heater coil. As soon as satisfactory operation is attained, the slurry-feeding system will be used to supply the steam-coal mixture for the high-pressure gasifier.

The steam-pickup equipment will be installed in 1955 and experimental work begun as soon as possible. Although preliminary estimates show that this method of coal feeding is promising costwise, an extensive program of equipment development will be needed to obtain a satisfactory device to feed coal into the pressurized hopper.

The pneumatic feeder is now the most practical known way of feeding coal to pressure gasifiers for experimental purposes. There are several inherent weaknesses of the system, however. Internal disturbances prevent good control of feed rate, and frequent refilling is necessary. Also, an excessive amount of coal dust is carried over from the feeder into the fluidizing gas-recycle line. Experimental work on a "two-zone feeder" is unde way (see fig. 26). By providing lower fluidizing gas velocities in the space outside the 13-inch tube, coal-dust carryover is reduced and the total feedable coal charge increased from 2,500 pounds to 4,000. To obtain better control of the feed rate, the entire feeder as now installed is supported on two Monsell pneumatic weight transmitters. Additional work will be done, in connection with the high-pressure-gasification tests, on improving the two-zone feeder. Coincidental with the work done on the pneumatic coal feeder, some data have been obtained on the flow characteristics of luidized coal in long lines. Preliminary studies have indicated that this method of coal transport may be feasible in some cases.

Oxygen Plant and Coal-Preparation Facilities

The oxygen plant described in the 1952 annual report has been moved to the new station and placed in operation (see fig. 27). Additional high-pressure storage is contemplated so that longer runs can be made with the high-pressure gasifier.

All compressing facilities to supply air, inert gas, natural gas, and synthesis gas have been combined in one building. Figure 28 shows some of the compressors.

The coal-preparation plant has been expanded and improved. In addition to the equipment shown in figure 14, a coal drier was provided to prepare lower rank coals for test use. Additional storage hoppers are being installed so that large batches of coal of uniform composition can be prepared. Figure 29 shows part of the coal-preparation facilities.

Gas Purification

Analytical Methods

Crude synthesis gas made from pulverized coal instead of coke contains a high concentration of dust. Thus, dust determination and removal are important. In previous years a method was developed for determining the dust and moisture concentration in hot, crude synthesis gas containing a high concentration of solids. Methods also were developed for determining gravimetrically the dust concentration in highly purified gas or atmospheric air by accurate weighing procedures and large-area filters. Attention then was turned to particle-size determination, and a method has been developed for obtaining a uniform dry dust dispersion across a microscope slide. The standard deviation is only 2 percent. This makes it possible to determine accurately the particle-size distribution in a dry state after all agglomerates are dispersed by a liquid.

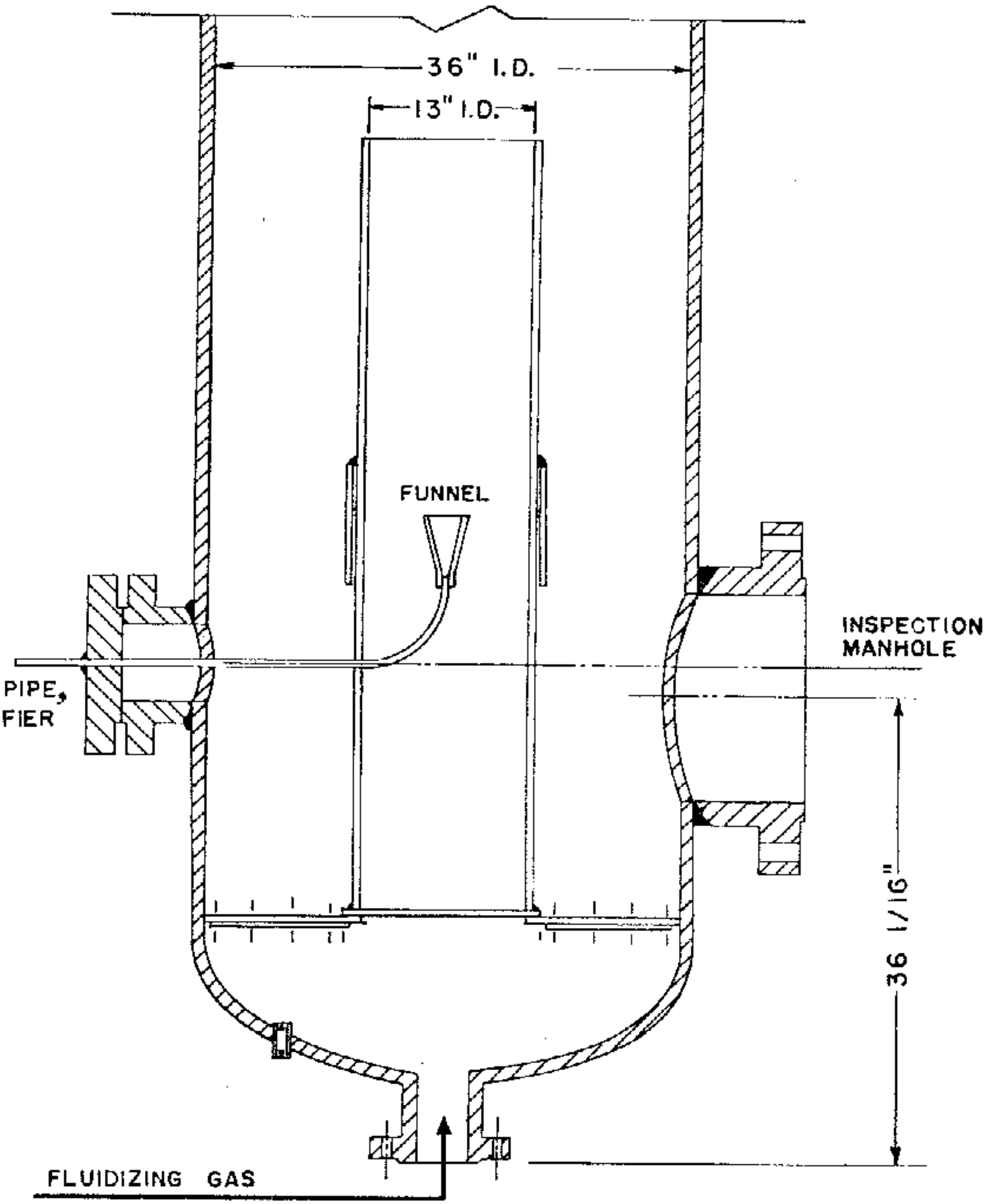


Figure 26. - Two-zone 450 p.s.i. feeder.

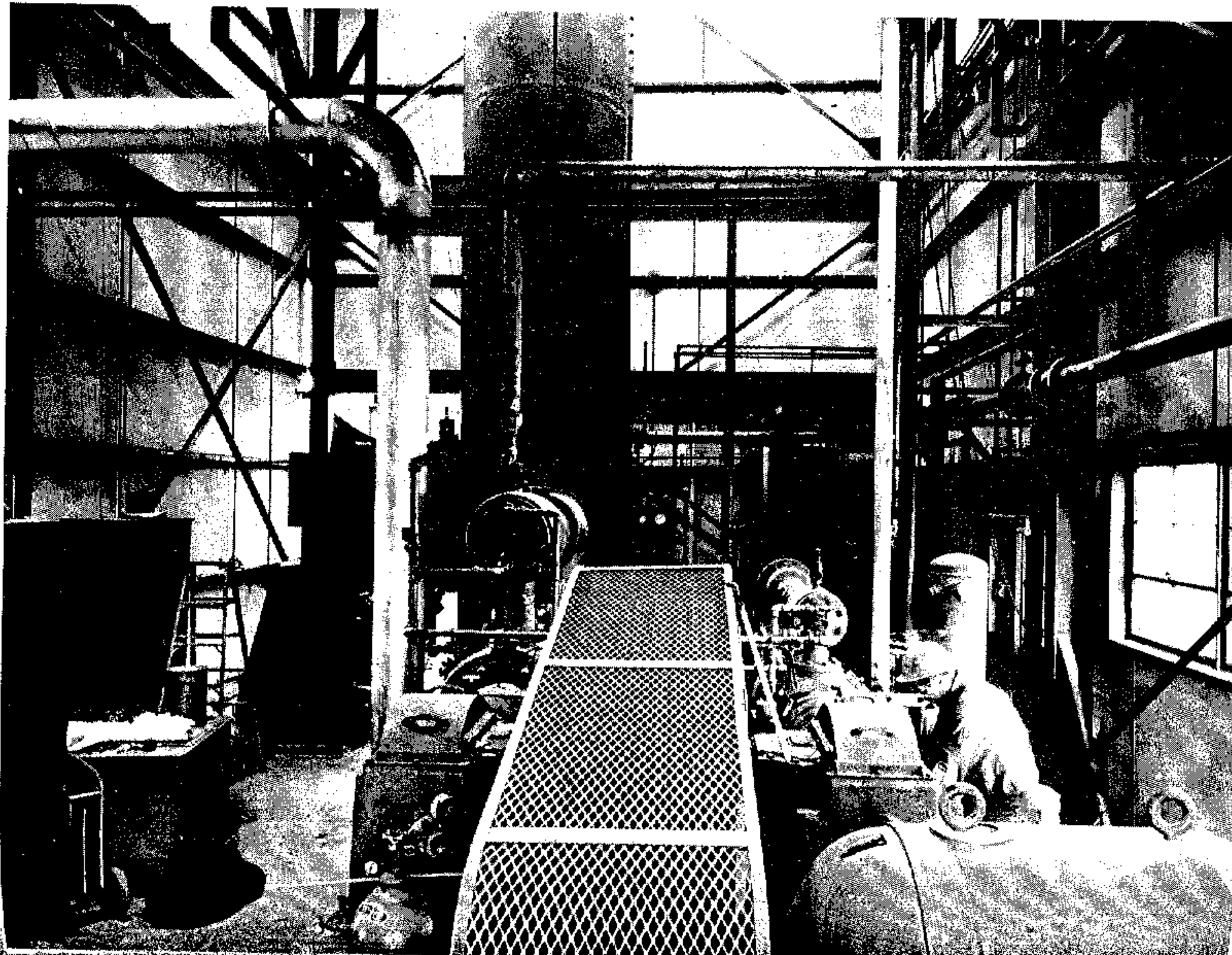


Figure 27 – Oxygen plant being erected with fractionating tower shown in background, building 7

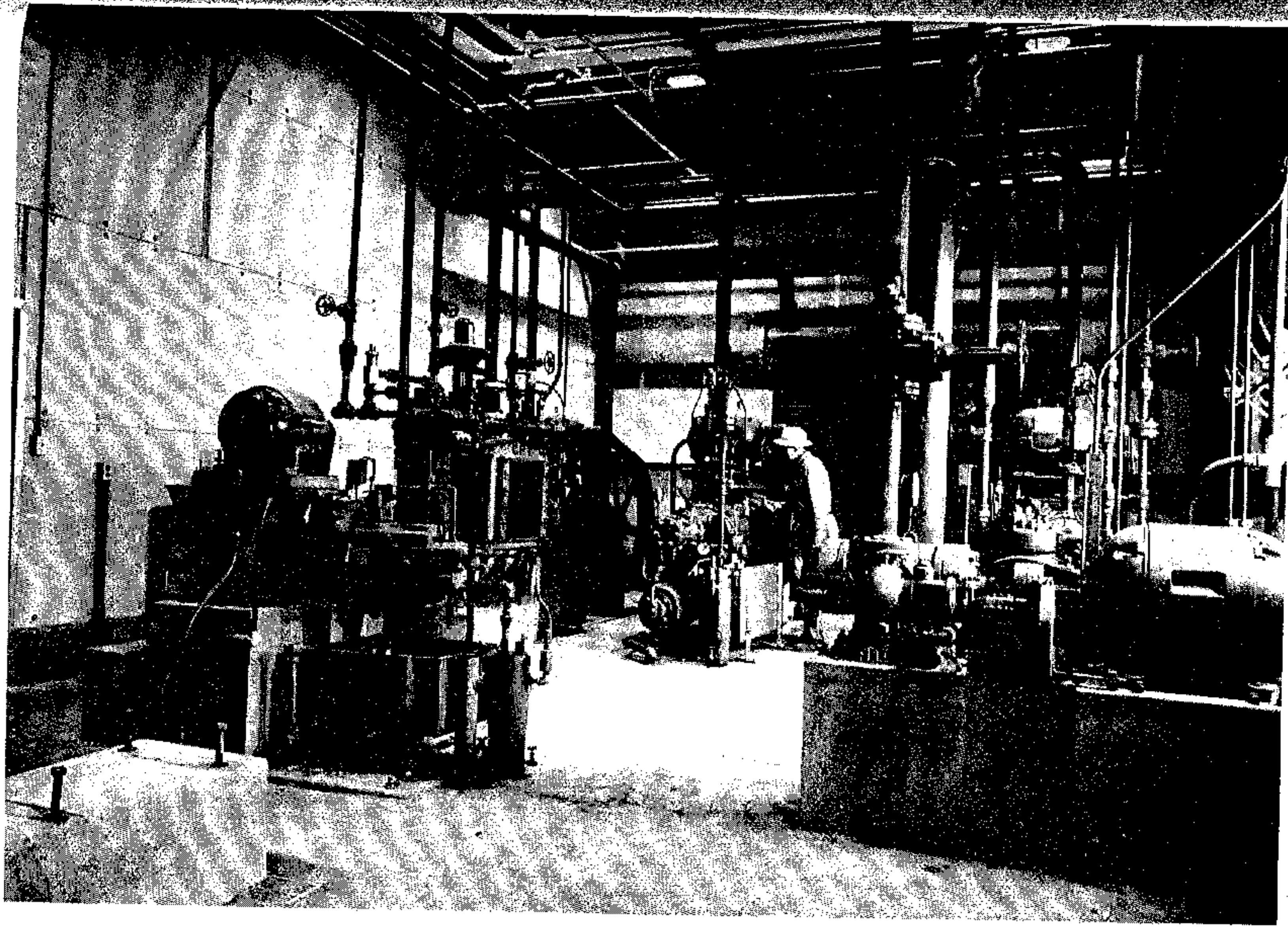


Figure 28. - East end of compressor room in Building 5.

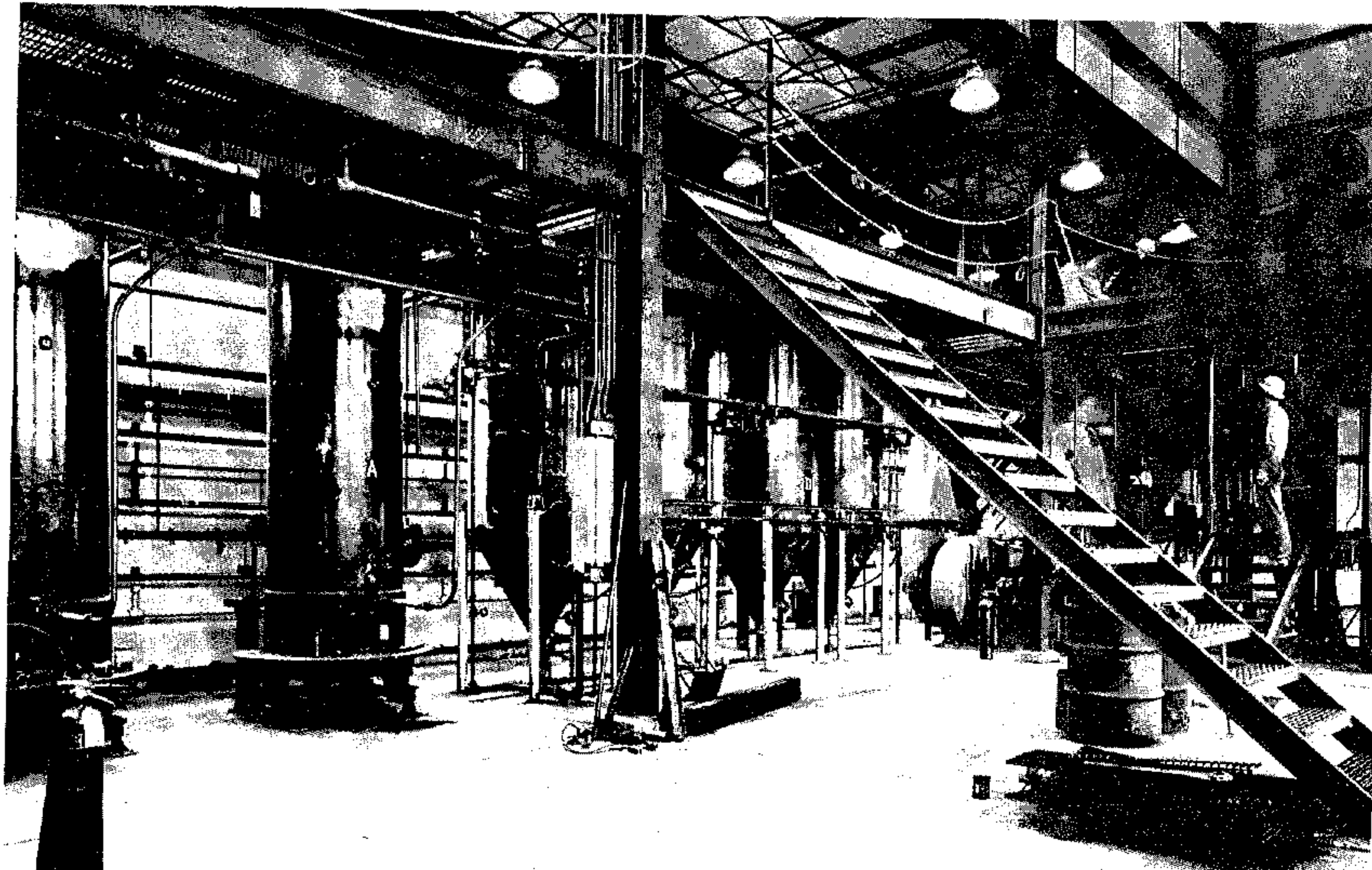


Figure 29. - Coal preparation and transfer equipment in Building 6. Operator is standing near pulverizer. At left, 600 p.s.i.g. transfer hoppers on scales; at near center, 40 p.s.i.g. storage hoppers.

More important from a practical standpoint, however, is the size of the agglomerates as they actually exist in the gas stream. This, rather than ultimate particle size, is the true criterion of performance of dust-removing equipment. The moving-bed filter, for instance, gave far better results on dust-laden air streams than on actual synthesis gas containing much larger particles, probably owing to agglomeration of the particles in the air stream.

After many methods for determining the particle size as it exists in the air stream were tried unsuccessfully, plastic filters known as molecular or millipore filters were found effective. The particles and agglomerates remain where they hit the filter. Pore size of the filter is fine enough to retain the smallest particles, and, more important, the surface is smooth enough so that they can be viewed and measured in the microscope. In the filters previously tried, particles were embedded some distance into the matte of fibers so that viewing was difficult. Also, the particles concentrated at preferential spots instead of remaining where they hit the filter. Although black particles are readily seen, white particles of small size are almost invisible on white filters. This problem was solved by dyeing the filters blue, a procedure that does not seem to affect their filtering action.

Bench-Scale Experiments

To test dust-removing equipment, it often is necessary to prepare a dust-laden gas stream. Work in the past has been handicapped by lack of a satisfactory method. A counterflow feeder now under investigation shows great promise as a solution to this problem. Reproducibilities average about 5 percent, except at very low dust concentrations. This idea may have many other applications, such as in feeding coal to gasifiers.

The effectiveness of the high-pressure scrubbing tower for dust removal was described in the 1953 annual report. This tower consists of a wet cyclonic chamber at the bottom and a ring packed column above. To ascertain the effectiveness of each, the dust concentration between the sections was determined. The dust concentration was reduced from about 2,000 grains per 100 std. c. f. to 77 grains by the cyclonic section and piping ahead of it, and from this to 4 grains in the ringed packed scrubbing section. As the last of the dust is much harder to remove, the ring-packed tower was the more effective of the two. It was impossible to obtain many design data, however, because variables were adjusted to determine information on gasifier operation. Smaller scale equipment is being designed to determine the effect of water and gas rates, types and height of packing, etc.

Investigations in the past on possible disposal of the solid residue from gasification operations as a compounding agent for rubber showed that it had some reinforcing power, and might be used as a filler, but would be no competitor for carbon black. Use of residue as a soil conditioner is now being investigated. Fly ash is reported to be used for this purpose.

Field experiments at Gorgas, Ala., have demonstrated that the electrolinking-carbonization of coal is physically and chemically feasible. This process eliminates the need of underground mining and materially reduces the overall cost of producing synthesis gas by underground gasification. Laboratory experiments are being initiated to study further the theory of the process, including the effect of anisotropism on the resistivity of coal and the time required to attain a satisfactory breakthrough (electrolinkage). Experiments also will be conducted to determine the rate of power application, optimum time for the electrocarbonization period, and factors affecting the direction of the electrical path.

Pilot-Plant Operation

It has been demonstrated that raw synthesis gas produced directly from coal can be purified to meet tentative specifications established for the Fischer-Tropsch synthesis. The total sulfur content, organic and inorganic, can be reduced to less than 0.1 grain per 100 std. c. f., carbon dioxide to 2 to 4 percent by volume, and dust to less than 0.25 grain per 100 std. c. f. before entering the synthesis plant. To attain this purity with respect to sulfur and carbon dioxide, the bulk of the hydrogen sulfide and carbon dioxide is removed with 40 percent diethanolamine in a packed or bubble-cap column, residual hydrogen sulfide is absorbed on iron oxide shavings, and organic sulfur is removed by adsorption on activated carbon. About 80 percent of the total cost is represented by the diethanolamine scrubbing, and about 60 percent of this cost lies in the steam required to regenerate the foul solution. Few savings can be realized by improvements in the iron oxide and activated carbon steps. However, a substantial reduction in purification costs may be possible in the liquid scrubbing step.

Under a cooperative agreement between the Bureau and General American Transportation Corp., small-scale pilot plant experiments have been initiated to reduce steam and investment costs in which the conventional packed column is replaced by a turbomixer type gas-liquid contactor. It is believed that since absorption of carbon dioxide and hydrogen sulfide is controlled almost entirely by liquid-film resistance, agitation of the liquid phase, resulting in a spray of fine liquid droplets, would increase the rate of mass transfer and also result in a greater pickup of carbon dioxide per volume of diethanolamine circulated.

The contactor consists of a 42-inch length of 18-inch schedule 80 carbon-steel pipe, 4 vertical baffles 1 inch wide and equally spaced, 9-inch-I.D. lift tube, annular ring, and impeller (see fig. 30). A 1-hp. motor (1,750 r.p.m.) is used to drive the impeller, and the diameters of the sheaves are chosen to given the shaft a speed of 500 to 900 r.p.m.

Experiments to date have been made with inert gas containing varying amounts of carbon dioxide. The gas is fed into the bottom of the contactor to the right of the lift impeller so that it passes through a spray of liquid distributed by the impeller. A 40-percent solution of diethanolamine enters at the top of the absorber and is distributed by a sparger. The level of the solution in the contactor is maintained above the annular ring, for foaming occurs whenever the level is below this point. Otherwise, the amine solution is free of foam. Purified gas leaves the top of the contactor through a separator that removes entrained liquid from the gas.

Any increase in the rate of mass transfer will result in greater gas throughputs. Present compressor facilities have limited the operating pressure and gas flow, and it has not been possible to determine the maximum capacity of the agitator. The highest gas rate studied to date has been 3,000 std. c. f. per hour at 250 p.s.i.g.

The principle of agitation may effect an increase in the amount of carbon dioxide absorbed per volume of solution circulated, or, in other words, reduce the liquid-gas ratio as low as possible. Any reduction in solution rate results in less solution to be regenerated and, perhaps, less steam consumption. The following preliminary data indicate that there is a 30- to 50-percent greater pickup of carbon dioxide per volume of solution using the contactor than with the packed or bubble-cap column.

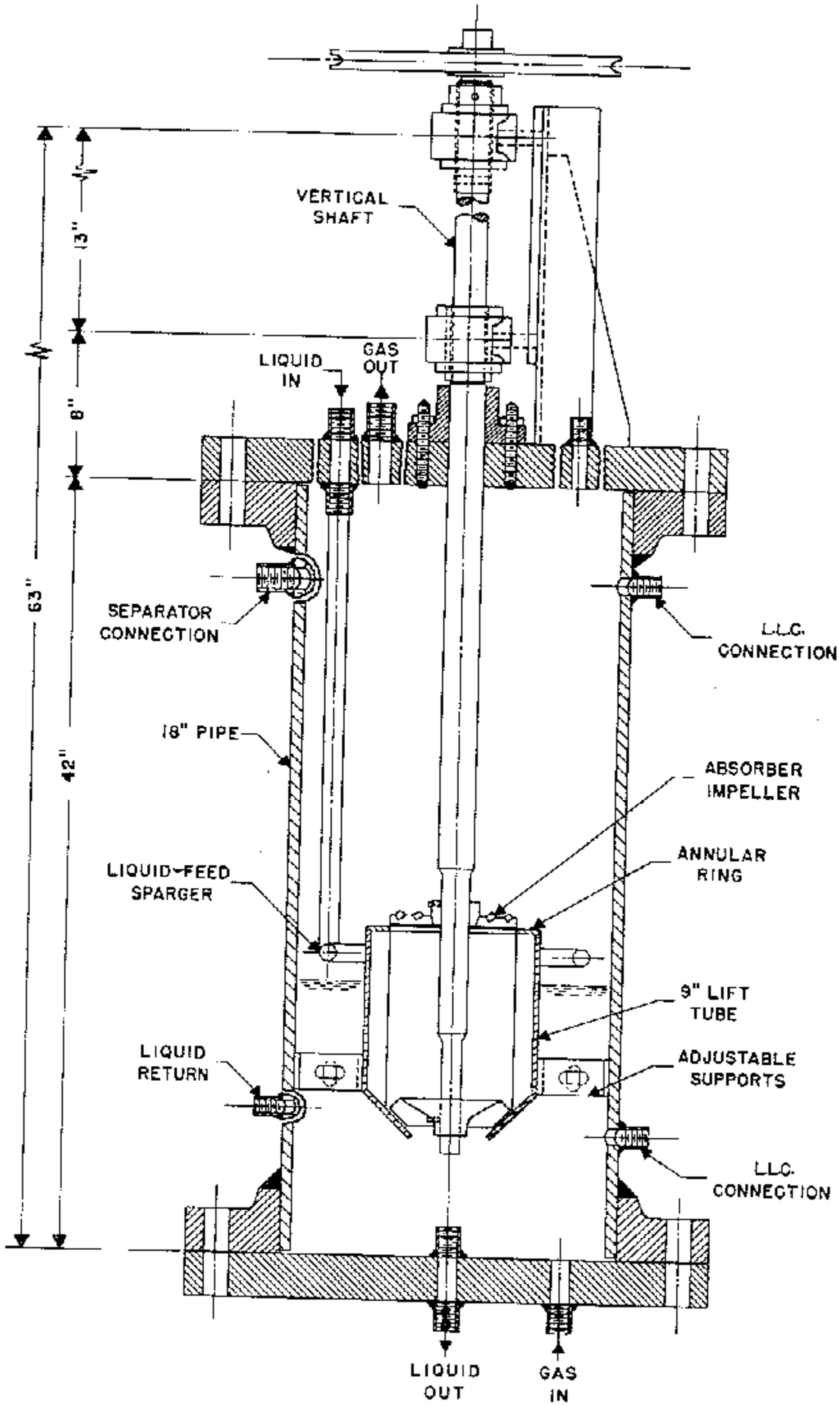


Figure 30. - Contactor for gas absorption.

	CO_2 in, percent	CO_2 out, percent	CO_2 removed per gallon solution, cu. ft.	Absorber pressure, p.s.i.g.
Morgantown Packed Column	20.8	5.1	5.40	300
Bubble-Cap Column	18.4	3.0	5.29	340
Morgantown Agitator	18.2	3.6	7.77	250

These initial experiments were conducted primarily to study absorption characteristics of diethanolamine in a gas-liquid contactor. As it has been shown that absorption can be improved, experimental data will be obtained so that a correlation can be made between the carbon dioxide pickup per gallon and the regeneration efficiency (defined as carbon dioxide removed per pound of steam).

Assuming only chemical reaction, one gallon of 40 percent diethanolamine solution will absorb, theoretically, about 6.3 cu. ft. of carbon dioxide if the carbon dioxide is converted completely to the amine carbonate and about 12.6 cu. ft. if the carbon dioxide is converted to the amine bicarbonate. As only a small amount of bicarbonate reportedly is formed in the amine process, it is believed that in runs where 7 or more cu. ft. of carbon dioxide is absorbed, the theoretical pickup has been attained. This indicates the need for investigating higher amine concentrations. The ability to use concentrated solutions is an important advantage of the contactor over the conventional column. Highly concentrated solutions of amine are too viscous to be used in packed columns.

Dust concentrations leaving the pilot-plant electrostatic precipitator normally varied from 0.02 to 0.3 grain per 100 std. c. f., rising occasionally as high as 3 grains when it was not operating properly. The gas fed contained 10 to 40 grains.

The moving-bed coke filter, as previously reported, reduced the dust concentration from 30 to about 1.5 grains per 100 std. c. f., a removal of 95 percent. When used after the precipitator, however, it was able to remove 86 to 95 percent of the remaining dust, yielding extremely pure gas containing only 0.004 to 0.07 grain per 100 std. c. f. This was possible probably because the electrostatic precipitator leaves in the gas many of the larger particles which are easily removed by the filter.

Laboratory-Scale Research - Exploratory Studies

Kinetic Study of Steam-Carbon Reaction

In industrial processes based on chemical reactions, such as the gasification of pulverized coal entrained in steam and oxygen, knowledge of the mechanisms and rates of reaction are most important.

A kinetic study of the steam-carbon reaction was made as a partial solution to this problem. An isothermal reactor was built for the gasification of 200- to 230-mesh petroleum coke and electrode graphite with a high excess of steam. Under such conditions the change in composition of the gas phase surrounding the fine fuel particles was negligible, and the reaction could proceed free from retarding effects of such changes. The apparatus and cross-sectional views of the electrically heated 6-1/2-foot vertical reactor tube of 3-inch internal diameter are shown in figures 31 and 32.

Carbon particles were dropped at a constant rate of 4 to 5 grams per hour from a vibrated feeder bowl through a 23-inch-long refractory feed tube of 5-mm. diameter

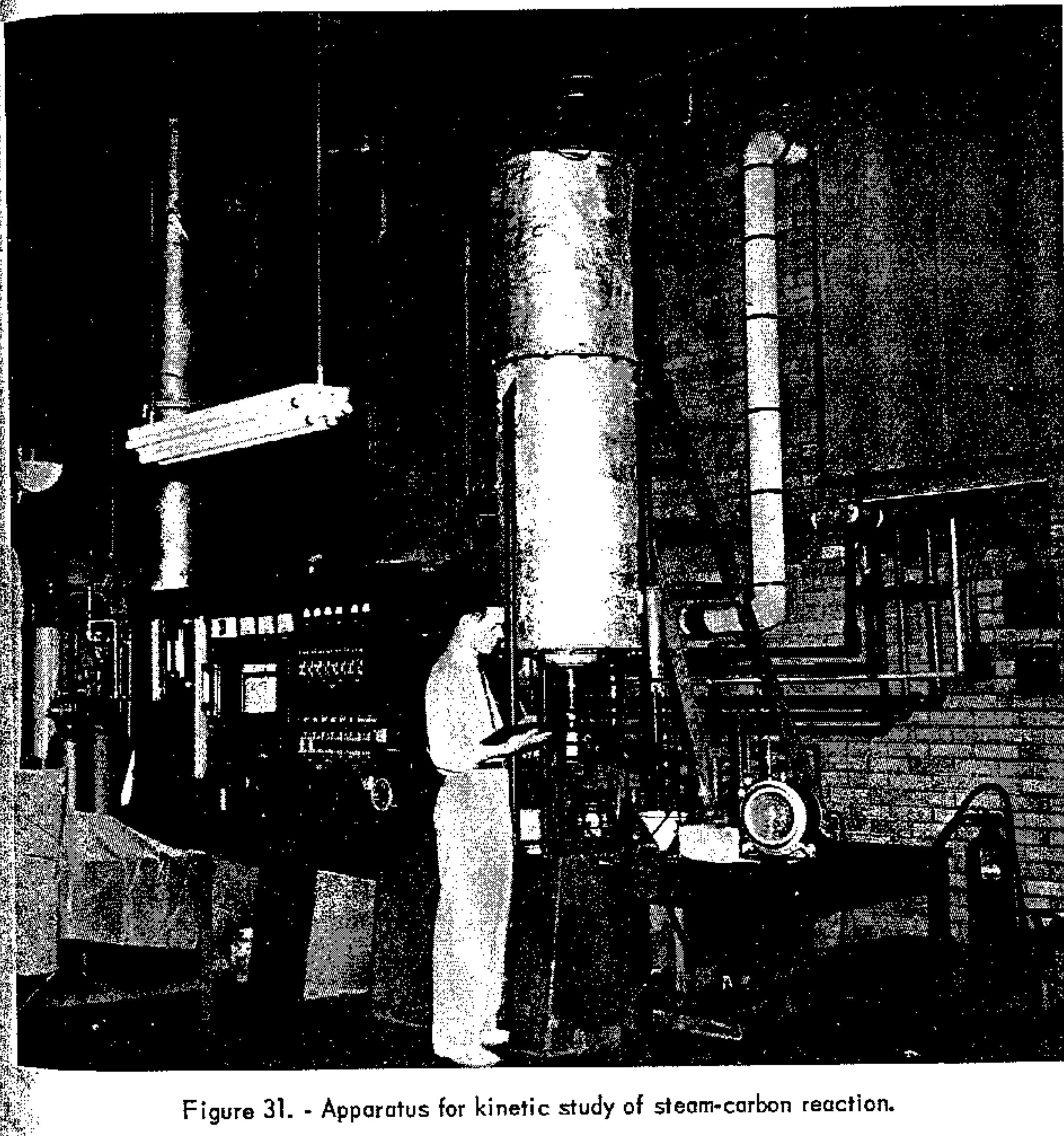
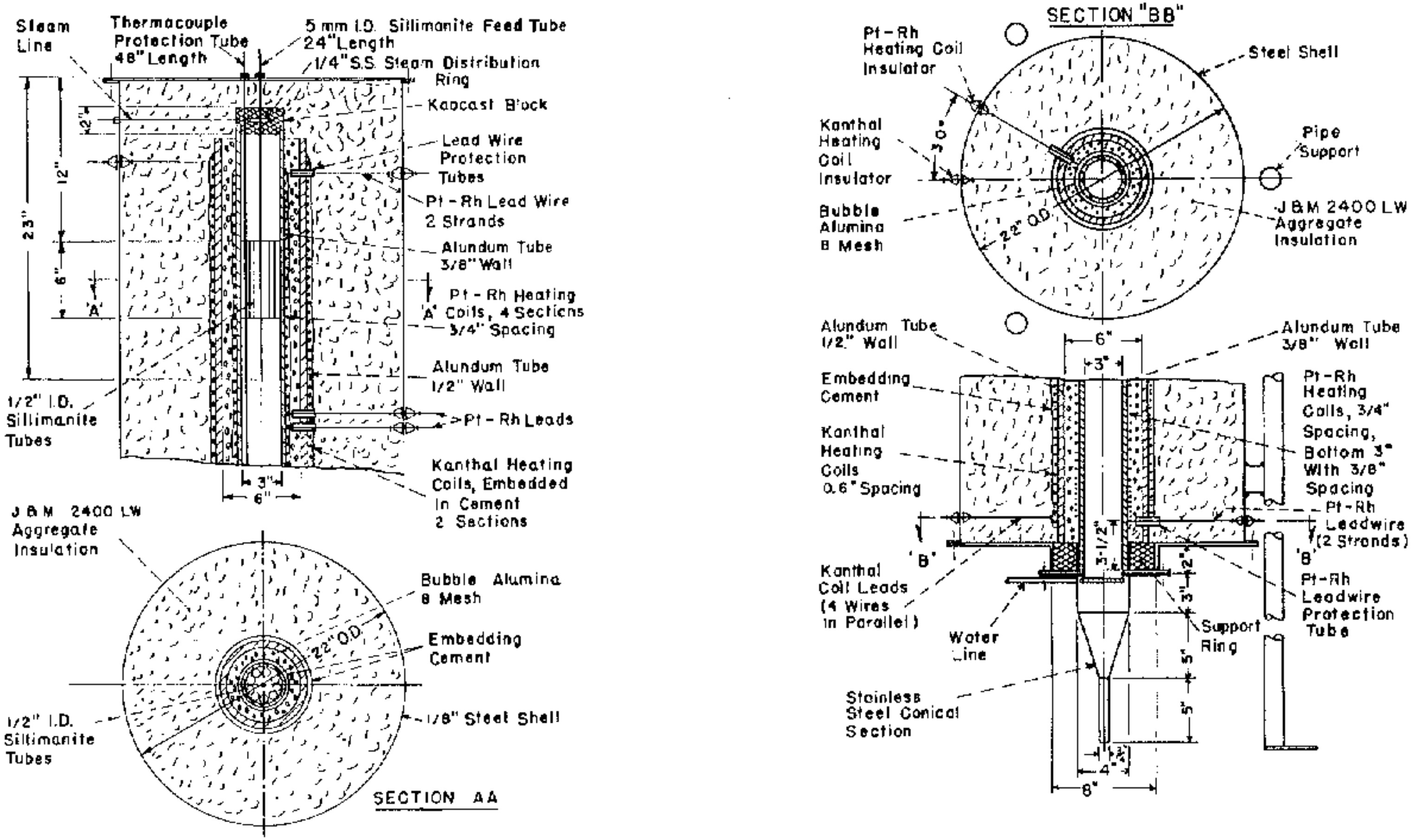


Figure 31. - Apparatus for kinetic study of steam-carbon reaction.



CROSS-SECTIONAL VIEWS OF THE UPPER PORTION OF REACTION FURNACE

CROSS-SECTIONAL VIEWS OF THE LOWER PORTION OF REACTION FURNACE

Figure 32. - Cross-sectional views of upper and lower portions of reaction furnace.