

## ORIGIN OF PROGRAM

Readers of this report who have not referred to the two earlier reports<sup>1/</sup>, <sup>2/</sup> may be interested to know that the part of the Synthetic Liquid Fuels Extension Act of March 15, 1948 (Public Law 443, 80th Congress), which applies especially to the twofold program discussed in the following pages is an amendment to section 1, which reads as follows:

"..... and that not to exceed \$1,000,000 of the amount authorized by this Act may be applied to a program of production research on secondary recovery from stripper oil fields and in refining processes."

In the 1948 annual report of the Secretary of the Interior on Synthetic Liquid Fuels, which covered only the first 6 months of activity after funds became available, the several parts of the program relating to secondary recovery and petroleum chemistry and refining were described. These fitted admirably into the broad, continuing petroleum and natural-gas research objectives of the Bureau, which are to devise means to obtain more of these natural resources from underground reservoirs and to use them and their products more efficiently.

In selecting the problems, certain controls were kept in mind. These are briefly restated:

1. They were chosen to meet the program pattern stated in the amendment, namely, to deal with stripper oil fields and refining processes.
2. They were correlated with work already in progress directed toward these objectives but supported by other funds available to the Bureau of Mines.
3. They were chosen to meet recognized important needs of industry.
4. Duplication of the work of other research groups was avoided so far as possible.
5. The work was planned to smooth out peaks and valleys of activities that frequently occur when funds to support a given project are on a yearly basis, with no assurance of continuity.

The secondary-recovery research program made possible by the provisions of the act was conducted at the Petroleum Experiment Station, Bartlesville, Okla.; the Petroleum and Oil Shale Experiment Station, Laramie, Wyo.; the Petroleum Field Offices at San Francisco, Calif., Dallas, Tex., and Franklin, Pa., and the Wichita Falls, Tex., and Bradford, Pa., Suboffices. The chemistry and refining studies were conducted at Laramie, Wyo., and Bartlesville, Okla.

---

<sup>1/</sup> Synthetic Liquid Fuels, 1948 Annual Report of the Secretary of the Interior, Part IV. Secondary Recovery, and Petroleum Chemistry and Refining Research: Bureau of Mines Rept. of Investigations 4458, 1949, pp. 13-25.

<sup>2/</sup> Synthetic Liquid Fuels, Annual Report of the Secretary of the Interior for 1949, Part IV. Oil from Secondary Recovery and Refining: Bureau of Mines Rept. of Investigations 4654, 1950, pp. 1-26.

The general outline used in the report for last year is followed again, and the results of secondary-recovery research are presented first. This is followed by a discussion of the chemistry and refining research. Because of the consolidation of appropriation items in the appropriation act for fiscal year 1951, this research program on secondary recovery and chemistry and refining was removed from the Synthetic Liquid Fuels program and combined with the Bureau's oil and gas investigations to form a new unit known as "petroleum and natural gas." This change occurred on July 1, 1950, hence this report covers only the first 6 months of the calendar year and will be the last report on oil from secondary recovery and refining in this series.

## SECONDARY RECOVERY

In the beginning of the program and in conformance with the major controls, mentioned previously, an earnest effort was made to consider in the first progress report only those problems that received their main support from the specified Synthetic Liquid Fuels funds. This practice was soon abandoned because it was found that interrelations of various problems developed as the work progressed on different parts of the program and that the results of the research were of more importance than the source of the financial support. It soon became evident, therefore, that the whole integrated secondary-recovery program of the Bureau should be included in the scope of subjects treated to give a true picture of the accomplishments. This plan was followed in the report for the last year and is used again in this report, covering only the first 6 months of 1950.

A discussion of the separate problems follows in accordance with that format.

### Engineering Studies of Secondary-Recovery Fields

#### Mid-Continent (Bartlesville, Okla.)

Case histories of successful water-flooding projects serve as excellent guides for the development and operation of other similar projects. The Humboldt-Chanute field, in Neosho and Allen Counties, was one of the first in Kansas to attract the attention of water-flood operators. The Lynde, Walter, & Darby project was begun in December 1937. It is the oldest and largest secondary-recovery project in the field and covers over 1,020 productive acres. Other major projects are those of the Keas Drilling Co., Deep Rock Oil Corp., and Carl Weiner. At the end of 1949 there were 1,500 acres in the three major projects, and each of these was being extended rapidly. Present plans call for them ultimately to cover more than 3,000 acres. During 1949 these projects produced more than 450,000 barrels of oil; and, on the basis of the present trend of developments, it is estimated that they will produce 575,000 barrels of oil in 1950. Figure 1 shows the production history of the Lynde, Walter & Darby project. A report<sup>3/</sup> prepared in cooperation with the Kansas-Oklahoma oil-flood operators gives the case history of the four projects.

<sup>3/</sup> Joers, J. C., Grandone, Peter, and Taliaferro, D. B., Water Flooding in the Humboldt-Chanute Oil Field, Neosho and Allen Counties, Kans.: Pamphlet, 19 pp., 1950. Producers Monthly, vol. 14, No. 8, June 1950, pp. 12-21, 24-25. Petrol. Engineer (pub. in 2 parts), part I, vol. 22, No. 6, June 1950, pp. B-11, B-12, B-14, B-16 - B-18; part II, vol. 22, No. 9, August 1950, pp. B-56, B-57, B-60. Oil and Gas Jour. (pub. in 4 parts), part I, vol. 49, No. 8, June 29, 1950, pp. 60-62; part II, vol. 49, No. 9, July 6, 1950, pp. 46-48; part III, vol. 49, No. 10, July 13, 1950, pp. 82, 84, 86; part IV, vol. 49, No. 11, July 20, 1950, pp. 91-92, 97-98.

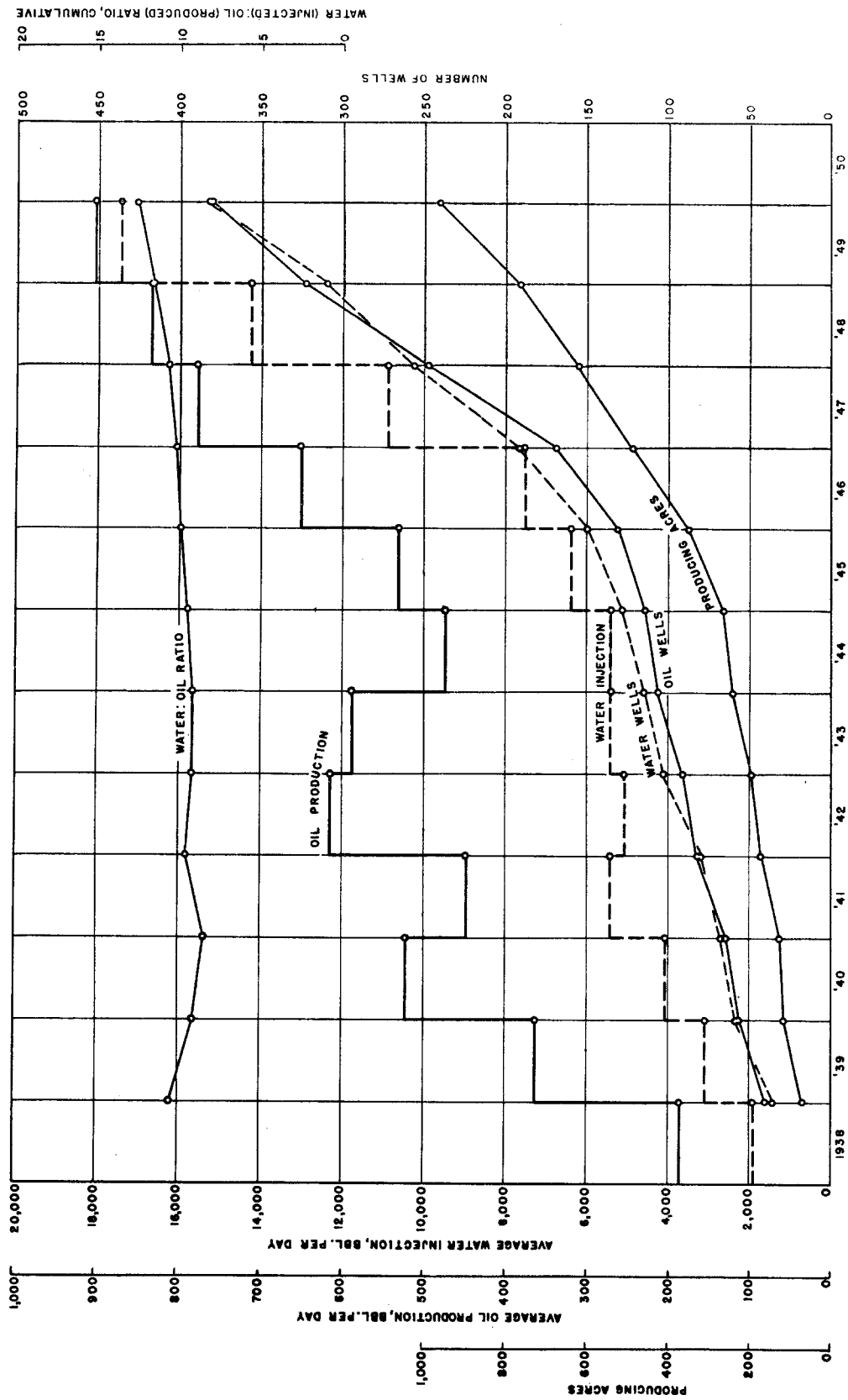


Figure 1. - Production history of Lynde, Walter & Darby water-flooding project.

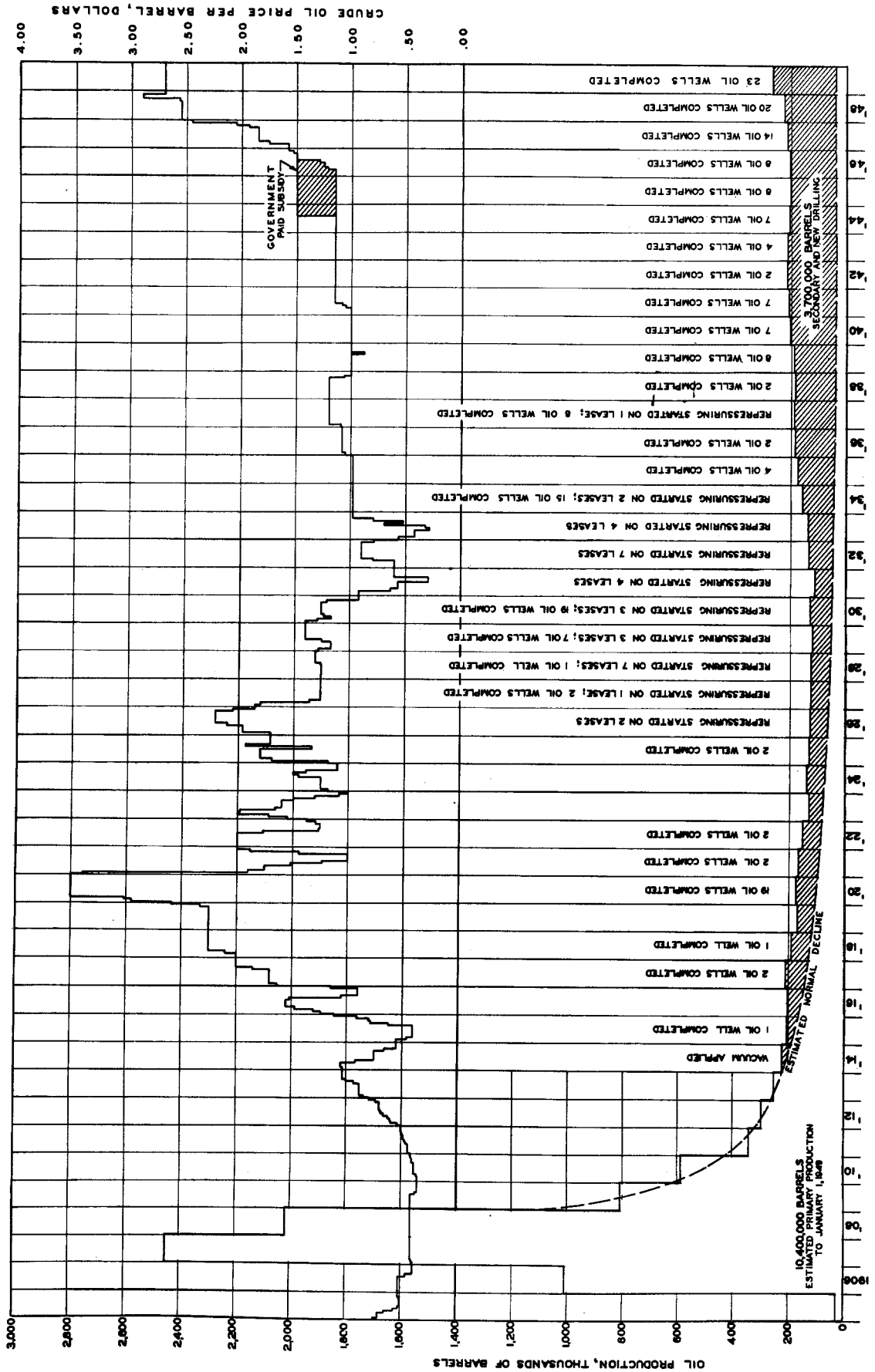


Figure 2. - Oil production by years and the average monthly price paid for a barrel of crude oil, Weber pool, Washington County, Okla.

Water-flooding operations in Oklahoma were originally concentrated in Nowata and Rogers Counties in the northeastern part of the State. Although the Bartlesville sand, which has been flooded successfully in these counties, extends westward into Washington and Osage Counties, the latter areas were neglected because the sand dips to the west and thus increases the development and operating costs. Recently Washington and Osage Counties have been the scenes of intensive water-flooding activities. One area has been particularly active in the Weber pool<sup>4/</sup> and has been studied by Bureau of Mines engineers. The Weber pool, discovered November 11, 1905, includes an estimated 2,700 productive acres. From date of discovery to 1949, it is estimated that 10,400,000 barrels of oil would have been produced from the Bartlesville sand in the Weber pool without the benefit of secondary-recovery operations. In addition, 3,700,000 barrels of oil were gained by applying vacuum, drilling new wells, injecting gas into the producing formation, and water-flooding operations. The application of vacuum in the latter part of 1914 retarded the decline in rate of oil production. In 1926 an operator in the northern part of the pool began to inject casing-head gas into the producing zone through two old oil wells. The resulting increase in the rate of oil production encouraged other operators to adopt this practice; and by 1937, 1,461 productive acres in eight projects were affected by gas repressuring. Approximately 3,000,000 of the 3,700,000 barrels of oil gained by secondary-recovery operations were gained as a result of repressuring operations on these eight projects. Acreage included in four of the repressuring projects was further developed in 1949 by water flooding. It is estimated that 41,000 barrels of oil were gained by January 1, 1950, as a result of water-flooding operations. The engineering study shows that the average oil saturation in the reservoir is high and that the field as a whole is well-suited for water flooding. It is estimated that the recoverable oil reserves in the field exceed 17-1/2 million barrels or nearly 25 percent more than was recovered in the 45 years since the field was discovered. Figure 2 shows the production history of the field to the end of 1949.

Intensive work has been done on the petroleum-engineering study of the 7,500-acre Healdton field, Carter County, Okla., to call attention to oil reserves in this area that may be recovered by secondary-recovery methods. The producing formations in this field are a complex series of lenticular sands, few of which have been flushed by a natural water drive. Gas injection has recovered additional oil on the few projects where it has been applied intensively, but the recent drilling of inside and edge wells has opened new sands to production and added valuable reservoir data. The mineral and liquid content, grain and pore size, permeability, and resistivity have been measured on cores taken during the recent drilling operations to aid in interpreting the reservoir conditions. Samples of produced water have been obtained from different areas and horizons to be used with production data in fixing the extent of natural and accidental water flooding. All data obtained indicate that there are appreciable petroleum reserves in this field that can be recovered by well-engineered water-flooding projects.

A survey of all water-flooding operations in Oklahoma is nearing completion, and a report on this work is being prepared. This report will present the production history of each of more than 180 water-flooding projects in 23 counties of the State. The report will contain many field maps, production curves, and tabulated data.

---

<sup>4/</sup> Johnston, Kenneth H., and Moot, C. W., Jr., Petroleum-Engineering Study of the Weber Pool, Washington County, Okla.: Bureau of Mines Rept. of Investigations 4740 (in press).

### Texas (Dallas and Wichita Falls)

The engineering study of the southwestern part of the K.M.A. field, Wichita and Archer Counties, Tex., was continued by Bureau of Mines engineers. This study was initiated at the request of the North Texas Oil and Gas Association. Considerable progress has been made in analyzing the K.M.A. reservoir, which covers an area of about 12,000 acres and is controlled by 60 oil companies. This comprehensive study is nearly complete; and, among other things, the report will discuss the feasibility of water-flooding the reservoir as a means of increasing the ultimate recovery.

### California (San Francisco)

A survey of current secondary-recovery operations in California oil fields (including 12 gas-injection projects and 4 water-injection projects) has been made, and the draft of a report for publication is nearly completed.

Fields selected for study were those that will best illustrate the principal problems facing secondary-recovery operations in California, to describe the techniques applied to solve these problems, and to indicate the results thus obtained. It was also desirable to obtain the most representative cross section of reservoir types and conditions possible. To this end, data were selected, assembled, and analyzed for fields in the San Joaquin Valley, Santa Barbara Coastal district, Ventura district, and Los Angeles Basin. These fields include oil-productive formations, typical of Upper Pliocene through Oligocene strata, ranging in depths from 1,400 to 11,000 feet subsea level and producing various black oils and gas-condensate fluids ranging from 19° to 60° A.P.I. gravity. Stimulative methods of production include water injection, waste-water disposal, pressure restoration by gas injection, and pressure maintenance by gas injection. The data pertaining to these projects are being assembled in final form and will be published as a Bureau of Mines Report of Investigations.

### Appalachian Region (Franklin, Pa.)

In the Appalachian region, where less than 20 percent of the crude-oil-productive area has been subjected to any type of secondary-recovery operation, it is highly important that operators know the probable chance of success and reward they may expect by initiating gas-injection or water-flooding operations. Almost all of the oil fields in the Appalachian region have been depleted to the extent that most of the oil-driving gas energy has been dissipated, although large quantities of oil remain in the sands. Thus, engineering field studies are particularly valuable in disseminating knowledge about the application of secondary-recovery methods in fields and the results obtained so this information can be used to advantage elsewhere in initiating new secondary-recovery projects.

The report of an engineering field study of secondary-recovery operations in the McDonald field in southwestern Pennsylvania, published last year,<sup>5/</sup> appeared this

---

<sup>5/</sup> Tignor, E. M., and Nabors, Wm. M., Secondary Recovery of Oil in the McDonald Field, in Southwestern Pennsylvania: Producers Monthly, vol. 8, No. 6, April 1949, pp. 20-26.

year<sup>6/</sup> in a second publication. Bureau of Mines engineers completed an engineering study of the Brenneman field, Hancock County, W. Va. This field was discovered in 1906; and the report<sup>7/</sup> is an engineering appraisal of the 348-acre field, its development, and operation from the date of discovery to that of probable abandonment. Estimates of the probable total volume of oil to be recovered and the quantity of oil remaining in the sand are also included in the report. Surface maps of the property and isopachous and contour maps of the sand are presented.

The engineering analysis shows that the cumulative oil produced in 17 years of primary-recovery operation amounted to 23.5 percent of the original oil in place; that, following a 3-year period of abandonment, 22 years of secondary-recovery operations utilizing gas drive raised the total production to 35.0 percent of the original oil; and that, with four additional years of operation, before probable abandonment and using the same production techniques, the total volume of oil recovered would amount to 35.5 percent of the oil originally in the reservoir. Furthermore, the oil saturation at the estimated abandonment date would be 45.9 percent of the total pore volume. The engineering appraisal indicates the possibility of recovering additional oil by water flooding from the Brenneman field.

Engineering field studies of three air-gas injection projects in the Oil City-Titusville (Pa.) area reached various stages of completion, and drafting of manuscripts has been initiated. An engineering field study of gas-injection operations in the Cabin Creek field near Charleston, W. Va., was completed and a report written.

#### Physicochemical Studies of Interfacial Forces in Relation to Oil Production

The study of interfacial-energy phenomena at solid-fluid interfaces has been attacked from three angles. First, a new method, mentioned in the last report of this series, has been developed that permits precise measurements of permeabilities of packed beds of sands and powders to flowing liquids. The results of permeability measurements made by the new method, a pressure-decline technique using liquids, agreed closely with values calculated from specific surface areas determined by precise quantitative microscopy techniques perfected as part of this work. Further work has demonstrated that the permeability of beds of fine powders to liquid vary with the nature of the flowing liquid. The second phase of the work is concerned with the effect of streaming potentials on the liquid permeabilities of beds of fine powders. A theoretical analysis of the phenomena involved has been made, and preliminary exploratory studies have been completed. An apparatus is being assembled for making precise measurements of streaming potentials. Other work is concerned with gas-adsorption measurements. An apparatus built for making these measurements will make it possible to determine specific surface areas of fine powders and to calculate free energies of adsorption for the solid-liquid systems used in the permeability research.

---

<sup>6/</sup> Tignor, E. M., and Nabors, Wm. M., Secondary Recovery of Oil in the McDonald Field, in Southwestern Pennsylvania, Part II, McDonald and Adjacent Oil Fields, Allegheny and Washington Counties, Pa.,: Bulletin M29, Pennsylvania Geological Survey Bull. M29, 4th. ser., 1949.

<sup>7/</sup> Tignor, E. M., Nabors, Wm. M., Jennings, Thomas, and Krause, Leon, Secondary Recovery of Oil by Air and Gas Injection in the Brenneman Field, Hancock County, W. Va.: Bureau of Mines Rept. of Investigations 4690, 1950, 26 pp.