expressed in terms of oxygen and coal saved; and if the oxygen and coal costs are known, the value of the steam for the production of synthesis gas may be found. As long as the value of the steam thus found is greater than the cost of producing and superheating the steam, the use of superheated steam is justified. Costs of superheating steam will be covered in a later publication.

PLANS FOR FUTURE PILOT-PLANT OPERATIONS

Description of New Apparatus and Reasons for Design

Based on the data and operating experience gained from the use of the experimental apparatus which has been described, a completely new dust-removal system has been designed, and the pebble heaters have been redesigned to secure slightly more capacity. Increased coal-feeder capacity has been built, and an apparatus for continuous slag removal designed.

Construction work on this new arrangement has begun, and gasification runs will be resumed soon. This equipment will provide for complete dust removal from the gas stream, allow for easy quantitative determination of the residues, and permit operation for as long a run as desired. The flow sheets for the new unit are given in figures 46 and 47.

Coal Feeder

The coal feeder will remain substantially a previously described. Work will be continued in improvements in control and safety features.

Royster Pebble Stoves

It had been assumed in the original design of the stoves that the pebble beds would be fixed, that is, not dumped or moved except at long intervals. Our experimental work has indicated that the beds will need to be moved rather frequently to overcome some tendency for agglomeration of the pebbles. Consequently, the stoves are being completely rebuilt to provide a refractory lining capable of standing higher operating temperatures, better means of changing the pebble bed, a larger combustion space over the pebble bed, and better burners. (See figs. 48-50).

Shown in figure 51 is the refractory-lined water-cooled valve which will be installed in the steam line between the Royster pebble stove and the generator. These valves will be closed while the pebble beds are being heated and will be controlled by the Flex-O-Timer units through air-operated diaphragm motors. The differential pressure control device, previously described, will also be used, since these valves will not be completely tight.

The stoves will be equipped so that the top pebble-bed temperatures can be measured by both optical and radiation-type pyrometers and the steam temperatures calculated from the top pebble-bed temperature. In the steam inlet lines to the generator, thermocouples protected by two types of special high temperature refractory tubes will be tried out.

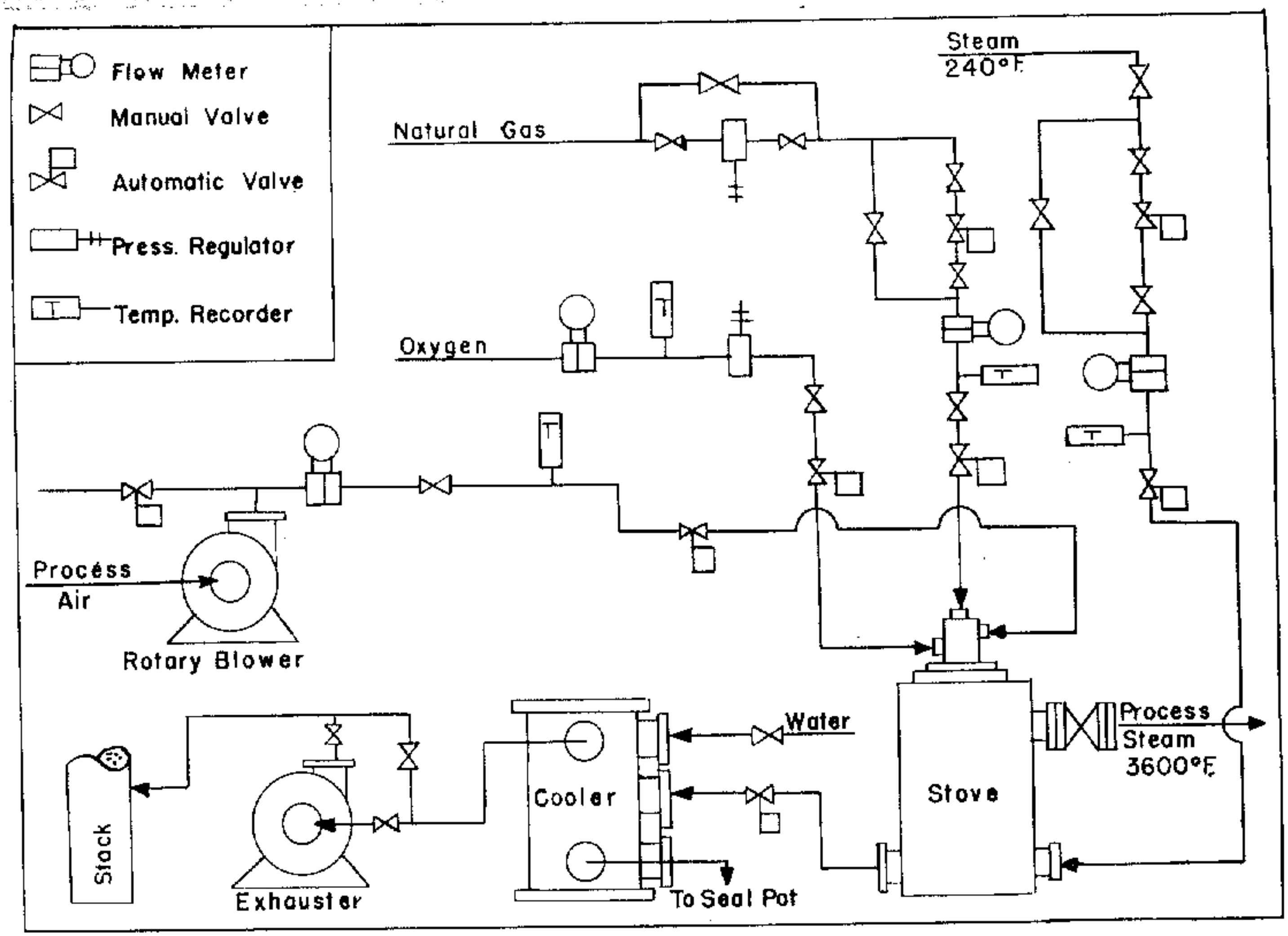


Figure 46. - Flow sheet for preparation of highly superheated steam.

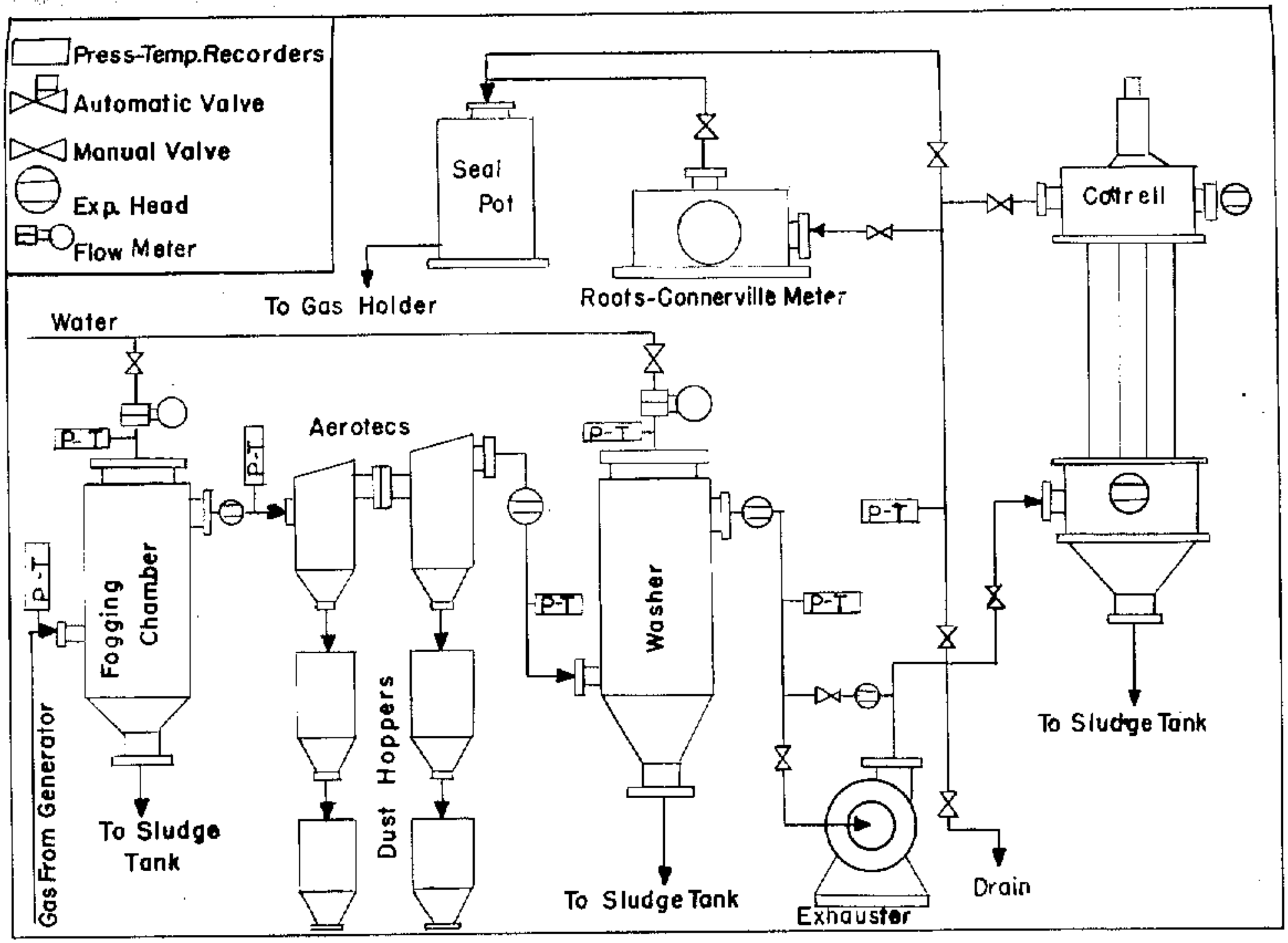


Figure 47. - Flow sheet of dust-removal and cooling system.

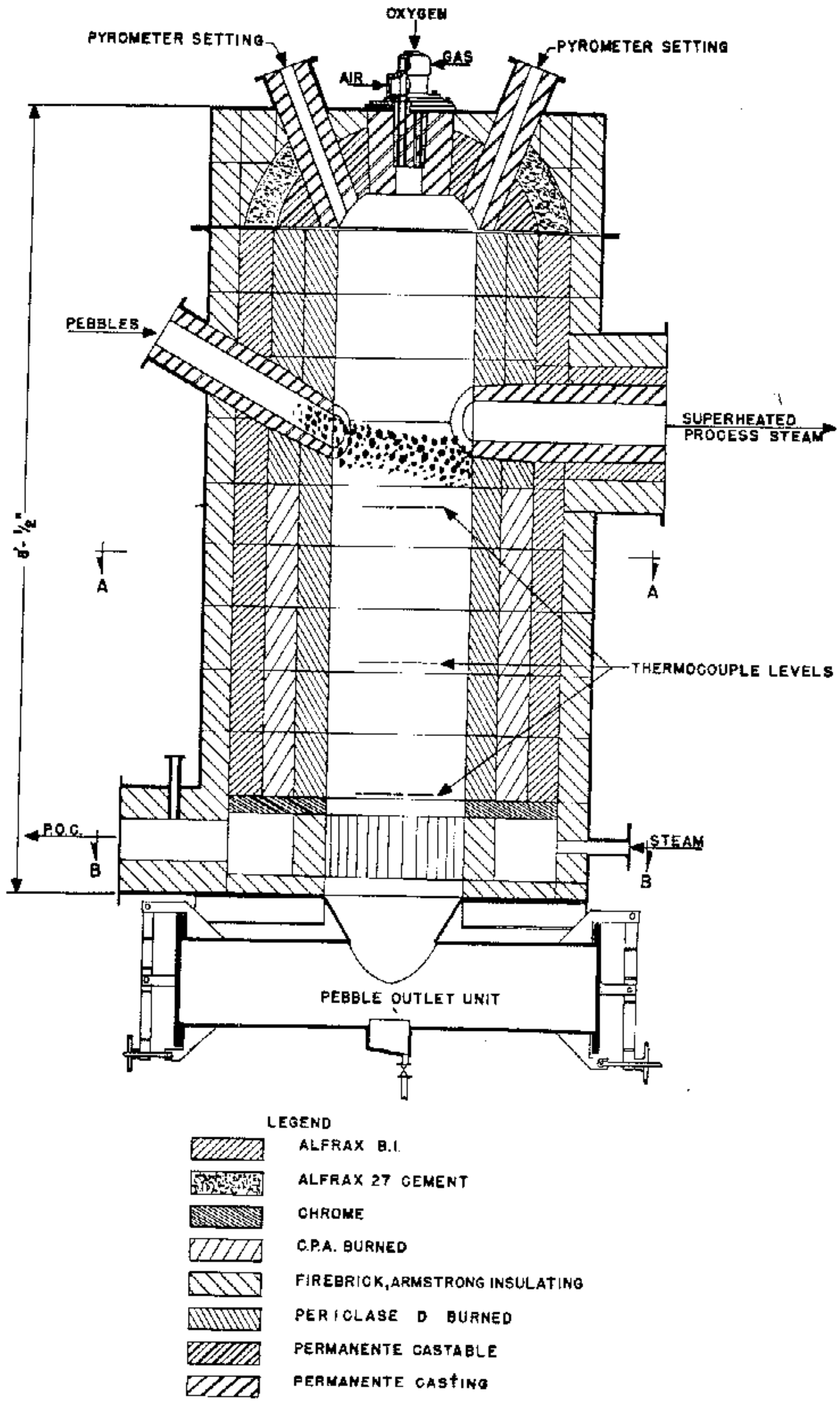
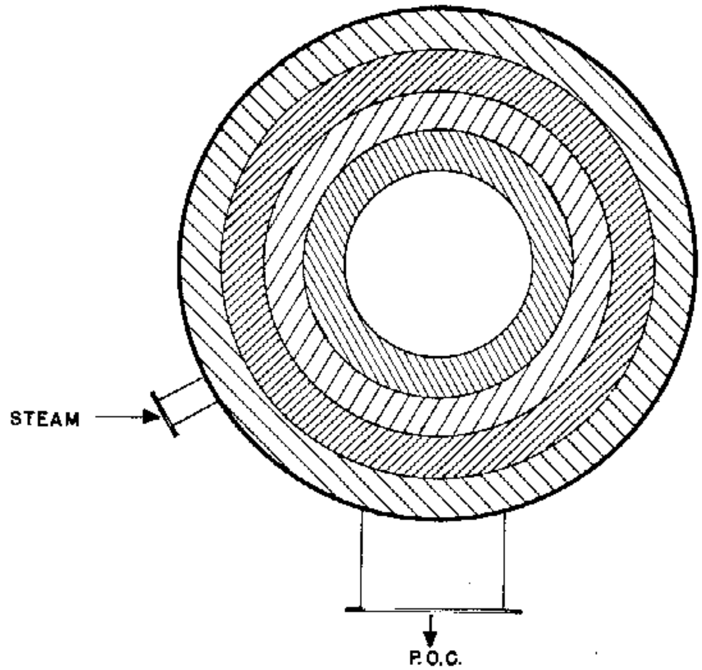
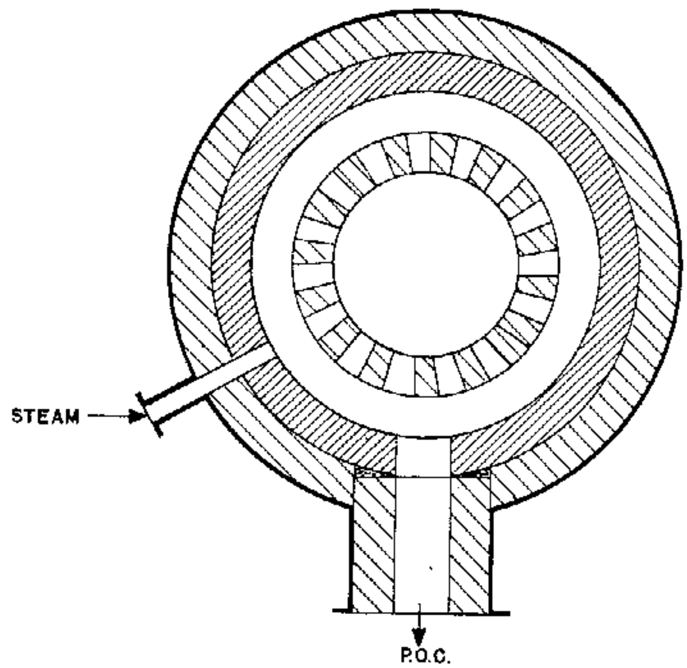


Figure 48. - New Royster pebble-stove refractory detail.



SECTION A-A



SECTION B-B

Figure 49. - New Royster pebble-stove refractory detail; cross section.

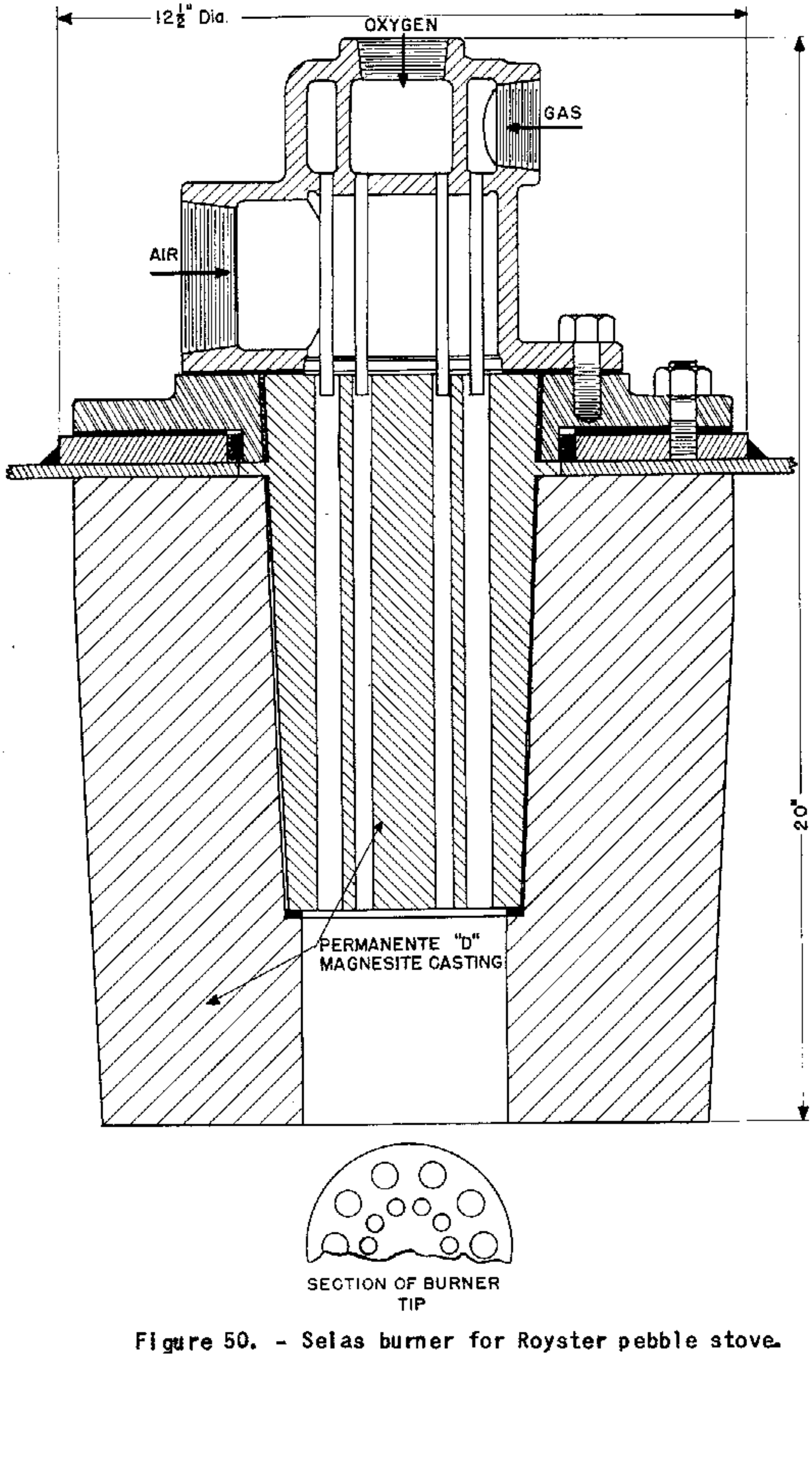


Figure 50. - Selas burner for Royster pebble stove.

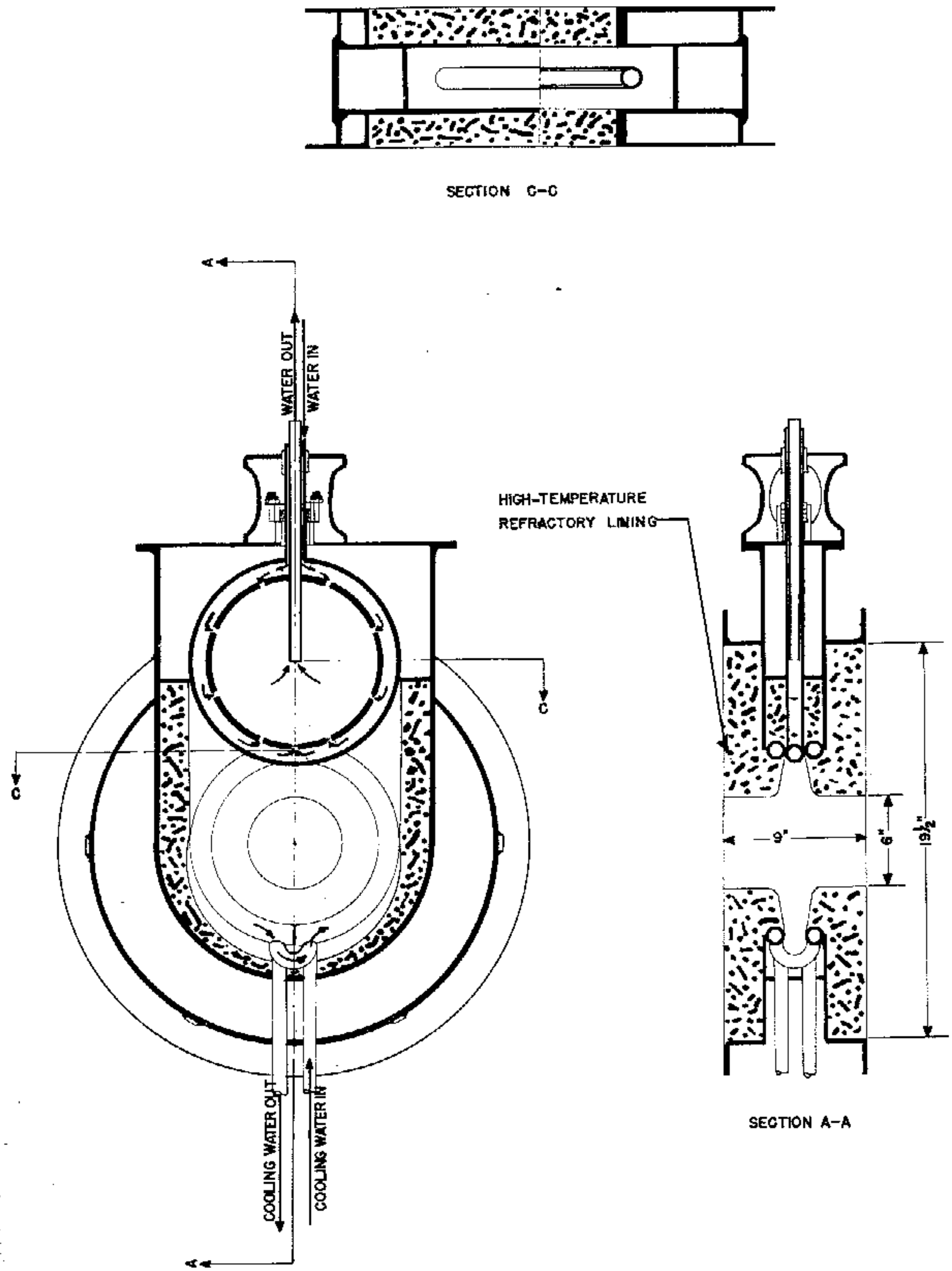


Figure 51. - Water-cooled valve for use in steam lines from stoves to gas generator.

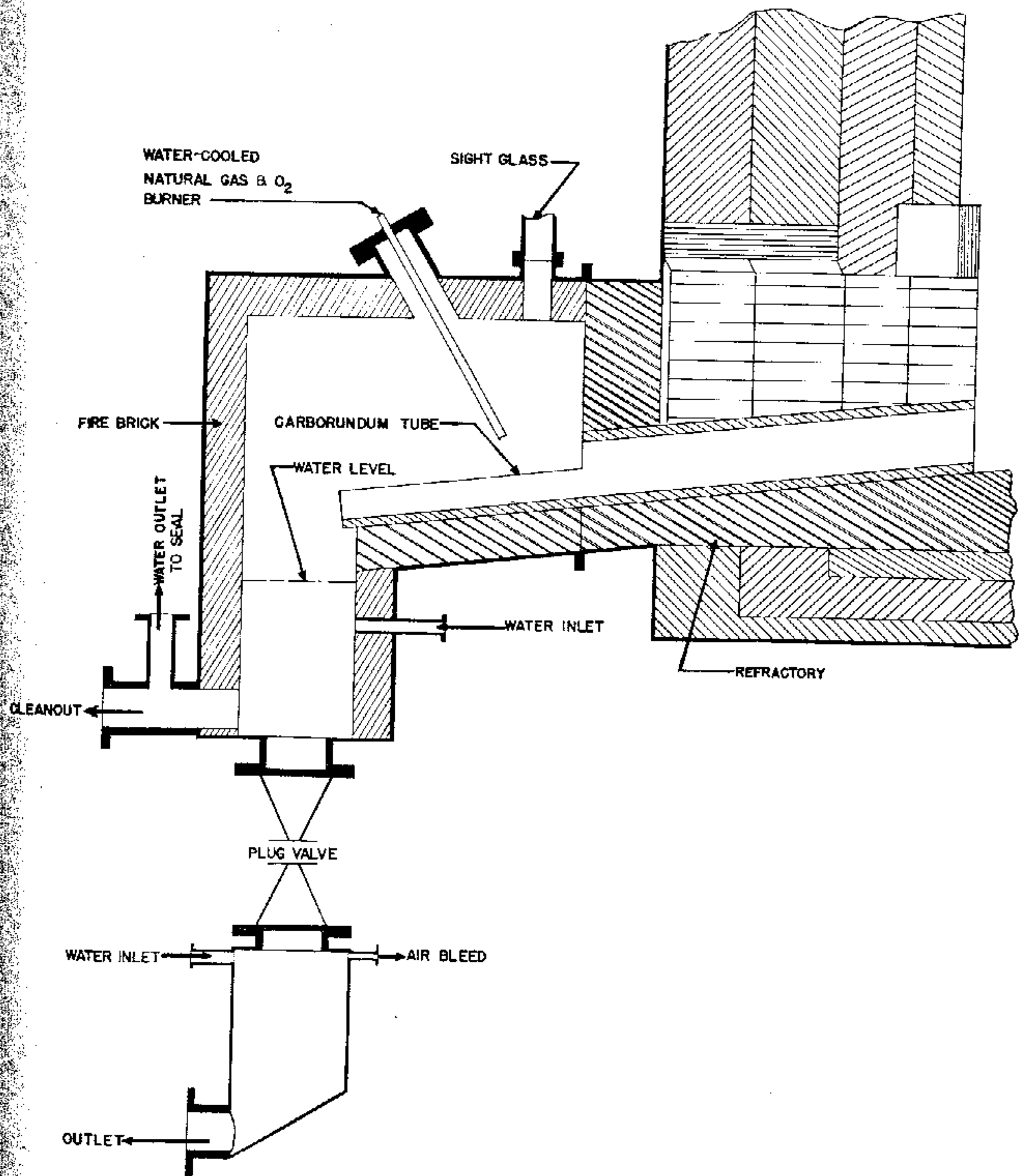


Figure 52. - Continuous slag-tap device for gas generator.

Generator

The generator will remain fundamentally as described previously; that is, the same steam and coal admission ports will be used, and the locations of the various temperature measuring points will be unchanged.

Since the capacities of the steam superheating units will not be materially increased, the maximum coal throughput will be set at approximately 500 pounds per hour by the limited amount of steam available. The generator size will be reduced from an effective volume of 86 cubic feet to approximately 52 cubic feet in order that data on generator capacity for this type of unit may be secured, that is, runs can be made at full capacity of the generator. Silicon carbide type refractory lining and cements will be used to reduce the inside diameter from the present 39 inches to approximately 30 inches.

When the inside diameter is reduced, the angle of the steam admission ports will be changed slightly so that they will be tangential to an 18-inch circle instead of a 24-inch circle. This will maintain approximately the same relationships between the steam stream and the wall as before. It will not be possible to change the angle of the coal port and it will remain tangential to a 24-inch circle. An auxiliary coal port is available for admission along a radius of the generator.

In order that the slag may be removed during each run, the continuous slag-tap device shown in figure 52 will be installed. In addition to aiding in securing better material balances, its use will permit generator operation for longer period. Studies of slag distribution have shown that we can expect to remove at least 50 percent of the ash in the form of slag.

Dust-Removal Train

Consideration of the heat content of the gases leaving the generator shows that, for economical over-all operation of this type of gasifier, a waste-heat boiler or air preheater (or perhaps both) should be used immediately after the generator. Calculations made using the data from two of the runs, with steam from the stoves at approximately 3,300°F. and gas leaving the generator at 1,800°F., show that all the combustion air for the stoves could be preheated to the necessary temperature to obtain a theoretical flame temperature of 3,500°F. Also from the heat in the gas, approximately three-fifths of the required steam for the operation could be generated. However, the actual use of such equipment as a waste heat boiler and/or air preheater in a pilot plant of this small size would involve an expense out of proportion to the value of the data obtained. Consequently, it was decided to use a simple fire-brick lined chamber into which water could be fogged to lower the gas temperature to about 400°-500°F. Enough heat-removal data can be obtained with this apparatus for proper design of waste-heat boilers and air preheaters for large-scale operation.

The fogging chamber shown in figure 53 consists of a steel sheel 4 feet 6 inches in diameter by 10 feet high, lined with fire brick to an inside diameter of 3 feet. Gas leaving the generator at 1,800°F. is sprayed by a very fine mist of water upon entering the fogging chamber. Any condensation or precipitated dust is removed through the conical shaped bottom by a water stream introduced tangentially into the cone and carried to the sludge tank. When the unit has reached stable operating temperatures, only the very heavy dust particles will be removed here, as the amount of water used will be limited to that necessary to secure the exit gas temperature of 400°-500°F. needed for satisfactory operation of the Aerotec dust collectors.

As shown in the flow sheet, figure 47, the Aerotec dust collectors will be of No. 316 stainless steel and contain nine tubes each 2 inches in diameter. Double hoppers are used and so valved that they may be purged and emptied while the unit is operating. This will make it possible to bring the unit up to stable operating conditions before collecting residues for the material balance data.

Following the Aerotec collectors, the gas will be scrubbed in a spray washer to lower its temperature to 90°- 100°F. and to remove as much fine dust as possible. This washer is a steel shell 4 feet in diameter by 12 feet 8 inches high, equipped with three sprays. Material washed from the gas will be conveyed to the sludge tank, where it can be recovered.

The sludge tank, shown in detail in figure 54, will collect residues from the dust-train equipment in particular the residues from the spray washer, fogging chamber, and Cottrell precipitator. The tank is arranged to allow for settling out of the heavier materials and for filtering the overflow water through bag filters. With this equipment, all residues will be collected during any test run, and accurate material balances obtained.

The spray washer is followed by a Cottrell precipitator, which is a standard unit built for experimental purposes and has four tubes each 8 feet long and 8 inches in diamter. The unit will be adapted for wet operation and provision will be made for fogging water into the inlet gas if needed to improve the dust removal. It is also intended to make trials of the unit operating dry; that is, on gas saturated at 90° to 100°F.

A Sutorbilt exhauster will be included in the train before the Cottrell precipitator so that the gas generator may be operated at zero gage pressure, or slightly above, and the Cottrell under positive pressure at all times. Operation of the present generator has shown this procedure to be advisable. With the inevitable minor fluctuations which occur in reactant feed rates, the operation of both the coal feeder and Royster pebble stoves is improved if a positive control of the generator pressure can be maintained. Also on the reversal of the stoves, the surge can be minimized by having such control. A standard Askania unit will be used for the control.

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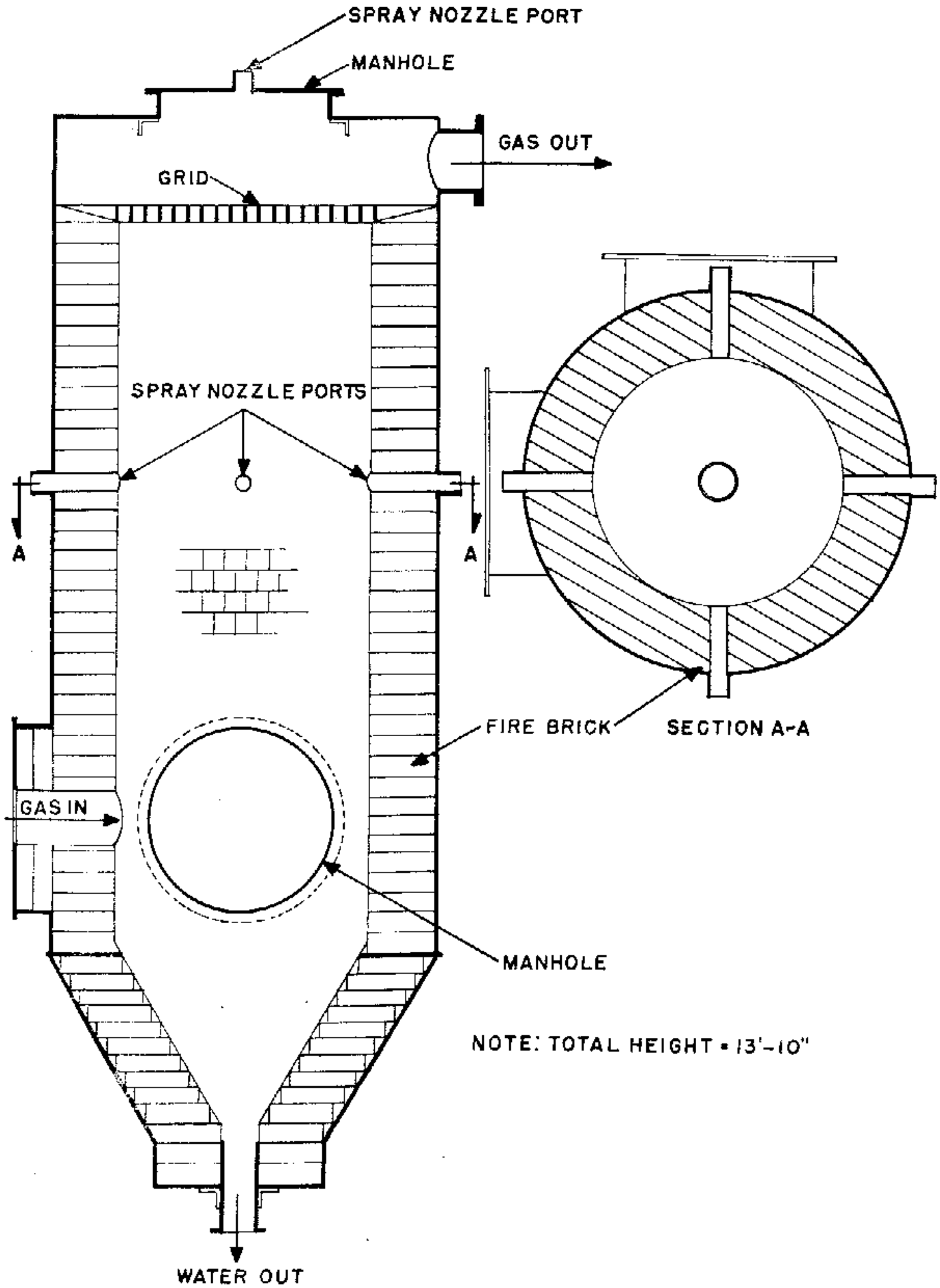
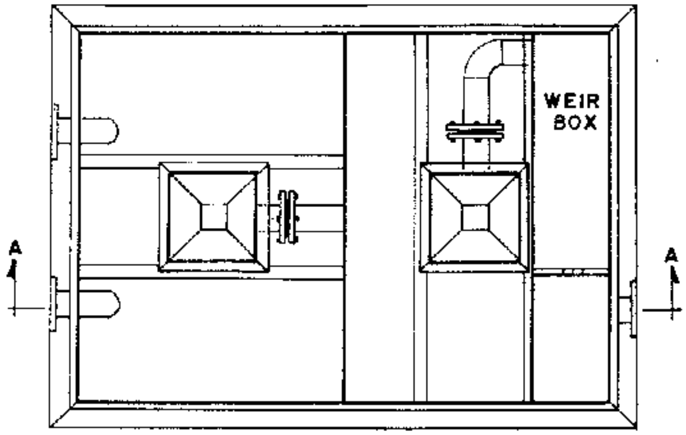
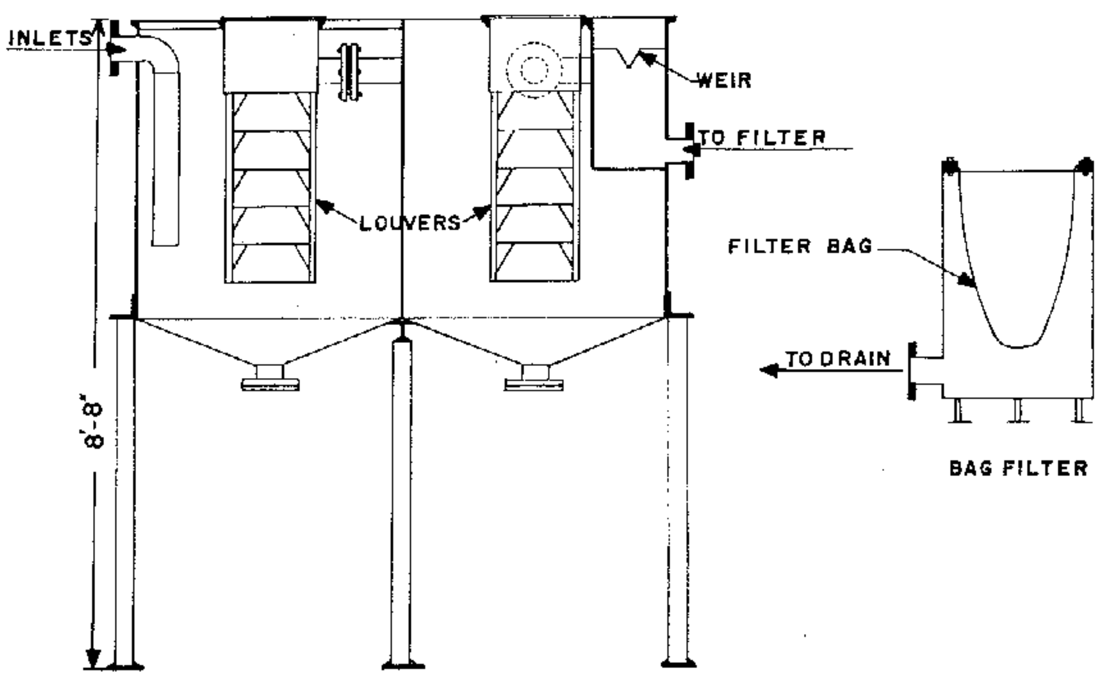


Figure 53. - Construction detail of fogging chamber.



TOP VIEW



SECTION A-A

Figure 54. - Construction detail of sludge-collecting tank.

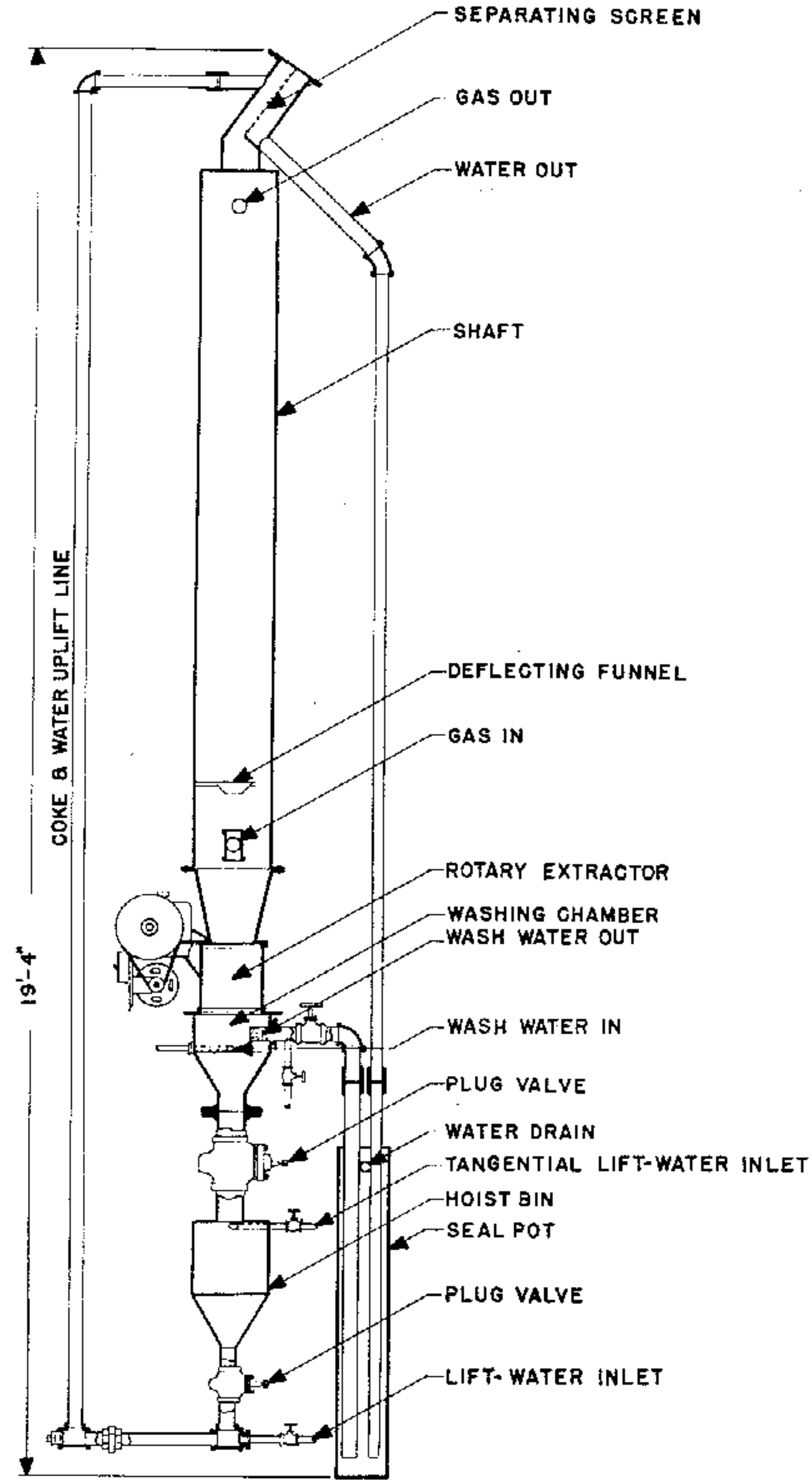


Figure 55. - Construction detail of moving-bed coke filter.

Previous work[22] has shown that an experimental coke filter for removing very fine dusts entrained in air has very high efficiencies and probably economical operation. This unit will be modified for use in the pilot plant (see fig. 55) and will be tested as a substitute for the Cottrell precipitator and also as a final clean-up device following the Cottrell to determine its best application.

The coke filter consists of a steel shell 1 foot diameter by 12 feet over-all height. The active filter bed height is 8 feet 8 inches and the unit will be filled with coke particles of 0.125- to 0.375-inch diameter and having an apparent specific gravity greater than that of water. The coke will be moved down by a rotary feeder to the washing hopper. After washing, the coke will be elevated in a water stream to the top of the unit, sent over a screen to remove excess water, and then reintroduced into the bed. Provision will be made for measuring the amounts of wash and elevating water required.

After final cleaning, the gas will be metered through a standard Roots-Connersville-type meter and sent through seal pots to the holder or to the flaring stack. The seal pots, or automatic back-pressure valves, are provided to prevent any back flows from the holder or air flow into the dust train. Auxiliary metering equipment will consist of standard orifice type flow meters.

Projected Experimental Work

Since the results on coal ground to 90 percent through 200-mesh indicated that all except the very fine coal particles may have been driven to the generator wall and held in the slag until gasified, it appears probable that coarser coal will give equally high carbon gasification. Coal gasification tests on a coarser sample of Sewickley bed coal are planned to determine experimentally the effect of a larger coal size on gasification efficiency. Coal-feeder calibration tests have been made on such a sample, prepared by passing unground coal through a hammer mill so that the largest particles just pass through 10-mesh. The use of a sample of this size consist, with the resultant elimination of ball-mill pulverization, would reduce significantly the cost of coal preparation in a large scale plant.

Pulverized coal may also be gasified by a mixture of air and steam which has been superheated to a high temperature, for example, in the Royster pebble stove. By this means, an alternative process of making synthesis gas is presented. This method may also be used to make from pulverized coal a high-B.t.u. producer gas or a gas for the synthesis of ammonia. Theoretical calculations have shown that the hydrogen plus carbon monoxide:nitrogen ratio may be varied over a wide range and that the ratio of 3, desired for ammonia synthesis may be easily obtained. It is planned to make runs using mixtures of air and steam superheated in the Royster pebble stove to test operation of the generator for coal gasification by this process.

22/ Egleson, G. C., The Design and Operation of a Moving Bed Filter for the Removal of Dust from Gases: Submitted for Master of Science Degree in the Department of Chemical Engineering, West Virginia University, 1949.