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PRETREATMENT UNIT OPTIONS

INDUSTRIAL FUEL GAS DEMONSTRATION-PLANT PROGRAM

Submitted by

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MASTER

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Prepared for the

UNITED STATES DEPARTMENT OF ENERGY

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MEMPHIS INDUSTRIAL FUEL GAS DEMONSTRATION PLANT PROJECT

PRETREATMENT UNIT OPTIONS
(Deliverable #41)

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PREPARED FOR THE
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IN ACCORDANCE WITH THE STATEMENT OF WORK UNDER DOE CONTRACT ET-77-C-01-2582, MLGW SUBCONTRACT NO. 8803, IGT IS TO PROVIDE OPTIONS FOR INCORPORATING A PRETREATER REACTOR INTO THE U-GAS® GASIFICATION SYSTEM. COST AND SCHEDULE IMPACTS ARE TO BE PROVIDED. THIS DOCUMENT WITH ATTACHMENTS IS IN FULFILLMENT OF THESE CONTRACT REQUIREMENTS.

SUMMARY

Three approaches to pretreatment for the Industrial Fuel Gas Demonstration Plant project in the Institute of Gas Technology (IGT) Pilot Plant have been examined. Analyses of these approaches, selection of the best alternative among the three, and detailed design and evaluation of cost and schedule impacts were made.

The best approach available to pretreatment demonstration is an integrated pretreater — an ash agglomerating gasifier (AAG) that uses the existing AAG system, a new pretreater pressure vessel, and needed ancillary equipment.

Based on pilot plant results, IGT does not recommend pretreatment for the Industrial Fuel Gas Demonstration Plant or testing pretreatment in the IGT Pilot Plant, but merely suggests the above approach to pilot plant testing of pretreatment as the most viable.

IGT recently investigated the possibilies of having a large quantity of coal devolatilized in an outside facility and preparing a feed material that would resemble pretreated coal. A rotary kiln operated by Peabody Coal Company in Columbia, Tennessee, meets the requirements. Its charges are $2000 per day for operating the unit, which handles about 5 to 10 tons per day of coal.

DISCUSSION OF PRETREATMENT

Pretreatment refers to any method of rendering an agglomerating (or caking) coal nonagglomerating. In this case, agglomeration does not refer to the sticking together of the ash in the coal to form large dense particles that exit the reactor from the venturi; it refers to a tendency of raw coal to pass through a sticky phase at temperatures far below the ash deformation temperature. This behavior causes problems of material transfer, accumulations on reactor internal surfaces, and defluidization.

Several methods of pretreatment have been proposed; however, only the method of fluidized-bed oxidation is discussed in this report. This method involves subjecting the raw coal to mild oxidation in an oxygen-steam or air-steam environment with a small percentage of oxygen. A temperature range of 700° to 800°F is typical as are residence times of 1/2 to 1 hour. Water-cooling coils are provided to control the temperature of the fluidized bed and are a source of steam in a commercial plant.

IGT has demonstrated pretreatment in the HYGAS® Process Pilot Plant, which has processed highly caking coals from the Illinois basin that are not unlike the Western Kentucky No. 9 coal. A discussion of several of the alternatives or options available to IGT to test and demonstrate pretreatment operation for the Industrial Fuel Gas Demonstration Plant Program follows.

After examining the options available for pretreatment, it was concluded that the following three alternatives had the best prospects for implementation:

I. Integrated Pretreater — AAG Pilot Plant Reactor

II. HYGAS Pretreater

III. Modifications and Addition of Bench-Scale AAG Reactor to Existing 10-Inch Pretreater Process Development Unit (PDU)

These three alternatives were examined and analyzed for technical feasibility by IGT personnel and are discussed in greater detail in the following section. The reasons for eliminating a particular alternative from further consideration (in the case of Alternatives II and III) and for selecting Alternative I for a more detailed evaluation are also discussed.

DESCRIPTION OF ALTERNATIVE PRETREATMENT METHODS

Alternative I. Integrated Pretreater — AAG Pilot Plant Reactor

This method involves incorporating a pretreater vessel near to or within the existing AAG Pilot Plant building. A rerouting of feed solids and gas piping would be made so that coal and coke feed would proceed directly to an oxygen-steam-blown fluidized bed. A transfer line would be provided to move the pretreated solids directly into the AAG reactor where further processing would be conducted essentially as currently practiced. Provisions for gas cleanup or disposal of tar-laden pretreater off-gases would be required. This alternative was chosen for further study; it will be discussed in more detail later in this report.

Alternative II. HYGAS Pretreater*

As part of the HYGAS Pilot Plant, IGT operates an atmospheric pressure coal pretreater. This vessel has an internal diameter of 98 inches and has processed up to 3 tons/hr of highly caking coal. Removal of excess heat and temperature control are obtained through the use of internal water-cooling coils. A char cooler is provided to reduce the exiting solids temperature from approximately 800° to 200°F by direct water spray in a connecting vessel called a char cooler. Off-gases from the pretreater and the char cooler are treated by venturi scrubbing and water quench and are then sent to an incinerator. This method involves using the pretreater system to produce a non-agglomerating char, which would be removed from the HYGAS pretreater storage tank or char cooler and transported to the AAG reactor site. A sufficient quantity would have to be produced in advance to fill the AAG coal silo. The operation of the AAG system with this material would be essentially unchanged, except that different quantities of steam and oxygen would be required for use with the pretreated char than with the coal to obtain a particular gas product quality.

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* For a more detailed discussion of this pretreatment section, see: Institute of Gas Technology, "HYGAS — 1964 to 1972 Pipeline Gas From Coal-Hydrogenation," R&D Report No. 22, Final Report, Vol. 2. Chicago, July 1975. (Also see subsequent HYGAS Progress Reports.)

Alternative III. Modifications to the Existing 10-Inch Pretreater PDU and Addition of a Bench-Scale AAG Reactor*

IGT operates a pilot pretreatment unit of 10-inch ID. This system is a continuous flow, moving-bed arrangement. Solids are screw-fed to the bottom of the reactor at a controlled rate and discharged from a standpipe of variable height and diameter, the latter being the means by which residence time is varied. Gases for fluidization are provided, and measurements of product gas yields can be performed.

This method incorporates a suitable agglomerating reactor to accept the discharge from the 10-inch pilot unit and subjects the discharge to steam and oxygen environments to determine the necessary conditions of agglomeration and the ensuing gas yields for a given degree of pretreatment. The range of raw coal feed that this pretreater can accommodate is 25 to 300 lb/hr.

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*For a more detailed discussion of this system, see: Pyrcioch, E. J., et al., Production of Pipeline Gas by Hydrogasification of Coal," IGT Res. Bull. No. 34. Chicago, 1972.

EVALUATION OF ALTERNATIVES — TECHNICAL

Alternative III has several critical shortcomings that were identified shortly after the detailed evaluation work began. One of these limitations is the severe scale-up problems associated with translating the results of the 10-inch pilot unit to demonstration plant conditions. This was caused not only by differences of size, i.e., reactor diameter and height, but also by the moving-bed nature of the reactor. This reactor mode is quite different from the well-mixed fluidized bed that is believed to exist in a large-scale unit. In addition, the coarse nature of the Western Kentucky coal feed used in the pilot plant requires high fludizing velocities, which were not customary for use in this apparatus. These high velocities may cause too much elutriation of char out of the system. The remaining difficulties with this system involve the design and implementation of an appropriately small-scale agglomerating gasifier to go along with this pretreater. It is reasonable to assume that the required ash discharge venturi dimensions are quite small and that there is a distinct possibility that this zone might become plugged with material.

Alternative II is deficient in several ways. The HYGAS development program would take precedence, and when operating on a caking coal the pretreater would be unavailable. Continuous operation of several weeks is not uncommon in the HYGAS program, and this could conceivably interfere with the AAG Pilot Plant operation schedule. Operation of this system would not strictly simulate the integrated operation of pretreatment and ash agglomeration because the char is cooled to ambient temperature and reheated to AAG reactor temperature rather than being fed directly. The location of the pretreatment equipment in the HYGAS Plant is inconvenient for access by solids moving equipment such as the front-end loader, and, therefore, transporting the 80 tons of material necessary to begin the AAG run would be painstaking and time consuming. It also might involve an element of danger, i.e., a collision of the payloader and a piece of process equipment.

The coarse feed material (-1/4 inch U.S.S. sieve) used in the AAG Pilot Plant is considerably larger in size than the typical feed material (-100 mesh) to the HYGAS Process. The latter feed is adequately fluidized at approximately 1 ft/s. The air compressor for the HYGAS pretreater is sized accordingly, and, in order to obtain the additional fluidizing velocity required for our larger feed, additional equipment would be required. This includes an air preheating apparatus and additional or modified gas quench equipment, i.e., quench-water pumps, venturi scrubber and quench tower, quench water coolers, larger incinerator piping, and possibly a larger incinerator.

EVALUATION OF ALTERNATIVES — COSTS

A brief and cursory evaluation of the costs involved in Alternative III was performed. As a basis for these estimates, a sketch of the reactor required and a list of ancillary equipment and their associated costs was prepared. (See Figure 1 and Table 1.) Many ancillary equipment items, for example, a steam generator, were required because of the lack of utilities in the old pilot plant building. No cost information for Alternative II was obtained. The costs of running the HYGAS pretreater were not available on an allocated basis. Negligible capital equipment was required for this alternative.

Table 1. ITEMIZED COSTS FOR ALTERNATIVE III

Item	Estimated Cost, $
Reactor	5,000
Grid	1,000
Start-Up Burner	1,500
Reactor Refractory (Installed)	3,000
Quencher	2,500
Quencher Refractory	1,000
Cyclone	1,500
(2) Ash Lockhoppers	2,500
Feed Hopper	1,500
Blower (50 SCFM)	2,000
Steam Generator	1,500
Addition Capacity for N_2 Vapor	2,000
Instrumentation and Control Valves	10,000
Equipment Cost	35,000
Installation Cost	70,000
TOTAL	105,000

No preliminary cost estimate was prepared for Alternative I because it was chosen as the preferred method for technical reasons. As a result, a construction task chart and detailed vessel drawings were prepared. Quotes for the vessel were received. A schematic process and instrumentation diagram (P&ID) and a preliminary material balance were prepared. These matters are discussed subsequently.

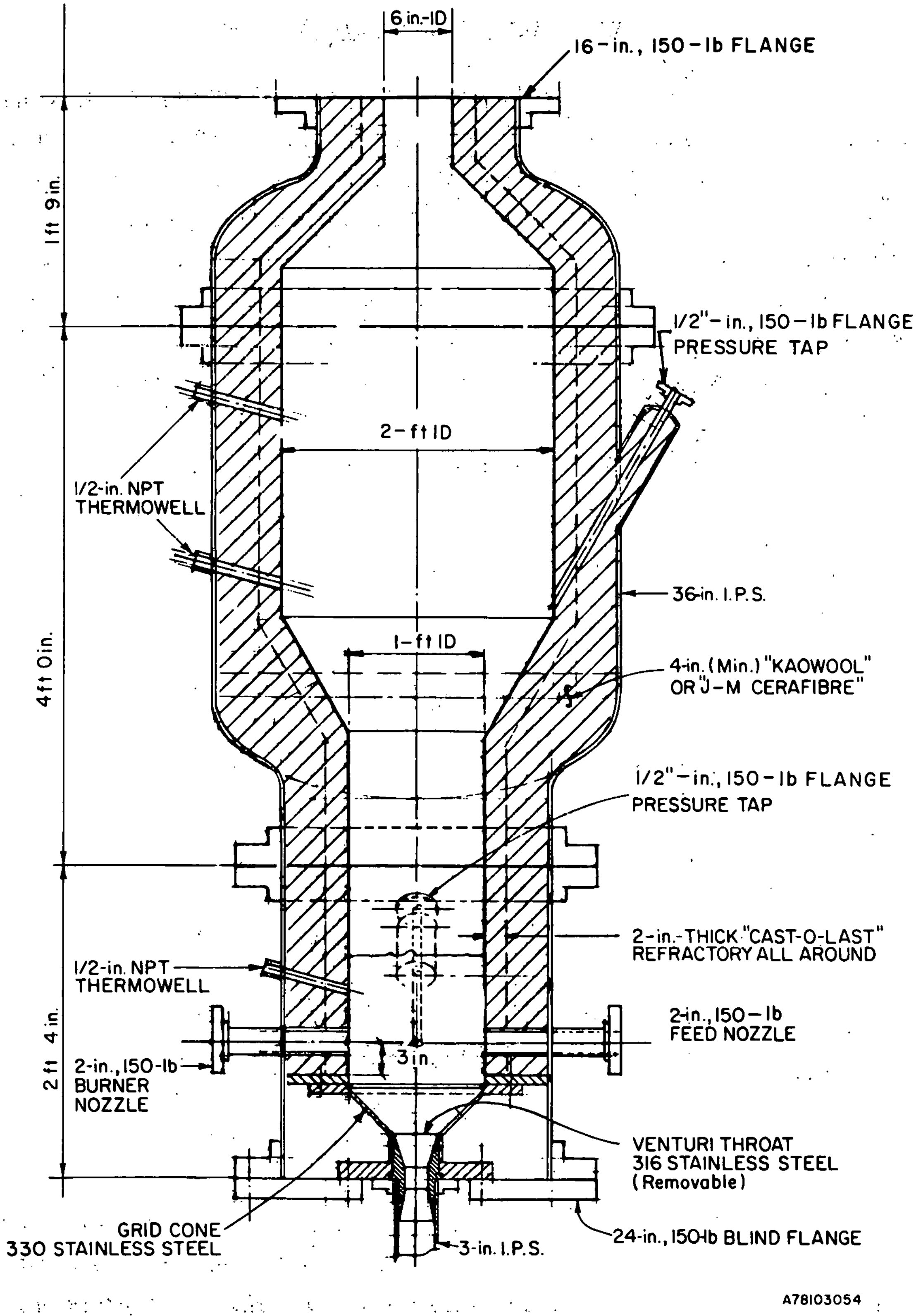

Figure 1. ALTERNATIVE III CONCEPTUAL PRETREATER

DETAILED DISCUSSION OF ALTERNATIVE I

A P&ID (Figure 2) and a detailed vessel drawing (Figure 3) were prepared for this method. Quotations for this vessel, F.O.B. IGT's pilot plant, were requested and received. A cost estimate and a construction task chart and schedule (Figures 4 and 5) were prepared; the cost estimate, prepared from the P&ID diagram, is shown in Table 2. Actual costs are shown only for the vessel; all other costs were estimated based on IGT's experience. A total cost of $239,000 results for this alternative. The cost does not include the charge for air compressor capacity; this is to be obtained by use of rental compressors. Calculations of costs of this nature are accurate only within $\pm$35%.

Table 2. COST ESTIMATE FOR INTEGRATED PRETREATER FOR ALTERNATIVE I

Item	Purchased Equipment Cost (1977 Basis), $
Vessel	18,800
Refractory (Lining)	2,200
Cyclone	3,000
Boiler Feedwater Pump	2,000
Boiler Feedwater Condenser	10,000
Venturi Scrubber	7,000
Air-Preheater (Start-UP)	18,000
Oil-H_2O Separator	5,500
TOTAL	66,500

Factored Cost (Installed Cost) 3.6 X $66,500 = $239,400

As can be determined from Figure 5, a period of 10 months is required for construction and installation of the integrated pretreater. For reference purposes, the schedule is shown with a January 1978 starting date.

A material balance for Alternative I was prepared and is shown in Figure 6. The base coal used in this design has been subsequently modified especially with respect to moisture content, and this material balance should not be used for current design calculations. In addition, because of the complex nature of the reactions of devolatilization and tar formation that occur in pretreater systems, the predictions are not very accurate, show no definite amount of tar formation, and permit a reasonable degree of variability in steam and oxygen flows with a still acceptable degree of pretreatment.

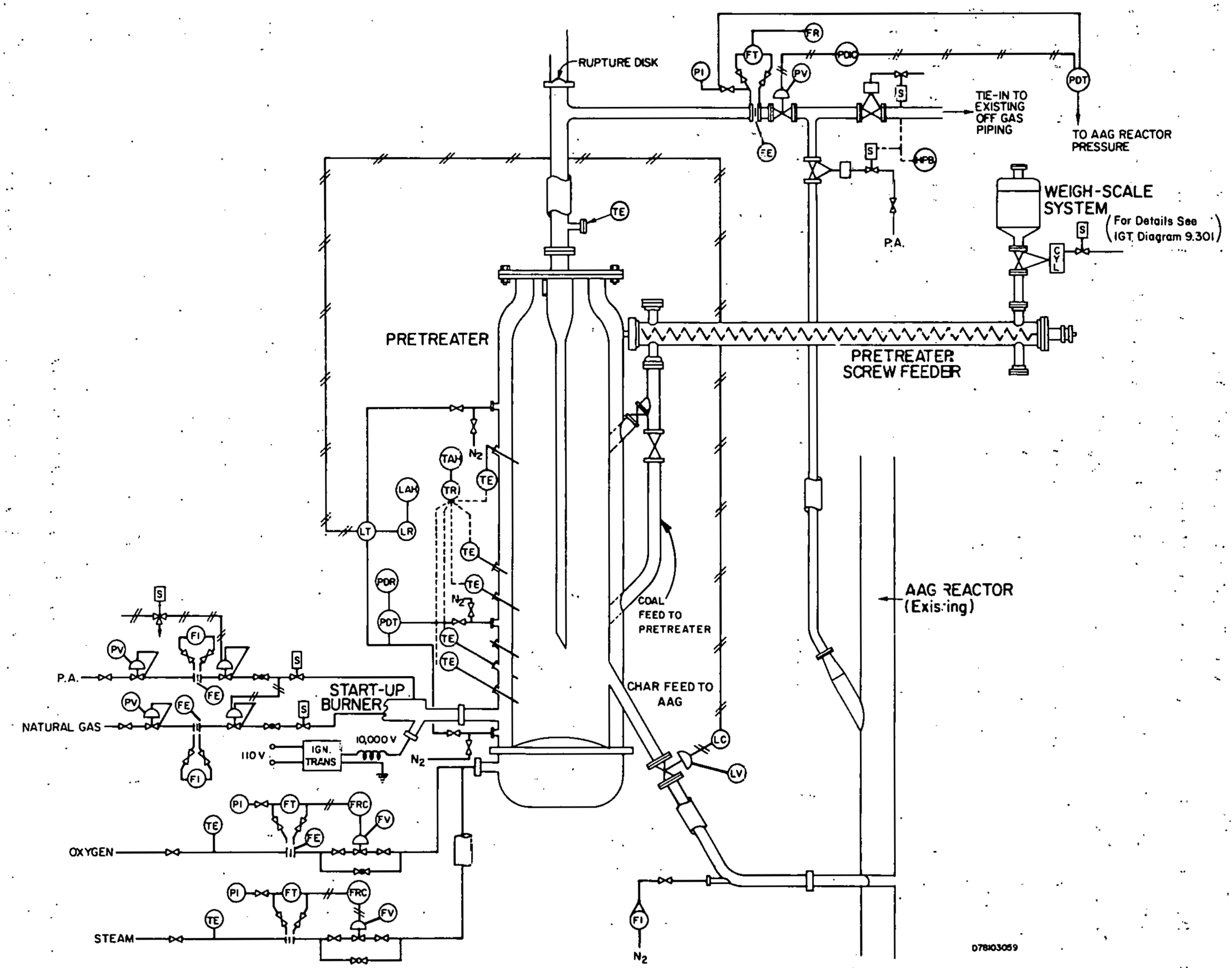

Figure 2. P & ID DIAGRAM OF INTEGRATED PRETREATER FOR ALTERNATIVE I

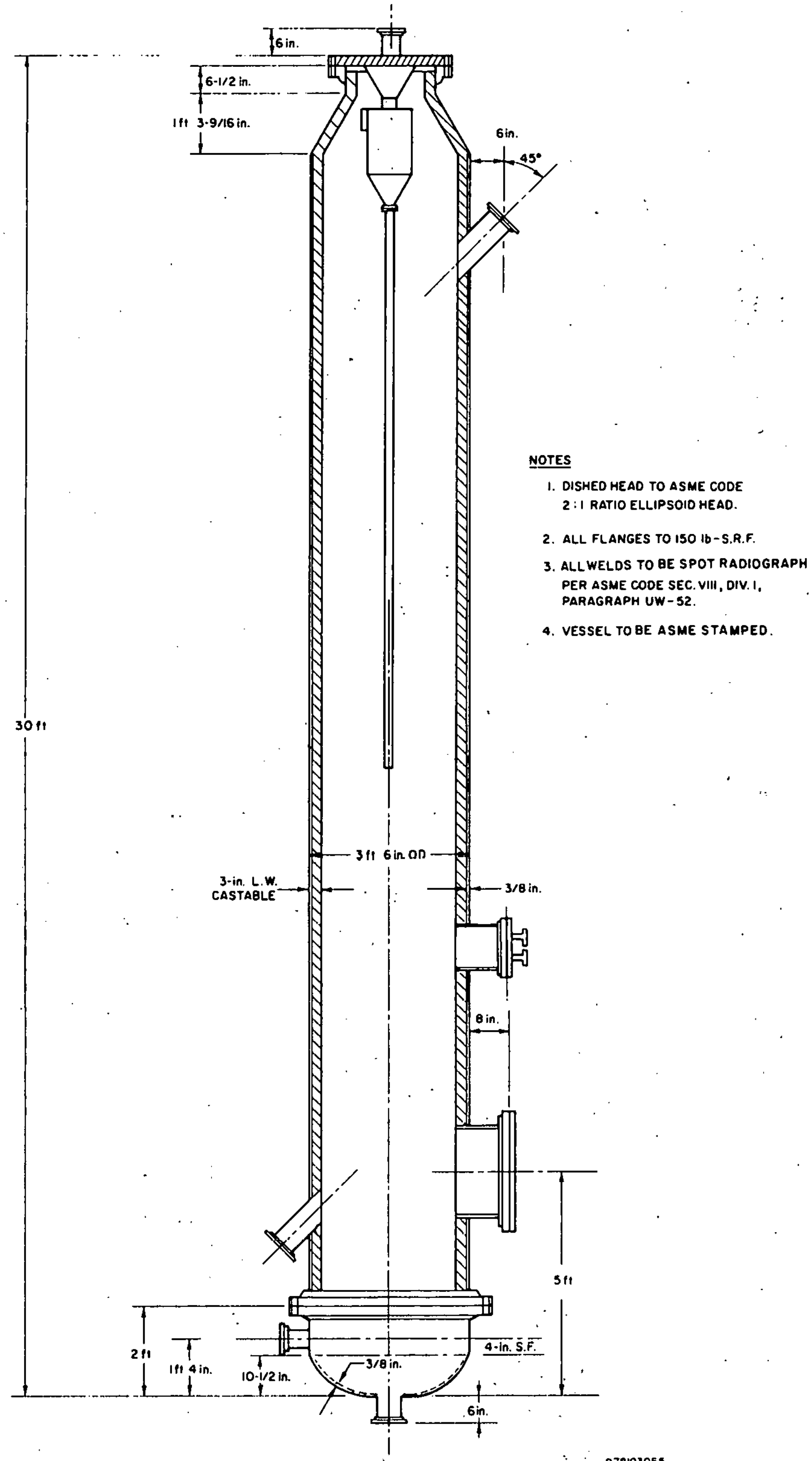

Figure 3. ALTERNATIVE I VESSEL DRAWING OF INTEGRATED PRETREATER

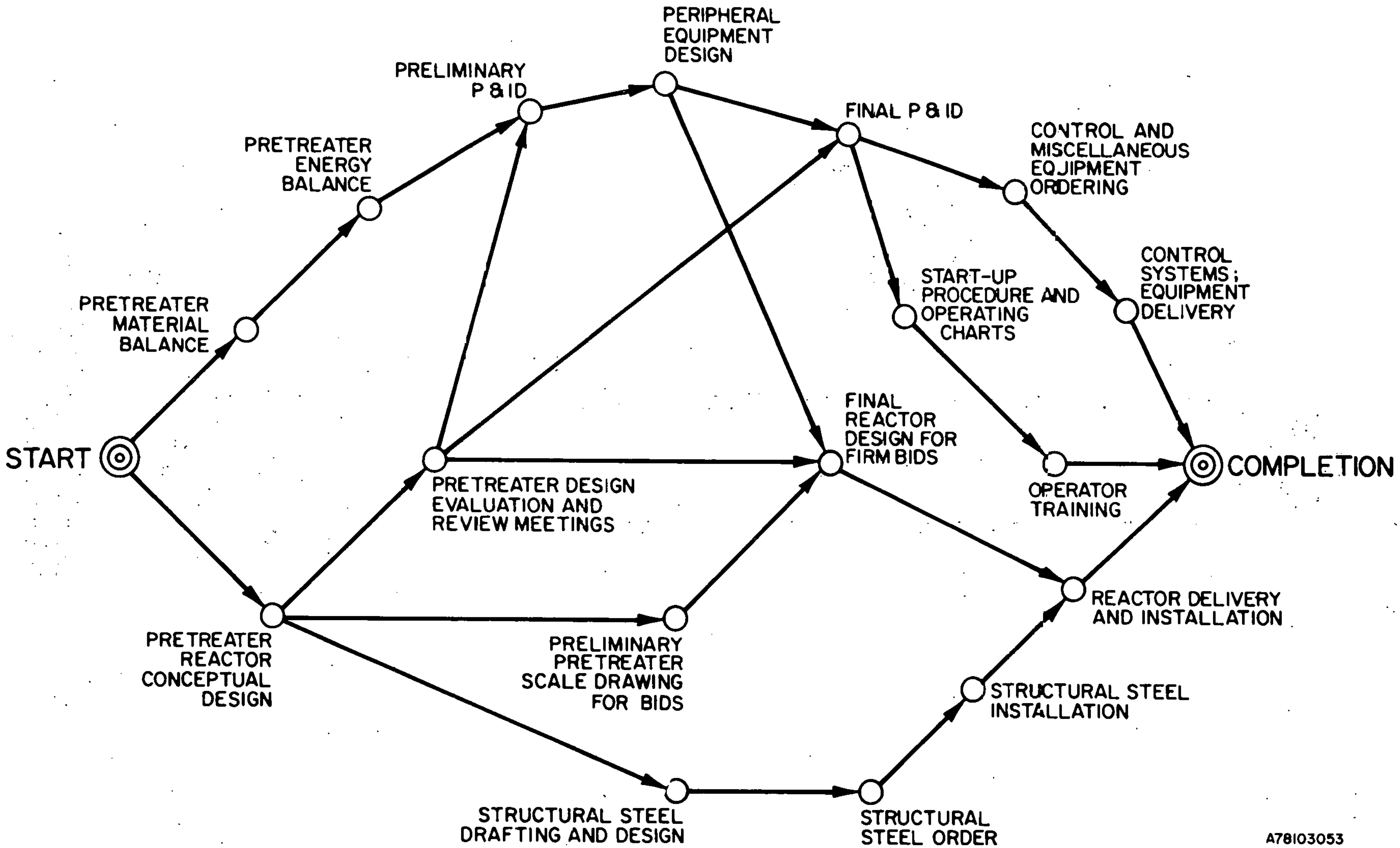

Figure 4. CONSTRUCTION TASK CHART FOR INTEGRATED PRETREATER FOR ALTERNATIVE I

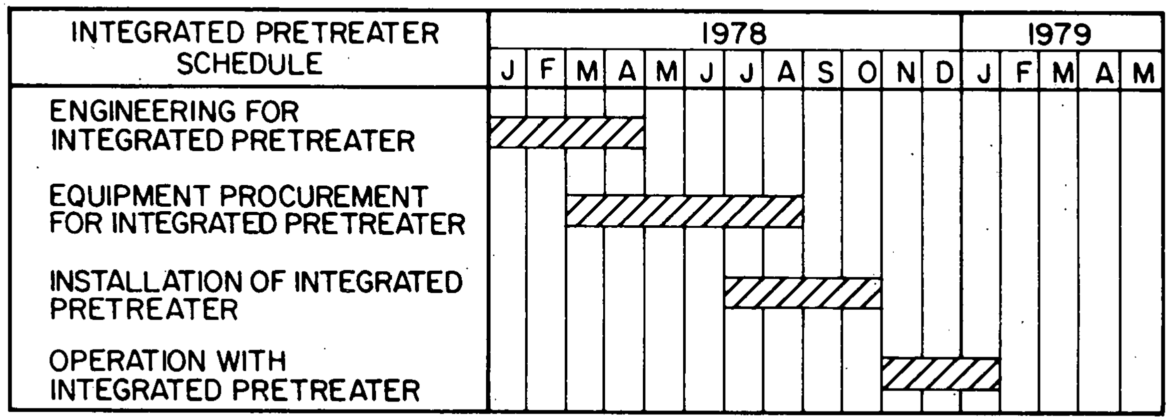

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Figure 5. INTEGRATED PRETREATER SCHEDULE

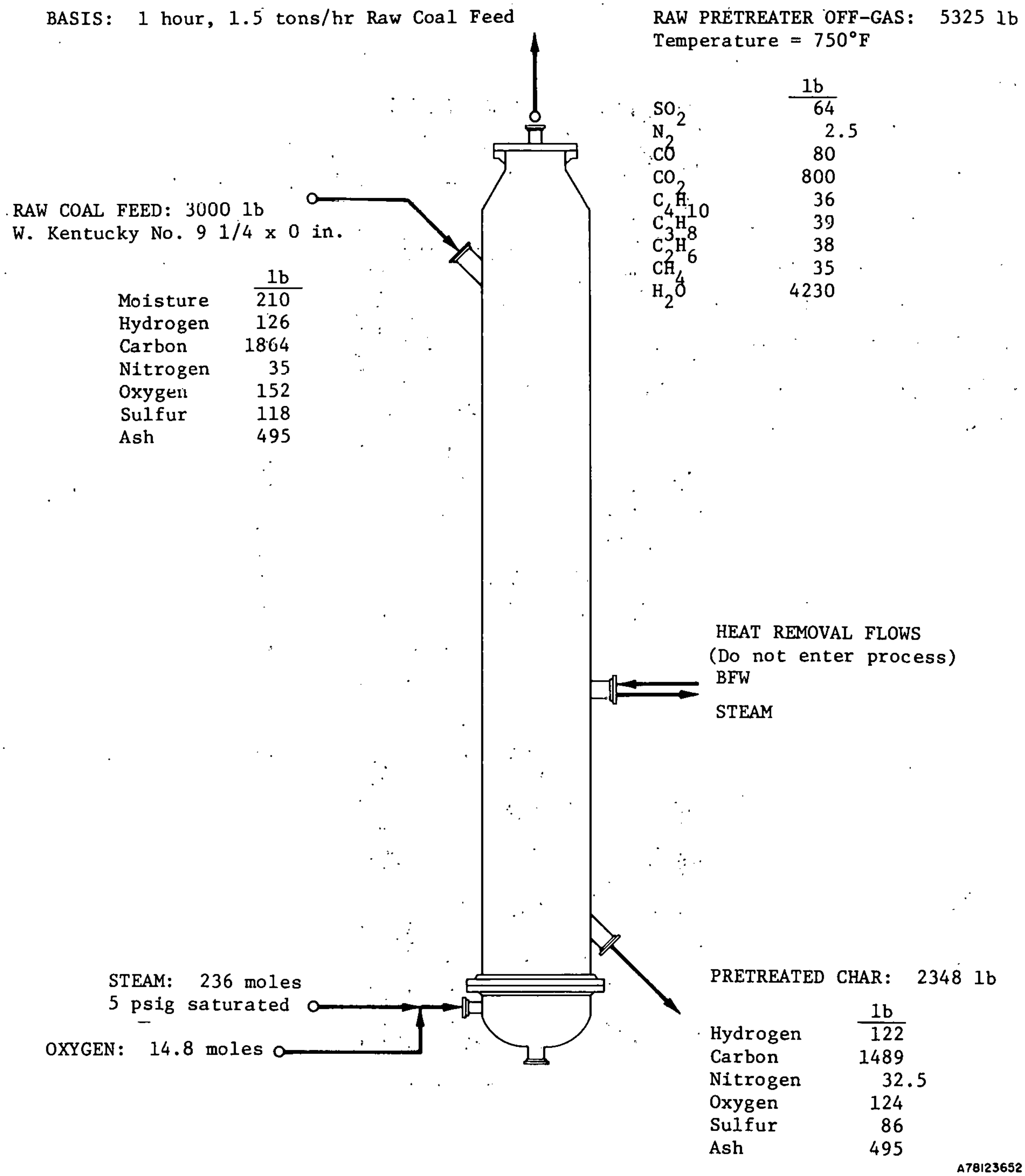

Figure 6. PRETREATER MATERIAL BALANCE FOR WESTERN KENTUCKY No. 9 COAL FEED FOR INTEGRATED PRETREATER OPERATION IN THE AAG PILOT PLANT

CONCLUSIONS AND RECOMMENDATIONS

Based on pilot plant tests, IGT does not feel that pretreatment is necessary for operation of the ash agglomerating gasifier with Western Kentucky No. 9 coal. Although this coal is highly caking as evidenced by a free-swelling index of 4.5 to 6.5, IGT has developed a feeding technique that enables raw coal to be fed directly to the gasifier without plugging of the feed nozzle lines. This has been demonstrated in several tests.

Should pretreatment prove necessary because of unforeseen circumstances, IGT has studied the available alternatives and has selected the best alternative for detailed consideration. Flow diagrams, vessel drawings, PERT-type project management diagrams, and material balances have been prepared and a budgetary cost estimate made. A preliminary schedule has been prepared. Major equipment item requirements have been defined. If pretreatment is required, it can be implemented efficiently in accordance with these plans.