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PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS. RESEARCH AND DEVELOPMENT REPORT NO. 114. QUARTERLY REPORT, APRIL--JUNE 1977

PARSONS (RALPH M.) CO., PASADENA, CALIF

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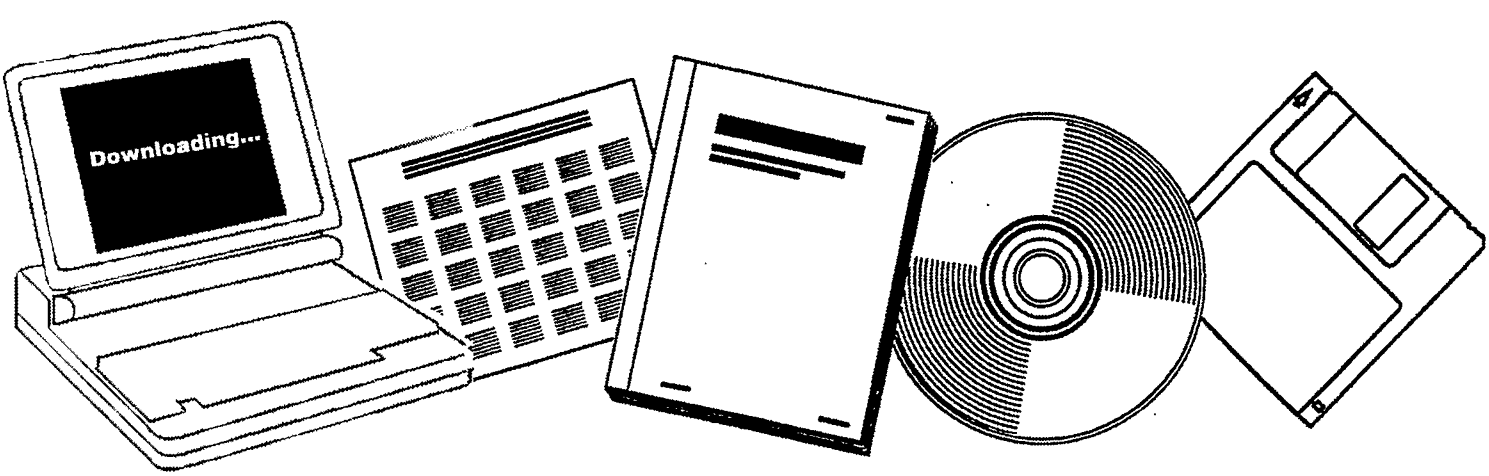

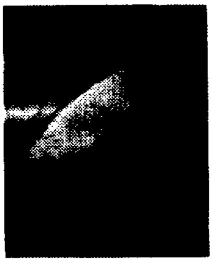

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PRELIMINARY DESIGN SERVICES COAL CONVERSION DEMONSTRATION PLANTS

RESEARCH AND DEVELOPMENT REPORT NO. 114
QUARTERLY REPORT
FOR THE PERIOD: APRIL – JUNE 1977

Prepared by:
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100 West Walnut Street
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WASHINGTON, D.C. 20545

SECOND QUARTERLY REPORT

PRELIMINARY DESIGN SERVICES

THE RALPH M. PARSONS COMPANY

I. OBJECTIVE AND SCOPE OF WORK

The objective is to develop preliminary designs and economic evaluations for a number of types of coal conversion plants. The following designs are included in the scope of work:

- Conceptual commercial plant for a coal-oil-energy-development (COED) plant
- Oil/Gas plant to produce liquid fuels plus substitute natural gas (SNG)
- Commercial-scale Fischer-Tropsch plant with motor fuel and SNG as the main products
- Coal conversion plant to produce power, oil, gas, and other products (POGO)
- Facilities complex capable of demonstrating the commercial feasibility of a variety of coal conversion processes that show promise during pilot plant operations

  The facilities will be considered for conversion of coal to:

  1. Low-to-high Btu fuel gas
  2. Methanol/motor fuel by Fischer-Tropsch process
  3. Clean liquid fuels by alternate liquefaction processes

- Prepare conceptual designs, define construction procedure and develop economics for three types of prestressed concrete pressure vessels for use in coal conversion plants.

In addition, supporting efforts will be provided for the above activities. These efforts include planning and progress monitoring, equipment development, construction materials development, and environmental factors.

II. SUMMARY OF PROGRESS TO DATE

A brief review of the status of the major active design efforts is given below, followed by a more detailed reporting on the progress of individual tasks.

A. POGO Design

Process design was essentially completed for the base case, which is based on coal from the Eastern Region of the Interior Coal Province.

Equipment and design engineering for the various units was underway.

Mining plans and basic mine designs were developed for the alternate Powder River area of the Rocky Mountain Coal Province and the Appalachian Region of the Eastern Coal Province.

Optimization studies were conducted on five electrical power generation cases using specific combinations of gas turbines and steam generators.

We transmitted to ERDA draft copies of R&D Report No. 114, Interim Report No. 5, titled "COG Refinery Design Criteria, Project POGO, Total Coal Utilization" for review and patent clearance. The report summarizes the results of a program to analyze the technical and economic elements of a number of candidate processes and process combinations; also, the selection of the preferred process combination and the design criteria for preparation of the final design.

B. Multi-Process Demonstration Plant Design

Process and equipment design have been completed for Phase 1. which is an air-blown gasification system. Preparation of the fixed capital investment estimate was begun.

Process design for Phase 2 was completed along with the heat recovery systems; this is an oxygen-blown gasification system with power generation. Designs for the coal handling facility and power plant were begun.

The Phase 3 process design was well underway; this phase consists of a Fischer-Tropsch unit to convert a portion of the syntheses gas to liquid and gaseous hydrocarbons. A CO_2 removal unit plus hydrocarbon recovery and separation units are also included.

C. Prestressed Concrete Pressure Vessels

Work proceeded on the preparation of preliminary designs for three types of prestressed concrete pressure vessels for use in coal conversion plants.

A process flow sheet, vessel outline drawings, and design criteria were prepared for the first vessel, which is a high pressure gasifier with dimensions 25 feet ID x 125 feet tangent-to-tangent. It contains integral coal drying and solids separation vessels.

Process flow sheets, vessel outline drawings and design criteria have also been prepared for the second vessel which is a dissolver reactor-separator vessel with dimensions 33'4" diameter by 122' tangent-to-tangent. Similar information has also been prepared for the third vessel - an absorber of 23'4" internal diameter by 120'0" tangent-to-tangent.

T. Y. Lin International (Lin) our subcontractor, conducted studies on the structural and construction feasibility of these large concrete pressure vessels. These studies have indicated that these vessels can be designed and constructed using prestressed concrete construction techniques. Lin also offered suggestions on the gasifier reactor and dissolver separator vessels to improve their viability for construction in prestressed concrete.

D. Supporting Areas

We continued work in development of equipment needs with vendors of valves, solids-gas separation equipment, and feeders.

The review of materials of construction for coal conversion plants continued.

We continued our investigation of areas of environmental sensitivity of coal conversion where additional information is to be developed.

E. General

We prepared nine invited manuscripts for publication in the field of coal conversion technology and projected economics.

III. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. POGO Plant Design

1. Objectives

To develop preliminary designs of three coal processing plants which will produce power, oil, gas and other products. The plants are to be located in the Eastern Region of the Interior Coal Province, the Appalachian Region of the Eastern Coal Province, and the Powder River Region of the Rocky Mountain Coal Province. The process employed in this plant design shall be the result of an economic selection from the candidate coal conversion processes available.

2. Activity This Quarter

The process is depicted schematically in the block flow diagram shown in Figure 1.

We transmitted to ERDA draft copies of R&D Report No. 114, Interim Report No. 5 titled "Project POGO, Total Coal Utilization, COG Refinery Design Criteria," for review and patent clearance.

We completed the Rocky Mountain Region coal mine design in support of the alternate 2 POGO design case. This will be a surface mine with two mine faces. Manning lists and fixed capital investment estimates were completed.

We completed the design and fixed capital investment estimates for Unit 10 (coal storage, grinding, and drying) for the Appalachian (alternate 1) and the Rocky Mountain Regions (alternate 2) of the POGO design cases.

We completed process design, flow sheet preparation, material balances and materials of construction reviews for the process units listed below for the base case (Eastern Region of the Interior Coal Province).

Unit	Name
10	Coal Preparation
11	Oxygen Plant
12	SRC Dissolving
13	SRC Atmospheric Distillation
14	SRC Vacuum Distillation
15	Pyrolysis
16	Pyrolysis Atmospheric Distillation
17	Sour Gas Compression
18	Process Gasification
19	Shift Conversion
20	Selective Acid Gas Removal

c. Phase 3: Provides for the conversion of synthesis gas equivalent to 750 tons of feed coal per day to liquid and gaseous hydrocarbon fuels by the Fischer-Tropsch process. Downstream process units are provided for the separation of the various product streams.

The Phase 3 process design was well underway; this phase consists of a Fischer-Tropsch unit to convert a portion of the synthesis gas to liquid and gaseous hydrocarbons. A CO_2 removal unit plus hydrocarbon recovery and separation units are also included.

3. Activity Forecast Next Quarter

We will complete the process design for the facility. We will complete the estimates for the fixed capital investment costs.

We will begin writing the final report.

C. Prestressed Pressure Vessels

1. Objective

To prepare preliminary designs, technical analysis of construction and operating performance, and economics for three types of prestressed concrete pressure vessels (PCPV).

These will be compared against conventional steel pressure vessels in the same duties. The three types are:

a. A large, high pressure, 25-foot ID X 125-foot tangent-to-tangent gasifier reactor vessel

b. A combination of a large dissolver reacot vessel and a flash drum. These vessels would operate at about 2,025 psig and 850°F.

c. A large diameter absorber column operating at about 1,075 psig and 150°F. This vessel will have internal components such as trays.

2. Activity This Quarter

We prepared outline drawings and design criteria for the gasifier reactor vessel, the dissolver reactor-separator, the absorber column. These are shown in Figures 4, 5 and 6, respectively. These drawings were transmitted to our subcontractor, T. Y. Lin International (Lin) for their use in designing the concrete structures.

We prepared process flow sheets for each case.

Lin's efforts during this period consisted of familiarization with the vessel requirements, structural feasibility studies and initial review of the vessel outline drawings.

The structural feasibility study of the vessels' design in prestressed concrete consists primarily of analytical investigations by qualitatively assessing the vessels stress response behavior due to pressurization and prestressing. The investigation was based upon the integral coal gasification reactor vessel.

Basically, the reactor vessel is represented as a thick-walled cylinder subjected to both internal and external pressures. Closed form solutions are available which provide some insight into this type of problem. In the case of the integrated gasifier reactor vessel, multiple cavities exist within the thick cylindrical wall. It is necessary to develop the analytical capability to rapidly determine the effect of these cavities under various pressure conditions and relative positions, in terms of functional efficiency, economy, and constructional feasibility. The finite-element method of analysis is particularly suitable for this type of investigation.

The well known Lame's solutions for thick-walled cylinders were used in this investigation. The equations have been programmed for computer calculation. Two findings are noteworthy:

a. Under internal pressure alone, maximum tensile stress occurs at the inner surface of the cylinder, and is always numerically larger than the applied pressure, regardless of the thickness of the wall. In the extreme case, where the wall thickness is increased to infinity, the maximum tensile stress approaches the intensity of the internal pressure.

b. For external prestressing, the maximum stress, also occuring at the inner face, becomes compressive, and approaches twice the magnitude of the prestress as the wall thickness increases.

This initial analysis shows the definite advantage in using prestressed concrete, whereby the magnitude of the stresses within the PCPV can be controlled by varying the wall thickness and the amount of prestressing.

The finite element analysis uses computer program SAP IV for stress analysis. Plane strain analyses have been carried out for the integrated coal gasification reactor and the dissolver vessels. The results indicate that the pressure in the cavities appear to have only a minor effect on the overall stress configuration. The results also show that the stresses due to the pressure in the centrally located gasifier reactor vessel can be comfortaly contained with the external prestressing for the given vessel conditions and configuration.

Construction feasibility of the PCPV was also examined by Lin during this period. So far, no serious problems have been encountered since all necessary techniques are well within the present state-of-the-art. The main task is therefore in the selection and evaluation of possible construction methods most able to meet the special conditions and requirements governing the construction of our PCPV. Some of these special requirements are listed below:

a. The preinstallation of the heavy process cells, piping, cooling and instrumentation systems, in addition to the steel reinforcements and prestressing cables, many of which are crowded in a few specific places, requires the installation of a rigid and carefully planned support system, temporary or otherwise, before the concreting operation.

b. The almost universal presence of Nelson studs, cooling coils, etc., around each internal cell and pipe, would pose special demands on the method and procedure of casting concrete, firstly to avoid causing damage to the installations, and then to ensure the concrete will reach and encase these installations as designed.

c. Because of the great quantity of concrete to be placed in each PCPV, procedures for preparation and composition of the concrete mix plus the rate and manner of delivering/placing the concrete must be carefully worked out in order to minimize the effect of heat of hydration and the problem of shrinkage; particular attention will be paid to differential shrinkage between concrete poured at different times.

Lin is evaluating the relative merits of various candidate concreting methods; the preferred procedure selected. The following three methods are receiving most attention:

a. Vertical Transport Method - This entails the use of a tower crane mounted on construction scaffolding over the vessel to transfer materials, including concrete, to and from the vessel during construction. The crane will be large enough to deliver concrete at a minimum rate of 120 cubic yards an hour; this 1,000 cubic yards per 8-hour working day is sufficient to concrete a 4-foot high section of the larger vessel in a day. This would require a crane to use a 4 - 5 cubic yard bucket and make an average of 30 delivery trips per hour.

b. Pumped Concrete - Currently available concrete pumps are capable of delivering good concrete (with slump of 3") in sufficient quantity to meet the needs of the PCPV. In this operation, concrete is pumped up a truck-mounted and articulated boom which reaches up to a height of about 120 feet, or up a preinstalled stand pipe to deliver concrete to greater height -- perhaps 350 feet or 400 feet. Delivery rate varies according to height, etc. Assuming an average rate of 70 cubic yards per hour, or some 500 cubic yards per working day, it will take 3 sets of pumps, including one on standby, plus associated delivery systems to pour about 1,000 cubic yards of concrete a day.

   The prime long-standing objection to this method of casting concrete has been excessive shrinkage cracks due to high cement content resulting from compensation for the necessary use of high water content for the concrete to be pumpable. Modern concrete pumping equipment has largely eliminated this problem.

c. Intrusion Grouting - This method consists of first placing the coarse aggregate, usually by conveyor belts, then grouting the voids between the stones with a mixture of cement and pozzolanic material (Alfesil) under pressure. The greatest advantage of this method of concreting is the reduction of shrinkage and the heat of hydration, which can cause problems. The disadvantage of this method, however, is the greater risk of damaging the equipment and piping system during the process of placing, or more correctly, dropping the coarse aggreages within the forms. Unlike wet concrete which sets and becomes fairly self-supporting a few hours after casting, the coarse aggregates impose its full lateral pressure on the internal cell wall and continues to do so until it is grouted and forms a part of the concrete.

Shown in Figure 7 is a preliminary drawing by Lin of the integrated gasifier/reactor vessel.

A preliminary Lin drawing, Figure 8, shows the construction sequence of the integrated gasifier reactor vessel. This conceptual drawing is based on the vertical transport concreting system as described above.

3. Activity Forecast Next Quarter

We will commence preparation of fixed capital investment estimates. We will begin studies comparing the operability and maintainability of prestressed concrete pressure vessels versus conventional steel pressure vessels.

Lin will:

a. continue investigation of vessel design problems

b. continue investigation of vessel construction problems

c. start investigation of foundation work for proposed site and the design and construction problems in the absorber column.

D. <u>Equipment Development</u>

1. Objective

To define the equipment and control system development program required to assure reliability of coal conversion processes being developed. To recommend appropriate development programs to ERDA - Fossil Energy Division.

2. Activity This Quarter

We attended the seminar on coal feeding systems held at the Jet Propulsion Laboratory in Pasadena, California.

The results to date are encouraging, but much additional work is required before reliable commercial equipment is available.

We discussed coal drying processes with vendors of such equipment.

We also kept abreast of the available solids pumping systems.

In the field of solids/gas separation, proposals were received from vendors of electrostatic precipitation and collection systems.

E. Materials of Construction

1. Objective

To define the preferred materials of construction for use in coal conversion projects.

2. Activity This Quarter

We continued to support design efforts by supplying materials of construction specifications.

We completed review of a draft of report "Assessment of Materials Technology of Pressure Vessels and Piping for Coal Conversion Systems" ORNL-5238. Our comments were transmitted to ERDA on June 30, 1977.

We attended a Materials Property Council meeting on Coal Liquefaction in Denver, Colorado on June 1. We examined the coal slurry test loop at the Colorado School of Mines Research Institute on June 2.

We attended a meeting of the Materials Property Council Phase 5 group on mechanical properties of materials in coal gasification on May 10.

We presented an invited paper on April 7 at the American Metals Symposium on Materials Requirements in Future Energy Systems. This symposium was held at Argonne National Laboratory. The subject of the paper was "Material Requirements for Coal Liquefaction."

3. Activity Forecast Next Quarter

We will complete the materials of construction reviews for the various units in the POGO and Multi-Process Demonstration plant designs.

We will review the materials of construction for the prestressed concrete pressure vessels.

F. Environmental Considerations

1. Objectives

To define environmental factors for proposed coal conversion complexes, to define facilities required for the coal conversion complexes to meet environmental standards, and to define product quality standards to meet environmental regulations for product users.

2. Activity This Quarter

The preliminary designs of the separate units in the Multi-Process Demonstration Plant and of the POGO complex were reviewed as they were completed. The environmental acceptability and compliance with specific environmental laws and regulations were assessed.

Environmental standards issued by the states where the facilities could be located have been collected.

Special attention was dedicated to the Western location (Wyoming), due to area-specific environmental factors, such as water supply and land use.

We transmitted a manuscript for a paper titled "Environmental Factors for Fischer-Tropsch Coal Conversion Technology" to be presented at the Second Pacific Chemical Engineering Congress (PACHEC '77) in Denver, Colorado, on August 30, 1977. The meeting is sponsored by the Inter-American Confederation of Chemical Engineering and the Asian-Pacific Confederation of Chemical Engineering, and is organized by the American Institute of Chemical Engineers.

3. Activity Forecast Next Quarter

We will complete our assessment of the environmental requirements for the POGO and Multi-Process Demonstration Plant Designs.

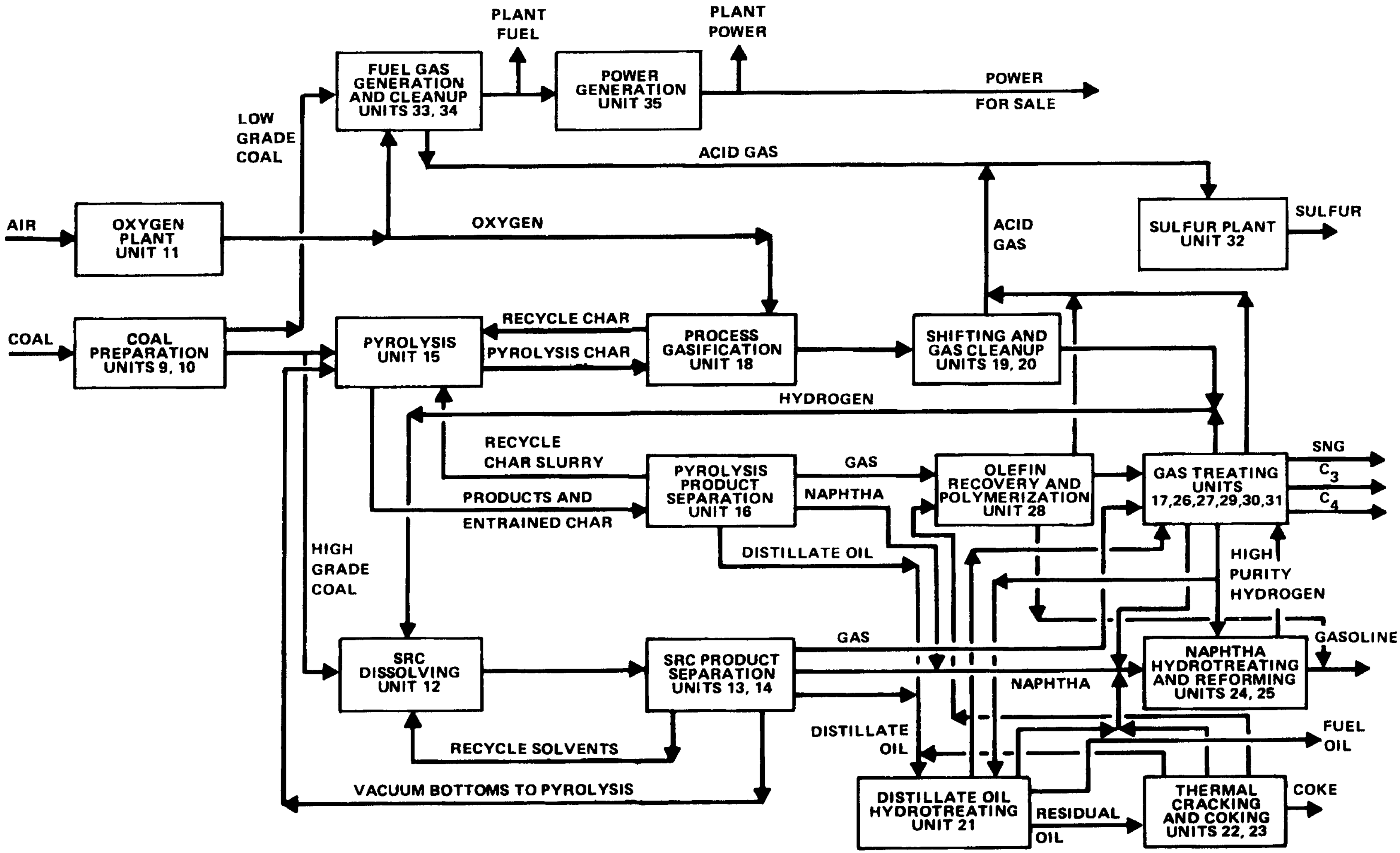

Figure 1 - Simplified Block Flow Diagram
POGO Coal Conversion Complex

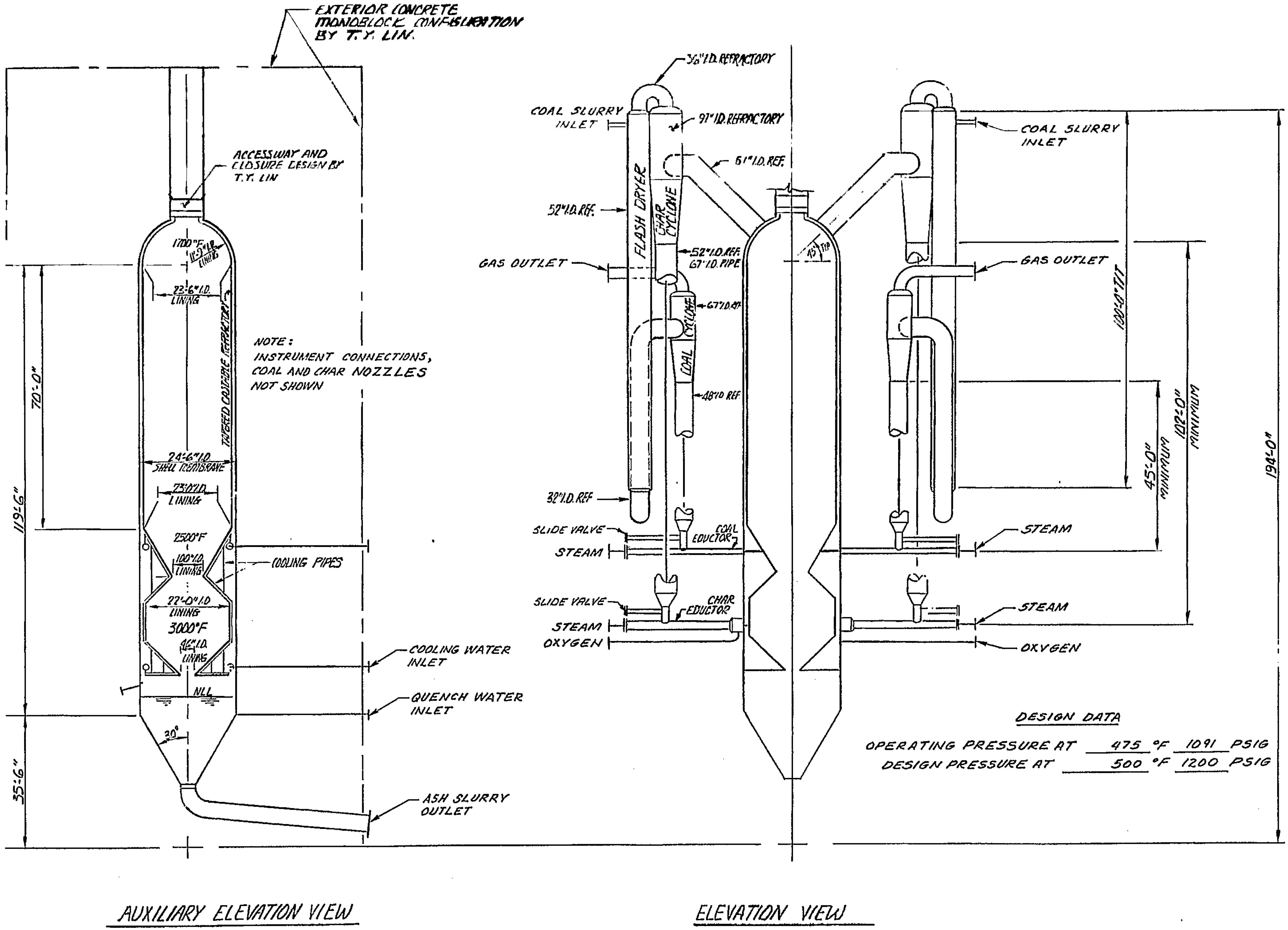

Figure 4 - Conceptual Gasifier Sketch
Prestressed Concrete Vessel

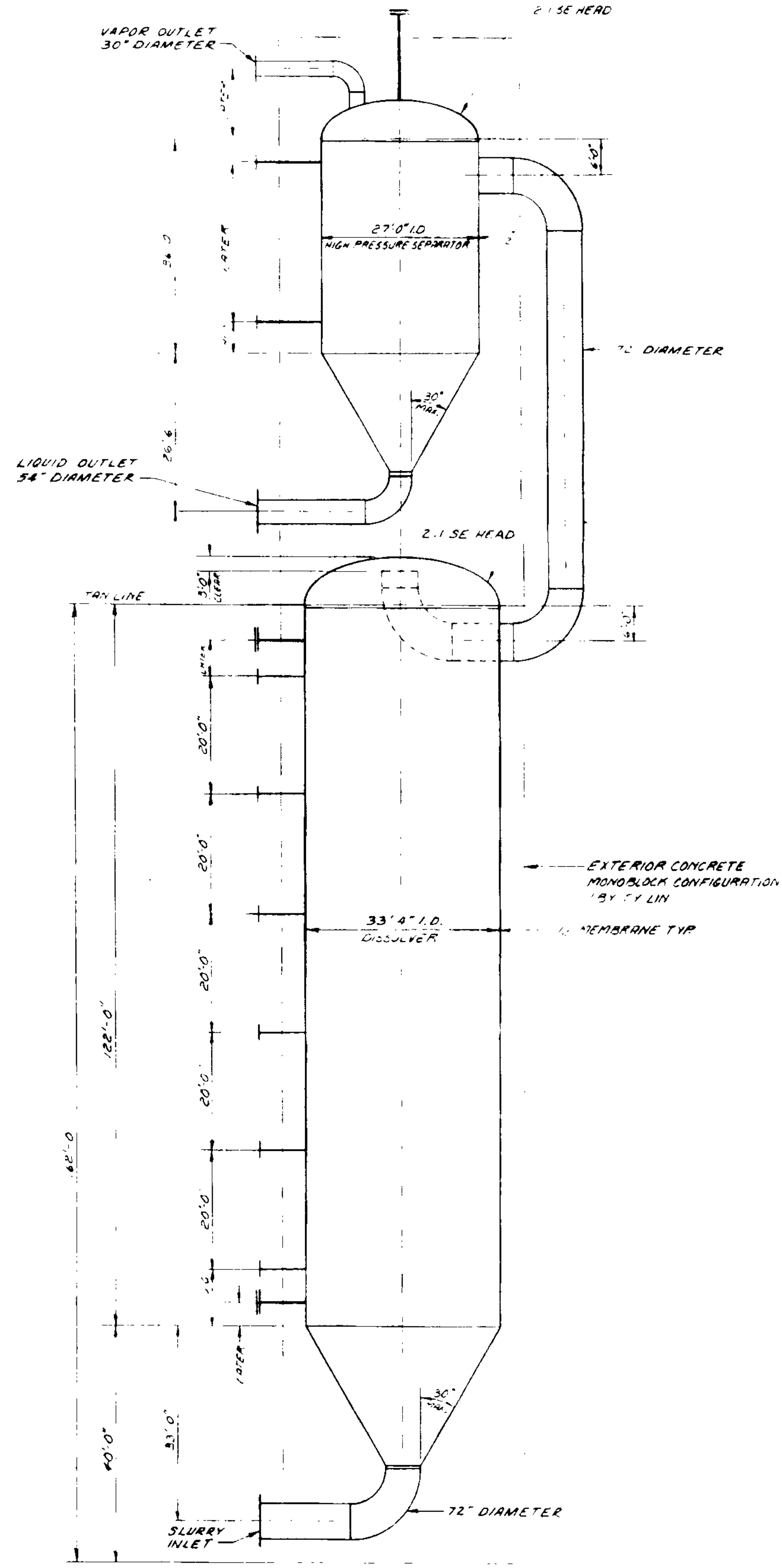

Figure 5 - Dissolver–Separator Prestressed Concrete Vessel

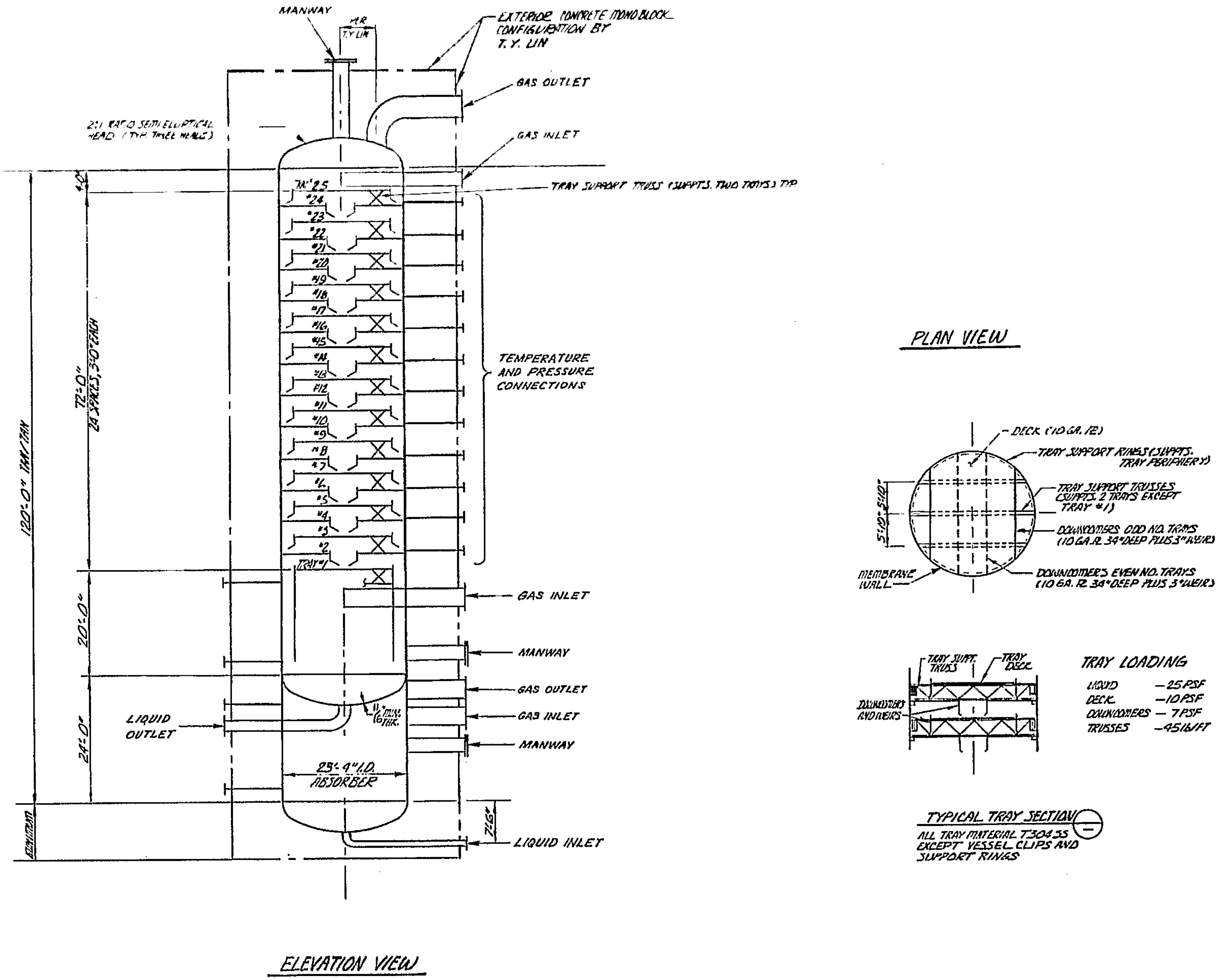

Figure 6 - Absorber Column Prestressed Concrete Vessel

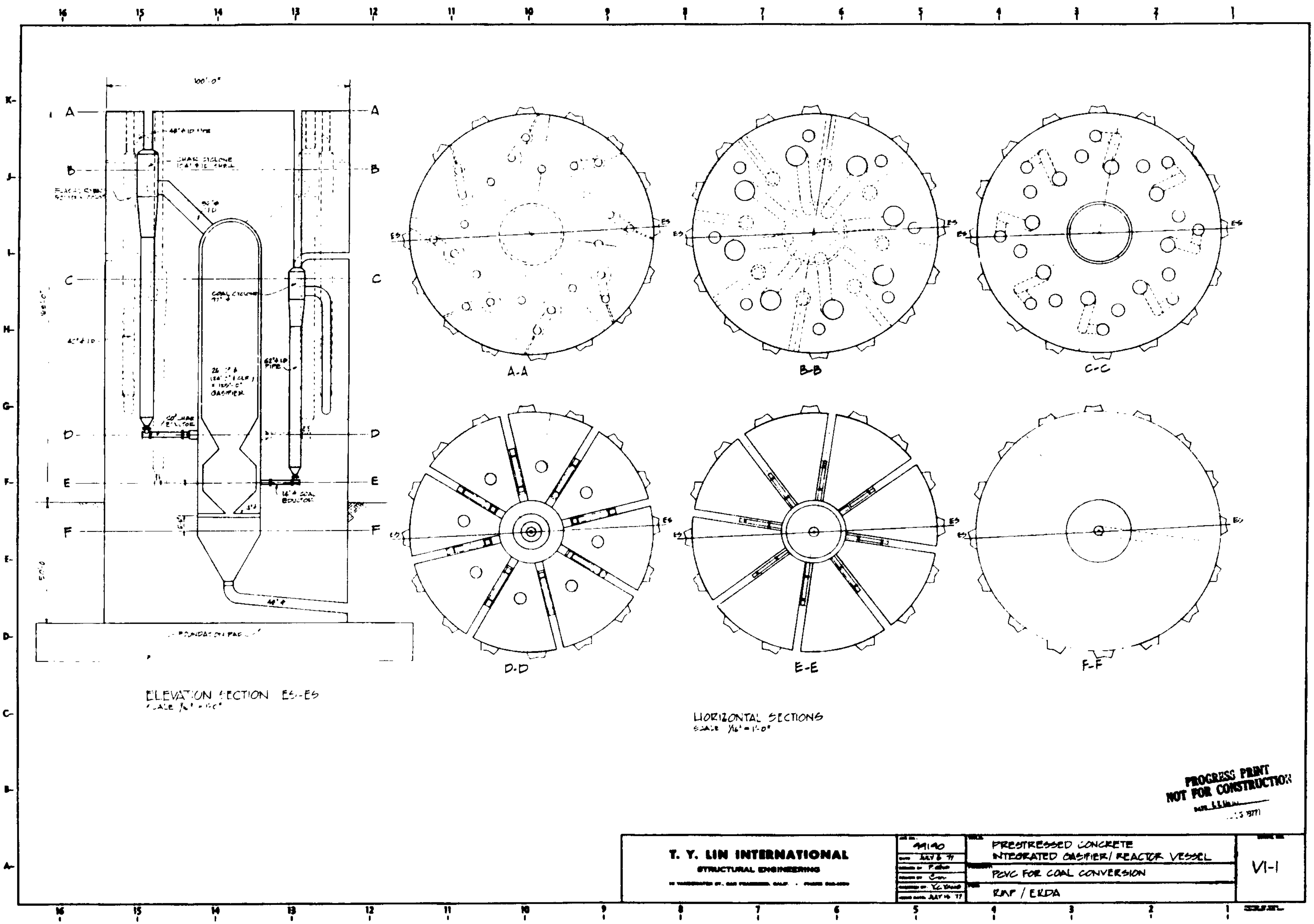

Figure 7 - Integrated Gasifier Reactor Prestressed Concrete Vessel

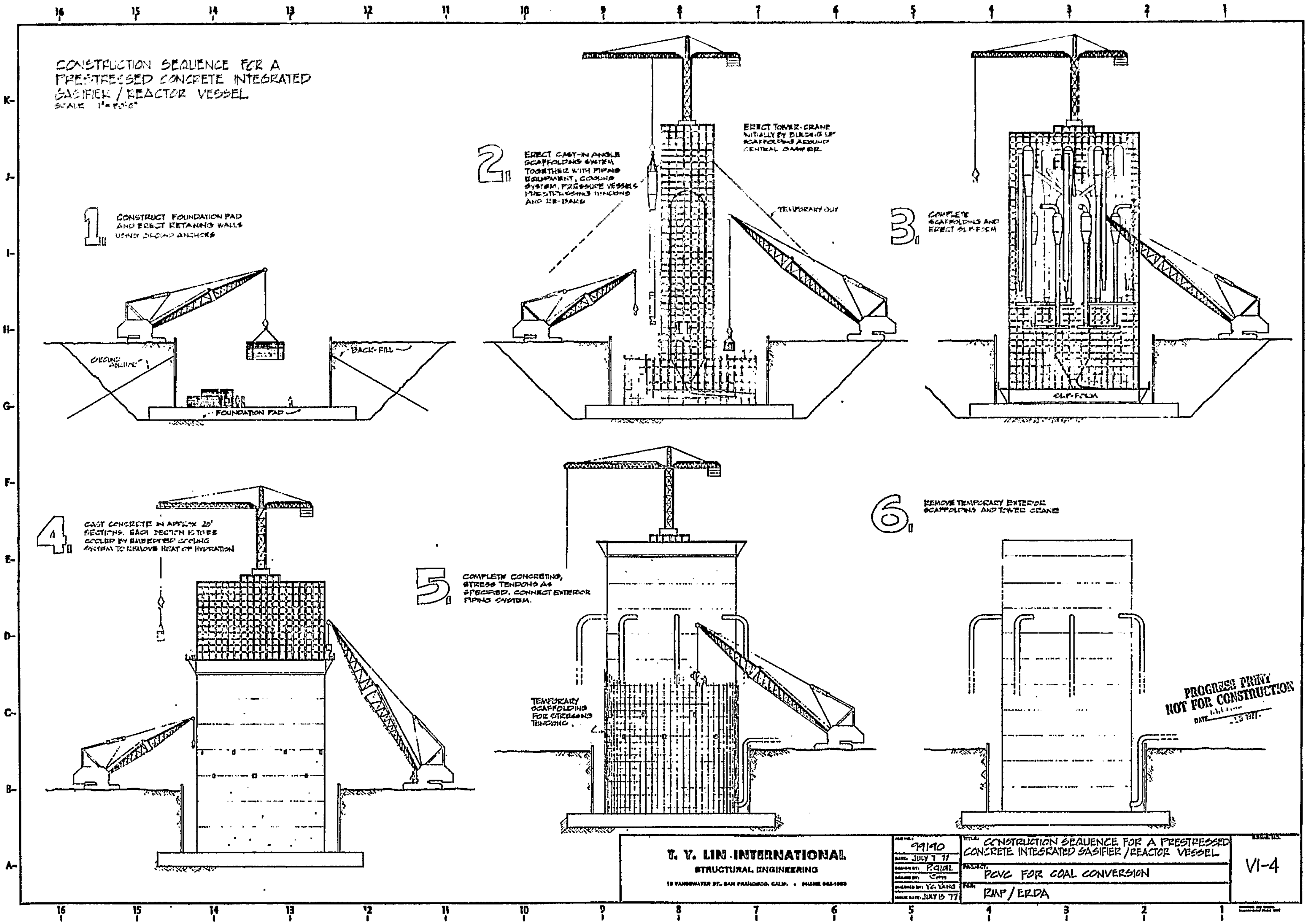

Figure 8 - Construction Sequence for Integrated Gasifier Reactor Prestressed Concrete Vessel

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