2,050° F. by the combustion of a mixture of gas, air, and products of combustion. Thus far, during 1,400 hours of operation at 2,000° F. maximum temperature, the alloy retort shows no evidence of failure. It is believed that the retort will last several thousand hours, which will be ascertained during 1947, when the large plant will be operated 4,000 to 5,000 hours. Figure 25 shows the arrangement of the Grand Forks plant as it was operated during 1946.

This investigation has demonstrated the value of pilot-plant steps in the development of a process. The small plant incorporates the major features of a commercial-size plant on a reduced scale, and changes can be made quickly at low cost. The experience gained from its operation was useful in the design of the large plant. The size ratio of the two plants is 1:5. Tables 21 and 22 compare the performance of the plants on a unit basis. It is shown that the large plant is more efficient, whereas performance of the small plant indicates improvements that can be made on a larger scale. The operating characteristics of each plant are about the same, and experimental results obtained on coals tested in the small unit compare well with those obtained in the large unit.

A Report of Investigations describing the small pilot plant and other experimental work in connection with gasification of low-rank fuels has been published.73/

Gasification Processes Using Oxygen

Oxygen has been used extensively in Europe for the production of gas. The use of oxygen permits the continuous gasification of coal in gas producers yielding a substantially nitrogen-free gas superior in quality to normal producer gas. Oxygen gasification has not been utilized in the United States on a commercial scale because of the high cost of oxygen. As a result of recent developments in large-scale production of oxygen at lower cost and demands for gas for special purposes or from fuels not generally gasified, an intense interest in all gas-production processes using oxygen has been expressed by industry and research workers in the United States.

73/ Parry, V. F., Gernes, D. C., Goodman, J. B., Wagner, E. O., Koth, A. W., Patty, W. L., and Yeager, E. C., Gasification of Lignite and Subbituminous Coal Progress Report for 1944, (I) Carbonization and Gasification of Lignite in Laboratory Retorts; (II) Gasification of Lignite in Glover-West Retorts; (III) Gasification of Lignite Char Briquets in a Water-gas Machine; (IV) Gasification of Subbituminous Coal and Lignite in the Golden, Colo., Pilot Plant: Bureau of Mines Rept. of Investigations 3901, 1946, 59 pp.

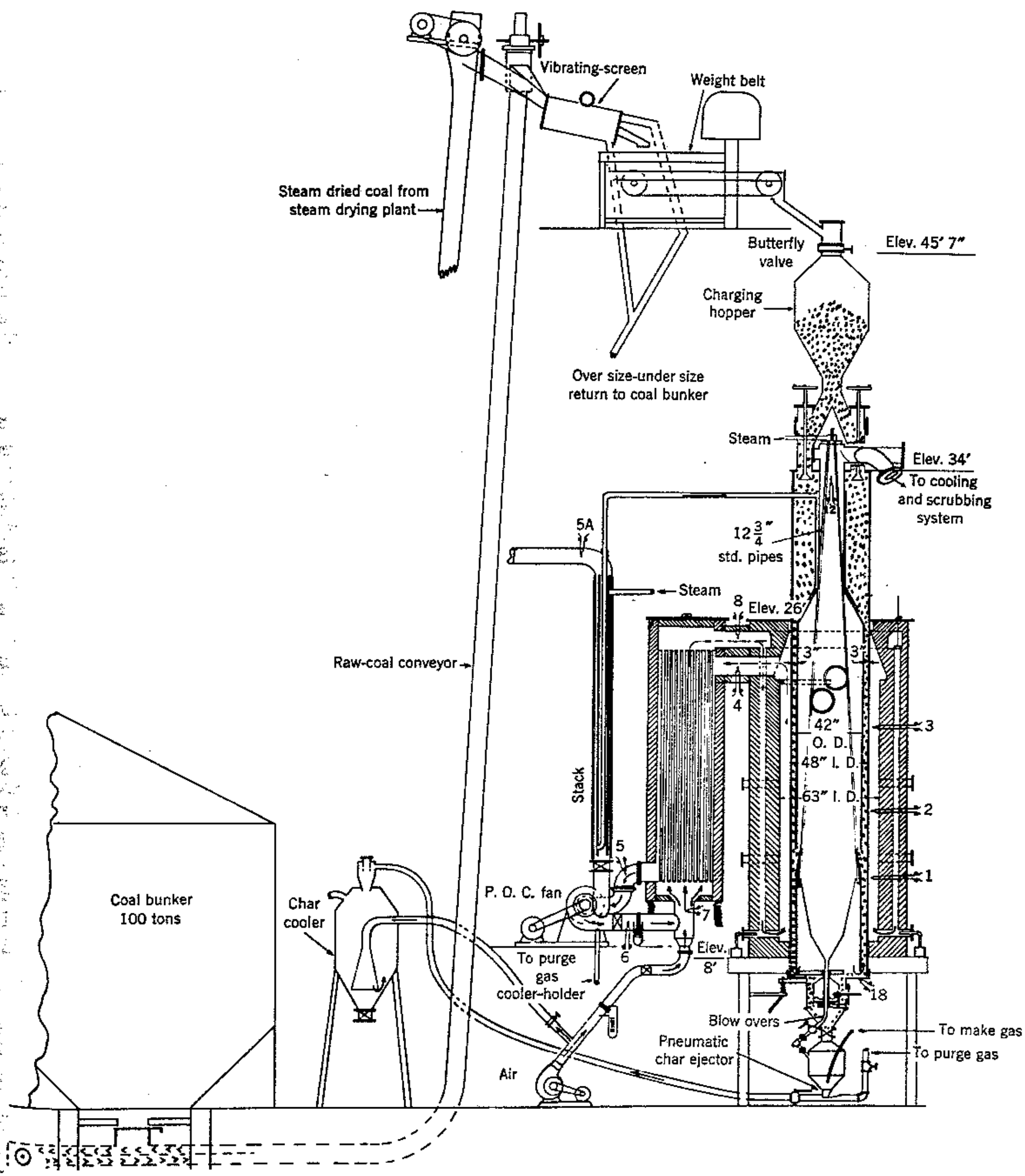

Figure 25. - U. S. Bureau of Mines pilot plant for gasification of lignite, Grand Forks, N. Dak., December 1945.

TABLE 21. - Gasification of coal in small pilot plant, Golden, Colo.

	Test No.					
	5B	5C	8B	9D	10B	12C
Kind of coal	Subb.	Steam-dried lignite	Natural lignite	Wyoming subb.	Subb.	Natural lignite
Coal-charging rate, pounds per hour per square foot of retort surface	1.44	1.24	1.45	1.68	2.95	3.25
Percentage gasified[1]	76.6	94.4	89.8	74.7	73.4	64.2
Steam:						
Pounds per hour per square foot of retort surface:						
Upper annulus	4.0	3.8	1.9	2.6	3.1	3.6
Lower annulus	8.0	8.2	2.2	4.4	5.4	4.9
Used per mol of carbon gasified	7.0	6.25	2.93	3.65	2.02	2.81
Converted = Z[2]	1.75	1.65	1.49	1.47	1.37	1.36
Net heat used:						
B.t.u. per cubic foot of gas made	190	180	202	180	138	166
MB.t.u. per hour per square foot of retort surface	9.19	9.40	8.03	9.29	11.29	10.52
Average furnace temperature, °F.	1,540	1,605	1,690	1,730	1,800	1,750
Gas made:						
Cubic feet per hour per square foot, SGC[3]	46.6	50.5	38.7	50.3	81.5	63.3
Cubic feet of dry gas per pound of coal	32.9	41.4	27.0	30.4	27.1	19.1
H_2/CO ratio = R	7.18	4.73	2.72	3.04	2.0	2.11
Retort arrangement:						
Width of annulus, inches	3	3	3	3	2	2
Ratio of length of top to bottom annuli	2.45	2.45	2.45	2.45	2.79	2.11

1/ Percentage of carbon in coal converted to gas.
2/ Per mol of carbon gasified, $Z = H_2/CO+CO_2$.
3/ Saturated at 60° F. and 30 in. Hg.

92

TABLE 22. - Gasification of coal in large pilot plant, Grand Forks, N. Dak.

	Test No.							
	Preliminary A	1B	2B	2E	3A	3B	3G	X1/
Kind of coal	Lig.	Lig.	Lig.	Lig.	Lig.	Lig.	Lig.	Lig.
Coal-charging rate, pounds per hour per square foot of retort surface	3.00	3.46	2.43	3.64	2.00	3.30	2.69	3.71
Percentage gasified2/	48.7	47.0	85.7	74.9	58.8	77.4	74.6	80.0
Steam:								
Pounds per hour per square foot of retort surface:								
Upper annulus	3.5	3.0	2.0	2.4	4.9	2.5	1.8	2.0
Lower annulus	2.9	9.7	3.2	4.0	4.6	4.6	2.3	4.0
Used per mol of carbon gasified	4.86	5.76	2.30	2.20	8.74	2.61	1.94	1.90
Converted = Z3/	1.56	1.65	1.41	1.42	1.70	1.48	1.37	1.33
Net heat used:								
B.t.u. per cubic foot of gas made	144	130	126	127	201	123	121	110
MB.t.u. per hour per square foot of retort surface	6.47	6.54	7.80	9.84	7.66	9.23	7.22	9.35
Average furnace temperature, °F	1,825	1,670	1,770	1,790	1,345	1,785	1,810	1,825
Gas made:								
Cubic feet per hour per square foot, SGC4/	46.1	50.3	61.7	77.6	38.2	74.9	59.9	85
Cubic feet of dry gas per pound of coal	15.1	14.3	25.0	20.9	18.8	22.3	21.8	22.5
H_2/CO ratio = R	2.37	2.58	2.44	2.48	5.43	2.71	2.18	2.0
Retort arrangement:								
Width of annulus, inches	4	4	3	3	3	3	3	2.5
Ratio of length of top to bottom annuli	2.02	4.03	2.26	2.26	2.11	2.11	2.11	2.0

1/ Desired conditions for 2,000-hour test.
2/ Percentage of carbon in coal converted to gas.
3/ Per mol of carbon gasified. $Z = H_2/(CO + CO_2)$ in the water gas formed.
4/ Saturated at 60° F. and 30 in. Hg.

Results of the investigations in Europe by the members of the Technical Oil Mission were embodied in a report by the Bureau of Mines.[74] In this report, the oxygen-gasification processes were divided into four groups: (1) Processes in which fine fuel is gasified in a fluidized bed, (2) processes in which fine fuel is gasified in suspension, (3) processes in which fine fuel is gasified in a fixed bed, and (4) processes in which lump fuel is gasified in a fixed bed. The Winkler process was described as typical of the first group; the Koppers powdered-fuel process and the Schmalfeldt gasification process are typical of the second; the Lurgi pressure gasification process typifies the third; and the Thyssen-Galocsy and Leuna slagging generators are representative of the fourth.

As oxygen production is one of the prime considerations in connection with gasification processes, the most recent available results of oxygen production and its utilization in gas-making processes both at home and abroad were summarized in a more comprehensive publication,[75] which includes a brief history of the process, a discussion of the production of oxygen by the Linde-Fränkl process, by electrolytic dissociation of water, and by the use of regenerative chemicals. The gasification processes described again included the Winkler, the Koppers powdered fuel, the Lurgi pressure gasification method of gasifying fine fuel in a fixed bed, and touched upon the Steere-Airco and Van Nuys methods of gasifying fine fuel in a fluidized bed or in suspension. In addition, methods of gasifying lump fuel in a stationary bed at normal pressures were described, and the results of operation of a pilot plant at Leaside, Ontario, were given. Slagging operations were covered in the descriptions of the Thyssen-Galocsy and the Leuna generators, which were observed in Germany.

LIQUEFACTION

Research on the production of liquid fuels from coal and lignite was begun by the Bureau of Mines in 1924. After collecting many fundamental data, the work was recessed until 1936, when a laboratory-scale experimental coal-hydrogenation plant capable of hydrogenating about 100 pounds of coal in 24 hours was designed and constructed. From 1936 to 1944, 16 coals were assayed, and the results demonstrated that low-ash and low-carbon coals were the most suitable varieties for liquefaction.

74/ Newman, L. L., Oxygen Gasification Processes in Germany: A.I.M.E. Tech. Paper 2116, 1946, 16 pp.

75/ Newman, L. L., Oxygen Production and Utilization in Gas-Making Processes: Report of Gas Production Committee, American Gas Association 1946 Proceedings, 24 pp.

The passage of Public Law 290 in April 1944 permitted expansion of the Bureau's program in this field.76/ New buildings to house the research and development laboratories have almost been completed on a 12-acre portion of the Bureau of Mines Experimental Coal Mine and Explosives Testing Station property at Bruceton, Pa. While construction is going on at Bruceton, the Research and Development Division has been functioning in laboratory space provided at the Bureau's Central Experiment Station at Pittsburgh, Pa.

To carry the hydrogenation processes for the production of oil and gasoline toward commercial utilization, demonstration plants are to be built to furnish the necessary cost and engineering data for the development of a synthetic-liquid-fuels industry. New equipment and methods devised in the research and development program can thus be tested on a larger scale.

An extended study of some 206 proposed locations in 21 coal-producing States was made to select a plant site.77/ When it became apparent that some of the Government-owned synthetic-ammonia plants used in the production of munitions during the war would be closed down, it was decided that one of these would provide an ideal location. The War Department, acting through the Quartermaster-General, has made the synthetic-ammonia plant at Louisiana, Mo., available to the Bureau of Mines. The acquisition of this plant will result in a material saving in construction costs and will greatly speed the demonstration-plant program, as general facilities are immediately available, as well as much specialized equipment that can be incorporated into the demonstration plant.

Preliminary-flow diagrams and plot plants are now being prepared for this plant. Initial design is based upon about 200 barrels of oil per day, a figure that may be modified materially.

Reaction of Natural Gas and Steam

To evaluate proposals by industrial engineering companies to design and construct equipment for use by the Division at Bruceton, Pa., for synthesis-gas and hydrogen production, a study was made of the uncatalyzed natural gas-steam reaction. The proposed process was to heat the natural gas-steam mixture in a "pebble" furnace, in which alundum-clay spheres 1/2 inch in diameter are preheated by combustion of natural gas and then passed into the reaction vessel, where they transfer their heat to the

76/ Fieldner, Arno C., Liquid Fuels from Sources Other than Petroleum. Statement in Investigation of Petroleum Resources (New Sources of Petroleum in the United States, Hearings before a Special Committee Investigation Petroleum Resources, United States Senate, 79th Cong., June 19, 20, 21, 22, and 25, 1945, pp. 336-349).
Fieldner, Arno C., Synthetic Liquid Fuels Program: National Petroleum News, vol. 37, No. 36, sec. 2, Sept. 5, 1945, pp. R-709-15.

77/ Unpublished report of the Secretary of the Interior to the 79th Cong. on the Synthetic Liquid Fuels Act from Jan. 1, 1945, to Dec. 31, 1945.

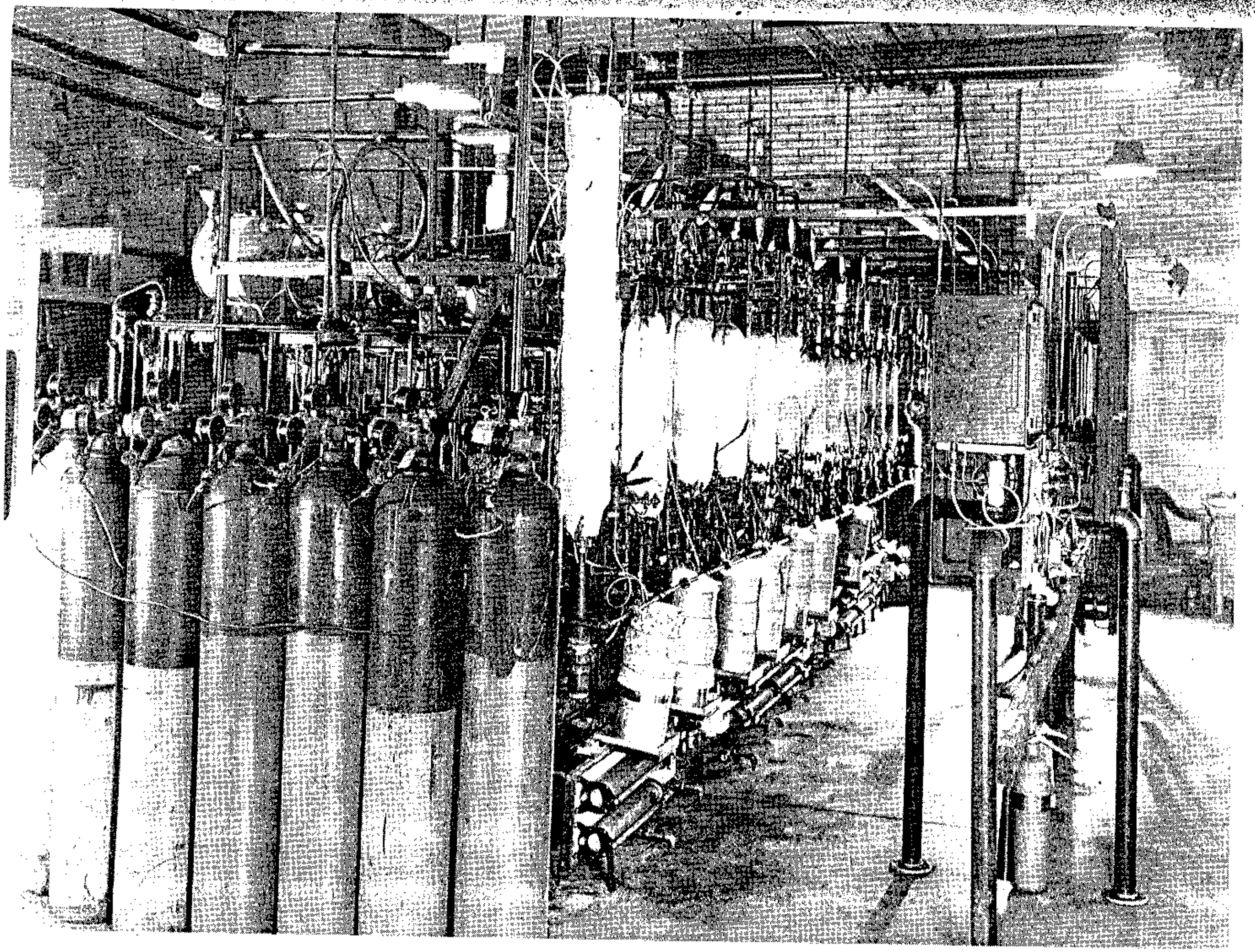

Figure 26. - Fischer-Tropsch catalyst testing units.

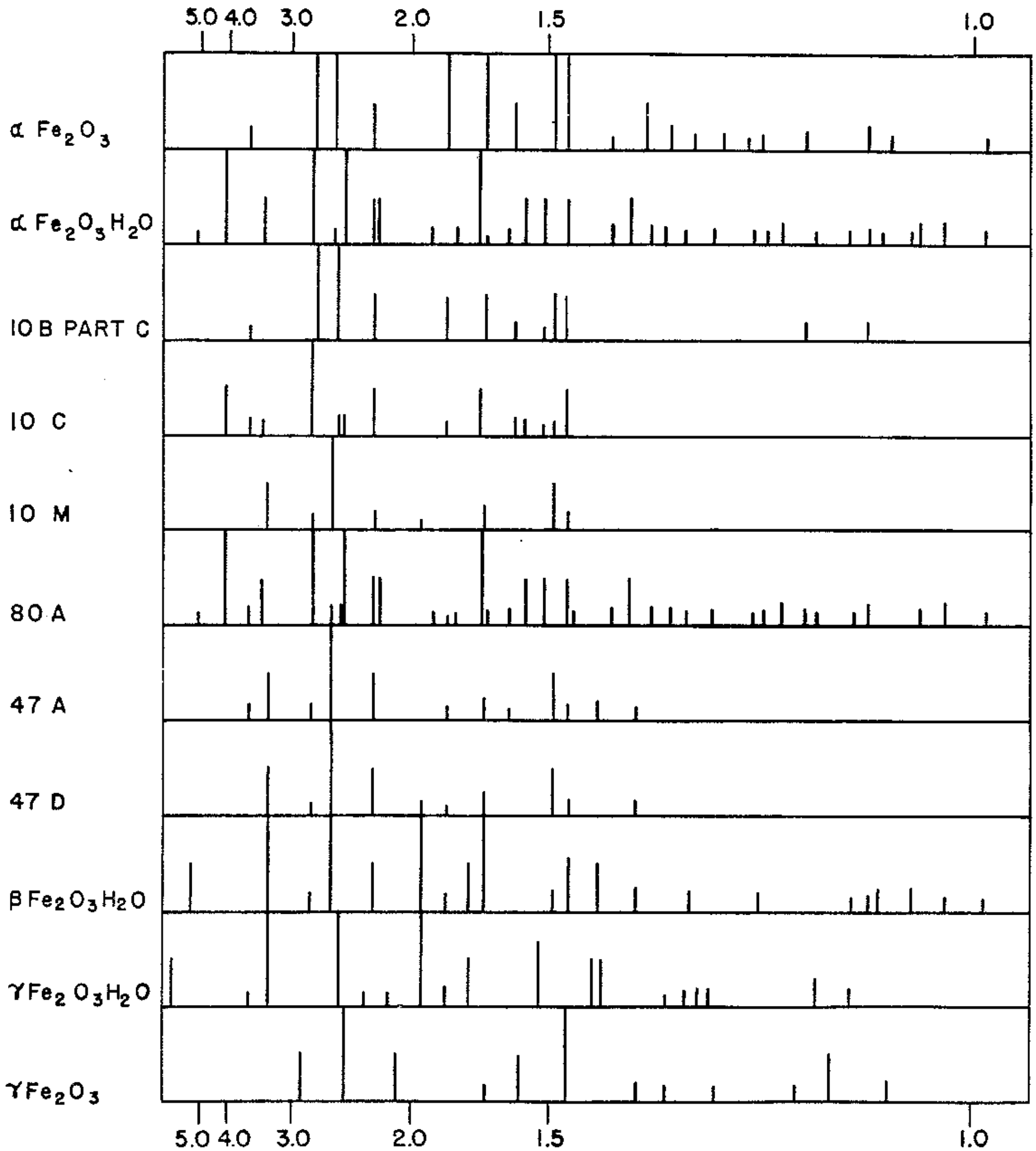

Figure 27. - X-ray diffraction powder patterns of various iron Fischer-Tropsch catalysts and the crystalline ferric oxides and ferric-oxide hydrates.