products is sufficiently large so that only little advantage is obtained, so far as space-time-yield is concerned, by increasing the operating pressure to 5 to 20 atmospheres.

Research on Water-Gas Production

In an analysis of data in the literature on the reaction between steam and carbon98/ a mechanism of the reaction was proposed in which the rate of gasification increases with increasing steam pressure up to a critical pressure beyond which the rate does not change with pressure. The relationship is apparently determined by an adsorption isotherm with a saturation pressure. All of the available data had been obtained in systems at constant pressure in which the partial pressure of steam was varied by the change in the fraction of steam decomposed by altering the velocity of the steam passing through the bed of carbon particles. It was found that with increase in the partial pressure of the steam the rate of gasification approached a constant value. In these experiments, however, the gaseous atmosphere surrounding the carbon is not pure steam but a mixture of steam and the reaction products, hydrogen, carbon monoxide, and carbon dioxide, any of which may be adsorbed on the carbon surface. A more rigorous test of the proposed mechanism can be obtained by changing the total pressure of the system and maintaining a steam velocity high enough to obtain an atmosphere consisting almost entirely of steam. The partial pressure of the steam is then virtually equal to the total pressure.

As this reaction is typical of other gas-solid reactions such as carbon dioxide-carbon, it was considered desirable to undertake experiments at various total pressures and high-space velocities of steam. This work is also of importance in comparing carbons for reactivity in water-gas generators because the saturation pressure may vary with different types of carbon, and it should furnish basic information for the design and operating procedure of water-gas generators.

The apparatus designed for this work has been described.99/ 1/ The results show that for electrode carbon in the temperature range 850° to 950° C. a saturation pressure of about 800mm. of mercury exists. The use of higher steam pressures does not increase the rate of gasification.

Development Work on the Fischer-Tropsch Process

Equipment has been installed at the Central Experiment Station, Bureau of Mines, Pittsburgh, Pa., for chemical-engineering development work on the synthesis of liquid fuels by the catalytic hydrogenation of carbon monoxide.

98/ Warner, B. R., Mechanism of the Steam-Carbon Reaction: Jour. Am. Chem. Soc., vol. 65, 1943, pp. 1447-1451.

99/ Warner, B. R., An Improved Pressure-Regulating Device: Ind. Eng. Chem., anal. ed., vol. 15, 1943, pp. 637-638.

1/ Warner, B. R., Pressure Dependence of the Rate of Gasification of Carbon: Jour. Am. Chem. Soc., vol. 66, 1944, pp. 1305-1309.

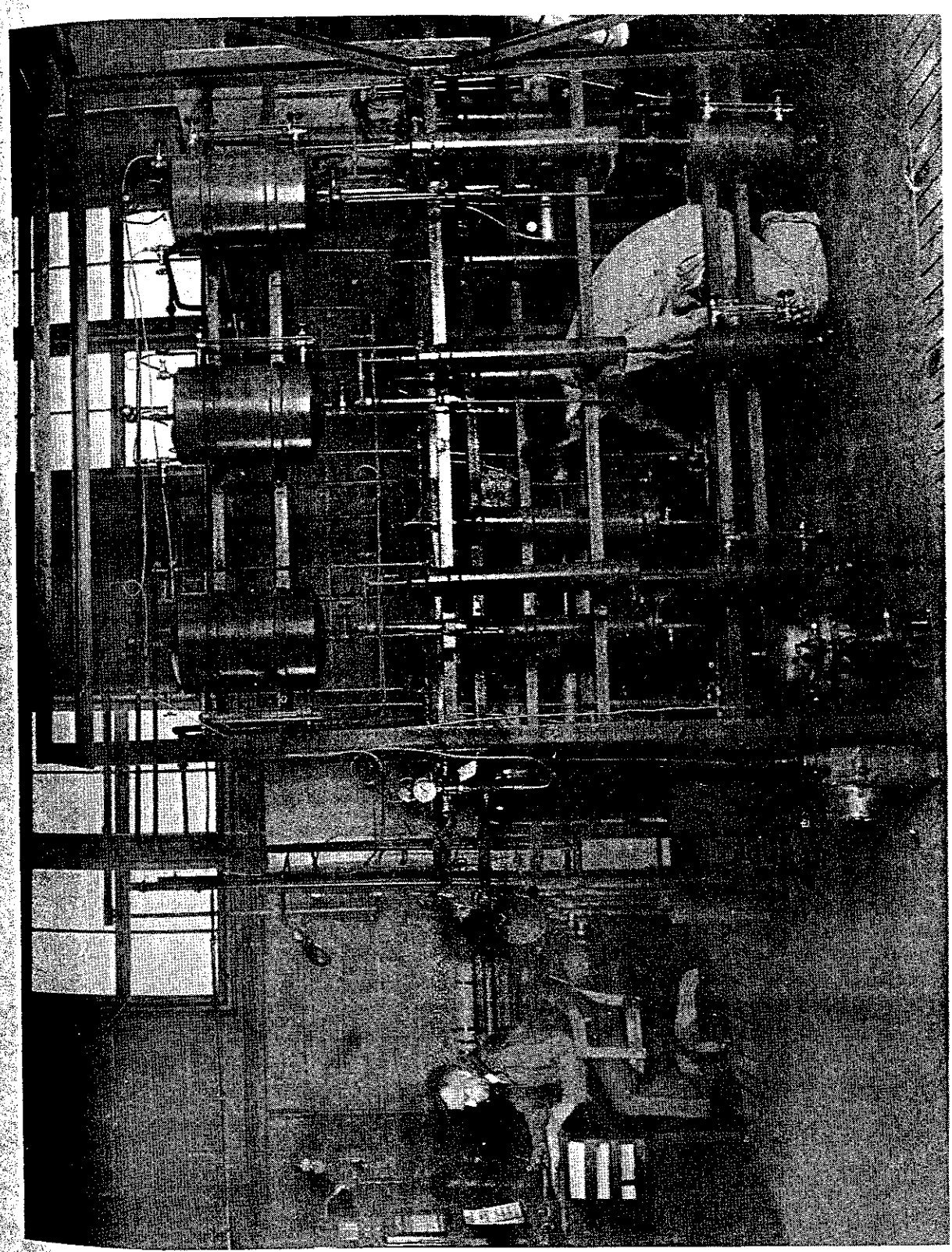

FIGURE 12.- Three-stage experimental Fischer-Tropsch unit.

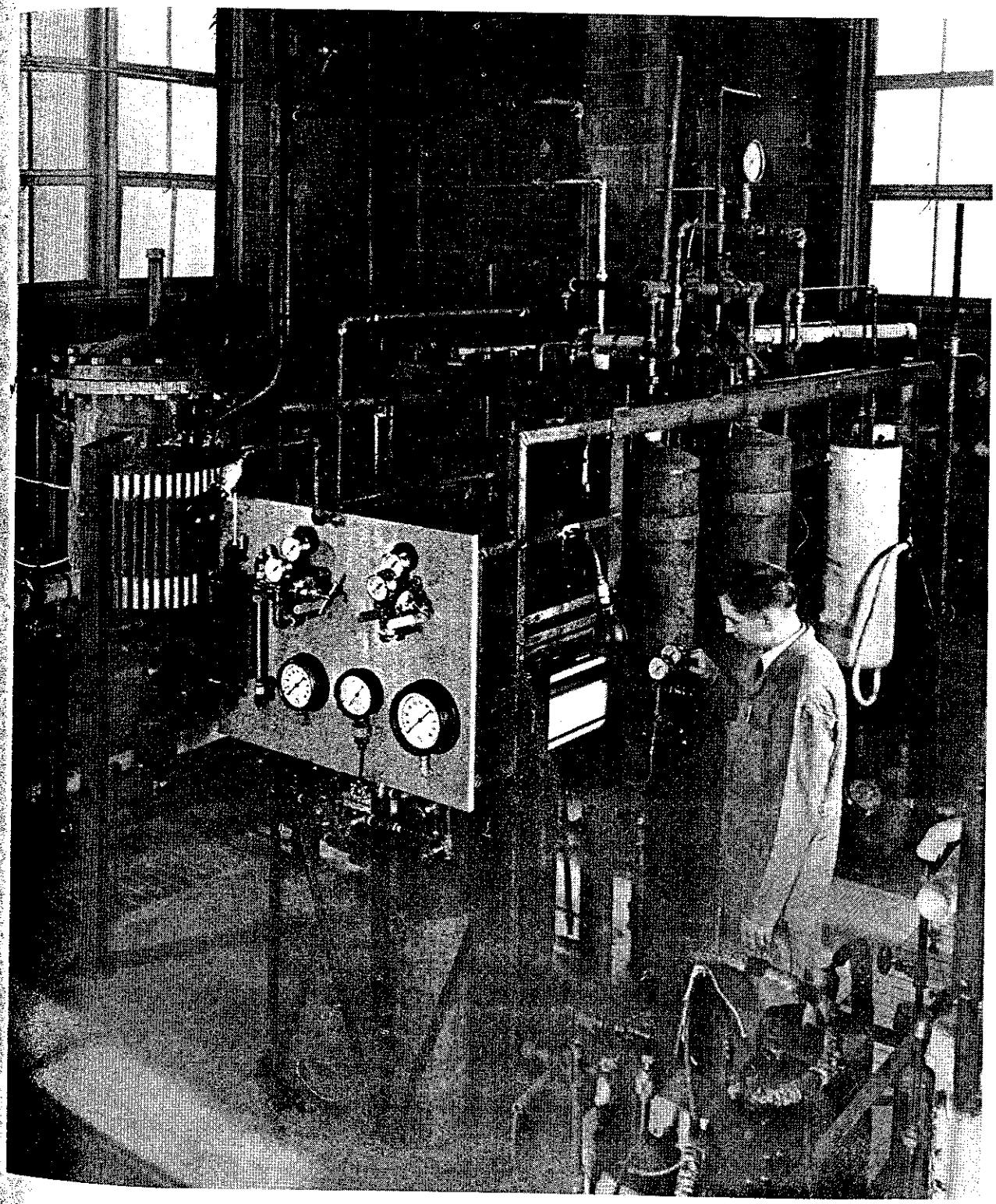

FIGURE 13.- Single-stage Fischer-Tropsch unit.

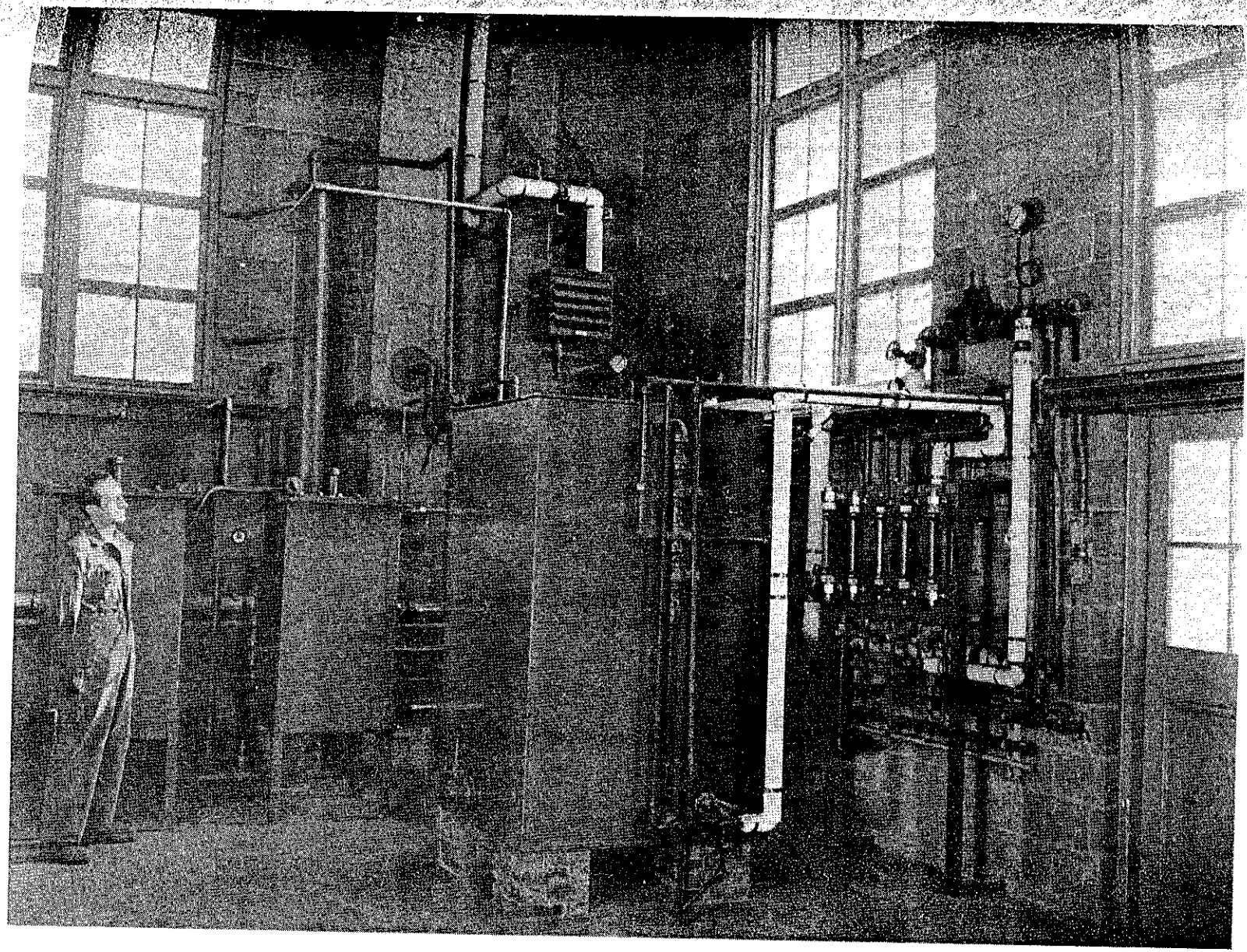

FIGURE 14.- Synthesis-gas generator.

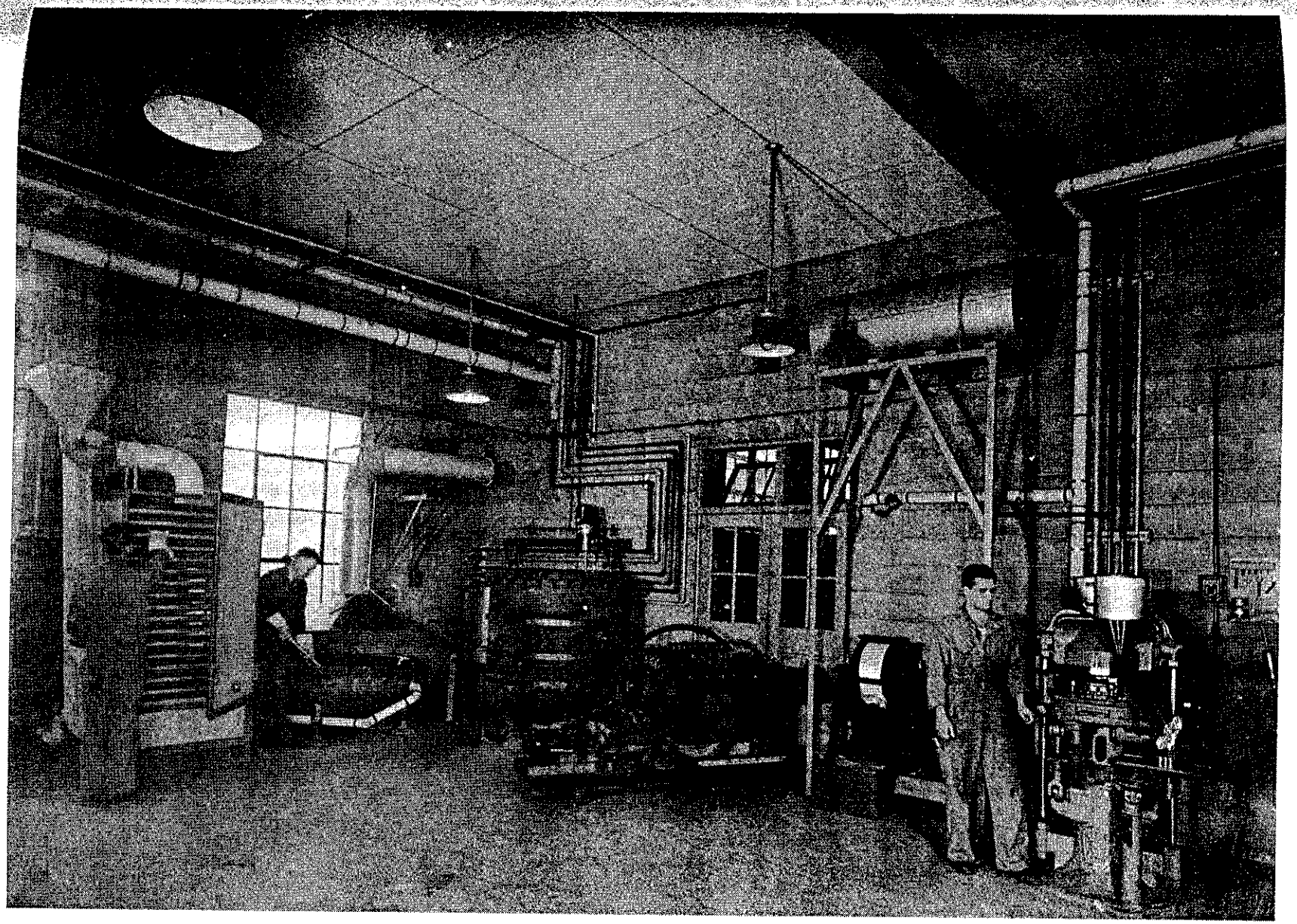

FIGURE 15.- Catalyst-preparation equipment.

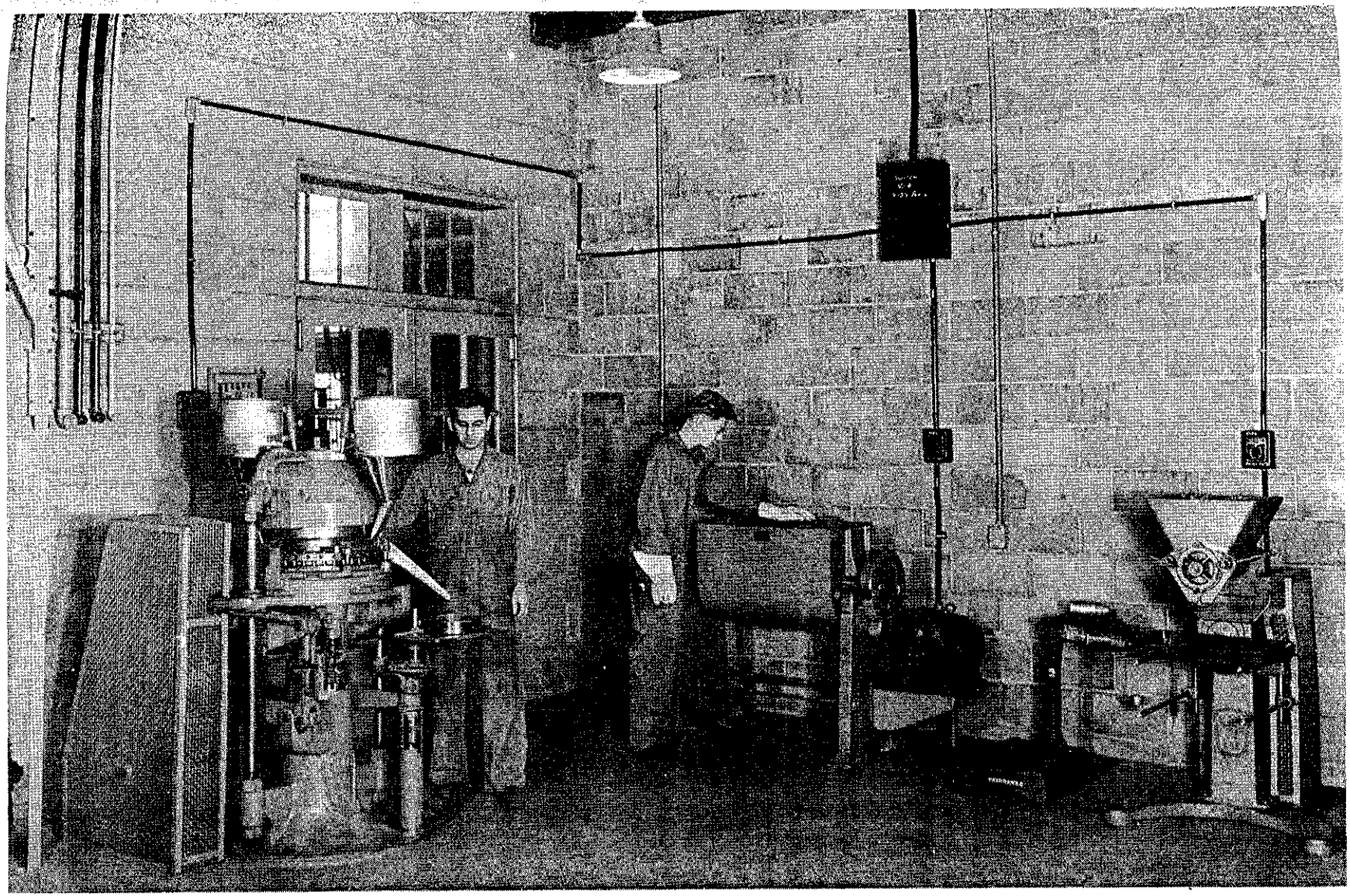

FIGURE 16.- Pelleting machine and granulators.

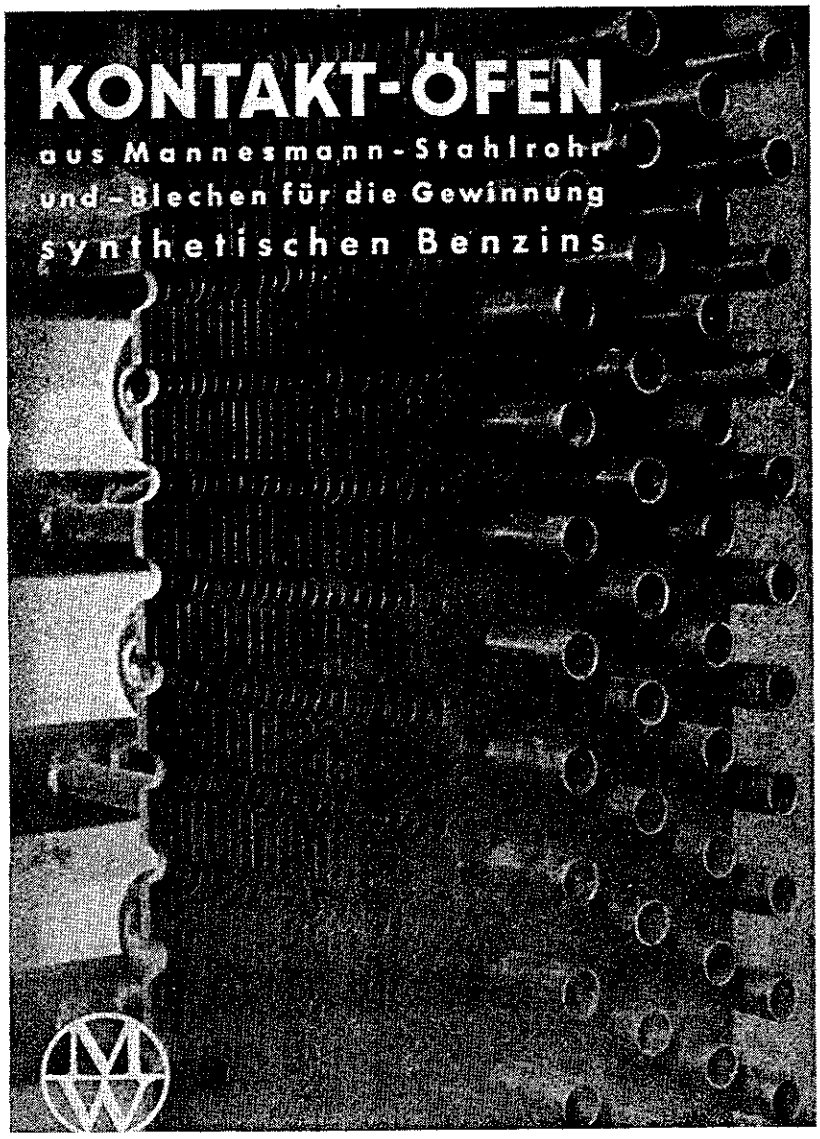

FIGURE 17.- Ruhrchemie Fischer-Tropsch converter.

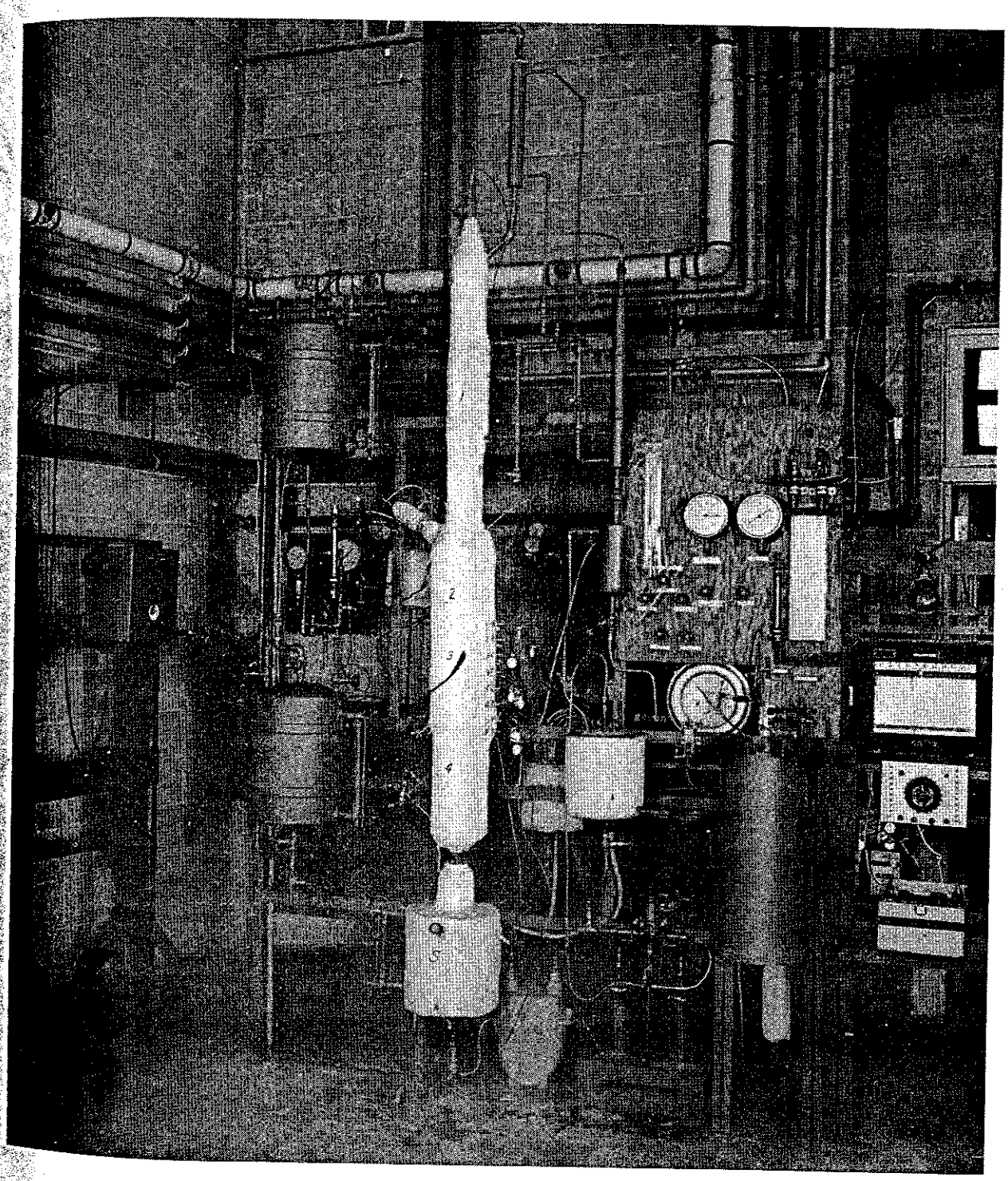

FIGURE 18.- Internally cooled experimental converter.

Figure 12 is a view of a three-stage experimental unit in which the liquid products from each stage can be condensed before the remaining gas is passed to the next stage. This plant will produce about 0.5 liter of liquid product per 24 hours. Figure 13 shows a single-stage unit with a capacity of about 3 gallons of liquid product per 24 hours. In figure 14 the synthesis gas generator is the large, rectangular chamber in the foreground. This steel box is lined with firebrick and contains a bed of nickel-alundum catalyst through which a mixture of oxygen, steam, and natural gas is passed. The resulting mixture of carbon monoxide and hydrogen is passed through a sulfur-removal system, part of which consists of the two smaller steel chambers in the background of figure 14.

Figure 15 is a picture of the catalyst-preparation equipment, showing the precipitation tank in the far corner of the room. To the right of this tank is a filter press and to its left a tray drier. Along the wall to the right of the filter press are a ball mill and pellet-making machine. A distilled water tank is supported on a steel frame above the ball mill. Figure 16 shows a closer view of the pelleting machine with a mixer and granulator to the right. The capacity of the catalyst-preparation plant is about 20 pounds of the finished catalyst per 24 hours.

Because the hydrogenation of carbon monoxide to produce liquid hydrocarbons is a highly exothermic reaction, and because of the narrow temperature range of efficient operation, the heat-transfer problem has been of great importance in the design of the Fischer-Tropsch converters. The type of converter used in most of the Ruhrchemie plants is illustrated in figure 17. The catalyst is packed in narrow spaces between steel sheets through which cooling tubes are interlaced. Water under pressure is circulated through the tubes. The cost of this converter is relatively high because the design necessitates large amounts of steel per unit of oil produced. Various ways have been suggested for removing the heat of reaction and controlling the reaction temperature. One of the most promising of these consists in flushing a cooling oil of proper boiling range over the catalyst particles, the heat of vaporization of this oil being supplied by the heat of the synthesis reaction. To test this procedure, the equipment of the type illustrated in figure 18 has been assembled and the temperature gradients and catalyst activities measured. Tests have been conducted with 1/2-, 1-1/2-, and 3-inch tubes, a catalyst bed about 12 inches deep, and the cooling oil condensed and returned by gravity flow to the catalyst bed. It has been found possible to maintain virtually completely adiabatic conditions in the converter, and precise temperature control has been readily obtained. Using a cobalt-thoria-magnesia-kieselguhr catalyst, at 75 to 100 pounds per square inch pressure of $2H_2+1CO$ gas, the yield of oil thus far has been about 75 percent of that obtained using the same catalyst in a Ruhrchemie converter.