A major objective of future experiments should be to decrease underground heat losses, possibly by increased production rates, simultaneous operation of several units located close together, and control of water inflow.

TABLE 5. - Gasification with oxygen, operating results with electrolinked boreholes XVI-XVII

Operating time......hr.	36
Oxygen input rate......c.f.m.1/	604
Effluent gas rate......do.1/	1,335
Properties of effluent gas	
Analysis, percent:	
Carbon dioxide......	47.8
Illuminants......	0.3
Oxygen......	0.2
Hydrogen......	24.5
Carbon monoxide......	21.2
Methane......	4.1
Nitrogen......	1.9
Heating value......B.t.u. per cu. ft.1/	195
Specific gravity......	1.0
Moisture content......mol of water per mol of dry gas	0.34
Oxygen:	
Cu. ft. per M cu. ft. of make gas......	452
Cu. ft. per M cu. ft. of ($CO + H_2$)......	990
Cu. ft. per million B.t.u. in the product gas......	2,320
Rate of coal utilization, basis of moisture- and ash-free coal, tons per day:2/	
a. Completely gasified3/......	33.1
b. Carbonized only......	0

1/ At 60° F., 30 in. Hg, dry.
2/ Calculated from material balance.
3/ This is fresh coal plus coke from previous gasification with air, all calculated as equivalent coal.

Field-Scale Test of Hydraulic Fracturing to Prepare a Coal Bed for Gasification

A hydraulic process called "Hydrafrac," developed by the Stanolind Oil and Gas Company and used successfully for oil wells, was applied to a coal bed with the objective of hydraulically fracturing the bed and thus producing flow paths suitable for gasification.

The site chosen at Gorgas, Ala., was some 370 feet west of prior gasification workings (see fig. 26). A 9-inch hole was drilled to a point 18 inches within the America coal bed, which is 155 feet below the surface at this point.

A 4-inch steel casing was placed in the well, seated 6 inches above the bottom, and cement was pumped around the casing. The hole was then extended an additional 7-1/8 inches into the coal; this exposed for treatment a cylinder 3-7/8 inches by 7-1/8 inches, with the bottom of the cylinder 2 feet below the top of the coal bed.

TABLE 6. - Water-gas production, from electrolinked boreholes XVI-XVII (average operating results for 12 consecutive cycles)

	Air blow	Steam run
Average length of period....................hr.	18.8	4.2 (3.85 to 5.08)
Input rate, air........................c.f.m.1/	1,250	-
Steam............................lb. per hr.	-	1,200 to 2,100
Gas production........................c.f.m.1/	1,800	585
Properties of effluent gas		
Analysis, percent:		
Carbon dioxide...........................	12.6	20.8
Illuminants..............................	0.3	0.4
Oxygen...................................	0.3	0.4
Hydrogen.................................	13.4	47.9
Carbon monoxide..........................	10.4	12.0
Methane..................................	2.8	7.6
Nitrogen.................................	60.2	10.9
Heating value............B.t.u. per cu. ft.1/	112	279
Specific gravity.........................	0.92	0.62
Moisture content....mol water per mol dry gas	0.19	0.56

1/ At 60° F., 30 in. Hg, dry.

The "Hydrafrac" treatment was applied by the Halliburton Oil Well Cementing Company. The injection well first was treated with 500 gallons of kerosine (containing 5 gallons of an antiemulsification additive) at 250 gallons per minute with a pump pressure of 250 p.s.i. Next, 9,550 gallons of viscous residual fuel oil, containing 10 gallons of additive and 15,000 pounds of Ottawa-flint shot sand, was injected in 22-1/2 minutes at a pressure of 700 to 900 p.s.i. Finally, 4,040 gallons of kerosine was injected in 22 minutes.

After the injection well was completed and before the "Hydrafrac" treatment, compressed-air permeability tests had been made. Approximately 6 std. c.f.m. of air could be forced through the coal bed at an applied pressure of 65 p.s.i.g. After the treatment, 520 std. c.f.m. could be forced through the coal bed at 65 pounds pressure, approximately an 85-fold increase in permeability.

The extent of the fracture was determined by drilling holes to a point immediately above the coal bed, testing for airflow, completing the hole through the bed, and again testing for flow (see fig. 26). No evidence of fracture was found above the coal bed. In the coal bed definite airflows were noted at holes 150 to 650 feet from the injection well along the face cleats and 200 to 580 feet along the butt cleats.

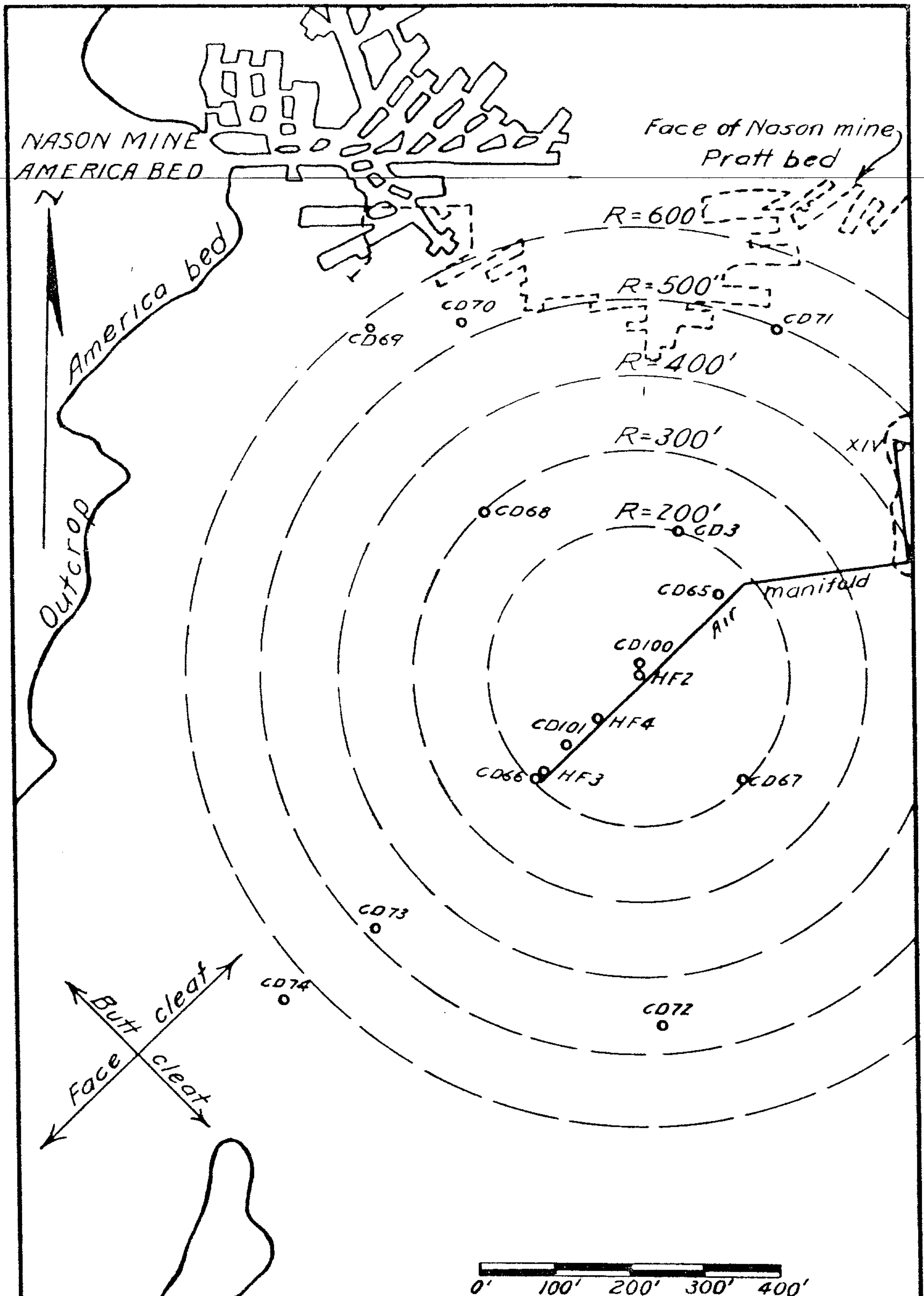

FIGURE 26. - Site of Hydraulic Fracturing Experiments.

A new hole was drilled 190 feet southwest of the injection hole along the face cleat line (see fig. 26), and the coal was ignited from a propane burner installed at the base of this hole. A path developed between this hole and one 10 feet to the southwest. Gasification was initiated admitting air at these two points and withdrawing the products at the injection well.

Although combustible gases were produced continuously throughout the test, the results indicated that it was impractical to establish a satisfactory reaction zone in a fractured coal bed by forward burning, with air being admitted behind the combustion zone and products withdrawn through the fresh coal ahead of the flame. Apparently the hot gases carried decomposition products such as tar downstream and deposited them in the fractures in the fresh coal, and the heat transferred induced swelling of the fresh coal. These two effects combined to plug the fractures. The increased resistance to flow necessitated higher air-input pressures, which in turn caused excessive leakage and poor recovery of products.

Backward burning (with the ignition front traveling against the direction of the airflow) has been used more recently to prepare gasification paths through the fractured coal bed. These tests have been satisfactory and indicate that hydraulic fracturing of a coal bed, followed by reaction-zone development by backward burning and gasification, holds promise of developing a successful process of underground gasification.

Some Problems in Underground Gasification

Underground gasification of coal is still in the early stages of exploration, and its practical usefulness in the United States has yet to be established. Further research would be necessary to determine which general process might be used for particular conditions and to develop details of operation.

The research so far has indicated some specific needs, such as for methods for passing air or other gasmaking fluids through the coal bed under conditions insuring close contact, so that excess oxygen would not be left to convert the CO produced to CO_2. Other variables affecting the quality and quantity of the gas produced, such as the proportion, rate, and duration of gasmaking fluids supplied, would require study.

Experimentation would need to extend beyond the high-volatile A bituminous coals so far tested in the United States, to find the adaptability of lower rank coals. For each site, prevention of leakage of gasmaking fluids and of the combustible products might present specific problems, and studies might be necessary on efficient design and simultaneous operation of series of underground gasification units.

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