SUMMARY AND CONCLUSIONS

In the first phases of this process-development work, major emphasis was directed toward obtaining an operable pilot plant. Early problems included steady feeding of pulverized coal, preheating of oxygen, steam, and coal, securing proper flow of slag without excessive refractory erosion, and lowering the material requirements per 1,000 cu. ft. of carbon monoxide and hydrogen produced. Twenty-two preliminary and test runs have been made on strongly coking Sewickley-bed coal at feed rates of 200 to 750 pounds of coal per hour and at gasifier pressures of 100 to 300 p.s.i.g. This investigation has progressed to the point where it has been indicated that surprisingly large throughputs will be secured with low materials requirements per 1,000 cu. ft. of CO + H_2 produced. The average results for the test runs at 100, 250, and 300 p.s.i.g. gasifier pressures and steam-coal ratios of 0.3 pound per pound are given in the following tabulation:

Pressure-capacity relationships and reactant requirements for test runs at 100, 250, and 300 p.s.i.g. gasifier pressures

Gasifier static pressure, p.s.i.g.	Coal throughput, lb./(hr.)(cu.ft. gasifier volume)	(CO + H_2) output, std.c.f./(hr.)(cu. ft. gasifier volume)	Requirements per 1,000 std.c.f. of (CO + H_2) produced		
			Coal, lb.	Oxygen std.c.f.	Steam, lb.
100.....	125	3,300	37	345	11.5
250.....	425	11,000	39	350	11.0
300.....	485	13,500	36	350	10.5

After elimination of initial difficulties, the plant has operated very well. There are no indications of mechanical or operational problems that cannot be solved by using adaptations of present well-known practices. Because of limitations imposed by the capacity of the present coal-feeding and inert-gas-compression equipment, individual test runs have lasted 10 hours or less; however, the condition of the refractory lining and the close temperature control possible have shown that longer runs can be made when the above limitations are removed. No special problems in gas purification have been encountered. Constructional details are briefly described, and the demands peculiar to gasification under pressure as regards safe operating practices and materials for constructing equipment are discussed.

This process is interesting to the gas industry because it provides a raw material for producing synthetic pipeline gas. The heat loss through the gasifier walls per unit of fuel input can be expected to be very low - in fact, almost negligible - in larger units. This may make possible the use of water-cooled refractory linings or even of bare water-cooled interior walls, with a reduction in maintenance cost of gasifier lining refractory to a very low value.

INTRODUCTION

The Bureau of Mines, U. S. Department of the Interior, at its Morgantown, W. Va., Station, operating under a cooperative agreement with West Virginia University, is conducting research and development on production of low-cost synthesis gas directly from raw coal. This synthesis gas, consisting essentially of carbon monoxide and hydrogen, can be converted by well-known procedures into gasoline, oil, pipeline gas, ammonia, alcohol, etc. For all such uses, the synthesis-gas mixture is required at pressures of 400 p.s.i.g. or higher. The power required to compress the synthesis-gas mixtures to 400 p.s.i.g. is one of the largest single cost items. Generation of the gas under pressure greatly reduces this cost by cutting the gas volumes to be compressed by two-thirds, because in this case only the oxygen needs to be compressed.

The work described in this report covers some of the experimental results of operating a pilot plant designed for gasifying pulverized coal, using oxygen and steam, at pressures up to 450 p.s.i.g. This plant has been described in detail in a previous report.4/ This report, giving some preliminary results in the pressure range 100 to 300 p.s.i.g., will deal more particularly with operational problems and reactand requirements.

The material presented here was given in a paper at the May 1952 meeting of the American Gas Association Operating Section. Certain minor revisions have been made to the text of that paper in this report.

ACKNOWLEDGMENTS

This investigation was conducted by the Synthesis Gas Branch of the Synthetic Liquid Fuels Branch, Bureau of Mines, Morgantown, W. Va., in cooperation with West Virginia University, under the general direction of J. D. Doherty, acting chief of the Synthetic Liquid Fuels Branch, Bureau of Mines, Washington, D. C. The authors wish to acknowledge the assistance and cooperation received from P. R. Grossman, N. W. Eft, and J. A. Danko of the Babcock & Wilcox Co. Under the terms of a cooperative agreement, that company participated in the Bureau's development program on pressure gasification and maintained a resident engineer to facilitate the collaboration. The main equipment items were designed, fabricated by, and purchased from this company. The operation of the plant has proceeded well and safely owing to the excellent cooperation of all the personnel of the local branch.

THEORETICAL AND ECONOMIC CONSIDERATIONS THAT MAKE HIGH-PRESSURE GASIFICATION ATTRACTIVE

In the synthesis processes using mixtures of CO and H_2, or of CO, H_2, and N_2, the catalytic equipment generally is operated at pressures of 400 p.s.i.g. or higher. If the gas is made at the pressures normally used in making blue gas from coke - 1 to 2 p.s.i.g. - the horsepower requirement and resultant compression cost of raising the product gas to the synthesis pressure is considerable.5/6/ This is shown by figure 1, which relates the pressure and horsepower requirements for various processes when the gas is compressed from atmospheric pressure to the process pressure. Generating the gas at pressure allows the compression costs to be reduced by about two-thirds. In

4/ McGee, J. P., Schmidt, L. D., Danko, J. A., and Pears, C. D., Pressure-Gasification Pilot Plant Designed for Pulverized Coal and Oxygen at 30 Atmospheres: Pres. before Am. Inst. Min. and Met. Eng., New York, N. Y., Feb. 20, 1952: Gasification and Liquefaction of Coal, Am. Inst. Min. and Met. Eng., New York, 1953, pp. 80-108.

5/ See footnote 4.

6/ Batchelder, H. R., Dressler, R. G., Tenney, R. F., Skinner, L. C., and Hirst, L. L., The Role of Oxygen in the Production of Synthetic Liquid Fuels from Coal: Bureau of Mines Rept. of Investigations 4775, 1951, pp. 8-13.

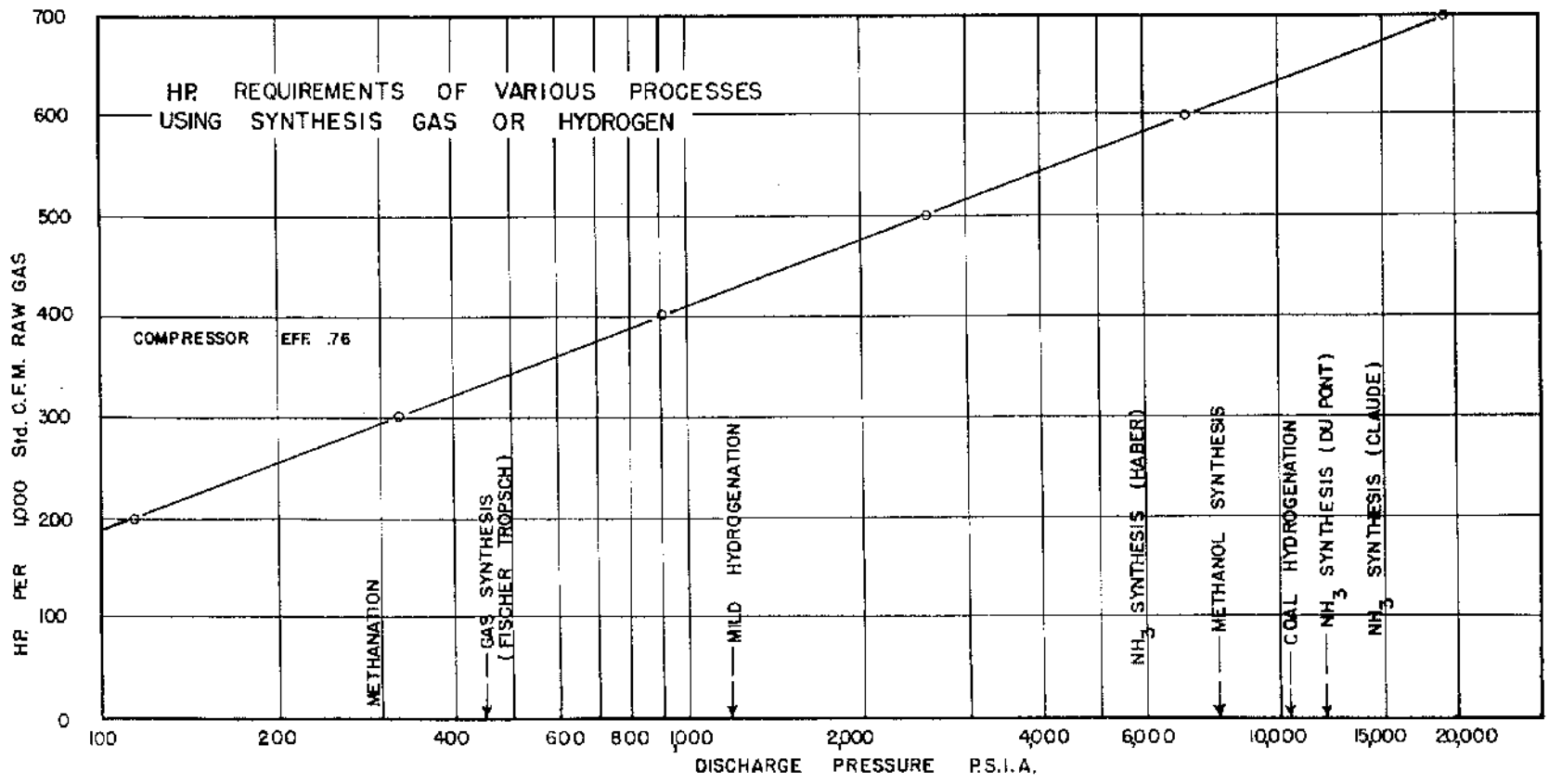

Figure 1. - Horsepower requirements of various processes using synthesis gas or hydrogen (when the gas is compressed from atmospheric pressure to the process pressure).

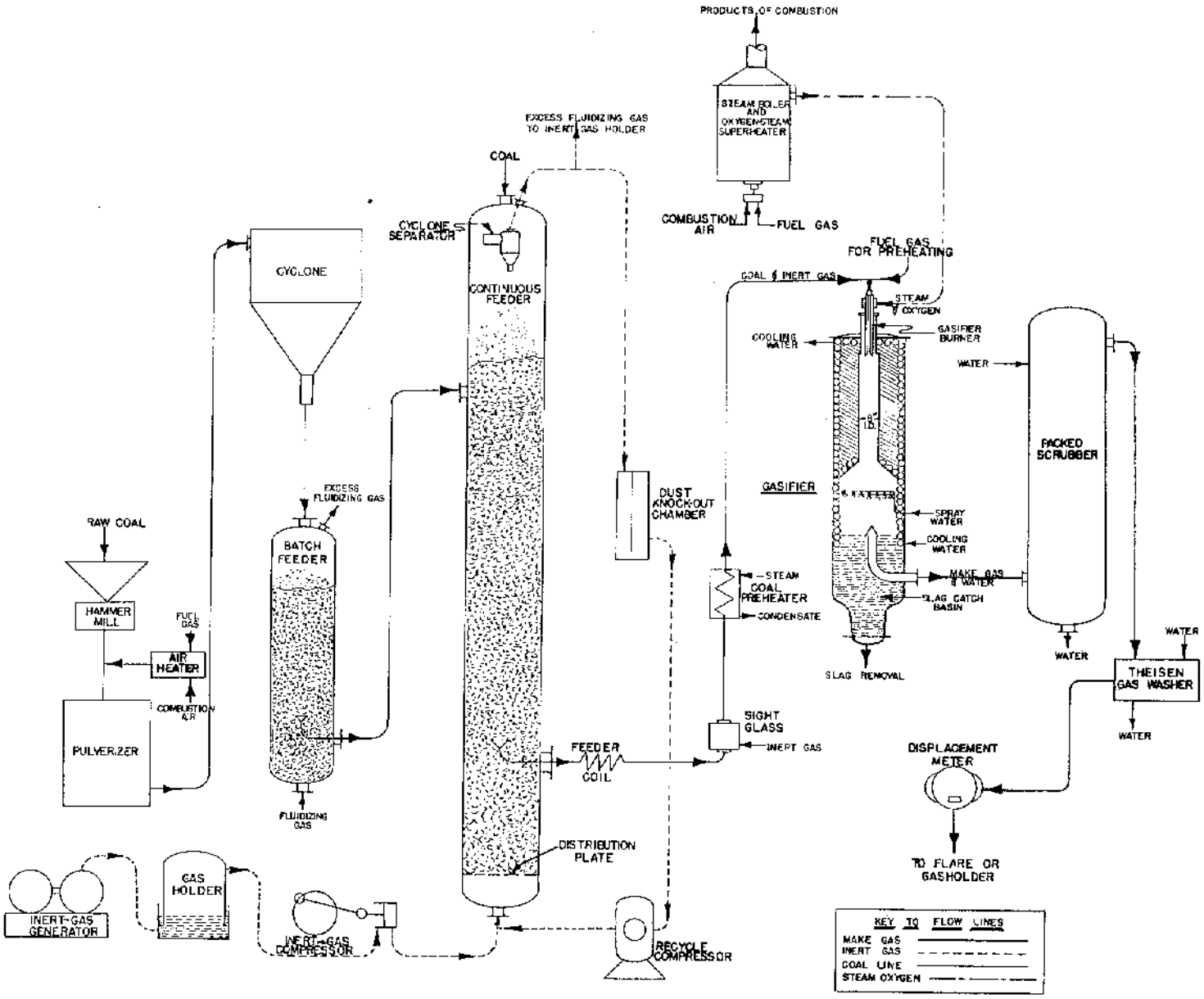

Figure 2 - Pilot-plant flowsheet for pressure gasification.

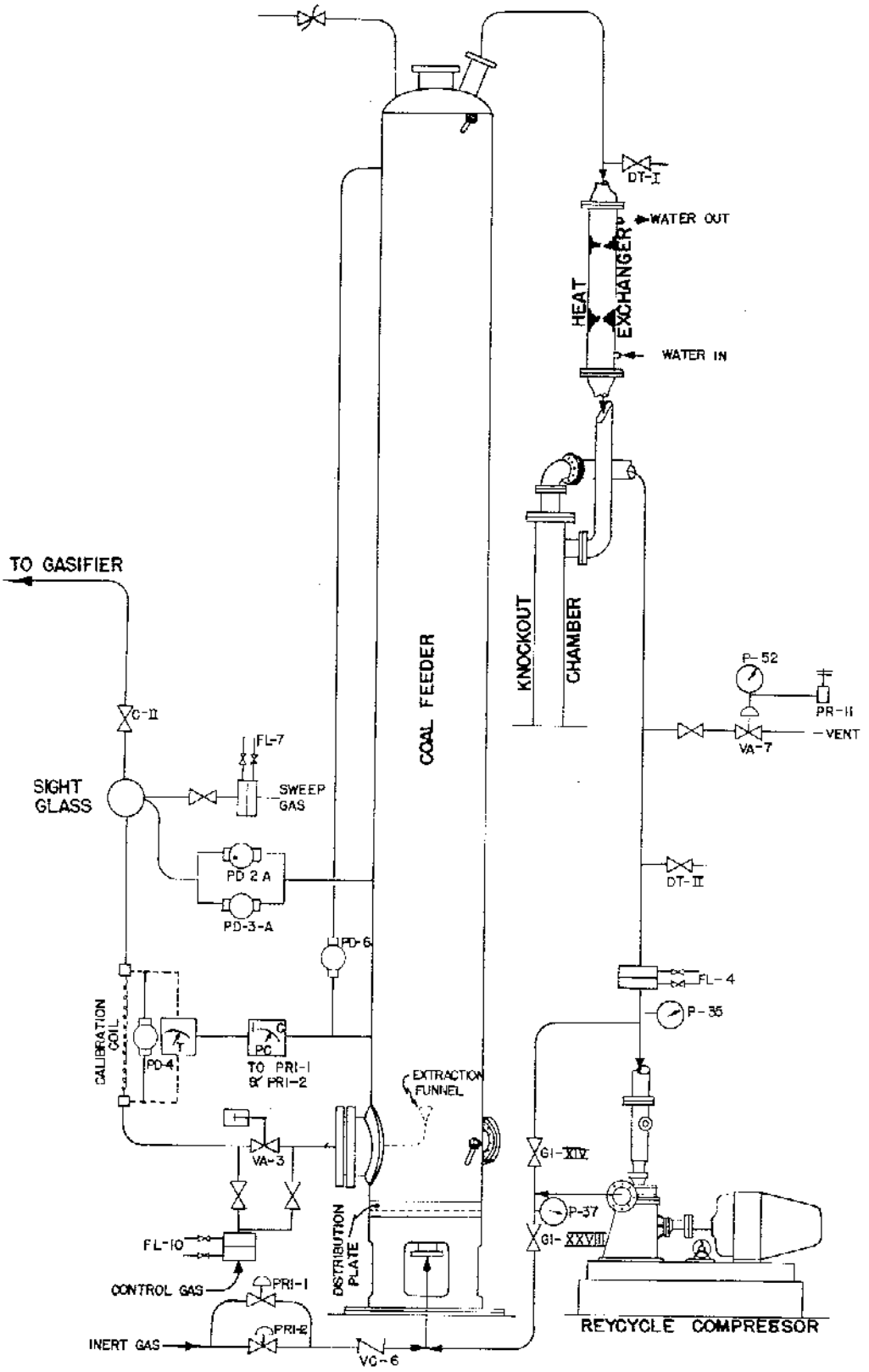

Figure 3. - Coal-feeder instrumentation flowsheet.

producing liquid fuels, particularly where the Fischer-Tropsch process is used, further compression of the synthesis gases would not be needed. Also, for those processes using mild hydrogenation of coal to produce aromatic chemicals,7/ the savings in compression costs are considerable.

In the gas-utility field it is presumed that this process will have application, at some future date, as a source of gas to supplement or eventually replace present pipeline supplies.8/ To avoid expensive changes in present distribution systems, any such gas used would be at pressures in the 300 to 500 p.s.i.g. range or possibly higher. Although various means will be available for enriching this base gas, it is apparent that the initial generation under pressure offers considerable economy.9/

From the work that has been done to date, it is evident that the capacities of the high-pressure gas-making equipment of the type described here will be very high. The preliminary tests at 300 p.s.i.g. have indicated that, at 450 p.s.i.g., throughputs of over 750 pound of coal per hour per cubic foot of gasifier volume should be attained. Consequently, it is very probable that considerable savings may be achieved in cost of equipment and housing. Present-day water-gas generators, auxiliary equipment not included, for producing about 60,000,000 cubic feet of $CO + H_2$ per day would require about 28,000 cu. ft. of inside volume. Assuming 30 cu. ft. of $CO + H_2$ yield per pound of coal, equivalent production capacity at 300 p.s.i.g. will require about 165 cu. ft. of reactor volume and much less at 450 p.s.i.g.

From the standpoint of the operator, another advantage is inherent in this approach to the problem; that is, the process appears to have no limitations as to the kind of coal used. No elaborate preparation of the coal is needed, such as may be required by most of our coals if used in a fixed-bed high-pressure gasification process. It is also probable that no complicated purification equipment will be needed, since similar gases have been successfully purified under pressure. This work has been done at the Morgantown Branch and at the Louisiana, Mo., Demonstration Plant.10/

Whatever the end use for the gas produced, the process appears to have a flexibility and an economy that should make it attractive to gas utilities, chemical companies, and future producers of synthetic liquid fuels.

DESCRIPTION OF PILOT PLANT

Since the original unit was constructed, changes have been made in the method of introducing and preheating the reactants, and minor changes in the gasifier and coal-feeding system make extended test runs possible.

The flowsheet (fig. 2) shows the pilot plant as it was being operated in March 1952. The apparatus for continuous feeding of coal under pressure is shown in detail in figure 3 and described later under Coal-Feeding Equipment.

Coal ground so that 90 percent will pass a 200-mesh screen (largest particle size, about 0.015 inch) is fluidized in the coal feeder, using inert gas consisting of CO_2 and N_2. The fluidized coal is fed through a 1/2-inch line to a preheater, where its temperature is raised to about 325° F.

7/ Callahan, J. R., Coal-Hydrogenation Process Unlocks Vast Aromatics Field: Chem. Eng., vol. 59, No. 6, June 1952, pp. 152-158.

8/ Hess, F. O., Wanted: Courage and Research to Live Up to the Future of Gas: Gas Age, vol. 108, No. 11, Nov. 22, 1951, pp. 33, 60, 62, 64 and 66.

9/ Breck, C. R., Pipeline Gas from Coal: Gas Age, vol. 109, No. 7, Mar. 27, 1952, page 40.

10/ Kastens, M. L., Hirst, L. L., and Dressler, R. G., An American Fischer-Tropsch Plant: Ind. Eng. Chem., vol. 44, No. 3, March 1952, p. 455.

The coal stream entering the top of the gasifier is broken up by high-velocity jets of the steam-oxygen mixture. The nozzle used for this is shown in figure 4.

The original gasifier design is shown in figure 5, and the gasifier as it is now used is shown in detail in figure 6. The shell, designed for working pressures of 900 p.s.i.g. at 650° F., is entirely protected in the hot zone by a water-cooled coil. Since it is always possible in an experimental apparatus that operating conditions will not be under continuous, exact control, the water cooling protects the steel shell against hot spots that might occur if the refractory burned through.

The original design (fig. 5) used horizontal, tangential injection of the three reactants - steam, coal, and oxygen - through individual nozzles. Because of the direct impingement on the refractory of the oxygen and coal, the original lining was burned out in a few runs, necessitating the rearrangement shown in figure 6. For preheating the gasifier (fig. 5), a natural-gas burner was inserted at the top as indicated. The rupture disk shown is protected from dirt by a loose filling of mineral wool in the pipe leading to it.

The first few runs indicated that the cooling action of the support coil (fig. 5) was excessive; the slag formed congealed in the throat (just above the support coil) and closed it off. Consequently, the four inner turns of the coil were removed (fig. 6), and slag tapping became possible.

The original lining was a Carbofrax silicon carbide tube, 12 inches i.d., 1 inch in wall thickness, backed up with Alfrax No. 27, electrically fused, aluminum oxide insulating cement. This was burned through as mentioned. A new lining was put in of 12 inches i.d., using B. & W. No. 80 firebrick 4-1/2 inches thick backed up by Alfrax cement as before. The reactant nozzle openings were closed off, one now being used as an observation port, and a new nozzle for vertical injection of all the reactants was designed. This nozzle (fig. 4) also serves as a preheating burner.

Owing to the high heat release near the nozzle, the upper refractory lining was eroded rapidly, and the combined molten refractory and slag solidified in the lower part. The bottom opening stabilized at about 5 inches diameter. Figure 7 shows the shape of the refractory lining after test run P-14. The runs made at 100 p.s.i.g. showed that the gasifier output at the interior volume then existing - about 4.3 cu. ft. - would be too great at the higher pressures for the capacity of the available auxiliary equipment.

Consequently, a third lining was put in, reducing the volume to 1.45 cu. ft., with an inside diameter of 8 inches. This lining was made of two rows of Carbofrax brick, and insulating cement were not used. All test runs after P-14, at 250 and 300 p.s.i.g., were made with the gasifier thus relined. Figure 8 shows the shape of the lining after run P-19, and figure 9 shows the shape after run P-22.

The volume of the refractory lined space shown in figures 8 and 9, approximately 1.45 cu. ft., was maintained with only small variations (less than 5 percent) for the heatup and gasification periods of runs P-15 through P-22, a total of over 80 hours at operating temperature. Most change in shape took place during the first 2 or 3 runs and consisted in refractory erosion in the upper portion and slag deposition in the lower portion of the gasifier. After that time the shape remained relatively constant, indicating that slag erosion could be controlled.

The product gas, ash, slag, and any unreacted carbon leave the refractory-lined throat and are sprayed with water. About half of the ash and part of the carbon drop into the water-filled space in the gasifier bottom and then into the slag pot. Periodically this pot is shut off from the gasifier, and the slag and water are blown out.

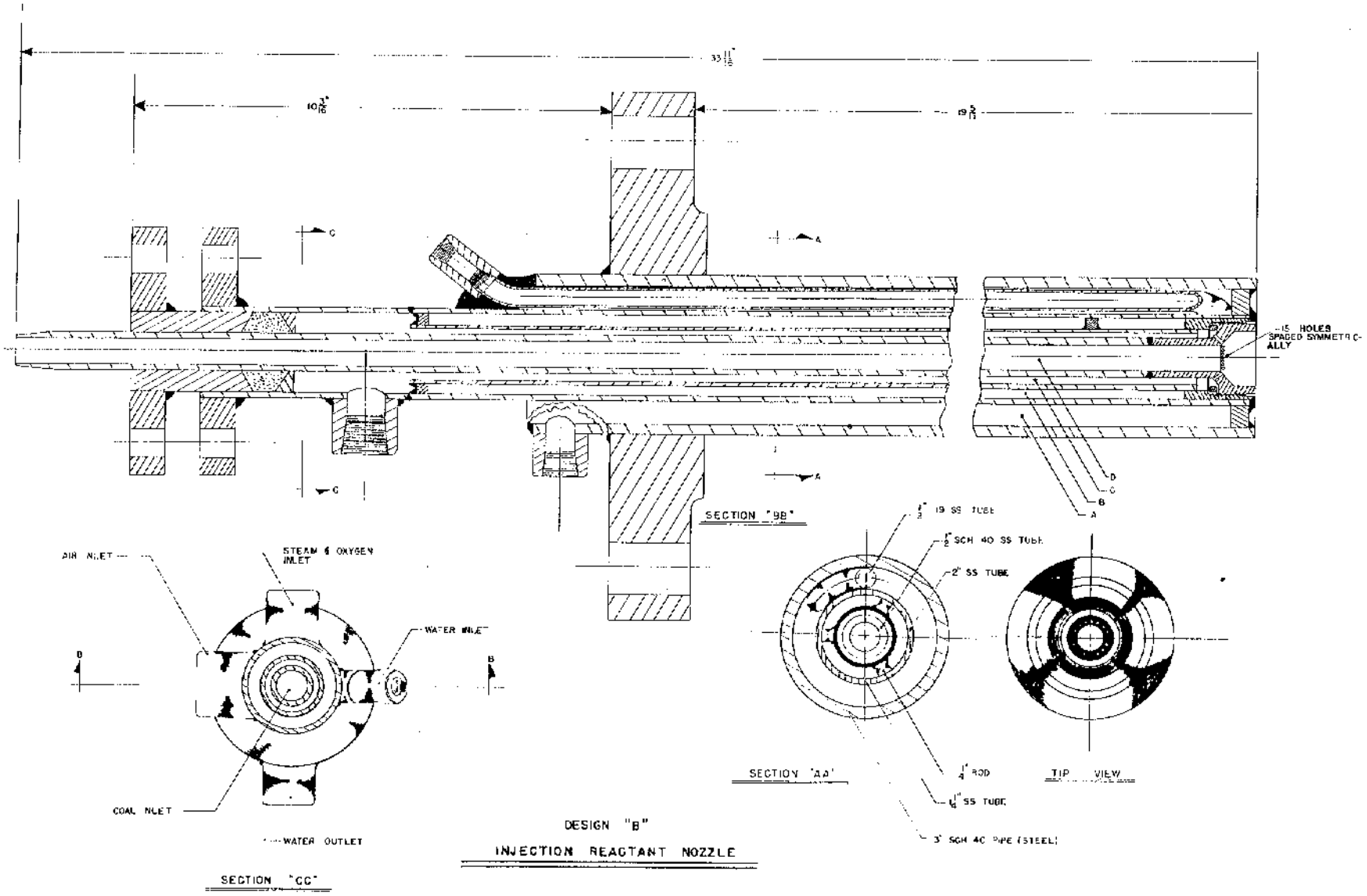

Figure 4. - Reactant injection nozzle, design "B" (used also as heat-up burner).

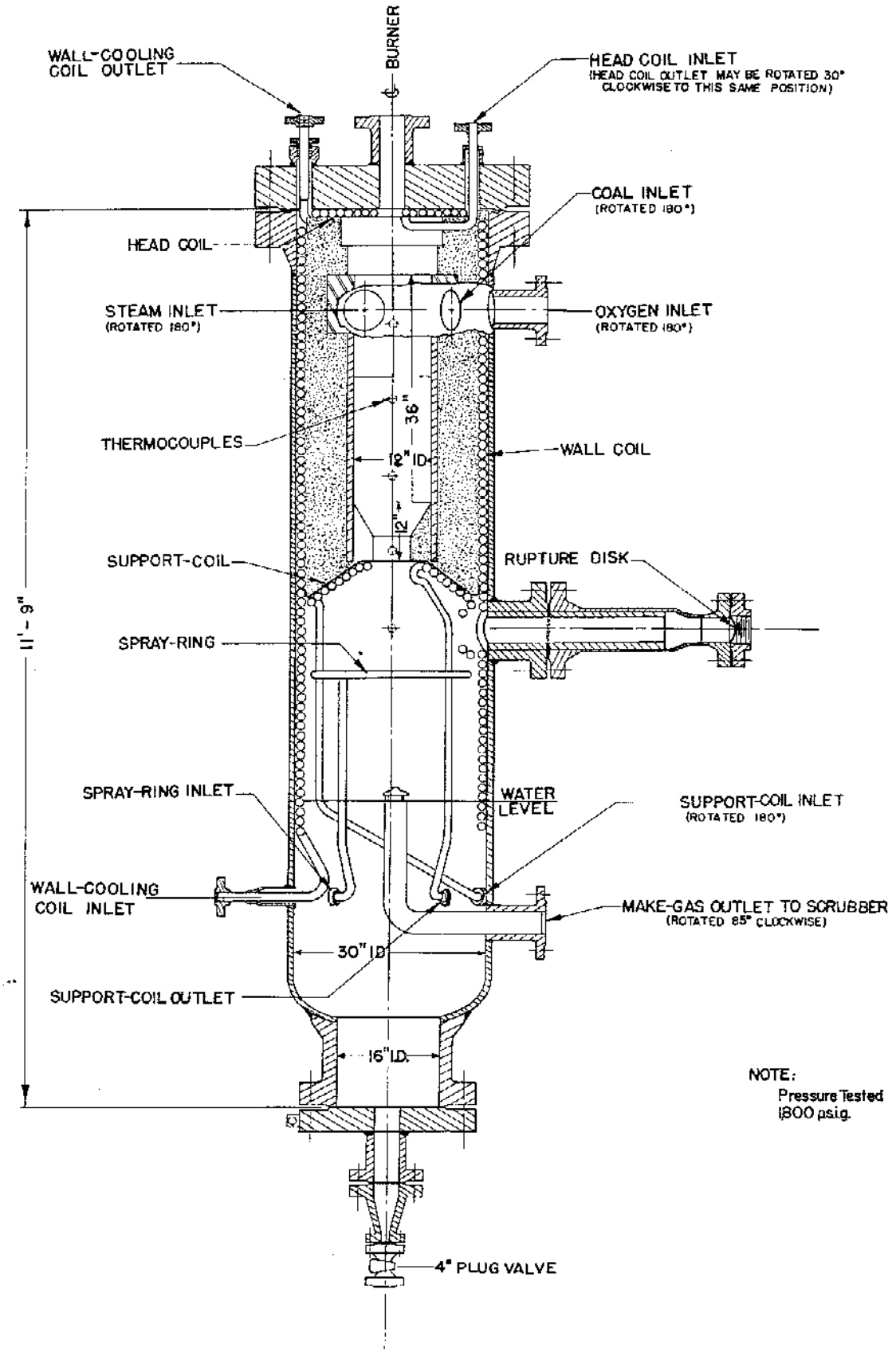

Figure 5. - Reactor for pressure gasification (as originally installed).

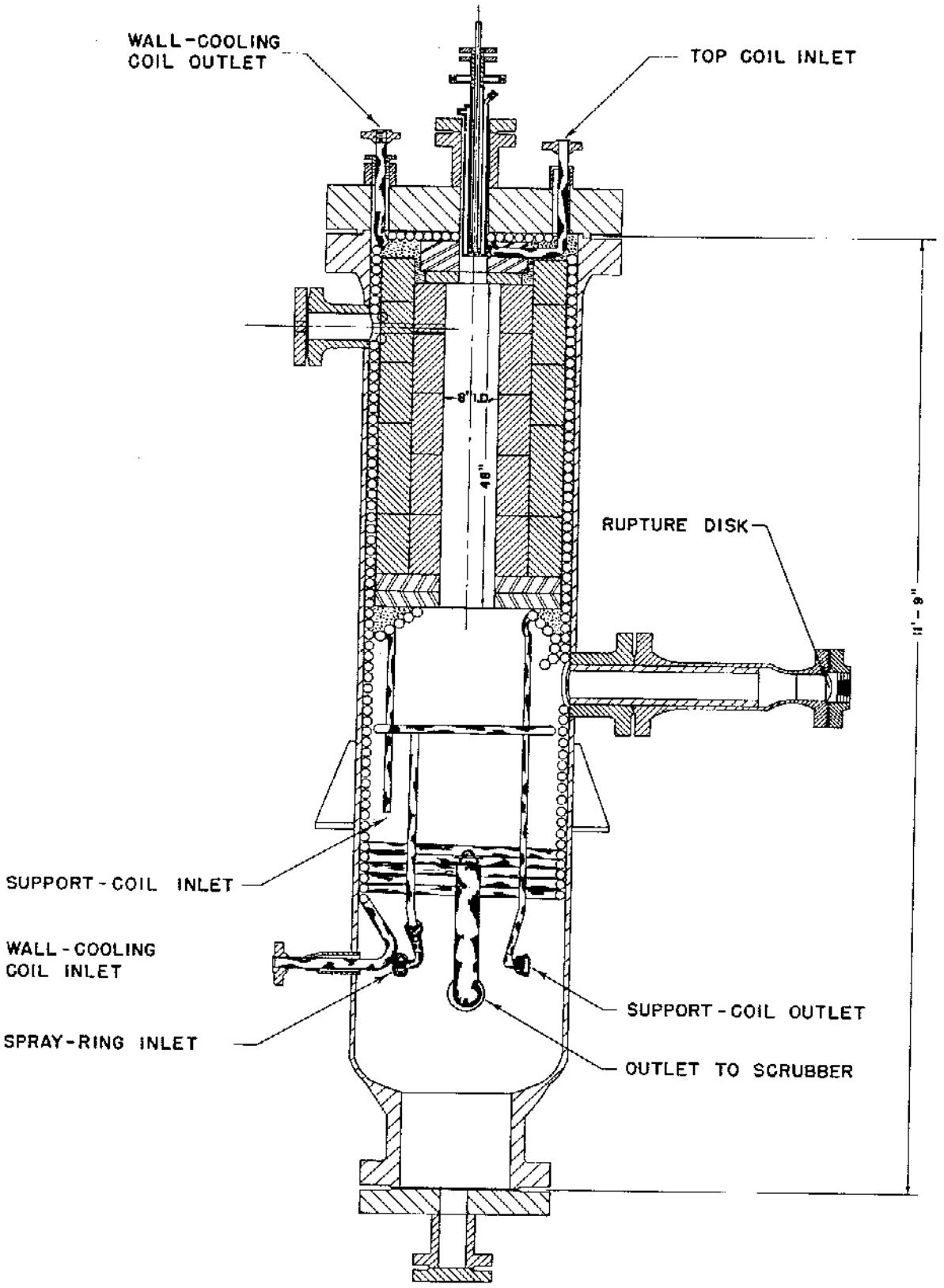

Figure 6. - Reactor for pressure gasification (as modified following run P-14).

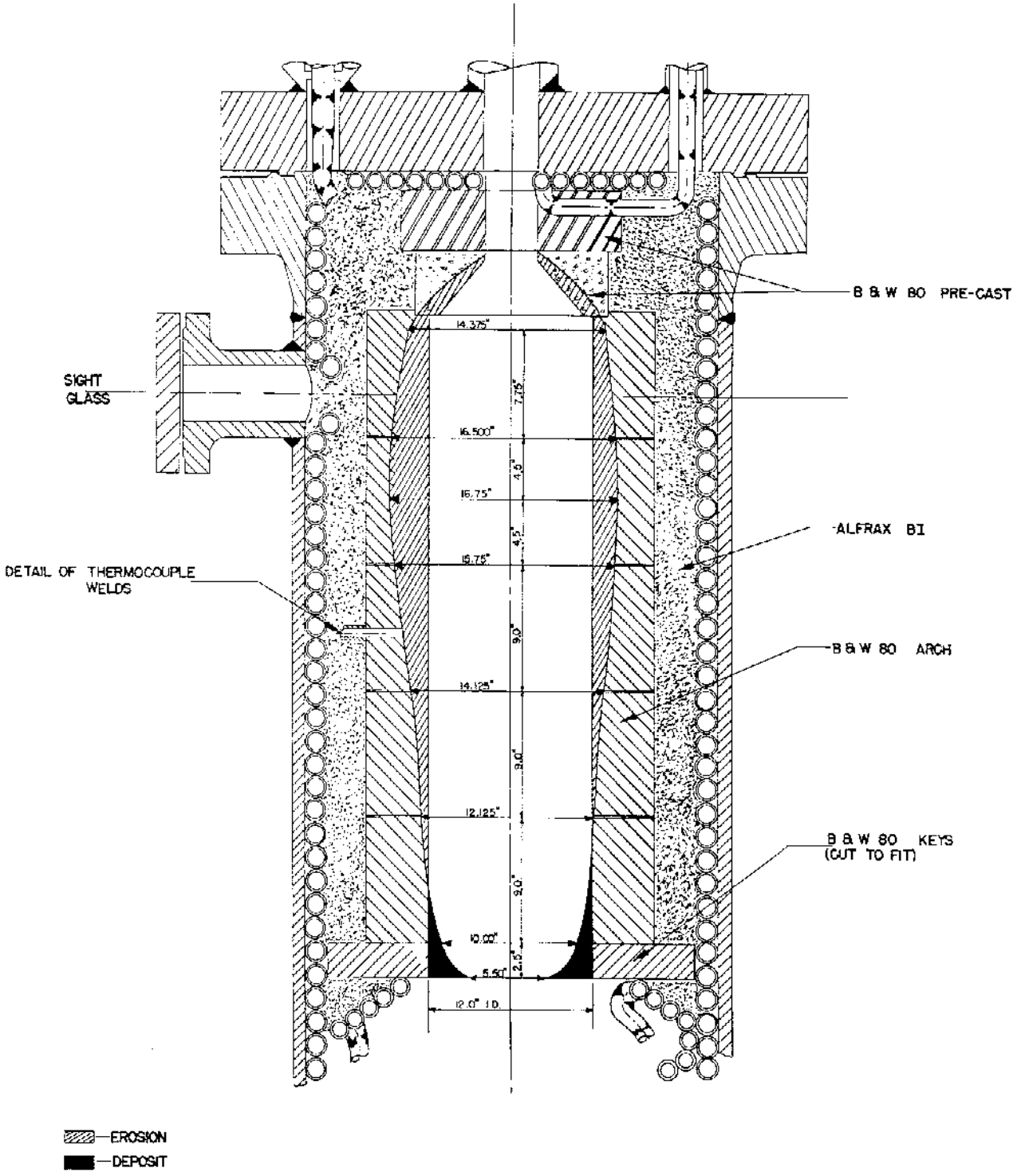

Figure 7. - Cross-section view of pressure gasifier, showing refractory condition after run P-14.

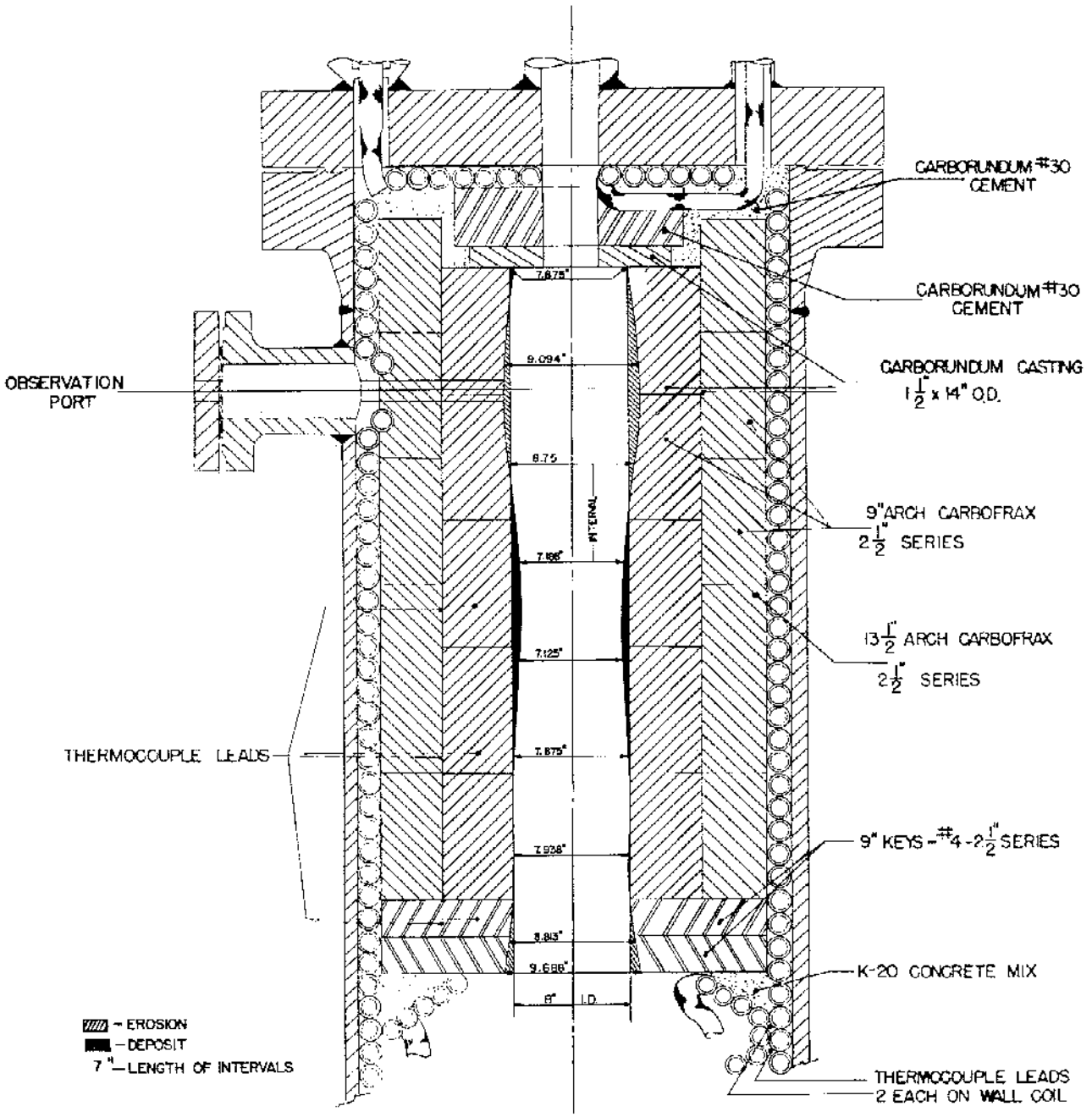

Figure 8. - Cross-section view of pressure gasifier, showing refractory condition after run P-19.

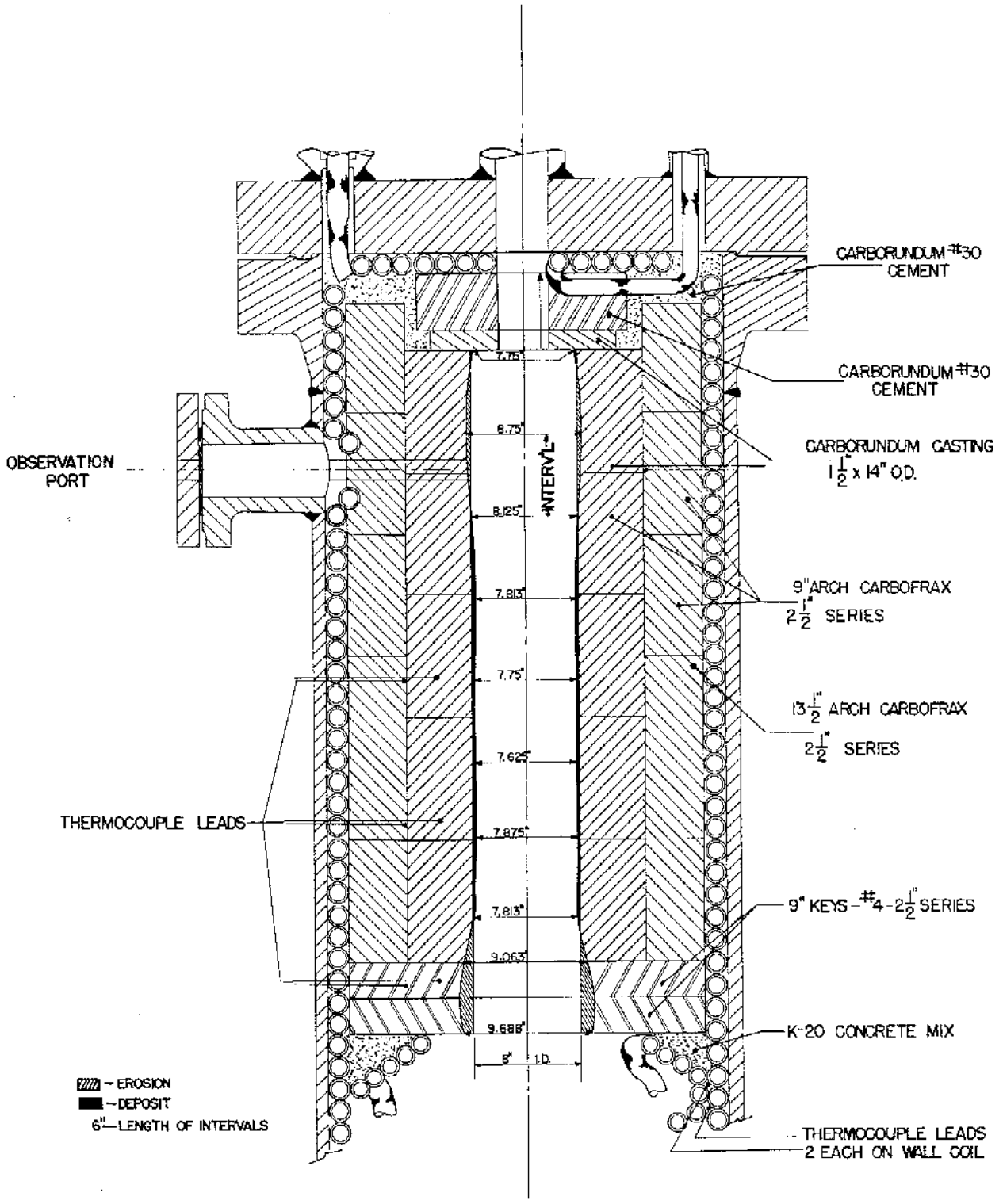

Figure 9. - Cross-section view of pressure gasifier, showing refractory condition after run P-22.

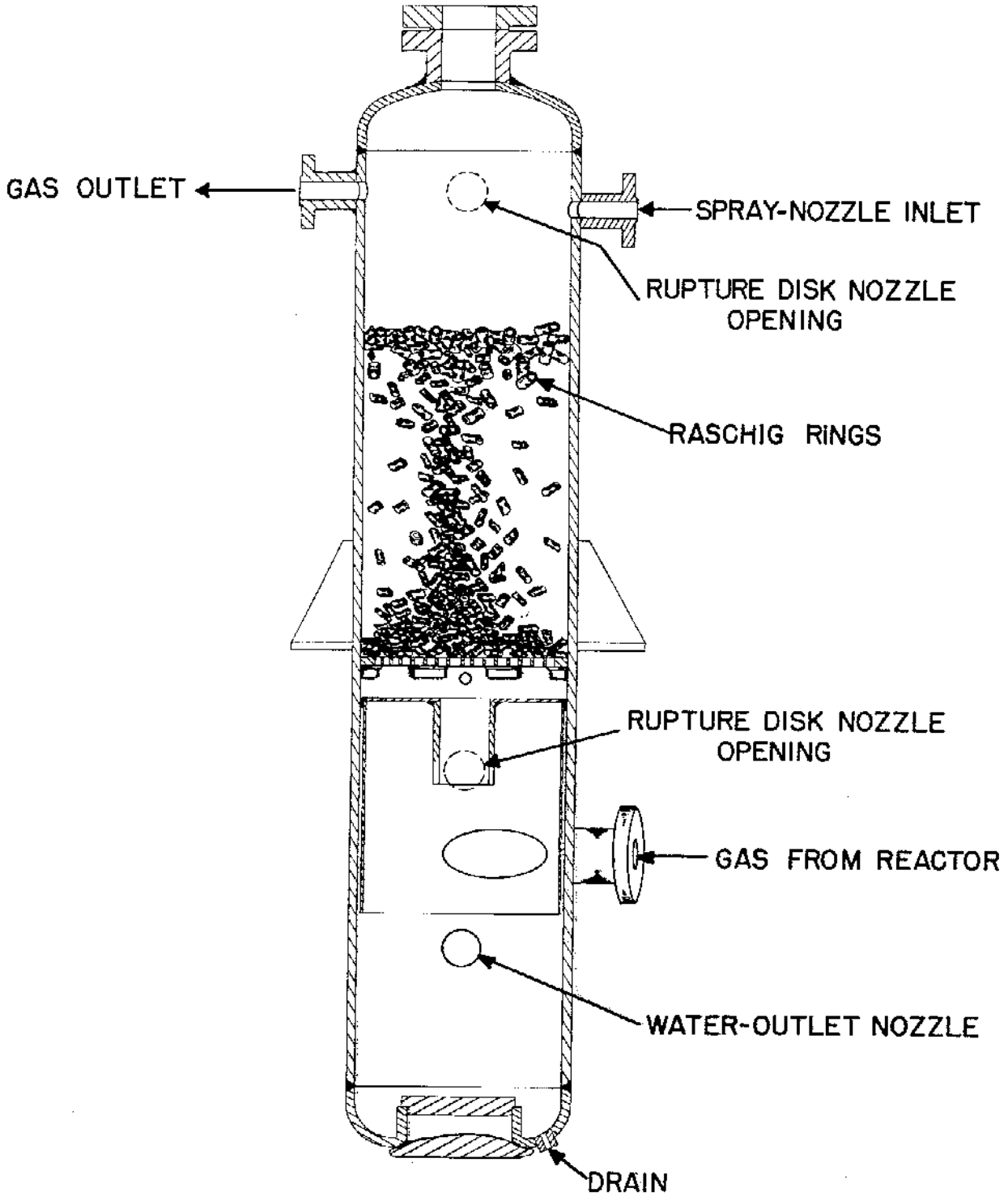

Figure 10. - Scrubber for pressure-gasification pilot plant.

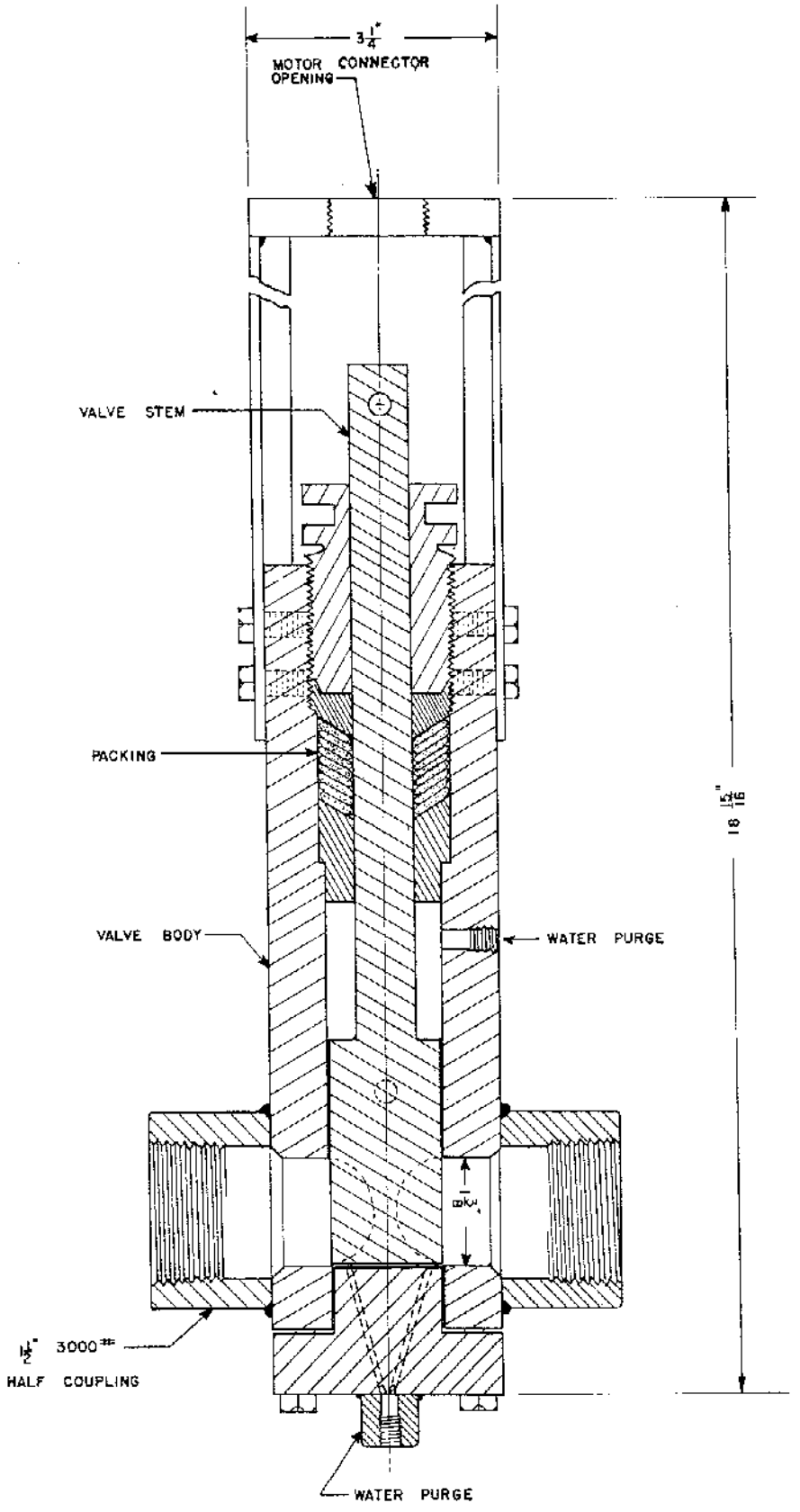

Figure 11. - High-pressure water letdown valve.

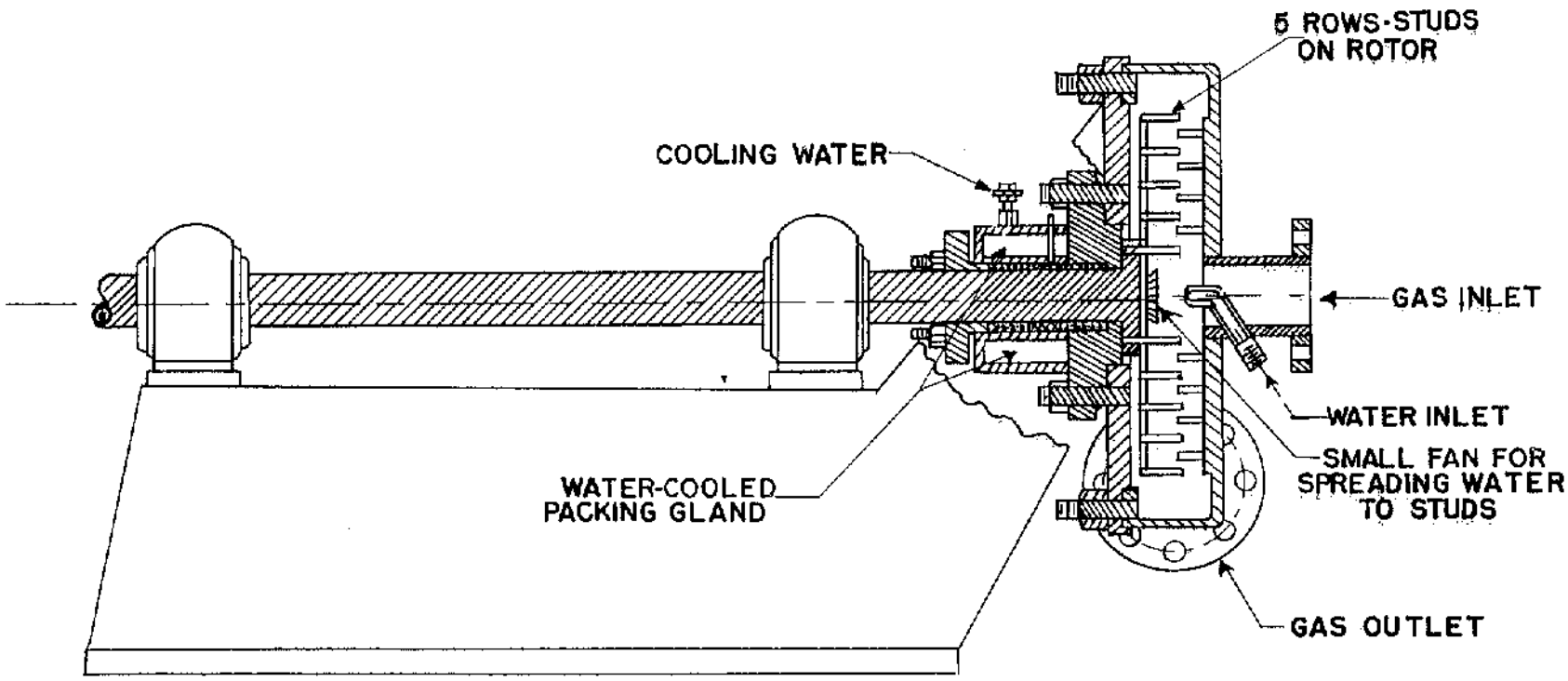

Figure 12 - Theisen gas washer, disintegrator type.