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STATE GEOLOGICAL SURVEY OF KANSAS
Raymond C. Moore, State Geologist and Director
Kenneth K. Landes, State Geologist and Assistant Director

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SECONDARY RECOVERY OF PETROLEUM

Part I—Bibliography

By JOHN I. MOORE

BULLETIN 25

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(3)

FOREWORD

Petroleum and natural gas occupy such a prominent position among the mineral resources of Kansas that the State Geological Survey feels warranted in devoting a portion of its annual expenditures to oil and gas investigations.

Some of the problems which concern the petroleum industry can best be studied by the trained geologist, others by the skilled chemist or the chemical engineer, and still others by the petroleum engineer. In some instances the combined resources and ingenuity of all of these men will be required. Hence, the University becomes an ideal center in which such problems can be attacked with hope of ultimate solution.

Among the problems of special concern to the producers of oil and gas in the state of Kansas are the following:

(1) A broader market outlet for oil and natural gas.

(2) Production methods which result in maximum recoveries of both the oil and the gas.

(3) Development programs which will not require excessive or prohibitive capital expenditures (see Oil and Gas Jour., June 9, 1938, pp. 36-39; "Some Consequences of Close Spacing in Kansas," by Eugene A. Stephenson).

(4) Adequate well logs, pressure data, and well cuttings, which can serve as a basis for correlation and for the computation of oil and gas content per acre.

(5) Suitable bottom hole samples of the reservoir fluids (oil, gas and/or water) from which the properties of these fluids can be determined.

(6) The compilation and preservation of such information as the above so that future students, reasearch workers, industrial representatives, and others concerned will have available the essential data pertaining to the various oil and gas fields of the state, particularly those fields now under development or not yet discovered. The information of this character, which was not secured during the early development of Eastern Kansas, would be of tremendous value to operators who are now endeavoring to use secondary recovery methods in that portion of the state.

With these facts in mind the State Geological Survey, in co-operation with the Department of Petroleum Engineering and the Engineering Experiment Station, has instituted a program of research on Kansas oil and gas problems. The initial step in any research program involves a comprehensive survey of all the previous work which has been done in that particular field, so that (1) future studies will be free from unnecessary duplication, (2) contradictory results obtained by different investigators can be analyzed and possible reconciliations achieved, (3) the unexplored fields of research may become more sharply delineated, (4) the workers will be enabled to plan their own special fields of endeavor over a longer range of time, (5) the cost of the research may be minimized.

The following bulletin is the work of Mr. John I. Moore, research assistant in the Department of Petroleum Engineering, and petroleum engineer of the State Geological Survey. Mr. Moore has personally read and abstracted every article listed which could be secured within the various libraries at the University; a few which could not be obtained have been designated as "not available."

EUGENE A. STEPHENSON,
Head of the Department of Petroleum Engineering,
University of Kansas.

CONTENTS

SECTION I

Methods of Drilling, Sampling, Analyzing and Evaluating Cores

AMERICAN PETROLEUM INSTITUTE, 1935, October, Standard Procedure for Determining Permeability of Porous Media, Code No. 27, first edition.

Contains definitions, theory, measurements and calculations, laboratory procedure, sample calculations, tables showing variation of viscosity of water and air with temperature, and conversion factors.

The design of apparatus and choice of fluid is left to discretion of individual laboratory; air, however, is recommended.

ANONYMOUS, 1937, February, Coring and Its Applications in Modern Petroleum Prospecting: Petroleum Engineer, Vol. 18, No. 5, pp. 162-71.

Description of coring methods, rotary core bits and barrels, cable-tool core barrels, formation testers, and sidewall sampling devices.

*ATHY, L. F., 1930, Density, Porosity, and Compaction of Sedimentary Rocks: Am. Assoc. Petroleum Geologists Bull., Vol. 14, No. 1, pp. 1-24.

An efficient laboratory method of obtaining the bulk volume of a chunk sample of rock is explained. The relation between depth of burial and the density, porosity, and compaction of different types of sediment is discussed, and data are presented. These relations can be expressed by exponential equations. Compaction as a cause of structure is substantiated by computation and data. A table is given showing the relation in north-central Oklahoma between depth of burial, height of buried hills, and closure resulting from compaction. An approximate idea of the thickness of material eroded from a given area may be obtained by density or porosity studies.

BARB, C. F., 1930, Porosity-Permeability Relations in Appalachian Oil Sands: Penn. State College Mineral Exp. Sta. Bull. 9, pp. 47-59.

A relationship was found to exist between porosity and permeability for the Pennsylvania sands. Grain size affects this relationship so that normally porosity alone cannot be used as an index of rate of fluid travel in the sand.

The effect of pressure, the quality of the water, and oil-wet sand, were studied.

BARNES, K. B., 1931, A Method for Determining the Effective Porosity of a Reservoir Rock: Penn. State College Mineral Exp. Sta. Bull. 10, 12 pp.; Oil Weekly, Vol. 60, No. 13, pp. 70-78.

Devised method for obtaining effective porosity with Russell porosimeter. Permeabilities, photomicrographs, thin sections, etc., can be obtained on same sample.

Bibliography of porosity methods.

NOTE.—Articles marked by an asterisk (*) are abstracted in the Annotated Bibliography of Economic Geology, published by the Society of Economic Geologists, Urbana, Ill. In most cases the abstract given in the Annotated Bibliography is reprinted here.

BARNES, K. B., 1932, Preliminary Experiments in Oil Recovery: Penn. State College Mineral Exp. Sta. Bull, 11, pp. 71-92.

Devised apparatus for determining permeability of cores to either gas or liquid.

Experiments show: Recovery obtainable by water flooding to be 40-45 percent from Bradford and 30-35 percent from Venango sands; hot-water flooding is effective if viscosity-temperature coefficient of the oil is high; sodium-soap solutions are effective recovery agents but difficult in operation; solutions of the carbonate, silicate, and hydroxide of sodium do not increase effectiveness; mixtures of sodium-soap and carbonate solutions are best driving agents, lowering the final saturation of the oil. The latter solution, however, will form a precipitate with calcium or magnesium and plug up the sand.

BARNES, K. B., 1935, August 8, Oil Bearing Formation, Character, Yield, Vital Data on Repressuring: Oil and Gas Jour., Vol. 34, No. 12, p. 31.

Porosity, permeability, and oil saturation need to be known before advisability of repressuring can be determined. A mineralogical study of thin sections of the sand is desirable, as well as a knowledge of the composition and texture of the sand.

BARNES, K. B., 1936, Porosity and Saturation Methods: Am. Petroleum Inst., Drilling and Production Practice, p. 191.

Prefacing his paper with a brief statement regarding the application of porosity, saturation, and permeability tests of cores to old and new fields, the author described the taking of cores, and various methods of laboratory analysis, identifying the retort method as the preferred method for making saturation tests. Several methods for determining porosity were described; typical calculations included, with comments on interpretation of results.

BOTSET, H. G., 1931, Feb., The Measuring of Permeability of Porous Alundum Discs for Water and Oils: Rev. Scientific Instruments, Vol. 2, No. 2, pp. 84-96.

If the crude used contained no unsaturated hydrocarbons, or the experiments were carried on in the absence of oxygen, the rate of flow of a crude in the presence of an illuminating gas was found to be practically constant. Permeability measurements with water were open to doubt, because of hydrolysis of the glass with which it was in contact.

BOTSET, H. G., 1938, A Method for Determining the Water Content of Sands; Am. Inst. Min. Met. Eng., Tech. Pub. 972; Petroleum Technology, Vol. 1, No. 3, August.

Water content of cores obtained by extracting oil from a crushed core with CCl_4, adding a known quantity of absolute alcohol and titrating with water until the solubility of water in the solution is exceeded, at which point cloudiness appears.

Detailed procedure, calibration curves, and results of test experiments are given. An accuracy of 92-95% was obtained with fresh water; brines, however, gave too low a value, the deviation being about 11%, and approximately equal to the volume of the salt content of the brine.

Principal advantages are the low cost of necessary equipment and the speed (about 15 minutes are required).

BRANKSTONE, H. R., SMITH, W. O., and GEALY, W. B., 1932, Sept., Improved Technique for Determination of Densities and Porosities: Am. Assoc. Petroleum Geologists Bull., Vol. 16, No. 9, pp. 915-923.

Russell's procedure is modified to eliminate various errors involved in direct, grain, and bulk volume measurements. Samples were coated with celluloid to prevent mercury from entering the pores.

BRAUCHLI, R. W., 1933, June 1, Statistical Analysis of the Relationship Between Recovery and Characteristics of Well Cores: Oil and Gas Jour., Vol. 32, No. 2, pp. 12, 69.

Data on recovery of cores from the formations in the Oklahoma City field. Limestones and dolomites yielded smaller recoveries than other rocks. A larger percentage recovery was obtained from the larger diameter cores.

BROWN, E. C., 1925, Basket Core Barrel, Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 62-4.

Describes, illustrates, and lists outstanding features of core barrel made from scrap casing in the field.

BUNTING, E. N., and WASHBURN, E. W., 1922.

See WASHBURN.

CAMPBELL, J. H., and LEWIS, J. A., 1938, July 25, Core Analysis Application to Well Completion, Oil Weekly, Vol. 90, No. 7, pp. 45-6, presented before Ind.-Ill. Pet. Conf., June 4, 1938.

Core analyses, when obtained in the field, can be applied to well completion by giving the operator:

(1) Production characteristics of formation profile.
(2) Approximate gas-oil ratio when producing from certain sections.
(3) Qualitative productive capacity of various zones.
(4) Actual productive capacity of oil zones deficient in gas.
(5) Gas-oil and water-oil contacts.
(6) Spacing program adaptable to future secondary recovery operations.
(7) Estimates of total oil reserves and net recoverable oil.

It was clearly pointed out that under conditions of sampling flush producing horizons, the core, when received, actually contained the oil that would remain unrecovered after gas and water drive had taken place.

CASE, J. B., 1922, Notes on the Use of Core Barrel with Rotary Tools: California Oil Fields, Vol. 7, No. 9, pp. 5-7.

Cites instances where the core-barrel became overheated to such an extent that the cores were fused.

CLARK, L. V. W., 1938, Core Drilling: Science of Petroleum, Vol. I, pp. 39-443.

Both rotary and standard core drills described.

CLARK, L. V. W., NASH, A. W., NISSAN, A. H., WOOD, C. E., 1938, July.

See NISSAN.

* CLARK, S. K., DANIELS, J. I. and RICHARDS, J. T., 1928, January, Logging Rotary Wells from Drill Cuttings: Am. Assoc. Petroleum Geologists, Bull., Vol. 12, No. 1, p. 59.

Because of the increased use of rotary drilling in Oklahoma, the collection of cuttings is necessary in order to prepare a satisfactory log. Settling devices have been found most effective in obtaining samples, which, of course, must be washed free of rotary mud.

Steel line measurements of the drill pipe are necessary, and where drilling is slow, the lag in return of cuttings to the surface must also be considered. In the latter part of the article the methods of examining and interpreting samples are outlined.

* CLAYPOOL, C. B., and HOWARD, W. V., 1928, Dec., Method of Examining Calcareous Well Cuttings: Am. Assoc. Petroleum Geologists, Bull., Vol. 12, No. 12, pp. 1147-1152.

The necessity of making quantitative mineralogical analyses of calcareous cuttings led to the development of a rapid method for the determination of the quantities of calcite and dolomite in material of this kind. The method is essentially centrifuging in heavy solutions.

* CLOUD, W. F., 1928, Sampling and Coring in Prospecting for Oil and Gas: Oklahoma Acad. Sci., Univ. Oklahoma, Bull. 410, Proc. 8, p. 128.

Samples of underground formations were secured (1) by using the diamond drill, (2) by collecting bit cuttings from a cable tool or rotary drilled well, or (3) by the use of various coring devices, or core barrels which were available. Correct examination of these samples involves not only the identification of the fluid content of the strata but also the determination of the lithological properties, such as percent of pore space, percent of saturation, and permeability.

CLOUD, W. F., 1930, Sept. 12, Physical and Chemical Characteristics of Oil Sands: Oil Weekly, Vol. 58, No. 13, pp. 40-2, 92.

A discussion of reservoir rocks.

CLOUGH, K. H., 1936, The Evaluation of Oil-Bearing Cores: Oil Weekly, Vol. 82, No. 1, pp. 67-9.

Describes equipment and method for obtaining complete core analysis.

CLOUGH, K. H., 1936, Sept. 28-Nov. 2, A Study of Permeability Measurements and Their Application to the Oil Industry (6 parts): Oil Weekly, Vol. 83, Nos. 3, 4, 5, 6, 7, 8.

Theory, design, calibration, and calculations for use of permeability apparatus explained. By ignoring minor temperature and barometric pressure changes in the laboratory, permeability charts may be drawn shortening time required immensely.

COBERLY, C. J., and STEVENS, A. B., 1933, Development of a Hydrogen Porosimeter: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 261-9; Oil Weekly, January 23, Vol. 68, No. 6, pp. 17-22.

The design, calibration and use of a porosimeter wherein the pressure change, which occurs when hydrogen is expanded into a chamber of known volume

containing the sample, is used to calculate the volume of the sand grains. The total volume is obtained by displacement of mercury from a pycnometer, and the percent void space calculated.

COOMBER, S. E., 1938, The Porosity of Reservoir Rocks: Science of Petroleum, Vol. I, pp. 220-3.

Character of various types of reservoir rocks and methods of determining porosity discussed.

COPELAND, W. A., and FETTKE, C. R., 1931.
See FETTKE.

CORWIN, W. S., 1936, June 15, The Permeability of Sands in Relation to Increased Recovery: Oil Weekly, Vol. 82, No. 1, pp. 58-62.

Discusses the relation of permeability to flooding in a number of properties.

* DANIELS, J. I., CLARK, S. K., RICHARDS, J. T., 1928.
See CLARK.

DAVID, M. W., and HOWARD, W. V., 1936, November.
See HOWARD.

DEWEES, E. J., JOHNSON, T. W., and TALIAFERRO, D. B., JR., 1937, Sept.
See TALIAFERRO.

DUNLAP, E. N., 1937, Influence of Connate Water on Permeability of Sands to Oil: Am. Inst. Min. Met. Eng., Tech. Paper 874.

Unconsolidated sand cores were saturated with water and displaced with kerosene under various rates of flow. Data show that where the water saturation exceeded 15 percent of the pore volume, the permeability decreases rapidly; and that it is possible to produce 100 percent oil from unconsolidated sands containing water saturation as high as 50 percent.

EDSON, F. A., 1926, Diamond Drilling with Special Reference to Oil Field Prospecting and Development: U. S. Bur. Mines, Bull. 243, 170 pp.

Describes equipment, operations and applications of the diamond core drill, and the use and preservation of cores.

ELLIOTT, J. E., 1925, The Elliott Core Drills: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 58-61.

Description and advantages of the double-barrel drills.

FASH, R. H., 1934, February, Analyses of Woodbine Cores for Presence of Salt Water: Am. Assoc. Petroleum Geologists, Bull., Vol. 18, p. 265.

Two instances cited where chloride content of water produced from a sand exceeded that obtained from a core analysis.

FETTKE, C. R., 1926, Core Studies of the Second Sand of the Venango Group from Oil City, Penn.: Am. Inst. Min. Met., Petroleum Dev. and Tech., pp. 219-30.

Analyses of core discussed under preliminary treatment, mineralogical and chemical composition, porosity, screen analyses, and oil and water content.

FETTKE, C. R., 1929, Core Studies of the Bradford Sand from the Bradford Field, Penn.: Am. Inst. Min. Met. Eng., Petroleum, Dev. and Tech., pp. 221-39.

Discussion of methods of coring, oil content, mineralogical and chemical composition, porosity, and the size and shape of the sand grains.

* FETTKE, C. R., and COPELAND, W. A., 1931, Permeability Studies of Pennsylvania Oil Sands: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 329-37.

Results obtained from a study of 18 samples showed porosity to be a more important factor in determining relative permeability than grain size, although grain size must also be considered. Equally important were grain size distribution, grain shape, packing, and degree of cementation, all of which had an important bearing on porosity and were reflected in it.

FISHELL, V. C., 1935, Further Tests of Permeability with Low Hydraulic Gradients: Am. Geophysical Union Trans., Part 2, pp. 499-503.

Tests showed Darcy's Law to hold good down to 2-3-inch gradient per mile and indicate it holds good indefinitely.

* FRASER, H. J., 1931, July, Sampling Incoherent Sands for Porosity Determinations: Am. Jour. Sci., Vol. 22, pp. 9-17.

The author cuts a trench in wet sand around the four sides of a two-inch cube of undisturbed sand. The cube is then lifted with a trowel, trimmed clean with a knife, and is then transferred to a dipper and immersed in melted paraffin. The paraffin coating protects the sample for transfer to the laboratory. Fine-grained dry sand may be wet with water and then collected as above. Coarser sand may be impregnated with hot paraffin and collected as a coherent sample.

FRASER, H. J., 1935, Experimental Study of the Porosity and Permeability of Clastic Sediments: Jour. Geol., Vol. 43, No. 8, Pt. I, pp. 910-1010.

Factors controlling porosity and permeability of ideal clastic materials evaluated; modifications caused by natural conditions determined; depositional effects on local permeability, relative permeability of unconsolidated sediments, and the effect of compaction, cementation, and recrystallization studied. The principles governing the flow of fluids through unconsolidated clastic materials are applied to the flow of hydrothermal solutions in an attempt to explain and predict the distribution and localization of hydrothermal mineral deposits.

FRASER, H. J., and GRATON, L. C., 1935.
See GRATON.

FURNAS, C. C., 1928, The Relation Between Specific Volume, Voids, and Size Composition in Systems of Broken Solids of Mixed Sizes: U. S. Bur. Mines Rept. Inv. 2894, 10 pp.

The smallest percentage of voids possible in a bed of closely packed, uniform size spheres is 30.2 percent, regardless of size, and is independent of the size of the individual particles. This is not true of mixed sizes. Graphs and calculations presented.

GARDNER, J. H., 1936, Feb. 6, Type of Well to Expect Determined by Kind of Extra Gas or Fluid in Core: Oil and Gas Jour., Vol. 34, No. 38, p. 15.

Stresses point that displacement may have taken place in formation and that core analysis showing both absorbed and adsorbed gas and fluids may lead one astray.

GEALY, W. B., 1929, Use of Mercury for Determination of Volume of Rock Specimens in Russell Porosity Apparatus: Am. Assoc. Petroleum Geologists, Bull., Vol. 13, pp. 677-82.

Suggests substitution of mercury for acetylene tetrachloride in Russell apparatus. Reduces time required, error due to temperature change, and requires no paraffin coating in determination of total volume.

GEALY, W. G., BRANKSTONE, H. R., and SMITH, W. O., 1932.
See BRANKSTONE.

GRATON, L. C., and FRASER, H. J., 1935, Systematic Packing of Spheres, With Particular Relation to Porosity and Permeability: Jour. Geol., Vol. 43, No. 8, Pt. I, pp. 785-909.

Geometrical arrangements of uniform spheres were studied and the relationship of permeability to porosity sought. The formulae of Slichter and of Fair and Hatch were found to yield only approximations, because of deficient regard for details of and effects of void geometry. The effects of void geometry on capillary phenomena were discussed.

GUENTER, E. A., 1936, July, Cable Tool Coring in Flooding Operations: Petroleum Engineer, pp. 62, 67-9.

Describes technique of coring with cable tools.

HARRIS, S., PLUMMER, F. B., and PEDIGO, Wm.
See PLUMMER.

HASSLER, G. L., 1938, The Measurement of the Permeability of Reservoir Rocks and Its Application: Science of Petroleum, Vol. I, pp. 198-208.

Revised methods for determination and use of dry permeabilities and grain analyses discussed.

The permeability, as defined, based on viscous flow of a single fluid, is only a relative figure when applied to oil fields where turbulent flow and where mixtures of oil, gas and water exist. Turbulent flow in porous rock, the effect of presence of liquid on the permeability to gas, the shape factor in mathematical analyses of oil-flow problems, and an analytical treatment of polyphase flow are discussed.

HEDBURG, H. D., 1937, Evaluation of Petroleum in Oil Sands by Its Index of Refraction: Am. Assoc. Petroleum Geologists Bull. Vol. 21, No. 11, pp. 1464-76.

Methods of determining refractive indices and relationship with specific gravity data discussed. Recommends that it supersede specific gravity as method of grading oils. Particularly advantageous since only minute quantity of oil is needed. It could therefore be used in preliminary evaluation of oil in cores. It is valuable in identifying oils and correlating horizons between wells.

HEYL, G. R., and HONESS, A. P., 1932.
See HONESS.

HILL, E. S., 1935, Methods of Determining the Oil Saturation of Oil Sand Samples: Pennsylvania State College Mineral Exp. Sta. Bull. 19, pp. 41-66.
Accuracy and correction factors for analyses of oil and water content of cores by the extraction and retort methods determined. The loss in weight extraction method is more desirable for research or valuation purposes, but requires more time than the retort method, which gives a relative oil content of the sand, sufficient for controlling operations.

HILLIS, DONUIL, 1937, Colorimetric Method of Determining Percentage of Oil in Cores: Am. Assoc. Petroleum Geologists Bull., Vol. 21, No. 11, pp. 1477-85.
To assist in deciding which sands should be tested in a zone where saturation varies, a small uniform sample of the oil sand and a solvent are placed in a sample botle, and, after shaking, the color of the solvent compared to samples of known concentration.

HONESS, A. P., 1930, Study of Microscopic Character of Pennsylvania Oil Sands with Special Reference to Porosity Determinations: Penn. State College Mineral Exp. Sta. Bull. 9, pp. 27-46.
Reports, size, shape, composition, cementing material, effect of heating on porosity, and effect of time on heating Pennsylvania oil sands.

HONESS, A. P., and HEYL, G. R., 1932, Further Observations on Temperature-Porosity relations in oil-sands: Penn. State Coll. Min. Exp. Sta. Bull. 11, pp. 93-105.
When baking sands, prior to porosity determinations, they should not be heated above 110° C. Averages of samples studied show an exaggerated porosity of 4% at 200° C., 9% at 300° C., 18% at 500° C., and 26% at 600° C., and 42.4% at 800° C.

HORNER, W. L., 1935, April, Demonstration of the Oil Content of Sands for Water-Flooding: Petroleum Engineer, Vol. 6, No. 7, pp. 33-35.
After investigation of several methods, distillation by the retort method is recommended.

HORNER, W. L., 1935, July 1, Contamination of Cores by Drilling Fluid Estimated by Dissolving Simple Chemicals in Mud: Oil Weekly, Vol. 78, No. 3, p. 29.
Recommends addition of normal or iso-propyl alcohol to drilling fluid to discover contamination in cores. Acetone and arsenic acid also used experimentally. Any chemical reacting with salts in brine or selectively adsorbed on sand should not be used; therefore, dyes are excluded. Discourages estimates of water contamination based on salt content of core.

* HORNER, W. L., 1936, June 1, Core Analyses as a Control to Well Completion: Oil Weekly, Vol. 81, No. 12, pp. 31-36.
Discusses the information obtainable from cores, and methods of analysis.

HORNER, W. L., and LEWIS, J. A.
See LEWIS.

HORNER, W. L., and LEWIS, J. A., 1936.
See LEWIS.

HOWARD, W. V., and CLAYPOOL, C. B.
See CLAYPOOL.

HOWARD, W. V., and DAVID, M. W., 1936, Nov., Development of Porosity in Limestones: Am. Assoc. Petroleum Geologists Bull., Vol. 20, No. 11, p. 1389.

The continuous porosity possessed by limestone reservoirs is developed mainly by solution in acids resulting from the bacterial decomposition of organic matter and by carbon dioxide formed during these processes. Porosity is shown to be of three types, namely equi-solution, channel, and cellular. In the development of these types of porosity, the composition of the rock and arrangement of mineral grains is important. Reactions taking place within the reservoir, both prior and subsequent to the entrance of oil, may result in the formation of much secondary calcite. The effect of this material upon the results of acid treatment, and also that of the insoluble residues released, are touched upon briefly.

JOHNSON, T. W., DEWEES, E. J., TALIAFERRO, D. B., 1937, September.
See TALIAFERRO.

JONES, P. H., and PYLE, H. C., 1936.
See PYLE.

KECK, W. E., OLDRIGHT, G. L., and SULLIVAN, J. D., 1930.
See SULLIVAN.

KRAUSE, L., and POWELL, G. N., 1937, Feb. 1, Core Analyses Valuable in Water Flooding Work: Oil Weekly, Vol. 84, No. 8, pp. 36-8.

Discusses methods of obtaining and applications of sampling, oil content, permeability, porosity, and oil saturation data; drilling costs are estimated.

KRESTOVNEKOV, W. N., and SILBERMINZ, W. A.
See SILBERMINZ.

* KRUMBEIN, W. C., 1935, Thin-Section Mechanical Analysis of Indurated Sediments: Jour. Geol., Vol. 43, No. 5, p. 482.

The writer discusses a method of mechanical analysis without separating the rock into its component grains. Check analyses on St. Peter sandstone and a glacial sand show that the range of error, average grain size and other statistical measures are within the limits permissible for mechanical analysis. The necessary mathematical theory to establish correction factors is given in an appendix.

KRUTTER, H. M., 1936, July 16, Nomographs for the Calculation of Permeability: Oil and Gas Jour., Vol. 35, No. 9, pp. 40-3, 48.

Three nomographs for rapid calculations of permeability.

LEVINE, J. S., and YUSTER, S. T., 1938, May 23.
See YUSTER.

LEWIS, J. A., and CAMPBELL, J. H., 1938, July 25.
See CAMPBELL.

LEWIS, J. A., and HORNER, W. L., 1936, Interstitial Water Saturation in Pore Space of Oil Reservoirs: Oil Weekly, Vol. 83, No. 6, p. 36; Geophysics, Oct. 19, 1936, p. 353.

The core analysis of a well, cored with oil as a fluid, checked with four adjacent wells cored with water in the hole. Interstitial water was found to be distributed throughout the complete sand section, indicating that a definite oil-water contact did not exist, and that water production is not necessarily derived from a definite water strata or structural position.

LINDTROP, N. T., and NIKOLOEFF, V. M., 1929, Oil and Water Content of Oil Sands, Grozny, Russia: Am. Assoc. Petroleum Geologists Bull., Vol. 13, pp. 811-22.

Based on Grozny sands, authors found 5-7% of strata contain connate water, 5-7% retain oil, 12½% produce oil, and 63½%-77½% are sand; air porosity is 25%. Experimental procedure: Dry sand was soaked with water, flooded with oil and then again flooded with water.

LYNTON, E. D., 1937, May, Laboratory Orientation of Wall Cores by Their Magnetic Polarity: Am. Assoc. Petroleum Geologists Bull., Vol. 21, No. 5, pp. 580-615.

Description of instruments, methods, magnetic deviation, and deflection curves.

MACGEE, A. E., 1926, Several Gas Expansion Porosimeters: Am. Ceramic Soc. Jour., Vol. 9, p. 814.

Not available.

MAY, D. T, and RYDER, H. M., 1938.
See RYDER.

McCURDY, R. C., TICKELL, F. G., and MECHUM, O. E.
See TICKELL.

* McQUEEN, H. S., 1931, Insoluble Residues as a Guide in Stratigraphic Studies: Mo. Bur. Geol. and Mines, Reprint of App. I, 56th Bienn. Report.

Insoluble residues of limestones in the Cambrian and Ordovician section in the Ozark mountains have been found to possess definite characteristics which render the correlation of drill samples possible over long distances. These characteristics result from silicification or dolomitization of the limestone, or from the admixture of certain types of clastic material.

MECHUM, O. E., TICKELL, F. G., and McCURDY, R. C.
See TICKELL.

* MEINZER, O. E., 1934, June, Permeability: Am. Geophysical Union, 15th Ann. Meeting, Trans., Pt. II, p. 316, Nat. Res. Council, Washington.

Discusses units used to express coefficient of permeability.

MELCHER, A. F., 1921, Determination of Pore Space of Oil and Gas Sands: Am. Inst. Min. Eng. Trans., vol. 65, pp. 469-497.
Detailed description of method and derivation of formula; considerable porosity data.

MELCHER, A. F., 1925, Apparatus for Determining the Absorption and the Permeability of Oil and Gas Sands for Certain Liquids and Gases Under Pressure: Am. Assoc. Petroleum Geologists Bull., Vol. 9, pp. 442-450.
Description of apparatus.

MELCHER, A. F., 1934, Texture of Oil Sands with Relation to Production of Oil: Am. Assoc. Petroleum Geologists Bull., Vol. 8, 716-74.
Attempts to correlate porosity with production record. Describes several porosimeters. Discusses the physical factors of the sand, chemical factors on the product, and artificial factors, such as the diameter of the hole, offsets, etc., which should be known by operator.

MUSKAT, M., REED, D. W., and WYCKOFF, R. D., 1933, July.
See Wyckoff.

NASH, A. W., WOOD, C. E., NISSAN, A. H., CLARK, L. V. W., 1938, July.
See Nissan.

* NEVIN, C. M., 1932, Permeability, its Measurement and Value: Am. Assoc. Petroleum Geologists Bull., Vol. 16, No. 4, p. 373.
Since there is no decrease with time in the flow of air through a test sample, a standard permeability test, using air as the fluid medium suggested. The importance of securing reliable permeability data emphasized.

NIKOLOEFF, V. M., and LINDTROP, N. T., 1929.
See Lindtrop.

NISSAN, A. H., WOOD, C. E., CLARK, L. V. W., and NASH, A. W.: 1938, July, The Application of Physico-Chemical Principles to the Investigation of the Properties of Rocks, Part II: Apparatus and Technique for Porosity Measurement; Inst. Petroleum Technologists Jour., Vol. 24, No. 177, pp. 370-92.
Bulk volume was determined by two methods, one based on micrometer measurements and one on displacement of mercury in a pycnometer, both within an accuracy of 0.2%. Total porosity determined by a special pycnometer method, though not recommended, was found reproducible within 0.25%. Available volume was determined by two methods, one based on liquid absorption and one on gas expansion, which were developed with a maximum deviation of 0.25% from a mean value.

NISSAN, A. H., 1938, July, The Application of Physico-Chemical Principles to the Investigation of the Properties of Rocks, Part I: Porosity—Origin, Significance, and Measurement; Inst. Petroleum Technologists Jour., Vol. 24, No. 177, pp. 351-369.
Discusses origin of porosity in rocks and its significance in estimating reservoir capacity, and provides a chronological study of quantitative porosity measurements from the gravimetric method of Melcher, through 1937.

NUTTING, P. G., 1929, Some Physical Problems of Oil Recovery. Oil and Gas Jour., Vol. 28, No. 27, pp. 44, 160.

Discusses grain size, pore size, structure, permeability, fall of permeability with time, and field problems in general.

* NUTTING, P. G., 1930, October, Physical Analysis of Oil Sands: Am. Assoc. Petroleum Geologists Bull., Vol. 14, No. 10, pp. 1347-1349.

Since the work on rock and grain densities by A. F. Melcher at the U. S. G. S., described by him in 1920, various improvements and refinements have been introduced in the methods and apparatus used there. A new form of precision pycnometer and new methods are described, with a simple method of measuring permeability. Common sources of error and interpretation of results are discussed in some detail.

OLDRIGHT, G. L., SULLIVAN, J. D., and KECK, W. E., 1930.
See SULLIVAN.

PANYITY, L. S., 1931, Practical Interpretation of Core Analysis: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 320-8.

Concludes that grain-size, rather than porosity, is the controlling factor in water-flooding. Presents several profiles of Bradford sand, showing porosity, oil saturation and grain size percentages.

PANYITY, L. S., 1937, New Method for Taking Core Samples at Well: Oil and Gas Jour., Vol. 36, No. 16, p. 46.

Suggests using retort method for saturation test, but send the retort to the field and have sample transferred to it directly from the core barrel.

PEDIGO, J., HARRIS, S., and PLUMMER, F. B.
See PLUMMER.

PLUMMER, F. B., HARRIS, S., and PEDIGO, J., 1935, A New Multiple Permeability Apparatus: Am. Inst. Min. Met. Eng., Tech. Pub. 578.

Designed permeability apparatus capable of holding four cores simultaneously; either linear or radial determinations may be made.

POWELL, G. N., JR., KRAUSE, L.
See KRAUSE.

PYLE, H. C., and JONES, P. H., 1936, Quantitative Determination of the Connate-Water Content of Oil Sands: Abs. API Prod. Bull. 218, Vol. 17, No. 4.

Dextrose was used as a tracer for measuring the contamination of core samples by drilling media. Results of tests showed that an average of 38% of the effective pore space was occupied by connate water.

REED, PAUL, 1937, Examination of Rotary Drill Cuttings: Oil and Gas Jour., 5 parts: Vol. 35, No. 51, pp. 42-3; Vol. 36, No. 4, pp. 42, 44, 48; Vol. 36, No. 5, pp. 48-9, 51; Vol. 36, No. 9, pp. 56-7, 59; Vol. 36, No. 10, pp. 53, 55.

Discusses sampling, microscopic examination, washing and cleaning, and storing of drill-cutting samples.

REED, D. W., MUSKAT, M., and WYCKOFF, R. D., 1933, July.
See WYCKOFF.

REED, R. D., 1931, Microscope Subsurface Work in Oil Fields of United States: Am. Assoc. Petroleum Geologists Bull., Vol. 15, pp. 731—.
An account of the rise in utility of subsurface micropaleontology.

RICHARDS, J. T., CLARK, S. K., DANIELS, J. I., 1928.
See CLARK.

RUBEL, ALBERT, 1924, May, Determination of Core Samples in Core Drilling: California Oil Fields, California State Mining Bureau, Vol. 9, No. 11.
Not available.

RUSSELL, W. L., 1926, October, A Quick Method for Determining Porosity: Am. Assoc. Petroleum Geologists Bull., Vol. 10, pp. 931-8.
Sample placed under acetylene tetrachloride in a high vacuum. The liquid enters the pore space; the specimen is then placed in the apparatus and the bulk volume determined; the sample is removed, crushed, and the same procedure applied to the grains. This permits calculation of total porosity.
Advantages and possible errors are discussed.

RYDER, H. M., 1936, Permeability Measurements Without Cores: Penn. State College Mineral Ind. Exp. Sta. Bull. 20, pp. 43-59.
Derived formula for calculating permeability of Bradford sand based on sieve analysis. Analyses of drill cuttings enables operator to adjust for permeablity.

RYDER, H. M., 1936, April 30, Permeability Measurements of Oil Sands Important Factor in Determining the Methods for Repressuring: Oil and Gas Jour., Vol. 34, No. 50, pp. 28-33.
Prefers sieve analyses from well cuttings to permeability determinations based on cores. Advantages lie in saving of time and money required for coring, and in a factual knowledge of the cause of lowered permeability in certain zones in the well profile.
Empirical equations, for any one sand, may be derived for converting sieve analyses into permeability in millidarcies.

RYDER, H. M., and MAY, D. T., 1938, Accurate Sand Measurements Aid in Establishing Method of Recovery: Oil and Gas Jour., Vol. 36, No. 49, pp. 48, 50, 53, 55.
Describes method of obtaining chip samples of the sand, which furnish best base for determination of oil saturation. Prefers extraction to retort method, and describes methods of obtaining correction factors. Prefers Russell method to Washburn-Bunting method for obtaining porosities.

SANDERS, T. P., 1936, Improved Equipment for Core Analysis Used at Penn. State: Oil and Gas Jour., Vol. 35, No. 24, p. 47.
Thin-walled soft steel tubing and crushed tool steel are now used in place of a diamond drill in cutting the laboratory specimen from cores. A cutter with tool-steel cutting edges enables square ends to be obtained without grinding. A multiple soxhlet extractor is in use for cleaning the cores.

SANSOM, C. A., 1933, The Interpretation of Core Evidence: World Pet. Congress Proc., Vol. 1, pp. 316-318.

Outlines data obtainable from core analyses.

SANSOM, C. A., 1938, Interpretation of Core Evidence: Science of Petroleum., pp. 502-7.

Examinations to be made and conclusions to be drawn from cores are listed in four classes: lithological, stratigraphical, structural, and physical characteristics.

SAWDON, W. A., 1936, August, Cable Tool Coring in Mid-Continent and Texas Fields: Petroleum Engineer, Vol. 7, No. 12, pp. 74, 76, 78.

Presents set of rules for coring and discusses methods inducive to full recovery of cores.

SCHILTIUS, R. J., 1935, Technique of Securing and Examining Subsurface Samples of Oil and Gas: Am. Petroleum Inst., Prod. and Drlg. Practice, pp. 120-9; Oil and Gas Jour., Vol. 33, No. 52, p. 69, May 16.

Describes bottom-hole sampler, method of sampling, and examination of samples. Analyses, charts, and drawings are given. Applications are outlined.

SCHILTIUS, R. J., 1938, Connate Water in Oil and Gas Sands, Am. Inst. Min. and Met. Eng. Tech. Paper 869.

Outlines method for core analysis and plots corresponding profiles of electrical logs, temperature, porosity, permeability, saturation percent of both oil and water, and the sodium chloride content of the water for several Texas fields.

* SILBERMINZ, V. A., and KRESTOVNIKOV, V. N., 1928 (Notes on methods for the determination of pore space in rocks): State Petroleum Research Inst. Trans., Moscow, Vol. 2, p. 1.

Comparative revision of the methods for determination of the porosity of rocks, and the results of their control in application to the oil-bearing sands and sandstones of the Grosno oil fields.

SMITH, W. O., BRANKSTONE, H. R., and GEALY, W. B., 1932.
See BRANKSTONE.

SMITH, W. O., 1933, Relation of Porosity to the Fundamental Densities of a Porous Substance: Am. Inst. Min. Met. Eng., mimeographed.

Not available.

SNEIGR, DENIS, 1938, July 18, The Life of a Core: Oil Weekly, Vol. 90, No. 6, pp. 19-26.

A pictorial story of a core, showing its release from the core barrel and testing in the paleontology, chemistry and mineralogy laboratories.

STEVENS, A. B., 1938, Oct., A New Porosimeter for the Determination of Porosity by the Gas Expansion Method: Presented at Am. Inst. Min. Met. Eng., Petroleum Division, San Antonio.

A gas porosimeter is described which operates in the manner of the Washburn-Bunting, but which prevents contamination of the specimen by mercury.

This is accomplished by putting the core in a small side chamber, separated from the large expansion chamber by a stopcock. When the expansion chamber has been evacuated by withdrawal of the mercury the stopcock is opened, permitting the air in the pores to expand. When equilibrium has been reached the stopcock is closed, the mercury level adjusted, and the amount of air removed read at atmospheric pressure on the calibrated glass stem above the expansion chamber.

STEVENS, A. B., and COBERLY, C. J.
See COBERLY.

SULLIVAN, J. D., OLDRIGHT, G. L., and KECK, W. E., 1930, October, Method for Measuring Voids in Porous Materials: U. S. Bur. Mines Rept. Inv. 3047, 8 pp.

The volume occupied by the solid is found by immersion under vacuum in water, and weighing on a hydrostatic balance. The volume of the solid plus the void space is found by coating the sample with paraffin and weighing on a hydrostatic balance. The volume of the voids is the difference between the above two determinations, after corrections have been applied for the paraffin.

* SUMAN, G. O., 1930, Dec. 12, Characteristics which Determine the Value of Oil Zones: Oil Weekly, Vol. 59, No. 13, p. 39.

Divides all sands into three groups, based on saturation, of which the first group, containing oils of 30 degrees or less, can be determined by observation, oils between 30 and 50 degrees by treatment with ether, and above 50 degrees by acetone. Visual tests are frequently of little value and may sometimes be actually misleading. The paper includes a detailed discussion of characteristics of oil sands and the possibility of making predictions regarding their productivity.

* SUTTON, CHASE E., 1928, Use of Acetylene Tetrachloride Method of Porosity Determination in Petroleum Engineering Field Studies: U. S. Bur. Mines Rept. Inv. 2876, June; Oil and Gas Jour., Vol. 27, No. 8, p. 34, July 12; Petroleum World, Vol. 13, No. 8, p. 74, August; Oil Age, Vol. 25, No. 8, p. 40, August.

The volume of a small chunk sample and of the powdered material is determined in a porosity apparatus with acetylene tetrachloride and the porosity estimated.

TALIAFERRO, D. B., JR., JOHNSON, T. W., and DEWEES, E. J., 1937, September, A Method of Determining Porosity: A List of Porosities of Oil Sands: U. S. Bur. Mines Rept. Inv. 3352.

Detailed description of gas-expansion porosimeter. Gas, at from 40 to 200 #/□″ is expanded to atmospheric pressure and the volume measured.

TAYLOR, F. B., 1936, Completely Equipped Laboratory: Oil Weekly, Vol. 84, No. 2, pp. 48-50-2-4.

Description of leases and laboratory of Greysolon Oil Company, of Independence, Kan., and Duluth, Minn.

TAYLOR, M. D., 1938, June 16, Determining Water Content of Cores: Oil and Gas Jour., Vol. 37, No. 5, pp. 59-60.

Water present in cores determined by extraction with solution of ethyl or isopropyl alcohol—kerosene mixtures and determination of the critical solution temperature, which varies with the water content. The method may be combined with porosity and oil content methods to yield a full core analysis.

* TICKELL, F. G., McCURDY, R. C., and MECHUM, O. E., 1933, Some Studies on the Porosity and Permeability of Rocks: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 250-269.

Porosity of a rock is governed by (1) the grain-size distribution, (2) the angularity of grain, (3) the degree of compaction and (4) the colloidal content. The effects of the first three are shown by means of curves for binary, ternary, and complex aggregates. Skewness of the grain-size frequency diagram is shown to be a good measure of the uniformity of grain size. Increase of angularity of grain is found to increase or to decrease the porosity depending upon the values of the angularities.

A portable air porosimeter is described. The unit and dimensions of absolute permeability are discussed and the word "perm" is suggested for its designation.

* TICKELL, F. G., 1935, August, Permeability of Unconsolidated Rocks: Am. Assoc. Petroleum Geologists Bull., Vol. 19, No. 8, p. 1233.

Describes a variable head permeability apparatus and the method of making the test. The effect of grain size and compaction on permeability is discussed and presented graphically.

WALDO, A. W., and YUSTER, S. T., 1937, February, Method of Impregnating Porous Materials to Facilitate Pore Studies: Am. Assoc. Petroleum Geologists Bull., Vol. 21, No. 2, p. 259; Penn. State College Mineral Ind. Exp. Sta. Tech. Paper No. 33.

To facilitate study of thin-sections, pores of cores were impregnated with brightly dyed molten balsam under vacuum.

WASHBURN, E. W., and BUNTING, E. N., 1922, The Determination of the Porosity of Highly Vitrified Bodies: Am. Ceramic Soc. Jour., Vol. 5, p. 527.

Not available.

WOOD, C. E., NISSAN, A. H., CLARK, L. V. W., and NASH, A. W., 1938, July.

See NISSAN.

WYCKOFF, R. D., MUSKAT, M., and REED, D. W., 1933, July, The Measurement of the Permeability of Porous Media for Homogeneous Fluids: Review Scientific Instruments, Vol. 4, No. 7, p. 394; Am. Assoc. Petroleum Geologists Bull., Vol. 18, No. 2, pp. 161-190, 1934.

Technique for determining permeability of cores by either gas or liquid described. Equations derived for calculating effective permeability of formation from field measurements. Curve obtained for correction factor for partially penetrated sand.

YUSTER, S. T., and WALDO, A. W.
See WALDO.

YUSTER, S. T., 1936, May, A Theoretical Consideration of Ideal Liquid Inclusions: Am. Jour. Sci., Vol. 31, pp. 363-372; Penn. State College Mineral Exp. Sta. Tech. Paper 25.

Equations, based on ideal liquid inclusions are derived to calculate the temperatures and pressures of formation of inclusions which were liquid or vapor at the temperature of inclusion. For those which were vapor, the magnitude of external stresses, the depth of the inclusion below the original surface of the formation and the extent of erosion may also be calculated.

YUSTER, S. T., 1937, Oct., Determining the Porosity of Oil Sands: Producers Monthly.

No copy available.

YUSTER, S. T., 1937, Dec., Determining Oil Saturation: Producers Monthly, p. 23.

No copy available.

YUSTER, S. T., and LEVINE, J. S., 1938, May 23, Determination of Oil and Water Saturation by the Retort Method: Oil Weekly, Vol. 89, No. 11, pp. 22-25.

The effect of heat on the sand and on the oil are discussed. Method of operation described. Experimental results show two methods of calculating correction factors, both of which are subject to error. Concludes that the retort method, although sufficiently accurate for correlation work should not be used whenever true saturation figures are desired.

ZOOK, R. T., 1928, July 12, Core Tests with Cable Tools: Oil and Gas Jour., Vol. 27, No. 7, pp. 90, 93.

ZOOK, R. T., 1928, Sept., Value of Core Studies in Fluid Drives: Am. Petroleum Inst. Dev. and Prod. Eng. Bull. 202, p. 152.

It has been found that underground conditions may be entirely different over a lateral distance of only a few hundred feet. With the information obtained from core tests a property of 300 acres in the Kane field, Pennsylvania, has been changed from one of questionable to definite value.

SECTION II

The Flow of Fluids Through Porous Media

* ATHY, L. F., 1930, January, Compaction and Oil Migration: Am. Assoc. Petroleum Geologists Bull., Vol. 14, No. 1, p. 25.

The primary cause of the movement of oil from a shale source bed to reservoir beds is compaction within the shale beds. Reservoir beds such as limestones and sandstones show little compaction in comparison with shale. Compaction in shale always occurs when there is an increase in depth of burial, and causes an outward movement of the fluid content of the shale toward adjacent noncompressible horizons of lower pressure or with easier outlet to the surface.

Compaction in shale may be expressed as an exponential function of the depth of burial, and continues to be operative to an appreciable extent at depths ranging from 3,000 to 4,000 feet.

Zonal migration of fluid as caused by compaction may help explain the variation in composition of waters at different depths.

Temperature changes, buoyancy, and capillarity are not effective in causing oil migration if the oil is in a disseminated state, or adsorbed on the mineral grains, or associated with free gas in bubbles.

BARNES, K. B., LEWIS, J. A., and FANCHER, G. H., 1933.
See FANCHER.

* BECKSTROM, R. C., and VAN TUYL, F. M., 1928, November, Compaction as a Cause of the Migration of Petroleum: Am. Assoc. Petroleum Geologists Bull., Vol. 12, No. 11, p. 1049.

The effect of generating carbon dioxide gas at the base of a charge of petroliferous sediments during compaction is described. Other tests with a cylinder of smaller bore, in which much higher pressures were applied, have indicated that a practically complete recovery of oil from a shale-water-oil-mixture can be effected within a period of less than 16 hours. The results warrant the conclusion that compaction is by far the most important cause of the migration of oil from shales into porous reservoirs.

* BOATRIGHT, B. B., 1932, Relation Between Gas Energy and Oil Production: Am. Inst. Min. Met Eng., Petroleum Dev. and Tech., p. 295.

The forms in which gas may be present, work of compressed gas, and the factors influencing production are discussed. A formula is given to determine the flow of oil through a sand assuming it to be the same as through a pipe. It is concluded that while the gas-oil ratio gives a fairly accurate basis for comparing relative flow efficiences in a given well, it cannot be applied quantitatively to a flow efficiency analysis of a pool, unless reservoir pressures are also considered.

* BOSE, N. K., and WILSDON, B. H., A Hydrodynamical Investigation of the Flow of Liquid in a Saturated Porous Medium Such as a Soil: Punjab Irrigation Research Laboratory, Lahore, Mem., Vol. 2, No. 1, p. 1, 1920; Abs., U. S. Bur. Mines, Inf. Circ. 6452, page 56, Feb., 1931.

Points out theoretical and experimental difficulties in studying flow of liquids in porous media. Mathematical treatment developed. Relation between the transmission constant of a soil and the viscosity of the model fluid is demonstrated.

BOTSET, H. G., MUSKAT, M., WYCKOFF, R. D., 1932, August.
See WYCKOFF.

BOTSET, H. G., MUSKAT, M., and WYCKOFF, R. D., 1933.
See WYCKOFF.

BOTSET, H. G., MUSKAT, M., REED, D. W., and WYCKOFF, R. D., 1934, February.
See WYCKOFF.

BOTSET, H. G., and WYCKOFF, R. D., 1934, September.
See WYCKOFF.

BOTSET, H. G., and WYCKOFF, R. D., 1934, September.
See WYCKOFF.

BOTSET, H. G., and REED, D. W., 1935, July, Experiment on Compressibility of Sand: Am. Assoc. Petroleum Geologists Bull., Vol. 19, No. 7, pp. 1053-1060.

Unconsolidated 30-40 mesh sand was compressed. Change in pore volume was in the order of two percent at 3,000 pounds per sq. in. pressure. The authors conclude that with a sand only slightly consolidated, compression is only a minor factor in oil production.

BOTSET, H. G., MERES, M. W., MUSKAT, M., and WYCKOFF, R. D.
See MUSKAT.

BOTSET, H. G., and MUSKAT, M.
See MUSKAT.

BOTSET, H. G., and MUSKAT, M., 1938, Oct., The Effect of Pressure Reduction Upon Core Saturation: Presented before Am. Inst. Min. Met. Eng., Petroleum Div., San Antonio.

Cores, saturated with kerosene, kerosene and gas, and water, kerosene and gas, under high pressure, were reduced to atmospheric conditions at varying rates. Measurements of percent of water and kerosene was made by weighing the core. A pressure reduction of 15#/□″/min. was assumed equivalent to that occurring upon removal of the core from the well.

No water was produced from cores with less than 60% water saturation; the final saturation of the oil decreased linearly with the water content. Higher initial pressure result in a lower final saturation, though not to a great extent. High pressure gradients, represented by high rates of pressure decline, are more able to overcome the surface tension effects, and result in increased recoveries; a minimum production, independent of the rate, was found, which is dependent on the size and distribution of the pores in the sand. At low rates of pressure decline, a minimum limit of recovery, corresponding to the equilibrium saturation of the cores, was indicated. For greater recoveries, it is necessary to have a mass gas flow with dragging effects.

* BUCKLEY, RONALD, 1931, January, Viscous Flow and Surface Films: U. S. Bur. Standards Jour. Research, Vol. 6, No. 1, p. 89.

Previous workers have observed that in many cases liquids flowing through capillary tubes have gradually clogged the tubes, and considered it due to the progressive formation of an immobile layer on the inside of the capillary due to orientation and selective adsorption of polar constituents. Experiments show that this clogging is due entirely to the presence of foreign matter and does not occur if the liquid has been properly filtered.

BURNETT, E. S., MILLER, H. C., and HIGGINS, R. V., 1937.
See MILLER.

BUSANG, D. G., FOOTE, P. D., SMITH, W. O.
See SMITH.

CHALMERS, J., TALIAFERRO, D. B., JR., RAWLINS, E. L., 1932, Flow of Air and Gas Through Porous Media: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 375-400; Oil Weekly, Vol. 64, No. 12, p. 19—, March 4, 1932.

An equation obtained by the U. S. Bureau of Mines is used as a basis of the work. It shows the capacity of sand to allow gas to flow through it, also affords a means of studying flow conditions in sands of varying grain size, grain shape, and porosity. Apparatus used in the supplementary experiments is described, and graphs of the results presented.

CLOUD, W. F., 1929, Some Laboratory Data Relative to Drainage, Flow, and Recovery of Crude Oil in Sand and Sandstone: Oklahoma Acad. of Sci. Proc. 9, Oklahoma Univ. Bull. 456, p. 106.

No copy available.

CLOUD, W. F., 1930, Variation of Pressure Gradient with Distance of Rectilinear Flow of Gas-saturated Oil and Unsaturated Oil Through Unconsolidated Sands: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 337-350.

Rate of flow and pressure drop of unsaturated oils found to be uniform and proportional to the input or discharge pressure. Effect of gas and air saturation of the crudes on rate of flow, viscosity, temperature, and pressure studied.

COMINS, D., 1938, Bottom-hole Samples: Science of Petroleum, Vol. I, pp. 523-530, Oxford Press, London.

Advantages and disadvantages of various types of samplers, the technique of collecting samples, the data obtainable and its applications were discussed. Data obtainable are: Saturation pressure, dissolved gas content and solubility curve, shrinkage, pressure-volume curve, and the physical properties such as specific gravity, viscosity, and surface tension of the reservoir crude at varying saturation pressures.

COOK, C. W., 1923, Study of Capillary Relationships of Oil and Water: Econ. Geology, Vol. 18, pp. 167-72.

Basing his discussion on capillary tube experiments (not reported) the author concludes that (1) the capillary force producing movement of petroleum is not equal to the difference in surface tension between oil and water and cannot be calculated on that basis; and (2) that the adhesion of water for rock must be recognized as a possible important force in producing migration of petroleum. Gas bubbles blocked all movement in the capillary tubes.

DAVIS, F. F., UREN, L. C., JARVIS, W. L., 1928.
See UREN.

* EHRING, K., 1936, Die Bewegung des Erdols in Seiner Lagerstatte (movement of petroleum in reservoir rocks); Oel u. Kohle, Vol. 12, No. 23, p. 501, June 15; Abs. Inst. Petroleum Technologists Jour., Vol. 22, No. 15, p. 389A, September.

Review of published work, chiefly of American origin, bearing on the theoretical and practical aspects of the subject. Considerable attention is devoted to artificial methods of influencing the movement of oil to the bore hole.

FANCHER, G. H., and LEWIS, J. A., 1932, April 29, A Note on the Flow of Fluids Through Porous Media: Science, Vol. 75, No. 1948, p. 468.

Reports data for more than 200 tests of flow of water, air, and crude petroleum through Ottawa sand, graded flint sand, and six sizes of lead shot, and a few tests of flow of water through consolidated sandstone. When the results are correlated by plotting a modified Reynolds number against a friction factor the points define a straight line parallel to that for flow in circular pipes.

FANCHER, G. H., and LEWIS, J. A., 1933, October, Flow of Simple Fluids Through Porous Media: Penn. State College Mineral Exp. Sta. Bull. 7; Ind. and Eng. Chem., Vol. 25, No. 10, pp. 1139-1147.

A chart is developed based on experimental studies that relates the modulus $\frac{duP}{n}$ to the friction factor. Determination of the porosity and screen analysis of the sand are sufficient to compute the condition of flow of any fluid, which may change from viscous to turbulent as velocities increase.

FANCHER, G. H., LEWIS, J. A., and BARNES, K. B., 1933, Some Physical Characteristics of Oil Sands: Penn. State College Mineral Exp. Sta. Bull. 12, pp. 65-169; also World Pet. Congress, London, Proc., Vol. I, pp. 332—.

Presents a critical study of the literature and experimental studies pertaining to measurement of porosity and permeability. The flow of fluid through porous media was studied. A chart representing the change in friction factor with the modulus $\frac{duP}{n}$ was plotted, from which the conditions of flow for any fluid could be computed if the screen analysis of the sand were known.

To be accurate and consistent any permeability apparatus should be constructed from insoluble, nonreactive, inert material, and the fluid used must be pure, reactive physically or chemically to a minimum extent with the core, contain no foreign matter, and a minimum of dissolved gas or condensible vapor.

FISHELL, V. C., and MEINZER, O. E., 1935.
See MEINZER.

FOOTE, P. D., SMITH, W. O., and BUSANG, D. G., 1929.
See SMITH.

GARDESCU, I. I., 1930, Behavior of Gas Bubbles in Capillary Spaces: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 351-70.

Defines Jamin action as resistance offered by detached gas and liquid bubbles confined to capillary tubes by boundary conditions which develop whenever the liquid does not wet the solid walls of the capillary. This is extremely small and need not be considered as compared to resistance by gas bubbles when forced through small openings. This latter is defined as a function of the surface tension, the capillary opening, and the maximum curvature of the distorted bubble.

* GIVAN, C. V., 1934, June, Flow of Water Through Granular Materials—Initial Experiments with Lead Shot: Am. Geophysical Union, 15th Ann. Meeting, Trans. Pt. II, p. 572, Nat. Res. Council, Washington.

Describes experimental work on flow of water through granular materials.

JARVIS, W. L., DAVIS, F. F., and UREN, L. C., 1928.
See Uren.

* HICKOK, G. H., 1934, June, Flow Through Granular Materials: Am. Geophysical Union, 15th Ann. Meeting, Trans. Pt. II, p. 567, Nat. Res. Council, Washington.

Author outlines a method of attack on the problems of streamline and turbulent flow through granular materials.

HIGGINS, R. V., BURNETT, E. S., MILLER, H. C., 1937.
See Miller.

HUNTER, J. C., TIMMERMAN, E. H., PLUMMER, F. B., 1937.
See Plummer.

HUNTINGTON, R. L., and REID, L. S.
See Reid.

HURST, Wm., MOORE, T. V., and SCHILTIUS, R. J., 1933, May 18.
See Moore.

HURST, WILLIAM, 1934, January, Unsteady Flow of Fluids in Oil Reservoirs: Physics, Vol. 5, pp. 20-30.

Unsteady flow equations were derived for wells producing with a constant pressure at the sand-face and for wells producing at a constant rate.

* KOEHNE, W., 1928, Grundwasserkunde: Stuttgart, E. Schweizerbartsche Verlagsbuchhandlung, Centralbl. Mineralogie, Abt. B, No. 4, p. 271.

Comprehensive textbook on ground water. Chapter 5 discusses formulae applicable to ground-water hydrology and states that Darcy's law is substantially valid though there are slight variations from it in coarse materials; concludes that mathematical formulae for yield of wells are inadequate for determining supplies available for large developments.

LAHEE, F. H., and WILDE, H. D., 1933.
See Wilde.

LEWIS, J. A., and FANCHER, G. H., 1932, April 29
See Fancher.

LEWIS, J. A. and FANCHER, G. H., 1933, October.
See FANCHER.

LEWIS, J. A., FANCHER, G. H., BARNES, K. B., 1933.
See FANCHER.

MAY, C. J., 1935, The Scientific Control, Development and Production of Reservoirs: Inst. Petroleum Technologists Jour., Vol. 21, pp. 516-522.

Discussion of advance of technical knowledge during preceding year. Bibliography.

* MEINZER, O. E., 1929, July, Relation of Ground-water Conditions to Leakage of Reservoirs: Am. Inst. Min. Met. Eng. Tech. Pub. 215, p. 19.

Discusses permeability of rocks, relation of reservoir sites to water table and outlines methods of investigation. Emphasizes application of general ground-water studies within the reservoir area.

* MEINZER, O. E., and FISHELL, V. C., 1934, June, Tests of Permeability with Low Hydraulic Gradients: Am. Geophysical Union, 15th Ann. meeting, Trans. Pt. II, p. 405, Nat. Res. Council, Washington.

A method and two general types of apparatus used for determining permeability described. Results of tests indicate that in the type of sand used the flow varies approximately with the hydraulic gradient, down to a gradient of one foot to a mile and probably to considerably lower gradients. The results appear to afford evidence of some movement of water with gradients as low as one inch to the mile. Also they strengthen the presumption that Darcy's law holds precisely for flow through permeable material under infinitely low gradients.

MERES, M. W., and MUSKAT, M., 1936, September.
See MUSKAT.

MERES, M. W., MUSKAT, M., BOTSET, H. G., WYCKOFF, R. D., 1937.
See MUSKAT.

MILLER, F. G., and MILLER, H. C., 1938, March, Resumé of Problems Relating to Edgewater Encroachment in Oil Sands: U. S. Bur. Mines Rept. Inv. 3392.

Literature surveyed for material relative to the effect of edgewater encroachment on ultimate production, the effect of production rates on water encroachment, reported rates of water encroachment, and investigations and theories advanced concerning displacement of oil by water. Suggest that if the properties of the oil, edgewater, and reservoir formation were known and expressed in terms of velocity, an optimum rate of encroachment might be predicted for a field.

MILLER, H. C., and MILLER, F. G., 1938, March.
See MILLER, F. G.

MILLER, H. C., BURNETT, E. S., and HIGGINS, R. V., 1937, Oil Well Behavior Study Based Upon Subsurface Pressure and Production Data: Oil Weekly, Vol. 87, No. 1, pp. 30-46.

Based on a study of the Kettleman North Dome oil field, Bureau of Mines

engineers find the mass rate of fluid production to be proportional to the drop in pressure; utilized mass rate as a productivity index.

MILLS, R. VAN A., 1920, Experimental Studies of Subsurface Relationships in Oil and Gas Fields: Econ. Geology, Vol. 15, pp. 398-421.

Experimental apparatus was devised at the Bureau of Mines to study the influence of the different factors on the movement of oil, gas, and water in subsurface formations. The various experiments are reported in this and a subsequent paper.

MILLS, R. VAN A., 1921, Relation of Texture and Bedding to Movement of Oil and Water Through Sands: Econ. Geology, Vol. 16, No. 2, pp. 124-42.

Using laboratory models of oil fields, the influence of texture and bedding upon the movements and flow of oil and water through sands were investigated; significant contribution.

MILLS, R. VAN A., 1928, Sept. 20, Water Control Problems Analyzed: Oil and Gas Jour., Vol. 27, No. 18, pp. 38, 39, 141.

Three types of water encroachment were found: (a) edgewater encroachment, (b) infiltration water, (c) water coning. The latter was caused by lowering the gas pressure which increased the viscosity of the oil to such an extent that water flowed into the well. The best way to combat coning would be to maintain the gas pressure by means of a gas lift which would also act as a propulsive agent.

MILLS, R. VAN A., 1929, March 7, Water Coning Prevention and Control: Oil and Gas Jour., Vol. 27, No. 42, p. 50.

Discusses underground conditions favoring water coning and advises procedure to prevent and control it.

MOORE, T. V., and WILDE, H. D., 1931.
See WILDE.

MOORE, T. V., and WILDE, H. D., 1932, Dec. 5.
See WILDE.

MOORE, T. V., and WILDE, H. D., 1938.
See WILDE.

MOORE, T. V., SCHILTIUS, R. J., and HURST, WILLIAM, 1933, May 18, The Determination of Permeability from Field Data: Third Mid-Year Meeting, API, Tulsa; Oil Weekly, Vol. 69, No. 10, pp. 19-34, May 22; Oil and Gas. Jour., Vol. 32, No. 1, pp. 58-60, 63-4.

The effective permeability of a formation was calculated from field tests made on flowing wells. Permeability was found to be directly proportional to productivity. It was noted that the drainage radius (as calculated) depends on time but not on the rate of production. Therefore, a well produced slowly should drain a much larger area than one produced rapidly.

MOORE, T. V., 1938, Behavior of Fluids in Oil Reservoirs, Am. Assoc. Petroleum Geologists Bull., Vol. 22, No. 9, pp. 1237-1249.

Discusses correct application of pressure maintenance, control of water front, and effect of rate of production on fluid flow in oil reservoirs.

MORRIS, A. B., 1937, October, Data on Behavior of Water and Oil Passing Through Unconsolidated Sand: Oil Weekly, Vol. 9, No. 1, pp. 108-114.

Performed rough experiments on flow of water, and oil through dry sand, and oil through sand wet with water and vice versa.

MUSKAT, M., and BOTSET, H. G., 1931, July, Flow of Gas Through Porous Materials: Physics, Vol. 1, pp. 27-47.

Theory developed for production from and pressure decline in a closed reservoir of uniform thickness producing into a well under conditions of radial two-dimensional flow. Equations are based on experiments performed with columns of glass beads, homogeneous and heterogeneous sands and samples of actual limestone. The gradient of the squares of the pressures was found to be proportional to a power of the mass velocity between the limits 1 and 2, corresponding to linear and turbulent flow, respectively; for any given sand, the exponent remains fairly constant over a considerable range in mass velocity.

MUSKAT, M., 1932, May, Potential Distribution in Large Cylindrical Disks with Partially Penetrating Electrodes: Physics, Vol. 2, pp. 329-364.

Analogy drawn between the fluid pressure in a sand through which a liquid is flowing into an artesian well and a velocity potential.

MUSKAT, M., BOTSET, H. G., and WYCKOFF, R. D., 1932, August.
See WYCKOFF.

MUSKAT, M., and WYCKOFF, R. D., 1934, A theoretical Analysis of Water Flooding Networks: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 62-76; also, Am. Inst. Min. Met. Eng. Tech. Paper No. 507 (1933).

Based on the assumptions that steady-state flow conditions exist, that the systems are two-dimensional, with no interference by gravity, and neglecting the difference in viscosity of water and oil, the efficiency and conductivity of water floods with various network patterns have been calculated.

Concludes that well spacing and arrangement are of relatively minor importance in determining the success of a flooding program. Attention should be concentrated on prevention of by-passing in high-permeability zones.

MUSKAT, M., BOTSET, H. G., REED, D. W., and WYCKOFF, R. D., 1934, Feb.
See WYCKOFF.

MUSKAT, M., 1934, March, The Flow of Compressible Fluids Through Porous Media and Some Problems in Heat Conduction: Physics, Vol. 5, pp. 71-94.

Equations derived for the flow of compressible fluids through porous media and solved for cases having the following applications to petroleum:

(1) Production history from a well whose pressure is reduced discontinuously to its final value.

(2) Production history from a well whose pressure is lowered so that fluid density at the well drops linearly with the time.

(3) The pressure rise in a well after shutting in.

(4) Pressure decline in E. Texas oil field.

(5) Production decline from a single well at constant pressure in a closed reservoir.

(6) Pressure decline in a closed reservoir drained at a constant rate by a central well.

Green's function corresponding to a well displaced from the center of a closed reservoir, is derived and applied to problem of interference between two wells draining same closed reservoir.

An approximation theory is given for nonisothermal gas flow from a circular reservoir into a central well.

MUSKAT, M, 1934, Sept., Two Fluid Systems in Porous Media. The Encroachment of Water into an Oil Sand: Physics, Vol. 5, pp. 250-64.

The encroachment of water into an oil sand was treated as two regions of different conductivities, separated by a surface. Strictly linear, radial and spherical systems were solved analytically and graphically and solutions presented for (1) systems with elliptical boundaries, (2) an infinite linear source driving fluid into an isolated sink, and (3) history of a ring of particles traveling from a source to a sink. The relationship to practical problems of water encroachment into oil bearing sands discussed.

MUSKAT, M., and WYCKOFF, R. D., 1935, An Approximate Theory of Water-Coning in Oil Production: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 144-163.

The water cone under a well rises as oil production rate is increased with a maximum point 50-75% of the height from the normal water table to the bottom of the well. Bottom water cannot be eliminated from thin oil zones without reducing production to uneconomical amounts. Any penetration up to 15-20% of sand thickness permits the maximum rate of production. Plugging back to an impermeable lens in the sand is the most effective method of lowering water production. It is more effective to shut-in a well and then increase the production to maximum water-free rate, than to try to pinch back on the rate of production. Less water will be produced by a steadily flowing well than one that is heading or being produced by swabbing.

The problem of gas-coning is the same, except that the system is inverted.

MUSKAT, M., 1935, December, The Seepage of Water Through Dams with Vertical Faces: Physics, Vol. 6, pp. 402-415.

The method of hodographs for the analysis of ground-water flow systems containing surfaces, was applied, numerically, to six cases of seepage through dams.

MUSKAT, M., and WYCKOFF, R. D., 1936, March, The Theory of Acid Treatment of Oil Wells Producing from Limestone Reservoirs: Physics, Vol. 7, pp. 106-115.

Theory derived based on the assumption of a potential flow of the liquid in the limestone.

Calculations for an increased permeability in an annular ring surrounding the well bore show the effects are maximal if the inner zone is initially of low permeability, while if the permeability is normal originally the effect of the acid will be small. For highly fractured limestones the productive capacity

may be increased 100 times or more if fractures are no larger than 1 mm.; for larger fractures, the effect is much less.

MUSKAT, M., and WYCKOFF, R. D., 1935.
See WYCKOFF.

MUSKAT, M., 1936, March, The Seepage Flux Under Dams of Extended Base Width and Under Cofferdams Resting on a Permeable Strata of Finite Thickness: Physics, Vol 7, p. 116-125.
An exact theory is given.

MUSKAT, M., and MERES, M. W., 1936, September, The Flow of Heterogeneous Fluids Through Porous Media: Physics, Vol. 7, pp. 346-63.
Steady state solutions are found to change but little from homogeneous flow as long as the pressure exceeds about half the saturation pressure of the gas, except for fact that the liquid saturation is approximately equal to the equilibrium value and the liquid permeability has a value very near to its equilibrium value. The drop in liquid permeability and saturation is highly localized about the outflow surfaces. Transient flow was treated as a succession of steady states. It was found that the liquid saturation at time of physical depletion of the system, corresponding to an equalization of the pressure to that maintained at the outflow terminal is quite uniform, being only 5% lower at the outflow terminal than at the closed terminal. The gas-liquid ratio is found to increase with time. Applications are discussed.

MUSKAT, M., 1937, Flow of Homogeneous Fluids Through Porous Media: McGraw-Hill Book Co., New York.
The results of investigations of the Physics Department of the Gulf Research Laboratory on the flow of fluids are embodied in this treatise, primarily devoted to petroleum production problems.
Each problem, developed mathematically from necessary fundamental experiments, is interpreted for practical usage.
The flow of gas, and both the steady and nonsteady state flow of liquids are covered for many applications.

MUSKAT, M., WYCKOFF, R. D., BOTSET, H. G., and MERES, M. W., 1937, Flow of Gas-Liquid Mixtures Through Sands: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., p. 69.
An experimental and analytical study of the flow of oil and gas mixtures through unconsolidated, homogeneous sands. The physical depletion of the sand is governed by the equilibrium saturation, and the recovery by the relation of the initial saturation pressure to that at equilibrium saturation. One well drains the reservoir regardless of size or permeability. Concludes that the question of well-spacing is merely one of economics.
The gas-liquid ratio increases as production declines; the efficiency of production being inversely proportional to the gas-liquid ratio, any attempt to increase the recovery below the equilibrium conditions results in decreased efficiency. Therefore efficiency of gas repressuring methods cannot be high, except where the gas is injected into a gas-cap or other structurally favorable parts of the reservoir so that it can effect a drive early in the life of the field.

MUSKAT, M., and BOTSET, H. G., 1938, October.
See BOTSET, H. G.

NOWELS, K. B., 1932, Mechanics of Water Movement in Natural and Artificial Flooding of Oil Sands: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 192-218; Oil Weekly, Vol. 67, No. 3, pp. 29-42, Oct. 3.

Well spacing in any form of artificial flooding is dependent on the resistance of the sand and the pressure necessary to overcome this resistance. The pressure may be calculated for any spacing program by formula derived. Pressure applied follows elliptically shaped area wherein the major axis equals the distance between water wells, and the minor axis equals the distance between oil and water wells. Too low an efficiency has been found in many floods; this was attributed to too low an input pressure.

NEWCOMBE, R. B. Jr., and PLUMMER, F. B.,
See PLUMMER.

*PIERCE, H. R., and RAWLINS, E. L., 1929, May, The Study of a Fundamental Basis for Controlling and Gauging Natural Gas Wells: Part I. Computing the Pressure at the Sand in a Gas Well; Part II, A Fundamental Relation for Gauging Gas-well Capacity; U. S. Bur. Mines Rept. Inv. 2929-2930.

Formulae and charts for calculating the pressure at the sandface are presented.

Study of many gas wells provided data for discussion of various methods of testing their delivery capacity.

Back-pressure gauge method advocated (complete discussion in Monograph No. 7, Bureau Mines.) Necessary equations and charts for its use are provided.

PLUMMER, F. B., and NEWCOMBE, R. B., JR., 1936, Laboratory Investigations on Acid Treatment of Sands: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 100-115.

Permeability tests on 4" cores before and after acid treatment resulted in decreased permeability after treatment. Assumes insoluble residues block the pore spaces. Most of the acid was used up in enlarging the bore-hole.

J. J. Greebe, physicist, Dow Chemical Company, took exception, stating many pitfalls which occur in laboratory procedure.

A partial bibliography on acidizing appended.

PLUMMER, F. B., HUNTER, J. C., JR., and TIMMERMAN, E. H., 1937, Flow of Mixtures of Oil and Water Through Sand: Am. Petroleum Inst., Drilling and Prod. Practice, pp. 417-21; Oil and Gas Jour., Vol. 35, No. 47, pp. 40-5; Oil Weekly, pp. 65-70, April 6.

Multiple radial permeability apparatus used to study flow of oil-water mixtures through cores. Addition of a soap solution to fresh water reduced proportion of water produced from 95-25%. This failed when used with salt water. Theory permits two solutions: Addition of chemicals which (1) precipitate in water solution and block the flow in water strata; or (2) reduce the interfacial tension of the water-oil phases, permitting the water cone to settle back to equilibrium height.

PLUMMER, F. B., and WOODWARD, J. S., 1937, Experiments on Flow of Fluids Through Sands: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 120.

Radial flow apparatus designed and built for studying the effect of amount of compaction, amount of cementation, the texture of sands, depth of penetration, and size of hole on the rate of flow of fluid.

* POWERS, W. L., 1934, Soil-water Movement as Affected by Confined Air: Jour. Agric. Research, Vol. 49, No. 12, p. 1125.

A series of experiments in which the writer determines the effect of air on the rate of wetting and the rate of percolation through a soil, and the relation of the depth of soil column to percolation of water under different air pressures. The tests do not conform to Darcy's law.

* RAWLINS, E. L., and PIERCE, H. R., 1929, May.
See PIERCE.

RAWLINS, E. L., CHALMERS, J., TALIAFERRO, D. B., 1932, March 4.
See CHALMERS.

RAWLINS, E. L., and SCHELLHARDT, M. A., 1936.
See SCHELLHARDT.

REED, D. W., MUSKAT, M., BOTSET, H. G., WYCKOFF, R. D., 1934, February.
See WYCKOFF.

REED, D. W., and BOTSET, H. G., 1935, July.
See BOTSET.

REED, D. W., and WYCKOFF, R. D., 1935, December.
See WYCKOFF.

REID, L. S., and HUNTINGTON, R. L., Flow of Oil-gas Mixtures Through Unconsolidated Sand: Am. Inst. Min. Met. Eng. Tech., Paper 873.

A series of tests, both at steady and unsteady state of flow, were run in a flow tube on a well location, using the crude produced and the gas from the high-pressure separator. Data indicated that (1) the maximum flow efficiency and minimum gas-oil ratio were obtained with a flowing BHP equal to at least 50% of the shut-in pressure; (2) the unsteady-state flow conditions resulted in curves very similar to those obtained in actual practice, showing the effect of a gas cap, and the variation in decline of oil and gas rates and gas-oil ratio for different withdrawal rates; (3) ultimate recovery is a function of the rate of withdrawal and an optimum rate exists, since ultimate recovery may be reduced by too low as well as too high a rate of production.

* SCHELLHARDT, M. A., and RAWLINS, E. L., 1936, Comparison of Output and Intake Characteristics of Natural-gas Wells in the Texas Panhandle Field: U. S. Bur. Mines Rept. Inv. 3303.

Gives results of study during past several years in Texas Panhandle field to determine (1) delivery capacities of wells under different pressure and operating conditions, and (2) relation between pressure and rates of delivery from gas wells.

SCHILTIUS, R. J., MOORE, T. V., HURST, WM., 1933, May 18.
See MOORE.

SCHRIEVER, WILLIAM, 1930. Law of Flow for the Passage of a Gas-free Liquid Through a Spherical-grain Sand: Am. Inst. Min. Met. Eng., Petroleum Dev. and Tech., pp. 322-350.

Derived formula for the law of fluid flow of gas-free oil. Found the rate of flow varied as the 1.68 power of the diameter of the pores. A 1% change in porosity of a fine-grained sand caused a greater change of flow than a 1% change in a coarser sand. The rate of flow was always proportional to the pressure drop through the sand.

SLICHTER, C. S., 1897-98, Theoretical Investigation of the Motion of Ground Waters: U. S. Geol. Survey 19th Annual Report, Pt. II. pp. 295-384.

Flow of ground water through soil was investigated and laws of flow determined for:

1. Rectilinear flow.
2. Motion in horizontal planes.
3. Motion in vertical planes.
4. Artesian wells and their mutual interference.
5. Wells in region where water flow has a constant velocity in a general direction.
6. Mutual interference of two, three, and a row of wells respectively.

Various pertinent tables of porosities, viscosity of water, and capacities of wells of various sizes were included.

*SMITH, W. O., FOOTE, P. D. BUSANG, D. G., 1929, Nov., Packing of Homogeneous Spheres: Physical Review, Vol. 34, No. 9, p. 1271.

The maximum and minimum porosities of aggregates of homogeneous spheres are given together with a simple method for finding the actual number of contacts per sphere for several porosities.

SMITH, W. O., and others, 1930. August. Capillary Retention of Liquids in Assemblages of Homogeneous Spheres: Physical Review, Vol. 36, No. 3, p. 524.

The pore space of an assemblage of uniform spheres was initially saturated with a liquid and then slowly drained. The retained liquid was measured.

SMITH, W. O., 1932, Sept., Capillary Flow Through an Ideal Uniform Soil, Physics, Vol. 3, pp. 139-146.

The velocity through the mean capillary is calculated and the number of capillaries per cm,^{2} the quantity of fluid per second crossing a section, s, of length L is a function of the porosity, diameter of the grains, viscosity of the liquid, and pressure gradient. Based on Slichter's equation.

SMITH, W. O., 1933, May, Minimum Capillary Rise in an Ideal Uniform Soil: Physics, Vol. 4, pp. 184-93.

Exact conditions controlling capillary rise are determined, and an approximation, developed in an earlier paper, is used with these conditions to calculate the minimum rise.

TALIAFERRO, D. B., RAWLINS, E. L., and CHALMERS, J., 1932, Mar. 4.
See CHALMERS.

*TICKELL, FREDERICK G., 1928, October, Capillary Phenomena as Related to Oil Production: Am. Inst. Min. Met. Eng. Tech. Pub. 138; Oil and Gas Jour., Vol. 27, No. 22, p. 172, Oct. 18.

Conclusions summarized:

1. Reservoirs may be of open or closed type. If open, rate of flow may be a function of hydraulic flow, and if closed, of hydraulic flow and release of gas pressure.

2. All influences that restrain the rate of flow have the same effect as increasing viscosity.

3. Release of pressure in a porous medium containing gas and oil is accompanied by increase of fluid viscosity.

4. The decline of production from the enclosed type of reservoir may be expressed as an exponential function of time.

5. The decline of production from a "combined" type is a very complicated function of time that has never been mathematically expressed.

6. Ultimate recovery from the closed type should be increased by repressuring methods.

7. Estimates of ultimate recovery, proper well spacing, etc., must be based on recognition of the combined type reservoir and the complex relations of its variables.

A classification of reservoir systems is also given.

TIMMERMAN, E. H., PLUMMER, F. B., and HUNTER, J. C., 1937.
See PLUMMER.

*UMPLEBY, J. B., 1932, Oct. 6, Reservoir Energy: Its Source, Ownership, and Utilization in the Production of Petroleum: Oil and Gas Jour., Vol. 31, No. 20, p. 52.

Cites the importance of gas in recovery of oil from the ordinary reservoir. A plea is made for legal steps to prevent its wastage, and for further technical progress to lower oil-gas ratios.

*UREN, L. C., DAVIS, F. F., and JARVIS, W. L., 1928, Dec. 14, Advantages of Large Diameter Wells in Exploitation of Oil Fields: Oil Weekly, Vol. 51, No. 11, p. 53.

Description of equipment used and results obtained in a series of laboratory experiments as to the production efficiency of large and small diameter wells. Conclude that a large diameter well increases both the rate of production and the ultimate recovery. The data are based on a small scale experiment, but the results obtained are probably applicable at least to some extent to commercial practice.

UREN, L. C., 1938, Fundamental Principles Governing Drainage of Petroleum from Its Reservoir Rocks: Science of Petroleum, Vol. 1, p. 541-51, Oxford Press, London.

Discusses the character of reservoir rocks, the properties of petroleum in the reservoir, and the factors affecting its flow through the reservoir.

* VERSLUYS, J., 1928, November, An Investigation of the Problem of the Estimation of Gas Reserves: Am. Assoc. Petroleum Geologists Bull., Vol. 12, No. 11, 1095.

Contributes to the solution of gas problems by direct application of the laws governing the movement of gas through porous media. Also, a correction is given for the determination of pressure at depth.

* VERSLUYS, J., 1930, The Equation of Flow of Oil and Gas to a Well after Dynamic Equilibrium Has Been Established: K. Akad. Wetenshc., Amsterdam, Proc. Sect. Sci. Vol. 33, No. 6, p. 578.

A formula is evolved to cover this phenomenon, which is practically the same as Dupuit's formula for the movement of water toward artesian wells.

VERSLUYS, J., 1931, Can Absence of Edge-water Encroachment in Certain Oil Fields Be Ascribed to Capillarity? Am. Assoc. Petroleum Geol. Bull, Vol. 15, No. 2, p. 189.

Capillarity cannot hold oil or water out of depleted zones. Jamin effect cannot stop flow altogether, because gas would diffuse through the films and light oils would evaporate from one film and condense on the next and so move toward the well, and would ultimately be followed by the water.

WENZEL, L. K., 1936, The Thiem Method for Determining Permeability of Water-bearing materials: U. S. Geol. Survey Water Supply Paper 679-A.

Method developed for computing permeability by observing drawdown in two adjacent water wells during pumping test at the well in question.

WILDE, H. D., Jr., The Value of Gas Conservation and Efficient Use of a Natural Waterdrive as Demonstrated by Laboratory Models: Am. Petroleum Inst. Production Bull. 210, p. 4.

Experiments, using sandbox, illustrate value of slow steady production with low gas-oil ratio.

* WILDE, H. D., Jr., and LAHEE, F. H., 1933, August, Simple Principles of Efficient Oil Field Development: Am. Assoc. Petroleum Geologists Bull., Vol. 17, No. 8, p. 981.

By a series of experiments, it is shown that uniformly distributed extraction yields more oil, yields it more efficiently and gives rise to fewer water difficulties than rapid and irregularly distributed extraction. They also demonstrate the advantages of conservation of gas.

* WILDE, H. D., Jr., and MOORE, T. V., 1931, Using Pressure-drop in Sand to Measure Well Capacities: Oil Weekly, Vol. 61, No. 12, p. 26; also "Substitute for Potential Production": Oil and Gas Jour., Vol. 30, No. 3, p. 21.

Existing methods of determining equitable allowable production are described and the disadvantages of each are noted. A new method is proposed, based on the drop in rock pressure in the producing sand caused by the flow of oil to the base of the well. The proposed method is offered as a substitute for the "potential production" determined by open flow tests. The data required may be taken at low rates of flow, thus reducing danger to the wells in the fields where water drive is found. The type of equipment on the well does not affect the results obtained. Numerical illustrations are given to show application of the method. The disadvantages attendant upon the method are minor and easily overcome.

WILDE, H. D., Jr., and MOORE, T. V., 1932, Dec. 5, Hydrodynamics of Reservoir Drainage and Its Relation to Well Spacing: Oil Weekly, Vol. 67, No. 12, pp. 34-40.

An inquiry into the mechanism of reservoir drainage. The flow of simple fluids through porous media, the flow of oil and gas mixtures in porous media, the pressure gradient around oil or gas wells, the regional drainage in reservoirs, the relation between pressure drop and depletion, the determination of physical constants of oil reservoirs from field data, and the effect of well spacing on ultimate recovery are considered; formulae developed to explain them, and utilized to give data regarding optimum well spacing relations.

WILDE, H. D., Jr., and MOORE, T. V., 1938, The Control of Water in Oil Reservoirs: Science of Petroleum, Vol. 1, pp. 568-576, Oxford Press, London.

Discusses various relationships of water to oil in reservoirs, calculations for steady-state water-drive types of encroachment, rate of encroachment, and methods of shutting off water in producing wells.

* WILSDON, B. H., and BOSE, N. K.
See Bose.

WOODWARD, J. S., and PLUMMER, F. B., 1937.
See Plummer.

WRIGHT, RANDALL, 1933, Jamin Effect in Oil Production: Am. Assoc. Petroleum Geologists Bull., Vol. 17, No. 12, pp. 1521-6. Discussion by Versluys, J.; Am. Assoc. Petroleum Geologists Bull., Vol. 18, No. 4, p. 547 (1934).

After defining Jamin effect as "that resistance to liquid flow through capillaries which is due to the presence of bubbles," the author concluded from experiments cited, that it does not arise in the case of petroleum moving toward a producing well.

Both an asphalt and a paraffin base oil exhibited greater adhesion for sand grains than water.

Hydraulic pressure produced more oil than air pressure from similar artificial formations.

WYCKOFF, R. D., BOTSET, H. G., and MUSKAT, M., 1932, August, Flow of Liquids Through Porous Media Under the Action of Gravity: Physics, Vol. 3, No. 2, pp. 90-113.

Gives description and results of experiments, performed with laboratory models, on radial flow through sand by gravity. Differentiates between fluid head and fluid level in sand and obtains formula for permeability from observed fluid heads in small observation tubes. Illustrates streamline and capillary flow of water in models.

WYCKOFF, R. D., and BOTSET, H. G., 1934, September, An Experimental Study of the Motion of Particles in Systems of Complex Potential Distribution: Physics, Vol. 5, pp. 265-75.

An electrolytic model was used in tracing the motion of the interface between two liquids of same viscosity and density moving through a porous medium. A blotter was moistened with a weak solution of potassium sulfate and phenophthalein to represent the oil field. Input and output wells were arranged as desired, as represented by the negative and positive electrodes.

The advance of the OH ions from the negative toward the positive electrode represented the flow across the field. Interference from the H ion was avoided by setting the positive electrode at a greater distance than the negative electrode from the output well, or by neutralizing the H ion with KOH solution. The experiments checked analytical determinations with an accuracy of 95-98%.

WYCKOFF, R. D., and MUSKAT, M., 1934.
See MUSKAT.

WYCKOFF, R. D., and REED, D. W., 1935, December, Electrical Conduction Models for the Solution of Water-seepage Problems: Physics, Vol. 6, pp. 395-401.

Electrical models were used to solve problems of the flow of liquids through porous media under action of gravity. The shape of the free surface and extent of the surface of seepage were determined simultaneously with the potential distribution within the flow system. Applied to seepage through dams.

WYCKOFF, R. D., and MUSKAT, M., 1936, March.
See MUSKAT.

WYCKOFF, R. D., and BOTSET, H. G., 1936, December, Flow of Gas-liquid Mixture Through Unconsolidated Sands: Physics, Vol. 7, pp. 325-345; Abs. Inst. Petroleum Technologists Jour., Vol. 22, No. 158, p. 529.

The conclusions reached from the experiments described are: (1) That under steady state conditions of flow of gas-liquid mixtures through unconsolidated sands, the liquid saturation of the sand is determined by the gas-liquid ratio, and for a given ratio is not appreciably different for large differences in the sand permeability; (2) that for all gas-liquid ratios below a certain critical value, the steady state condition for a given sand is always reached at the same saturation and permeability, called equilibrium, since they apparently represent a definite characteristic of the sand; (3) the equilibrium permeability and saturation of a sand may be predicted from measurement of its specific permeability, and this equilibrium permeability determines maximum recovery obtained from sand. Moderate variations in liquid viscosity and surface tension appear to have negligible effect on the permeability saturation relation for a sand; (4) gas-liquid ratios of the order of 20,000 cu. ft./bbl. are required to obtain a liquid staturation as low as 30% (or liquid recovery of 70%) a factor of major significance of a sand when considering efficiencies of secondary methods of recovery or natural recovery methods which depend on the sweeping action of gas traversing the sand, so-called gas-drive effects.

WYCKOFF, R. D., BOTSET, H. G., MUSKAT, M., and MERES, M. W., 1937.
See MUSKAT.

* YOSHIDA, Y., 1928, April, New Study on the Radius of Circle of Influence of Wells: Waterworks, Vol. 67, No. 4, p. 139.

Formulae derived by which the limit of the radius of the circle of influence of pumping wells may be determined.

SECTION III

Description of Water-flood Projects, Equipment, Well Patterns and Spacing, Production Data, and Operating Costs

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ALBRIGHT, J. C., 1935, Sept. 23, Acid is Being Used for Cleaning Intake Wells in Water-flooded Areas: Oil Weekly, Vol. 79, No. 2, pp. 24-8.

Input wells on some of the Bradford water-floods cleaned with HCl acid. One operator used compressed air to clean the well of sediment prior to adding the acid to clean the sand face.

ALBRIGHT, J. C., 1935, Nov. 11, Water-flooding Practices in Pennsylvania Vary but Follow Same General Principles: Oil Weekly, Vol. 79, No. 9, pp. 31-4.

Production practices, costs, and income from Pennsylvania water-flood projects presented in detail.

ALBRIGHT, J. C., 1935, Dec. 16, Water-flooding Work Requires Extensive Investigations of Formation and Lease Condition: Oil Weekly, Vol. 80, No. 1, p. 31-34.

Discusses the investigations necessary before a tract is water-flooded and gives some results obtained from floods.

ALBRIGHT, J. C., 1935, Dec. 23, Mid-Continent Flooding Project Started in North Oklahoma Involves Some Interesting Features: Oil Weekly, Vol. 80, No. 2, pp. 30-4.

A delayed flood with 330-foot spacing in Nowata and Rogers county is described. The water used, containing H_2S before treatment, was obtained from a formation below the oil-producing sand.

ALBRIGHT, J. C., 1936, Jan. 6, One of the Largest Modern Equipped Water-flood Properties Expected to be Profitable for Many Years: Oil Weekly, Vol. 80, No. 4, p. 28.

Describes a 5,000-acre water-flood property south of Bradford, Pa.

ALBRIGHT, J. C., 1936, Oct. 26, Texas Water-flooding project Indicates Possibilities of Process, Although Strictly Experimental: Oil Weekly, Vol. 83, No. 7, pp. 19-24.

A 144-acre flood southwest of Burkburnett is described. The 360- and 560-foot sands are flooded on an irregular spacing program. The 250- and 440-foot sands are not flooded.

ALBRIGHT, J. C., 1937, July, Successful Water-flooding Project Near Kanesholm, Pennsylvania: Petroleum Engineer, Vol. 8, No. 11, pp. 58-63, 66.

A detained description of the Olean Petroleum Company flood in Kane county; includes methods, production, and distributed cost figures.

ALBRIGHT, J. C., 1937, Much Value May be Procured by Reviewing Basic Operations of Bradford Water-flooding Principles: 3 parts, Oil Weekly,

Aug. 23, Vol. 86, No. 11, pp. 41-2; Sept. 6, Vol. 86, No. 13, pp. 34-42; Sept. 13, Vol. 86, No. 14, pp. 48-50.

Subject divided into three divisions: Preparatory work, drilling and production practice, and water operations. Discussion in general terms with very few specific data.

ANONYMOUS, 1923, August 18, Flooding Fields to Increase Oil Yield: Petroleum Times, p. 242.

Not available.

ANONYMOUS, 1925, July 18, Getting More Oil from Sands: Petroleum Times, p. 94.

Not available.

ANONYMOUS, 1925, August, Experiments in Getting More Oil from Various Oil-field Sands: Oil Age, Vol. 22, p. 82.

Not available.

ANONYMOUS, 1928, June, More Science Needed in Flooding Operations: Oil Field Eng., p. 30.

No copy available.

ANONYMOUS, 1928, July 7, Water-flooding Methods: Petroleum Times, p. 31.

Not available.

ANONYMOUS, 1930, May 28, Flooding Five Spot; Flooding for Declining Oil Wells: Petroleum World, p. 151.

Not available.

ANONYMOUS, 1930, January, Water Flooding in the Bradford Field: Oil Bull., p. 77.

Not available.

ANONYMOUS, 1933, Mar., The Effect of Sand Tamping on the Efficiency of Explosives in Oil-well Shooting: Petroleum Engineer, Vol. 4, No. 6, pp. 26-27.

Based on booklet by P. L. Lewis, of the American Glycerine Company. Sand tamping is preferable to water tamping. When explosion takes place the sand load confines the shot to the area surrounding the charge and the force of the explosion expends itself horizontally; with water tamping, part of the force of the explosion is wasted in blowing water up the hole, and the high velocity with which it travels is also likely to cause sand caving, etc., at undesired horizons.

Where fluid is in the hole, a considerable part of the force of the explosion is expended at the fluid level, sometimes rupturing casing. The well should either be bailed down or completely filled.

With sand tamping, shots may be made close to the casing seat without great danger: However, it requires the use of time bombs and necessitates a cleanout job afterward.

ANONYMOUS, 1935, Aug. 8, Five-spot Flooding Method Applied in Nowata and Rogers Cos., Oklahoma: Oil and Gas Jour., Vol. 32, No. 12, p. 40.

Discussion of Carter, Forest, and Wiser properties. The Wiser Company is using a line-flood with salt water, treated to prevent corrosion.

ARNOLD, L. M., 1938, Oct. 3, Evaluation of Mid-Continent Properties for Water Floods, Oil Weekly, Vol. 91, No. 4, pp. 32, 34, 38.

Preliminary factors to be considered are: past production of oil and water, old well logs, availability of natural gas, depth of sand, casing required, water supply, grade of oil produced, purchaser outlet, and previous repressuring operations.

A sufficient number of cores should be obtained and analyzed to give a clear picture of the physical condition existing in the reservoir, and the production to be expected under flood conditions.

A financial breakdown of production, equipment, labor, supplies, taxes, and interest should be made, the discount factor for present worth applied and the present value of the property determined.

A development budget for a 160-acre tract is shown in tabular form as an example.

ASHLEY, G. H., and ROBINSON, J. F., 1922, Oil and Gas Fields of Pennsylvania: Pennsylvania Geol. Survey, 4th Series, p. 79.

Discussion of physical laws related to petroleum. All available production and exploration in Pennsylvania surveyed.

BARB, C. F., 1929, November, A Renaissance in Petroleum: Colorado School Mines Mag., Vol. 19, No. 11, pp. 14-17.

Not available.

BARB, C. F., and SHELLEY, P. G., 1930, Production Data on Appalachian Fields: Pennsylvania State College, Mineral Exp. Sta. Bull. 6, 68 pp.

Summarizes pervious work pertaining to water-flooding and outlines the conditions favorable to such projects. Presents accepted theories and data pertaining to current practices.

BARNES, K. B., 1931, July 3, A Possible Method for Plugging Intermediate Sand Strata: Oil Weekly, Vol. 62, No. 3, pp. 16-18.

Suggests that a cement torpedo, loaded with quick-setting cement, and a gelatin core, should be lowered into the well opposite any intermediate porous and highly permeable sand streak, and exploded. The cement would be driven into the sand and would set immediately. To be effective, it is necessary that the permeability of the formation should be considerably greater parallel to the bedding planes than across them since, in the latter case, cross-flow would result behind the cement and nullify its effect.

BARNES, K. B., and FANCHER, G. H., 1936.
See FANCHER.

BELL, A. H., and PIERSOL, R. J., 1931, December 19, The Need for Sand Coring in the Southeastern Illinois Oil Field: Illinois State Geol. Survey Press Bull. Series, Illinois Petroleum 21.

Discusses information obtainable from cores and its application to improved recovery methods. Vacuum, water-flooding, and gas and air repressuring are compared.

BELL, A. H., and PIERSOL, R. J., 1932, June 18, Effects of Water Flooding on Oil Production from the McClosky Sand, Dennison Twp., Lawrence Co., Ill.: Illinois State Geol. Survey, Press. Bull. Series, Ill. Petroleum No. 22.

Geology and production records.

BELL, A. H., 1934, June, Further Data on Water Flooding in Illinois Oil Fields: Natural Floods: 2d Ann. Petroleum Conf., Illinois State Geol. Survey, pp. 11-26.

A detailed survey of the geology, history, water production, fluid levels, and production records of natural water floods in Illinois.

BELL, A. H., 1936, April 24, Studies in Repressuring and Water Flooding: Petroleum Engineer, Vol. 7, No. 8, p. 60, Aug. 1936; presented at 4th Ann. Mineral Industries Conf. of Illinois, Urbana, Ill., April 24, 1936.

In order to facilitate coring for the purposes of estimating underground oil reserves and determining the most suitable production method for each locality, the Illinois State Survey purchased a core barrel for use by operators when new wells were drilled.

A list of all floods (controlled, natural, or accidental) operating in Illinois is presented.

A field survey was made, seeking data on (1) areas affected by flood, (2) underground geological conditions in each area from well logs, structure contour maps, cross-sections, etc., (3) production records of oil, gas and water by leases, or wells, (4) cost data of production by various methods.

BIGNELL, L. G. E., 1933, July 13, Water Flooding: Oil and Gas. Jour., Vol. 32, No. 8, p. 43.

Points out danger of plugging from iron salts or suspended matter in water used.

BIGNELL, L. G. E., 1935, Aug. 29, Water-flooding Projects in Oklahoma Patterned after Eastern Methods: Oil and Gas Jour., Vol. 34, No. 15, pp. 41-3.

Discussion of preliminary work on Forest Production Company lease in Nowata county. Three counties—Nowata, Rogers, and Washington—contain over 2,000 wells, producing an average of less than ¾ barrels of oil per day from the Bartlesville sand. The Forest lease of 5,000 acres contained over 900 such wells. Core analyses showed an average oil content of 10,000 to 20,000 barrels per acre.

BIGNELL, L. G. E., 1936, January 30, New Methods of Control Seal off Salt Water from Oil Bearing Formations: Oil and Gas Jour., Vol. 34, No. 37, p. 59.

Discusses water shut-off methods, including several cementing methods, and Dowell's soap-solution seal.

BJORNSSON, C. A., and SCHALLER, A., 1923, Influence of Heat Upon the Recovery of Oil by Water Displacement: National Petroleum News Nov. 7, Vol. 15, No. 45, pp. 53-7; and Nov. 14, Vol. 15, No. 46, pp. 81-8.

Theoretical calculations made for adding heat to oil sand by water during a water flood. The addition of heat to the producing formation would be

desirable, since it would lower viscosity and adhesiveness of the oil and reduce paraffin trouble.

Calculations were based on assumed porosity of 12½% and sand thickness of 15 feet. Summary of heat losses included:

Heat loss in water behind well	276,000,000 B.T.U.
Heat loss in water pumped out	10,200,000 B.T.U.
Heat loss in oil pumped out	3,230,000 B.T.U.
Heat loss by conduction behind well	116,400,000 B.T.U.
Heat loss by conduction above and below sand	970,000,000 B.T.U.
	1,375,830,000 B.T.U.
Total heat introduced (boiling water 500 lbs. pressure),	2,155,000,000 B.T.U.
Net heat introduced =	779,170,000 B.T.U.

Conclusion: Hot-water flooding should not be attempted except with sands at least 30 inches thick and highly porous, and then only under most favorable conditions.

BOSSLER, R. B., 1922, Oil Fields Rejuvenated: Pennsylvania Geol. Survey, Bull. 56. Also, under title: 1923, March 28, Apr. 4, Several Methods Used for Increasing Oil Recovery in Pennsylvania: Two parts, Nat'l Pet. News, Vol. 15, No. 13, p. 75; Vol. 15, No. 14, p. 91.

Rejuvenation by means of water flooding, compressed air, and dewatering of flooded pools. Well cleanout methods also discussed.

BOSSLER, R. B., 1938, June 30, A Shot-hole Recorder: Oil and Gas Jour., Vol. 37, No. 7, pp. 44-5.

Instrument designed to measure diameter of hole, electrically. Profile can be plotted from ammeter readings versus depth.

BRACE, O. L., 1937, March, Factors Governing Estimation of Recoverable Oil Reserves in Sand Fields: Am. Assoc. Petroleum Geologists Bull., Vol. 18, No. 3, pp. 343-357.

Two methods listed as available for calculation of petroleum reserves. Production based on decline curves discredited, due to prolongation of the flush period under proration, resulting figure being too large. Volumetric calculations discussed in a nontechnical manner. Errors likely to occur noted. The predominant errors (1) overestimation of percentage of recoverable oil, (2) core analyses not truly representative of the field.

BREDBURG, L. E., 1936, Oct. 1, Water Flooding in Burkburnett a Success: Oil and Gas Jour., Vol. 35, No. 20, pp. 44-6.

McCarty Oil Company flood of 60 acres in Burkburnett field, Wichita county Texas, discussed.

BRUNDRED, W. J., 1932, Research in the Petroleum Industry: Pennsylvania State College Mineral Exp. Sta. Bull. 11, pp. 49-50.

Listed problems confronting water-flood operators.

CARLISLE, C. C., 1938, Reclamation of Partially Depleted Oil Pools: Oil Weekly, Vol. 90, No. 11, pp. 23, 30.

General discussion of water flooding and repressuring southeast Kansas

sands. Stresses necessity of obtaining adequate and accurate data concerning the history of the pool and core analyses from a modern laboratory before applying secondary recovery methods.

CLAPP, FREDERICK, G., 1935, June, Safety of Water-flooding Pressures at Bradford, Pennsylvania: Am. Assoc. Petroleum Geologists Bull., Vol. 19, No. 6, pp. 793-852.

Based on research in 1932. After reviewing earthquakes, gas and volcanic blowouts, surface subsidence, salt-dome mechanics, hydrostatic conditions in known aquifers, and various formulae for determining the strength of materials, a formula was derived for calculation of the limiting pressure which can be applied to any water-flooding project.

Formula for circular plates fixed at the edges and under uniform pressure on one side:

$$p = \frac{3ft^2}{2r^2}$$ where p = uniform press. in #/□″.
f = working stress which the rock can sustain.
r = radius of plate in inches.
t = thickness of plate in inches.

To this calculated pressure should be added the difference in pressure exerted by a column of rock (composition of the overburden) and a column of water of the same height.

This was calculated for Bradford field and found to be 2700 #/□″.

Tables are given for the compressive strength of rocks and bending strength under load.

CLOUD, W. F., and GEORGE, H. C., 1927, August, Oil Sands and Production Relations: Oklahoma Geol. Survey Bull. 43, 142 pp.

General discussion of structural features and physical characteristics of oil reservoirs. Methods of collecting and examining cores, factors affecting oil recovery, and methods of cleaning-out and rejuvenating old production, including vacuum, water flooding, and air repressuring, are described.

CONINE, R. C., 1933, Dec. 14, Bradford Field Only 19 Percent Flooded: Oil and Gas Jour., Vol. 32, No. 30, pp. 9, 10.

Various water-flood patterns; estimated future development of Bradford field; a diagramatic sketch of lease equipment.

CONINE, R. C., 1932, Sept. 27, Water Flooding Southwest of Bradford: Oil and Gas Jour., Vol. 33, No. 19, p. 56.

Discusses report of Pet. Adm. Bd. on costs of drilling and produccction of Penn Grade Oil. Lists water-flood operators in Pennsylvania.

CONINE, R. C., 1934, Reconditioning Restores 20-year-old Well Almost as Good as When First Brought In: Oil and Gas Jour., Vol. 33, No. 4, p. 10.

Recommends using 300-500 pounds calcium carbide and one barrel of water for each 100 pounds of carbide to recondition wells by treating after shooting with nitroglycerin.

Many small operators do not have funds available to apply secondary recovery methods, or a larger portion of the middle district would be repressured.

CONINE, R. C., 1934, Nov. 1, Modern Flood Methods Promise Large Reserve in Eastern Field: Oil and Gas Jour., Vol. 33, No. 24, pp. 14, 34.

Discussion of the flood by Olean Petroleum Company on a 5,000-acre block, 6 miles northeast of Kane, McKean county, Pa.

CONINE, R. C., 1935, Aug. 1, Pennsylvania Middle Field Operators Turning to Secondary Recovery: Oil and Gas Jour., Vol. 34, No. 11, pp. 17, 18.

Discussion of operations in the district between Kane and Butler.

CONINE, R. C., 1935, Aug. 22, Producers in Clarendon, Penn., are Using Delayed 5-spot Plan: Oil and Gas Jour., Vol. 34, No. 14, p. 27.

Water floods in Warren county, Pennsylvania, discussed, with details of Belleview Oil Corporation project.

CONINE, R. C., 1936, Jan. 23, How Would You Go About Equipping Old Properties for Water Flooding? Oil and Gas Jour., Vol. 34, No. 36, p. 33.

The development program, design, and cost of operating a water flood on a 100-acre property in the Bradford field were discussed.

CORWIN, W. S., 1934, June 1, Recent Results in Controlled Water Flooding: 2nd Ann. Conf. Illinois State Geol. Survey, pp. 37-38.

A brief discussion of a water-flooding project in Crawford county, Illinois, the various spacing programs existing at Bradford, and a number of water-treating methods.

CROUCH, A. W., 1928, February, Underground Water Flood Traced by Dye: Water Works Eng., Vol. 81, No. 5, p. 271. Also 1929, January, "Tracing Underground Waters": Municipal News and Water Works, Vol. 76, No. 1, p. 41.

While checking the course of underground water in limestone beds near Rock Island, Tenn., uranine dye traveled five miles in six days.

DALRYMPLE, DAL, 1936, June 18, Remarkable Results from Water Floods in Northeast Oklahoma: Oil and Gas Jour., Vol. 35, No. 5, pp. 21, 22.

Increased yields with a ratio of about 20 to 1 reported for projects by Forest, Carter and Brundred Oil Company in northeast Oklahoma.

DALRYMPLE, DAL, 1936, Oct. 8, Kansas Water-flooding Operations in Anderson County: Oil and Gas Jour., Vol. 35, No. 21, p. 32.

Description of a water-flooding project started in the Garnett Shoestring area by the Brundred Oil Corporation.

DAVIS, W. N., 1932, June, 60,000 Barrels Per Day from An Exhausted Field: World Petroleum, p. 249.

Not available.

DORN, F. D., 1928, Origin, Development of Water Flooding: National Petroleum News, Vol. 20, No. 22, pp. 59, 61, 64, May 30; Am. Petroleum Inst. Production Bull. 202, p. 141, Sept.

Traces early history of water flooding.

FANCHER, G. H., and BARNES, K. B., 1936, Water Flooding in the Mid-Continent: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 138-76; Oil Weekly, Vol. 79, No. 7, pp. 31-40, Vol. 34, No. 23, pp. 38-42.

Discusses water-flooding principles, with emphasis placed on the physical and economic problems encountered in the Mid-Continent area. Includes tables of producing formations and characteristics of fields which might prove susceptible to flooding, together with core analyses and water analyses of the general area.

* FETTKE, C. R., 1930, April, Recent Development in Flooding Practice in the Bradford and Richberg Oil Fields: Am. Inst. Min. Met. Eng. Tech. Pub., 328.

The sands of the two fields are compared and, after a historical summary of shooting methods, types of intensive flood patterns are described with examples of results as portrayed by production curves. Water supply and the present status of oil and gas drives are also discussed.

FETTKE, C. R., PANYITY, L. S., NEWBY, J. B., and TORREY, P. D. See NEWBY, J. B.

FETTKE, C. R., 1934, Feb., Physical Characteristics of Bradford Sand, Bradford Field, Pennsylvania, and Relation to the Production of Oil: Am. Assoc. Petroleum Geologists Bull., Vol. 18, No. 2, pp. 191-211.

The remarkable success of water-flooding operations at Bradford was attributed to—

(1) The relative low permeability of the sand.
(2) An original reservoir pressure that was probably subnormal.
(3) An unusually large percentage of oil remaining after the economic limit had been reached by ordinary methods.
(4) Although wide variations in total thickness and number of shale breaks occur in the sand body, in large parts of the field the individual sand layers show a remarkable degree of uniformity in texture, porosity, and oil content.
(5) The relative shallow depth of the sand.
(6) The superior quality of the oil.

Where the greatest difficulty was encountered in application of the water drive, core studies showed that alternate layers of sand were present which varied considerable in texture, viscosity, and permeability.

FETTKE, C. R., 1937, Aug. 5, Physical Characteristics of Bradford Third Sand and Relation to Occurence of Oil: Oil and Gas Jour., Vol. 36, No. 12, pp. 20-1, 24-5, 35.

Physical characteristics of Bradford third sand and relation to occurence of oil. Tables, charts, and graphs utilized to present data relative to the texture, porosity, permeability, oil content, lateral and vertical variations, conditions of sedimentation, and relation of oil accumulation to physical character and structure.

——— 1937a, Aug. 12, Surface Waters of Bradford Field. Oil and Gas Jour., Vol. 36, No. 13, pp. 49-53.

Connate water, salt water, flood water, and ground water discussed. Analyses of numerous samples presented.

——— 1937b, Aug. 19, Mech. of Water Flooding; Evolution of Practice at Bradford Field: Oil and Gas Jour., Vol. 36, No. 14, pp. 32-6.

Discussion of various flood patterns employed.

——— 1937c, Aug. 26, Relation of Production of Oil by Water Flooding to the Physical Characteristics of Bradford Field Sand: Oil and Gas Jour., Vol. 36, No. 15, pp. 48-50.

A summary of production data for each type of flood pattern used at Bradford.

——— 1937d, Sept. 2, Production, Reserves, and Future Life of Bradford: Oil and Gas Jour., Vol. 36, No. 16, p. 61.

Data giving past production by natural methods, estimated amount producible by flooding methods, and prediction of amount that will be left in sand after flooding.

FLOOD, M. H., 1936, Problems in Improved Recovery: Oil Weekly, Vol. 81, No. 13, pp. 37-38. Presented at 4th Ann. Mineral Industries Conf. of Illinois.

Outline of problems necessary to be solved in applying secondary recovery methods to an oil property.

GEORGE, H. C., and CLOUD, W. F., August.
See CLOUD.

GINTER, R. L., 1937, October 7, Influence of Connate Water on Estimation of Oil Reserves: Oil and Gas Jour., Vol. 36, No. 21, p. 97.

Investigations made indicate that an appreciable amount of water is distributed through a vertical section of a sand body containing oil where the pores are small enough to be classified as a capillary system, but very little water exists where the pores are large enough to be classified as a noncapillary void system.

This should be taken into account, as well as porosity, sand thickness permeability, etc., in estimation of oil reserves by volumetric methods.

GRETTUM, I. G., and STEPHENSON, E. A., 1930.
See STEPHENSON.

GRETZINGER, WM., 1930, April 1, Improved Systems of Water Flooding Have Increased Production 640 Percent: Oil Field Eng., Vol. 7, No. 4, p. 14.

Discussed and quoted from a group of A. I. M. E. papers, delivered in New York, Feb. 17, 1930.

HAWORTH, A. J., 1938, The Potential Yield of Reservoir Rocks: Science of Petroleum, Vol. I, pp. 552-5, Oxford Press, London.

Cities several ultimate recovery figures and concludes that, except under unusual conditions, 40% recovery is the maximum. Water flooding, mining, or edgewater encroachment may increase the recovery appreciably.

HEROLD, S. C., 1926, November, Some Analytical Principles Covering Oil Recovery by Forced Drive: Am. Inst. Min. Met. Eng. Pamphlet No. 1607-G; Abstr. Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 218; Oil and Gas Jour., Oct. 28, 1926.

Based on uniform, homogeneous sands containing no water, analytical methods covering the following problems are outlined: ideal drainage area, application of forced drive to exhausted wells, recovery of oil from an elliptical area, method of determining the area of the elliptical nondrained space and determination of whether it is less costly to space wells closely or apply greater pressure.

HORNER, W. L., 1935, Feb. 21, Engineer Says Surface Methods Can Produce as Much as Mining: Oil and Gas Jour., Vol. 33, No. 48, p. 16.

Underground mining methods are not recommended because: (1) Water flooding in some manner would still be necessary to produce a large percentage of the oil, (2) in most consolidated sands low permeability to gravity flow exists, (3) driving pressure of 300-400 pounds per square inch would be required to flush sand within reasonable time, (4) regardless of number of wells drilled from mine passages the same areal efficiency is in effect as for a surface flood, and (5) any increased recovery would be due only to closer control of flow, which may also be applied at surface if desired.

Longwall mining not to be considered, since the cost is prohibitive. It would, however, recover practically all of the oil remaining, which is estimated in fields where it might possibly be applied, at 500 barrels per acre-foot.

JAMES, H. P., 1923, Nov. 1, Bradford Still Much Alive: Petroleum Age, pp. 18, 19.

No copy available.

KATES, PHILLIP, 1926, Aug. 5, Can 40 Billion Barrels of Oil Locked in Sand of North America be Recovered? Oil and Gas Jour., Vol. 25, No. 11, pp. 22, 23, 123.

Attorney points out what estimated increase from water flooding with soda-ash solution may mean.

KENNEDY, H. T., 1936, Chemical Methods for Shutting Off Water in Oil and Gas Wells: Am. Inst. Min. Met Eng., Petroleum Devel. and Tech., pp. 177-186.

Antimony trichloride and silicon tetrachloride in oil solution were recommended for use in selective water shut-offs in producing wells.

McCLINTOCK, C. B., 1934, May 31, Water Flooding in Eastern Fields has Increased Recovery and Extended Life of Pool: Oil and Gas Jour., Vol. 33, No. 2, p. 45.

Also: 1934, Development in Eastern Production Practice: Am. Petroleum Inst. Production Bull. 213, pp. 67-70.

Discussion of flood operations in Bradford field; development costs (including small plants), $2,500-$3,000 per acre.

McCLINTOCK, C. B., 1936, Jan. 30, Water Flooding of Oil Sands Demands Well-planned and Executed Program: Oil and Gas Jour., Vol. 34, No. 37, pp. 56, 57.

The latest developments in water flooding are application of pattern drilling and core analysis. Flood has been changed from natural head to artificial pressure, which further reduces time before peak production ensues; delayed drilling and flowing production are used to some extent.

Studies are being made on capillary phenomena working within the sand such as adhesion, surface tension and viscosity. Experiments under way on solution flooding show a possible increase in production from 5-15%.

McCLINTOCK, C. B., 1937, Dec. 11, Water Flooding as a Means of Secondary Recovery: Presented before Kentucky Oil and Gas Assn., Louisville, Ky.

A general description of water-flooding practice at Bradford and other Allegheny fields. Statistical data covering typical core analyses, well-spacing patterns, yields, development costs, and water supply.

Experimental work reported on (1) capillary phenomena in the sand, such as adhesion, surface and interfacial tension, (2) viscosity, (3) selective plugging of the sand, (4) solution flooding.

McINTYRE, JAMES, 1926, Sept. 2, Various Methods of Restoring Pressure Using Water, Compressed Air and Gas, and Soda Ash to Recover Riches of the Bradford Sand: Oil and Gas Jour., Vol. 25, No. 15, pp. 30, 138-139.

Early history of Bradford water flooding reported.

McINTYRE, J., 1929, Feb. 14, Plan to Deplete Sands Quickly, Oil and Gas Jour., Vol. 27, No. 39, pp. 39, 146.

Discusses early development programs, as well as modern 5-spot arrangement. Costs are estimated.

McINTYRE, JAMES, 1929, Aug. 15, New Field for Scientist and Engineer: Oil and Gas Jour., p. 38.

The early history of Bradford water-flooding operations indicates a proper place for the petroleum engineering chemist and physicist.

McINTYRE, J., 1929, October 24, Problems Facing Bradford Operators: Oil and Gas Jour., Vol. 23, p. 38.

Discussion of water for flooding purposes, and methods of increasing the yield.

McINTYRE, J., 1935, June 27, Forest Oil Company Buys Big Nowata Block and Will Start Flooding Operations: Oil and Gas Jour., Vol. 34, No. 6, pp. 20-32.

News item.

MELCHER, A. F., and WHITE, DAVID, 1925, April 20, Much Oil Remains in Bradford Sand After Flooding Process: Oil City Derrick.

No copy available.

MILLS, R. VAN A., 1928, Aug. 16, Dangers of Water Flooding Explained: Oil and Gas Jour., Vol. 27, No. 13, pp. 38-9, 88.

A water flood may emulsify the oil and water without increased production; cites failures of attempted gravity flood in eastern Kansas.

MORRIS, A. B., 1936, May 7, Flooding Water Resources in Nowata, Oklahoma: Oil and Gas Jour., Vol. 34, No. 51, pp. 35-41.

Also, 1936, May 4, Large Water Source Needed if Mid-Continent Flooding Work to Extend Over Wide Area: Oil Weekly, Vol. 81, No. 8, pp. 20-24.

Suggests dam on Big Creek to supply water for project. The producing area covers approximately 50 square miles, sand is 30 feet thick, and has an average porosity of 19-20%. Approximately 40,000 barrels per acre required to completely flood the Bartlesville sand; if only half the area is found amenable to production 640,000,000 barrels would be required. Over a period of ten years this would average a daily demand of 174,800 barrels of water.

NEWBY, J. B., 1927, Recent Developments in Water Flooding: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 390-2.

No evidence of sand plugging was found, but the use of soda ash failed to increase the total yield from comparative wells, flattened the production curve, and took a longer time.

Increased pressures, use of 5-spot patterns, water analyses and uniform intake volumes are being used.

NEWBY, J. B., TORREY, P. D., FETTKE, C. R., and PANYITY, L. S., 1929, Bradford Oil Field, McKean Co., Penn., and Cattaraugus Co., N. Y.: Am. Assoc. Petroleum Geologists, Structure Typical American Oil Fields, Vol. II, pp. 439-483.

Discusses history, development, production data, producing formations, structural features, properties of the oil, and methods of production.

NEWELL, F. H., 1924, Many Refinements in Flooding Oil Sands Needed: National Petroleum News, Vol. 16, No. 38, p. 48.

Points out that most flooding to date has been done haphazardly.

NOWELS, K. B., 1932, May 16, Flooding Methods and Equipment Trends at Bradford: Oil Weekly, Vol. 65, No. 9, pp. 36-41.

Equipment trends are toward use of diesel engines, heavier powers with high belt speeds, and the use of dynamometers in weighing wells. Formulae were derived for adjusting spacing program to that of desired injection pressure.

NOWELS, K. B., 1933, Rejuvenation of Oil Fields by Natural and Artificial Water Flooding: World Pet. Congress Proc. Vol. I, pp. 310-315.

Bradford water-flooding projects were discussed, including history, type of installations, costs, and recoveries. The elliptical and circular theories of fluid movement were outlined.

O'DONNELL, J. P., 1936, Dec. 17, Sand-tamped Shots Prove Successful on Flood Project: Oil and Gas Jour., Vol. 35, No. 31, pp. 47-8.

The cleanout period with sand-tamped shots averages 4-7 days, as compared to one day for water-tamped shots, but productivity increases. Data obtained from lease at Clarendon, Pa.

O'DONNELL, J. P., 1938, July 14, Water Flood Curtailment Urged in Bradford-Allegheny: Oil and Gas Jour., Vol. 37, No. 9, pp. 20, 30.

According to July report of Penn Oil Producers' Association research staff at Pennsylvania State, curtailment of water flood production will not reduce ultimate recovery.

PANYITY, L. S., 1924, Oct. 10, The Flooding of Oil Sands at Bradford: Oil Weekly, Vol. 35, No. 3, p. 17.

Discusses possibilities and practical studies required before water flooding.

PANYITY, L. S., 1925, May, A Study of the Flooding Processes Used in the Bradford Area: Oil Trade Jour., pp. 19-20, 74.

Not available.

PANYITY, L. S., 1926, Valuation of Properties in the Bradford District: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 235-240.

In addition to data, similar to that ordinarily required, the following items are needed:

1. Condition of sand—its thickness, porosity, permeability profiles, and gas streaks.
2. Acre-yield preferred to a tabulated acre-ft. yield based on certain properties.
3. The direction and rate of flow of flood waters.

PANYITY, L. S., FETTKE, C. R., NEMBY, J. B., and TORREY, P. D.
See NEWBY, J. B.

PHILLIPPI, P. M., 1938, Sept. 12, Well-shooting Experiment May Develop Helpful Data, Oil Weekly, Vol. 91, No. 1, pp. 40, 42, 44, 48.

Experiments were conducted in laboratory of Penn State College and in the field, on an outcropping formation resembling the Bradford Sand, to determine the best method of tamping, size of shot, and effect of shot, etc. Tests were not conclusive, since opening the formation for observation showed many cracks made in the brittle sand during the opening, rather than when the nitroglycerin exploded.

Both water and sand tamps were utilized; the sand tamp provided the greater efficiency.

Laboratory experiments will be continued on reinforced blocks of sand shot by small charges of nitroglycerin.

PIERSOL, R. J., and BELL, A. H., 1931.
See BELL.

PIERSOL, R. J., and BELL, A. H., 1932.
See BELL.

PIPER, WM., 1925, July 15, Intensive Flooding Successfully Used on Small Pennsylvania Lease: National Pet News, Vol. 15, No. 26, pp. 72-75.

A fixed production pattern should not always be followed. Advantage should be taken of any natural formation trends, and if a well intended for a water well happens to be a good producer it should be produced. Various production methods described on a 60-acre lease at Duke Center, Pa.

A news item on the chemical addition to flood waters, based on the U. S. G. S. work.

REED, PAUL, 1936, July 30, Water Flooding in Nowata District Shows Increase: Oil and Gas Jour., Vol. 35, No. 11, pp. 66-70.

Development costs, practices, and water analyses were reported for Nowata, Okla., district.

REED, PAUL, 1936, August 6, Flooding of Forest's Second Project Will Start Soon: Oil and Gas Jour., Vol. 35, No. 12, p. 26.

Forest Oil Company's second project in northeast Okla., using 320-foot spacing and delayed flooding, was reported. A description of the filter plant was given.

REED, PAUL, 1936, August 13, Engineers Make Tour of Nowata Flood Area: Oil and Gas Jour., Vol. 35, No. 13, p. 11.

A. P. I. tour from Tulsa meeting visited the Nowata flood area. Due to high porosity, Forest Company at Big Creek added 40,000 barrels water per acre before recovery commenced. Alluwe, with 30% less porosity and 20% less permeability, is expected to yield about the same ultimate recovery. Pressure at Big Creek was 350 pounds; at Alluwe, 400 pounds.

REED, PAUL, 1936, December 3, Results of Five Years Flooding in Nowata by Carter: Oil and Gas Jour., Vol. 35, No. 29, pp. 43, 44, 48.

Discusses problems, methods, and results of the Carter Oil Company project.

The lease had been previously repressured with air. Proof of oxidation was obtained from cores found filled with black sticky carbon near old input wells. One well produced B. S. for six months, gradually increasing in quantity, then cleared up overnight and started producing 5-6 barrels of oil per day.

REED, PAUL, 1937, Sept. 2, Variety of Water-flooding Methods Used in South Kansas Projects: Oil and Gas Jour., Vol. 36, No. 16, pp. 40-43.

Methods used in projects of the McIntyre-Travis, Shell, Streeter, Brundred, Texas, Oil Recovery, and Converse oil companies are reported.

REED, PAUL, 1938, Water-flooding and Brine Disposal Methods Used in the Mid-Continent: Oil and Gas Jour., Vol. 36, No. 44, pp. 84-5, 88.

Relates to treatment of water for flooding and brines for disposal. Contrasts methods used in Pennsylvania and Mid-Continent water-flooding areas.

* REEVES, J. R., 1928, January, Possibility of Fusing Oil Sands When Shot: Am. Assoc. Petroleum Geologists Bull., Vol. 12, No. 1, p. 87.

It is popularly believed that oil sands may be and frequently are "burned" or fused when shot. The temperature developed by explosives is higher than the fusing points of the minerals in oil sands, but the time during which this temperature is maintained is very short, so that usually no fusion can take place. In the case of siliceous limestone there may be fusion by reason of fluxing of the silica. No examples of fusing have been observed by the author.

RICHART, F. E., 1926, Nov. 11, Marked Increase in Recovery of Oil by Water Drive and Added Pressure: Oil and Gas Jour., Vol. 25, No. 25, pp. 33, 148.

Line flood advised with pressure preferred to natural head. Data shows success of Ebenzer Oil Company flood.

RIKER, M. D., 1936, March 24, Why Not Put the Water in an Oil Well to Work? A Suggestion on Heating: National Petroleum News, Vol. 18, No. 12, pp. 82-3.

Advises heating the water in the formation by means of electricity. States 5-10 kw. per hour will heat 100-240 barrels of water 10° every 24 hours.

RYDER, H. M., 1936, Aug. 27, Many Factors to be Considered in Water Flooding: Oil and Gas Jour., Vol. 35, No. 15, pp. 50-2.

Cores should be taken frequently, permeability and saturation profiles made and water flow and pressure regulated accordingly; undesirable sands should be packed off; and the balance between recovery, land cost, development cost, and the price of crude considered.

*RYDER, H. M., 1936, Nov. 26, Problems Involved in Flooding to Obtain Maximum Results: Oil and Gas Jour., Vol. 35, No. 28, p. 48.

Discusses problems as encountered in the Bradford, Pa., field. These problems may be roughly grouped as follows: (1) water supply and treatment, (2) well pattern, spacing and pressure; (3) selection of strata for flooding, and means for restricting pressure water to such strata, (4) the physical equipment involved in the above, and its operation, (5) the raising of the oil and any accompanying water to the surface and their disposition.

RYDER, H. M., 1937, May 1, Well Shooting with Reference to Secondary Recovery: Presented at 7th Pennsylvania Mineral Industrial Conf., Pennsylvania State College; 1937, May 6, O. G. J., Vol. 35, No. 51, p. 62; 1937, May 10, Oil Weekly, Vol. 85, No. 9, pp. 18-23.

Data and conclusions drawn from work on his own lease. The amount of intake water is proportional to the effective permeability of the formation and roughly proportional to its dry permeability. For any given sand the amount of water a well will take is roughly proportional to the strength of the shot as measured in quarts of nitroglycerin per foot. Suggests strength of shot be adjusted inversely proportional to permeability profile. A possible variation in susceptibility of the sand to fracture under a given shock should be considered. Sand tamping seemed advantageous, giving better results with less explosive, but only a small amount of data presented. Liquid nitroglycerin preferred to the solid form.

SANDERS, T. P., 1936, Sept. 17, Modern Practices Followed in Bradford Field Flooding Project: Oil and Gas Jour., Vol. 35, No. 18, pp. 42-5.

Drilling practice, water treatment and pumping equipment described.

SAXE, A. J., and YUSTER, S. T., 1938, Jan. 20, Results of Flooding Correlated with Laboratory: Oil and Gas Jour., Vol. 36, No. 36, pp. 78-9, 82-3, 86, 93.

Equations and graphs based on Bradford Field data are developed for relating the initial water intake to various well-spacing programs for known sand capacities. The 5-spot spacing programs are also mathematically related to development costs.

SCHALLER, A., and BJORNSSON, C. A.
See BJORNSSON, C. A.

SCLATER, K. C., 1930, Nov., Water-flooding Problems in Bradford Field: Petroleum Engineer, Vol. 2, No. 2, pp. 26-9.

A general discussion of Bradford Field practice.

SCLATER, K. C., 1936, Increasing Ultimate Yield of Oil: Two parts; Petroleum Engineer, Vol. 7, No. 4, pp. 86, 88; Vol. 7, No. 5, pp. 88-9.
Describes gas-drive, repressuring and water-flooding practice.

SHELLEY, P. G., and BARB, C. F., 1930.
See BARB.

SIMMONS, A. C., 1936, Sept., Recent Development in Water-flooding Practice in Bradford Field: Petroleum Engineer, Vol. 7, No. 7, p. 124.
The use of wider well spacing, higher pressures, heavier lifting equipment, purchased gas, a greater number of core analyses, and universal water treatment and filtration described.

SIMMONS, A. C., 1938, Recent Developments in Water Flooding: Oil Weekly, Vol. 89, No. 7, pp. 19-26; April 25, presented at Ann. Meeting Eastern Dist. Am. Petroleum Inst. Div. of Prod., Pittsburgh.
Discusses a water-flood project in terms of cost of development, treatment of water supply, and production rates and decline curves. Advises water intake rate be maintained constant by increasing pressure whenever necessary.

SMILEY, T. F., 1936, April 2, Water Flooding Practiced Secretly in Kansas Fields for Twenty Years: Oil and Gas Jour., Vol. 34, No. 46, p. 49.
Prior to the spring of 1935 when the legislature passed a law legalizing the use of water in repressuring, several operators had slit their casing, or failed to replace it when it rusted through, and allowed water from higher horizons to enter the well, flooding the formation under a gravity-head pressure.

SMILEY, T. F., 1936, April 23, Many Advantages Are Likely to Be Gained by Water Flooding: Oil and Gas Jour., Vol. 34, No. 49, p. 54.
(1) Water provides energy to drive oil to wells.
(2) Dead or unsaturated oil may be recovered in a short time.
(3) Oil saturation of sand is reduced to 35-45% of oil present at time flood was started.

SMITH, L. E., 1924, Feb. 6, New Method of Flooding Bradford Sand Is Now Successful: National Petroleum News, Vol. 16, No. 6, p. 37.
Description of Forest Oil Company water-flooding project.

SMITH, L. E., 1925, July 1, Discussion of Flooding Chief Theme Before New York State Meeting: National Petroleum News, Vol. 17, No. 26, p. 31.
News item.

SMITH, L. E., 1926, May 26, Water and Compressed Air Drives Work Side by Side in Bradford Field: National Petroleum News, Vol. 18, No. 21, pp. 41-44.
Water flooding to protect lease boundary lines, and air repressuring in center of lease to increase production discussed; also Smith-Dunn-Lewis air lift process.

SMITH, L. E., 1929, Water Drive in Bradford Field Speeds as Technique Improves: National Petroleum News, Vol. 21, No. 22, pp. 54-60.
Central water plants are equipped with individual meters for each well.

Methods of coring given in detail, with data used to determine casing points, rate of flooding, etc.

SMITH, L. E., 1931, May, Old Wells Are Made to Flow: International Petroleum Technology, Vol. 8, p. 227.

Well on Drake lease of Forest Petroleum Company started flowing from 1,340-feet depth under 840-lb. pumps pressure. The well ceased to make any water and flowed at rate of five barrels of oil per day.

SQUIRES, FREDERICK, 1934, Accidental Floods in Illinois and Indiana Sands: 2d Ann. Petroleum Conf., Illinois State Geol. Survey, pp. 27-35.

A list of accidental floods in Illinois and Indiana, with discussion.

SQUIRES, FREDERICK, 1938, Feb. 3, Systematic Water Flood May Revive Older Illinois Fields: Weekly Derrick.

Data covering the natural floods in the McClosky, an artificial flood at Carlyle, and accidental floods at Allendale.

STAFFORD, R. B., 1926, New York Producers Hear of Experiences in Increasing Crude Recovery: National Petroleum News, Vol. 18, No. 45, pp. 26, 28, 30.

Papers read at New York State Oil Producers' Association, discussed water-flooding patterns, direction of flood movement, use of soda ash, rate of movement of fluids in oil formations, loss from evaporation of crude, air-and-gas method of repressuring, and methods for cleaning out old wells.

STEPHENSON, E. A., and GRETTUM, I. G., 1930, Valuation of Flood Oil Properties: Am. Inst. Min. Met. Eng. Tech. Pub. 323.

Flooding methods, recovery of oil per acre, rate of production per well per unit of time, the operating cost, the expected price of oil, and the discount factor to convert expected income into net present worth, are elements which should be considered and analyzed.

STOVALL, S. L., 1934, August 13, Recovery of Oil from Depleted Sands by Means of Dry Steam: Oil Weekly, Vol. 74, No. 9, pp. 17, 19-21, 24.

Discusses experimental study and application on two leases of a repressuring project using steam, superheated 5-10°. Works in same manner as gas repressuring or water flood except the steam heats the sand and oil.

SWINDELL, F., 1932, July 25, Oklahoma Experiment Promises Success in Water Flooding: Oil Weekly, Vol. 66, No. 6, p. 36.

Preliminary work started on B. H. Collins Lease, Alluwe Field, Rogers county, Oklahoma.

SWINDELL, F., 1936, Nov. 9, Economies Being Used in Applying Water-flood Drive to Shoestring Lense Type of Field: Oil Weekly, Vol. 83, No. 9, pp. 54, 58, 62.

Small shoestring in Waggoner county, Oklahoma, being flooded at 500#/□" pressure by Air Oil Company.

TAYLOR, F. B., 1936, Nov. 2, Important Possibilities Are Indicated by Northeast Oklahoma Water-flood projects: Oil Weekly, Vol. 83, No. 8, p. 19.

Reported well program, equipment, cost and production statistics on the Carter and Forest floods in northeast Oklahoma.

TAYLOR, F. B., 1937, Feb. 1, Constant Control of Level in Output Tanks Is Aid in Water-flood Operations: Oil Weekly, Vol. 84, No. 8, p. 28.

Illustrates device used to govern rate of filtration of filtered water, so that intake pump will always have water available.

TAYLOR, F. B., 1937, June 21, Mid-Continent Water-flood Survey Reflects Substantial Increase in Total Number of Projects: Oil Weekly, Vol. 86, No. 2, p. 5.

Twenty-eight projects started on 400-mile front, ranging from Miami county, Kansas, to Okfuskee county, Oklahoma.

TAYLOR, F. B., 1938, Sept. 26, Water Flooding of Shallow Sands Is Becoming Increasingly Important in the Mid-Continent Area: Oil Weekly, Vol. 91, No. 3, pp. 26, 29, 30.

Survey of Mid-Continent area reveals 29 floods operating 4,200 acres in Oklahoma, and 14 floods operating 1,000 acres in Kansas. The Bartlesville sand is the chief strata, but many different sands, at depths varying from 200 to 2,000 feet, are being flooded.

TORREY, P. D., 1926, Nov. 11, Conducting Valuable Research on Flooding of Old Oil Fields: Oil and Gas Jour., Vol. 25, No. 25, pp. 74, 76.

Studying geologic structure and lithologic character of reservoir rock, and relationship of these geologic features to flooding by air and water; well spacing; waters, both intake and output; evaporation losses of the produced crude.

TORREY, P. D., 1927, Sept. 1, Discoveries in Flooding Operations: Oil and Gas Jour., Vol. 26, No. 15, pp. 34, 35.

Progress report in study of Bradford field. Water input wells should be completed carefully, and input gas or water metered, to observe any by-passing. Gas is preferred to air in repressuring, since it does not oxidize the oil nor lower its gravity. The characteristics of Bradford sand are discussed.

TORREY, P. D., NEWBY, J. B., FETTKE, C. R., and PANYITY, L. S.
See NEWBY, J. B.

TORREY, P. D., 1928, Geologic Factors in Water-flooding: Am. Petroleum Inst. Production Bull. 202, p. 144; also, Oil Field Eng., Vol. 3, No. 5, p. 29, May; Oil Age, Vol. 25, No. 5, p. 33, May; OGJ, Vol.—, No.—, pp. 66, 111, 112, 115, May 17.

Discusses geology of the Bradford field, historically. The following geologic factors influence recovery:

(1) Effects of configurations of the top and bottom of the oil sands on the rate and direction of flood movement.

(2) Effect of variation in porosity and permeability of the reservoir rock.

(3) Effect of grain size and saturation of the oil sands.

(4) Effect of sand cement.

(5) Effect of oil gravity and natural rock pressure.

TORREY, P. D., 1928, Some Factors Influencing Production of Oil by Flooding the Bradford and Allegheny Fields: Am. Inst. Min. and Met. Eng. Tech. Pub. 39.

Discusses the effect of shooting intake wells, the selective abandonment of depleted wells, effect of new pumping wells, effect of previous natural production, various flooding patterns, favorable characteristics of oil sands, additional pump pressures, use of soda ash, and possible gas or air repressuring after flooding with water.

TORREY, P. D., 1930, The Operation of Water-flood Properties Under Proration Schedules: Pennsylvania State College Mineral Exp. Sta. Bull 9, pp. 82-7.

Floods in last stages of production would be seriously harmed by proration, and should be allowed to produce unrestricted; those still producing considerable oil should produce all possible, but return excess oil to the hole.

Suggests wells should be back-pressured and flowed by true hydraulic control from the injection pumps. Delayed drilling utilizes energy of any gas left in sand and permits lenses with variable permeability to be filled with liquid; the pump will then drive fluids through all strata at the same time.

TORREY, P. D., 1930, Modern Practice in Water Flooding of Oil Sands in the Bradford and Allegheny Fields: Am. Inst. Min. and Met. Eng. Petroleum Devel. and Tech., pp. 259-276.

Advantages of intensive development, such as the 5-spot pattern and delayed drilling over the line flood, are: Concentration of development and operations in one area, with a consequent reduction in capital and operating expenses; rapid depletion, which further reduces operating expenses and materially reduces interest charges; and a more efficient flooding of the sand, with a consequent increase in recovery.

Central water plants are now used, instead of depending on subsurface water-bearing formations. It is possible to meter water going to each well; therefore, a better control of the flood is possible. The meter record will also show any plugging action.

Coring has been general; both diamond drill and cable-tool core barrels are used.

TORREY, P. D., 1930, Feb. 27, Bradford Allegheny's Great Future: Oil and Gas Jour., Vol. 28, No. 41, p. 42.

Presents past production figures and outlines oil recovery program.

TORREY, P. D., 1930, June 1, Bringing Old Wells Back to Life: Railway Life, Vol. 17, No. 6.

Not available.

TORREY, P. D., 1930, Oct. 24, Operation of Water-flood Properties Under Proration Schedules: Pennsylvania State College Mineral Exp. Sta. Bull. 9, p. 82.

Floods were operating at all stages when proration was suggested.

Floods in last stages would be seriously harmed by proration and should be allowed to produce to their economic limit. Floods still producing considerable oil, but approaching economic limit, should produce all possible, but return excess oil to the hole.

Apply back-pressure and flow wells by true hydraulic control, with pumps injecting the water.

Delayed drilling utilizes energy of any gas lift in the sand and permits lenses with variable permeability to be filled with liquid, and the pump will drive from all beds at the same time.

TORREY, P. D., 1930, Dec., The Delayed System of Drilling, in the Water Flooding of Oil Sands: Petroleum Engineer, Vol. 2, No. 3, p. 111-2, 114, 116.

Advantages of the delayed drilling system are: (1) Greater ultimate recovery may be expected from sands of variable permeability; (2) wells may be flowed by hydraulic control at input wells; and (3) gas is compressed as pressure is built up, and aids in production.

TORREY, P. D., 1931, Water Flooding of Oil Sands: Petroleum Engineering Handbook, Vol. II, pp. 142-156, Palmer Publishing Co., Los Angeles.

Discussion of the location, history, stratigraphy, structure, and analyses of reservoir rock of Bradford field. The history of the development of water-flooding patterns outlined. Normal water-flood production statistics given. Estimates of development and operating costs for an average project made. When operated efficiently water flooding obtained 40% of the oil remaining in the Bradford sand, reducing the saturation to 15-20% in many cases; however, where irregularities occurred, cores have shown as much as 50% saturation after flooding.

TORREY, P. D., 1932, Recent Developments in the Operation of Water-Flood Properties: Petroleum Engineer, Vol. 3, No. 9, pp. 56-9.

Recent developments discussed were: (1) treatment and filtration of water, and substitution of pumps for air lifts in water wells, to lower corrosion and subsequent iron precipitation on sandface; (2) use of delayed drilling system, wherein the water is injected so as to force the oil to the center of a 5-spot until volume of input materially decreases, at which time the production well is drilled. The method places the formation under better hydraulic control, and to some extent offsets widely varying permeability profiles; (3) with the advent of proration, many producers back-pressured the wells, allowing fluid level to build up in them, while producing neighboring wells at a uniform rate. This also held back the water. Some operators flowed the wells, thus lowering lifting expense.

TORREY, P. D., 1933, February, Migration and Encroachment of Water in Bradford Sand: Petroleum Engineer, Vol. 4, No. 5, pp. 27-8.

Tables showing decrease in permeability, and in rate of linear migration per day, with increased oil saturation of the formation. Amount of water that can be put into formation, under a given pressure, decreases with time.

Author suggests that migration and accumulation of oil ceased, not because of lack of available oil and gas, but because of a decrease in permeability which precluded any further movement under the natural pressures available.

TORREY, P. D., 1937, Water Flooding of Oil Sands—Four Parts: Oil Weekly, Vol. 87, Nos. 12, 13, 14, 15, Nov. 29-Dec. 20, 1937. Presented before fifth annual meeting of the Illinois Mineral Industries Conference.

Discusses history of the process, geologic factors affecting successful flooding, physical and lithological characteristics of the producing formations, theoretical considerations involved, development of properties, drilling practice and

surface equipment, operating methods, and the application of electrical well logging.

TORREY, P. D., 1937, Determination of an Oil Field s Possibilities for Secondary Recovery: Petroleum Engineer, Vol. 8, No. 4, pp. 65-71.

Outline of knowledge desired in field study of oil-field property prior to application of secondary recovery methods.

Covers location, stratigraphical and structural conditions, characteristics of sands, production and development history, water and gas production and present availability, storage facilities, properties of the oil, market conditions and availability, and estimate of past recovery and remaining reserves.

TOWERS, L. H., 1935, November, Modern Controlled Water Flooding in Oklahoma: Petroleum Engineer, Vol. 7, No. 2, pp. 27-9.

Description of Forest Prod. Co., water-treating plant and operations on lease north of Cody's Bluff, Nowata county, Oklahoma.

TRIPLETT, GRADY, 1924, Oct. 10, Flooding Increases Bradford Production: Oil Weekly, Vol. 35, No. 3, pp. 16, 17.

Early report on floods in Bradford district.

TURNBULL, GEORGE, 1923, Oct. 25, Flooding Aids Recovery of Crude Oil: Oil and Gas Jour., Vol. 22, No. 22, pp. 100, 101.

Discussion of papers presented before New York State Oil Producer's Association in Wellsville, N. Y.

W. L. Russell, New York State Geological Department, discussed well patterns and conditions governing choice of repressuring with air-gas or water flooding. "If the finest 10% of the sand grains are less than 0.1 mm. diameter and the sands are uniformly fine, flooding will extract the most oil. If the finest 10% of the sand grains are coarser than 0.2 mm., compressed air or gas will give the greatest extraction." The sand must be uniform for water flooding to be used.

Forest Dorn pointed out the value of early returns on the investment in water-flooding properties, and discussed development thereon.

Alvin Schaller and Carl Bjornsson presented a paper suggesting heating of the flood water. Calculations were given showing the distribution of heat losses, using a given set of average figures; conclusion—that it is advisable only in very thick sand.

TURNBULL, GEORGE, 1926, Feb. 25, Experiment in Further Recovery Feature in Eastern Field in 1915: Oil and Gas Jour., Vol. 24, No. 40, p. 86.

Discusses water flooding, soda solutions, increased costs, and output figures.

UMPLEBY, J. B., 1925, Increasing the Extraction of Oil by Water Flooding: Am. Inst. Min. Met. Eng., Petroleum Devl. and Tech., p. 112.

Bradford water-flooding projects discussed relative to geology, water supply, patterns in use, rate of water migration, oil bank, character of the wells, and recovery per acre.

UREN, L. C., 1927, Aug. 24, Water Flooding Practical in Shallow Fields of High-grade Oil: National Petroleum News, Vol. 19, No. 34, pp. 52-60.

A description of the Bradford flooding practice. The effect of water pressure on well spacing, development, production cost, and efficiency of recovery thoroughly discussed.

UREN, L. C., 1936, May, Secondary Production Methods: World Petroleum, Vol. 7, No. 5, p. 240.

No copy available..

WALLS, W. S., 1938, Determining Productivity of Reservoirs by Bottom-hole Pressure and Core Analyses: Two parts, Oil and Gas Jour., Vol. 36, No. 42, pp. 64, 66, 69, 72, 74, 75, 78, March 3; Vol. 36, No. 43, pp. 53, 54, 56, March 10; presented at meeting of American Petroleum Institute, Division of Production, Amarillo, Tex., February 17, 1938.

Discusses various methods of determining the productivity of wells. The intake wells of water-flood projects are described as inverse production wells, and methods of calculating the amount of input are discussed.

WHITE, DAVID, and MELCHER, A. F., 1925, April 20, Much Oil Remains in Bradford Sand After Flooding Process: Oil City Derrick.

No copy available..

YUSTER, S. T., and SAXE, A. J., 1938, Jan. 20.

See SAXE.

YUSTER, S. T., 1938, Technological Aspects of Water-flood Curtailment, Two Parts; Oil Weekly, Vol. 90, No. 12, pp. 32-44; Vol. 90, No. 13, pp. 19-34, August 29-September 5.

Discusses advantages, disadvantages, and methods of calculation for adjusting input pressures, for six methods of curtailing production from water-flooded fields.

The case history of numerous properties in the Bradford field is presented. From comparison of actual recovery from curtailed property with that predicted from core data, comparison of recovery from curtailed property adjacent to property not curtailed, and examination of the continuity of fused decline curves of property which was under curtailment, the following conclusions were drawn:

(1) With the exception of one property where a thief sand existed, no appreciable quantities of oil were lost by reason of curtailment.

(2) The production will be deferred, and the time will depend upon total production during curtailment and during normal operations.

(3) The safest time to curtail is during early life of flood.

(4) Application of back pressure conserves the energy in the formation and makes the property respond more quickly upon reapplication of normal operating conditions.

(5) Oil-water relationships do not depart from normal because of shutdowns or curtailments.

SECTION IV

Study of Interfacial Tension Between Crude Oil and Oil-field Waters; Adhesion Tension of Crude Oil for Sand Grains; and Chemical Solutions Capable of Increasing the Displacement of Oil from Sand Grains by Water-drive Methods.

ANDERSON, C. O., and COGHILL, W. H., 1923.
See COGHILL.

ANONYMOUS, 1923, July 28, Method of Flooding to Make Oil Fields Produce Has Flaw According to Field Man: Oil Weekly, Vol. 30, No. 5, p. 24.
Staff writer saturated ball of sand with oil, submerged it in water. Capillary attraction proved greater than buoyancy of the oil and no oil was freed.

ANONYMOUS, 1925, Washing-soda Plan to Be Tested in Flooding Bradford Wells: Oil and Gas Jour., Vol. 24, No. 8, p. 104.
Experiments performed at meeting of Northwest Pennsylvania Oil Producer's Association showed that soda aided in separation of oil from sand grains. Several operators agreed to experiment with it in the field.

ANONYMOUS, 1925, July 15, Chemical Added to Water Helps Flooding of Bradford Sand: National Petroleum News, p. 75.
Not available.

ANONYMOUS, 1929, October 17, Displacement of Oil from Sands by Selected Aqueous Solutions: Oil and Gas Jour., Vol. 28, No. 22, p. 102. Progress report on Am. Petroleum Institute Research Project 27.
Interfacial tensions were measured and adhesion tensions calculated by two methods. By application of Gibbs adsorption formulation the adsorption of solute at the interface was calculated; a slightly modified equation was used to calculate adsorption at the liquid-solid interface from adhesion tension data.

BARTELL, F. E., 1911, The Permeability of Porcelain and Copper Ferrocyanide Membranes: Jour. Physical Chemistry, Vol. 15, pp. 659-674.
Poiseuille's Law, for both pressure and temperature, was found to apply to the passage of water through electrolytically precipitated membranes of copper ferrocyanide in porcelain.

BARTELL, F. E., 1912, Pore Diameters of Osmotic Membranes: Jour. Physical Chemistry, Vol. 16, pp. 318-335.
Experiments were made to determine the maximum pore diameter at which osmotic effects could be obtained.

BARTELL, F. E., and BARTELL, L. S., 1934, Quantitative Correlation of Interfacial Free Surface Energies: Am. Chemical Soc. Jour., Vol. 56, pp. 2205-2210.
Shows the mathematical relationship between the interfacial angle and the adhesion tension. Equations derived whereby it is possible, after making

only one accurate determination of adhesion tension or of contact angle of a given liquid for a given solid, to calculate the adhesion tension of this solid for water or for any other liquid whose interfacial tension against water is known.

BARTELL, F. E., and CARPENTER, D. C., 1923, The Anomalous Osmose of Solutions of Electrolytes with Collodion Membranes; Part II, The Effect of Pore Diameter: Jour. Physical Chemistry Vol. 27, pp. 252-269.

Diffusion rates of several salts, at different concentrations, through membranes with different-size pores, were measured. The work clearly indicated that the pore diameter of an osmotic membrane is a highly important factor in determining the exact nature of the osmose. It seems probable that the anomalous osmose and attending salt diffusion were controlled by the pore diameter of the osmotic membrane.

BARTELL, F. E., and GREAGER, O. H., 1929, Relation of Adhesion Tension to Liquid Absorption: Ind. and Eng. Chemistry, Vol. 21, No. 12, pp. 1248-51.

For all systems wherein the liquid formed a zero contact angle with the solid, a simple linear relationship was found between adhesion tension and liquid absorption. The liquid absorption is the least for those liquids which show the highest adhesion tension against the solid.

For all systems wherein the liquid formed a finite contact angle with the solid the liquid absorption is lower than would be expected from the above relationship.

The most favorable condition for oil absorption would be obtained with a liquid giving a zero contact angle with the solid, but having a low adhesion tension against the solid.

The Gardner-Cole method was used in the liquid absorption tests.

BARTELL, F. E., and HATCH, G. B., 1935, The Wetting Characteristics of Galena: Jour. Physical Chemistry, Vol. 39, pp. 11-23.

The surface properties of Galena were found to be considerably different from C, and SiO_2 previously studied. It gave widely different, but stable, advancing and receding contact angles. Its action as an organophilic or hydrophylic solid depends on whether it was first wetted by an organic liquid or by water.

BARTELL, F. E., and JENNINGS, H. Y., 1934, Adhesion Tension of Liquids Against Strongly Hydrophylic Solids: Jour. Physical Chemistry, Vol. 38, No. 4, pp. 495-501.

Adhesion tension values for several different solids were run and calculated. It was noted that practically the same result was obtained for each. It was explained by saying that the surfaces of strongly hydrophylic solids are covered with an adsorbed film of water which gives these solid surfaces such properties that their measured free surface energy values are of the same magnitude.

BARTELL, F. E., and MACK, G. L., 1932, March, A Double Capillary Method for the Measurement of Interfacial Tension: Am. Chemical Soc. Jour., Vol. 54, pp. 936-942.

Two new types of apparatus for determining interfacial tension by the capillary rise method were described. One required an accurate density determination, the other did not. The interfacial tensions of several organic liquids and water were determined and found to be in good agreement with accepted values.

BARTELL, F. E., and MERRILL, E. J., 1932, Determination of Adhesion Tension Liquids Against Solids. A Microscopic Method for the Measurement of Interfacial Contact Angles: Jour. Physical Chemistry, Vol. 36, pp. 1178-1190.

Photomicrographs of capillary tubes containing liquid-air-solid and liquid-liquid-solid interfaces were measured. The contact angles were found to be independent of the size of the tube, and showed good agreement with the results obtained by the Bartell-Osterhof pressure of displacement method. The adhesion tension measured is specific and definite for any given solid-liquid system.

BARTELL, F. E., and MILLER, F. L., 1928, July, A Method for the Measurement of Interfacial Tension of Liquid-Liquid Systems: Am. Chemical Soc. Jour., Vol. 50, pp. 1961-7.

A single capillary tube was developed for determination of interfacial tension of liquid-liquid systems. The method is rapid, nontransparent liquids and liquids of any density may be used. Results obtained were in close agreement with accepted values.

BARTELL, F. E., and MILLER, F. L., 1928, July, Displacement of Oils from Sands: Ind. and Eng. Chemistry, Vol. 20, No. 7, pp. 738-742; OGJ, Vol. 27, No. 8, pp. 102-4.

The adhesion tension of 13 crude oils and purified, 350-mesh, Tripoli silica were determined with the displacement cell.

It was found that increased temperature raises the rate of displacement, especially with the heavier oils, that the degree of wetting is independent of the pore size of the membrane (between 200 and 300 mesh) and, that the viscosity of the oil is not a factor.

BARTELL, F. E., and MILLER, F. L., 1932, Displacement of Crude Oil and Benzene from Silica by Aqueous Solution: Ind. and Eng. Chemistry, Vol. 24, No. 3, pp. 335-8. API Research Project, No. 27.

Salt solutions of various concentrations were tested for their ability to free oil from chemically treated silica. Adhesion tension was not calculated, due to variation in effective pore size, as the different fluids progress through the membrane.

BARTELL, F. E., and OSTERHOF, H. F., 1926-7, The Measurement of Adhesion Tension of Solid Against Liquid: Fourth Colloid Symposium Monograph, p. 234, 1927; Fifth Colloid Symposium Monograph, pp. 113-134.

Full discussion of work being done on measurement of adhesion tension and surface energies. By measuring the interfacial tension of water and organic liquids, and the equilibrium displacement of oil by water, or vice versa, in contact with various solids, chiefly silica, the adhesion tension or surface energy can be calculated.

BARTELL, F. E., and OSTERHOF, H. J., 1927, Determination of Wettability of a Solid by a Liquid: Ind. and Eng. Chemistry, Vol. 19, pp. 1277-1280.

Describes the "displacement cell" and its use in obtaining adhesion tension data, together with some tabulated data.

BARTELL, F. E., and OSTERHOF, H. J., 1928, The Pore Size of Compressed Carbon and Silica Membranes: Jour. Physical Chemistry, Vol. 32, pp. 1553-1571.

The use of the displacement cell requires knowledge of the radii of the pore space in the packed powder membrane. This was determined by Poiseuille's Formulation and the Capillary Rise Method.

BARTELL, F. E., and OSTERHOF, H. J., 1930, Three Fundamental Types of Wetting; Adhesion Tension as the Measurement of Degree of Wetting: Jour. Physical Chemistry, Vol. 34, pp. 1399-1411.

Adhesional, spreading, and immersional wetting defined and differentiated on the basis of surface energy relationships.

Wettability defined as the tendency of a solid to be wetted and wetting power as the tendency of a liquid to wet a solid; they are differentiated by surface energy equations.

BARTELL, F. E., and OSTERHOF, H. J. 1933, Adhesion Tension: Jour. Physical Chemistry, Vol. 37, No. 5, pp. 543-552.

An account of the preliminary work in the development of methods for the determination of adhesion tension data.

The pressure of displacement method for measurement of adhesion tension is described in detail. A diagram of the displacement cell is included.

Values for adhesion tension and the work of adhesion were obtained for a series of liquids against silica and against carbon.

BARTELL, F. E., SCHEFFLER, G. H., and SLOAN, C. K., 1931, Adsorption by Silica from Nonaqueous Binary Systems Over the Entire Range of Concentrations: Am. Chemical Soc. Jour., Vol. 53, pp. 2501-7.

In general, the order of increasing (or decreasing) adhesion tension values of a series of liquids versus carbon is the reverse of the order of increasing (or decreasing) values versus silica. The same relationship holds for absorption values. Each absorbent gives an S-shaped adsorption curve, the one for carbon being inverted and reversed as compared to the one for silica. Each component is preferentially absorbed over some portion of the concentration range, that component having the higher adhesion tension against the solid is preferentially absorbed over the greater portion of the concentration range.

BARTELL, F. E., and SMITH, C. N., 1929, Adhesion Tension Values of Different Types of Carbon Black, Against Water and Against Benzene: Ind. and Eng. Chemistry, Vol. 21, pp. 1102-6.

Shows that reliable data can be obtained only when the carbon particles are so large that the compressed membrane has a pore radii greater than $2x10^{-6}$cm.

Different commercial carbon blacks possess different adhesion values against water and against benzene. Heat treatment alters the adhesion tension of these carbons against different liquids.

BARTELL, F. E., and WALTON, C. W., Jr., 1934, Alteration of the Properties of Stibnite as Revealed by Adhesion Tension Studies: Jour. Physical Chemistry, Vol. 38, pp. 503-511.

It is possible to alter the preferential properties of certain solids, causing the surfaces to function either as hydrophobic or hydrophilic surfaces, the particle size, appearance, and pore radii remaining the same.

The degree of packing of a powder upon settling through a liquid is greatest in that liquid against which it possesses the greatest adhesion tension, and progressively less in those liquids against which it has a progressively lower adhesion tension.

BARTELL, F. E., and WHITNEY, C. E., 1932, Adhesion Tension III, A Receding Contact Angle, Pressure of Displacement Method: Jour. Physical Chemistry, Vol. 36, pp. 3115-3126.

The pressure of displacement measurement is modified to read the receding contact angle. The modified method is comparatively rapid, results are duplicable, and the adhesion tension values calculated from the data obtained are reliable for the systems studied.

BARTELL, F. E., and YING FU, 1929, Adsorption from Aqueous Solutions by Silica: Jour. Physical Chemistry, Vol. 33, pp. 676-687.

The degree of adsorption is determined by the specific properties of the adsorbent and adsorbate, the solubility of solute in the solvent, and by the solid-liquid interfacial tension relationships.

If the solubility of the adsorbate is the same in different solvents, greater adsorption will occur from solutions, the solvent of which has a lower adhesion tension against the solid. If the adhesion tensions of the solvent are the same, then greater adsorption will occur from those solvents in which the adsorbate is less soluble.

BARTELL, L. S., and BARTELL, F. E., 1934.
See Bartell, F. E.

BECKSTROM, R. C., and VAN TUYL, F. M., 1927.
See Van Tuyl, F. M.

BRAUCHLI, R. W., 1933, April 5, Increasing the Production of Oil Fields by Adding Solutions: Petroleum, Vol. 29, No. 14, p. 5.
Not available.

CARPENTER, D. C., and BARTELL, F. E., 1923.
See Bartell.

CLARK, HARKINS, and DAVIES, 1917.
See Harkins.

COGHILL, W. H., and ANDERSON, C. O., 1923, Certain Interfacial Tension Equilibria Important in Flotation: U. S. Bur. Mines Tech. Paper 262.

Part I, The Equilibrium of the Interfacial Tension Forces of Two Liquids and a Gas. By means of cathetometer measurements, and interfacial angles, calculated from interfacial and surface tension data by use of the Neumann equilibrium triangle, the spreading effect and angle of contact of lenses of various fluids on water were studied.

Part II, Surface-tension Phenomena of a Solid, a Liquid, and a Gas in Contact; the Angle of Contact and the Edge Effect. Study of contact angles and edges and their effect on spreading.

COOK, C. W., 1925, November, Fractionation of Petroleum During Capillary Migration: Econ. Geology, Vol. 20, pp. 639-41.

Reports experiment of oil saturated sand and water placed in contact through a capillary. The water slowly displaced the oil, several drops formed on surface of the water, and displacement appeared to end; after six months' time another drop separated from the oil sand and floated to the water surface. It, however, has a different shape, and will not coalesce with the earlier drops. Believes fractionation to have occurred and the last drop to have different chemical properties than the earlier ones.

CURTIS, H. A., and DAVIS, N. S., 1932.
See DAVIS.

DAHLSTROM, ROY, and HARKINS, W. D., 1930.
See HARKINS.

DANIELS, E. C. H., HARKINS, W. D., and CLARK, G. L., 1917.
See HARKINS.

DAVIS, N. S., and CURTIS, H. A., 1932, Preferential Wetting of Solids by Liquids: Ind. and Eng. Chemistry, Vol. 24, No. 10, pp. 1137-40.

Used Bartell cell in qualitative tests of preferential wetting of a group of solids by organic liquids and water. Quantitative measurements of 5 organic liquids versus solid sulphur are presented.

EL-DIFRAWI, A. H., and UREN, L. C., 1926.
See UREN.

FAHMY, E. H., and UREN, L. C.
See UREN.

GARRISON, A. D., 1935, Selective Wetting of Reservoir Rocks and Its Relation to Oil Production: Oil and Gas Jour., Vol. 34, No. 13, pp. 36-38. Am. Petroleum Inst., Drilling and Production Practice, 1935, Abs., Am. Petroleum Inst. Production Bull. 215, p. 8.

The effect of interfacial forces of water, oil, and reservoir rocks was interpreted as resulting in an equilibrium condition wherein there is no complete separation into layers in the reservoir, but where the water tends to fill the pores having a size, dependent on the chemical nature, elevation, and physical constants of the oil and water, below a certain magnitude.

At a low production rate, oil is produced only from the larger pores; at a high rate of production, the equilibrium is disturbed, drawing the water from the smaller pores into the larger ones and carrying it to the well-bore. Once the water wets the larger pores it continues to move into them with greater ease.

GREAGER, O. H., and BARTELL, F. E., 1929.
See BARTELL.

GORDON, W. E., and LUNG, O. T., 1930, A Report on the Progress of the Results of Flushing Oil Sands with Alkaline Solutions: Oklahoma Acad. Sci. Proc. 10, p. 92.

Not available.

HARKINS, W. D., and DAHLSTROM, ROY, 1930, Wetting of Pigments and Paint Powders: Ind. and Eng. Chemistry, Vol. 22, p. 897.

Developed method for measurement of total energy of immersion of a powder with a clean surface. Obtained data for several pigments in different liquids, which indicated that nearly all the energy is liberated in the adsorption of a monomelecular film from the liquid on the surface of the powder. For this reason small quantities of impurities in the liquid often have a great effect on the wetting of powders.

HARKINS, W. D., DAVIES, E. C. H., and CLARK, G. L., 1917, The Orientation of Molecules in the Surfaces of Liquids, the Energy Relations at Surfaces, Solubility, Adsorption, Emulsification, Molecular Association, and the Effect of Acids and Bases on Interfacial Tension: Surface Energy VI, Am. Chemical Soc. Jour., Vol. 39, pp. 541—.

Data tabulated for total and free-surface energies of liquids, temperature-coefficient of surface tension, and the latent heat of the surface. The effect of acids and bases on the interfacial tension between water and benzene is shown.

Molecules orient themselves on an aqueous surface so that the H atom turns toward the vapor phase and the O atom toward the liquid; at an organic liquid-water interface, the more active group turns toward the water. If the transition from one liquid to another is made through a saturated film of solute molecules, the free surface energy is greatly reduced. Stability of emulsoid particles is brought about by orientation of the molecules at the interface; the molecules should fit the curvature of the drop. The surface tension of very small drops is therefore a function of the curvature of the surface.

HATCH, G. B., and BARTELL, F. E., 1935.
See BARTELL.

*HOWARD, W. V., and LOVE, W. W., 1930, Nov., Some Properties of Limestone as a Reservoir Rock: Econ. Geology, Vol. 25, No. 7, p. 720.

Experiments were performed which show that most of the oil migrating through limestone under the influence of capillarity is absorbed by the limestone and cannot be recovered except by the use of solvents. The amount of oil recovered by water flooding (analogous to the encroachment of ground water) is from 67 percent to 87 percent of the total amount; the rest is absorbed by the limestone. In every case where oil comes in contact with limestone, the light fractions tend to be absorbed and the recovered oil has a lower gravity than the original oil. This is not so noticeable in oil in contact with water-soaked limestone. Oil will move downward against water in finely porous limestone.

HOWLEY, J. E., 1929, April, Generation of Oil in Rocks by Shearing: Am. Assoc. Petroleum Geologists Bull., Vol. 13, No. 4, pp. 303-65.

Experiments on extraction of organic matter from shale by various chemicals in the presence of, and after treatment with, other reagents.

INLAND OIL INDEX, 1925, July 11, Washing Soda Recommended in Oil Wells, p. 12.

Not available.

JENNINGS, H. Y., and BARTELL, F. E., 1934.

See BARTELL.

JONES, D. T., 1936, Determination of Surface Tension and Specific Gravity of Crude Oil Under Reservoir Conditions: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 81-8; World Petroleum Congress Proc., Vol. I, p. 467.

Describes method of measuring surface tension and specific gravity under pressure by means of an electromagnetic balance.

KERN, C. E., 1926, July 29, Far Greater Crude Recovery Possible, Government Permitting Soda-ash Process After Successful Experiments at Bradford: Oil and Gas Jour., Vol. 25, No. 10, pp. 39, 254.

In one shallow test, Bradford sand produced three times amount expected, by use of 40 pounds of soda ash per barrel of solution. 50-100 barrels of solution were followed with plain water.

KERN, C. E., 1926, August 19, Many Inquiries on Use of Soda Ash: Oil and Gas Jour., Vol. 25, No. 13, pp. 31, 157.

Explanation of process utilizing soda-ash water solution for a flood.

KERN, C. E., 1926, Aug. 26, Bradford Soda Test Interests Industry: Oil and Gas Jour., Vol. 25, No. 14, pp. 29, 129, 130.

The government process for adding soda ash to water for recovery of petroleum was made available to anyone. The government approved joint action of groups of producers and offered to advise oil producers' associations anywhere in the United States as to the best experimental procedure.

KERN, C. E., 1926, Sept. 16, Dr. Thom on Use of Soda-ash Method: Oil and Gas Jour., Vol. 25, No. 17, pp. 122-126.

Advised that soda ash may react to form insoluble salts, such as $CaCO_3$, which precipitate and plug the formation.

KERN, C. E., 1926, Sept. 30, Many Questions Pour into United States Geological Survey on Soda Ash: Oil and Gas Jour., Vol. 25, No. 18, pp. 140-3.

Quotes from data presented by U. S. G. S.

Two to three tons of soda ash per well is the usual quantity of soda ash added with three wells per acre density. An extra large amount of soda ash is required when water comes in contact with brines containing salts of calcium or magnesium; the precipitation, when diluted by the amount of water present, is insufficient to plug the sand pores.

A water solution of any first group salt which hydrolyzes into the hydroxide is effective in driving petroleum from silica or silicates. Cyanide functions as well as carbonate, but attacks the oil and leaves poisonous waste waters. Sulfide solutions drive well, but attack oil and iron piping.

KERN, C. E., 1926, Oct. 14, Suggestions on Soda-ash Recovery: Oil and Gas Jour., Vol. 25, No. 21, p. 110.

The author quotes Dr. P. G. Nutting as advising the use of saturated soda or soda-ash solutions ahead of the water flood. The strength of the solution rate of solution input, and rate of drive per day were advised. Dilute solutions, though driving out more oil, must be operated at a slower rate.

KERN, C. E., 1926, Nov. 4, Interest in Soda-ash Process of Recovery Is Spreading: Oil and Gas Jour., Vol. 25, No. 24, pp. 162-4.

Questions and replies by the United States Geological Survey concerning the soda-ash process.

KNAPP, ARTHUR, 1926, August 20, Sodium Carbonate as Flooding Agent Revises Estimate on Oil Reserves: Oil Weekly, Vol. 42, No. 9, pp. 28-9.

Points out great quantity of oil left in formation after natural production ends. Ordinary water encroachment pushes oil through sands, but does not remove the film from the sand grains. If soda-ash solutions succeed in this effort the estimate of reserves will again need revising.

* LOVE, W. W., and HOWARD, W. V., 1930, November.
See HOWARD.

LUNG, O. T., and GORDON, W. E., 1930.
See GORDON.

MACK, G. L., and BARTELL, F. E., 1932, March.
See BARTELL.

McINTYRE, JAMES, 1926, Aug. 26, Bradford Soda Test Interests Industry: Oil and Gas Jour., Vol. 25, No. 14, pp. 29, 129, 130.

Considerable interest displayed in results reported by Pressure Oil Company, where three wells yielded considerably more oil under soda-ash flood than had been predicted.

McMILLEN, E. L., 1929, Wetting of Pigments and Its Relation to Various Paint Characteristics: Ind. and Eng. Chemistry, Vol. 21, pp. 1237-9.

Bartell's method was used in the study of wetting of pigments by various liquids and oils. Experimental data showed the better the liquid wets the pigment the more pronounced becomes the flocculation and plasticity.

McMILLEN, E. L., 1930, The Adhesion Tension Cell in Paint Investigations: Ind. and Eng. Chemistry, Vol. 22, No. 8, pp. 890-2.

Used Bartell cell in investigation of wettability measurements on lithophone. Data indicate poor wettability is not the cause of plasticity of solid-liquid systems.

Defines and illustrates terms pertaining to wettability.

MERRILL, E. J., and BARTELL, F. E., 1932.
See BARTELL.

MILLER, F. L., and BARTELL, F. E., 1928.
See BARTELL.

MILLER, F. L., and BARTELL, F. E., 1928, July.
See BARTELL.

MILLER, F. L., and BARTELL, F. E., 1932.
See BARTELL.

MILLS, R. VAN A., 1927, Mar. 23, Some Oil-field Problems Considered in the Light of Modern Recovery Methods: National Petroleum News, Vol. 19, No. 12, p. 32.

Doubted value of soda ash in water flooding, and points out the dangers encountered in attempting flooding operations.

MUNSEL, ROYE, 1926, Nov. 12, Soda Solution Action Too Slow to Yet Judge Results: Oil Weekly, Vol. 43, No. 8, pp. 29, 44.

News reported from Pennsylvania soda-ash flood. No results as yet.

NUTTING, P. G., 1925, Chemical Problems in the Water Driving of Petroleum from Oil Sands: Ind. and Eng. Chemistry, Vol. 17, No. 10, pp. 1035-60; Oil and Gas Jour., Oct. 1, 1925, pp. 76, 302.

Numerous experiments outlined lead to conclusion that the proper fluid or solution for water flooding should be one in which the silica grains lose their affinity for oil, which will not react with the oil and hence be used up, and which must not clog the pores of the sand.

The stronger acids react with the oil, some appearing to give a curdling effect, and detergents such as soap clog the sand pores; weak organic acids, some of which are quite excellent, are quite expensive. Solutions of a salt of a strong base and weak acid proved most effective, especially sodium carbonate.

NUTTING, P. G., 1926, Jan. 21, Action of Silicates with Petroleum: Oil and Gas Jour., Vol. 24, No. 35, p. 137.

Primarily devoted to filtering action and catalytic action of silica on formation of gases. Sand ordinarily carries a thin adsorbed moisture film. If dehydrated and in contact with petroleum, the silica would attach itself first to weakly attached $H+$ ions, then to the chain or ring with the formation of a coating of hydrocarbon silicates, such as R-SiOOH.

NUTTING, P. G., 1926, May, Geochemical Relations Between Petroleum, Silica, and Water: Econ. Geology, Vol. 21, pp. 234-42.

Numerous experiments cited, giving rise to a theory of filtration and surface reaction of silica for both water and petroleum. There appears to be a slight hydrolysis of petroleum by water, resulting in a film of higher alcohols. It is this film, occurring in water flooding, which the addition of soda ash appears to prevent.

NUTTING, P. G., 1926, Movement of Fluids in Porous Solids: Oil and Gas Jour., Vol. 25, No. 31, pp. 26, 125.

Develops law of flow for fluids in small tubular duct, and discusses the wetting of solid surfaces.

NUTTING, P. G., 1927, February, The Movements of Fluids in Porous Solids, Franklin Inst. Jour., p. 313.

Derives equations for calculating specific conductivity of a solid from experimental data and fundamental laws of flow.

Wetting of surfaces believed to be combination of chemical and physical causes. The advance of the thin edge of the film involves chemical forces in the case of water and silica at least. Water rises through coarse sand in succession of double steps: (1) a creep over the surface of each grain by wedge action, and (2) a capillary leap to neighboring grains near points of contact. The rate of rise depends on rate at which supply of fluid is kept up. The wetting of the grain is almost instantaneous, with delay occurring just prior to each leap to a fresh grain. Some finely divided solids, such as fine clay, bentonite, shale, adobe, etc., absorb water layers and become almost impenetrable by water and some other fluids.

NUTTING, P. G., 1927, March 31, Soda Process for Petroleum Recovery: Oil and Gas Jour., Vol. 25, No. 45, pp. 76, 150.

Data for the preparation of a soda-ash flood given; the cost increased about 5 percent.

NUTTING, P. G., 1927, May 5, Principles Underlying Soda Process: Oil and Gas Jour., Vol. 25, No. 50, pp. 32, 106.

A full description of requirements of a chemical for solution flooding. Soda ash approaches these better than any other known reagent.

* NUTTING, P. G., 1928, October 18, Petroleum Recovery by Soda Process: Oil and Gas Jour., Vol. 27, No. 22, p. 146.

Present results of attempts to remove oil from sand by means of sodium-carbonate solution. The solution removes oil if permitted to advance through the sand at a rate of from two inches per hour to two inches per day, depending on the fineness of the sand, etc. Silicates, limestone, and gypsum were found to behave in the same way as quartz sand, but pulverized coal and metallic sulphides showed a decided preference for oil over water or water solutions.

If sand is coated with tar, the process is still effective, but takes a longer time to insure complete removal of the oil.

The process is being tried on a commercial scale in the Bradford field, but sufficient time has not yet elapsed to allow the solutions to cause any increased yield.

NUTTING, P. G., 1928, November, Some Geological Consequences of the Selective Adsorption of Water and Hydrocarbons by Silica and Silicates: Econ. Geology, Vol. 23, No. 7, pp. 773-7.

Water, adsorbed on silica and silicates as H and OH ions, may be displaced by the stronger alkyl hydrocarbons, but not by weaker ones.

Petroleum, with basic constituents stronger than OH, may enter and fill sands previously filled with water.

The silicate changes from hydrophilic to hydrophobic, when adsorbed film changes from OH to alkyl hydrocarbons.

The most efficient flotation oils for sulfide ores are composed of hydrocarbons, a little weaker than OH.

NUTTING, P. G., 1930, Sept. 5, Chemical Activation of Quartz Surfaces: Science, Vol. 72, p. 243.

Certain pure quartz sands (Tensleep, Wyo.) are coated with thick brown

coatings (about 0.7 micron thick) which will not work off with water. Oxidation with chromic acid leaves a pure white quartz crystal which, upon soaking overnight in a heavy crude, will reabsorb the brown coating.

Any quartz surface attacked by strong alkalis forms a layer of alkali silicate on the surface. Replacing the base by H with an acid treatment, then driving the H and OH groups off by heating leaves open bonds. KOH solutions are too slow for the first step, though capable; fused sodium or potassium carbonate (at) 850° C. is too violent; fused KOH (at) 350° C. works well and does not crack crystals of considerable size. A minute or two is sufficient time. Boiling in HCl, washing and drying completes the activation.

A bath in HF activates quartz or sea sand just as well as when treated by alkali and HCl.

* NUTTING, P. G., 1931, Feb. 4, Absorption and Basic Exchange: Washington Acad. Science Jour., Vol. 21, No. 3, p. 33.

One substance is adsorbed by another when it is not removable by a neutral solvent. Adsorption is not limited to the visible surface, but shades off into true chemical reaction. It is sensitive to changes in temperature and pressure or concentration. Material adsorbed may be either molecular or ionic. Other physical and chemical properties of adsorption discussed. Oil sands nearly always have adsorbed coatings which are silicates, black hydrocarbon, (Fe, Ca, Mg) carbonates, or colloidal iron. Some of the properties of the filtering clays are considered.

NUTTING, P. G., 1934, Some Physical and Chemical Properties of Reservoir Rocks Bearing on the Accumulation and Discharge of Oil: Am. Assoc. Petroleum Geologists, Problems of Petroleum Geology, pp. 825-32.

Oil sands vary in grain diameter from .07-.21 mm.; usually 80-90% lie between one size and twice or half that size; uniform size grains, settling into water, assume a porosity of 39%, with an effective pore diameter of 0.2 the grain diameter.

Movement of fluids depends on the permeability and pressure gradient. Three relationships—permeability-pore diameter, permeability-grain diameter, and permeability-porosity—provide a severe test for similarity between sands. Oil will drain by gravity from sands over 0.20 mm. grain diameter. Silica hydrolyzes in presence of water and tends to block small pores.

Oil is adsorbed on surface of silica grains; chromic acid or hydrofluoric acid removes it, but is used up in the process. Sodium carbonate replaces the oil in the surface layer without attacking it.

OSTERHOF, H. J., and BARTELL, F. E., 1926.
See BARTELL.

OSTERHOF, H. J., and BARTELL, F. E., 1927.
See BARTELL.

OSTERHOF, H. J., and BARTELL, F. E., 1928.
See BARTELL.

OSTERHOF, H. J., and BARTELL, F. E., 1930.
See BARTELL.

OSTERHOF, H. J., and BARTELL, F. E., 1933.
See BARTELL.

PYM, L. A., 1938, Bottom-hole-pressure Measurements: Science of Petroleum, Vol. I, pp. 508-15, Oxford Press, London.

Describes methods, instruments, and applications of bottom-hole-pressure measurements.

SCHEFFLER, G. H., BARTELL, F. E., and SLOAN, C. K., 1931.
See BARTELL.

SLOAN, C. K., BARTELL, F. E., and SCHEFFLER, G. H., 1931.
See BARTELL.

SMITH, L. E., 1926, May 12, Adding Soda Ash to Flood Water at Bradford: National Petroleum News, Vol. 18, No. 19, pp. 41-44.

Soda-ash flood commenced by Petroleum Reclamation Company. Ten wells charged with 35½ tons of soda ash, then pressured with water.

SMITH, L. E., 1926, Sept. 29, Indicates Soda Ash Travels Through Sand and Does Not Filter Out: National Petroleum News, Vol. 18, No. 39, p. 47.

Producing well of W. C. Purple reported soda ash; it was the best producer on the property.

An unnamed engineer was quoted, "A field must first be susceptible to flooding, the salt water must be washed out to prevent precipitation in the pores, and then soda ash is more likely to channel than fresh water, though, its effectiveness depends on it not channeling."

SMITH, C. N., and BARTELL, F. E., 1929.
See BARTELL.

SPEAR, MARY, 1926, Dec., Some Data on the Use of Soda Ash in Oil Recovery: Natural Gas, p. 15.

Not available.

STRONG, M. W., 1938, Bottom-hole Temperature Measurement: Science of Petroleum, Vol. I, pp. 516-522, Oxford Press, London.

Methods and use of bottom-hole temperature measurements described. Geologic causes of temperature variation discussed under (a) old structures, (b) strata not in geothermal equilibria.

THOM, W. T., JR., 1926, Possible Natural Soda-drive Aids Salt Creek Type of Pool, and Its Significance in Terms of Increased Oil Recoveries: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 210-217.

Basing his views on a natural soda-ash flood from the first Salt creek sand as compared to the second Salt creek sand which was also high in sodium chloride content, the author suggests the use of soda solution at Bradford.

Careful planning and control must be assured for the plan to be a success, however.

THOM, W. T., JR., 1926, Dec. 8, Natural Soda Drive in Salt Creek May be Aiding Oil Recovery: National Petroleum News, Vol. 18, No. 49, pp. 74, 77-8.

Water encroachment in Salt Creek, Wyo., fields containing high soda content thought to aid total recovery from field.

TRAXLER, R. N., and PITTMAN, C. U., 1932, Interfacial Tension Between Asphaltic Materials and Various Aqueous Solutions: Ind. and Eng. Chemistry, Vol. 24, p. 1003.

Interfacial tension data were obtained between two asphaltic refluxes and sodium hydroxide solutions, and alkaline media containing sodium chloride, calcium chloride, and the two salts together. Over a limited concentration range the interfacial tension is reduced by sodium chloride, increased by calcium chloride, and very little effect is obtained from a mixture of the two salts.

TRAXLER, R. N., and PITTMAN, C. U., 1932, Interfacial Tension between Asphaltic Materials and Solutions of Alkaline Inorganic Salts: Ind. and Eng. Chemistry, Vol. 24, No. 12, p. 1391.

The interfacial tension between two asphaltic fluxes and various concentration of 5 salts which hydrolyze to give sodium hydroxide were determined. Solutions of trisodium phosphate and sodium metasilicate give lower interfacial tension than those of disodium phosphate and sodium tetraborate. Sodium carbonate solutions are intermediate between the two groups. When a reaction occurs at the interface, the nature of the products formed may influence the type and stability of the resulting emulsion. The effect of pH was also discussed.

UREN, L. C., and EL-DIFRAWI, A. H., 1926, Capillary Retention of Petroleum in Unconsolidated Sands: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 70-95.

Capillary force is a combination action of molecular attraction, molecular cohesion and surface tension. It is effective in cavities of 0.5 mm., or less, diameter. Surface tension is influenced by temperature, pressure, dissolved substances, and by the nature of gas or liquid with which the surface is in contact.

The surface tension of hydrocarbon oils varies from 16 to 40, about one-half that of water at 20° C. Screeen analyses, porosities, viscosity, capillarity, are discussed with regard to capillary retention.

The capillary hold may be reduced by decrease in surface tension, which requires gas at high pressures, by application of high temperatures, or by flooding with water containing a suitable flooding agent.

UREN, L. C., and FAHMY, E. H., 1927, Factors Influencing the Recovery of Petroleum from Unconsolidated Sands for Water Flooding: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 318-335, also, Oil Field Eng., 1928, April, Vol. 3, No. 4, pp. 11.

Conclusions based on flow-tube experiments:

(1) Course or uniform grain size, higher temperatures, low viscosity, low surface tension, and low rate of displacement increased efficiency of recovery.

(2) Fine or variable grain size and secondary mineral coatings decreased efficiency of recovery.

(3) Capillarity proved not to be a factor.

(4) The efficiency of the flood was directly related to the interfacial ten-

sion of the oil against the flooding medium. Alkaline reagents were effective in every case due partly to lowered interfacial tension and partly to chemical reaction with the silica sand grains.

(5) Order of effectiveness of addition of water-soluble salts to flooding water:

a. Alkaline salts.
b. Divalent salts of weak acids, after hydrolyzing.
c. Univalent salts of weak acids, after hydrolyzing.
d. Neutral and strongly acid salts.

UREN, L. C., 1927, Aug. 3, Increasing Oil Recovery by Flooding: National Petroleum News, Vol. 19, No. 31, pp. 50-59.

The theoretical principles underlying water-flooding processes reviewed. Factors found to influence the efficiency of water flooding are grain size, porosity, continuity and uniformity in permeability and texture of the reservoir sand, the viscosity, surface tension and density of the oil, the temperature, the rate of water input, the input pressure, and the size of the well cavity. Interfacial tension and the use of soda ash as a flooding agent discussed. A successful flooding reagent should be inactive to both oil and water, and not become diluted by either.

VAN TUYL, F. M., and BECKSTROM, R. C., 1927, Effect of Flooding Oil Sands with Alkaline Solutions: Am. Assoc. Petroleum Geologists Bull., Vol. XI, pp. 223-35; also, 1927, Jan. 13, Oil and Gas Jour., Vol. 25, No. 34, pp. 34, 106-10.

A study of the effect of various solutions upon freeing oil from sand grains; salts of strong bases and weak acids make the most effective solution. Soda ash is selected because of its low cost. A 1% by weight solution appears to be the ideal solution.

WALTON, C. W., and BARTELL, F. E., 1934.
See BARTELL.

WHITNEY, C. E., and BARTELL, F. E., 1932.
See BARTELL.

YING FU and BARTELL, F. E., 1929.
See BARTELL.

SECTION V

Analysis, Classification, and Purification of Water for Use in Water Flooding

ALBRIGHT, J. C., 1937, July, Providing Water for Water-flooding Operations: Petroleum Engineer, Vol. 8, No. 11, p. 80.

The Petroleum Reclamation Company produced water from gravel near the Allegheny river. Estimates of production and transportation costs are given.

AMERICAN PUBLIC HEALTH ASSN., Methods of Water Analysis, Washington, D. C.

ASSN. of OFFICIAL AGRICULTURE CHEMISTS, Water Analysis: Washington, D. C.

BARB, C. F., 1931, Oil Field Waters of Pennsylvania, Pennsylvania State College Mineral Exp. Sta. Bull. 8, 34 pp.

Report of quantity, quality, and use of waters available for flooding oil-producing properties.

BEHRMAN, A. S., 1930, March 6, Flood Water Purification Problems, Oil and Gas Jour., Vol. 28, No. 42, pp. 248, 249.

Suspended matter and iron should be precipitated and filtered out. Further iron corrosion should be prevented through pH control.

BIGNELL, L. G. E., 1936, April 2, Character of Water Plays Important Part in any Flooding Operation: Oil and Gas Jour., Vol. 34, No. 46, pp. 24-6.

Describes H. J. Walter Company flood in Alluwe district, Nowata county, Oklahoma. The gravity of the oil increased from 33° to 38° after production had been under way for some time. The field had been previously repressured with gas.

BOWEN, A. R., 1938, The Interpretation of Oil-field Water Analyses: Science of Petroleum, Vol. 1, pp. 653-6, Oxford Press, London.

Discusses uses, methods of recording, and graphical classification of oil-field brine analyses.

CLARK, L. J., 1934, January 11, Treating Flood Waters in Bradford Field for Removal of Corrosive Suspended Matter: Oil and Gas Jour., Vol. 32, No. 34, pp. 16-18.

Advocates a lime treatment to control the pH and alkalinity and build a thin protective coating of $CaCO_3$ on the walls of the pipe.

CONINE, R. C., 1934, March 22, Pipe-line System Supplies Water for Flooding Operations in the Bradford, Penn. Field: Oil and Gas Jour., Vol. 32, No. 44, pp. 13-31.

A fifteen-mile, 24-inch pipe line was constructed from the Allegheny river to supply the Bradford water-flood operators with water at 2 cents a barrel at a sufficient pressure to hold 1000#/□" on the sand face.

CORPS, E. V., 1933, Sept. 11, A Pictorial Method for Recording Water Analyses: Oil Weekly, Vol. 70, No. 13, p. 18; also, 1933, July 19, World Petroleum Congress Proc., London, pp. 338-40.

The sectors of a circle were colored differently and divided proportionately to represent the various components. The radius in millimeters equalled the square root of the total concentration.

Modification of method of Parker and Southwell.

EMBSHOFF, A. C., 1936, May 14, Treatment of Waters and Brines for Flooding and Disposal Purposes: Oil and Gas Jour., Vol. 34, No. 52, pp. 199-202.

Recommends aeration for the removal of H_2S, stabilization of the solution by the liberation or addition of free CO_2 if super- or under-saturated, aeration, coagulation with alum and filtration for the removal of iron and suspended matter.

EMERY, F. H., 1937, Spectographic Analysis of Oil-well Brines: Oil and Gas Jour., Vol. 35, No. 42, p. 53, March 4.

Analyses showing the small content of elements not observed in ordinary chemical analysis, provide method of correlating brines from different formations, checking casing leaks, and tracing flow through the formation.

GILL, STANLEY, 1932, July 11 and 18, Application of Water Analysis to Petroleum Technology. Two parts: Oil Weekly, Vol. 66, No. 4, pp. 30-4; Vol. 66, No. 5, pp. 24-30.

Several methods of reporting water analyses are illustrated, methods of treatment of the waters and disposal of the brines are discussed.

GRETZINGER, WILLIAM, 1930, Aug. 1, Filtering Plants and Delayed Flooding at Bradford: Oil Field Eng., Vol. 7, p. 17.

Discussion of water filtration and treatment to remove iron oxide, algae, etc. Delayed 5-spot drilling and delayed methods of production are outlined.

LANE, E. C., and REISTLE, C. E., 1928.
See Reistle.

* MEINZER, O. E., Outline of Methods for Estimating Ground-water Supplies: U. S. Geol. Survey Water-supply Paper 638, p. 1932. Also, Water and Water Engineering, Vol. 34, p. 603, Dec. 20, 1932, and Vol. 35, p. 25, Jan. 20, 1933.

Describes available methods for estimating the rate at which rock formations will supply water, the hydrologic principles on which the methods are based, their historical development, and their applicability. Quantitative methods are divided into two groups according to whether they regard rock formations as reservoirs or as conduits of water. Reservoir methods are based on measurements of intake, discharge, or changes in storage. Includes brief discussion of evaluation of extraneous influences on water levels, such as barometric and tidal effects.

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O'CONNOR, BUELL, 1938, August 4, Chemical Phases of Treating Water for Flooding Oil Properties: Oil and Gas Jour., Vol. 37, No. 12, pp. 43, 56, 57.

Discusses treatment for calcium carbonate supersaturation, organic growth, and coagulation.

PALMER, CHASE, 1911, The Geochemical Interpretation of Water Analyses: U. S. Geol. Survey Bull. 479, 31 pp.

Classification of waters.

PARKER, J. S., and SOUTHWELL, C. A. P., 1929, The Chemical Investigation of Trinidad Well Waters and Its Geological and Economical Significance: Inst. Petroleum Technologists Jour., Vol. 15, pp. 138-182.

Analyzed mineral waters of Trinidad and reported them graphically.

REED, PAUL, 1936, Aug. 13, Accelerator Water Treatment Process Installed on 4-flood Project in Nowata: Oil and Gas Jour., Vol. 35, No. 13, pp. 24-27.

Four projects at Nowata are described which utilize International Filter process to clean, ppt., coagulate, and stabilize CO_2 saturation before pumping the water into the sands.

REISTLE, C. E., JR., and LANE, E. C., 1928, A System of Analysis for Oil-field Waters: U. S. Bur. Mines Tech. Paper 432.

Presents the methods used by the Bureau of Mines in estimating the characteristic constituents of oil-field waters, and for calculating and reporting results. Four steps of equal importance are recognized, viz.: (1) Collection of samples, (2) preliminary treatment and examination before making analysis, (3) actual chemical analysis, and (4) computation and presentation of results. The detailed procedure of the four steps is described.

RYDER, H. M., 1937, Sept. 23, Preparation of Flooding Water to Prevent Plugging Oil Sands: Oil and Gas Jour., Vol. 36, No. 19, pp. 60-62.

Lists, explains, and gives correction for causes of sand-face plugging in the Bradford field.

SIMMONS, A. C., 1935, Higher Recovery Possible by Water Conditioning: Oil and Gas Jour., Vol. 34, No. 6, p. 34.

Approves conditioning of water by filtration and alum treatment. Warns that settling period is required when mechanical aeration is practiced; the oxygen content of the water renders it corrosive. If this happens, the water must then be treated chemically and refiltered.

Describes oil production versus water production curves for various projects

SMILEY, T. F., 1936, Feb. 6, Kind of Water Employed in Flooding Operations an Important Matter: Oil and Gas Jour., Vol. 34, No. —, p. 45.

Urges that filtered water treated to remove both organic and inorganic substances, and not contaminated between the filter and the sand face, be used.

SOUTHWELL, C. A. P., and PARKER, J. S.

See PARKER.

TORREY, P. D., 1927, Oil-field Waters of the Bradford Pool: Am. Inst. Min. Met. Eng. Tech. Pub. 38.

Analyses and discussion of connate, ground, and flood waters in the Bradford field.

Changes in concentration during the flood are noted.

* TORREY, P. D., 1928, Feb. 23, Flood Waters of Bradford Pool and Relation to Oil Production: Oil and Gas Jour., Vol. 26, No. 40, pp. 155-62.

In the Bradford pool, the main production comes from the Bradford sand which, outside of the main pool, yields a homogeneous mixture of oil and water. In spite of the vast production from the sand, water encroachment is negligible and it is believed that the connate water present in the sand is practically stagnant.

The surface waters used in flooding the sands contain very little dissolved salts, so that as flood waters approach an oil well there is a decided decrease in the salinity of the brine. The movement of the flood may also be noted by contouring the ratio between the water and oil production in individual wells.

The approaching depletion of a well can best be predicted, however, by comparing the cumulative production with the chloride content of the brine, and even if production records are not available a mere inspection of a water analysis may indicate how nearly the sand is depleted.

Oil migration within the sand is extremely slow, being dependent upon the rate of evaporation of the connate water; migration ceases when the capacity of the field is reached. There is possibly more oil in the sand outside of the field, but so mixed with water that it cannot be recovered economically.

Changes in the character of the connate water are due in part to evaporation by means of migrating gas and in part to chemical reactions such as hydrolysis of magnesium chloride.

WOOD, C. E., 1938, Methods of Analysis of Oil-field Waters: Science of Petroleum, Vol. I, pp. 646-52, Oxford Press, London.

Methods outlined for chemical analysis of water.

SECTION VI

Gas or air repressuring projects; application of vacuum; solubility of gas in crude oil; explosive limits of air-gas mixtures; production data and operating costs; equipment; well patterns and spacing.

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* ALBRIGHT, J. C., 1931, Jan. 16, Gravity and Output Respond to Repressuring Plan: Oil Weekly, Vol. 60, No. 5, p. 28.

The Red river field in southern Oklahoma has produced a total of 4,000,000 barrels of oil from a number of sands, which owe their productivity to local porosity rather than to structure. Repressuring commenced in the early part of 1929; no immediate effect due to channelling in sand. A well drilled solely for the purpose of injecting gas resulted in increased production. Since that time other input wells have been drilled and production in the field has increased steadily.

ALBRIGHT, J. C., 1938, October, Repressuring Depleted Sands in Kentucky Fields: Petroleum Engineer, Vol. 9, No. 1, pp. 66-74.

Applications of vacuum and gas repressuring in western Kentucky.

BAKER, W. L., 1933, January, Successful Repressuring of Nowata Field Largely an Economic Problem: Petroleum Engineer, Vol. 4, No. 4, p. 20.

Discussion of repressuring methods in this district prior to advent of water flooding (1925-1931).

BARNES, K. B., 1935, Sept. 5, Crude-oil Character Determines Value of Repressuring Operations: Oil and Gas Jour., Vol. 34, No. 16, p. 54.

While the properties of the sand cannot be changed, their effect can be altered by varying the well spacing and pattern of the wells. The properties of the crude may be altered by gas repressuring. Wet gas is preferable to dry gas, which in turn is preferable to air. The latter often forms oxidation products with the oil, especially if naphthenic compounds are present. The solubility of the gas in the crude oil is a function of both pressure and temperature, and results in lowering both the viscosity and surface tension of the oil. The rate of solution is also an important characteristic.

BARNES, K. B., 1935, Sept. 12, Selection of Proper Equipment for Repressuring Operation Important: Oil and Gas Jour., Vol. 34, No. 17, p. 54.

Discusses force diagrams of central pumping units; discusses explosibility of air-gas mixtures; recommends large-scale operations; and warns not to begin operations unless core analyses show a sufficiently high oil content and permeability and not too irregular permeability profile so that a profitable recovery may be predicted.

BAY, B. R., 1934, Nov. 5, Compressor Station Problems: Oil Weekly, Vol. 75, No. 8, p. 29.

Discusses the selection of equipment, location, design and construction, and operation and maintenance for compressor stations.

BEECHER, C. E., and PARKHURST, I. P., 1926, Effect of Dissolved Gas Upon the Viscosity and Surface Tension of Crude Oil: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 51-62.

Data were obtained showing that gas in solution in oil lowers the surface tension and viscosity. Increased temperature was found to decrease the solubility of gas in crude oil.

BEECHER, C. E., 1928, Repressuring in Early Stages of Development: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 137-150; Oil and Gas Jour., Vol. 27, No. 22, p. 166 (Oct. 18); Oil Weekly, Vol. 51, No. 5, p. 132 (Oct. 19); Oil Age, Vol. 25, No. 11, p. 38 (Nov.).

With present methods the amount of oil recovered from a sand depends on the efficiency with which the energy stored in the gas is used. Additional production can be expected by supplying more energy in the form of gas under pressure, and the gas which is now wasted in earl stages of development should be returned to the well. Repressuring during the period of flush production should result in a greater ultimate recovery in a shorter period of time and at a more uniform rate.

If wet gas is returned to the sand both recovery and gravity of the oil will increase and the hazard of by-passing of the gas is reduced. Gas returned to the sand will hold back edge-water, and fewer wells should be required to drain effectively a given area being repressured during flush production.

Unit operation of or coöperation in fields is essential for the successful application of improved methods for recovering oil.

BELL, A. H., 1929, April, Repressuring as a Conservation Measure: Oil Bull., Vol. 15, No. 4, p. 357.

Recent proposals for conservation have brought forth the realization that waste can be overcome, at least partially, by some form of repressuring. Because of divided ownership in most pools, operators doing repressuring work must secure the coöperation of all interests concerned. This makes conservation by repressuring a rather difficult problem. Methods of repressuring include:

Repressuring in old low-pressure fields where all wells are shut in, i.e. gas storage.

Repressuring old exhausted fields to increase oil production.

Repressuring fields in the semiflush stages for purposes of gas storage and to increase ultimate yields with reduced operating costs.

The repressuring methods are all securing either greater yields or gas preservation.

BELL, A. H., and WEBB, E. W., 1930, Repressuring in the Selover Zone at Seal Beach and the Effect of Proration: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 240-245.

Study of repressuring project. Gas tended to short-cut to wells up structure while wells down structure had large production increases without increases in formation gas-oil ratios. Ideal location for injection well, therefore, would be on top of dome, so that gas would have less tendency to break through, and water encroachment could be retarded.

BELL, A. H., and SQUIRES, F., 1932, Sept. 24, Preliminary Survey of Repressuring Operations in the Southeastern Illinois Oil Field: Illinois State Geol. Survey, Press Bull. Series, Ill. Pet. 23.

Repressuring operations on 107 leases representing, 3,488 acres are discussed. Production equipment and economic records are given.

* BERWALD, W. B., and LINDSLY, B. E., 1930.
See LINDSLY.

BRUNDRED, L. L., 1926, Theories of Normal Production and Methods of Introducing Gas and Air to Increase Normal Recovery: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 40-50.

Discusses theory of normal production, subsurface movement, solubility of gas in oil, gas-oil ratio, methods of introducing gas or air into formations and the subsurface action and gasoline recovery incident to gas repressuring.

* BRUNDRED, W. J., 1929, Results of Repressuring Depleted Sands in Old Pennsylvania Fields: Two parts, National Petroleum News, Vol. 21, No. 6, p. 51, Feb. 6; No. 7, p. 62, Feb. 13.

The results of repressuring five properties in Venango county, Pennsylvania, are given. On the first of these repressuring was begun in 1916. Four wells were drilled between 1920 and 1925 and none since. The 1927 production was only about 1,000 barrels below the peak in 1920. On the second property, repressuring since 1924 resulted in an increase in production from 12,000 barrels to 19,000 barrels in 1927. Here the peak was expected some time during 1930. Comparable results were obtained on the other properties.

CALKINS, L. P., and DOW, D. B., 1926, Feb.
See Dow, D. B.

CHALMERS, JOSEPH, 1930, Recent Studies of the Recovery of Oil from Sands: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 322-8.

Report of Bureau of Mines study pertaining to merits of various pressure media in the recovery of oil from a sand reservoir. Experiments were conducted (1) under a constant input pressure and (2) at a constant volume rate. The total gas-oil ratio for equal recoveries were much lower under constant volume input. The density of the pressure medium was found to affect recovery and was explained as due to greater kinetic energy.

The solubility of the pressure medium was also considered. As much gas as practicable was forced into solution then by controlling the pressure gradient to the producing wells, the dissolved gas was expanded from solution and did its full quota of work before reaching the well. Gas which went into solution too easily did not have sufficient potential energy to expand from solution when pressures were reduced. Dissolved gas reduced the viscosity of the oil, but the resulting benefits were less than those due to the complete utilization of the energy of the gas.

CHALMERS, J., DESMOND, J. S., MILLS, R. VAN A.
See MILLS.

CONINE, R. C., 1934, March 29, Secondary Recovery on Pennsylvania Fields by Air and Gas Repressuring Methods: Oil and Gas Jour., Vol. 34, No. 45, p. 18.

Diagrams of well connections and plan of air or gas repressuring plant shown. Well connections are itemized and priced.

CONINE, R. C., 1934, Oct. 25, Three Important Steps Must Precede Repressuring the Venango Sands: Oil and Gas Jour., Vol. 33, No. 23, p. 11.

The inlet wells should be cored, the cores analyzed, and the producing sand tested at close intervals in order to ascertain the proper pressure necessary to introduce 1,000 cubic feet of air/gas per 24 hours for every foot of sand area. Porosity and permeability determinations reported.

CONINE, R. C., 1936, Jan. 2, Repressuring Sands with Gas in Pennsylvania: Oil and Gas Jour., Vol. 34, No. 33, p. 38.

Repressuring with gas is becoming a more popular method of producing oil in the older Eastern fields and a most recent installation of this type of oil recovery system is described. Map and photographs.

———, 1936, Jan. 16, Kentucky Fields Being Repressured by Combination of Several Processes: Oil and Gas Jour., Vol. 34, No. 35, p. 32.

After careful study many operators have decided to apply gas repressuring methods to several Kentucky fields.

COWARD, H. F., and JONES, G. W., 1931, Limits of Inflammability of Gases and Vapors: U. S. Bur. Mines Bull. 279, 108 pp.

Tables, charts, and discussion of the limits of inflammability of gases and vapors.

COZZENS, F. R., 1937, January 11, Water Control with Air Pressure Revives Old Wells: Oil Weekly, Vol. 84, No. 5, p. 18.

Back pressure with air at 1,000 #/□″ was applied to wells which made water in Berea and Cow-run fields, Ohio.

DESMOND, J. S., CHALMERS, J., and MILLS, R. V.
See Mills.

DOW, D. B., and CALKINS, L. P., 1926, Feb., Solubility and Effects of Natural Gas and Air in Crude Oils: U. S. Bur. Mines Rept. Inv. 2732.

Effect of pressure and temperature on the solubility of gas and air in various crudes, and the resultant effect on the viscosity were studied.

Order of solubility in crudes—wet gas, dry gas, air.

Wet and dry gas caused a decrease in viscosity, but air caused an increase.

ELIAS, GWYN, 1929, August, Repressuring of Oil Sands: Inst. Petroleum Technologists Jour., Vol. 15, No. 75, p. 428.

Discusses methods of repressuring, air and gas drive, pressure maintenance, and gas storage.

ELLIS, B. J., 1931, Gas in Relation to Oil Production: Inst. Petroleum Technologists. Jour., Vol. 17, p. 2, January.

Divides reservoirs into three classes—hydraulic, volumetric, and capillary controlled—and discusses field practice for each. Covers repressuring and gas

drive. Discussion of potential energy of dissolved gases by W. C. A. Bowles, in appendix.

FLOOD, M. H., 1938, July 14, Air Repressuring in Colman-Plymouth Field in Illinois: Oil and Gas Jour., Vol 39, No. 9, pp. 44-6, 49, 50.

Structure, development program, production curves, and plants installed.

FORAN, E. V., 1930, June 1, Problems in Air and Gas Injection in Producing Oil Sands: Oil Field Eng., p. 41, presented at Spring Meeting, Southwest District, Am. Petroleum Inst., Midland, Tex., April 10.

Described four years' operation on four adjoining leases where air, wet gas, and dry gas were applied successively. Concludes (1) air may be used as a substitute for gas only when no water is produced, (2) gravity of the oil will not be reduced during gas recirculation, (3) dry gas has a greater tendency to channel than either air or wet gas.

GARDESCU, I. I., 1930, Behavior of Gas Bubbles in Capillary Spaces, Am. Inst. Min. and Met. Eng. Tech. Pub. No. 306; Am. Inst. Min. and Met. Eng., Petroleum Devel. and Tech. pp. 351-370.

The Jamin effect for oil and sand is zero or very small. The magnitude of the resistance offered by gas bubbles forced through small openings so far exceeds any possible resistance caused by the Jamin effect that the latter phenomenon need scarcely be considered in dealing with the movement of oil and gas through natural reservoir rocks.

FRANCIS, C. K., 1938, Oct. 6, Explosive Limits of Hydrocarbons as Related to Repressuring: Oil and Gas Jour., Vol. 37, No. 21, p. 61.

The explosive limits of hydrocarbons in air are tabulated as follows:

	Percent of gas in air	
	Low	*High*
Methane	5.3	14.0
Ethane	3.2	12.5
Propane	2.4	9.5
Butane	1.9	8.5
Pentane	1.4	8.0

GARDESCU, I. I., 1932, Some Experiments on the Behavior of Natural Gas in an Oil-sand Reservoir: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 467; Oil Weekly, Vol. 64, No. 13, p. 22, Mar. 11; Oil and Gas Jour., Vol. 30, No. 41, p. 22.

An apparatus simulating a sand reservoir was constructed. Experiments were performed showing the effect of the surface area of the occluded gas masses originally present in the reservoir, on the further evolution of gas from the oil and its consequent effect upon the rate of production of oil. Results indicate that if a great many gas bubbles are formed in the reservoir, conservation of gas, higher reservoir pressures, higher rates of flow, and better control of flow rates will result.

GORKA, HENRY, 1937, Feb. 22, Pressure Restoration in the Oil Fields of Poland: Oil Weekly, Vol. 84, No. 12, pp. 188, 194.

Application of gas repressuring by the Smith-Dunn process to several Polish fields.

HASKELL, R. M., 1928, May 24, Pressure Recovery in Eastern Fields: Oil and Gas Jour., Vol. 27, No. 1, pp. 32, 79; also, 1930, Sept., Pressure Restoration in Eastern Fields: Am. Petroleum Inst., Devel. and Prod. Eng. Bull. 202, p. 150.

Based on an analysis of air repressured properties of the Associated Producer's Company in eastern Ohio and in the Bradford field, the author believes air repressuring would prove profitable in eastern sands, except where exceptionally tight.

The chief drawbacks are: (1) an air-gas mixture, received from the formation is dangerous and weak when utilized as fuel; (2) considerable trouble with cut-oil exists. This has been reduced considerably by maintaining a back-pressure of approximately 80#/□" on the producing wells.

HASSLER, G. L., 1936, "Production of Oil by Gas Drive": Pennsylvania State College Mineral Ind. Exp. Sta. Bull. 20, pp. 19-42; Oil and Gas Jour., June 11, p. 44.

Experiments with air drive on dead Bradford crude showed, (1) that the presence of oil in sand does not affect correctness of Darcy's Law if the saturation is low enough to permit open gas passages; (2) the permeability of oil-saturated sandstone is equal to the dry permeability times a function of the saturation; (3) a quantity, oil-gas ratio divided by the pore volume, increases as the square root of the viscosity, is an exponential of the saturation, has no systematic variation with permeability, and increases as the square of the pressure gradient.

HASSLER, G. L., RICE, R. R., and LEEMAN, E. H., 1936, Investigation on the Recovery of Oil from Standstones by Gas Drive: Am. Inst. Min. Met. Eng. Petroleum Devel. and Tech., pp. 116-137; Abs. Min. and Met. Vol. 17, No. 356, p. 402, August; Pennsylvania State College Mineral Exp. Sta. Tech. Paper 26, 21 pp.

Short homogeneous cores of known porosity and permeability were saturated with dead oils of known viscosity and surface tension; then cleared of oil by blowing with air at a constant pressure gradient.

The saturation and rate of flow of gas were obtained at time intervals and equations derived showing, (1) the loss of saturation with time, (2) the variation of saturation with volume of gas driven through the sand, and (3) the variation of permeability with saturation.

HEITHECKER, R. E., and MILLS, R. VAN A., 1928.
See MILLS.

HILL, H. B., 1930, Results of Air Repressuring and Engineering Study of Williams Pool, Putnam-Moran district, Callahan County, Texas: U. S. Bur. Mines Tech. Paper 470.

Repressuring the Williams pool is of considerable interest on account of low recovery per acre, small amount of gas production, shallow wells, and lenticular pay sands. Results for 61 wells show decline from 185 barrels in May, 1926, to 116 barrels in December, 1929, as against estimated production at the end of this period of 62 barrels, an increase in daily production, due to repressuring, of 87 percent.

HOGG, C. C., Increased Recovery by Applying Air and Gas Pressure to Oil Sands: Am. Inst. Pet. Prod. Bull. 213, p. 71.

Discusses air repressuring project in Gordon sand, middle Pennsylvania district.

HUTCHINSON, N. M., 1936, Feb. 27: Program of Gas and Air Repressuring in Eastern Kansas Proves Profitable: Oil and Gas Jour., Vol. 34, No. 41, pp. 33-4, 38, 40; presented before Am. Petroleum Devel. and Tech., Mid-Cont. Div. of Prod, at Wichita.

Discusses application of gas repressuring to Bartlesville shoestring sands in Greenwood, Butler, Cowley, Lyon, and Woodson counties, Kansas. Method, equipment, and production data are given.

LACEY, W. N., 1931, Testing Rates of Solution of Oil and Gas: Two parts, Oil and Gas Jour., Vol. 30, No. 9, pp. 68, 113-16; Vol. 30, No. 8, pp. 15, 118-19.

A progress report on the API research problem on solubility, viscosity, and surface tension to determine rate at which a given gas sample would dissolve in a body of petroleum. Methane used with varied crudes and prepared liquids at 86° F. Various charts of results with round-table discussion.

LEEMAN, E. H., RICE, R. R., HASSLER, G. L.
See HASSLER.

LEVINE, J. S., 1937, Surveying the Economic Field of Repressuring Oil Sands: Two parts, Oil Weekly, Vol. 87, No. 2, pp. 15-19; Vol. 87, No. 3, pp. 32-36.

Resumé of conditions favoring gas or air repressuring, determination of feasibility, equipment necessary, operation problems, influence of solubility of gas in the crude, and ultimate yields.

LEWIS, J. O., 1917, Methods for Increasing the Recovery from Oil Sands: U. S. Bur. Mines Bull. 148. Two parts, National Petroleum News, Feb. 17, p. 92, and Feb. 24, 1926, p. 81.

Discussion of following topics:

1. Physical properties of petroleum and gases.
2. Character of oil sands and effect on petroleum retention.
3. Smith-Dunn or Marietta compressed air process, theory, engineering data, costs, and results of some practical applications.
4. Water displacement, theory, principles, and applications.
5. More effective utilization of natural pressures.
6. Previous publications on petroleum technology by Bureau of Mines.

LEWIS, J. O., 1922, April 5, Comparative Values of the Flooding and Air-pressure Methods: National Petroleum News, Vol. 14, No. 14, pp. 83-4, 87-8.

Discredits use of gas, and then compares air repressuring with water-flood. Favors the use of air, quoting lower initial costs and quicker pay-out as reasons.

LEWIS, J. O., 1926, February 17 and 24, Methods of Recovering More Oil: Two parts, Nat. Pet. News, Vol. 18, No. 7, pp. 48M-48O, Feb. 17; Vol. 18, No. 8, pp. 81-2, Feb. 24.

Discusses oil recoveries under normal operating conditions, and points out advantages received from utilization of air or gas repressuring, water flooding, or mining depleted sands.

LEWIS, J. O., 1934, Feb. 19, Advantages of Unitization in Repressuring: Oil Weekly, Vol. 72, No. 10, pp. 19, 20; Oil and Gas Jour., Vol. 11, No. 30, p. 28.

In addition to economics obtained by centralized management, operations may be carried out without protecting property lines and without diversified opinion on pressures, etc. Cites property of Delaware Consolidated Company, where one-half the field is operated by one company, and the other half by individuals. The unitized part has produced at almost double the rate of the others, though prior to repressuring the production was equal.

* LINDSLY, B. E., and BERWALD, W. B., 1930, Effect of Vacuum on Oil Wells: U. S. Bur. Mines Bull. 322.

Experiments show variable results from application of vacuum to oil wells. Production appears to increase from wells in coarse sands with low rock pressure; production of gas and yield of natural gasoline increases, while gravity of oil decreases; the water-oil ratio decreases slightly. The effect of vacuum in certain oil fields is discussed.

LINDSLY, B. E., 1931, Preliminary Report on an Investigation of the Bureau of Mines Regarding Solubility of Nat. Gas in Crude Oils: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., pp. 252-78.

Appliances used and solubility curves of gas and typical crude oils presented and discussed.

* LINDSLY, B. E., 1933, Nov. 16, Effect of Gas Withdrawal Upon Reservoir Fluids: Oil and Gas Jour., Vol. 32, No. 26, p. 19.

Bottom-hole samples from various fields showed a shrinkage in volume of from 11.2 to 40.5 percent when the naturally dissolved gas was liberated.

* LINDSLY, B. E., 1935, Jan. 24, Practical Application of Petroleum Solubility and Liberation Phenomena: Oil and Gas Jour., Vol. 33, No. 36, p. 37.

The author discusses the solubility of gas in oil, the conditions underground, the energy which may be obtained from the compressed gas, conditions under which the gas is liberated in the sand and flow string. Methods for bottom-hole sampling of oil are considered, as well as the pressure-volume-temperature relations. Bibliography.

LONGFELLOW, G. E., 1931, March, Operators Are Repressuring Successfully at Burbank: Petroleum Eng., Vol. 2, No. 6, pp. 40-2.

Discussion of production at Burbank and practices of Sinclair, Carter, Phillips, and Skelly operators.

McCLINTOCK, C. B., 1936, Jan. 23, Systematic Program Is Essential in the Proper Application of Repressuring: Oil and Gas Jour., Vol. 34, No. 36, pp. 24, 56.

New phases and improvements developed during previous five years in repressuring discussed:

a. Coring of wells.
b. Core analysis.
c. Packer application.
d. "Pattern" drilling.
e. Use of gas and air-gas mixtures.
f. Measurement of air-gas input and output volumes.
g. Control of air-gas production.
h. Electrification of leases.
i. Unit operations.

MILLER, H. C., 1932, June, Migration of Injected Gas Through Oil and Gas Sands of California: U. S. Bur. Mines Report Inv. 3177, p. 29.

Discussion of gas-injection methods, injection volumes and pressures, p-v field data; pressure gradient between injection and producing well; examples of projects.

MILLS, R. VAN A., CHALMERS, J., and DESMOND, J. S., 1928, October, Investigation in the Recovery of Oil: Am. Inst. Min. Met. Eng., Tech. Pub. 144; Oil and Gas Jour., Vol. 27, No. 22, pp. 151-4, 207.

Description of apparatus, problems to be solved, and experimental work attempted in an effort to obtain information relative to oil recovery by repressuring with air or gas.

Data covers the change in composition of air injected into an oil sand, percentage of oil recoverable by repressuring both early and late in the life of the field, relative advantages of pressure maintenance and repressuring, and the relative propulsive efficiencies of air and natural gas.

MILLS, R. VAN A., and HEITHECKER, R. E., 1928, Volumetric and API Gravity Changes Due to Solution of Gas in Crude Oils: U. S. Bur. Mines, Rep't. Investigation 2893, October; Oil and Gas Jour., Vol. 27, No. 29, p. 97, Dec. 6.

Experiments show that decided increases in volume and in API gravity are caused by the solution of gas in oil under pressure and that the reverse took place on liberation of gas from solution. Analyses of the gas used show a high absorption and long retention of ethane and the converse condition for methane.

MILLS, R. VAN A., 1929, April 18, Recovery Methods in Control of Water: Oil and Gas Jour., Vol. 27, No. 48, pp. 86-96.

Repressuring, gas lift, and dewatering practices for preventing water encroachment.

MORRIS, C. E., 1934, Sept. 17, Northeast Kansas Pool Shows Value of Repressuring Shallow Property: Oil Weekly, Vol. 75, No. 1, pp. 27, 28.

Big Lake Pool, with 75 producing wells on 380 acres was repressured with air at 40#/□" through 15 injection wells, drilled to form a 5-spot pattern.

MORRIS, C. E., 1934, Oct. 1, Back-pressure Is Held on Northeast Kansas Wells When Repressured: Oil Weekly, Vol. 75, No. 3, p. 22.

As soon as air reaches the producing wells, operation with least slippage is

determined, and the gas flow from the casing head decreased by means of a suitable orifice. This holds a back pressure against the formation, which is not permitted to become high enough to flow the well. Wells allowed to flow intermittently under back pressure fail to make their production, and pumping fails to make up the difference.

MORRIS, C. E., 1935, Jan. 14, Vacuum Is Profitable in Bush City, Pennsylvania During Repressuring: Oil Weekly, Vol. 76, No. 5, pp. 25, 26.

A 700-acre property with 116 producing wells and 9 air input wells was operated on vacuum—only one well channelled.

NEYMAN, E., and PILAT, S., 1935, April 25, Heat of Solution of Natural Gas Associated with Petroleum Oils: Oil and Gas Jour., Vol. 33, No. 49, p. 13.

The heats of solution of a natural gas in benzene, pentane and heptane were measured in a bomb calorimeter at high pressures. After deducting the calculated heat of compression from the total heat evolved, the difference proved to be of small amount, or negative. This is explained by the statement that no heat of solution is produced; the small thermal effect produced is caused by mixing the two hydrocarbons, and the negative values resulted from an increase in liquid volume.

* NICKERSON, C. M., 1929, March 8, The Effect on Producing Wells of Shutting in the Offset Wells: Oil Weekly, Vol. 52, No. 12, p. 24.

Among the author's conclusions are the following: (1) Subsurface conditions in California indicate that the upper part of the pay in fields past their flush stage contains mostly wet gas; (2) if wells in the flush stage are shut in, the offsets will have a larger drainage area, production will probably increase, the gas-oil ratio remaining the same or even decreasing; (3) in areas where the wells are pumping and the fluid level is low, the shutting in of wells increases oil production of offsets, but also increases the gas-oil ratio greatly; (4) where gravity is the principal force in bringing oil to the well, little change results from shutting in wells; (5) gas should be prevented from migrating from formation to formation in shut-in wells, by the use of mud; (6) when it is necessary to curtail production by shutting in wells, a program of repressuring should be considered, planned to prevent undue migration of the gas and to increase the future recovery of oil from the shut-in wells when they are again put on production.

NICKERSON, C. M., 1929, Repressuring in Depleted Oil Zones: Am. Inst. Min. Met. Eng., Tech. Pub. 254, Oct.; Oil Weekly, Vol. 55, No. 4, p. 44, Oct. 11, Am. Inst. Min. Met. Eng., Pet. Devel. and Tech., pp. 246-257.

The repressuring of a depleted lease producing as little as three to five barrels of oil per well per day is feasible. Leases as small as a quarter section may be repressured, and by adjustment of back pressures on the wells, the benefit may be confined to the lease. Outlines methods in use on several small California leases.

OIL-WELL SUPPLEMENT I, 1937, June, Repressuring Equipment: Petroleum Engineer, p. 75.

PARKHURST, I. P., and BEECHER, C. E., 1926.
See BEECHER.

PILAT, S., and NEYMAN, E., 1935.
See NEYMAN.

POWER, H. H., 1928, Relative Propulsive Efficiencies of Air and Natural Gas in Pressure-drive Operations: Am. Inst. Min. Met. Eng., Tech. Pub. 148, Oct.; Oil and Gas Jour., Vol. 27, No. 22, p. 164, Oct. 18; Oil Weekly, Vol. 51, No. 5, p. 150, Oct. 19; Am. Inst. Min. Met., Petroleum Devel. and Tech., p. 313.

The conclusions obtained from experimental evidence show that:

1. Up to a certain saturation, air is more efficient than natural gas as a repressuring agent.

2. Rate of oil production is increased and rate of gas production is decreased by pressure-control methods, as gas is kept in solution, thus maintaining viscosity and surface tension more nearly uniform from the interior of the reservoir to the well, reducing bubble resistanace and thereby requiring less energy to propel a given amount of oil per unit of time.

3. In any method of recovery greater production is obtained if gas is not permitted to permeate the oil body near the well.

Among other results, it was noted that, volume for volume, nitrogen is superior to natural gas as a propulsive agent.

RICE, R. R., LEEMAN, E. H., HASSLER, G. L.
See HASSLER.

ROTH, J. E., 1926, The Application of Pressure to the Elliott Pool, Nowata county, Oklahoma: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 195.

Elliott pool history and installation were described. Factors which affect efficient operations are: Location of air wells, oil-gas ratios, casinghead gasoline in connection with air plants, and the danger of use of air-gas mixtures.

RYDER, H. M., 1937, Nov. 4, Development of Repressuring Operation Involves Many Factors: Oil and Gas Jour., Vol. 36, No. 25, pp. 38, 40, 42, 49.

Outlines and discusses factors involved: Geography of area, well locations, pay sand thickness, sand structure, limits of pool, study of stratification, permeability, saturation, porosity, continuity of pay or breaks, viscosity of crude, adherence of crude to sand, total and recoverable oil content, cost of drilling and completing wells and crude price structure. From them the fundamental conditions controlling the layout may be obtained, such as: The absence or presence of any preferential trend in the flow through the sand, its direction and extent, if present, economically best well spacing, drilling pattern, probable maximum pressure necessary, probable average gas or air input, need of intermediate packers, and need for additional coring.

SANDERS, T. P., 1936, Oct. 29, Intermittent Application of Gas is Beneficial in Repressuring: Oil and Gas Jour., Vol. 35, No. 24, p. 42.

By applying gas pressure intermittently greater yields are obtained. Explained by attributing increase to oil which comes out of pores into main channels when pressure is off, and then forced on through when pressure is applied. Continuously applied pressure resulted in gas channeling with low recoveries.

SHAW, S. F., 1938, Oil-field Repressuring: Science of Petroleum, Vol. I, pp. 577-82, Oxford Press, London.

Three types of repressuring—pressure maintenance, pressure restoration, and gas drive—discussed. Costs for typical plant estimated. Data for a large number of projects listed.

SMITH, L. E., 1924, May 7, Restoration of Pressure to Oil Sand Increasing in Oil Fields: National Petroleum News, Vol. 16, No. 19, pp. 71-74.

Discusses plans for repressuring the Pennsylvanian fields.

SQUIRES, F., and BELL, A. H., 1932, Sept. 24.
See Bell.

STEVENS, L. C., 1931, Feb., Methods of Increasing the Yield from Oil Sands, With Special Reference to Repressuring: Inst. Petroleum Tech. Jour., Vol. 17, No. 88, p. 73.

Discusses vacuum pumping, water drive, and repressuring methods. The latter is discussed fully for both exhausted and semiflush production under location and number of wells, repressuring medium, equipment, costs and causes of failure. The effects of gas solubility, pressure, Jamin effect, efficiency of control, and of hydrostatic pressure, are noted.

SWINDELL, FLOYD, 1931, July 24, Burbank Repressuring Meets with Varying Success: Oil Weekly, Vol. 62, No. 6, p. 26.

The relation between the physical features of sands and success of repressuring is demonstrated; comment made on the good lease layout of the pool for coöperative work. A careful study is made of the program of the operator who has carried on the most progressive and successful campaign. The article includes a map of the leases, and thirteen graphs illustrating the text material.

TOLLEFSON, E. H., 1938, April 25, Gas and Air Repressuring: Oil Weekly, Vol. 89, No. 7, pp. 64-6-8. Presented at Annual Meeting Eastern Dist., Am. Petroleum Inst., Div. of Production, Pittsburgh.

Discussion of operating problems encountered in West Virginia and Ohio fields.

WEBB, E. W., and BELL, A. H., 1930.
See Bell.

WILDER, N. M., 1936, June 8, Repressuring Limestone Production Area in Kentucky: Oil Weekly, Vol. 81, No. 13, p. 31; Oil and Gas Jour., Nov. 21, 1935, p. 30; Am. Petroleum Inst., Drilling and Production Practice, p. 84.

Problems and methods of recovering petroleum from limestone by repressuring. Compares texture of limestone and sandstone reservoirs and effect on permeability. Attempts to show that the problems differ from sandstone repressuring insofar as regular patterns would not always prove successful; outlines of affected areas would be extremely different in most cases. Calcium carbonate sealing the walls of the wells makes shooting or the drilling of new wells advisable. Difficulties experienced in presenting a satisfactory permeability profile are discussed with reference to core recovery and the type of core analyzed.

WILDER, N. M., 1938, Practical Repressuring: Am. Assoc. Petroleum Geologists Bull., Vol. 22, No. 2, pp. 189-200.

Discusses repressuring projects on the "Corniferous" (Onondaga) formation in eastern Kentucky. Details given for well-spacing patterns, preparation of wells, injection volumes and pressures, and production figures.

Additional References on Repressuring

Albright, J. C., 1935, Oct. 14, Repressuring Project Includes Well Rehabilitation and Use of One Engine for Compressing and Generating: Oil Weekly, p. 19.

Albright, J. C., 1936, Jan. 13, Gas Drive and Storage Projects at Burbank is Well Equipped: Oil Weekly, p. 31.

Albright, J. C., 1937, Jan. 18, Repressuring Increases the Ultimate Yield of a Small Field Near Electra, Texas: Oil Weekly, p. 28.

Anonymous, 1930, March, Systematic Planning a Big Factor Toward Insuring Success of Repressuring: Petroleum Engineer, p. 96.

Anonymous, 1935, Sept. 12, Magnolia's New Type Repressuring Plant Sustains Reservoir Energy: Oil and Gas Jour., p. 30.

Anonymous, 1936, June 11, Venezuela Problems Involve Pumping, Dehydration and Repressuring Units: Oil and Gas Jour., p. 27.

Anonymous, 1937, Mar. 17, No Change Due to Repressuring Noted in Character of Crude: National Petroleum News, p. 161.

Baker, W. L., 1934, April 19, Lenticular Sands on the Gulf Coast are Repressured Successfully: Oil Weekly.

Bell, A. H., 1927, Summary of Repressuring Experiments in California Fields: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 299.

Bell, A. H., 1936, August, Studies of Repressuring and Water Flooding: Petroleum Engineer p. 60.

Bignell, L. G. E., 1930, Nov. 30, Repressured Wells in Bartlesville Sand: Oil and Gas Jour.

Bignell, L. G. E., 1937, Oct. 7, Recharge Deep Formation to Add to Ultimate Recovery of Crude Oil: Oil and Gas Jour., p. 160.

Bredburg, L. E., 1934, June 21, Stripper Operators in Wichita Falls and Ranger Districts are now Turning to Repressuring: Oil and Gas Jour., p. 15.

Bredburg, L. E. 1937, June 24, Repressuring in Wichita Falls and Ranger Area: Oil and Gas Jour.

Burrell, G. A., and Roberston, I. W., 1916, Effects of Temperature and Pressure on the Explosibility of Methane-air Mixtures: U. S. Bur. Mines Tech. Paper 121, pp. 7-10.

Chalmers, Nelson and Taliaferro, 1930, Recovery of Oil by Gas Drives: U. S. Bur. of Mines, Rept. Inv. 3035.

Cloud, W. F., 1931, July 24, Laboratory Data Regarding Repressuring and Total Recovery: Oil Weekly, p. 17.

Cloud, W. F., 1937, Repressuring: Petroleum Production, Univ. Oklahoma Press, p. 419-37.

Coleman, Wilde and Moore, 1930, Quantitative Effect of Gas-oil Ratios on Decline of Average Rock Pressure: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech., p. 170.

Conine, R. C., 1933, Oct. 12, Repressuring with Air and Gas in Pennsylvania: Oil and Gas Jour.

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Conine, R. C., 1934, Nov. 8, Natural Gas Repressuring Reviving Triumph Hill and Fagundus Pools: Oil and Gas Jour., p. 13.

Conine, R. C., 1935, Dec. 12; 1936, Jan. 16, Repressuring Depleted Oil Producing Sands in Kentucky Receiving Study: Oil and Gas Jour., p. 35, p. 32.

Conine, R. C., 1935, Dec. 26, Study of Air or Gas Drive at Pennsylvania State: Oil and Gas Jour.

Conine, R. C., 1936, Jan. 23, Systematic Progress Essential in Proper Application of Repressuring: Oil and Gas Jour., p. 24.

Conine, R. C., 1934, June 14, Repressuring and Reconditioning in Kane and Butler Counties, Pennsylvania: Oil and Gas Jour.

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Fettke, C. R., 1927, Ten Years' Application of Compressed Air at Hamilton Corners: Am. Inst. Min. Met. Eng., Petroleum Devel. and Tech.

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Flood, M. H., 1937, June 8, Problems in Improved Recovery: Oil Weekly, p. 37.

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Hartnagel, C. A., 1922, Oct. 28, Restoring Pressure to New York Oil Sands: Oil Weekly, pp. 14, 80, 90.

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Jones, G. W., and Kennedy, R. E., 1932, Inflammability of Mixed Gases: Methane. Ethane, Hydrogen and Nitrogen: U. S. Bur. Mines, Rept. Inv. 3172.

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Kauffman, H. L., 1929, March 1, Factors Involved in Lessening Evaporation Losses: Oil Weekly, Vol. 52, No. 11, p. 28.

Layton, C. I., 1934, Dec. 10, Repressuring Experiment in Bourbon County, Kansas is Interesting: Oil Weekly, p. 21.

Lindsey, R. J., 1935, Jan. 24, Practical Application of Pet. Solubility and Liberation Phenomena: Oil and Gas Jour., Vol. 33, No. 36, p. 37.

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Shaw, S. F., 1933, April, Repressuring of Oil Sands: Petroleum Engineer, p. 29.

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Smiley, T. F., 1936, Sept. 24, Concerning Use of Gas and Air-gas Mixtures in Repressuring Work: Oil and Gas Jour., p. 81.

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Tucker, Mitchell, 1936, Dec. 10, Ohio's Repressuring Project Increases Ultimate Recovery of Haynesville: Oil and Gas Jour., p. 32.

Turnbull, George, 1926, Feb. 2, Experiments in Further Recovery Feature in Eastern Field in 1915: Oil and Gas Jour., p. 86.

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SECTION VII

Description of Methods and Projects for Mining Petroleum

* BIGNELL, L. G. E., 1933, January 5, Many Interesting Facts About Oil Accumulation Revealed by Examination of Sands in Place: Oil and Gas Jour., Vol. 31, No. 33, p. 33.

Report of paper on mining oil in Electra, Tex., and a translation of portions of "Mining of Petroleum by Shafts and Galleries," by Paul de Chambrier, dealing with the Pechelbronn mines. Among the interesting facts related is that, prior to oxidation, the oil sand is white.

DE CHAMBRIER, P., 1938, A Method of Working Petroleum by Means of Underground Drainage: Science of Petroleum, Vol. I, pp. 637-9, Oxford Press, London.

Discussed history, methods used, and technique of production from Pechelbronn Oil Mines.

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Concludes that mining methods may be used in depleted fields, under favorable conditions, and might bring large financial returns and recover much oil which would be lost by ordinary methods. To depths of 4,000 feet, with 1,500 to 3,000 feet optimum, the mining methods offer cheaper recovery than flooding or repressuring. The proposed methods could not be applied to new fields because of the pressure and toxic conditions which would be encountered. Approximately 100 percent recovery is anticipated.

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