu/lb	1,850	
Total products' heating value				13,164	
Thermal efficiency					61
Based on Synthesis Gas Feed to F-T Reactor					
Feeds					
Syngas feed	44.00 MMscf/d		330 Btu/scf	14,529	
Add: fuel gas equivalent for electric power consumed	3,417 kW-h		*7,606 Btu/kW-h Heat Rate	624	
Total energy in				15,153	

SECTION 5

PRESTRESSED CONCRETE PRESSURE VESSELS

5.1 INTRODUCTION

A study was completed which determined that the use of large prestressed concrete pressure vessels PCPVs in coal conversion plants is technically feasible and offers potential economic advantages.[9]

A study of the conceptual design and projected economics of four types of PCPVs for use in coal conversion plants was completed. The designs and economics were then compared with alternative steel vessels when used in the same service.

The Ralph M. Parsons Company (Parsons) of Pasadena, California was the prime contractor and T.Y. Lin International of San Francisco, California served as subcontractor with responsibility for the structural design of the prestressed concrete pressure vessels.

The prime incentives for this study were:

- The development of PCPVs would permit the use of larger high pressure vessels than presently considered practical in steel construction.
- PCPVs would provide a competitive alternative to the use of steel vessels. This could be a major consideration if a number of coal conversion complexes were to be constructed simultaneously to meet national alternative energy supply goals as described in U.S. energy plans. This alternative is particularly important because of the limited U.S. capability to produce numerous large high pressure vessels simultaneously, and because of possible shortages of alloy materials for high strength steel alloys.
- PCPVs could reduce the FCI of large coal conversion plants. The profitability of coal conversion plants is highly sensitive to the FCI; therefore a successful PCPV program would assist in making these plants economically viable.

The designs developed in this study were chosen to illustrate the potential of representative vessels selected from a large number of possible uses for PCPVs in coal conversion processes. The four PCPVs studied were: a dissolver-separator used to liquefy coal, an absorber used to purify gases, a coal gasifier reactor and an integrated coal gasifier vessel. The vessels studied range from 23'-4" to 33'-4" inside diameter. They were each designed to replace one or more conventional steel pressure vessels with no change in the process flow from conventional practice. Figure 5-1 illustrates the projected size and characteristics of one of the vessels - note the 6-foot man for size comparison.

5.2 TECHNICAL FEASIBILITY

A PCPV is a structure wherein concrete, reinforcing steel, and high strength steel tendons are used to form the pressure containment shell. Well over 90 percent of the mass is concrete.

Prestressing means the intentional creation of permanent stresses in a concrete structure, for the purpose of improving its structural behavior under various load conditions. The prestressing forces can be applied by means of stressing the tendons. Figure 5-2 shows the general arrangement of the tendons in a PCPV. Similar to reinforced concrete, prestressed concrete involves combined action between the concrete and the prestressing steel tendons, and interaction between the internal prestressing force and the externally imposed loads. For PCPVs, the prestressing forces are applied by post-tensioning the steel tendons after the concrete has hardened. The post-tensioned tendons place the vessel in compression and enable it to resist the high operating pressures.

There are several additional elements required for a PCPV to perform successfully as a process pressure vessel. One of these is a metal membrane internal liner, which serves to prevent escape of process gases and liquids into the concrete structure. The metal membrane liner also serves as a form during concrete placement.

Another important element is a cooling system plus insulating concrete which is necessary to control the structural concrete temperature whenever the metal liner temperature exceeds 200°F. Also, internal refractory is used when necessary to shield the metal membrane liner against very high temperature.

The general methods of PCPV design have been established. They have been used by the nuclear industry for design of prestressed concrete reactor vessels (PCRVs) for use at pressures in the 600-700 psig range. They are also used routinely in the design of nuclear secondary containment vessels of which approximately 60 are under construction or in use today. These methods have also been applied in the design of vessels for storage of water, oil, LNG and coal. However, because of the higher operating temperatures and pressures, and the thicker concrete walls for the coal conversion plant operations discussed here, some confirmatory tests should be performed to further substantiate the design.

The materials required for construction of large PCPVs are widely available in the United States. At present there is a temporary shortage of cement in the western states caused by the building boom. Indications are that structural concrete in the desired quantities and quality will be produced throughout the United States when needed. There are presently four U.S. companies that supply 270 ksi strength cable tendons required for this type of construction. Two other major U.S. firms have also produced this cable in the past.

Other required metal components are also readily available in the United States. In contrast, there are a very limited number of suppliers of large heavy-wall pressure vessel-grade steel plate in the United States. There is one company in the United States, one in Europe and one in Japan with capability to produce 12 to 15-inch thick plates which weigh up to 50 tons. There are a number of suppliers of pressure vessel-grade steel plate of lesser thickness.

The field fabrication of large heavy-walled pressure vessels has been limited in the United States to one firm. At least two other firms have organizations capable of the field fabrication of large heavy-walled pressure vessels. There are presently about 10 shops in the United States capable of building heavy walled pressure vessels of 10 to 12-inch wall thickness for all uses.

The method of construction of the PCPVs utilize well proven technology. The equipment for construction of the vessels is presently available and in use in construction of large concrete structures. The construction sequence of the integrated gasifier PCPV is shown in Figure 5-3.

The operation of a PCPV process vessel will be generally similar to that of a conventional steel pressure vessel. For PCPVs with internal process temperatures over 200°F, a closed cycle cooling system will be required which will add some complexity to the system due to the addition of pumps, piping and heat exchange equipment.

The development of methods for operational inspection and monitoring of the vessel integrity will be required for some vessel elements. These elements include the external cooling system, the insulating concrete and the concrete to membrane wall attachments.

The maintenance of PCPVs is expected to be more difficult than steel vessels. This is due to the more difficult entrance into the vessel internals caused by very large and heavy closure plugs, the lack of accessibility to the embedded cooling coils, and the additional equipment maintenance for pumps and heat exchange equipment for the cooling systems. Further, it will be difficult to modify a PCPV because of the locations of tendons and reinforcing steel.

The inherent safety characteristics of a PCPV appear better than for a steel vessel. Teses conducted on PCPVs indicate that the concrete will crack and relieve excessive pressures, and after pressure relief, the steel tendons will again compress the concrete and seal the PCPV.

There are presently no commercial code criteria for PCPVs for coal conversion plants. The American Society of Mechanical Engineers Pressure Vessel Code, Section III, Division 2 covers the requirements for PCPV nuclear containment vessels and nuclear reactors. However, this code does not appear applicable to PCPVs for coal conversion processes because of the different characteristics required. It will be necessary to perform studies and tests to demonstrate their viability and to obtain data for design criteria for coal conversion PCPVs.

5.3 VESSEL COMPARISONS

The three basic types of process pressure vessels, dissolver-separator, absorber and gasifier, were selected to be representative of those utilized in coal conversion plants. They cover a wide range of process requirements with regard to pressures, temperatures, process stream compositions, and configurations.

The PCPVs in this study were compared with steel pressure vessels for identical process duties. The steel pressure vessels had been investigated and reported in earlier studies made by Parsons.[3,39]

5.3.1 DISSOLVER-SEPARATOR

The dissolver-separator is a key vessel in coal hydroliquefaction processing; a similar process is under development at the SRC pilot plant located at Fort Lewis, Washington for the U.S. Department of Energy.

Figure 5-4 is a simplified cross sectional view of the PCPV. Here, the main process elements, the dissolver-separator vessels, operate at 850^{o}F and 2,025 psig. The metal membrane wall is directly exposed to the process environment. A process flow diagram describing the process duties and conditions is shown in Figure 5-5 at the end of this section.

5.3.2 ABSORBER

The process design for this acid gas removal contactor originated in an earlier conceptual design published by Parsons.[3] For this study only t the absorber vessel was investigated.

A cross sectional view of this PCPV is shown in Figure 5-6. The vessel has internal trays and intermediate heads, which require carrying these loads into the concrete structure.

A process flow diagram is shown in Figure 5-7 at the end of this section.

5.3.3 GASIFIERS

The gasification process flow scheme is the same for the gasifier reactor and the integrated gasifier vessel. The process scope covers from the point of feeding a coal-water slurry to the gasifier to the discharge of solids-free gas for further downstream processing. The process design is based on a two-stage entrained gasification process. A typical similar process would be the Bi-Gas process being developed at Homer City, Pennsylvania for the U.S. Department of Energy; the first stage of the gasifier operates at 3,000^{o}F, at a pressure of 1,085 psig.

A process flow diagram showing the process conditions and major equipment items is shown in Figure 5-8 at the end of this section. The key gasifier vessels operate in a severe process environment with temperatures ranging from 1,700 to 3,000^{o}F at a pressure of 1,085 psig. Further, they have a complex internal geometry. Two types of possible gasifier configurations were investigated. For the first type, only the gasifier reactor is contained in the concrete structure. Figure 5-9 is a simplified cross sectional view of this vessel. The second type is referred to as an integrated gasifier vessel. This unit, shown in Figure 5-10, has the closely associated ancillary equipment - coal and char cyclones, flash dryers, and coal and char eductors embedded in the concrete structure.

5.4 RESULTS

The results of the study indicate:

- The design and construction of PCPVs was found to be generally within the present state of knowledge. Subscale testing should be performed to confirm some design judgements.
- The use of PCPVs can reduce the FCI requirements. To illustrate, substitution of a single PCPV for as many as 18 steel vessels might reduce the FCI by approximately 70 percent, amounting to as much as $300 million. Replacement of a single steel vessel with a PCPV can reduce the FCI by approximately 10 percent. Details are summarized in the following report section.
    - Thus, there is a definite economic incentive to carry further the development of PCPVs to demonstrate their technical feasibility and economic viability.
- PCPVs offer an alternative for construction of large scale coal conversion plants.
- Improved vessel safety performance is expected because of the benign failure characteristics of PCPVs.
- PCPVs have the potential to be operational in a shorter schedule than steel vessels.
- At the time of this writing, supply projections indicate that the materials of construction for PCPVs can be readily available in the U.S. while the capacity to fabricate and install large numbers of large heavy walled steel pressure vessels was found to be currently limited by the number of suppliers and availability of fabrication facilities.

It is recommended that a demonstration scale PCPV be designed, constructed and operated in a coal conversion plant and the results be used as a basis for commercial plant design.

5.5 ECONOMICS

FCI and operating costs were estimated for the four PCPVs and compared with equivalent economic parameters for steel pressure vessels in the same process service. The results are summarized here.

To develop the estimates, process flow sheets, equipment sizes and equipment lists were prepared for each PCPV case. Equipment costs were obtained using either historical cost data or vendor-supplied information. The FCIs for the steel vessel cases were escalated to December 1977 values from those given in previous Parsons' studies.[3,39]

Table 5-1 summarizes the FCI comparison for the four types of PCPVs. The results indicate that very significant reductions in FCI can occur by the substitution of large PCPVs for multiple smaller steel vessels. The largest FCI reduction, $300 million or approximately 70 percent, was for the case of the dissolver-separator where one PCPV essentially replaced nine dissolvers and nine separators of conventional steel construction. Substitution of one large PCPV for six steel absorbers might reduce the FCI by 60 percent.

The projected annual and unit product cost savings using the PCPV when compared to steel vessels are shown in Table 5-2. Again, the largest saving was in the dissolver-separator case where a savings of about $0.20 per million Btu's of coal feed to the unit is projected; for a plant feeding 55,500 TPD of coal, this would result in a yearly savings of over $90 million. Approximately 80 percent of this savings is directly related to the predicted lower fixed capital investment.

The economic analyses were based on a 12 percent DCF rate of return on invested capital and a 20-year plant operating life at an operating rate of 330 stream days per year. Operating labor was based on a wage rate of $7.50 per hour with a payroll burden of 35 percent.

Table 5-1 - Fixed Capital Investment Comparison

Vessel	Type of Construction	Number of Trains	Capacity per Train	Number of Major Vessels per Train	Total Number Of Major Vessels	FCI ($ Million)	Percent Reduction in FCI Compared to Steel Vessel
Dissolver-Separator	Steel	3	20,000 TPD of Coal	6	18	430	0
	PCPV	1	55,000 TPD of Coal	1	1	130	70
Absorber	Steel	3	23 million scf/hr	2	6	10	0
	PCPV	1	69 million scf/hr	1	1	4	60
Gasification	Steel	2	55,000 TPD of Coal	1	2	255	0
	PCPV-Gasifier Reactor only	2	55,000 TPD of Coal	1	2	225	12
	PCPV-Integrated Gasifier	2	55,000 TPD of Coal	1	2	230	10

Table 5-2 - Savings Using Prestressed Concrete Vs. Steel

Item	Dissolver-Separator		Absorber		Gasifier Only		Integrated Gasifier	
	Uniform Annual Cost ($ Million)	Feed Coal ($/MMBtu)	Uniform Annual Cost ($ Million)	Feed Gas ($/MMscf)	Uniform Annual Cost ($ Million)	Product Gas ($/MMBtu)	Uniform Annual Cost ($ Million)	Product Gas ($/MMBtu)
Operating Costs								
Operating Labor and Materials	-0.512	-	0.062	-	-	-	-	-
Maintenance	10.732	-	0.240	-	1.158	-	0.977	-
Utilities	-1.227	-	-	-	-0.025	-	-0.142	-
Plant Overhead	2.326	-	0.088	-	0.278	-	0.234	-
Property Tax and Insurance	7.381	-	0.165	-	0.796	-	0.671	-
G and A	0.293	-	0.008	-	0.033	-	0.027	-
Savings Subtotal	18.993	0.043	0.563	0.001	2.240	0.003	1.767	0.003
Capital Burden Costs								
Capital Investment	46.080	-	1.029	-	4.970	-	4.193	-
Working Capital	1.484	-	0.035	-	0.165	-	0.136	-
Income Taxes	26.062	-	0.585	-	2.815	-	2.374	-
Savings Subtotal	73.626	0.166	1.649	0.003	7.950	0.010	6.703	0.009
Total Savings	92.619	0.209	2.212	0.004	10.190	0.013	8.470	0.011

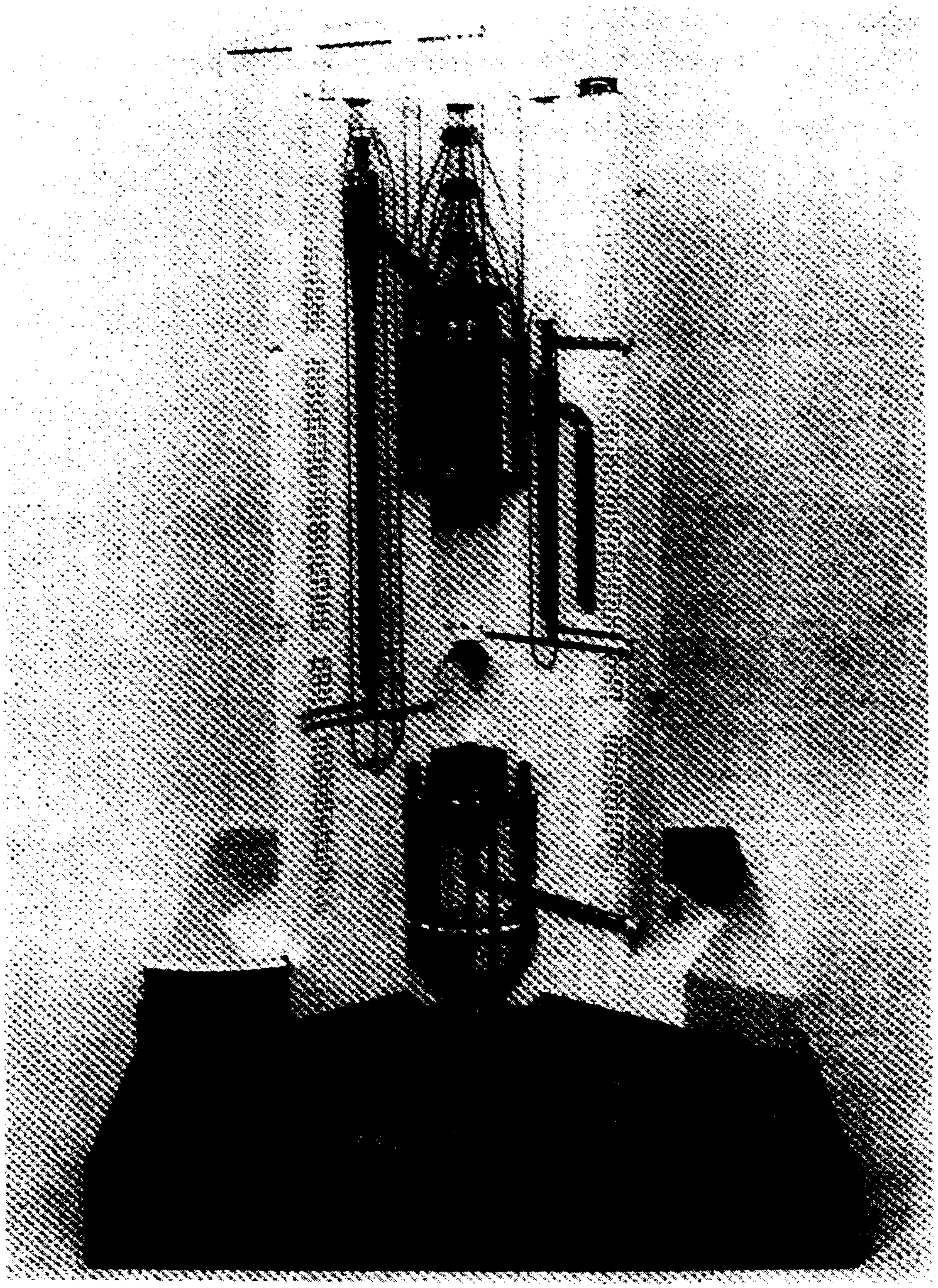


Figure 5-1 - Model of Conceptual Integrated Gasifier Vessel
Cross Sectional View

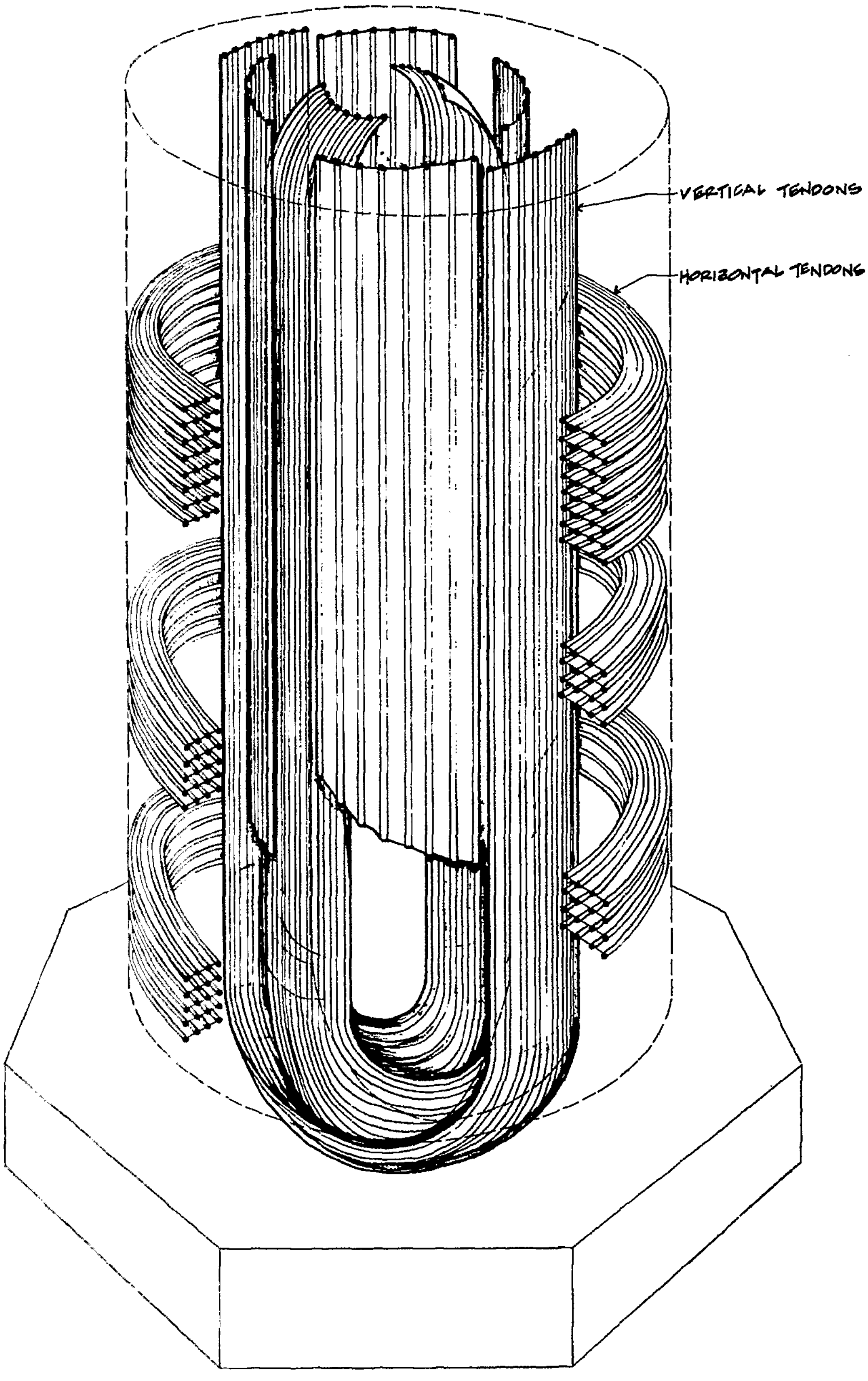
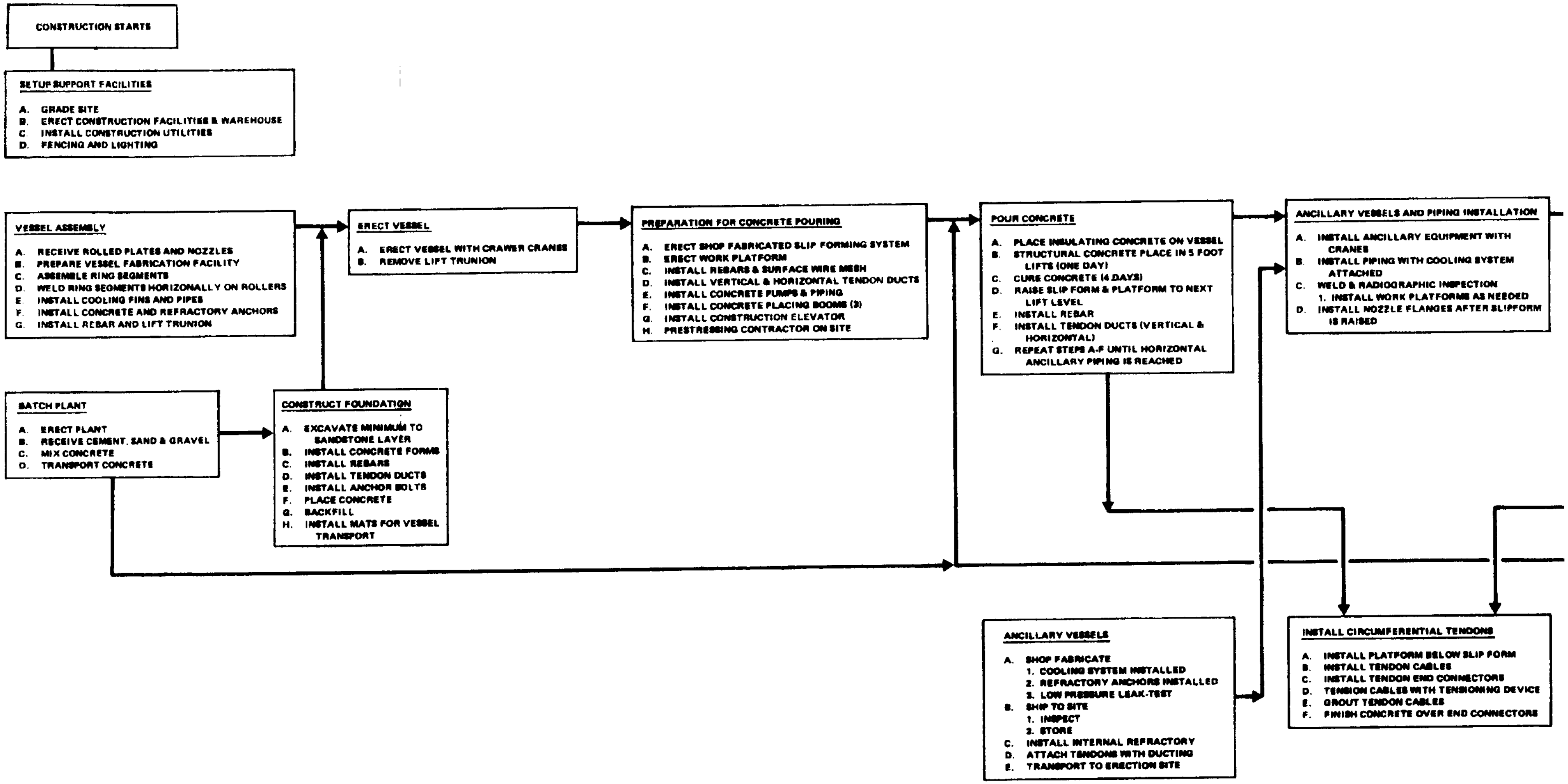


Figure 5-2-Looping Tendon Arrangement Schematic


CONSTRUCTION STARTS
SETUP SUPPORT FACILITIES
A. GRADE SITE
B. ERECT CONSTRUCTION FACILITIES & WAREHOUSE
C. INSTALL CONSTRUCTION UTILITIES
D. FENCING AND LIGHTING
VESSEL ASSEMBLY
A. RECEIVE ROLLED PLATES AND NOZZLES
B. PREPARE VESSEL FABRICATION FACILITY
C. ASSEMBLE RING SEGMENTS
D. WELD RING SEGMENTS HORIZONALLY ON ROLLERS
E. INSTALL COOLING FINS AND PIPES
F. INSTALL CONCRETE AND REFRACTORY ANCHORS
G. INSTALL REBAR AND LIFT TRUNION
ERECT VESSEL
A. ERECT VESSEL WITH CRAWLER CRANES
B. REMOVE LIFT TRUNION
PREPARATION FOR CONCRETE POURING
A. ERECT SHOP FABRICATED SLIP FORMING SYSTEM
B. ERECT WORK PLATFORM
C. INSTALL REBARS & SURFACE WIRE MESH
D. INSTALL VERTICAL & HORIZONTAL TENDON DUCTS
E. INSTALL CONCRETE PUMPS & PIPING
F. INSTALL CONCRETE PLACING BOOMS (3)
G. INSTALL CONSTRUCTION ELEVATOR
H. PRESTRESSING CONTRACTOR ON SITE
POUR CONCRETE
A. PLACE INSULATING CONCRETE ON VESSEL
B. STRUCTURAL CONCRETE PLACE IN 5 FOOT LIFTS (ONE DAY)
C. CURE CONCRETE (4 DAYS)
D. RAISE SLIP FORM & PLATFORM TO NEXT LIFT LEVEL
E. INSTALL REBAR
F. INSTALL TENDON DUCTS (VERTICAL & HORIZONTAL)
G. REPEAT STEPS A-F UNTIL HORIZONTAL ANCILLARY PIPING IS REACHED
ANCILLARY VESSELS AND PIPING INSTALLATION
A. INSTALL ANCILLARY EQUIPMENT WITH CRANES
B. INSTALL PIPING WITH COOLING SYSTEM ATTACHED
C. WELD & RADIOGRAPHIC INSPECTION
1. INSTALL WORK PLATFORMS AS NEEDED
D. INSTALL NOZZLE FLANGES AFTER SLIPFORM IS RAISED
BATCH PLANT
A. ERECT PLANT
B. RECEIVE CEMENT, SAND & GRAVEL
C. MIX CONCRETE
D. TRANSPORT CONCRETE
CONSTRUCT FOUNDATION
A. EXCAVATE MINIMUM TO SANDSTONE LAYER
B. INSTALL CONCRETE FORMS
C. INSTALL REBARS
D. INSTALL TENDON DUCTS
E. INSTALL ANCHOR BOLTS
F. PLACE CONCRETE
G. BACKFILL
H. INSTALL MATS FOR VESSEL TRANSPORT
ANCILLARY VESSELS
A. SHOP FABRICATE
1. COOLING SYSTEM INSTALLED
2. REFRACTORY ANCHORS INSTALLED
3. LOW PRESSURE LEAK-TEST
B. SHIP TO SITE
1. INSPECT
2. STORE
C. INSTALL INTERNAL REFRACTORY
D. ATTACH TENDONS WITH DUCTING
E. TRANSPORT TO ERECTION SITE
INSTALL CIRCUMFERENTIAL TENDONS
A. INSTALL PLATFORM BELOW SLIP FORM
B. INSTALL TENDON CABLES
C. INSTALL TENDON END CONNECTORS
D. TENSION CABLES WITH TENSIONING DEVICE
E. GROUT TENDON CABLES
F. FINISH CONCRETE OVER END CONNECTORS

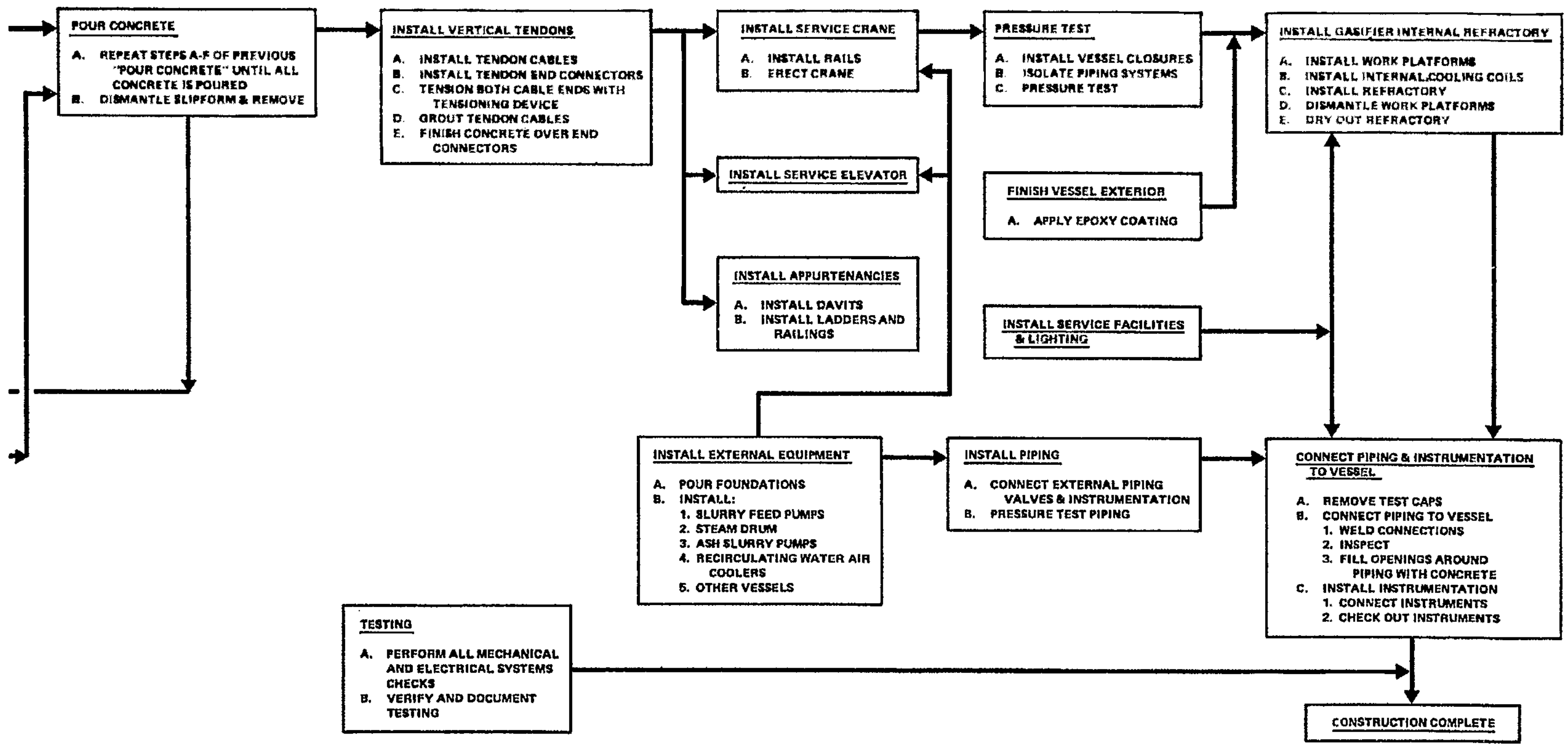


Figure 5-3 - Construction Sequence — Integrated Gasifier Vessel

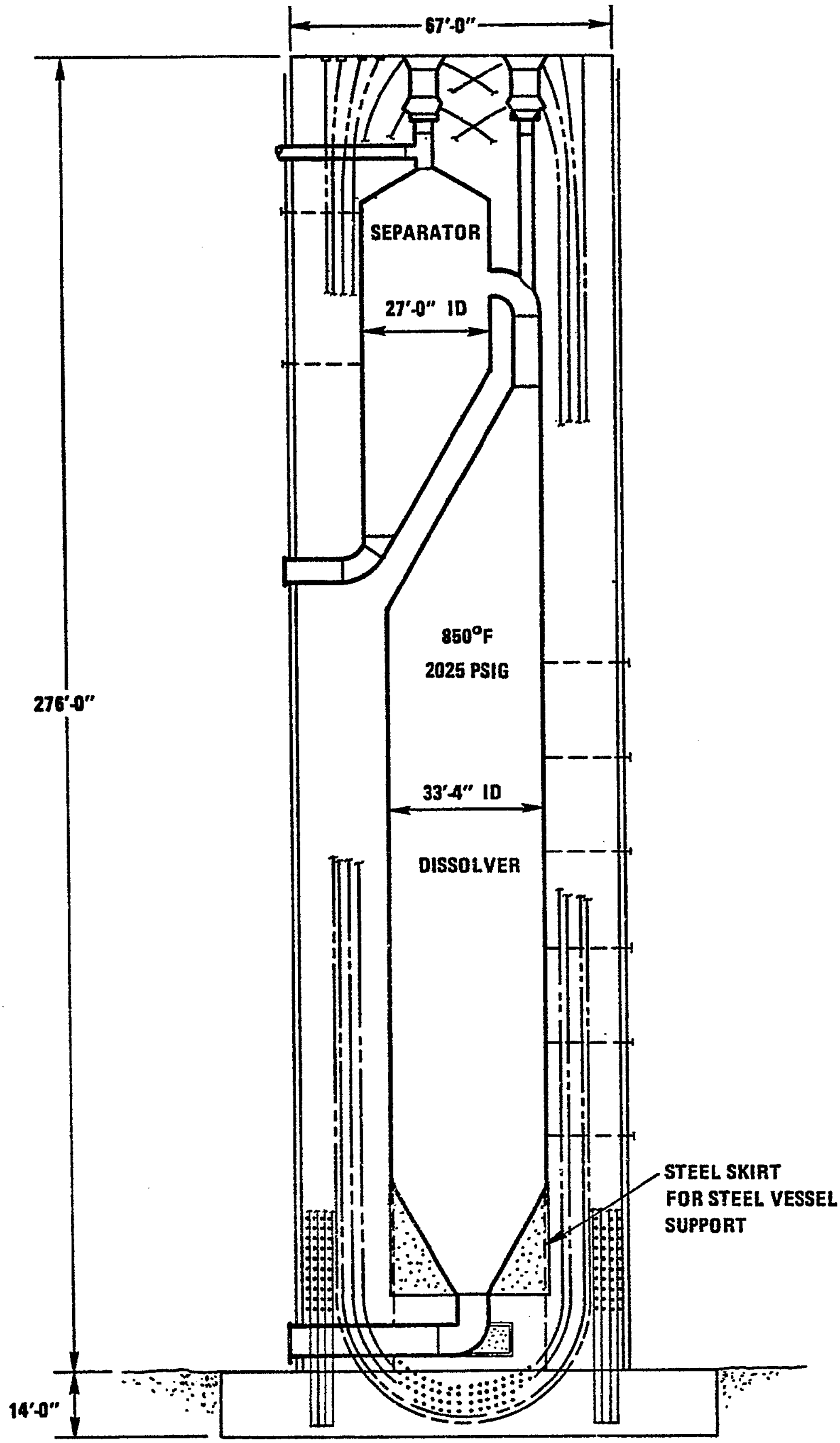
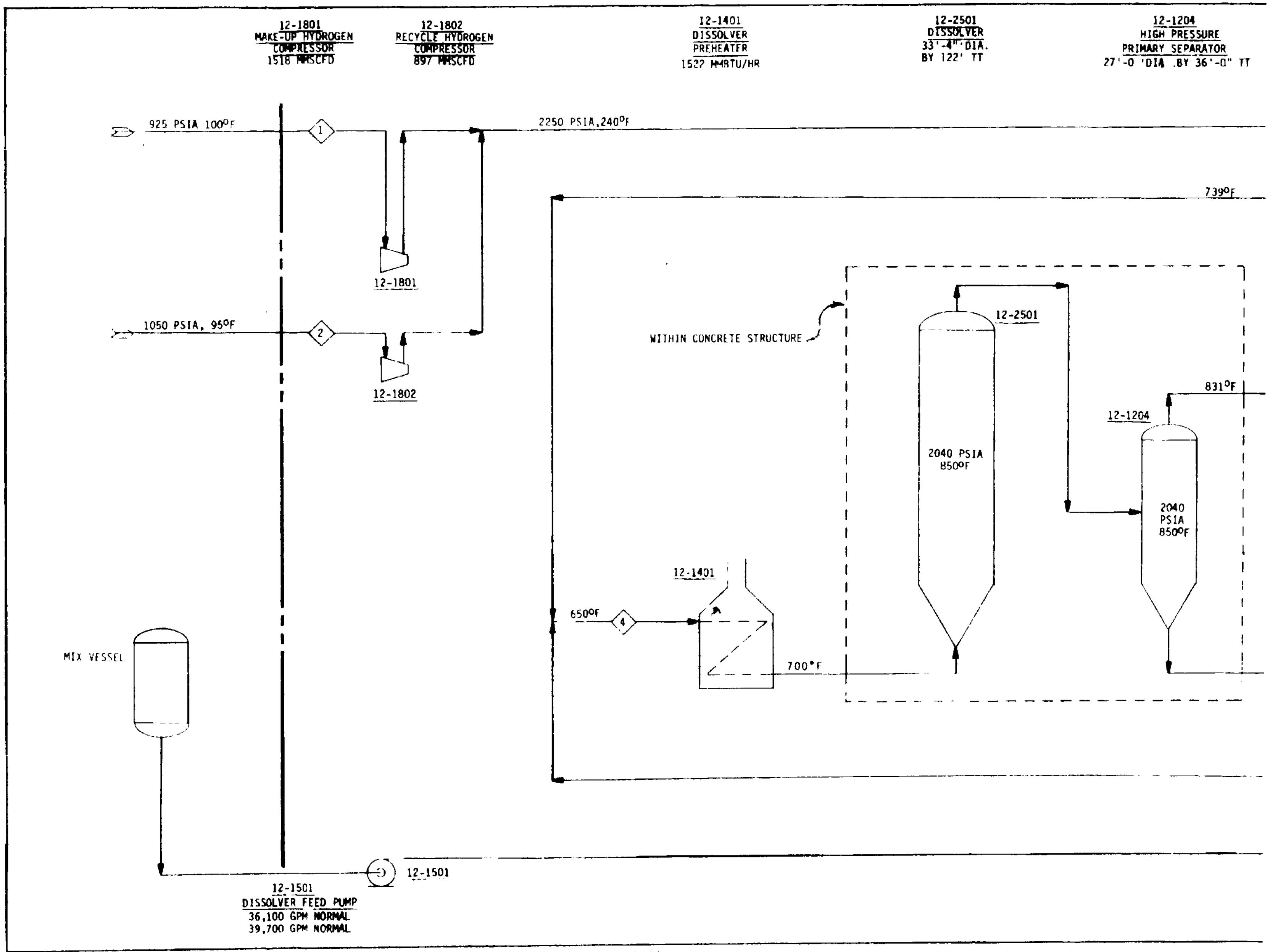


Figure 5-4 - Dissolver-Separator Vessel Sketch


12-1801
MAKE-UP HYDROGEN
COMPRESSOR
1518 MMSCFD
12-1802
RECYCLE HYDROGEN
COMPRESSOR
897 MMSCFD
12-1401
DISSOLVER
PREHEATER
1522 MMBTU/HR
12-2501
DISSOLVER
33'-4" DIA.
BY 122' TT
12-1204
HIGH PRESSURE
PRIMARY SEPARATOR
27'-0 'DIA .BY 36'-0" TT
925 PSIA 100°F
1
2250 PSIA, 240°F
739°F
12-1801
1050 PSIA, 95°F
2
12-1802
WITHIN CONCRETE STRUCTURE
12-2501
831°F
12-1204
2040 PSIA
850°F
2040
PSIA
850°F
12-1401
650°F
4
700°F
MIX VESSEL
12-1501
12-1501
DISSOLVER FEED PUMP
36,100 GPM NORMAL
39,700 GPM NORMAL

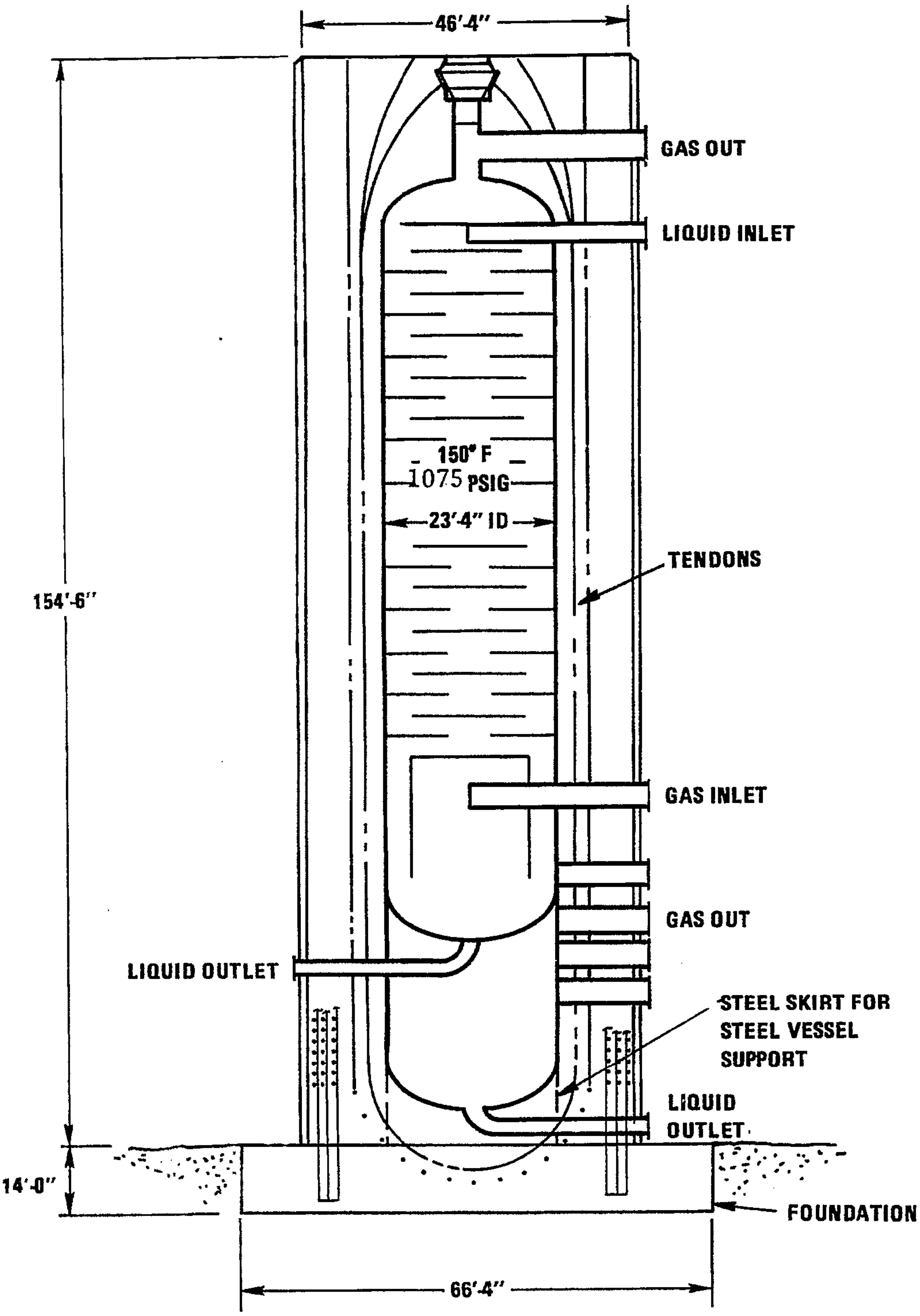
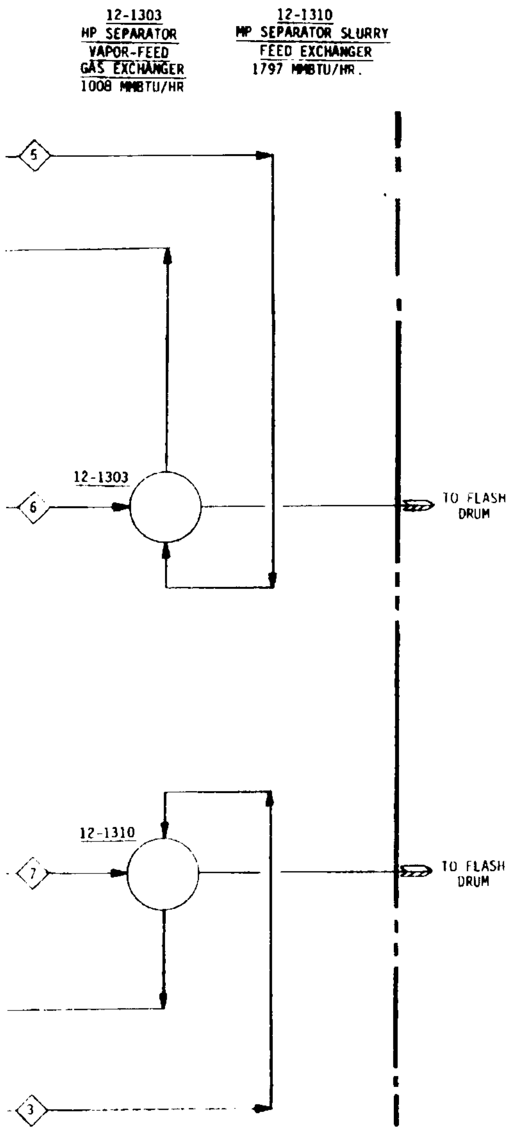


Figure 5-6 - Absorber Vessel Sketch



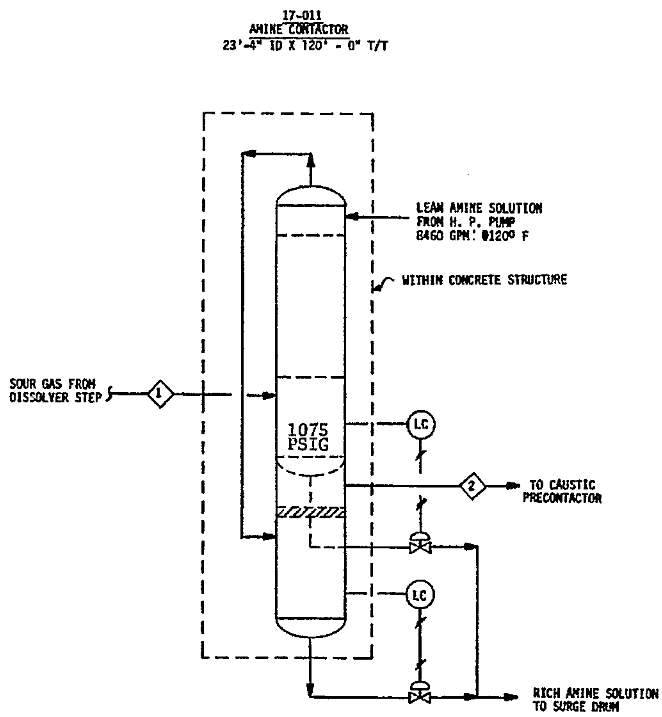
COMPONENT	① MAKE-UP HYDROGEN	② RECYCLE HYDROGEN	③ SLURRY TO DISSOLVER	④ SLURRY & GAS TO FURNACE	⑤ TOTAL HYDROGEN GAS	⑥ HP SEPARATOR VAPOR	⑦ HP SEPARATOR SLURRY
H_2 MOLES/HR.	132,590	94,308	---	226,898	226,898	103,460	9,989
N_2	1,827	945	---	2,772	2,772	1,681	1,090
CO	5,582	2,422	---	8,004	8,004	5,396	2,608
CO_2	166	---	---	166	166	1,142	199
NH_3	---	---	---	---	---	594	87
H_2S	86	---	---	86	86	3,451	423
H_2O	127	---	105	229	229	7,288	158
C_1	26,317	768	---	27,085	27,085	36,846	4,496
C_2	---	---	---	---	---	3,885	849
C_3	---	---	---	---	---	3,534	732
NC_4	---	---	---	---	---	1,274	300
IBP-200	---	---	---	---	---	310	95
200-400	---	---	-	---	---	1,791	1.387
400-450	---	---	---	---	---	388	533
450-500	---	---	---	---	---	285	509
500-600	---	---	285	285	---	586	1,687
650+	---	---	34,507	34,507	---	1,412	38,576
RESIDUE	---	---	37	37	---	---	70
ASH	---	---	126	126	--	---	126
COAL (MAF)	---	---	427	427	---	---	---
TOTAL MOLES/HR	166,696	98,442	35,488	300,626	265,138	172,735	63,916
LB/HR	909,536	296,750	19,866,890	21,073,176	1,206,286	2,491,344	18,581,832
BPD	---	---	1,097,886	---	---	---	1,100,316
MMSCD	1,518.213	896.589	---	--	2,414.8	1.578.6	---
MW	5.456	3.014	559.82	---	4.55	14.37	290.73
LB/GAL	---	---	10.340	---	---	---	9.650

FIGURE 5-5

REV NO		DATE	REVISION	BY				
0								

PROCESS FLOW DIAGRAM
DISSOLVER - SEPARATOR
PRESTRESSED CONCRETE
PRESSURE VESSEL

THE RALPH M PARSONS COMPANY PASADENA, CALIFORNIA	JOB NO 5435-6	DWG NO R 1-FS-2	REV 0

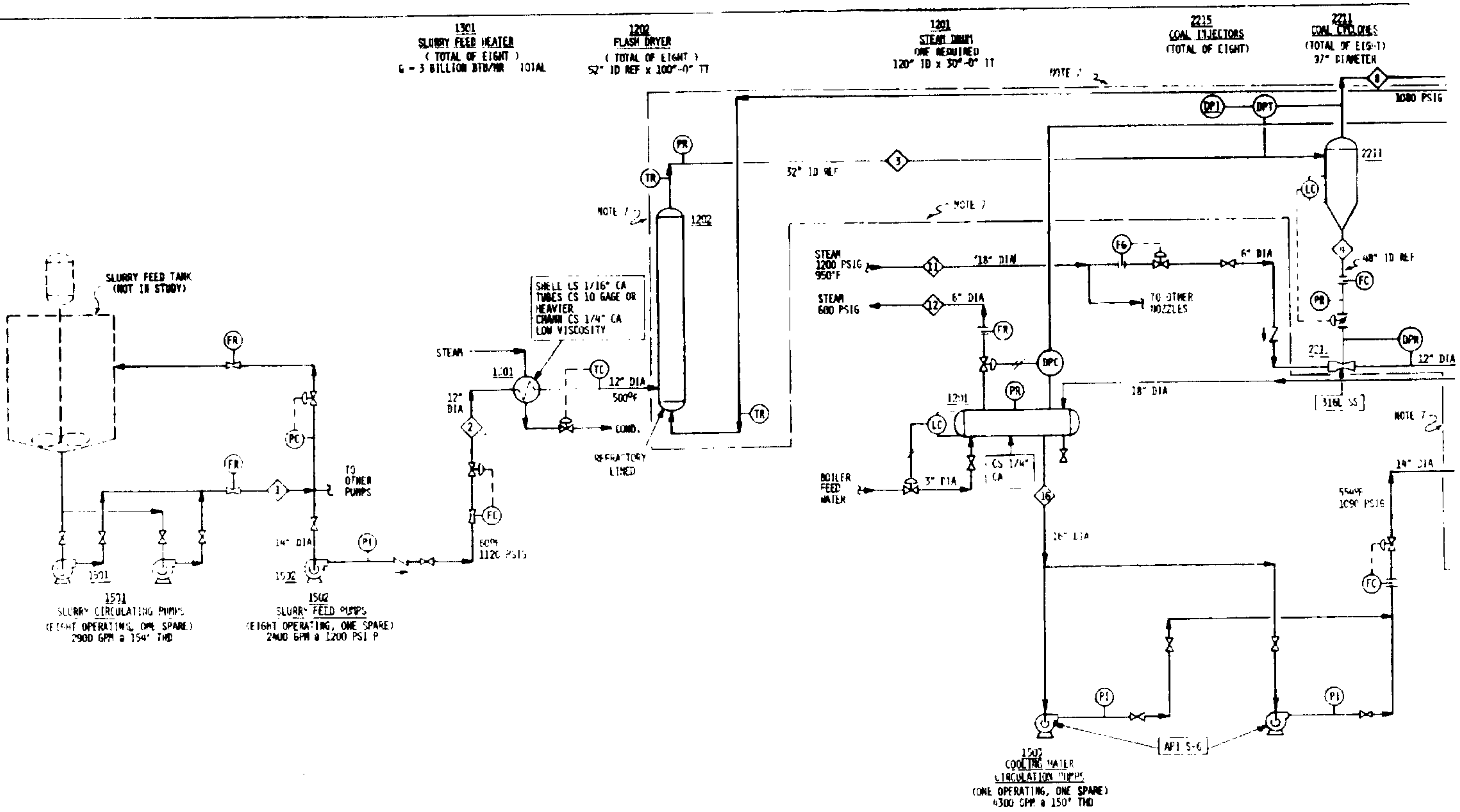


COMPONENT	⟨1⟩ GAS TO CONTACTOR	⟨2⟩ GAS FROM CONTACTOR
H_2 Mols/Hr	113,756	113,598
N_2	2,803	2,798
CO	8,004	7,997
CO_2	1,173	---
NH_3	16	---
H_2S	3,371	---
H_2O	148	148
CH_4	41,650	41,587
C_2H_6	4,798	4,791
C_3H_8	4,285	4,280
C_4H_{10}	1,417	1,415
IBP-200°F	259	258
200-300°F	88	88
300-350°F	5	5
350-400°F	1	1
400-450°F	---	---
TOTAL MOLS/HR	181,773	176,966
LB/HR	1,816,392	1,647,375
MSCFH	69,078	67,158
M.W.	9,993	9,309

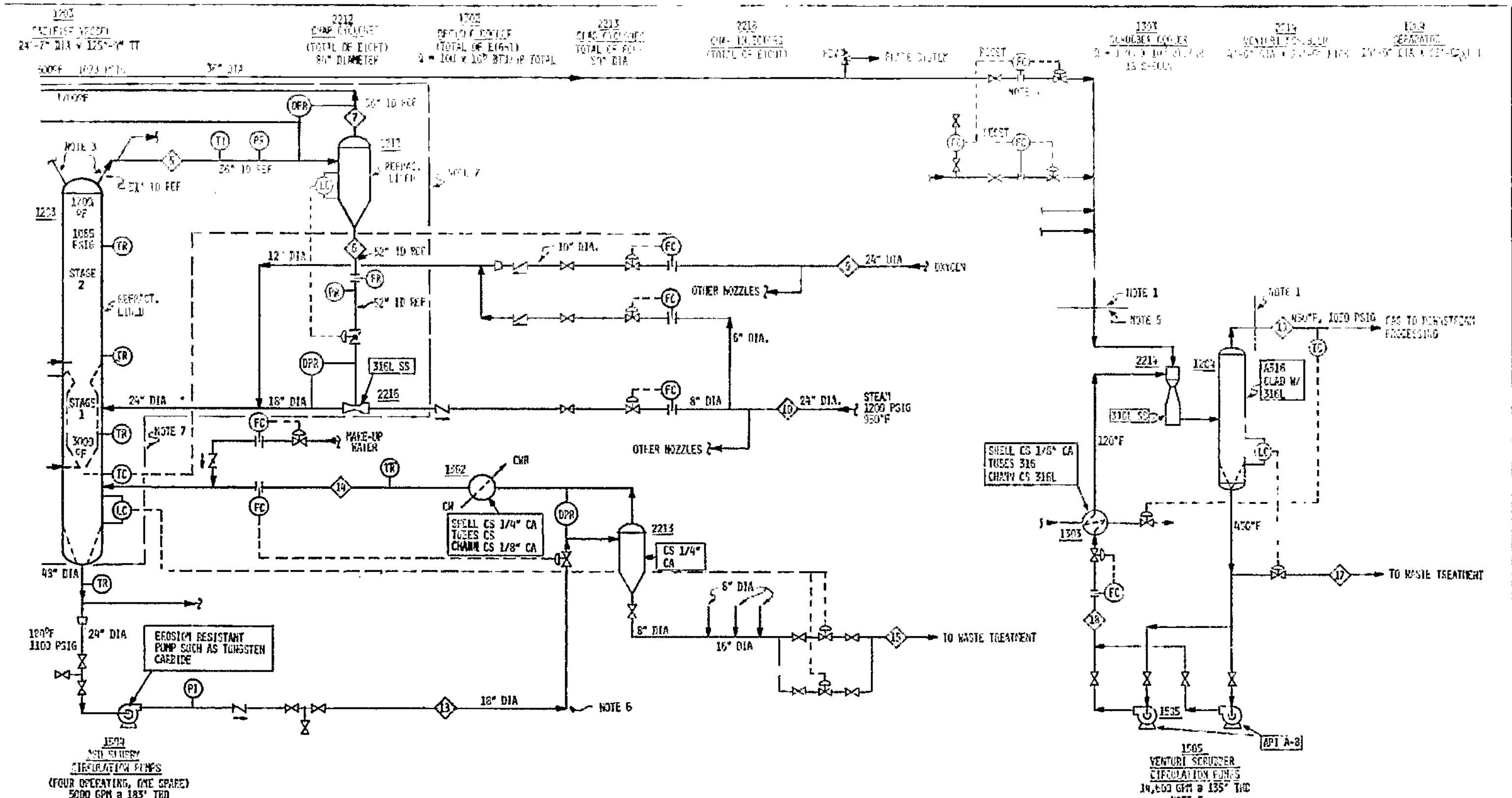
FIGURE 5-7

PROCESS FLOW DIAGRAM
ABSORBER
PRESTRESSED CONCRETE
PRESSURE VESSEL

THE RALPH M PARSONS COMPANY, PASADENA, CALIFORNIA | 5435-6 | R-1-FS-3 | 0



STREAM NO.	1	2	3	4	5	6	7	8	9	10	11
GASES MOLS/HR											
H_2	-	-	113,310	-	113,310		113,310	113,310	-	-	-
CH_4	-	-	51,230	-	51,230	-	51,230	51,230		-	-
CO	-	-	132,460	-	132,460	-	132,460	132,460		-	-
CO_2	-	-	72,070	-	72,070		72,070	72,070	-	-	-
H_2O	-		408,880	-	87,950	-	87,950	408,880	-	101,760	50,880
H_2S	-	-	5,270		5,270		5,270	5,270	-	-	-
NH_3	-	-	4,200	-	4,200		4,200	4,200			-
N_2	-	-	1,320		1,320	-	1,320	1,320	1,320	-	-
O_2			-	-	-	-	-		64,570		-
Total Mols			788,740	-	467,810	-	467,810	788,740	65,890	101,760	50,880
Total Lbs		-	15.58 × 10^6	-	9.80 × 10^6		[illegible]	15.58 × 10^6	4.10 × 10^6	1.33 × 10^6	0.92 × 10^6
SOLIDS AND LIQUIDS LBS/HR											
C	3.98 × 10^6	3.28 × 10^6	3.50 × 10^6	3.35 × 10^6	3.95 × 10^6	3.29 × 10^6	220,000	196,600			-
H	.27 × 10^6	0.22 × 10^6	0.22 × 10^6	0.21 × 10^6	-	-	-	13,400	-	-	-
O	.62 × 10^6	0.43 × 10^6	0.43 × 10^6	0.40 × 10^6		-	-	25,900	-		
N	.07 × 10^6	0.08 × 10^6	0.08 × 10^6	0.08 × 10^6	-	-	-	3,900	-		
S	.22 × 10^6	0.18 × 10^6	0.18 × 10^6	0.17 × 10^6	-	-	-	10,900	-	-	-
Ash	.72 × 10^6	0.60 × 10^6	0.64 × 10^6	0.62 × 10^6	1.?? × 10^6	1.02 × 10^6	50,000	14,800	-	-	-
H_2O	7.15 × 10^6	5.92 × 10^6	0.34 × 10^6	0.11 × 10^6	-		-	8,200	-		-
Total	12.51 × 10^6	10.69 × 10^6	5.19 × 10^6	4.89 × 10^6	6.58 × 10^6	4.31 × 10^6	270,000	264,200	-	-	
Total Lbs/Hr	12.51 × 10^6	10.69 × 10^6	20.77 × 10^6	4.89 × 10^6	14.40 × 10^6	4.31 × 10^6	10.0? × 10^6	15.8? × 10^6	[illegible]	1.33 × 10^6	0.92 × 10^6



NOTE 1 NOTE 5

12	13	14	15	16	17	18	19
-				-			111,310
-				-			61,250
-				-			132,460
-				-			72,570
1,940	Note 2	Note 2	Note 2	-	Note 2	Note 2	207,470
-				-			5,270
-				-			4,200
-				-			1,320
-				-			-
1,940				-			827,330
35,000				-			12.67×10^5
-	32,600	1,600	31,000	-	97,300	373,000	2,000
-	-	-	-	-	6,600	25,800	130
-	-	-	-	-	12,600	49,200	200
-	-	-	-	-	1,500	7,300	40
-	-	-	-	-	5,400	21,000	110
-	560,300	29,500	540,800	-	17,700	69,800	360
-	8.92×10^5	7.60×10^5	1.26×10^6	1.57×10^6	1,458,000	5,677,400	60
-	9.52×10^6	7.60×10^5	1.83×10^6	1.57×10^6	1.60×10^6	6.23×10^6	2,870
35,000	9.52×10^6	7.60×10^6	1.83×10^6	1.57×10^6	1.60×10^6	6.23×10^6	12.68×10^5

NOTES:

1. ALL FLOW RATES TOTAL FOR TRAIN. TWO TRAINS REQUIRED.
2. DISSOLVED GASES ARE NOT INCLUDED AS THEY ARE RECOMPRESSED INTO MAIN GAS STREAM.
3. FOUR NOZZLES ON GASIFIER VESSEL TWO PARALLEL BRANCH LOOPS FROM EACH NOZZLE.
4. PRESSURE CONTROLLER TO RESET FLOW CONTROLLERS FOR EIGHT PARALLEL PATHS.
5. FOUR PARALLEL TRAINS TO HANDLE GAS FROM TOTAL PLANTS (BOTH TRAINS).
6. ONE LOOP SHOWN, FOUR LOOPS TOTAL.
7. ALL EQUIPMENT WITHIN THIS AREA TO BE IN PRE-STRESSED CONCRETE PRESSURE VESSEL.

FIGURE 5-8

REV NO	CUST APPR	DATE	REVISION	BY	PROC ENGR	CHECK	CHIEF PROC ENGR	CH LP SPEC ENGR	PROJ ENG
0			INITIAL ISSUE	RR					

PROCESS FLOW DIAGRAM
GASIFICATION REACTOR
PRESTRESSED CONCRETE CONCEPT

THE RALPH M. PARSONS COMPANY PASADENA, CALIFORNIA	JOB NO. 5435-6	DWG NO R-1-FS-1	REV 0

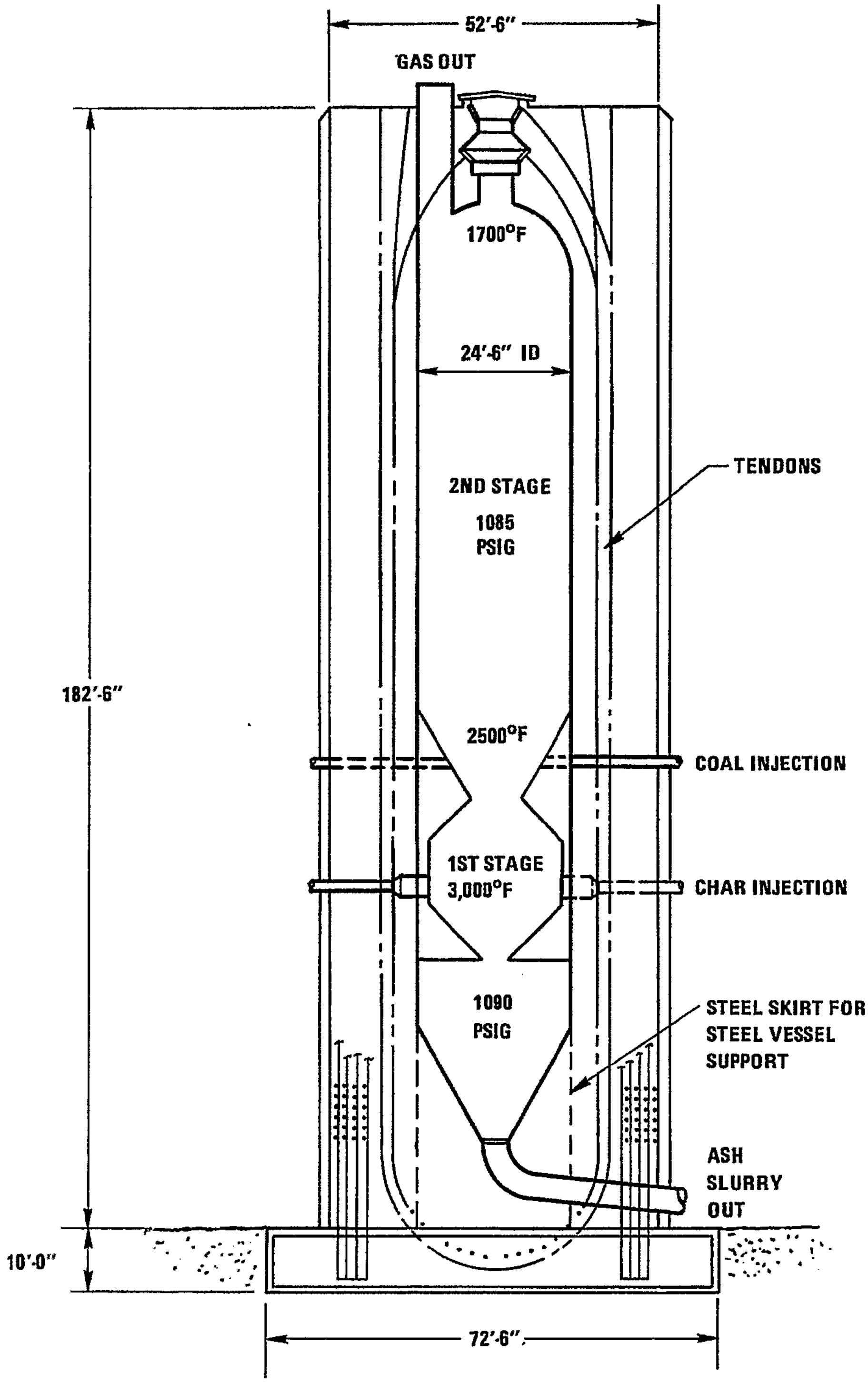


Figure 5-9 - Gasifier Vessel Sketch

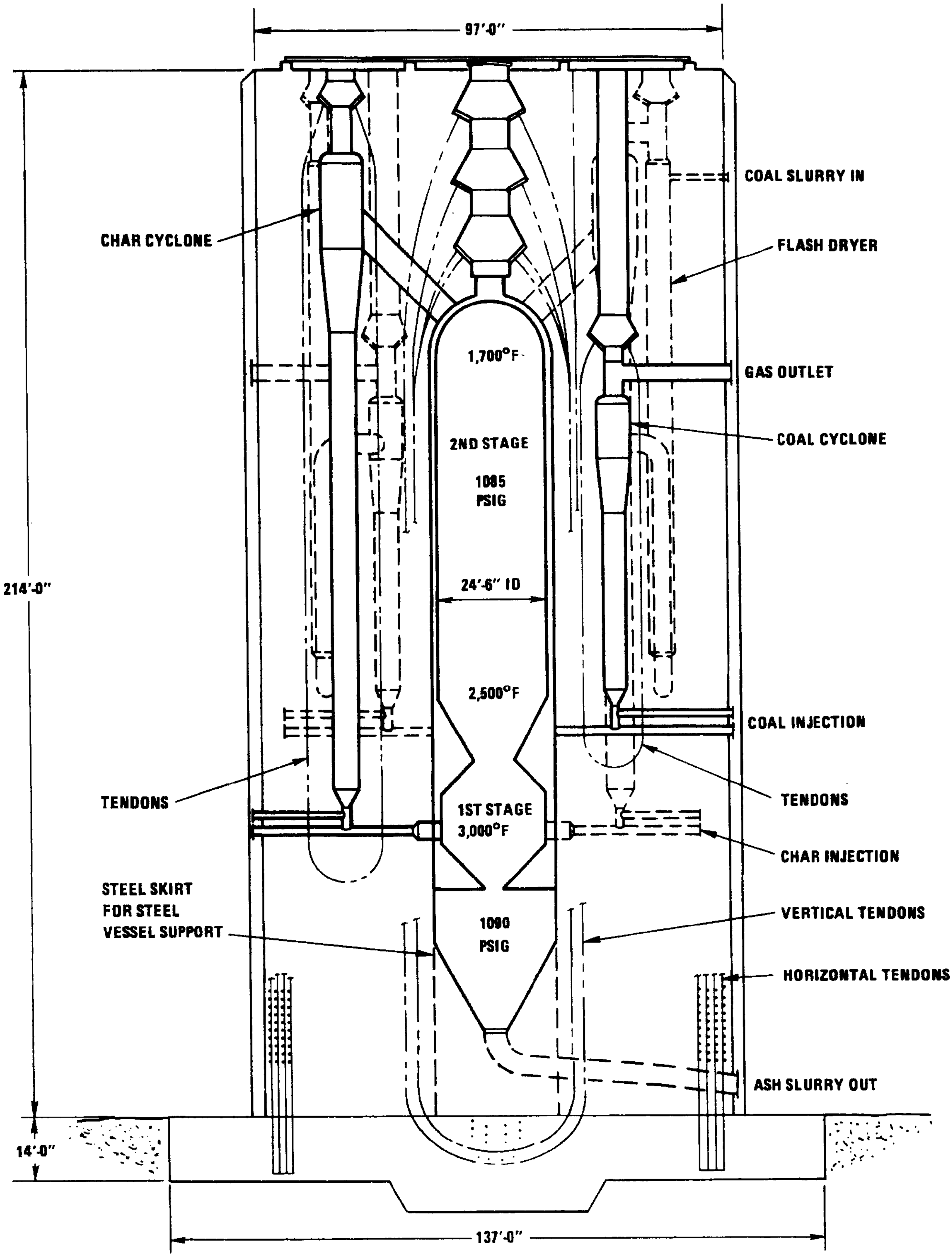


Figure 5-10 Integrated Gasifier Vessel Sketch

SECTION 6

SUPPORT SERVICES

In addition to the primary design assignments, support services included:

- Definition of equipment and control system development programs required to assume reliability and viability of coal conversion processes.
- Definition of a similar program for required materials of construction for coal conversion plants.
- Definition of environmental control facilities to assume the operation of coal conversion facilities within applicable environmental requirements.
- Prompt dissemination of the program results to the public.

The results of these supporting programs are summarized below.

6.1 EQUIPMENT DEVELOPMENT

Preliminary definitions were developed for approximately 6,000 separate equipment items during creation of the conceptual and preliminary designs under this contract. For each design, conclusions regarding the projected performance of the facility and the equipment used in that facility were recorded. The resulting listing of equipment types having potential, or need, for improvement, served as the basis for communications with equipment vendors and developers. The definition of the availability of equipment from domestic and foreign sources to provide the required performance and reliability was a primary objective. Particular areas investigated included solid coal feeders to gasifiers and pyrolyzers, pressure letdown valves, control valves, coal slurry pumps, gas/solid separation devices for performance at high temperature and pressure, large compressors, waste heat boilers and heat exchangers for operation at high temperatures and pressure, and pressure letdown turbines.

The equipment requirements for scale-up from pilot plants to commercial scale plants were reviewed[10] and we organized and presented to a national technical meeting a session titled "Equipment Applications to Coal Conversion Operations" in which specific equipment, instrumentation, control and process unit capabilities were described by 10 major suppliers.[11]

6.2 MATERIALS OF CONSTRUCTION

To accomplish the objective, we played an active role in the DOE/ERDA/OCR Materials Evaluation Program as well as the Materials Property Council (MCP) Development Programs. We monitored the performance of materials in coal gasification and liquefaction pilot plants, including on-site visits and consultations, and made recommendations where appropriate. We used this background to select the preferred materials for the 6,000-plus equipment items included in the conceptual and preliminary designs developed under this contract.

We responded to requests to present and publish the results of our work in this field; the result was six presentations to technical societies[12,13,14,15,16,17] and seven publications[10,18,19,20,21,22,23] to transmit the results of our work.

6.3 ENVIRONMENTAL FACTORS

The objective was to define environmental control procedures and facilities to assure operation of coal conversion plants within applicable environmental requirements.

For each conceptual or preliminary design developed under this contract, the procedures, equipment, estimated costs and projected performance of environmental control facilities were developed. The projected performance was then compared with the relevant emission standards or, if these did not exist, emission standards for related facilities such as oil refineries, petrochemical plants, or coal processing facilities. Where inadequate information was available, consultation and independent analysis was undertaken.

The results of our work in this field were summarized in seven presentations,[12,24,25,26,27,28,29] and six publications[10,30,31,32,33,34] in addition to inclusion of a separate section on environmental factor in each of the four conceptual designs and in the MPDP.

6.4 PUBLICATION OF CONTRACT WORK RESULTS

The results of the contract work has been placed in the public domain by means of approximately 21 separate publications. In addition, copies of thirty-nine papers prepared to summarize the results of our work are in press in a DOE publication titled "Coal Conversion Applications, Collected Works 1972 through 1977."[35]

SECTION 7

PROJECT SCHEDULING ADMINISTRATION AND REPORTING

Items communicating specifics regarding project scheduling, project administration control and reporting are contained in letters PN-1 through PN-522 dated 3/6/75 to 10/20/78.

7.1 INVENTION DISCLOSURES REPORTING

The invention disclosures listed below were submitted to the California Patent Group (CPG) of ERDA/DOE for patent consideration; some of them have been released by CPG and some are still under consideration by ERDA/DOE.

(1) Reynolds, David G., "Fin Tube Catalytic Reactor," submitted to CPG December 29, 1975, patent case S-47,381 (RL-6574), released to Parsons August 8, 1976.

(2) Malek, John M., "Improved Process for Hydrogenating-Liquefying Coal or Like Carbonaceous Solid Material," submitted to CPG June 17, 1976, patent case S-47,917 (RL-6610), released to Parsons September 8, 1976.

(3) Jentz, Norman E. et al, "A method to Transport Heat from an Exothermic to an Endothermic Process with a Stream of Internally Generated Inert Solids," submitted to CPG December 29, 1977, patent case S-49,382 (RL-7075), released to Parsons March 25, 1978.

(4) Jentz, Norman E. et al, "A Process to Pyrolyze Coal and Simultaneously Recover Liquid Values from Solids Bear ing Liquids," submitted to CPG December 29, 1977, patent case unknown, status: pending.

(5) Jentz, Norman E. et al, "A Process to Pyrolyze Coal and Simultaneously Recover Liquid Values from Solids Bearing Liquids (Heat Conveying System Fixed)," submitted to CPG December 29, 1977, patent case unknown, status: pending.

(6) Rice, Louis F., "Fluidized-Bed Gasifier with Integral Pretreating Facilities," submitted to CPG March 8, 1978, patent case unknown, status: pending.

SECTION 8

LITERATURE CITED

1. O'Hara, J. B. "Technical Evaluation Services, Final Report," R&D Report No. 82, FE-1234-9. Prepared for the Department of Energy, Washington, D.C., November 1977.

2. O'Hara, J. B., C. L. Crawford, H. F. Hincks and E. A. Mills. "Commercial Complex, Conceptual Design/Economic Analysis, Oil and Power by COED-Based Coal Conversion," R&D Report No. 114 - Interim Report No. 1, FE-1775-1. Prepared for the Energy Research and Development Administration, Washington, D.C., September 1975.

3. O'Hara, J. B., G. H. Hervey, S. M. Fass, N. E. Jentz, H. W. Klumpe, B. I. Loran, E. A. Mills and R. V. Teeple. "Oil/Gas Complex Conceptual Design/ Economic Analysis, Oil and SNG Production," R&D Report No. 114-Interim Report No. 4, FE-1775-8. Prepared for the Energy Research and Development Administration, Washington, D.C., March 1977.

4. O'Hara, J. B., F. E. Cumare and S. N. Rippee. "Synthetic Fuels from Coal by Fischer-Tropsch," Coal Processing Technology: a CEP Technical Manual. Prepared by the Editors of Chemical Engineering Progress. Vol. II, pages 83-87, August 1975.

5. O'Hara, J. B., A. Bela, N. E. Jentz, S. K. Khaderi, H. W. Klumpe, B. I. Loran, D. G. Reynolds and R. V. Teeple. "Fischer-Tropsch Complex Conceptual Design/Economic Analysis, Oil and SNG Production," R&D Report No. 114 - Interim Report No. 3, FE-1775-7. Prepared for the Energy Research and Development Administration, Washington, D.C., January 1977.

6. O'Hara, J. B., A. Bela, N. E. Jentz, H. W. Klumpe, B. I. Loran, E. A. Mills, R. J. Newton and R. V. Teeple. "Project POGO - Coal Refinery Complex, Conceptual Design/Economic Analysis, Power-Oil-Gas-Other Products," R&D Report No. 114 - Interim Report No. 6, FE-1775-13. Prepared for the Department of Energy, Washington, D.C., December 1977.

7. O'Hara, J. B., N. E. Jentz, H. T. Syverson, G. H. Hervey and R. V. Teeple. "Project POGO, Total Coal Utilization, COG Refinery Design Criteria," R&D Report No. 114 - Interim Report No. 5, FE-1775-11. Prepared for Energy Research and Development Administration, Washington, D.C., August 1977.

8. O'Hara, J. B., A. Bela, N. E. Jentz, H. W. Klumpe, B. I. Loran, P. F. McElherne and R. V. Teeple. "Multi-Process Demonstration Plant," R&D Report No. 114 - Interim Report No. 7 FE-1775-18. Prepared for the U.S. Department of Energy, Washington, D.C., September 1978.

9. O'Hara, J. B., R. D. Howell, et al. "Prestressed Concrete Pressure Vessels, Conceptual Design/Economic Analysis," R&D Report No. 114 - Interim Report No. 8., FE-1775-20. Prepared for the U.S. Department of Energy, Washington, D.C., October 1978.

10. O'Hara, J. B., N. E. Jentz and G. H. Hervey. "Commercial Coal Conversion Plant Design: Translation from Pilot to Commercial-Scale Plants." Clean Fuels from Coal Symposium II Papers, Institute of Gas Technology (IGT), Chicago, Ill., pages 817-836, June 23-27, 1975.

11. O'Hara, J. B. Chairman and Bela, A. Co-Chairman, of the Poster Session on "Equipment Applications to Coal Conversion Operations" for the 70th Annual Meeting of American Institute of Chemical Engineers (AIChE), New York, N.Y., November 13-17, 1977. To be published in a coming CEP Technical Manual.

12. O'Hara, J. B., N. E. Jentz and G. H. Hervey. "Commercial Coal Conversion Plant Design, Translation from Pilot to Commercial Scale Plants." Presented at the Clean Fuels from Coal Symposium II of the Institute of Gas Technology (IGT), Chicago, Ill., June 26, 1975.

13. O'Hara, J. B., W. J. Lochmann and N. E. Jentz. "Coal Liquefaction: Materials, Systems Design." Presented at the American Society for Metals (ASM) Symposium, Pittsburgh, Pa., April 26, 1976.

14. Lochmann, W. J. "The Materials Problems in Coal Gasification and Liquefaction." Presented at a Symposium of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME), Niagara Falls, N.Y., September 22, 1976.

15. Raisbeck, W. C. "Materials, Needs, Opportunities and Problems." Presented at an ERDA/EPRI/AGA- sponsored conference on Materials for Coal Conversion and Utilization, Washington, D.C., September 30, 1976.

16. Lochmann, W. J. and R. D. Howell. "Corrosion Engineering - Design Interface for Coal Conversion." Presented at the National Association of Corrosion Engineers (NACE) International Corrosion Forum, San Francisco, Calif., March 15, 1977.

17. O'Hara, J. B. and W. J. Lochmann. "Materials Requirements for Coal Liquefaction." Presented at the American Society for Metals (ASM) Material Requirements in Future Energy Systems Seminar, Chicago, Ill., April 7, 1977.

18. O'Hara, J. B., W. J. Lochmann and N. E. Jentz. "Material Considerations in Coal Liquefaction." Metal Progress, pages 33-38, November 1976.

19. O'Hara, J. B., N. E. Jentz and W. J. Lochmann. "Material Challenges of Coal Liquefaction." Chemical Engineering, Vol. 84, No. 8, pages 147-154, April 11, 1977.

20. Lochmann, W. J. and R. D. Howell. "An Overview of . . . Equipment for Coal Conversion." Hydrocarbon Processing, Vol. 56, No. 5, pages 197-199, May 1977.

21. Lochmann, W. J. and R. D. Howell. "Corrosion Design Problems in Coal Conversion Plants." Material Performance, Vol. 16, No. 7, pages 43-47 July.1977.

22. Lochmann, W. J. "Coal Gasification, Corrosion Interface." Presentation to the 16th Annual Conference of Metallurgists, sponsored by the Canadian Institute of Mining and Metals, Vancouver, B.C., Canada, August 23, 1977.

23. Lochmann, W. J. "Materials Problems in Coal Gasification and Liquefaction." Metallurgical Transactions, Vol. 9A, pages 175-181, February 1978.

24. O'Hara, J.B., S. N. Rippee, B. I. Loran and W. J. Mindeheim. "Environmental Factors in Coal Liquefaction Plant Design." Presented at Environmental Protection Agency (EPA) Symposium on Environmental Aspects of Fuel Conversion Technology, St. Louis, Mo., May 14, 1974.

25. Loran, B. I., J. B. O'Hara, N. E. Jentz and H. F. Hincks. "Gaseous Environmental Factors in Coal Pyrolysis Plant Design." Presented to the ASME-IEEE Joint Power Generating Conference sponsored by the American Society of Mechanical Engineers (ASME), Portland, Ore., October 1, 1975.

26. O'Hara, J. B., B. I. Loran, G. H. Hervey and S. M. Fass. "Environmental Factors for Oil/Gas Coal Conversion Technology." Presented at the 69th Annual Meeting of the American Institute of Chemical Engineers (AIChE), Chicago, Ill., December 1, 1976.

27. O'Hara, J. B., B. I. Loran, A. Bela and N. E. Jentz. "Environmental Factors for Fischer-Tropsch Coal Conversion Technology." Presented at the Second Pacific Chemical Engineering Congress (PACHEC '77) at the 84th National Meeting of American Insitute of Chemical Engineers (AIChE), Denver, Colo., August 29, 1977.

28. Loran, B. I. and J. B. O'Hara. "Specific Environmental Aspects of Fischer-Tropsch Coal Conversion Technology." Presented at the 3rd Environmental Protection Agency (EPA) Symposium on Environmental Aspects of Fuel Conversion Technology, III, Hollywood, Fla., September 15, 1977.

29. O'Hara, J. B., B. I. Loran and W. H. Shallenberger. "Project POGO Coal Refinery, Air Emission Control Procedures." Presented at the 85th National Meeting of the American Institute of Chemical Engineers (AIChE), Philadelphia, Pa., June 4-8, 1978.

30. O'Hara, J. B., S. N. Rippee, B. I. Loran and W. J. Mindeheim. "Environmental Factors in Coal Liquefaction Plant Design," R&D Report No. 82 - Interim Report No. 3. Prepared for the U.S. Department of the Interior, Office of Coal Research, May 1974.

31. Loran, B. I., J. B. O'Hara, N. E. Jentz and H. F. Hincks. "Gaseous Environmental Factors in Coal Pyrolysis Plant Design." Published by the ASME-IEEE Joint Power Generating Conference sponsored by the American Society of Mechanical Engineers (ASME), Portland, Ore., Publication No. 75-Pwr-3, October 1, 1975.

32. O'Hara, J. B., B. I. Loran, A. Bela and N. E. Jentz. "Environmental Factors for Fischer-Tropsch Coal Conversion Technology." Proceedings of the Second Pacific Chemical Engineering Congress (PACHEC '77), at the 84th National Meeting of American Institute of Chemical Engineers (AIChE), Denver, Colo., Vol. II, pages 855-863, August 28-31, 1977.

33. O'Hara, J. B., B. I. Loran, A. Bela and N. E. Jentz. "Environmental Factors for Fischer-Tropsch Coal Conversion Technology." Accepted for publication in a future Chemical Engineering Progress Technical Manual.

34. Loran, B. I. and J. B. O'Hara. "Specific Environmental Aspects of Fischer-Tropsch Coal Conversion Technology," Symposium Proceedings: Environmental Aspects of Fuel Conversion Technology, III (September 1977, Hollywood, Fla.), EPA-60017-78-063. Prepared by the Research Triangle Institute, Research Triangle Park, N.C. under Contract No. 68-02-2612. Prepared for the U.S. Environmental Protection Agency, Washington, D.C., pages 409-423, April 1978.

35. O'Hara, J. B., et at. "Coal Conversion Applications, Collected Works, 1972 through 1977," FE-1775-15. Prepared for the U.S. Department of Energy, Washington, D.C., February 1978.

36. U.S. Army Engineer Division, Huntsville (USAEDH), "Oil/Gas Plant Design Project Capital Cost Validation," FE-1759-1, Energy Research and Development Administration, Contract No. EX-76-C-01-1759, March 30, 1977.

37. U.S. Army Engineer Division, Huntsville (USAEDH), Fischer-Tropsch Design Project Capital Cost Validation," FE-1759-2, Department of Energy Contract No. EX-76-C-01-1759, October 1977.

38. U.S. Army Engineer Division, Huntsville (USAEDH), "POGO Design Project Capital Cost Validation," Draft Report prepared for the Department of Energy, Washington, D.C., May 1978.

39. Pfieffer, L. S. (CB&I), W. G. Bair (IGT) and R. D. Howell (Parsons). "Cost Study, Shop Assembly Vs. Field Assembly of Heavy Wall Coal Gasifier Reactor Vessels," Final Report, FE-2009-13. Prepared by the Chicago Bridge & Iron Company, Chicago, Ill., for the Energy Research and Development Administration, Washington, D.C., December 1976.

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