THE MINES MAGAZINE

NOVEMBER 1960

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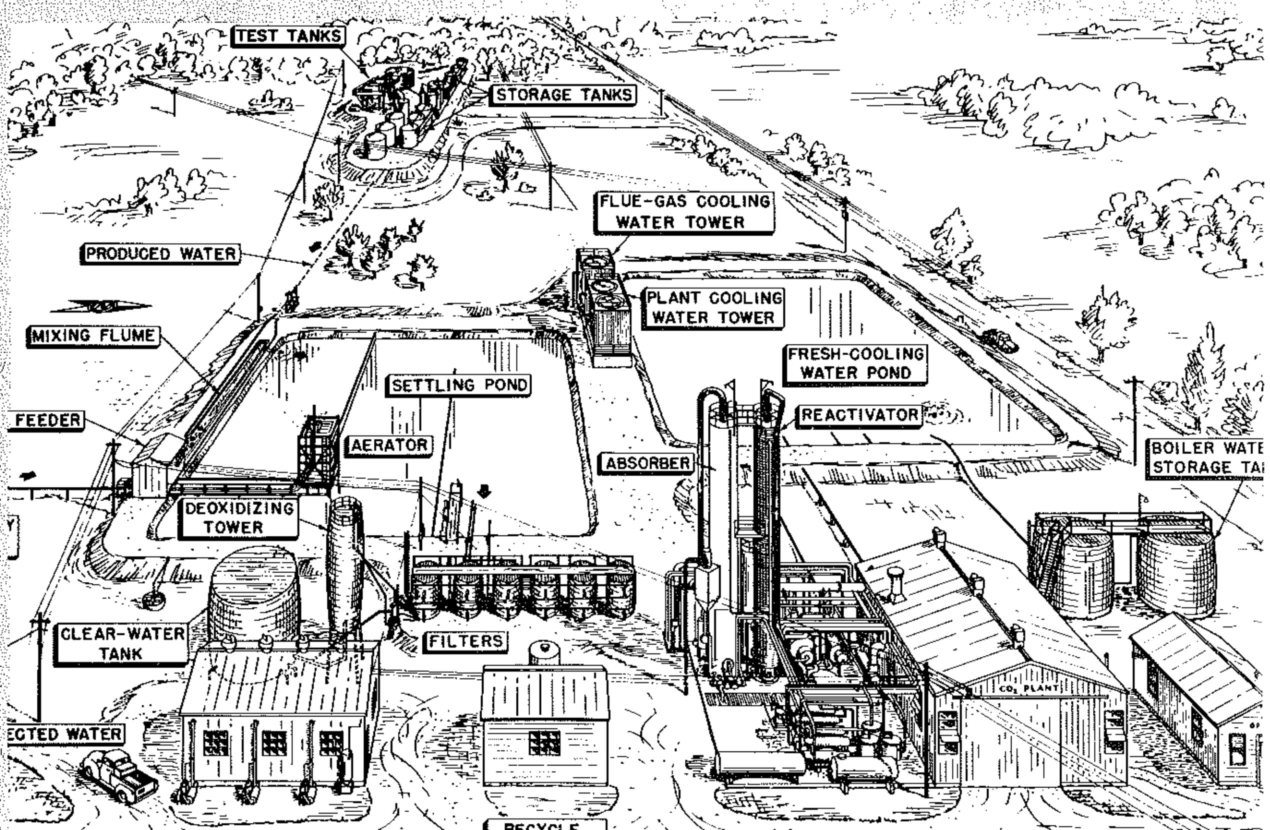
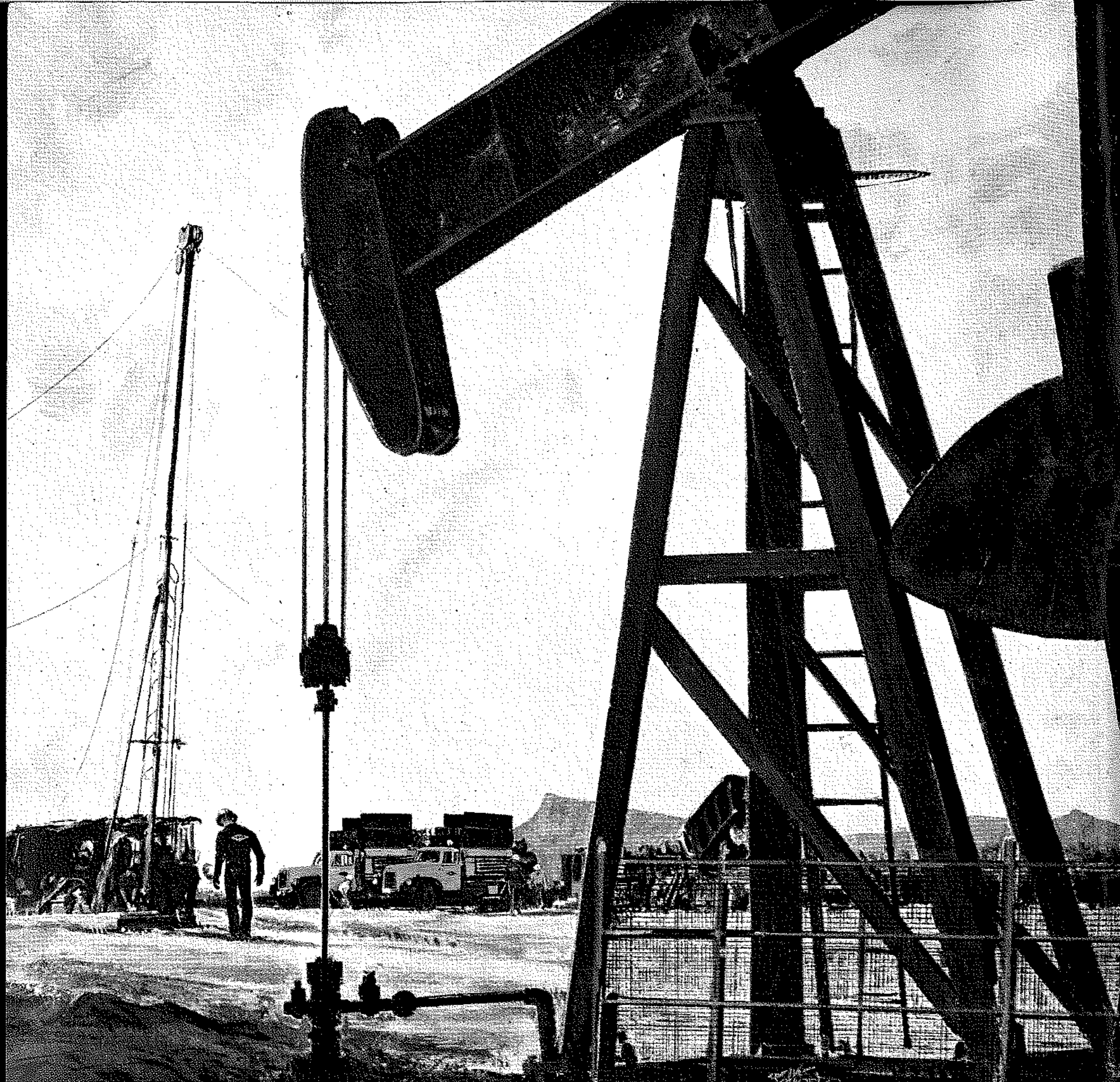




CLASS NOTES

When advising us of a change of address, please confirm your postition or title and company affiliation.

1882-1930

FRANK E. LEWIS, '01, of 303 W. 6th, Pittsburg, Kans., writes that he uses the Mines Men Directory a great deal. He adds: "Don't think any other School has anything like it."

HENRY E. KING, '03, 1600 Hill Dr., Los Angeles 41, Calif., recently broke his hip and is recuperating in a sanitarium. Mrs. King writes that "it will be some time before he is able to walk or be about."

W. C. CHASE, x-'05, advises that his new permanent address is 879 Gene Reed Rd., Birmingham 15, Ala.

ARTHUR R. BRANDT, '07, has moved from Denver to Georgetown, Colo.

EDWARD D. WILCOXSON, '12, has moved from Rio Vista, Calif., to 1535 Wisteria Lane, Los Altos, Calif.

MEARLE G. HEITZMAN, '17, has moved to 3010 East 7110 W., Salt Lake City 17, Utah. He is consultant for United Park City Mines Co.

R. S. COULTER, '19, whose home address is 2629 Martinez Dr., Burlingame, Calif., is assistant to the general manager of operations, Bethlehem Steel Co., 100 California St., San Francisco, Calif.

JOSE ZAMBRANO, '21, is engineer for Minera de Penoles with home address Nunez de Arce # 710, Colonia Anahuac, Monterrey, Mexico.

R. B. LOWE, '22, vice president of engineering and construction for Union Carbide Plastics Co., gives his new business address as c/o Union Carbide Corp., 270 Park Ave. (R-4694), New York 17, N. Y.

ADOLPH W. BECK, JR., '23, general superintendent of ore mines and quarries, Tennessee Coal, Iron & R. R. Division of U. S. Steel Corp., has moved from Bessemer, Ala., to 1603 Shades Glen Circle, Birmingham 9, Ala.

Col. MERLE Q. DANNETTELL, '23, U. S. Army retired, is living at 1207 Crest Dr., Encinitas, Calif.

BAILEY E. PRICE, '23, whose home address is 866 E. Broad St., Columbus, Ohio, has been promoted by National Electric Coil Co. from general sales manager to manager of sales and advertising.

PAUL A. GRANT, '23, may be addressed at 3441 Wellington Rd., Ft. Worth 16, Texas.

E. R. HARRINGTON, x-'24, 223 Cedar St. NE, Albuquerque, N. M., is director of secondary education, Albuquerque Public Schools.

G. WOOD SMITH, '24, is vice president for construction, Sverdrup & Parcel Engineering Co., 915 Olive St., St. Louis 1, Mo. His home address is RFD 13, Box 1555, Kirkwood, Mo.

JOHN L. HUTTON, '25, has changed his mailing address from Cleveland, Ohio to P. O. Box QQ, Pompano Beach, Fla.

L. A. SHAW, '25, is manager, refinery laboratory, Shell Oil Co., Wilmington, Calif. His home address is 4253 Pine Ave., Long Beach 7, Calif.

QUENTIN L. BREWER, '26, is operating his engineering office and is city engineer for Bonners Ferry, Idaho, His P. O. box number is 381.

HAROLD W. McCULLOUGH, '27, advises that his mailing address is now 2112 Cherokee Ave., Apt. 12, Columbus, Ga.

A. S. MacARTHUR, '27, consulting mining engineer, has a new street address in San Leandro, Calif.: 338 Callan, #3.

DOUGLAS M. SHAW, '28, is manager of engineering for Utah Australia Ltd. His mailing address: Flat 1, 25 Millswyn St., South Yarra, Melbourne, Victoria, Australia.

PHILIP W. SIMMONS, '29, has moved out of Washington D. C., to nearby Arlington 6, Va., where his street address is 48 South 28th St., A-2.

1931-'40

GEORGE T. GOULD, '32, owner of the Gould Engineering Co., has a new business address: 808 Beacon Bldg., Tulsa 3, Okla.

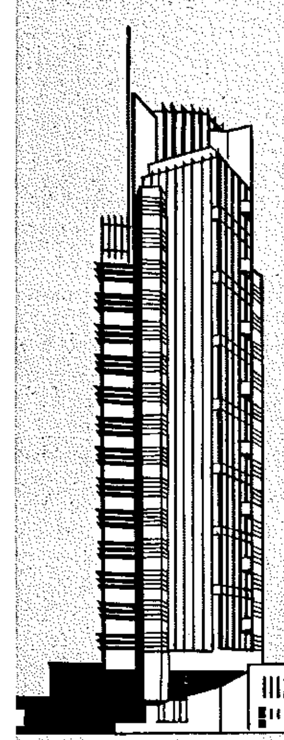
LOWELL O. GREEN, '32, has moved from 411 Vermilion to 11 E. Woodlawn, Danville, Ill.

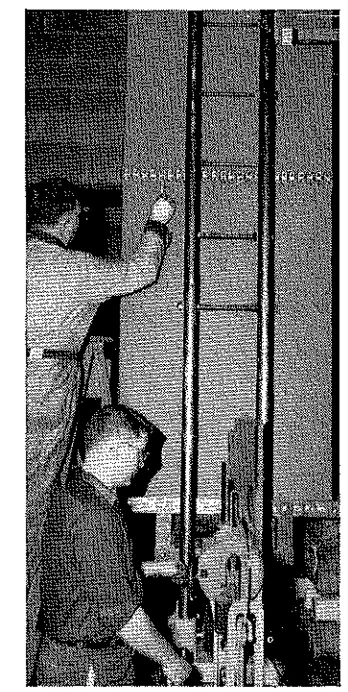
HOWARD A. WOLF, '32, has retired and is taking it easy at 100 NW 22nd Dr., Gainesville, Fla.

HOWARD F. LESLIE, '32, whose mailing address is 1461 Diolinda Rd., Santa Fe, N. M., is highway engineer for the state of New Mexico.

ROBERT W. PRICE, '35, has moved from Tucson, Ariz. to Salt Lake City, Utah, where he is vice president of Minerals Engineering Co. His home address is 1595 Evergreen Lane.

(Continued on page 6)





NEWS OF THE MINERAL INDUSTRIES

Companies Form Joint Venture To Produce Vanadium Pentoxide

A plan to produce vanadium pentoxide has been announced jointly by Minerals Engineering Co. of Grand Junction, Colo., and Susquehanna-Western, Inc., Denver subsidiary of The Susquehanna Corp., Chicago.

The two companies have formed a joint venture operation to produce vanadium pentoxide, an important steel alloying material, in a newly acquired plant near Salt Lake City, Utah.

An entirely new process, first of its kind in the United States, will be employed to chemically extract vanadium from vanadium-bearing slag, a heretofore wasted by-product of western phosphorous operations.

As a heat and corrosion resistant metal, vanadium finds its principal use as an alloy in the manufacture of steel. New opportunities for the extensive use of vanadium have been opened by successful experimental extrusions of pure vanadium tubing for use in the nuclear and process industries, and as a result of qualities which make it a suitable anti-smog agent.

Four Wyoming Projects Proceeding on Schedule

The Columbia-Geneva taconite project at Atlantic City is proceeding on schedule, according to an item in the Oct. 3 Wyoming Mining Assn. Newsletter.

Other Wyoming projects moving ahead are (1) the Stauffer Chemical Co. which has begun construction work on a trona mine and plant north of Green River; (2) a reservoir being constructed by Utah Power & Light for cooling water for the power plant to be built near Kemmerer; (3) the Foods Machinery & Chemical Corp.-U. S. Steel joint venture, a $5 million pilot plant for coking low-grade coals, now just about completed with test runs being made on the equipment.

Ohio Oil Assumes Ownership Of Kinney-Coastal Properties

The Ohio Oil Co. recently announced that it has assumed ownership of all Kinney-Coastal Oil Co. properties for $1,629,000 cash plus an oil and gas production payment of $7,300,000. The latter payment is expected to cover a period of about seven years.

Glenn F. Bish, Ohio Oil vice president of domestic production, said that Kinney-Coastal net production amounts to about 2,300 barrels of oil daily, mostly from Garland Field in Big Horn Basin of Wyoming where it holds a half interest. Ohio Oil, owning the other half, has operated the Kinney-Coastal properties in the field for the past 30 years. The Garland Field represents approximately 80 per cent of the acquisition.

Kinney-Coastal also holds a one-fourth interest in production from Dorman and Rapp leases in Nebraska, as well as other holdings, consisting of royalties and leases in Kansas, Nebraska, Oklahoma, Texas, Mississippi and Colorado.

Kinney-Coastal has some natural gas production.

Mr. Bish said the purchase is a part of the Ohio Oil program to build up its domestic reserve holdings. Kinney-Coastal is the third company in which Ohio Oil has acquired major interests this year. The previous two were McClure Oil Company of Michigan, and Oregon Basin Oil and Gas Company in Wyoming.

Bureau Releases Film On California Resources

An all-new version of "California and Its Natural Resources," one of the most popular films in the Bureau of Mines motion-picture library, is now available on free short-term loan for group showings throughout the United States, the Department of the Interior has announced.

The film was completed recently under the sponsorship of the Richfield Oil Corp., Los Angeles, which paid all production costs and provided prints for circulation to schools, universities, scientific, civic, and industrial groups, and similar organizations. It can be obtained on request directly from the Bureau of Mines at Pittsburgh 13, Pa., or from depositories in 40 States.

The Bureau of Mines said the new version of "California" emphasizes the contribution of mineral and energy resources to the Golden State's notable industrial and economic progress, much of which has occurred since the film was last revised. Sequences picturing mining operations, irrigation projects, petroleum production, modern farming, and forestry practices show how Californians are developing and conserving their natural resources to provide an ample foundation for present and future growth.

(Continued on page 16)

Professional . . . CARDS

CLASS NOTES

(Continued from page 3)

MILTON A. LAGERGREN, '33, project engineer for Kennecott Copper Corp., lives at 3588 South 24th East, Salt Lake City 9, Utah.

JOHN B. TRAYLOR, '36, gives his new mailing address as 1374 Glencoe, Denver 20, Colo.

JAMES E. WERNER, '36, has moved from 2500 E. Van Buren to 1213 South 9th Ave., Phoenix, Ariz.

RICHARD JOHN SCANLON, '38, reports a new P. O. Box number, 1258, in Farmington, N. M.

CHARLES M. TARR, '38, senior staff engineer for Continental Oil Co., has moved from 180 Allison to 560 Dudley St., Denver 26, Colo.

ROSCOE C. McCUTCHAN, '38, assistant district engineer, Phillips Petroleum Co., has a new street address in Odessa, Texas: 207 Santa Rita.

HENRY B. ESTABROOKS, '38, whose mailing address is Box 266, Ducktown, Tenn., is mine foreman, Calloway Mine, Tennessee Copper Co.

WILFORD L. HARTZ, '39, whose mailing address is P. O. Box 3784, Lowell, Ariz., is test engineer, Phelps Dodge Corp., Copper Queen Branch, Bisbee, Ariz. He was formerly assistant mill metallurgist at Kennecott Copper Corp.'s Chino Mines Div., Hurley, N. M.

CHARLES R. CUTLER, '39, engineer for Christensen Diamond Products Co., lives at 38 Rue de l'Yvette, Paris 16eme, France.

LYNN D. ERVIN, '40, has built a new home at 350 Tynebridge Lane, Houston 24, Texas.

CHARLES S. LINDBERG, '40, is a "lost" alumnus whose address has been found: 909 North Butler, Farmington, N. M.

1941-'45

R. E. PIERSON, '41, has moved from Chicago to 4550 W. 185th Pl., Tinley Park, Ill.

ROBERT E. MOYAR, '41, has asked to have his mailing address changed from Karachi, Pakistan, to Box 234, Rouseville, Pa. Moyar, an employee of Standard-Vacuum Oil Co., wrote on Sept. 26 that he would "be leaving soon for the U. S. A. and vacation."

GEORGE W. KING, '42, receives mail at 247 Cayton, Houston 17, Texas.

ROBERT E. SIMPSON, '42, of 6016 Parfet St., Arvada, Colo., is mining engineer for Titan, Inc. He was formerly a sales engineer for Morse Bros. Machinery Co.

FRANKLIN S. CRANE, '43, still lives in San Luis Obispo, Calif., but his new street address is 281 Albert Dr.

KENNETH E. GIBBS, x-'44, plant engineer for El Paso Natural Gas Co., has moved 14 blocks on Maple St. to 1616. The town is Aztec, N. M.

FRANK J. ADLER, '44, geologist for Phillips Petroleum Co., has moved from Durango, Colo., to 2403 Braun Court, Golden, Colo.

B. R. HUDSON, '45, a hydro-geologist for the United Nations Bureau of Technical Assistance Operations, may be addressed at 720 Green St., Yellow Springs, Ohio. A recent note from the United Nations advises us that "this address is the most current one on our records." Mr. Hudson's article, "Carnival in the High Andes," was published in the January 1960 issue of The MINES Magazine.

1946-'50

JOHN P. COGAN, '47, area petrophysical engineer for Shell Oil Co., has a new street address in Midland, Texas. It is 3225 Dengar.

WILLIAM F. SPAIN, '47, who was general manager of Wah Chang Corp. Australian operations, has returned to the company's New York office in the Woolworth Bldg., New York 7.

WILLIAM K. ALKIRE, '48, may be reached at P. O. Box 237, Westwego, La. He is division exploitation engineer, Shell Oil Co.

LAWRENCE B. MYERS, '48, is division engineer, Production Dept., Continental Oil Co. His mailing address is Box 680, Casper, Wyo.

M. T. RADER, '48, has been transferred by Creole Petroleum Corp. from Caracas to Apartado 172, Maracaibo, Zulia, Venezuela, S. A.

LOUIS HIRSCH, '49, has moved to 4519 Grimsby Rd., Columbus 13, Ohio. He is senior engineer for North American Aviation.

P. G. MIDDLETON, '49, who was in the Aviation Gas Turbine Division of Westinghouse Corp. in Kansas City, Mo., has moved to 7648 Sale Ave., Canoga Park, Calif.

MORRIS W. MOTE, '49, has a new street address in Pleasanton, Calif.: 324 Adams Ct.

DANIEL OAKLAND, '49, has moved to a pleasant Chicago suburb: Oak Lawn, Ill. The street address is 10332 S. Kolin.

HOMER N. OPLAND, '49, is living at 408 Delaware Rd., Frederick, Md., where he is administrative assistant with Aerojet General Corp.

Maj. K. G. COMSTOCK, '50, is studying at the U. S. Army Command and General Staff College. His address is 17 Bullard Ave., Fort Leavenworth, Kans.

ANDREW G. KELEHER, '50, former manager of Benders Bakeries in Denver, Colo., is field representative for Nalco Chemical Co. His home address is 5208 Paxton Ct., Fremont, Calif.

F. P. MERCIER, '50, formerly of Ceres, Calif., is now living at 406 Northgate Dr., Modesto, Calif.

PAUL E. MOOREHEAD, '50, is metallurgist for Bell Aerosystems with mailing address 120 Evergreen, Tonawanda, N. Y. He has been living in Warren, Ohio.

JOHN D. McIVER, '50, managed to get his first vacation away from the job this year, after four years, and traveled north through Maine and Canada. The family, including three sons and one daughter, went along. The family visited Lewis D. T. Geery, formerly with Anaconda in Chile, Phelps Dodge and Kennecott. Mr. McIver writes that he managed to reel in his first "white Marlin" off Ocean City, Md., this fall. Mr. McIver is production superintendent of Kennecott Refining Corp.'s electrolytic copper refinery near Baltimore, Md. His address is 47 Cedar Rd., Severna Park, Md.

CARL J. WATSON, '50, is sales engineer for King & East Machinery Corp. with home address 5109 Iris, Arvada,

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CLASS NOTES

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Colo. He was formerly sales engineer with Johnston Testers, Inc. in Casper, Wyo.

E. C. SPALDING, '50, a staff geologist for Texas-Zinc Minerals Corp., is being transferred back to the parent company, New Jersey Zinc, on a new assignment. He'll continue to reside in Grand Junction, Colo., which he writes "is a break as this is a pretty nice town."

1951

CHARLES R. CLARK has been transferred by Pure Oil Co. from Durango, Colo. to 1575 Sherman, Denver 3, Colo.

JEAN F. HARTMAN, 1736 South Johnstone, Bartlesville, Okla., is staff geologist, International Dept., Phillips Petroleum Co.

PAUL A. JOHNSON, formerly of Andover, Mass., is living at 5408 Thurlow St., Hinsdale, Ill.

ROBERT W. MacCANNON's new mailing address is Box 1211, Cedar City, Utah. Mr. MacCannon's article, "CF&I Sunrise (Wyo.) Mine's Safety Program," was published in the September 1960 issue of The MINES Magazine.

CHARLES C. STEWART, Jr. 326 Moran, Grosse Pointe Farms, Mich., is assistant vice president and manager of the Petroleum Department, National Bank of Detroit.

B. E. VAN ARSDALE, Jr., 1710 Robert St., New Orleans 15, La., has left the employ of Sinclair Oil & Gas Co. and has joined Continental Oil Co.

1952

MILLARD E. BENSON, field foreman for Texaco Inc., has moved from Buena Park, Calif. to 845 Olive St., Paso Robles, Calif.

RUSSEL CHECK'S new address is 2139 Elphinstone St., Regina, Saskatchewan, Canada. He was living in Karachi, Pakistan.

ARTHUR J. GRAVES may be addressed c/o Getchell Mine, Golconda, Nev.

ROGER A. HITCHINS, II, former superintendent of National Refractories Co., Thomsontown, Pa., is now plant superintendent, Van Dyke Plant, Kaiser Aluminum & Chemical Co. His mailing address is Box 187, Thomsontown, Pa.

JOHN T. LINDQUIST, engineer for Trinity Dam Contractors, has been transferred from Lewiston, Calif., to Challenge, Calif., where his mailing address is P. O. Box 82.

EUGENE L. McDANIEL has moved to one of Denver's pleasant and fast-growing suburbs, Thornton, Colo. His address is 9250 Harris Dr., Thornton 29, Colo.

JOHN B. SERVATIUS, farm manager for Big Oak Farms, Inc., lives at 306 Williams, East Prairie, Mo.

1953

THOMAS S. AFRA's new address in Tulsa, Okla., is 5114 S. Wheeling.

1954

ARTHUR B. COADY has moved from Cardston, Alberta, to Calgary, Alberta, where he may be addressed c/o Canadian Fina Oil, Ltd., Bamlett Bldg.

JOHN A. DORR's new address is 1703 W. 7th St., Apt. 73, Frederick, Md.

JOHN W. ERWIN and family have moved from 1770 Field Crest Lane to 3120 Coronet Dr., Salt Lake City 17, Utah.

JAMES E. HALE has left Climax, Colo., for 2185 Bernard Way, Sacramento 22, Calif.

CHARLES R. HEATH lives at 2220 North 68th, Lincoln 5, Nebr.

HARLAN G. LANG has returned to the United States from Maracaibo, Venezuela. His address is 1255 McCormick St., Dubuque, Iowa.

ABDUL Q. MAJEED is chief petroleum engineer, Ministry of Mines and Industries, Kabul, Afghanistan.

1955

H. B. AYCARDO is now in England training as a refinery operator by Shell Oil Co. His address is Haven Hotel, Shell Haven, Standford-Le-Hope, Essex, England. He will return in two years as an operator at the new Shell refinery in Batangas, Philippines.

DANIEL GILBERT, formerly with Texas Petroleum Co. in Caracas, Venezuela, is now reservoir engineer for Midwest Oil Co., 1700 Broadway, Denver 2, Colo.

CLYDE R. INGELS, senior dynamics engineer for Convair, Pomona, Calif., lives at 1565 N. Laurel Ave., Upland, Calif.

DORRANCE PARKS BUNN, Jr. formerly of Port Arthur, Texas, lives at 5206 Grape Rd., Houston 35, Texas.

NORMAN F. VOTE is living at 585 N. 25th St., Grand Junction, Colo., where he is geological engineer with AEC.

D. P. WINSLOW has moved from Joplin, Mo., to 4250 Tulane, Long Beach 8, Calif.

1956

GEORGE W. ANDERSON is now metallurgical engineer in the Denver office of American Smelting & Refining Co. His home address is 7151 Raritan, Denver 21, Colo. Until quite recently Anderson was a first lieutenant, U. S. Army, 9th Aviation Company, Ft. Carson, Colo.

CALVIN A. DENNISON, Jr., formerly of Rangely, Colo., may be addressed c/o The California Co., 1045 Forest, Birmingham, Mich.

JOHN G. HILL, 4419 Manzanita Dr., San Jose 29, Calif., is metallurgical engineer for Advanced Technology Laboratories.

K. WILLIAM JEFFERS has moved from Seattle, Wash., to 513 Gibson Dr., S. W., Vienna, Va. His present position is geophysicist with the U. S. Coast and Geodetics Survey, Washington 25, D. C.

LAWRENCE M. JONES's new address is 207 E Street, Taft, Calif.

CHARLES A. KOHLHAAS, petroleum engineer for Mobil Oil Co., has been transferred from Colorado Springs, Colo., to 904 N. Thorp St., Hobbs, N. M.

BRUCE M. MILES is petroleum engineer for The Ohio Oil Co., Royal Bank Bldg., Calgary, Alberta. Before joining Ohio Oil, he was employed as a petroleum engineer with Tennessee Gas & Transmission Co. in High River, Alberta.

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CONTENTS—

DEPARTMENTS—

FRONT COVER—

Water-treating and CO_2 plant of Wellsville Oil Co. and Oil Recovery Corp. K. & S. Project, Washington County, Okla. The plant has a capacity of 30 tons of carbon dioxide per day and consumes about 600,000 cubic feet of natural gas. (For details, see article in this issue of The MINES Magazine entitled "ORCO Process Used on K. & S. Project" by J. P. Powell. Figure 3.)

TECHNICAL SOCIETIES and ASSOCIATIONS

Thermoadhesive Separation Process Displayed at Meeting

What was a research idea a few years ago is now a practical industrial separation process. Here, Robert Brison shows a working model of the thermoadhesive separation process which was displayed (Oct. 10-13) at the American Mining Congress Show in Las Vegas. Brison and other minerals beneficiation specialists at Battelle Memorial Institute developed the process for the International Salt Co., which is now using it to upgrade rock

salt mined under the city of Detroit. The process is expected to prove valuable in a number of other industrial applications.

In this process, material to be separated—rock salt and rock salt impurities—is heated (center) and fed onto a conveyor belt (right) coated with a heat-sensitive resin. The pure salt, which absorbs only a small part of the radiant heat, remains relatively cool and falls off the end of the belt into a catch bin. The impurities, however, because they absorb heat more readily, adhere momentarily to the belt, falling into another bin.

Drilling-Blasting Symposium Held Oct. 16-19 at Mines

Technological advances and innovations in production drilling for the mineral and construction industries were the topics of discussion Oct. 16-19 at the 10th Annual Drilling and Blasting Symposium.

The annual meeting is sponsored on a revolving basis by the Colorado School of Mines, Pennsylvania State University, and the University of Minnesota.

This year's meeting marked the first time that the symposium has been held at Mines. Chairman for the conference was Prof. Lute J. Parkinson, head of the Mining Engineering Department at Mines. Co-chairmen were Dr. Howard L. Hartman, head of mining at Penn State, and Prof. E. P. Pfleider, chief of the division of mineral engineering at Minnesota.

Included among speakers were nine professioal industrial engineers, eight educators and several guest speakers from abroad, all of whom presented papers dealing with advances in drilling equipment and methods.

(Editor's Note. Abstracts of these papers will be published in the December 1960 issue of The MINES Magazine.)

68 Technical Papers Presented at SPE Meeting

New methods of recovering oil by injection of alcohol and by injection of steam into underground oil reservoirs were explained to engineers attending the 35th Annual Fall Meeting of the Society of Petroleum Engineers of AIME in Denver, Colo., Oct. 2-5.

In all, some 20 technical papers on drilling and recovery of petroleum were read to the 3,000 persons attending the meeting from throughout the oil world. Sessions covered such subjects as: oil recovery processes, drilling, reservoir fluid flow mechanics, and production operations.

Two papers written by students and faculty members at the Colorado School of Mines were featured at the Rock Mechanics technical session. Mines papers were "Geological Aspects of Fracturing Reservoirs," by P. C. Badgley of the Colorado School of Mines, W. C. Pentilla of The Atlantic Refining Co. and J. K. Trimble of the Ohio Oil Co.; and "Fracture and Craters Produced in Sandstone by High Velocity Projectiles," by J. S. Rinehart and W. S. Maurer, Colorado School of Mines.

H. K. van Poollen, research engineer for the Ohio Oil Co., and special lecturer at the Colorado School of Mines, arranged the Rock Mechanics session and served as presiding chairman—along with T. O. H. Mattson of Texaco, Inc.

Earl M. Kipp will be the 1961 president of the Society, taking office in February, 1961. Kipp is special consultant—producing problems on the staff of the vice-president in charge of producing for Standard Oil Co. of California in San Francisco.

Kipp will replace 1960 President Wayne E. Glenn, production manager for Continental Oil Co.

Lloyd E. Elkins, a 1934 graduate of Mines and production research director for Pan American Petroleum Corp., Tulsa, will become president-elect in 1961 of the American Institute of Mining, Metallurgical and Petroleum Engineers (AIME). In 1962, he will assume the presidency. (See p. 39, Sept. 1960 issue of The MINES Magazine.)

Elkins was nominated for this position by the Society of Petroleum Engineers, one of the three constituent societies of AIME. He is a past president of the Society and has served as a member of the AIME Board (1949-1953) and as vice-president of AIME (1953-1958). AIME is composed of 36,000 member-engineers throughout the world.

Rocky Mountain Oil & Gas Convention in Denver

The 15th Annual Rocky Mountain Oil & Gas Assn. convention was held Oct. 19-21 in Denver, Colo. Some 700 representatives of the oil and gas industry heard such convention speakers as George H. Weber, eidtor of the *Oil & Gas Journal;* Dr. Arthur A. Smith, vice president of the First National Bank in Dallas, Texas; Kerryn King, vice president and assistant to the chairman of the board of directors of Texaco, Inc.; Michel T. Halbouty, independent oil producer of Houston, Tex., and Morgan J. Davis, president of Humble Oil & Refining Co., Houston, Texas.

AMC Show in Las Vegas, Nev. Successful and Outstanding

The 1960 Mining Show of the American Mining Congress held Oct. 10-13 in Las Vegas, Nev., was one of the largest, most successful and outstanding events in the minerals industry.

Convention sessions covered every phase of mining—from national mineral policies to the operating problems of mines, quarries and processing plants. Especially noteworthy was the mammoth exhibit by 200 of the nation's leading machinery manufacturers (chairmanned by Albert A. Seep) which featured the latest developments in mining machinery, equipment and supplies.

The mining industry will profit from the benefits of space-age electronic break-throughs, Henry Harnischfeger, president of Harnischfeger Corp. of Milwaukee, told delegates. Pointing out that the mining industry is undergoing unprecedented changes, Harnischfeger said these changes are being made necessary by multiplied requirements of free-world markets, diminishing ore deposits and inflationary costs.

"Mining equipment has historically been big and heavy and that's about all," he noted. "The machines have been largely a matter of hardware—nuts and bolts and so much steel plus enough power to rip up the overburden in sufficient quantities to get the job done.

"But today," he stressed, "these same types of machines have become precision tools made up of components which are, in at least some instances, as precision engineered as your electronic wrist watch."

He explained, for example, that a number of models of Harnischfeger mining shovels now are controlled almost completely by electronic components and thus actually are "sophisticated units which make use of the techniques of miniaturization and controlled atmosphere often thought of only in relation to missiles and electronic brains."

The two most important results of these electronic advancements, he said, are proving to be greatly increased production capacity and less maintenance or downtime.

ASM Tapes Inform Companies On Technical Subjects

Many nationally-known companies are subscribing to the new Information Searching Service now being offered by the American Society for Metals, Metals Park, Novelty, Ohio.

Every metals article from more than 900 of the world's leading technical magazines is being abstracted and coded on electronic tape—government reports, patents, books, etc. Every week nearly 700 abstracts are added to this magnetic tape "library"—more than 35,000 a year.

Subscribers to the Information Service tell ASM the subject in which they are interested. Then every two weeks ASM sends them abstracts of all the information that has just been published on this particular subject.

Some of the current searches ASM is doing are on the following subjects, defined precisely as the subscribers wish: refractory metals, explosive forming, rare earths, low temperature properties, die casting, powder processing, reactor fuel rods, shear forming.

CLASS NOTES

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1957

LOUIS M. BONNEFOND has moved from Silver Spring, Md. to 6107 Dunleer Ct., Washington, D. C., where he is metallurgist with the U. S. Atomic Energy Commission.

Lt. WILLIAM H. ISAACS, U. S. Army, is stationed at Camp Walters, Texas, where his address is Co. "A", 864th Engr. Bn.

ROB L. ROARK is living at 1731 Breckon Dr., Hobbs, N. M. He was formerly in the U. S. Marine Corps, Air Facility, Santa Ana, Calif.

Lt. TIMOTHY M. RYDER, U. S. Marine Corps officer, lives at 1742 W. Raymar, Santa Ana, Calif.

W. A. THOMPSON, III, engineer-partner of Petroleum Maintenance Co., has moved from Orange, Calif., to 2804 W. San Raiton Dr., Miraleste, Calif.

FRANCIS W. WOLEK, 10 Saran Ave., Bedford, Mass., is a graduate student at Harvard Business School.

1958

J. RANDALL BURKE received a Master's degree in geology from Stanford University last June. He worked on the Quebec northshore this past summer as a senior field geologist for the Quebec Dept. of Mines. His present address is Rm. 10411, Centennial Hall, University of Minnesota, Minneapolis 14, Minn.

JON F. HAMLIN has changed his mailing address from Lafayette, La., to Bay Drive, Sarasoto, Fla.

JOHN L. HOLT, formerly of Lakeport, N. H., is living at 3 Wilmont Ave., Washington, Pa.

NORMAN S. SMITH, 1371 Allen Park Dr., Salt Lake City, Utah, is level foreman, Bingham Canyon, Kennecott Copper Corp.

PAUL C. OPEKAR, who graduated as a petroleum refining engineer with highest honors in his class of 1958, is now associate research engineer for Continental Oil Co. His home address is 1205 E. Central Ave., Ponca City, Okla. Before joining Continental Oil he was technologist for Socony Mobil Oil Co. in Paulsboro, N. J.

RALPH Z. MARSH, engineer with the Martin Co., may be addressed at Box 119A, Star Route, Morrison, Colo.

ERNEST BERKMAN's new mailing address is Box 5374, El Paso, Texas.

EDWIN L. BEAUCHAMP, Jr., is doing production and development work for Esso Standard (Libya) Inc. His address is Esso Standard (Libya) Inc., P. O. Box 281, Benghazi, Libya.

1959

IVAN D. ALLRED, Jr., formerly of Casper, Wyo., is junior petroleum engineer for Tennessee Gas & Oil Co. His address is 438 Apache Trail, Shreveport, La.

JOHN T. CHANDLER, 1307 Elm St., Liberal, Kans., is petroleum engineer for United Producing Co., Inc.

CHARLES J. GUNTNER has moved from Golden, Colo., to 5871 Lee St., Arvada, Colo. He is metallurgist, National Bureau of Standards, Cryoganic Engineering Laboratory.

RICHARD L. HOUGH is now living at 746 N. 17th, San Jose, Calif.

2d/Lt. LARRY D. SIMPSON is stationed at Fort Lewis, Wash., 4th Engr. Battalion.

ROBERT E. VAN HARE's new mailing address is Route 1, Box 89, Platteville, Colo. Until recently Mr. Van Hare was living in Carlsbad, N. M., where he was junior mine engineer for International Mining & Chemical Corp.

Lt. RICHARD L. LEA's address is 63rd Engineer Company (PD), Columbus General Depot, U. S. Army, Columbus 15, Ohio. He was formerly with Engineering Consultants, Inc. in Denver.

HARRY B. HINKLE, now a student at the University of Texas, is living at 3304-B Tom Green, Austin, Texas.

Capt. RICHARD C. GERHARDT, 6116 Tomberg St., Dayton 24, Ohio, is project engineer, USAF-Wright Air Development Division, Wright-Patterson AFB, Ohio. His former position was research metallurgist at the Denver Research Institute.

KEITH GEORGE, project engineer for Western Contracting Corp., has moved from Vero Beach, Fla., to 3237 N. E. 11th St. Pompano Beach, Fla.

JOHN T. DONOHUE, 624 E. 22nd, Cheyenne, Wyo., is engineer technician for the Wyoming State Highway Dept.

1960

MOHAMMED HASSAN ALIEF, a graduate student at the University of Idaho, lives at 413 N. Jefferson, Moscow, Idaho.

GEORGE BEATTIE is development foreman at New Jersey Zinc Co.'s Flat Gap Mine. His address is Route 1, Box 4, Treadway, Tenn.

THOMAS M. CARROLL, III, spent the past three months in Jonesville, Mich., as a sales engineer with Franklin Supply Co. He is now in Denver employed as a civil engineer with Meuer-Serafini-Meuer, Engineers. His mailing address is 2051 S. Clayton, Denver, Colo. Tom says he really enjoyed the climate and beautiful scenes in Michigan (Chamber of Commerce, please note.)

I. W. ENGEL, metallurgical engineer with Bethlehem Steel Corp., Los Angeles, Calif., gives his temporary mailing address as 1831 E. Center, Denver, Colo.

JAMES R. HEAVENER, who until recently was a graduate student at Southern Methodist University, Dallas, Texas, may now be addressed at 2027 Arapahoe, Boulder, Colo.

WILLIAM N. HOUSTON has moved from one Denver suburb to another—from Arvada to 7465 W. Oregon Dr., Lakewood, Colo.

ROBERT B. HOFFMAN, 751 Layne Ct., #26, Palo Alto, Calif., will be a graduate student at Stanford University's Graduate School of Business for the next two years. He adds: "My best to you and continue the great job you're doing on the Magazine."

J. DONALD LONGENECKER is research assistant, Department of Industrial Management, Massachusetts Institute of Technology. His address is Apt. 3-B3, 1105 Lexington St., Waltham, Mass.

HARRY E. McCARTHY is working for Du Pont. His address is 223 B. Thomas Dr., Wilmington 6, Del.

KENNETH M. O'CONNELL, formerly of Colorado Springs, has moved to 510 Sevila Dr., Security, Colo.

(Continued on page 60)

MINERAL INDUSTRIES

(Continued from page 4)

$80 Million Beryllium Industry Foreseen

Bruce Odlum, president of Beryllium Resources, Inc., said recently the nation's scientists know now that beryllium minerals exist "in sufficient quantity" to free the United States from its "absolute dependence on foreign ore."

Speaking before the Utah Securities Dealers Association, Odlum said: "As a result of our work at Delta, Utah, in Alaska, elsewhere in the U. S. and in foreign countries, we know now that beryllium minerals occur in sufficient quantity to allow the industry to expand to a major industry."

Beryllium, Odlum said, "is taking on the insidious characteristics of 'glamour' that were attached to uranium and titanium a few years ago."

Beryllium is a high-heat resistant, strong metal used in satellites, missiles, heat sinks, nuclear reactors and for other uses.

Odlum pointed out that the structural uses for beryllium can be unlimited, because of the metal's strength-to-weight ratio. Its stiffness, he said, "is almost unbelievable. Its weight is negligible."

He pointed out that if a DC-7 were made of beryllium, it would weigh only about half what it weighs today.

Odlum said that "one can speculate and dream of a metal empire in beryllium which might seem as real, as large and as universal as the present day aluminum empire." But he pointed out that beryllium occurs in the earth only about as often as arsenic and is about one-seventh as abundant as tin.

He said that in relation to nuclear power plants, for example, "it is estimated that if England's gas-cooled reactor at Windscale performs as expected, it will create a demand in the United Kingdom for between 40 and 100 tons of beryllium annually. This is the equivalent of between 1,000 and 2,000 tons of beryl ore—the equivalent of nearly 20 per cent of all the beryllium ore consumed in the U. S. today."

Odlum pointed out that "continuous growth of the beryllium industry is clearly indicated—growth to date has doubled every other year. Today's $40-million industry will surely be tomorrow's $80-million industry."

He predicted that because of beryllium's composition and its position in the periodic table, it is likely to be replaced by a newer alloy.

Contribution of Nickel To Alloys Highlighted

The many unique contributions of nickel to alloy steels and stainless steels keynoted International Nickel Co.'s participation at the National Metal Exposition and Congress in Philadelphia, Oct. 17-21. The Inco exhibit featured nickel's role in these alloys.

The part nickel plays in carburizing steels was highlighted by the announcement of two new nickel-molybdenum steels, one an economical light duty type, and the other an extra heavy duty grade with improved processing characteristics. Both new steels combine the outstanding processing qualities and reliable service performance which are characteristic of the older members of the nickel-molybdenum family.

Aerial Mapping of Libya Completed by Fairchild

One of the most difficult and dangerous aerial mapping assignments has just been completed in Libya by Fairchild Aerial Surveys, Inc., a wholly-owned subsidiary of Fairchild Camera and Instrument Corp.

The survey, which covers 260,000 square miles of Southern Libya's barren, featurelesss, wasteland (equal to six New Yorks or one Texas) was completed in spite of blistering temperatures, violent dust storms and completely unreliable base maps.

Flying a specially modified Lockheed Lodestar at altitude ranging from 23,000′ to 25,000′, the Fairchild crew averaged about 3,000 square miles of photography a day. Aerial pictures were taken with two Fairchild mapping cameras, specially mounted and triggered simultaneously to provide "dihedral" coverage of an angle of 134°.

The dual oblique photographs were then transformed to equivalent vertical photography by correction at the base laboratory. With this wide-angle dihedral photography overcoming in some part the physical difficulties of operating, aerial coverage of the area was achieved in less than half the time required for normal vertical aerial photography.

The project was undertaken on a non-exclusive basis for nine United States and foreign oil companies engaged in active exploration in this remote area. As the first reliable information of Libya's interior, it will serve many purposes. Of vital interest in the exploration field is the value of the aerial photograph for photo geological study.

From interpretation of the air photography, oil exploration experts will be able to evaluate the terrain and select concession areas. Equally important is the value of the photography as graphic presentation of physical detail of the virtually unexplored terrain. With this information, access routes, camp locations and physical advantages can be analyzed along the best possible lines for the immediate development of this Southern Libya hinterland.

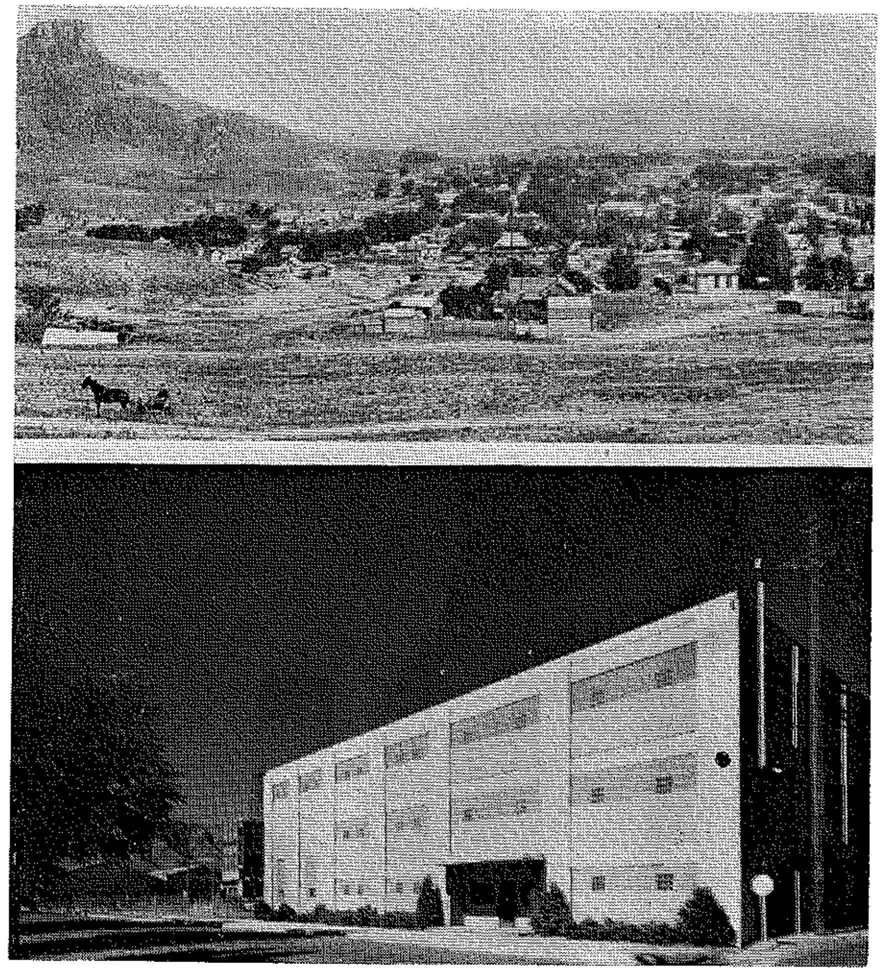
Magnetometer Survey In Northeastern Alaska

An airborne magnetometer survey of a 21,000 square mile area in northeastern Alaska was completed this summer by Fairchild Aerial Surveys.

The survey, performed for five U. S. oil companies, was designed to give a quick overall picture of the important and significant geologic features of this relatively unexplored area.

(Continued on page 19)

"COORS U. S. A." TRADEMARK Well Established in Every Chemical Laboratory Throughout Country



▼Top picture, foreground, shows the Coors Porcelain Company in the "horse-and-buggy days." In the lower picture is the Coors plant as it looks today.

During the past 50 years the name "Coors, U.S.A."—trade mark of the Coors Porcelain Co.—became well established. Coors products are used, to some extent, in every chemical laboratory throughout the country. In addition, the high alumina ceramics, more recently introduced, have been used in the petroleum industry for pump plungers, rotary seals and other applications where corrosion and abrasion have been problems.

Porcelain Imported From Europe

Before World War I all laboratory porcelain was imported from Europe. The war cut off this supply in 1914, and chemists in this country could not obtain porcelain with which to perform analyses vital to the processing of materials of all types. The original pottery, now the Coors Porcelain Co., was asked by the government, along with other potteries, to produce chemical ware.

In 1915 satisfactory pieces were made and became the standard. Since World War I the Coors Porcelain Co. has been the principal supplier and today is the largest laboratory porcelain factory in the world. Also, Coors is one of the largest manufacturers of ceramic tubes for laboratory and industrial use.

Again in a time of crisis during World War II, Coors was called upon to produce special insulators of a superior type of electrical porcelain for a very important government installation. Many thousand insulators were made allowing continuous production of a most critical war material.

Ceramics in New Fields

Since World War II new ceramics are becoming successful in new fields. Some of these new materials are made mainly of aluminum oxide. In the growing Electronic industry, alumina provides higher strength, increases allowable temperature limits and possesses desirable electrical properties. As noted before, typical mechanical applications include pump parts, such as plungers and cylinder liners, check valves, and seals where alumina can provide mechanical strength and superior resistance to corrosion and abrasion. Special metering orifices and nozzles have gained acceptance in the petroleum industry.

Balls and Linings Internationally Known

Coors aluminum oxide ceramic grinding balls and mill linings have become internationally known. This is because their great hardness and high specific gravity enable the users to increase greatly their grinding capacities with the same equipment.

Coors has greatly expanded its Research and Development Department and promises newer materials for the future. Beryllium oxide ceramic, now in regular production is one of these newer compositions—an excellent electrical insulator, yet it conducts heat better than yellow brass! This material plus newer ones having even more unusual properties will contribute to the changing world of the future.

MINERAL INDUSTRIES

(Continued from page 16)

90 Million Barrels of Oil May Be Recovered in Future From Existing U. S. Fields

"The future recovery from existing oil fields in the United States may be as much as 90 billion barrels," said Paul D. Torrey, University of Texas, department of petroleum engineering, in a report recently presented to the secondary recovery and pressure maintenance committee of the Interstate Oil Compact Commission. In presenting his report on the "Evaluation of United States Oil Resources as of Jan. 1, 1960," Mr. Torrey pointed out that the application of known improved recovery methods would undoubtedly add more than 44 billion barrels to our presently proven reserves of more than 30 billion barrels and that the additional oil would come by more experience in those states in which these improved methods have not been utilized.

This survey indicates that 14,822,000,000 barrels can be recovered in addition to the primary reserves by the application of conventional gas and water injection under presently existing economic conditions.

Mr. Torrey reviewed the present status of distribution of world oil reserves as of 1959 and compared them to the situation as existed in 1946. During this period, although the United States has increased its proven reserves by more than 50 per cent, all of the other oil producing countries have increased their reserves by many times as much as the United States has; and as a result, the United States has dropped from a rank of first to fourth in regard to proved reserves.

In conclusion Mr. Torrey pointed out that the United States has an abundance of oil and there are available means of recovering even greater amounts. Only the actual discovery of oil reserves outranks the development and application of fluid injection methods in contributing additional reserves in the United States. In many states it is by far the most important single factor in maintaining the oil industry in these states.

New Nickel Mine

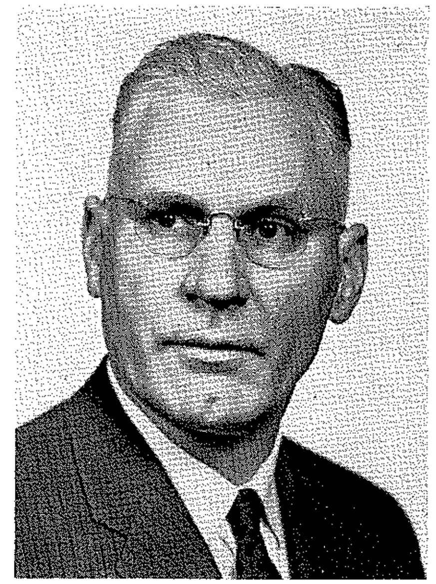
As part of a long-range program to maintain the continuity of its extensive operations in the Sudbury District of Ontario, International Nickel is developing a new open pit mine which is scheduled to go into production in the latter part of 1961.

(Continued on page 92)

Dry Hole Money . . .

The Fair Contribution*

By JOHN H. FOLKS



JOHN H. FOLKS

There are certain features concerning dry hole contributions under serious consideration today which should result in more uniform thinking. If accepted, these would serve to curtail the greed which exists in all of us, so that more advantageous contributions may be granted and received with the end result that more deals will be consummated.

This is being made in the belief that the "sharp trading" days are rapidly vanishing. There appears everywhere a clearly defined trend that the vast majority of management wants to bear the true burden in acreage evaluation.

Under consideration for use in arriving at fair contributions are six "yardsticks." The usage of these and the inequities involved in three traditional committments are discussed here.

* Presented as an address before the American Association of Petroleum Landmen at San Antonio, Texas, April 26, 1957, and published in The Petroleum Engineer, July 1957.

1. Circle Method

This is frequently referred to as the Proximity System. It consists of a series of circles, the first being of sufficient size to embrace one drillsite; three additional ones exist, each covering an area two drillsites greater in diameter than the former. The contribution to be borne by any tract of drillsite size which is traversed by more than one circle is determined by that circle which includes the greater portion of the tract.

This method takes no cognizance of structure, faults or any other technical data; neither is any credit given for any acreage lying outside the scope of the largest circle. The amount of money to be borne by each tract is determined by its geographical distance from the proposed location (Fig. 1).

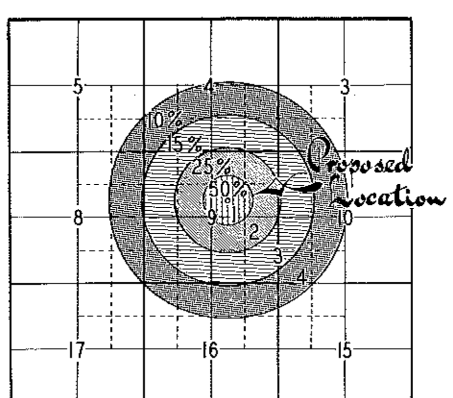
In applying this method, 50 percent of the dry hole cost is charged to the owner of the well simply because of the well's ownership. It should be pointed out that this is somewhat arbitrary, since the area covered by the inner circle includes only one drillsite, the assessment should be the national pool dry hole risk ratio, which approximates only 30 percent. The risk of drilling a dry offset to the first well is, of course, the reason for assessing a larger proportionate part of the drilling cost to the owner of the tract on which the first well is located.

The owners of the eight tracts (quarter quarter sections in this instance) which tracts are embraced by the second circle, bear 25 percent of the total dry hole risk. Each drillsite, therefore, bears $3000 dry hole money.

The owners of all drillsites within the third circle bear 15 percent of the cost, a total of $14,400. Within the circle there are 12 tracts which participate equally in the cost so that each tract bears $1200.

Ten percent ($9600) is borne by the owners within the fourth circle. This circle contains 16 participating tracts and each tract, therefore, bears $600.

As is generally the case, this system compels the drilling party to pay or bear that part attributable to any tract which, either because of being unleased or because its lessee refuses to support, does not bear its burden.



BURDEN OF SHARING
$96,000 DRY HOLE COST:

Tract No. 1	$48,000
Tract No. 2	3,000
Tract No. 3	1,200
Tract No. 4	600

▼Figure 1. Circle method of computation, often referred to as the proximity system in determining dry hole contributions. This system does not consider structure, faults or other technical data.

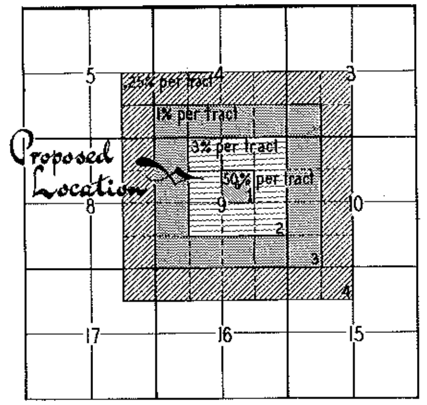
THE AUTHOR

Folks, a native of Oklahoma, received an AB degree from Southwestern State, an LLB from the University of Oklahoma, and went to work for The Carter Oil Co. more than 20 years ago. He has been Central Area landman for Kansas, Oklahoma, North Arkansas, Missouri and Nebraska since 1951.

Folks has memberships in the American Association of Petroleum Landmen, the Oklahoma Landmen's Association, Oklahoma State Bar, and the Mid-Continent Oil and Gas Association.

His service to industry includes heading a committee to produce the Model Form Operating Agreement from 1952-56 and liaison representative to the Legal Committee in 1955-56. These committees produced the Model Form Operating Agreement now widely used throughout the nation. For the past three years he has served as vice-chairman of the Public Information Committee and last year as third vice president of the American Association of Petroleum Landmen. He now serves as national chairman of the AAPL Unit Procedure Manual Committee.

Folks has contributed to industry publications on subjects involving unit operations and contributions, and has lectured on these subjects at Land Institutes at the Southwestern Legal Foundation and the University of Oklahoma.



BURDEN OF SHARING
$96,000 DRY HOLE COST:

Tract 1	$48,000
Tract 2	3,000
Tract 3	970
Tract 4	250

▼Figure 2. Square method of computation is another form of the proximity system, and like the circle method, does not consider structure or technical data.

2. Square System

This again is a proximity method and in principle is the same as the circle method. This system consists of a series of four square rectangles (Fig. 2). The first will embrace only one drillsite. Each additional one will be two drillsites greater in width than the former. This "yardstick" is more easily employed than the circle method since no tract is traversed by more than one rectangle.

The owner of the drillsite bears 50 percent of the cost plus, of course, that part attributable to any tract which does not bear its part. Each of the eight tracts within the second rectangle bears 3 percent of the cost. Those within the third rectangle each bear 1 percent and those within the fourth rectangle 25 percent.

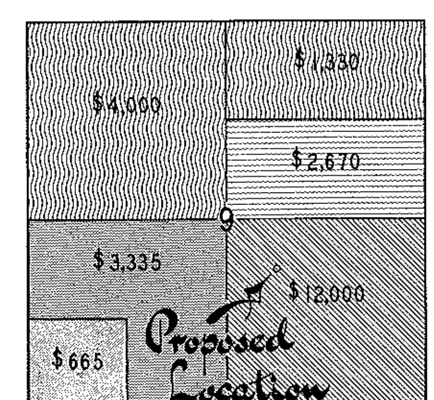
A mechanical tool can easily be made and employed for using the square system as a basis of computation. On any transparent material place light colored lines so that quarter quarter sections can be outlined. A scale of two inches to the mile is quite practical. Bold lines should be drawn to delineate the four rectangles. By marking in one's holdings on a work sheet plat of the same scale as the tool and then by placing the tool over the plat, the appropriate percent of cost for each tract will be instantly apparent. The total contribution will consist of the sum total of the percentages multiplied by the total dry hole cost.

Those technical considerations normally prevalent in arriving at a fair contribution are in no manner considered. The question of how much or how little acreage the contributing party has outside the square is unimportant. Those objections which prevail both in the circle and square methods quite generally prevent a literal application of either. While strict application will often result in worthless acreage bearing a share of the cost which the usage of available technical information would prevent, by the converse, some application of either will normally result in a contribution being made which, because of the total absence of technical information, could not otherwise be granted.

3. Adjacent Quarter Section System

A method which some contend to be fair, particulrly in areas of little control and universally small fields as exist in Kansas, Eastern Oklahoma, Illinois, Indiana, and Kentucky, is the "adjacent quarter section system."

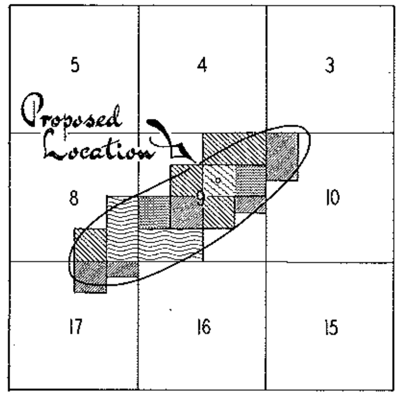
This method requires the owners of the well and the quarter section on which the well is located to bear ½ the dry hole cost. Each of the three offsetting quarter sections bear 1/6. The owner of the inside 80-acre tract in each quarter section pays twice that of the outside 80-acre owner. In event the owner of the well owns less than the quarter section on which the well is located, the owner bears ⅓ of the cost for the well's ownership and the owner or owners of the remaining portions of the quarter bear the 1/6 in proportion as they own in the remainder of the drillsite quarter. Referring to the illustration (Fig. 3) it is observed that Able plans to drill a well, the dry hole cost of which is $24,000. Able owns the



BURDEN OF SHARING
$24,000 DRY HOLE COST:

ABLE	50%	$12,000
BAKER	11%	2,670
CHARLEY	22%	5,330
DOG	15%	3,335
LOVE	2%	665

▼Figure 3. Adjacent quarter sections method is considered by many as a "fair system" in areas of small fields as exist in Kansas, Eastern Oklahoma, Illinois, Indiana, and Kentucky.



BURDEN OF SHARING
$100,000 DRY HOLE COST:

	COST PARTICIPATION		PERCENTAGE OWNERSHIP
ABLE	50%	$50,000	Not Applicable
ABLE	6%	6,500	13%
BAKER	16%	16,100	32%
CHARLEY	15%	14,500	29%
DOG	13%	12,900	26%

▾ Figure 4. Proportionate ownership method is converse in theory from the circle and square systems, as proximity is entirely disregarded. The contributing party is the sole judge of limits of the producing structure.

SE/4 Section 9 and will, therefore, bear $12,000 of the cost. Baker owns the S½ NE/4 Section 9 and since this is an inside 80-acre tract, Baker will bear ⅔ of the 1/6 of the cost, or $2670. Charley will contribute 1/6 for the NW/4 and ⅓ of 1/6 for the N½ NE/4 Section 9, a total of $5330. Dog will bear $2670 for the N½ SW/4 and $665 for the SE SW Section 9, a total of $3335. Love will bear ½ of ⅓ of 1/6 for the SW SW, a total of $665.

Inasmuch as the adjacent quarter section method is one of proximity, all of the objections prevailing against usage of the circle and square systems may likewise be asserted against employing this system.

4. Proportionate Part of Structure or Anticipated Producing Area

This method is the complete converse to the circle and square systems. Proximity is totally disregarded. Technical data determine wholly the contribution. The contributing party is the sole judge as to the geographical confines of the producing structure. He may select only the top closing contour for an outline or that one which he believes will define the oil/water contact.

He who insists upon using this "yardstick" will frequently invite the soliciting party to show evidence of the ultimate producing area as a prerequisite to a contribution, or he may simply advise that he, or his company, does not have evidence of a trap and hence cannot support with cash.

Once, however, the contributing party has concluded as to the size of the ultimate producing area, he determines the contribution by first deducting 50 percent of the dry hole cost which is to be borne by the owner of the well and drillsite. (Fig. 4.) He then determines the total remaining acreage within the producing area and the percentage thereof which he owns. His percentage is multiplied by ½ the drilling cost and the result is the correct contribution.

Once again should any owner refuse to support, his interest is borne by the drilling party.

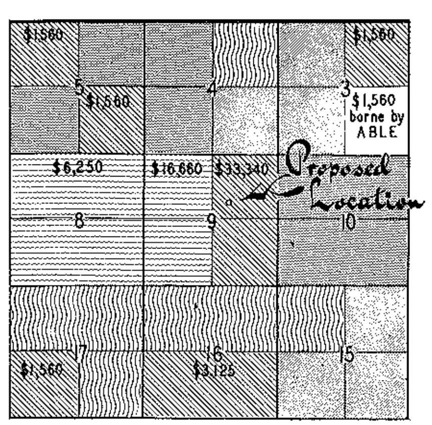
The folly of this system seems to lie in its failure to recognize proximity. Failure to do so denies the existence of that well-established dry hole risk in pool well development. Obviously those owners of tracts on the edge, such as Able, should not be required to bear the risk of two intervening wells while Charley bears only one, unless the edge owner is to stand initially less of the dry hole cost.

5. The Nine Section Pattern

In areas for which gas is the primary objective and 640-acre spacing is universal and where little technical control exists, such as in Texas and Oklahoma Panhandles and in Southwestern Kansas, a feeling is shared by some that the owner of a well and the 640-acre drillsite should bear ½ the dry hole cost and the owners of the adjacent eight sections should bear the other half. If the drillsite section be owned by more than the drilling company, each of the owners including the drilling company pays in the ratio that his ownership bears to the section times ⅓ the cost of the well. The owner of the well will bear 1/6 of the cost plus the additional cost chargeable to his lease ownership. The 1/6 cost to the owner is charged because of the possibility that the well may be completed as a producer of oil, in which event the drilling company would own all of the well. Each owner within the drillsite section participates in an agreement which permits him to share in proportion as he owns in the section in any gas well that may be completed upon reimbursement for a like amount of the total cost of drilling and completing a well.

Since only one well will be drilled in each offsetting section, there is no advantage to being on the inside in the offsetting sections and, therefore, the owners in each offsetting section pay in proportion as they own in the section.

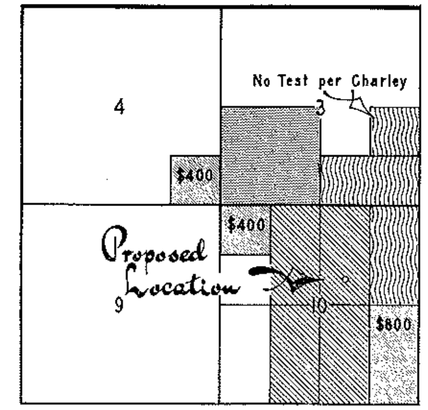
In the illustration (Fig. 5), Able bears 1/6 of the cost because of ownership of the well plus ½ of ⅓ for ownership of the E½ Section 9. The two components are expressed as "⅔ of ½." In addition, Able bears 1/32 of ½ for each quarter section it owns in the eight offsetting sections, a total of 6/32 of ½, and, as is always the case, the drilling company must carry the open acreage, so Able bears an additional 1/32 of ½ for the SE/4 Section 3



BURDEN OF SHARING
$100,000 DRY HOLE COST:

ABLE	⅔ x ½ + 6/32 x ½ + 1/32 x ½	$44,260
BAKER	⅓ x ½ + ⅛ x ½	22,960
CHARLEY	7/32 x ½	10,920
DOG	¼ x ½	12,500
LOVE	6/32 x ½	9,360

▾ Figure 5. Nine section pattern method is used in natural gas objective areas and 640-acre spacing areas and where little technical control exists, such as in Texas and Oklahoma Panhandles and in Southwestern Kansas.



BURDEN OF SHARING
$24,000 DRY HOLE COST:

LOVE	$10/Acre	$ 1,600
CHARLEY (for acreage evaluated)	$15/Acre	$ 2,400
DOG	Gives Nothing	—
ABLE (Drilling Company)		$17,600

▾ Figure 6. Per acre basis for figuring dry hole contributions is perhaps the most widely used method. An operator arbitrarily agrees to pay a specified sum for each acre that is evaluated.

which is unleased. In all, Able bears $44,260.

Baker contributes ½ of ⅓ for the W½ Section 9 plus ⅛ of ½ for Section 8, a total cash contribution of $22,960 for which Baker gets the right to participate 50 percent in a completed gas well at cost.

Each of the other owners in the offsetting sections pays 1/32 of ½ for each quarter section of ownership.

6. Per Acre Basis

This, bye and large, seems to be one of the most widely used of all the "yardsticks." An operator arbitrarily agrees to pay a specified sum for each acre that is evaluated. This sum may be set on a tract-to-tract basis, or for all acreage in a township, county, or geological province. The contributing party, of course, decides the amount of acreage that is being evaluated. In the minds of many there seems to be concern that only acreage which is directly offset can be considered as evaluated. Perhaps a much fairer approach is to first exploit all known technical data in possession of the contributing party, and if this does not define specific limits, to then employ one of the proximity methods discussed earlier.

In Fig. 6, Love considers all of its acreage as being tested and contributes $10 per acre, but concludes that the NE SE of Section 3 is not being tested. Dog follows traditional thinking and declines all support since it has no direct offsetting acreage.

Many of the companies that use the per acre basis first determine a gross sum and then convert the sum into a per-foot-of-drilling unit. The ease with which this method can be applied, coupled with the emphasis which it places on pecuniary benefit to the contributing party, probably accounts for its widespread usage.

Traditional Contribution Inequities

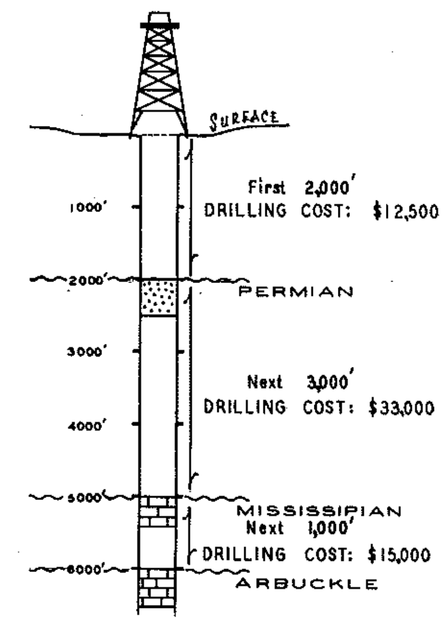
There are several inequities in the three traditional contributions to be considered. In Fig. 7 Good Company proposes to drill a test of sufficient depth to test the Arbuckle, unless production, 6000 ft., granite or impenetrable substances be encountered at a lesser depth, and in support therefor receives three traditional commitments:

(A) *Fixed sum dry hole contribution.* Able commits $10,000 provided the well is abandoned as a dry hole 120 days from commencement of drilling. This type of contribution makes possible situations as follows:

1. Good drills to a depth of 3000 ft. and hits a granite boulder, following which the well is abandoned. Although neither company anticipated this occurrence, Able is required to pay the full $10,000. This sum of money represents approximately 70 percent of the expenditure incurred by Good, although at the inception both companies intended that Able bear only 16 percent of it. Obviously, alertness on the part of Able would have averted this embarrassing occurrence.

2. Good drills to the total depth and finds the Arbuckle dry. Although the Mississippian was of poor quality, Good feels there is a chance of making a small well which would return more than enough to pay the $28,000 required for completing the well. Good requests Able to convert its dry hole money to bottom-hole money in order that pipe may be run. Able concludes that, while undoubtedly Good has the situation correctly analyzed with regard to profits, nevertheless, it must not violate tradition and establish a policy which will open the door to argument on every dry hole commitment in which a well of questionable capabilities is to be completed. Good concludes its profit picture would be better to accept the dry hole contribution and forego the opportunity of possibly completing a small well which might lead to more development.

3. Good drills to a total depth and incurs an expenditure of $60,000. At a depth of 2000 ft. an excellent Permian show is had. Good completes the well as a producer and then asks Able for the sum of $6600 being the prorata drilling cost below the Permian. Able replies that its commitment for a contribution was predicated on the well being abandoned as a dry hole. Clearly, the intent of the parties



OPERATOR :
Good Co.

OBJECTIVE :
Arbuckle or
6000 ft. or
Production or
Granite

COST :
Dry Hole $60,000
Completed $88,000

CONTRIBUTIONS :

Able	$10,000 DHM
Baker	$1.00 per ft. DHM
Charley	160 acres

▾ Figure 7. Proposed well, as shown here, points to inequities in the three traditional contribution methods.

was that Able share in approximately 16 percent of the drilling cost below the Permian. Yet, because of tradition which prevented appropriate negotiation of true intent, Able bears none of the $6600 which it justly owes.

(B) *Stipulated sum per foot of drilling.* The flexibility afforded by this method tends to minimize some of the inequities which exist in the fixed dry hole contribution.

1. In event Good encounters granite at a depth lesser than the objective and is forced to abandon, the per foot sum will result in Able paying more nearly in proportion as was intended by the parties than in the case of the fixed sum.

2. Should Good complete in the Mississippian or Permian, and Baker desire to pay for the deeper drilling for which it has received benefit, the per foot of drilling establishes a satisfactory sum to both parties which can be consummated with a minimum of negotiation.

3. Should Good drill to the agreed upon stop depth of 6000 ft. without having reached the Arbuckle, the per foot formula makes for ease in extending the depth although increasing the per foot price is normally at this point in order.

4. Should Good complete a producer of gas in the Permian or Mississippian and the contribution letter contain a "back-in provision into such gas well at cost of drilling to and completing in the productive formation," the per foot basis of cost lends itself to easy negotiation should Baker desire to pay in addition to the back-in cost, for the nonproductive drilling below the formation in which the well is completed.

(C) *Assignment of all rights in leaseholds or portions thereof.* Although in the case of a cash contribution most of the advantage is with the contributing company, such is not the case in the matter of acreage contributions. This type of contribution distinctly differs in that the contributing company assigns the acreage whether the well be completed as a dry hole or producer. The traditional agreement gives assignee many rights to which there is much question as to whether he is so entitled, some of which are:

1. In event Good finds the Permian productive, it may complete the well and under the traditional agreement receive an assignment of all rights. Clearly, the Mississippian and Arbuckle have not been tested as was the intent of the parties. Some companies would insert a proviso which would reserve all rights below those tested. In the event of such an attempt, the technique to be employed in each instance must be thoroughly considered. In areas of gentle relief and thick formations, such as those of thick Mississippian which contain possible productive horizons throughout the formation, Good can more nearly accomplish equity by reserving rights below the depth drilled, otherwise a mere penetration of the formation may result in Charley being assigned hundreds of feet of potential production on which there has been no test. On the other hand, in areas of steep dip a reservation of rights below the depth drilled may result in severe complications. In one case involving steep dip, Charley assigned rights down to 4000 ft. to Good. Later development demonstrated that production on the same lease could be had from one portion above 4000 ft. and on another portion below 4000 ft. Yet, all the production was from the same reservoir. In this case, the court held that Good owned all the reservoir and Charley was forced to shut-in wells which were taking production from it. Charley in the future will, of course, avert such unfortunate occurrences by assigning to the base of the deepest formation tested.

2. Equity in rental obligations. In those cases in which Charley reserves deep rights, however expressed, fairness also dictates a proviso which causes each company to share in rental payments, Normally the assigning company continues to pay delay rentals since it has necessary records already set up.

Picking the Method

Of the listed six "yardsticks," namely: The circular method, the square system, adjacent quarter section, proportionate part of the structure, nine section pattern, and the per acre basis, none can normally be used in itself, but a consideration of those appropriate will give consolation to him who in his heart desires to be absolutely fair and a like application by the recipients will assure him that the contributing party has been abundantly fair.

Management demands that we stray from the paths of our fathers urging that we use all the "yardsticks" coupled with any others which may become known to us. Management is entitled to protection from the inequities which are contained in normal contribution letters. Keen foresight and negotiating ability, properly utilized with a keen sense of fairness will truly bring about the fulfillment of a law which precedes our industry by many decades—"Do unto others as you would have them do unto you."

GAS WELL Contributions**

Certain features which should result in more uniform thinking within the industry concerning contribution to gas wells which are drilled in areas capable of producing gas only are under consideration. If accepted these should serve to promote cooperation by all parties concerned so that more advantageous contributions may be granted and received with the end result that more wells will be drilled in search of gas.

In provinces of 640-acre spacing for gas many members of the industry feel that the drillsite section only should pay one-half the dry-hole cost of a well and that the owners of the surrounding eight sections should pay the remainder. For wells costing $100,000 or less there seems to be agreement among many parties concerned that this is a fair approach.

In areas of sparse specific control in which drilling is more or less random and in which the dry-hole cost exceeds $100,000, the nine-section formula creates a burden of such magnitude as to become impractical. In such cases the burden must be borne by owners within a larger geographical area. Employing the "Two-Section Offset Principle" distributes the cost over a twenty-five-section area and serves to reduce the burden for all.

By application of this principle the owners of the drillsite section bear one-third of the dry-hole cost of the well. This is required since the risk of drilling a producer of gas as an offset to a producing well statistically approaches thirty-three per cent. The fact that gas wells are drilled at wider intervals than oil causes the pool development risk to be higher for gas drilling than for oil.

** Mr. Folks has written this additional information on "Gas Well Contributions" especially for the 25th Annual Petroleum Issue (November 1960) of The MINES Magazine.

Naturally all owners within a drillsite section may not desire to participate in drilling a wildcat. The lack of adequate acreage in the area, the desire to wait for development from nearby production, or to wait for imminent expirations of leases owned by others are all adequate reasons to forego participation. One gets something for nothing to the extent that one does not pay his true share in the drillsite.

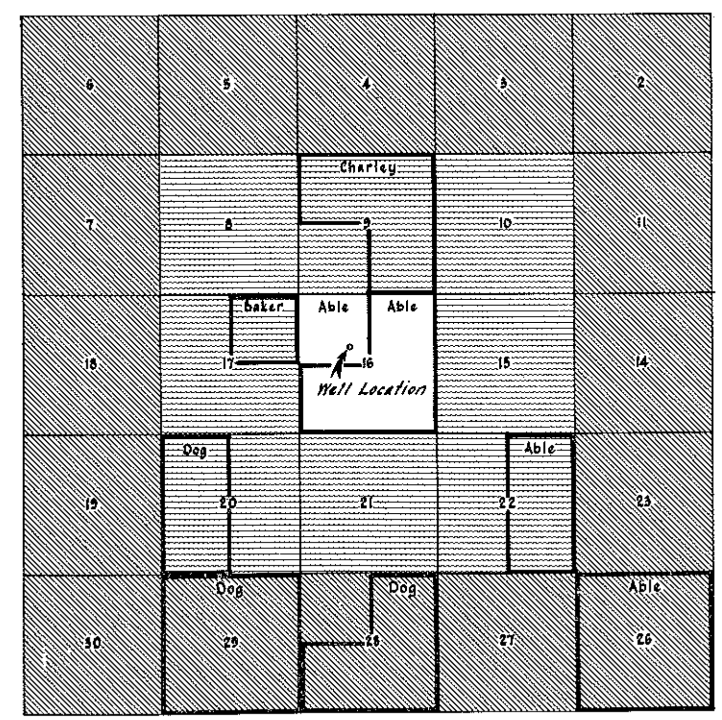
Those who do not desire to pay their full participating share may find paying 50 percent or something greater in the form of dry-hole money an approach that will facilitate consummation of the project. Occasionally an inequity of the type caused by an owner in the drillsite failing to participate can be adjusted by effecting an exchange of properties. The drilling party may assign to the non-drilling party acreage in sections adjacent to the drillsite and then the non-drilling party may contribute dry-hole money in accordance with the "Two-Section Offset Principle."

Under this formula the owners of leases in the first and second sections offsetting the drillsite pay two-thirds of the dry-hole cost. Inasmuch as the hazard of getting production on the second drillsite removed from the initial well is several times as great as the hazard on the first offset, the owners within the second tier of sections pay only one-third as much as those in the first tier. The owners of the first tier pay one-half of the dry-hole cost while those of the second tier pay one-sixth of the cost. The hazard of getting production in all of the sections within the second tier of sections is admittedly greater than the ratio of one to three for production in the first tier of sections. The geological information that has tangible value to the owners of the second tier of sections serves to adjust any inequity created by virtue of their overpayment. As is the case in the nine-section approach, whether an owner be on the inside (nearest the well) or outside in the section is not material since only one well will be drilled in each section.

By referring to the illustration one observes that the dry-hole cost of a $300,000 well is borne $100,000 by the owner of the drillsite section, $150,000 by the owners of the eight sections surrounding the drillsite, and $50,000 by the owners of leases in the second tier of sections removed from the well. Each owner determines the proportion of each category he owns and shares accordingly. The "Two-Section Offset Principle" allocates the total cost of the well to a total of 16,000 acres and in so doing, spread the burden to bearable proportions.

Generous application of this method will permit the drilling of many deep and expensive wildcats that otherwise will never be drilled.

SHARING $300,000 DRY HOLE COST



Owners of these 16 Sections pay 1/6 cost $50,000.00
Each Section bears .... $ 3,125.00

Owners of these 8 Sections pay 1/2 cost $150,000.00
Each Section bears .... $ 18,750.00

Drill Site — Owners pay 1/3 cost $100,000.00

ABLE assigns NE 1/4 Section 17 for NW 1/4 Section 15 - Then assumes-
Drill Site $100,000.00
E 1/2 Section 22 (1/2 x 1/8 x 1/2 of $300,000) .... $ 9,375.00
Section 26 (1/16 x 1/6 of $300,000) .... $ 3,125.00
ABLE pays $112,500.00

BAKER .... $ 4,687.50
NE 1/4 Section 17 (1/4 x 1/8 x 1/2 of $300,000)

CHARLEY $14,062.50
N 1/2; SE 1/4 Section 9 (3/4 of 1/8 of 1/2 of $300,000)

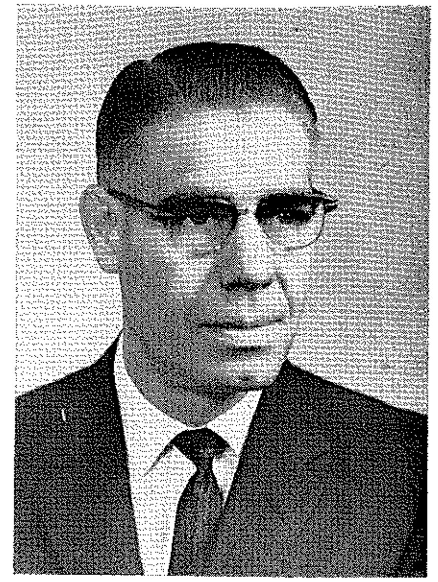
DOG
Section 29 (1/16 of 1/6 of $300,000) .... $ 3,125.00
S 1/2; NE 1/4 Section 28 (3/4 of 1/16 of 1/6 of $300,000) .... $ 2,343.75
W 1/2 Section 20 (1/2 of 1/16 of 1/6 of $300,000) .... $ 1,562.50
DOG pays .... $ 7,031.25

▼ Figure 8. Sharing $300,000 dry hole cost.

Unusual Design

Results In Low Cost Large Volume Water Supply for Flood at Sholem Alechem

By W. C. PEARSON, '39, and
W. A. VAN HOOK, '35



W. C. PEARSON, '39

W. A. VAN HOOK, '35

Introduction

Engineering planning of the Sholem Alechem Fault Block "A" Waterflood indicated a water supply of over 100 million barrels would be necessary. Total water to be handled by surface injection equipment was estimated at 150 to 300 million barrels depending on the degree of recycling required to achieve floodout of the Sims Sands. The initial requirement of 45,000 BWPD combined with a water compatibility problem involved unusual features in the water supply system designed, the subject of this paper.

The Fault Block "A" Sims Sand Unit of the Sholem Alechem Field is in Stephens County, Okla., 70 miles south of Oklahoma City. It is the largest of the five major fault blocks in the Sholem Alechem Field and comprises 245 wells on a 10-acre spacing pattern. The average depth of the Sims Sand is 4900 feet and the effective pay zone ranges from 60 to 230 feet in thickness. Two major zones are being flooded concurrently in the Sims Sand, the upper called the First Sims and the lower member called the Second Sims. Each of these zones has a gas cap in both domes; however, the Second Sims gas cap in the west dome is not of significant size. This waterflood is on a peripheral pattern, except for an area of poor sand development on the southwest flank which is being handled with a modified line drive.

Figure I is a map of the Unit showing injection well locations, injection plant sites and gas cap boundaries. The solid lines labeled C-1 are the gas cap boundaries for the Second Sims gas caps. The First Sims pinches out near the southern edges of the gas caps although the Second Sims extends over the entire fault block. Also on this map are shown the locations of a Pontotoc Sand salt water disposal well on the west side plus two wells being used for injection of produced water into the large east side gas caps of the Sims Sand.

A major fault in the northwest portion of the Unit Area and the large gas caps on the east dome provide a logical division of the Unit into three flooding areas. Each is served by separate injection facilities. A fourth injection plant is now being installed to handle increased water injection into the large gas caps. Control of the gas caps through stabilization by water injection has been discussed in a previous paper[1] which was presented at the 1959 Fall Meeting of the Society of Petroleum Engineers. This paper will be published in the near future in the *Journal of Petroleum Technology*.

Water Supply Reservoir

The best source for the large volume of water needed was considered to be the Pontotoc Sand found at a depth of approximately 1900 feet. The Pontotoc formation is a blanket sand of Pennsylvanian age ranging from 200 to 300 feet in thickness in this vicinity. Drill stem test data indicated the sand had adequate producing capacity but the regional extent of the reservoir was not well known. Samples of Pontotoc water were tested on Sims Sand cores saturated with reservoir oil and Sims Sand water in Pan American's research laboratory. These tests indicated good compatibility provided the Pontotoc water was not exposed to air. After exposure to air, mixing of Pontotoc and Sims waters resulted in severe plugging of the oil saturated core samples. Further testing indicated corrosion would be only a minor problem.

The laboratory tests showed a closed water supply system would be necessary. This work also demonstrated that reinjection of produced water into the Sims oil sand would not be practical because expensive filtering and treating would be necessary. This problem, combined with some uncertainty as to the extent of the water supply sand, led to the decision to return produced water to the Pontotoc Sand rather than to attempt to reinject it into the Sims Sand which was being waterflooded.

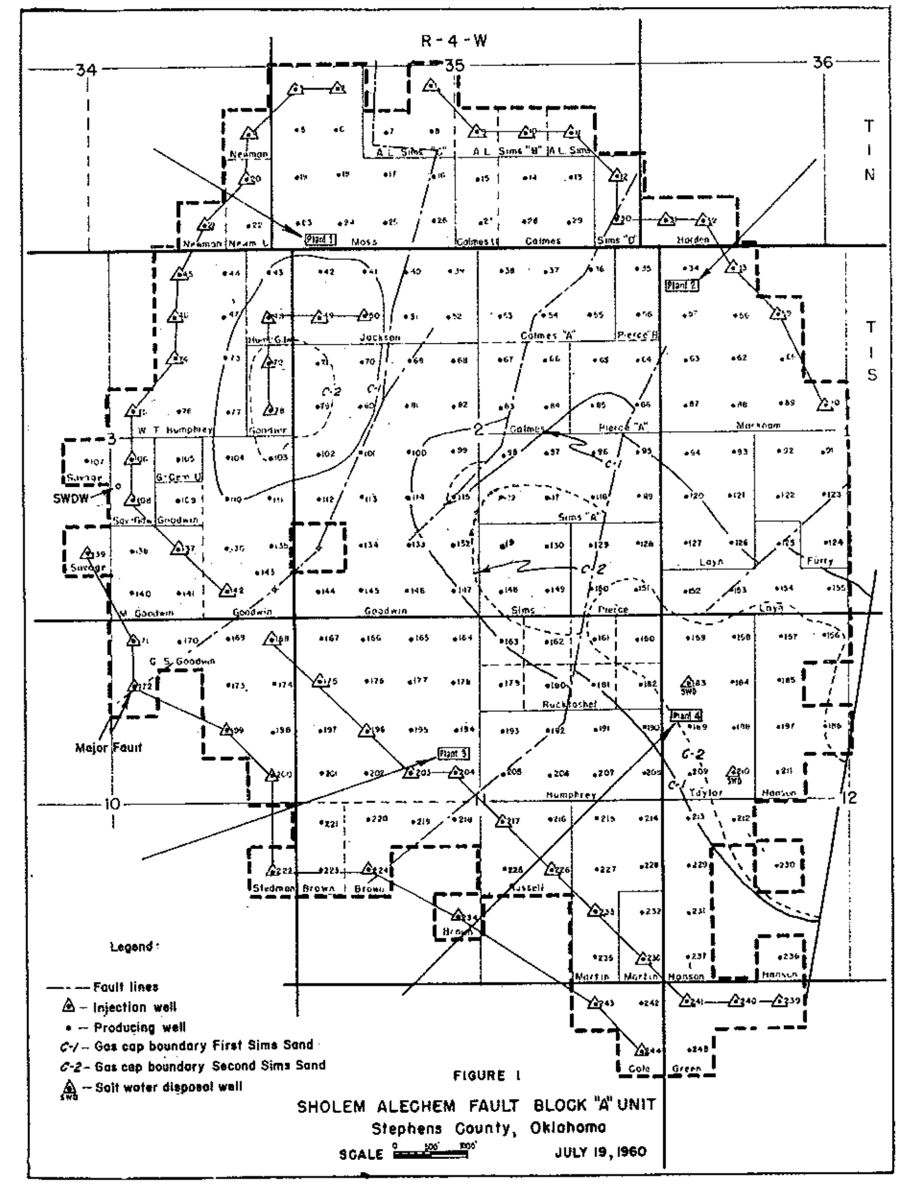
A closed system transporting water direct from supply well to injection well without treatment was designed and estimated to be reasonably inexpensive and simple to operate. This plan had several advantages with the most outstanding being elimination of investment in elaborate treating facilities for produced water; the supply sand would serve as a natural filter. Secondly, net withdrawals from the water source beds were limited to the net water injection requirements, thus aiding to maintain a higher pressure and productivity in the water supply reservoir.

A third advantage not originally anticipated was a leveling of the load requirements on the water supply lifting equipment. Produced water volumes fluctuate appreciably on a day-to-day basis. If water produced with the oil were reinjected in the Sims Sand, frequent adjustment of the producing rates from the Pontotoc water supply wells would be necessary to maintain a balanced and reasonably even total injection rate. With the injection water being supplied direct from water supply wells only, a much more constant load factor could be maintained with minimum supervision of the lift equipment. Variations in daily water requirements from the Pontotoc and water production from producing oil wells appear on *Figure II*.

Water Supply Wells

In the initial planning it was desired, from the standpoint of initial investment and maintenance expense, that the number of supply wells be held to a minimum. Therefore, high capacity was the objective in designing completion of these wells. It was intended that one well supply the needs of each injection plant with the supply well at Plant 1 serving as a means of evaluating this possibility. To achieve the volumes required to serve each plant high-capacity lift equipment would be necessary. Therefore, the casing program for the well was designed to handle a lineshaft turbine pump. Twenty inch surface casing was set at 350 feet with a 13⅜ inch production string set at 1970 feet; total depth is 2400 feet.

An unusual precaution taken in drilling these wells was restriction of deviation to a maximum of 1° to 1800 feet and 2° to total depth. Such restriction was considered advisable to reduce flexing in the rotating lineshaft driving the turbine. Early testing of the initial supply well indicated that the volumes required would be available with operating level at approximately 700 feet. No stimulation was performed in this well or either of the other two wells in the first three plants. A loose liner was inserted in the supply well serving Plant 2 to overcome caving problems encountered. The supply well to serve Plant 4, which is currently under construction, was completed with a set-through casing string, horizontal slot-type hydraulically



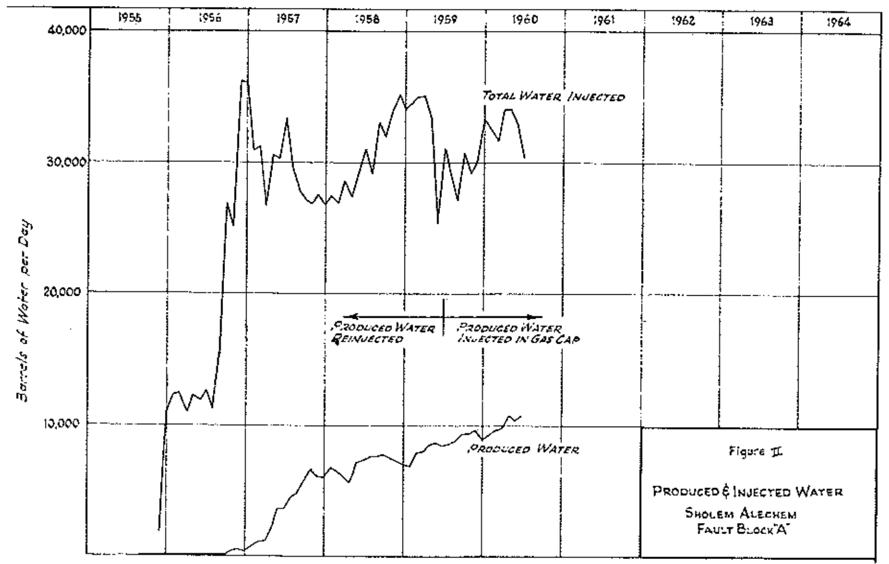
▼Figure I. Sholem Alechem Fault Block "A" Unit.

THE AUTHORS

Walter C. Pearson, a native of Wheatridge, Colo., received his P.E. degree from the Colorado School of Mines in 1939. He has been employed by Pan American Petroleum Corp. since graduation from Mines, except for a three-year tour with the Army (Combat Engineers) during World War II. He is now assistant division engineer for Pan American at Oklahoma City. Mr. Pearson is a member of the AIME and API.

W. A. Van Hook, a native of Hinsdale, Ill., has been employed by Pan American Petroleum Corp. since receiving his petroleum engineering degree from the Colorado School of Mines in 1935. He is now assistant division production superintendent of Pan American's Central Division at Oklahoma City.

1. "A Study of Gas Cap Water Injection in a Peripheral Waterflood" by J. D. Griffith, F. F. Craig, Jr., H. G. Riley, R. J. Wagner—Pan American Petroleum Corporation. Presented at 1959 Fall Meeting of the Society of Petroleum Engineers of AIME at Dallas, Texas.



▼ Figure II. Produced and injected water, Sholem Alechem, Fault Block "A".

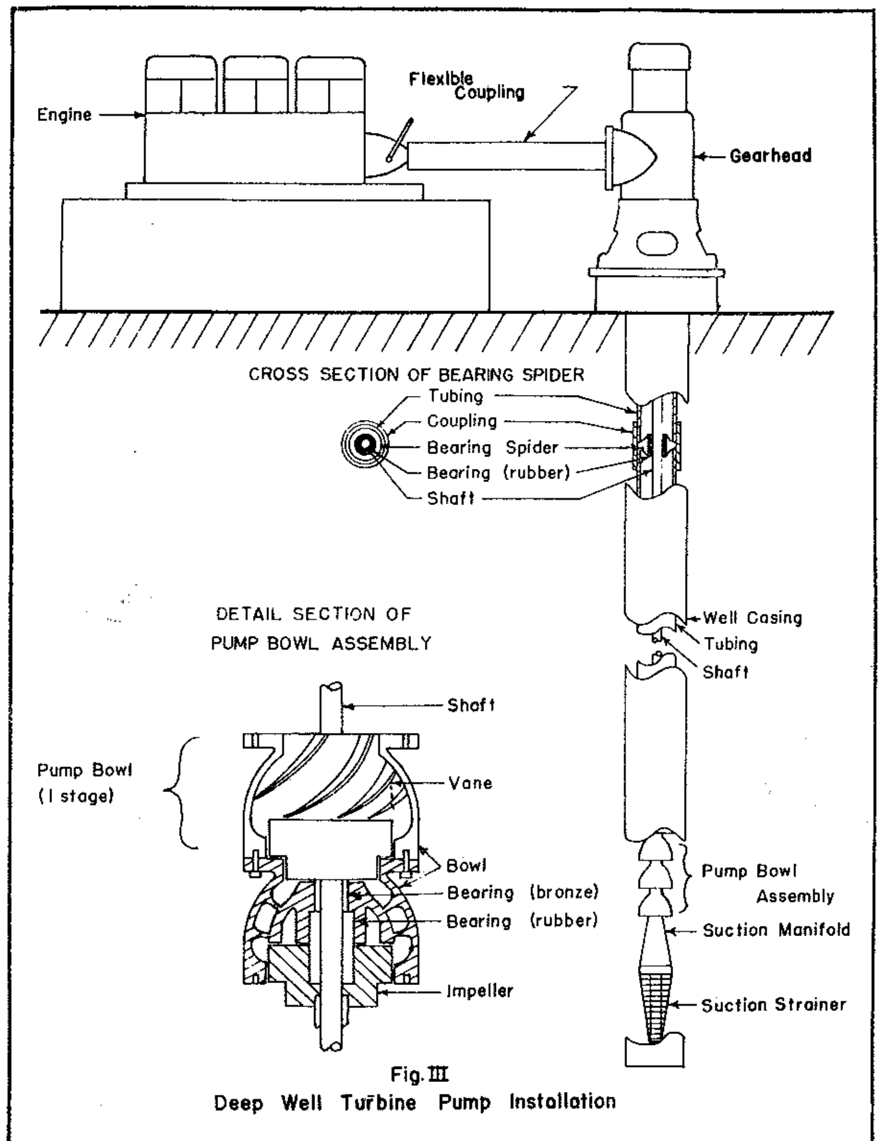
cut perforations and the well was given a sand-water fracture treatment; a well comparable in capacity to the previously drilled wells was obtained with less investment.

Lift Equipment

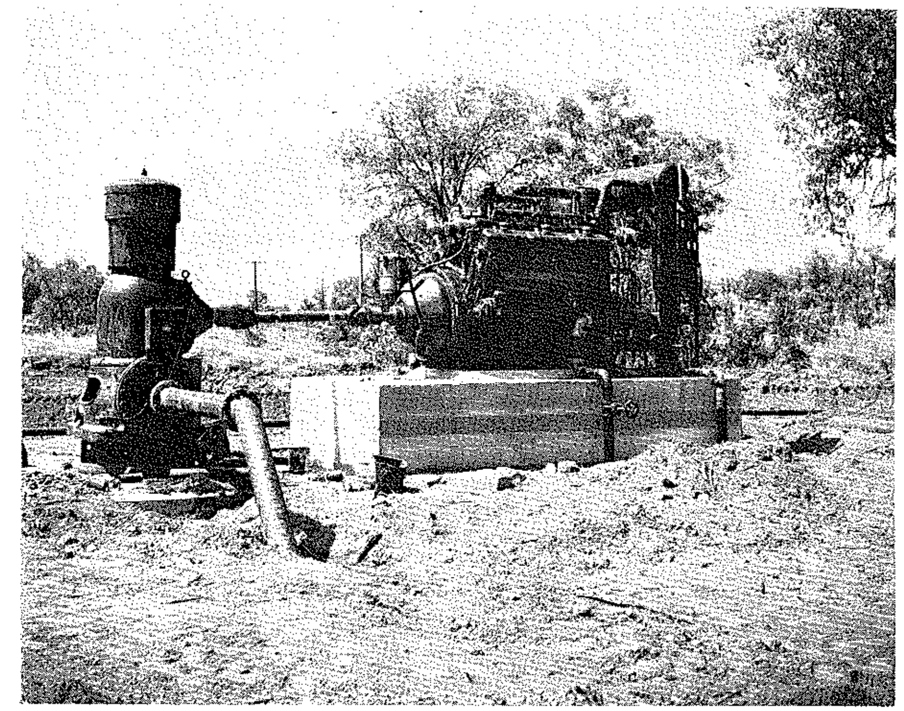
While waiting on fabrication and delivery of deep well turbine pumps, an electric-powered submersible turbine pump was employed to evaluate the capacity of the first three supply wells. Well No. 246, serving the Plant 1 area, was put in service with this equipment in November, 1955 and was operated for a period of nine months. During this period, over 3 million barrels of water were produced from this well. Wells Nos. 247 and 248 serving Plants 2 and 3 operated in this manner seven and five months respectively, producing 2.4 and 1.0 million barrels. Operation of this equipment was evaluated carefully as a possible alternative to the line-shaft turbine-type equipment. Overall lifting cost with electric-powered submersible turbine pumps was $.00365/barrel.

In August, 1956, the first line-shaft turbine pump was delivered and installed in the well serving Plant 1. This equipment consists of a 10 inch 41-stage deep well turbine pump with a column of 8⅝ inch 24 lb. casing as the tubing string. The pump is driven by a 1-15/16 inch shaft centered in the 8⅝ inch tubing by rubber bearings held in steel bearing spiders which are mounted in the center of each coupling between the ends of the 10 foot joints. Both metal and rubber bearings are used on the impeller shafts. All bearings are water lubricated, thus requiring filling the column pipe from the surface before starting up. A high pressure discharge base with a special steel top-column flange sits on the wellhead with a gearhead completing the wellhead assembly.

This equipment is driven by a 12 cylinder 3006 cubic inch displacement oilfield engine rated at 402 HP at 1000 RPM. Engine cooling is accomplished through heat exchangers using Pontotoc supply water as the heat removal medium. The engine is coupled to the gearhead through a 48 inch flexible coupling. The gearhead serves as a right angle drive and also as a speed increaser with a ratio of 2:1. Pump speed varies from 1200 to 1550 RPM in normal operation.



▼ Figure III. Deep well turbine pump installation.



▼ Figure IV. Engine and gearhead assembly being installed at Plant 4.

Figure III is a schematic diagram illustrating the installation of the subsurface lift equipment. Installation of an engine, coupling and gearhead assembly being made at Plant 4 is shown in *Figure IV*.

Design capacity of the assembly is 15,840 barrels per day at 1760 RPM from 1200 feet. Initially each pump was set at 1230 feet. The actual maximum withdrawal from any well has been 14,990 BPD.

As of Aug. 1, 1960, the three lineshaft turbine pumps serving Plants 1, 2, and 3 had lifted 40,770,000 BW. This volume was produced with only one pump failure and one scheduled overhaul. The one breakdown resulted from failure of the top bearing on the pump serving Plant 1. Bearing failure resulted in wearing of the shaft and lower bearings in the pump itself with final failure of the shaft at the top bearing. The bearing which caused the failure was a nickel-cast iron alloy. The other pumps are equipped with all bronze bearings. Servicing the pump from the Plant 2 supply well after producing approximately 13.5 million barrels found the pump in much better condition than the one serving Plant 1 which produced 14 million barrels before failure.

Total lifting cost for the turbine pump equipment has been $.00152/barrel. This, compared with the electric-powered submersible turbine, shows a saving of $.00213/barrel. Considering total requirements for the life of the flood in excess of 100 million barrels of water, an overall saving of $210,000 in lifting costs for the supply wells should result. A turbine pump installation such as has been outlined costs approximately $43,000 which is considerably greater than the electric-powered submersible turbine installation cost of $15,600. However, the overall difference for four installations for SAFBAU of $110,000 deducted from the aforementioned savings in lifting costs still leaves a net $100,000 saving for the 22-year life of this turbine pump project as compared with electric-powered submersible turbine installations.

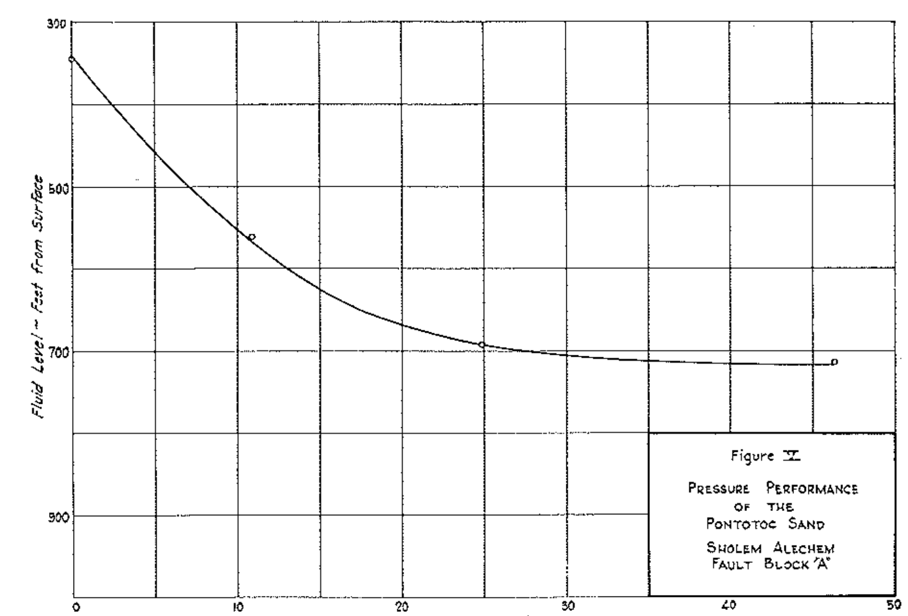
This turbine pump equipment is applicable generally to high capacity shallow supply wells. The wells in SAFBAU are considered unusually high capacity shallow wells. Performance of these wells is indicated in *Table I* below:

These data show the high capacity of the supply wells. The stable performance of the water reservoir after the withdrawal of some 47 million barrels of water is evident from *Figure V*, plot of cumulative withdrawal versus fluid level for the Pontotoc reservoir.

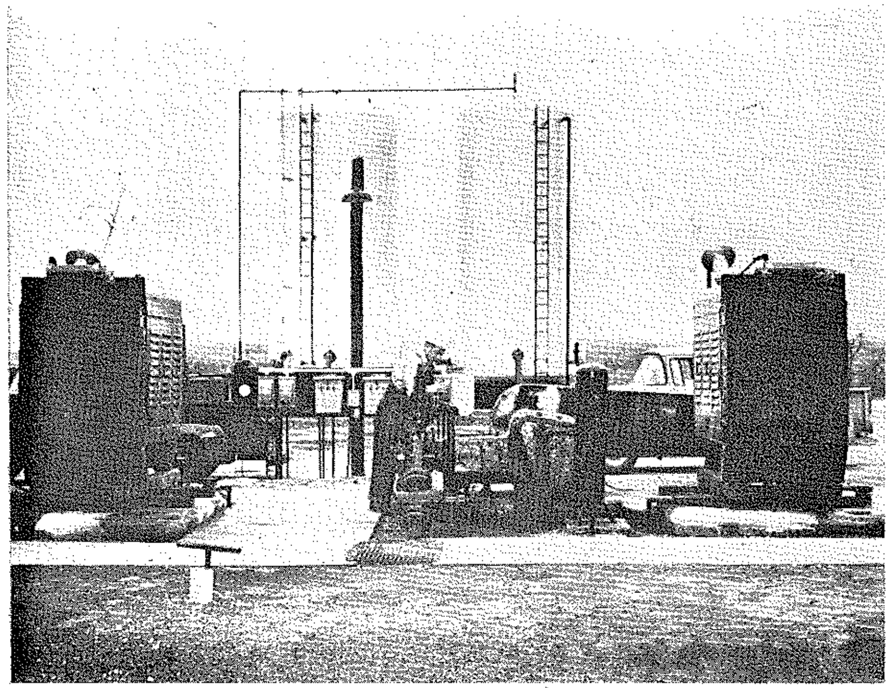
Tests of the water supply wells indicated production of the first 20 million barrels from the Pontotoc Sands had reduced static fluid levels 324 feet whereas the last 20 million barrels has reduced the

TABLE I

Well No.	Static Fluid Level Ft. From Surf.	Pump Depth	PI-BPD/Ft. Drawdown	Ind. Cap. at Pump Depth BPD	Current Rate BPD	Cum. 8-1-60
246 (Plant 1)	704	1,362	25	16,450	6,500	18,380,000
247 (Plant 2)	696	1,230	54	28,800	10,500	14,332,000
248 (Plant 3)	736	1,230	44	21,736	13,250	14,470,000
249 (Plant 4)	650	1,230	Currently being completed			



▼ Figure V. Pressure performance of the Pontotoc Sand.



▾ Figure VI. Injection pump and engine with 480 Bbl. surge tanks in background.

static level by only 20 feet. The average productivity of the three supply wells during the latter production interval had declined from 46 barrels per day per foot of drawdown to 41 barrels per day per foot.

Injection Equipment and System

From the discharge head on the supply well at each of the four plants water goes to two vertical 480 barrel 30 psi working pressure surge tanks. A backpressure of 15 to 30 psi is maintained on these tanks through controlling the venting of gas evolving from the Pontotoc water. This pressure serves to reduce the rolling within the tanks and keeps a positive gas blanket on the water, eliminating aeration and assuring a positive charging head to the injection pumps.

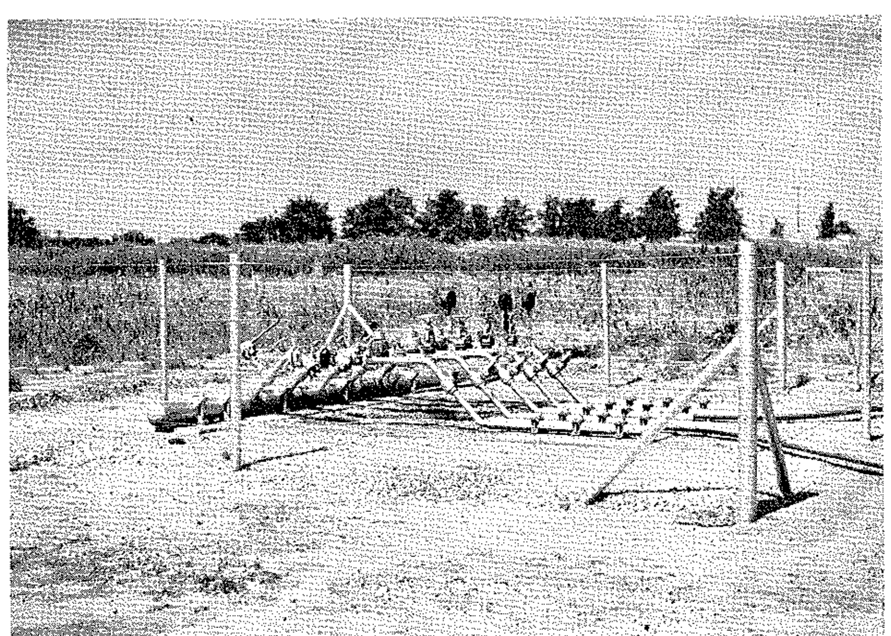
The injection pumps are horizontal, single acting, triplex plunger pumps powered by 6 cylinder, 970 cubic inch displacement engines equipped with heavy duty oil field radiators, 220 volt electric starters, mufflers, automatic oil level controllers and exhaust condensers for cooling water makeup. This combination appears to be a well matched package and performance has been quite satisfactory.

Test of the injection pumps indicates 96 to 97 per cent efficiency. Operating pressure was 1,000 psi initially and the triplex pumps are now operating at 1200 psi. Changes are being made in a portion of the system to raise injection pressure as high as 2000 psi., the maximum anticipated when ultimate fill-up of the reservoir is realized. This will be accomplished by the installation of one quintuplex plunger pump at Plant 2 with a capacity of 15,880 barrels per day at 2000 psi.

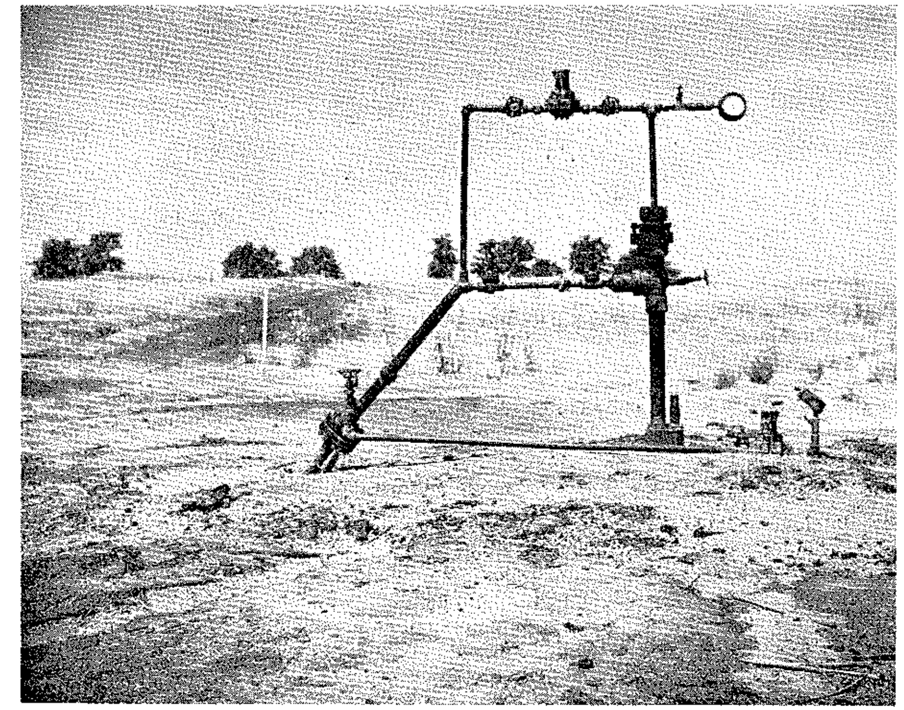
Originally no automatic control devices were installed in the water plants and differences between supply well production and injection pump withdrawal were adjusted manually through observing fluid level change in the surge tanks from internal floats operating ground level gauging devices. More recently gas-operated pressure-sensing throttle controllers have been employed to maintain a constant fluid level in the surge tanks at one plant regardless of variations in withdrawal rates. These devises are giving satisfactory service and all plants are to be so equipped in the near future.

Other protection devices are employed to afford insurance against high discharge pressure on the discharge pump, low water level in the surge tanks, low engine oil pressure, high cooling water temperature on the supply well engine and injection pump engines and low pump oil pressure on the injection pumps. A vibration detection switch is mounted on the well gearhead to shut down the supply pump in the event unusual vibration is detected in the lift equipment. "Tattletale" switches indicate the function causing the shutdown so as to identify the source of trouble. The photograph in *Figure VI* shows an injection pump and engine assembly with the surge tanks in the background.

The injection system in the first three plants consists of 6 inch trunklines and 2½ inch laterals from header stations throughout the field *(Figure VII)*, terminating at each injection well where injection into each zone is controlled



▾ Figure VII. Injection system header showing 2½" laterals for distribution of injection water to individual input wells.



▾ Figure VIII. Injection well hookup to control injection into different sand intervals.

(Figure VIII). All these lines are cement-lined butt-welded pipe with all connections and fittings of 2,000 psi working pressure. Test nipples were installed at representative points in the system for study of corrosion and scaling tendencies. Careful observation of these nipples and other equipment exposed to the injection water indicates negligible corrosion and recent additions have been completed with bare pipe having no internal protection.

The high working pressure of the field system was based on a foreseen necessity of increasing injection pressure as the flood front progressed inward from the outside injection wells. Injection pressures have increased as anticipated and some portions of the injection systems are operating at pressures up to 1800 psi. Further modifications and changeouts are being made to progressively increase injection pressures as necessary to maintain the fluid movement in the reservoir.

The preliminary findings of negligible corrosion tendency, and of injection well plugging being minimized by employing a totally enclosed air-free system, have been substantiated through actual experience. Thus, considerable savings have resulted through use of a simplified water treatment system consisting of surge tanks only with no filtering, precipitation, or neutralization being required. No evidence of injection well plugging due to precipitation has been noted.

Injection of Water in Gas Caps

As discussed in the previous paper[1] on this project, water injection in the gas caps became necessary as a control measure. The large volume of water required for this purpose exceeded the capacity of the three water supply wells. Utilizing produced water for gas cap injection was considered as a solution to this problem.

Performance of the Pontotoc water supply reservoir indicated the presence of a sufficiently large acquifer to provide ample productivity for the overall water injection requirements without the necessity of returning produced water in the Pontotoc Sand. However, since the residual oil saturation in the gas caps was very low (5 per cent of pore space), it was believed that water produced from the Sims Sand might be successfully injected in the gas cap without plugging difficulties. This would avoid the continued expense of injecting produced water into the Pontotoc Sand and relifting it for gas cap injection.

On a trial basis, injection for produced water into the First Sims Sand was started near the south edge of the large gas cap close to the pinch-out of the sand. The location was well removed from the oil column in this sand member which minimized the possibility of damage to the oil bearing part of the formation. The trial was successful and currently all produced water is being injected into two gas cap wells in this area without any difficulty. Produced water for injection is handled in a separate system from the regular water supply to preclude any mixing of produced water with the water being injected into the oil saturated sands.

Summary

Operation of the water supply system in SAFBAU shows deep well turbines are economical for a high-rate large-volume shallow water supply in waterflooding. Maintaining compatibility of the injection water with the flood reservoir formation water by handling all injection water through a completely closed system successfully eliminates treating and filtering expense. Thorough preliminary planning of the original construction of supply facilities and application of early experience to later modifications and additions in the supply-injection systems will result in significant savings to the operators during the life of this waterflood.

Oil Recovery By Thermal Methods

By S. E. SZASZ

STEPHEN E. SZASZ

I. Introduction

Conventional methods of oil recovery, based on flow and on fluid-fluid displacement, leave behind as "unrecoverable," on the average, about two-thirds of the oil originally in place. This astoundingly low recovery is due mainly to two causes: retention of the oil by capillary forces, and inefficiency of the mechanism which drives the oil to the producing wells in a reservoir which is far from homogeneous and uniform. The use of heat, in addition to mechanical energy, is intended to mitigate the above effects: capillary forces are eliminated when some of the oil is vaporized, and heat transport by conduction overcomes, at least in part, permeability inhomogeneities in the reservoir.

Over 20 thermal recovery projects have been planned, started or concluded in this country; but only a few have been adequately described and analyzed in the literature. Our present knowledge is based on these, and also on laboratory experiments and on theoretical considerations; but we have to learn much more before we have a complete, quantitative knowledge of the thermal recovery process.

This article is intended to review our present knowledge based on theoretical and laboratory research as well as on field tests, and to furnish some guideposts to the petroleum engineer planning a thermal recovery project.

II. Description of the Heat Wave Process

In the basic case which we will consider first, air is injected into wells initially heated to the ignition point, and oil, water and gaseous products emerge from the producing wells. A wave-like zone of elevated temperature moves through the formation, in the same direction as the flowing gas; and at any instant, the formation can be divided into five temperature zones:

1.) A low temperature zone around the injection well, cooled down by the injected cold air;

2.) A zone of increasing temperature where the flowing air picks up sensible heat, thereby cooling the formation;

3.) The combustion zone including the peak temperature, where heat is generated by the reaction between injected oxygen and fuel left behind by the original oil content;

4.) A zone of decreasing temperature, where the streaming gas loses and the formation gains heat, like in a conventional heat exchanger;

5.) A low temperature zone extending to the producing well, not yet affected by the heat wave.

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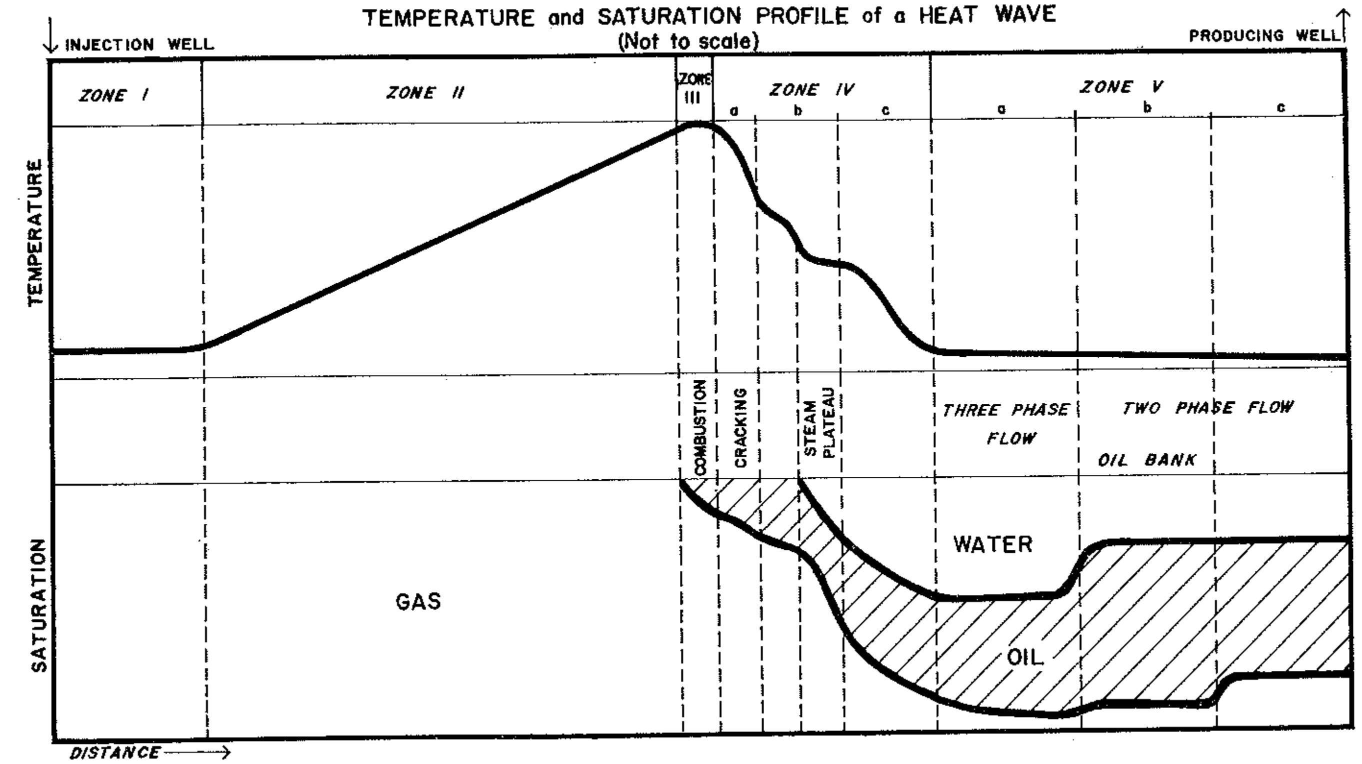
Looking at a fixed point in the formation as the heat wave approaches, we find first a saturation distribution of oil, water and gas corresponding to the initial condition of the reservoir (Zone 5-c), followed by an increase in oil saturation due to oil being driven ahead and banked up by the advancing heat wave (Zone 5-b) and still later, a zone (5-a) where water also has been banked up so that it can flow through the reservoir. When Zone 4 reaches our point, the temperature starts to rise: light components of the oil are vaporized and carried forward in the gas stream, but they recondense when they again hit a region of low temperature, thus creating a bank of lighter hydrocarbons which helps push ahead the original oil, in a manner similar to miscible displacement. Note, however, that during most of the time, oil of original, unchanged quality arrives at the producing well, the zone of light hydrocarbons being confined to the boundary between Zones 4 and 5. Water also moves ahead by vaporization and recondensation. Besides, the movement of liquid oil and water in Zone 4 is facilitated by the decrease in viscosity due to higher temperatures.

FIGURE I

TEMPERATURE and SATURATION PROFILE of a HEAT WAVE

(Not to scale)



▼Figure I. Temperature and saturation profile of a heat wave.

When the temperature reaches the boiling point of water under the prevailing pressure, we have a steam plateau (Zone 4-b); and when it exceeds the cracking temperature (about 700°F., Zone 4-a), the remaining oil is chemically changed into two components: solid or semisolid coke, tar and/or pitch which cannot move and constitutes the primary fuel in the combustion zone, and a vaporizable light product which recondenses farther downstream, but which also includes non-condensible "cracking gas" which appears in the produced gas and imparts to it a heating value of perhaps 50 Btu/std. cu. ft. Finally, in the combustion Zone 3, the residual fuel burns with the oxygen in the injected air, generating water vapor, CO_2 and some CO. If the temperature in this zone is high enough, its advance is given by the following two conditions: no combustible fuel is left behind, and no free oxygen can pass forward through it. Thus, if we know the rate of oxygen (air) injection and the amount of residual fuel, we can calculate the rate of advance of the combustion front.

An idealized graph of temperature and saturation distribution in the formation is given in *Figure 1.*

The real, physical picture is much more complicated than the above simplified description. In Zones 2 and 4, heat also moves by conduction in the matrix due to the temperature gradient; the latent heat of vaporization and condensation, and exothermic and endothermic effects associated with cracking and with phase changes in the matrix influence the temperature level; and some heat is lost by vertical conduction to the over- and under-burden. This makes a complete theoretical treatment of the system almost impossible.

Research into the heat wave process has progressed mainly along the following three lines of approach:

1.) Neglecting, in a first approximation, the influence of moving fluids other than the air (gas) stream, and thermal effects of phase and chemical changes except the combustion reaction, the movement of the heat wave appears as the solution of a partial differential equation, with proper boundary conditions, including terms for heat exchange between stationary matrix and flowing gas, for heat conduction both in the direction of gas flow and toward the over- and under-burden, and for heat generation in the proper amount and in the proper place. Papers based on this approach, with certain simplifying assumptions, were published by Ramey[1] and by Bailey and Larkin[2].

Tadema[3] and Cooperman [4], have attempted to show that in a linear system without heat losses, the temperature profile reaches steady state, which would reduce the problem to an ordinary differential equation; but Cooperman's assumptions were too far removed from physical reality[5, 6], and besides, it is easy to see that in the case of steady state, the heat content of the wave is constant, which is possible only if the rate of heat generation is exactly equal to the rate of heat loss from the system; thus, the assumption of steady state without heat loss is untenable.

The picture which emerges from this work is a temperature profile similar to that in *Figure 1;* because of heat losses to the surroundings, the peak temperature is highest in the center of the formation and declines as we approach the over- and under-burden. But the value of the peak temperature probably influences the amount of residual fuel left behind, while the theoretical treatment was based on a known and uniform fuel concentration. Also, especially where the temperature does not reach a high enough level, the assumption of instantaneous and complete reaction between oxygen and fuel might not represent a sufficiently good approximation: the reaction rate, which decreases sharply with declining temperature, might be so low that the reaction is not completed during the residence time of the injected air in the high-temperature zone, and some free oxygen breaks through into Zone 5 and to the producing well. This has actually been observed in field tests. Note that on its way through Zone 4, this break-through oxygen may burn some movable oil, so that the immovable, coke-like residue is not the only fuel used by the process. Further work in this respect will be necessary.

2.) Wilson et al[7] have tried to reduce the treatment of the heat wave process to classical considerations of fluid flow and relative permeability, without regard to temperature distribution and changes in the composition of the oil phase, but taking into account the "loss" of liquid oil as fuel. Their approach, however, requires a prior knowledge of the peak temperature in order to estimate the fuel requirement.

The theoretical studies mentioned in paragraph 1 above furnish a value for the peak temperature, it is true, but they require knowledge of the residual fuel and therefore cannot be used as an independent source of information to calculate the peak temperature for the Wilson approach; also, the peak temperature in laboratory and field experiments has not always been in good agreement with calculated values, perhaps because of heat loss. In the Wilson method, the water resulting from combustion should also be taken into account; Benham and Poettman[8] have shown that the residual fuel has an atomic H:C ratio of about 1.6. This, and the assumption of complete oxygen utilization, furnish a better approach to the calculation of oil loss as fuel.

3.) Wilson et al[7], and Martin et al[9], have tried to circumvent the difficulties of a theoretical approach by performing laboratory experiments in linear systems compensated for heat loss so as to make them quasi-adiabatic. In this, they were only partially successful, as shown by the appearance of a double temperature peak in Martin's paper. The main drawback of this approach is the necessity to conduct such experiments under conditions, e.g. of air flux rate, different from those in the field; and in the absence of a complete understanding of the process, no reliable scaling procedure is available to translate laboratory results into expected behaviour in the field.

Field experiments have been described and analyzed, to the extent that some general information can be derived from them, by Smith and Watson[10], Kuhn and Koch[11], Grant and Szasz[12], and Gates and Ramey[13].

III. Engineering Methods

The reservoir engineer called upon to predict the technical and economic performance of a proposed thermal recovery project is directly interested in the following four parameters:

—Air requirement, i.e. the quantity of air which must be injected to drive the heat wave over one unit of reservoir volume,

—Rate of injection and production per well,

—Liquid oil recovery efficiency, i.e. what percentage of the initial oil content of the swept reservoir volume will be put into the stock tanks, and

—Volumetric sweep efficiency, i.e. what percentage of a given reservoir can be swept with a given number and array of wells.

The first tells him the cost of the project; the second, the size of the compressor plant required and the schedule of disbursements and of income; the third, the income to be expected per unit volume swept; and the fourth, the oil reserves made available by the thermal recovery process.

A. Gas requirement: Laboratory results have yielded values between 230 and 1300 std. cu. ft./cu. ft. of reservoir; the range of values from field tests is 350-700 std. cu. ft./cu. ft.

This value seems determined mainly by the residual fuel content and hence, can be expected to increase with increasing residual oil content and with decreasing oil gravity: this is borne out by the field results mentioned above. Porosity, permeability and rate of air injection, at least within reasonable limits, seem to have only minor influence. If we attempt to use laboratory determinations of residual fuel concentration to calculate the rate of movement of the combustion zone, and hence the air requirement, two things must be kept in mind: first, Zone 4 is expected to increase in width with time, especially in a system of radial geometry, and therefore, the average point of oil removal travels faster than the combustion zone. Second, laboratory tests conducted with an inert gas tend to yield too little residual fuel, i.e. injected air under field conditions may burn more fuel than the residue determined by a nitrogen drive in the laboratory. Besides, the effect of the bank of recondensed light hydrocarbons is difficult to duplicate in the laboratory.

A word about the produced gas: with its low heating value of perhaps 50 Btu./std. cu. ft. it has no sales value, but part of it can be used as project fuel (after some enrichment and in specially equipped engines, or under steam boilers), or for reinjection, to be discussed later.

B. Rate of Injection and Production: Past field experiments have been conducted with air injection rates from 500 to 5000 std. cu. ft./hr./ft. of sand. The air injection rate is determined by the effective gas permeability, by the maximum safe injection pressure (about 1 psi per foot of depth) and the back pressure held on the producing wells. This rate varies only little over the lifetime of the project, after an initial transient period, because the flow resistance is determined primarily by the low relative permeability to gas in Zone 5 which becomes shorter with time, and especially by the three-phase-flow Zone 5-a which increases with time: the two effects nearly cancel each other. It appears from field experience that, because of its high temperature, the combustion zone causes some additional flow resistance.

The rate of oil production is determined by the capacity of the producing well, the gas production rate and the producing GOR (see later). Note that the oil production rate drops rather sharply when the three-phase-flow Zone 5-a reaches the producing well, i.e. when it starts producing a substantial water cut. Hence, for a more thorough economic analysis, it is recommended to run a material balance type calculation along the lines of the paper by Wilson, et al [7], and to consider abandoning the project at water break-through: despite lower total oil recovery, this scheme of operations may be more advantageous from the economic point of view.

C. Liquid Oil Recovery Efficency: Although there will be no oil left behind in the area swept by the heat wave, not all the original oil content will be recovered, because the fuel used up in the combustion reaction and the cracking gas which imparts some heating value to the produced gas are lost. Early estimates

ranging from 85 to 98 per cent liquid recovery efficiency appear today as overly optimistic. A better estimate can be had by a calculation which is best done, in view of the chemical changes involved, on a heating value basis, as shown by the following example:

—Original oil content, 1000 bbl./a. ft. STO,

—Air requirement, 350 std. cu. ft./cu. ft., or 15 million std. cu. ft. per acre-foot. One std. cu. ft. of air generates by combustion about 100 Btu. with practically any kind of petroleum fuel; hence, 15 million std. cu. ft. of air will generate 1.5 x 10^9 Btu./a. ft. taking the heating value of oil as 6 x 10^6 Btu./bbl., this represents an equivalent of 250 bbl./a. ft. oil used as fuel.

—If the produced gas has a heating value of 50 Btu./std. cu. ft., the combustible components in 15 million st. cu. ft. are equivalent to 0.75 x 10^9 Btu./a. ft. of oil.

—Therefore, liquid oil recovery will be 1000-250-125 = 625 bbl./a. ft., or 62.5 per cent. With this, the overall average GOR is calculated to be 15 million std. cu. ft. ÷ 625 bbl., or 24,000 std. cu. ft./bbl.

The above considerations call for several qualifying remarks. First, in view of the fact that low-gravity-crude reservoirs seem at a disadvantage both because of higher air requirements and because of low well productivity caused by high oil viscosity, it may seem surprising that most of the past field experiments were conducted in such reservoirs. The explanation is not only that these reservoirs respond poorly to conventional recovery techniques, but that they usually have a high initial oil content, which is of paramount economic importance. If, for example, we repeat the above calculations for a reservoir containing originally only 800 bbl./a. ft. STO, the oil recovery is only 425 bbl./a. ft. and the GOR, 35,000 std. cu. ft./bbl. Thus, for the purpose of thermal recovery, a reservoir should be thought of in terms of oil content in bbl./a. ft., not in terms of oil saturation in per cent of pore space.

Second, it is apparent that even in a favorable case, the producing GOR will be high: the key to economic application of the process lies in reducing air compression costs which constitute the major operating expense.

Third, the average GOR calculated above does not imply that this value will prevail uniformly over the lifetime of the project. Especially in the early stages, oil recovery is due not only to the advancing heat wave, but also to conventional gas drive in Zone 5; therefore, the GOR starts out low and increases with time. This furnishes another possibility of improving the economics of the process by cutting off before the GOR reaches too high a value, although again at the expense of total oil recovery.

Fourth, as mentioned earlier, the produced gas is not always completely free of oxygen: some can get through to the producing well either through strata which contain too little oil, or through the portions of the formation near the over- and under-burden where, because of heat losses, the temperature remains below the ignition point or the reaction rate is so slow that during the residence time of the streaming gas, the reaction between oxygen and fuel does not reach completion. Nevertheless, a systematic increase in oxygen content of the produced gas is an early sign of trouble: it indicates that for some reason, combustion cannot be maintained.

D. Volumetric Sweep Efficiency: The combustion front follows the streamlines for gas; and even in a perfectly homogeneous and uniform reservoir, the areal sweep efficiency with a given array of wells is less than 100 per cent. From the standpoint of fluid flow, the thermal recovery process is a gas drive and this determines primarily its areal sweep efficiency; but because heat can move by conduction in all directions, not only in the direction of gas flow, we can expect a slightly better sweep efficiency than in a conventional gas drive. An interesting model study of this problem was published by Ramey and Nabor[14].

In recovery processes based on fluid flow alone, the vertical variations in permeability impose a serious limitation, over and above that due to areal sweep efficiency, on the fraction of the reservoir volume which is swept and from which oil is recovered. Here, the thermal recovery process is at a distinct advantage: heat conduction in the vertical direction between strata of different permeabilities, usually over distances much smaller than the horizontal length of path of the combustion zone, serves as equalizer, and oil may be completely removed even from low permeability strata. This was found to be the case in the field test described by Grant and Szasz[12], where extensive coring has shown that the horizontal distance between the points of greatest and smallest advance of the oil recovery front was certainly less than 30′.

In the field test described by Gates and Ramey[13], however, the combustion front has covered only about 30 per cent of the formation thickness, probably due to higher injection rates (faster travel of the combustion zone and less time for heat conduction) and to the combination of good vertical connection and high oil viscosity causing, by gravity drainage, high oil saturation and low, even zero, gas permeability in the lower part of the formation. Despite its low volumetric sweep efficiency, this was one of the more successful field tests: vertical heat conduction raised the temperature and lowered the oil viscosity in that part of the formation thickness which was not swept by the combustion front, resulting in recovery, by ordinary gas drive, of a very substantial amount of oil. The drawback of this scheme of operations is that production must be maintained even after the heat front breaks through to the producing wells, a complicated and expensive operation.

IV. Variations of the Basic Process

The foregoing discussions were based on injection of air, and a combustion zone traveling in the same direction as the injected fluid. Various changes in the operating procedure have been proposed which might improve the technical or economic performance of the thermal recovery process, or extend its applicability. These variations will now be discussed.

Walther[15] describes a field test in which part of the combustion reaction occurred in a special chamber above ground, and the exhaust gas from this chamber, together with steam, was injected instead of air. The reported data are not sufficient for complete evaluation of the project, but the performance in terms of air requirement was no better than in the basic process: the added heat capacity of the steam was apparently counter-balanced by the low injected oxygen concentration which slowed down the movement of the combustion zone. Economically, this process seems inferior because of the expensive combustion chamber and the necessity to burn in it some fuel which has already been produced and which otherwise could be sold.

Smith and Watson[10] have suggested to reinject some of the produced gas, according to a schedule adapted to the characteristics of the formation and of its oil content. Injecting a mixture of air and produced gas dilutes the oxygen concentration and might provide a better balance between the total gas volume (heat carrying capacity or "convection wave") and the amount of oxygen (heat generating capacity or "combustion wave"); also, it might cut down on the amount of oil burned as fuel over and above the immobile coke-like residue.

If the concentration of this residue is too low, the heating value of the produced gas might also provide, at no cost, the necessary supplementary fuel. If, on the other hand, the residual fuel concentration is too high, alternate injection of air and of produced gas might be the answer: during the gas cycle, the heat wave might be driven forward far enough so that upon resumption of air injection, a band of residue cooled down below the ignition point is left behind; this is then equivalent to a reduction in average residual fuel content. All these suggestions are based on the realization that if the produced gas is available under some pressure, its cost of recompression is substantially less than that for an equal amount of atmospheric air.

The most interesting attempt to extend the range of applicability of the thermal recovery process goes back to a suggestion by Morse[16]. In reservoirs containing extremely viscous crude, e.g. the Athabasca tar sands, any banking-up of oil in Zone 5 would immediately block the permability to gas. Morse proposes to establish cold air permeability and then ignite the producing, not the injection well: a combustion front then moves counter-current to the air stream, and oil flow occurs only between the combustion front and the producing well, i.e. in a zone of increased temperature and greatly decreased oil viscosity. Reed et al[17], Warren et al[18] and Berry and Parrish [19] have made experimental and theoretical studies of this "reverse burning" process and have shown its characteristics. The main problem seems to be that, because the reaction between crude and oxygen proceeds at some very low rate even at ordinary temperature, the vicinity of the injection well will heat up spontaneously and a forward heat wave will be started; note that such spontaneous ignition also occurred in the field test described by Gates and Ramey[13].

V. Conclusions

From the preceding considerations, it is apparent that the characteristics of any thermal recovery process are sufficiently different from conventional processes based on fluid-fluid displacement to require some reorientation in the thinking of the engineer called upon to plan and evaluate a prospective field project. The large volume of air to be injected probably precludes its application unless the entire reservoir is under the control of the same operator. Contrary to early opinions, the process is not a "tertiary recovery" method, to be applied after primary depletion and after flood-out: the costs being largely independent of previous production and because no oil is left in the formation after burnout, the best time to start is as soon as some effective permeability to gas has been established.

Complete details concerning procedures for planning and evaluation cannot be given here, but the following general approach is suggested:

—Based on pressure limitations and relative permeability data, estimate the air injection rate per well; this and the number of wells used for injection at the same time will determine the specifications for the compressor plant.

—From the characteristics of the reservoir and the nature of the oil, estimate the air requirement by comparison with published field tests. This will determine the rate at which the reservoir is swept.

—By a calculation similar to that given in chapter III-C, determine the liquid oil recovery efficiency, the oil production rate, and the average producing GOR.

—Check whether the production rate is consistent with the known or estimated productive capacity of the producing wells: if not, modify the previous estimates accordingly.

—Estimate the life of the project or, if it is to be conducted in stages, the lifetime for each stage, and arrange the schedule for full utilization of the compressors during their entire useful life expectancy. Consider as an alternative, abandonment of producing wells at water breakthrough.

—With the above data, and according to standard accounting procedures, make an economic analysis of the proposed project.

It is realized that there are several questions which cannot be answered reliably from our present knowledge; for instance, we do not know for how long, or over what maximum distance of travel, the heat wave can be kept "alive," i.e. above ignition temperature despite ever-increasing heat losses, a consideration which could impose a lower limit on the acceptable well spacing. However, as research data and field experience accumulate, it is hoped that the petroleum engineer will be in measure to more and more reliably predict the performance of a thermal recovery project.

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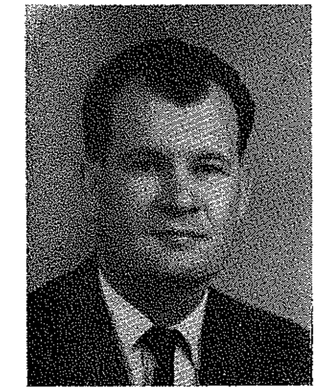
Waterflood Performance, Upper Terminal Zone Fault Block VB, Wilmington Oil Field



R. L. PIERCE

MARTIN J. GARRITY, '51

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Introduction

An evaluation of results to date of the Upper Terminal VB waterflood in the Wilmington Oil Field appears to disprove the opinion of some petroleum engineers that profitable waterflooding would not be feasible in California reservoirs containing thick multi-sand sections of low gravity, viscous crudes. The results of a pilot waterflood initiated in June 1953 in the HX sub-pool of the Upper Terminal Zone encouraged the City of Long Beach to expand this flood to include the full Upper Terminal Zone in Fault Block VB. Sufficient time has elapsed since expanding the flood in June 1958 to permit engineers to examine the reservoir performance and to draw some preliminary conclusions as to the success of the program.

The injection program in Fault Block VB, along with similar programs in other fault blocks of the Wilmington Field, has been accelerated for a twofold purpose: arresting subsidence, and secondary recovery of oil.

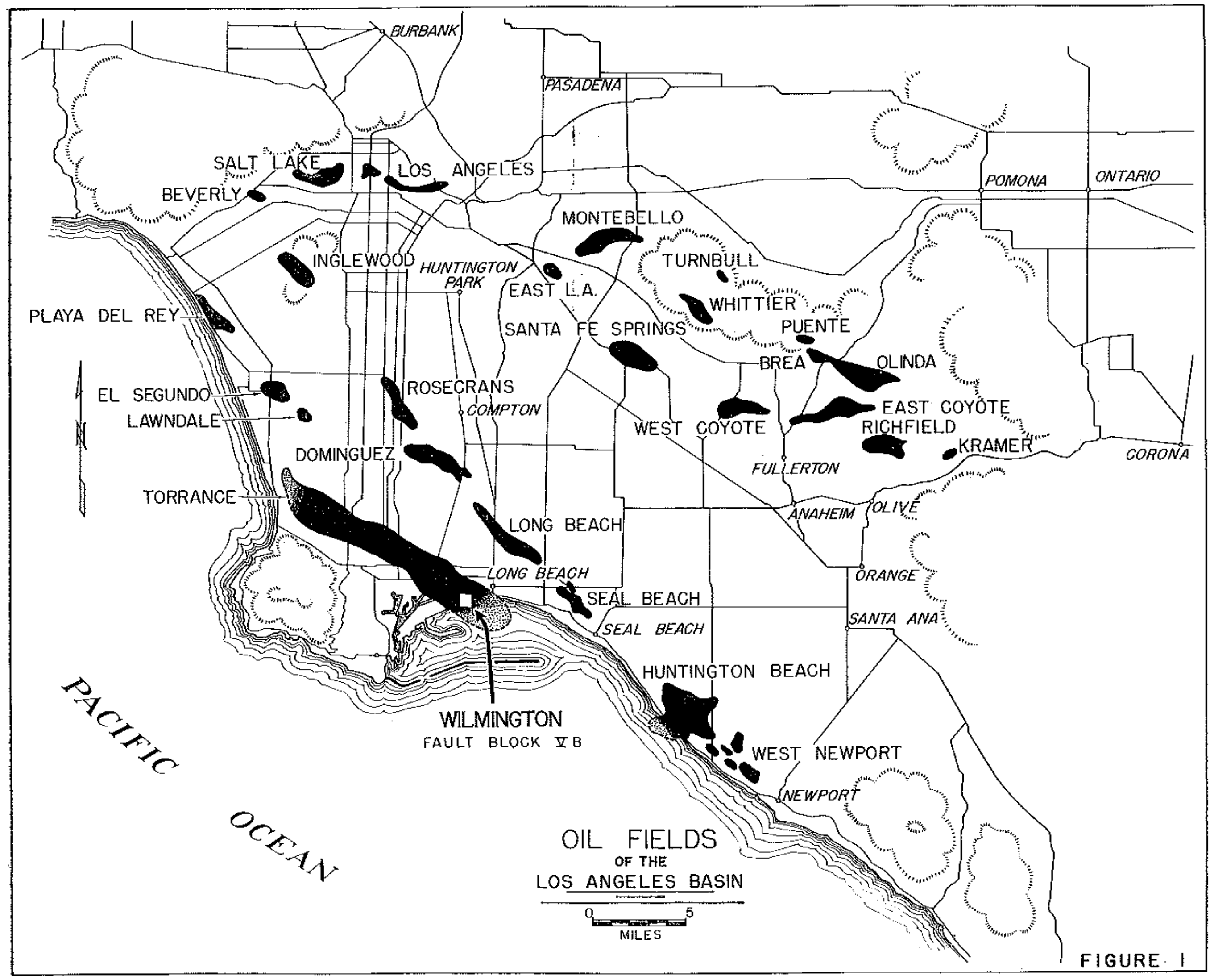
Land subsidence is a major problem in the Wilmington Field. The center of the subsidence bowl is in the eastern section of Terminal Island near the Southern California Edison Co's power plant. Maximum subsidence to date is approximately 26 feet at the center of the subsidence bowl where a subsidence rate of 2.4 ft. per year was measured in the early 1950's. This rate has decreased to 0.5 foot per year, and is continuing to decrease.

Repressuring brought on by waterflooding appears to have been the major factor in arresting the current rate of sinkage. There are some areas in the field where the sinkage appears to have been completely stopped. These areas overlay the sections of Zones which have exhibited a considerable pressure response from the floods. Fault Block VB lies to the east of the point of maximum subsidence. The subsidence in the areas encompassed by Block VB varies from 3 to 16 feet. The fact that the harbor area is highly industrialized and contains a large, vital U.S. Naval Shipyard has made it imperative that an attempt be made to completely eliminate the subsidence phenomenon. It is generally agreed that this can best be accomplished by repressuring the upper four oil producing zones. The resulting increase in oil production over the estimated primary production should make this twofold program economically attractive.

Location and Geology of Wilmington Field

Location—The Wilmington Oil Field is in the Wilmington area and Harbor District of the City of Los Angeles and the Harbor District of the City of Long Beach, Los Angeles County, Calif. The location of the Wilmington field with respect to other oil fields in the Los Angeles Basin is shown in *Figure 1.*

Geology—The oil producing structure is an anticlinal fold with its main axis in a northwesterly and southeasterly direction. The producing zones are highly faulted. The six main fault blocks have been



▼Figure I. Oil Fields of the Los Angeles Basin.

designated by Roman numerals I to VI and the large subfault blocks by the suffix A, B and D. Although the faulting may have begun during late Upper Miocene time, most of it probably occurred during the Lower Pliocene time. The strike of the faults is approximately north and south. The majority of the faults hade to the east with the exception of the Powerline Fault series together with the Pier A and Daisy Avenue Faults which hade to the west as shown in cross section in *Figure 2.* The vertical displacement of the major faults varies from a maximum of 350 ft. at the top of the Terminal Zone on the Wilmington Fault to less than 100 ft. on the Allied Fault. The subsurface structure is not reflected on the surface owing to the existence of an unconformity at a depth of about 2000 feet. Consequently, subsurface studies have guided the exploration of the field.

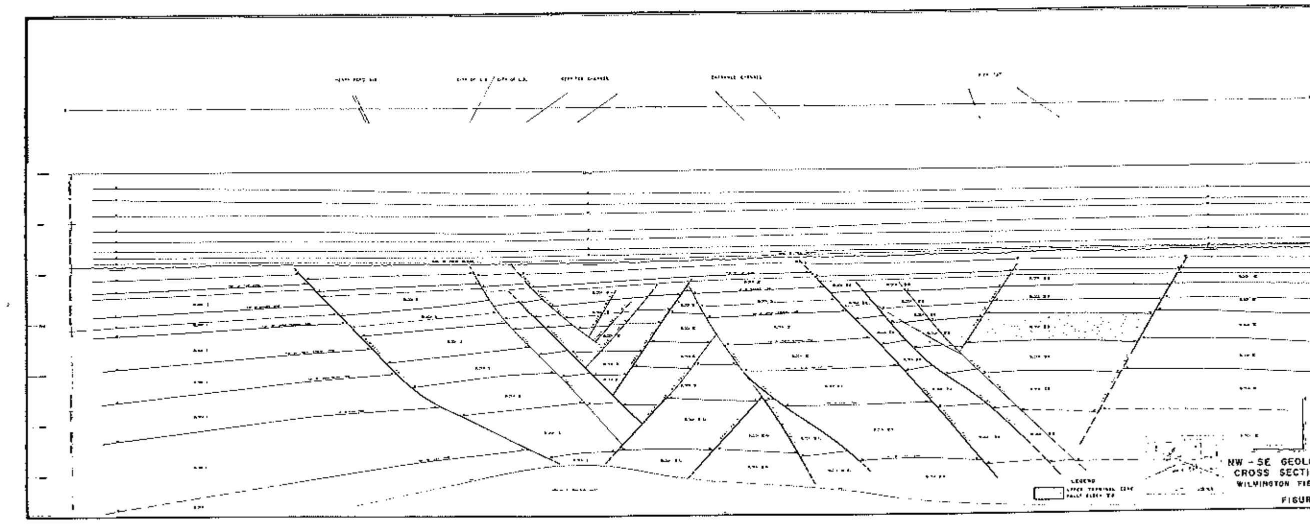
The upper 800 to 1000 feet of formation is Quaternary and Pleistocene in age and below this lies the Pico formation of Upper Pliocene age with a thickness varying from 1000 to 1200 feet. The Pico beds lie unconformably on the Repetto formation, which varies in thickness from 900 to 1500 feet and contains the Tar Zone and the upper portion of the Ranger Zone. The underlying Puente formations of Miocene age contain the lower portions of the Ranger Zone, the Upper Terminal, Lower Terminal, Union Pacific, Ford and "237" Zones extending to the Basement-Schist, believed to be the Franciscan of Jurassic age. The total thickness of the Miocene varies from 3200 to 3800 feet.

The crest of the structure extends to the southeast from beneath the northeastern portion of Terminal Island to an unknown distance beneath the Pacific Ocean. The southeasterly plunge extends to some point offshore from Seal Beach.

Fault Block VB Upper Terminal

The fault block with which this report is concerned is VB. Fault Block VB is located in the eastern one-half of the presently developed area of the Wilmington Field. The western boundary of the fault block is the Allied and Allied A-1 Fault system, and the eastern boundary is the Golden Avenue-Daisy Avenue Fault system. North and south limits are defined by the oil-water contacts of the various sand members, *Figure 3.*

An electrical log typical of that measured in the Upper Terminal Zone of Fault Block VB is shown in *Figure 4.* The log shows the seven major sand bodies in the Upper Terminal Zone. These sands are designated by electrical log markers HX, J, Y, K, Z, W and A. The HX sand is further divided into upper, middle and lower HX. The average section between markers HX and AA is 540 feet with approximately 300 feet being net oil sand.



▼Figure 2. Geologic cross section of Wilmington Field.

The following table presents a summary of reservoir rock and fluid properties of the Upper Terminal Fault Block VB sands:

RESERVOIR DATA

	HX Sands	J Thru A Sands
Sand Volume, Acre-Feet	23,000	76,000
Average Porosity	35	34
Arithmetic Average Permeability, md	1284	780
Interstitial Water, Percent	24	25
Average Oil Gravity, °API	18	21
Average Gas Specific Gravity (Air=1)	0.73	0.73
Datum-Weighted Average Sub-sea Depth—Ft.	2950	3200
Initial Reservoir Pressure at Datum, psi	1320	1420
Original Solution Gas-Oil Ratio SCF/ST Bbl.	160	200
Bubble Point Formation Volume Factor	1.097	1.120
Average Zone Temperature °F	140	148
Viscosity of Reservoir Oil at Time of Flood, Centipoises	17	15

Primary reserve estimates for the Upper Terminal pools of the Wilmington Oil Field have ranged from 350 to 460 barrels per acre-foot. Upper Terminal, Fault Block VB has a higher average oil viscosity than the Upper Terminal pools to the west and was considered to have the lowest ultimate primary reserve.

Water Injection System

The water injection system consists of salt water source wells, facilities for treatment of the salt water, pipe lines, and water distribution plants with the capacity to inject the water under pressure to the subsurface formations.

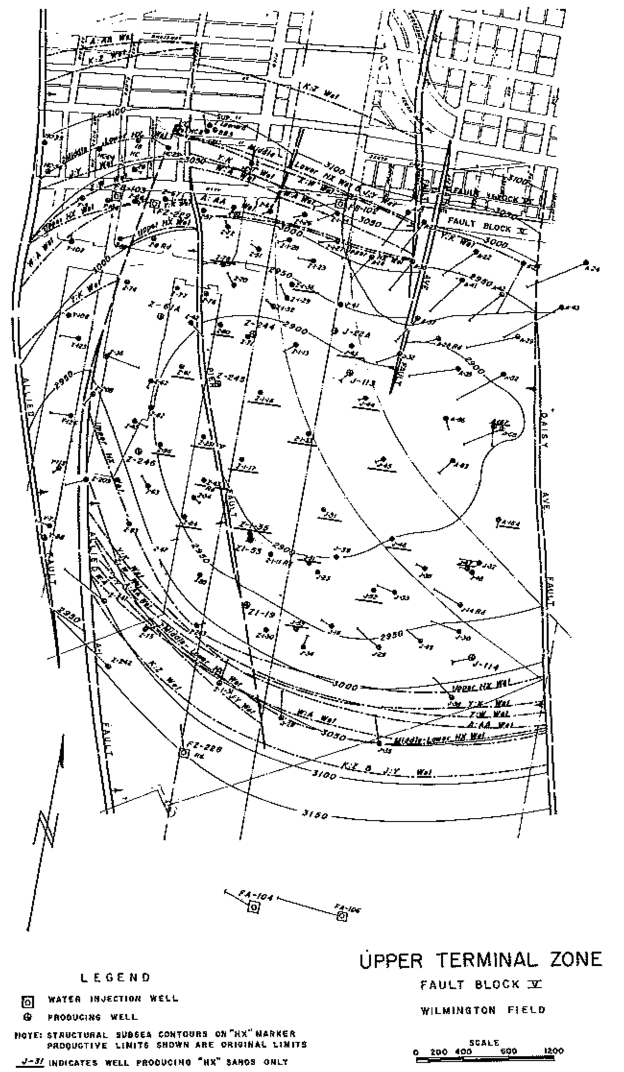
Source Wells—Injection water is salt water obtained from shallow source wells ranging in depth from 115 to 400 feet. The sands and gravels containing the source water apparently outcrop offshore and, as a result, are constantly replenished by ocean water. These beds act as a natural filter in addition to furnishing a supply of water much lower in free oxygen content and suspended solids than water obtained directly from the ocean. With the exception of the free oxygen content, the source water has the same composition as ocean water.

The water leaving the source wells is run through desanders (sand settling tanks or cyclone separators) prior to receiving chemical treatment. A variety of chemical inhibitors have been used to reduce corrosion in the pumps, distribution systems and in the injection wells.

Injection Wells—The first injection wells in the pilot flood, Z-228F and Z-229F, were completed in May and June 1953 on the north and south flanks of the structure. These wells were completed by cementing 7-inch casing solidly through the HX sands, and selectively gun perforating the upper one-third of the HX interval. Normal completion practice has been to circulate the hole clean after perforating and to place the well on injection by injecting down the casing or a combination casing and tubing and packer arrangement, or to inject down the tubing only with the tubing set on a packer at the top of the injection interval. In most of the injection wells, blank intervals opposite shale beds are tested for soundness of the cement bond between the casing and the wall of the hole prior to perforating the injection interval. This is done in order to obtain a means of subdividing a large sand body or individual sand groups into subsections where selective injection may be required to control the advance of the flood water.

In the past, many wells in the Wilmington Field have been seriously damaged in the casing string by differential horizontal movements of strata which have, in many cases, completely sheared the casing, resulting in total loss of the well. This damage occurs between the 1400 ft. and 2000 ft. subsea interval. For the past several years a great majority of the new producing wells and injection wells have been provided with a "bell-hole" which is an enlarged diameter section of the drilled hole through the 1400-2000 ft. drilled interval. This is accomplished by scraping the drilled hole from the normal hole diameter of 10⅝ in. or 12¼ in. to 22 inches. The annulus between the casing and the hole is then filled through ports in the casing with a high gel strength fluid from the top of the cement outside of the casing to the surface. The "cushion" provided has been very effective in minimizing casing damage.

Experience gained during the operation of the first injection wells led to more satisfactory completion techniques in the remaining wells. It was observed that running and pulling packers in constant diameter casing was slow and wore the packers excessively. It was also believed that the swabbing action



▼Figure 3. Upper Terminal Zone, Fault Block V, Wilmington Field.

induced by the packers when pulling them might cause premature casing failure if done too often. A combination 9⅝ in. x 7 in. casing string was tried in a follow up injection well; however, this completion method was discarded in favor of a water string and liner type completion where a 9⅝ in. water string is cemented at the top of the producing zone, and a 5½ in. blank liner is then cemented solidly through the zone and selectively jet perforated using two to four holes per foot. Factors such as lost circulation, caving hole, high angle holes (as much as 56°), requiring very close control, made it desirable and prudent to adopt the water string and liner type completion. In addition, improved injectivity has been realized by changing the mud system over to special completion fluids after setting the water string.

It is of interest to note that several of the wells drift horizontally over 3100 feet from the surface location. Subsea depths of approximately 3500 feet coincide with a drilled depth of 5000 feet, with measurements made from the rig floor at an elevation of approximately 27 feet above sea level. The availability of surface locations has been a critical problem in the development of Fault Block V in that much of the productive sands are overlain by the Harbor waters. As a result, surface locations and bottom hole locations are usually separated horizontally by several hundred feet.

Injection well costs have varied from $85,000 per well to $139,000. Included in the $139,000 figure is a $14,000 coring program.

Injection Plants—Three plants supply the water to the Upper Terminal Zone injection wells. These plants utilize both triplex and quintuplex plunger pumps driven by gas powered reciprocating engines. Plant capacities vary from 21,000 B/D to 121,000 B/D at pressures up to 2000 psi. In addition to supplying water to the Upper Terminal VB injection system, these plants also provide water for other injection projects in operation in Fault Block VB and in other fault blocks. The cost of the original 21,000 B/D plant was approximately $180,000. The cost of the 121,000 B/D plant was $978,000.

Production and Injection History

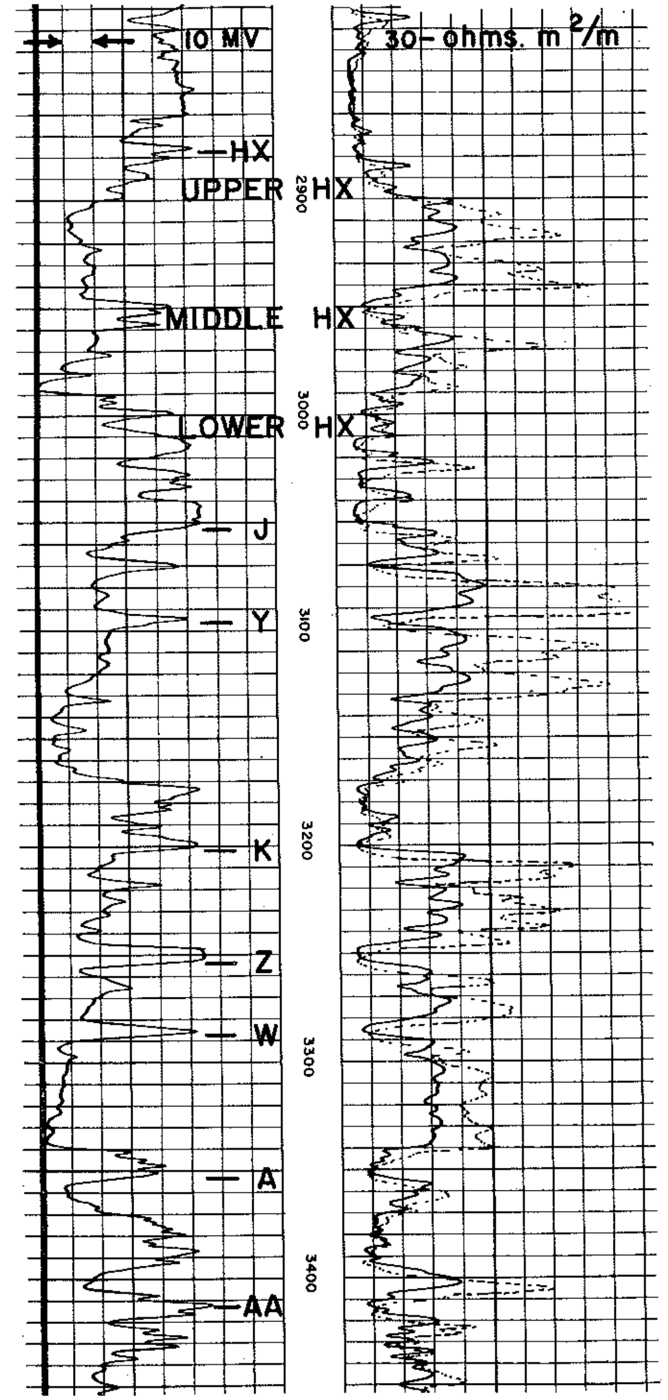
History of Production—The first production from Upper Terminal VB was from a crestal well completed in December 1944. This well was shut in because of an excessively high gas-oil ratio and full development of the zone was not resumed until late 1947 when several downstructure locations were drilled. Orderly development continued until March 1950 when the K and Z sands were found productive in the townlot area to the north. This touched off a competitive drilling campaign that resulted in the completion of 70 new wells and brought the pool total to 126 wells by January 1952.

Heavy withdrawals caused rapid water encroachment on the north flank and the early abandonment of townlot wells. As a result, by early 1952 it was possible for the Harbor Department to resume gas-oil ratio control and to prepare plans for gas and water injection in the Upper Terminal VB pool since essentially all commercial oil production was on Long Beach Harbor Department tidelands property. The production history for the the period 1951 through August 1960 is shown in *Figure 5.*

The large drop in producing wells in early 1952 reflects the curtailment of high gas-oil ratio producers. The subsequent decline in producing wells during 1952 and 1953 was a result of shutting in watered out K and Z sand producers north of the tidelands boundary, and the conversion of a few Harbor Department wells to gas injection. In December 1958 a further curtailment of high gas-oil ratio wells took place. Most of this group of wells have since been put back on production as low gas-oil ratio producers as a result of the flood.

History of Injection—The Long Beach Harbor Department during the year 1952 formalized plans to proceed with pilot waterflood operations in order to establish the economics of flooding, and to explore the possibility of flooding as a method of subsidence alleviation.

In June 1953 a pilot water injection program was started into the upper HX sand in Fault Block VB between the Allied A-1 and the Pier A Faults on the belief that the Pier A Fault separated the main part of the block from the pilot area. Subsequent performance indicated injection water was not confined to the pilot area as the main portion of the block was being influenced by the flood. Since the producing wells in the main area, unlike the pilot area, generally included the full section of HX, it was necessary in



TYPE
ELECTRICAL
LOG

UPPER TERMINAL ZONE
FAULT BLOCK VB
WILMINGTON FIELD

FIGURE 4

▼Figure 4. Type electrical log. Upper Terminal Zone, Fault Block V-B, Wilmington Field.

March 1957 to start injection into the full HX interval.

In June 1958 injection was started into the J, Y, K, Z, W and A sands on the south flank of the structure and subsequently in May 1959 the Y, W and A sands were included on the north flank. This was followed in September 1959 by the J, K and Z sands which put the full Upper Terminal Zone of VB on flood. Currently, there are six water injection wells operating in the zone. The wells operate with surface injection pressures ranging from 860 to 1050 psi. Individual injection well rates range from 3500 barrels per day to 15,000 barrels per day.

In July 1953 gas injection was started on the crest of the structure in the Upper Terminal Zone of Fault Block VB, and except for a short period in 1953 and early 1954 when the HX sand received gas, all Upper Terminal gas injection was confined to the six lower sands. The gas injection program was suspended in February 1960. The effect of water injection by this time had been to cause the high gas-oil ratio area to contract and several wells which were previously curtailed were found to be low gas-oil ratio producers. During 1960 additional wells near the crest of the structure have exhibited low gas-oil ratio performance and as a result have remained on production.

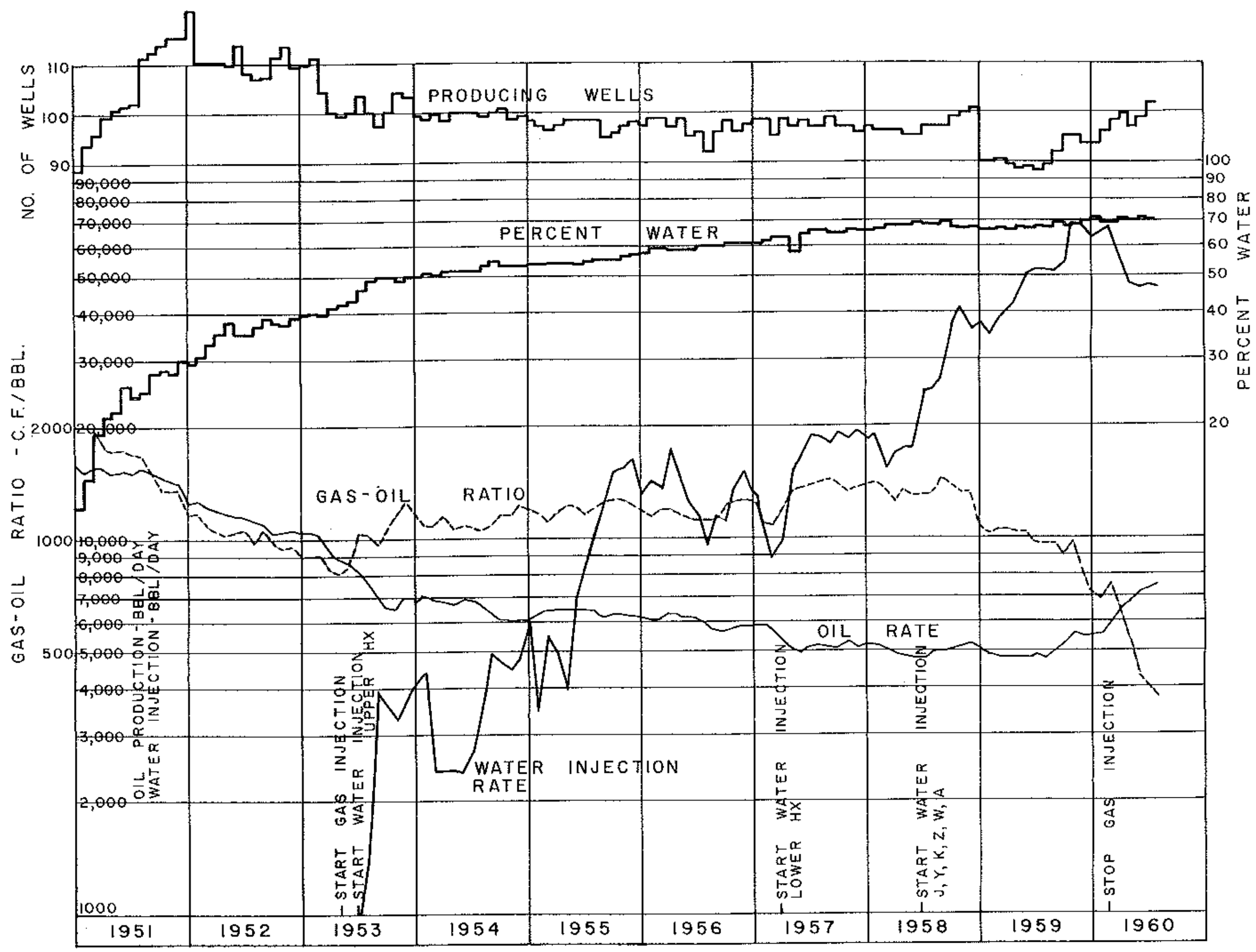
Waterflood Performance

Injection Water Control—Distribution of injection water to meet the requirements of individual sands has been based on volumetric calculations utilizing original sand volumes, original productive limits, and formation and saturation characteristics of each sand. This should assure repressurization of all sands. In addition, vertical distribution has been designed to flood the lowermost sands progressively ahead of the upper sands.

General practice in injection well completions throughout the tidelands properties has been to open the first injection well to all the productive sands in each zone. The exceptions to this are the two pilot injection wells. Subsequent injection wells are then selectively perforated to complement first wells for selectivity of injection. Adjustments for control of the selectivity in the completion program and control of individual well injection rates during subsequent operations have been based on information obtained through the periodic running of spinner and temperature surveys.

Distribution of injection water in multi-sand injection wells has been improved by selective plugging and the use of formation testers to cause the well to backflow and clean out the well bore. Where additional control has been necessary, single and multiple packers have been used. As mentioned previously, the cement bond in the blank intervals between the main sand bodies is tested to insure an effective separation of the main sands. Considerable success has been realized in obtaining the desired distribution of injection water by the foregoing methods.

The volumetric approach for estimating the desired injection volumes for each sand was considered a necessary starting procedure. It has always been considered that these pre-determined rates would require adjustment based on observation. In order to observe the flood progress in detail and to more closely control the distribution of injection water to individual sands, a series of single sand producing wells has been placed about mid-way between each flank and the crest of the structure. A continuous



▼Figure 5. Upper Terminal Zone, Fault Block V-B.

check on productivity, water-oil ratio and gas-oil ratio is made in these wells. Periodically, pressures are taken in the wells in order to develop trends that will aid in checking on the balance between withdrawals and injection rates into each sand.

The histories of all producing wells are up-dated monthly and reviewed for anomalous performance in respect to water-oil ratio, gas-oil ratio and total stimulation. In cases where a high water producing edge well has reached the economic limit of production, and is subject to being shut in, a review is made on the desirability of continuing the well on production for the purpose of using the well as a means of controlling the flood front. Further consideration is given to the possibility of converting the well to an injection well.

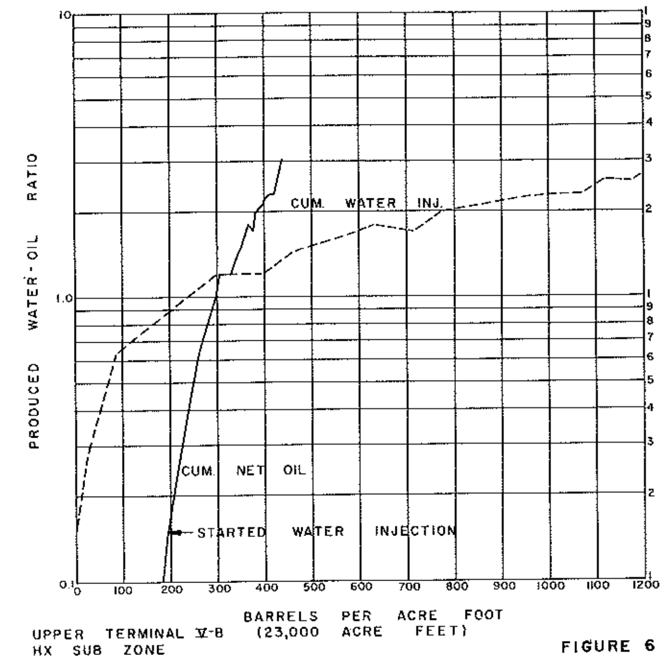
Performance—During the first two years of injection, the improved performance of the HX pilot flood was limited to reduced producing gas-oil ratios and reduction of the pool decline rate. After observing that injection was not confined to the sub-fault block, it was concluded that injection rates were too low for the total HX sand in Block VB. It has been determined that the injection rate averaged approximately 0.15 barrels per day per acre-foot of sand during this period.

Injection rates were substantially increased in May 1955 and preparations were started for opening the full interval of the HX sand to injection. During 1956 and 1957 individual well gas-oil ratios declined sharply throughout the HX sand with accompanying increases in oil rate or a reduced rate of decline in most wells. Water production has increased continuously since the start of injection in HX and, except for isolated cases where a well produces in a trapped area next to a fault, subordinate phase flooding has been the rule. Current gross rates in wells producing the HX sand only average 340 barrels per day. The gross production ranges from 80 to 725 barrels per day.

Figure 6 shows the relationship of produced water-oil ratio to cumulative oil production in the HX sub-pool for the past seven years of flooding. Current oil production of the HX sand is .08 barrels per day per acre-foot.

When the lower six sands of the Upper Terminal VB pool were included in the waterflood program, an initial injection rate of approximately 0.5 barrels per day per acre-foot was used. As a result, the effect of flooding these sands has been much sharper and was obtained much sooner than in HX, in that first line wells to the aquifer were showing stimulation within three to four months.

Edge wells in the lower six sands have increased in water production along with oil stimulation; however, a large prolific crestal area has developed where producing wells show good oil stimulation and little



▼Figure 6. Upper Terminal V-B, HX Sub Zone.

or no water production. This is reflected in the average pool water cut which has shown little increase since the start of full scale flooding, *Figure 5*. The oil production rate for the lower six sands of the Upper Terminal Zone, Fault Block VB in July 1960 was 3000 barrels per day above that which would be expected for the normal primary production. This is based upon an extrapolation of the primary production curve from June 1958. Approximately 2400 barrels per day can be accounted for in individual well stimulation, and the remaining 600 barrels per day is due to resumed production in the previously high gas-oil ratio crestal area. In addition to this, a projection from 1953 for the HX sand indicates a current oil rate which is approximately 1300 barrels per day above that normally expected under primary operations.

Average reservoir pressures had increased by July 1960 from 625 psi to 830 psi in the HX sand and from 440 psi to 575 psi in the J through A sands.

The crestal area of the structure contains several locations for new well development that heretofore were not drilled because of the high gas-oil ratio performance indicated. Recent isogors drawn across this area indicate that development of these locations can be started. These locations should add substantially to the total pool oil production rate with only a minor increase in water production.

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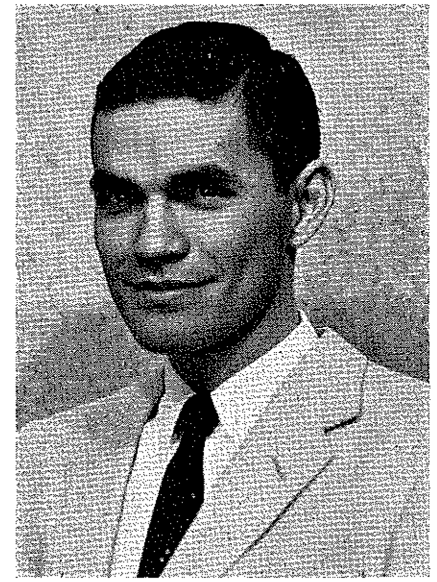
Miscible Displacement

By J. B. MATTEI



J. B. MATTEI

Introduction

During the past few years there has been a great deal of attention given by the oil industry to various new recovery processes, all of which have the same objective—to get more oil out of the ground than has been possible in the past by primary means and by conventional water or gas injection techniques.

One class of these new recovery processes is termed "miscible displacement." This term means that oil is displaced by a fluid which is completely miscible with the oil—in other words, by a solvent in which the oil can dissolve if it is not pushed out of the way. The usual displacing fluids, water or gas, are not miscible with oil because capillary forces hold some of the oil in place and prevent its displacement even under the best natural drive or conventional secondary recovery conditions. The capillary forces are not present if the oil is pushed by a liquid that is miscible with the oil.

It should be pointed out that solvents have been used for many years to clean cores of their residual oil for core analysis measurement. The oil-miscible solvents, however, are expensive and it has long been thought that miscible displacement in a reservoir, though efficient, would be uneconomical because of the cost of the great quantities of materials necessary to replace all of the oil produced. The average costs of some of the materials that can be used in oil displacement are shown in the following table:

Material	Cost $/Barrel Injected
Water	0.02
Gas	0.15
LPG	1.75
Crude Oil	2.50

Research had to come up with some way of using a fairly small amount of miscible material for miscible displacement to be a practical process in the field. This has been accomplished to some extent by laboratory work; however, miscible displacement is still in its infancy and has been proven generally successful only in the laboratory. There have been about 44 field projects put into operation in the United States (some of which will be discussed in

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some detail later on), of which nine have been terminated. Most of the active projects are too new for satisfactory evaluation, and all of the major projects are still currently in operation.

The most widely discussed miscible displacement processes have been termed (1) "high-pressure gas," (2) "LPG or solvent slug," (3) "enriched gas," and (4) "simultaneous enriched gas and water." Each of these processes has received a great deal of attention in the laboratory by many oil companies, and all are currently being tested in the field. In all of these processes except the slug process, miscibility has to be developed in the reservoir. In the slug process, the slug itself is miscible with the reservoir oil. For the other processes to work, the sharp interface between the displaced and displacing fluids must be eliminated. This is accomplished by creating in the reservoir a mixing zone between the injected and produced fluids, in which the fluid properties grade from those of the displaced to the displacing medium. Under these conditions, capillary and interfacial tension forces are not believed to be present.

The elimination of these capillary forces makes 100 per cent recovery from contacted areas possible. However, the adverse mobility ratio present in the various miscible displacement processes results in fingering and channeling and tends to cause poor pattern and conformance efficiency. This condition is responsible for the currently widespread belief that the favorable mobility of simultaneous enriched gas and water injection will make that process more applicable than any other, although the other types of miscible displacement will continue to be useful in certain cases.

Each of the four miscible displacement recovery processes will be discussed separately, first by explaining the theory by which these processes are believed to operate and then by given examples of their

application in the field. In this discussion, several terms will be used which it would be well to define at this time. These terms are "pattern," "conformance," "displacement," and "recovery" efficiencies:

Pattern Efficiency—The volume enclosed by the outer limits reached by the displacing fluid at depletion divided by the total volume of the reservoir.

Conformance Efficiency—The pore space in the pattern volume through which the displacing fluid actually moves divided by the total pore space in the pattern volume.

Displacement Efficiency—The amount of oil displaced from the conformance portion of the pattern volume divided by the oil originally present in the conformance portion of the pattern volume.

Recovery Efficiency—The product of pattern, conformance, and displacement efficiencies.

High-Pressure Gas Process

The high-pressure gas injection process will be discussed first because it is the process which was first tried in the field, and it is one which is easily understood. This process was developed by Atlantic Refining Co. The Atlantic process involved injection at a pressure of 3,000 psi or more into a reservoir containing undersaturated oil having a fairly high concentration of intermediate components. The injected gas is enriched through vaporization of these intermediate components from the residual oil in the vicinity of the injection well so that it becomes completely miscible with the reservoir oil. This type of gas drive is quite different from the conventional gas injection process. Normal dry gas injection results in a recovery which may range from as low as 30 per cent to as high as 80 per cent. This wide range of gas drive recovery results from variations of such factors as sand permeability, oil viscosity, and structural dip.

The high-pressure gas process involves the injection at relatively high pressures of a lean (dry) natural gas, mainly methane. Methane is not miscible with most crudes except at extremely high pressures. However, under favorable circumstances, a miscible band can be developed within the reservoir by methane injection. This is viewed as creating miscibility in the reservoir.

What happens with a small "batch" of injected gas when the injection operation is started? This gas comes immediately into intimate contact with the reservoir oil. These are two immiscible phases that will come to equilibrium with each other. The gas will be enriched with intermediates from the crude. In turn, the crude will be stripped of these intermediates. The enriched gas has a greater mobility and velocity than the oil, and it moves on to contact a new "batch" of oil. Again the enriched gas is in intimate contact with the oil and the gas is further enriched.

Each additional contact with the reservoir oil further enriches the gas by a continuation of the process just described. The gas is finally enriched to the point that it has a composition which is miscible with the reservoir crude. Thus, there is developed a band of material in the reservoir that will miscibly displace the reservoir crude. This material will in turn be miscibly displaced by less rich gas following it.

There is one main restrictive condition that must be satisfied in order to develop a miscible displacement by the high-pressure gas process: the reservoir oil must be capable of becoming miscible with the injected material. There is a range of reservoir oil compositions which are suitable for the high-pressure gas process (at a given pressure). If the reservoir oil composition lies in the unsuitable composition" area, the enrichment of the gas will not continue until the gas becomes completely miscible with the reservoir oil.

The gas compositions needed for miscibility may be changed by increasing the pressure. This increases the range of compositions suitable for high-pressure gas. The pressure limit is mainly dependent upon how much pressure the formation overburden will take. Frequently, the formation will not withstand the required pressures—thus, the limited applicability of the high-pressure gas process. In general the high-pressure gas process is applicable only with reservoir fluids relatively rich in intermediate components.

University Block 31 Field Project

The Block 31 (University Lands) Field is located about 20 miles south of Odessa in Crane County, Texas. It was discovered in 1945. The producing formation is the Devonian which is encountered on an anticlinal structure at a depth of 7,900 feet. The reservoir rock is a calcareous and dolomitic limestone. The field covers 7,000 acres and is developed on 80-acre spacing with 73 wells.

The lack of an effective natural water drive and the need for maintenance of reservoir pressure were recognized early in the development of the field, as the reservoir pressure declined rapidly. During the first 3½ years of production, 3.7 million barrels of oil were produced, with a decline in pressure of 500 psi from the original pressure. Gas injection was commenced in 1949.

The original intent was to inject field-produced gas into two or three wells along the crest of the structure to provide partial pressure maintenance in the reservoir, maintain productivity, and increase recovery. However, when laboratory research demonstrated that much greater additional recovery could be obtained by high-pressure gas injection, the injection program was expanded in 1952 to full pressure maintenance. This gas injection program became known as the "high-pressure gas process."

Laboratory research by Atlantic Refining Co. showed that ultimate recovery of oil in the Block 31 Field could be increased by the injection of natural gas at high pressures (3,500 psi) because of: (1) evaporation of oil into the injected gas phase, thus enriching the gas, (2) dissolving of gas into the undersaturated oil, causing an increase in volume of the oil in contact with the gas, and (3) the simultaneous increase of the viscosity of the gas phase and decrease in the viscosity of the oil phase because of the mutual solution effects, effects which increase the efficiency of displacement of oil as the viscosity of the gas phase approaches that of the oil phase.

After the Texas Railroad Commission approved Atlantic's application to undertake full pressure maintenance in the Block 31 Field in 1952, an initial MER (rate) of 10,000 barrels per day was assigned. Increases in this rate were granted as the injection capacity was increased by conversion of additional producing wells to injection wells. By January 1953, with 12 injection wells, the field allowable was set at 13,000 barrels of oil per day. In September, 1953, the rate was increased to 13,500 barrels per day; and currently, with 15 injection wells, the reservoir is assigned an allowable of 15,400 barrels per day.

Gas is being injected on 80-acre spacing with three large nine-spots in the center of the field and fragments of other patterns toward the edge of the field. The mobility ratio is about 10. Approximately 100 billion cubic feet of gas have been injected to date. This injection operation, now completing its eleventh year, still has experienced no major gas channeling or breakthrough.

The only problem that Atlantic has encountered in the Block 31 project is difficulty in building up the desired miscibility pressure in the southern part of the field. This problem is believed due to communication with other reservoirs behind the pipe and is gradually being solved by pressure studies and workovers.

LPG or Solvent Slug Process

The next miscible displacement process to be tried in the field (about 1952) was the LPG or solvent slug injection process. Here, a band or slug of LPG is injected into the reservoir, followed by gas or gas and water injection. The objective is to maintain the band of LPG "wedged" between the gas and oil phase and achieve miscible displacement since the LPG is completely miscible with the reservoir oil. Unfortunately, the slug, which is generally propane, will become diluted through mixing and diffusion as it flows through the reservoir. The factors which control dilution of the propane slug are not readily understood, apparently, and the method of determining the size of the slug to use in a given reservoir is a problem which has not yet been solved satisfactorily.

In the slug process, the oil will be miscible with the propane, and there will be no two-phase region. Thus, at the leading edge of the slug, where propane is mixing with and displacing oil, there will not be an interface. The propane will also be miscible (at reservoir temperature and a reservoir pressure above 1,000 psi) with the gas following it. This means there will not be a two-phase region existing between the propane and the gas. Thus, at the trailing edge of the slug, where gas is mixing with the propane, there will be no interface. It should be noted that a minimum reservoir pressure needs to be exceeded before miscibility will be achieved in the reservoir.

Since a small slug of propane is used, and since there is mixing of propane and oil at one end of the slug and propane and gas at the other end, the slug is continually being dissipated. After some stage of the program, there no longer will be a 100 per cent propane slug present. Instead, an enriched gas will be miscibly displacing the oil.

Miscible displacement will continue until sufficient mixing of the slug with the oil and gas has occurred such that the composition of the diffused slug has fallen below the composition necessary for miscible displacement. This will cause the displacement process to break down into the much less efficient immiscible gas drive. A field operation should be designed (if possible) such that a sufficient slug material is injected to tolerate the mixing without diluting the slug below the composition needed for miscible displacement.

Slaughter Field Project

The Slaughter Field is one of the biggest fields in West Texas. The field covers an area of about 85,000 acres and is developed on 35-acre spacing with approximately 2,500 wells. The top per-well allowable is 74 barrels per day prorated.

The Slaughter Field was discovered in 1937 and has produced approximately one-fourth billion barrels of oil, or about 75 per cent of the estimated primary recovery of one-third billion barrels. The productive formation is the San Andreas limestone found at 5,000 feet. The reservoir produces by dissolved gas drive. The huge field had approximately 1½ billion barrels of oil in place and the prospect is for over 1 billion barrels being left in the ground after primary depletion. However, the size of the field has made cooperative or unitized secondary recovery projects difficult and additional recovery projects within the field are scattered and small.

Currently the Atlantic Refining Co. has a propane slug project on a 1,247-acre lease in the middle of the field. This lease is completely surrounded by other producing properties. This is a factor which has greatly complicated Atlantic's plans for initiating an additional recovery project on their lease because the recovery plans involve a substantial pressure build-up. In spite of this problem, Atlantic decided in 1955, after more than 5 years of laboratory and analytical work, to attempt a miscible displacement of oil from this lease.

In November 1957, the Texas Railroad Commission approved Atlantic's plans. These plans included converting three of the 35 wells to injection service and injecting about 255,000 barrels of propane to be followed by about 3.4 billion cubic feet of gas over the next 2 to 3 years. Then the plans called for injection of about 6,000 barrels of water daily to the end of the program.

This project would force oil toward surrounding leases where the pressure would be much lower. Thus Atlantic felt they would be able to afford a miscible front only until it swept about 40 per cent of their lease. After that, too much oil would migrate off the lease. At that point, the pressure would be allowed to decline to a level comparable to neighboring leases, and the project would be carried to conclusion under declining pressure.

The Atlantic estimate of oil originally in place under their lease was about 32 million barrels. Recovery at the start of the project was approximately 5 million barrels, or about 15 per cent of the original oil. It was estimated that an additional 5 per cent of the original oil could be recovered by continued primary operations. Under the miscible program, Atlantic estimated total recovery from their lease to be about 62 per cent of the original oil or an additional 16 million barrels over primary. As compared with waterflood, the miscible program will net only about 2½ million barrels more of the original oil, but would be higher if the operation dealt with an entire reservoir and did not face the problem of pushing oil off the lease.

In May 1958, Atlantic commenced injection of propane and by early July 1958 had injected the 255,000-barrel slug as planned. This was quite an accomplishment in itself, as large quantities of propane are hard to find in West Texas. Atlantic managed to get the required volume by having it hauled from nine gasoline plants scattered over a 150-mile radius in West Texas. Twenty-five tank trucks worked 24 hours a day for nearly 60 days to haul propane to the Atlantic lease. Atlantic timed their propane purchase to obtain seasonally low prices.

Immediately after propane injection was completed in July, 1958, Atlantic switched over to gas and injected gas continuously into all three injection wells until early 1959. Atlantic started injecting water into one well in January 1959 and in the other two injection wells in July 1959. Later, Atlantic started injecting alternate slugs of gas and water in all three wells. An attempt was made to inject water and gas simultaneously in one well, but this method failed as the injection facilities were not designed for this operation.

Atlantic believes that a portion of the reservoir has responded as expected, indicating a fairly homogeneous reservoir with only a minor degree of stratification. Other areas have shown a greater degree of permeability stratification. Early breakthrough of propane has been experienced in some individual strata, but Atlantic believes an oil bank is developing in the major part of the reservoir. A complete study is being made to determine what effect this stratification will have on the entire project. In one area, the performance shows that pressure was not raised fast enough to support miscibility in some of the individual strata.

Although there have been variations in performance, Atlantic concludes that the results to date indicate the project is proceeding largely according to plan. Atlantic also points out that the project is furnishing valuable knowledge concerning miscible-type displacement which could not be predicted by normal engineering calculations or through laboratory experiments.

Although many difficulties have been experienced with the miscible slug method, it still remains the most popular approach to miscible displacement. Nearly half of the 44 miscible displacement projects currently active or completed in the United States are using the technique of injecting LPG followed by dry gas. The main reason favoring this miscible process is economic. However, there still remains considerable disagreement on the question of how much LPG is needed in the miscible slug process. Laboratory work by the Humble Oil & Refining Co. has indicated that the amount needed will vary greatly from reservoir to reservoir. In many instances the slug process must be ruled out from the beginning because of unfavorable reservoir conditions.

Enriched Gas Drive Process

The third miscible displacement process to be field-tested was the enriched gas drive process developed by the Humble Oil & Refining Co. As in the high-pressure process, the injected material is not miscible with the reservoir fluid. This process involves the injection of a gas which has been enriched through the addition of intermediates such as ethane or propane. In the enriched gas drive, the intermediate components are absorbed into the residual oil, with a resulting expansion of the oil, and a decrease in its viscosity. Ideally, a bank of swelled oil is formed which is miscible in all proportions with the oil ahead and the gas behind. In other words the phase boundaries between the oil and the gas disappear.

If the gas is not rich enough or the pressure is not great enough to make the phase boundaries disappear, an immiscible displacement will result. This is the type of displacement that takes place in a water drive or in a normal gas drive. However, even an immiscible displacement using enriched gas can greatly increase recovery because of a reduction in oil viscosity, a swelling of the oil, and vaporization of residual oil into the injected gas.

Note that in this process the mass transfer is opposite to that obtained in the high-pressure gas process. In the enriched gas drive process, the intermediates go from the gas to the oil. In the high-pressure gas process, the gas gets the intermediates from the oil.

The enriching of the oil with intermediates from the injected gas continues with each new contact between the oil and "fresh" injected enriched gas. Finally, the oil will absorb enough intermediate components so that it becomes miscible with this enriched gas, and no two-phase region will exist between them.

Any free gas in the reservoir at the start of the operation will be in equilibrium with the reservoir oil. This gas is miscible with the injected gas and is completely displaced by the injected gas.

During the initial stages of the operation, before the miscible band is built up, the enriched gas moves into the reservoir and residual oil is left behind. As the gas comes into intimate contact with the reservoir oil, the intermediates are partially stripped from the gas. The farther out into the reservoir the gas travels, the more it is stripped of intermediates by the additional contacts with the oil. The gas composition approaches equilibrium with the unenriched crude oil, and no further stripping will occur.

From an economic standpoint it is desirable as soon as possible to stop injecting enriched gas and to shift to a dry gas. Thus, the enriched gas is injected as a slug, and it is displaced miscibly by dry gas. Two questions immediately arise: (1) how rich must the enriched gas be, and (2) how large a slug of enriched gas is necessary. Both of these questions have to be answered to some extent in the laboratory.

The enriched gas must be miscible with the reservoir oil of critical composition, if the enriched gas is to displace this oil miscibly. Also, the enriched gas must be sufficiently rich in intermediates so that when it is in contact with the oil, intermediates will be transferred to the oil. It should be noted that any injected material so rich in intermediates as to be miscible with the reservoir crude without an exchange of components will create a miscible slug process rather than an enriched gas drive. There is also the danger of not enough intermediates being present in the enriched gas to form a miscible front, in which case an immiscible gas drive process will take place.

Seeligson Zone 20-B Project

Seeligson Zone 20-B is one of numerous productive sands of the Frio formation in the Seeligson Field in South Texas. It occurs at a depth of 6,000 feet and has an areal extent of approximately 600 acres.

After discovery in the latter part of 1946, it soon became apparent that the reservoir was producing under a dissolved gas drive mechanism. Because of several favorable conditions, such as uniformity of the sand, complete development, and the need for some form of pressure maintenance, Zone 20-B was selected for an experimental field application of the enriched gas drive method. Unitization was not necessary as there is only one operator and one royalty owner involved. In addition, a field trial of enriched gas drive in the Seeligson area was desirable to determine the applicability of the process to other substantial reserves in the area. The additional recovery of oil from enriched gas drive, as compared with conventional waterflood, is estimated to be 2 million barrels.

Injection of enriched gas commenced in March 1957 through two upstructure injection wells. The injected material was composed of approximately 50-per cent propane and 50-per cent separator gas. The project proceeded smoothly with no indication of rich gas channeling until November 1957, when it was noted that the propane content of the separator gas from a well in the first row of oil wells downstructure from the injection wells had increased. By March and April 1958, the propane content of the separator gas from the three other wells in the first row of offset wells to the injection wells had also slightly increased. On June 1, 1958, these four wells were shut in and their allowables were transferred. Each of the shut-in wells has been tested monthly, however, to aid in evaluating the project.

Current oil allowable in Zone 20-B is 1,000 barrels per day. Cumulative oil production since the project began is approximately 1 million barrels. Cumulative enriched gas injection is approximately 3 billion cubic feet or 20 per cent of the original oil in place. Total recovery to date from the zone is about 1.7 million barrels, or approximately the volume expected to be recovered under primary operations.

Excellent displacement efficiency is being attained in the swept areas as shown by cores and drill-stem tests of a well drilled 100 feet downstructure of an injection well in December 1957. These tests indicated that the sand has been swept virtually clean of oil; however, it is too early in the life of this project to evaluate the degree of pattern and conformance efficiency being achieved.

Simultaneous Enriched Gas-Water Process

When the three miscible displacement processes which have just been discussed were developed, tested in the laboratory, and given an initial field trial, they appeared to be the ultimate in oil recovery because they did flush all of the oil from the formation which they contacted. However, it was soon realized that the high mobility of the injected gas (because of its relatively low viscosity) created very unfavorable mobility ratios.

This meant that the benefits derived from the excellent displacement efficiency would be offset to a great extent by the poor pattern-conformance efficiency that would prevail. To approach the goal of complete oil recovery, the pattern-conformance efficiency of a miscible displacement process must approach 100 per cent. These efficiencies are determined to a great extent by the ratio of the mobilities of the injected fluid and the oil in place.

A practical way to decrease the mobility of the injected material would be to inject water (which has a viscosity of about 1 centipoise) instead of gas which has a viscosity of about 0.02 to 0.03 centipoise. This, however, would not be a miscible displacement since gas must be the displacing fluid for the process to work. What can be done, however, is inject rich gas to form the miscible displacement front and follow this with water and rich gas injected simultaneously. The oil is pushed toward the producing well by the band of gas which is miscible with the oil. This gas band is pushed by water through which flows enough gas to keep the gas band at the proper size. Thus, if the gas band is kept small, the mobility of the water-plus-gas region will determine the pattern-conformance efficiency. It has become apparent that most future miscible displacement programs will involve the injection of water sometime during the life of the project.

An enriched gas-water injection project was initiated by Humble Oil and Refing Co. in the Seeligson Zone 21-A sand in June 1960. This reservoir is a small strand-line deposit covering about 760 acres at a depth of about 6,800 feet.

At the start of the project, there was one injection well and 11 producing wells. A slug of propane was initially injected in order to form a miscible bank. This will be followed by a simultaneous injection of a displacing fluid composed of 50 per cent water and 50 per cent enriched gas. The enriched gas portion will be made up of 50 per cent ethane and 50 per cent dry gas. It is planned to drill another producing well to this reservoir and to convert one of the current producers to an injection well in the near future.

Since this project has just gotten underway, no results can be presented. It is believed, though, that the mixing of the water and enriched gas will lead to low mobility displacement and that the "streaking" effect that occurs under the slug method of injection can be avoided. Humble also believes the water and enriched gas drive will enable it to recover 75 per cent of the original oil in place, compared with an estimated 25 per cent by primary means.

There is one additional miscible displacement process involving gas. This process involves the use of flue gas. Considerable laboratory work has been conducted in evaluating this process, but it has not been tried in the field. Flue gas is a relatively inexpensive replacement for hydrocarbon gases in the various miscible displacement processes but the miscibility relationships are less favorable. A larger slug of gas is required, and it is a problem of economic evaluation whether flue gas should be substituted for hydrocarbon gas.

Conclusions

Given below is a list of some of the reservoir factors which make the miscible displacement process attractive:

1. High dip, elongated oil column, and little or no gas cap.
2. Uniform sand development with good permeability.
3. Low recovery under the primary producing mechanism.
4. Good geologic control.
5. A convenient supply of enriching material.
6. Reasonably high reservoir pressure (about 1,000 psi or more).

Another factor to be considered, the most important of all, is the economic factor. Some of the items which must be considered are (1) the cost of the injected material, (2) the length of time the enriching materials will be tied up in the reservoir, and (3) the amount and value of the injected material that is recovered.

As indicated earlier, there is a considerable spread in cost on a per-barrel basis between injecting water and injecting enriched gas or LPG. For this reason, the economics of miscible drive processes, when compared to full-scale waterflooding are very close, even though the miscible drive process recovers a greater amount of crude oil from the reservoir.

The length of time the enriching materials are tied up in the reservoir is dependent to a great extent upon the oil producing rate to be expected. In many cases, reservoirs with short depletion times must be chosen for miscible displacement projects. In other fields special allowables must be received in order to make these projects economically attractive. Special treatment that some of these projects have already received include Atlantic's allowable of 15,400 barrels per day for the Block 31 project, and a net gas-oil ratio credit for Atlantic's slug process at Slaughter.

Finally, the amount and value of the recovered material must be considered. Since no major field projects have been completed, evaluations to date mainly have been based on laboratory studies. These studies in general indicate that up to 30 to 50 per cent of the injected liquids may be recovered, and up to 70 to 80 per cent of the injected gas may be recovered. Depending on gasoline plant contracts and plant efficiency, about 10 to 30 per cent of the value of the injected liquids may be recovered. Depending on operating conditions and handling costs, about 60 to 70 per cent of the value of the injected gas may be recovered. These are average values and could vary widely for individual fields. Also, if water is injected simultaneously or alternately with the LPG or gas, recovery of the injected materials may be even lower because of the increased lifting costs associated with handling any produced water. The loss in the reservoir of part of the value of the injected material also tends to close the economic gap between miscible drive projects and water-flooding projects.

In conclusion, it can be stated that the various miscible displacement processes offer considerable potential. Miscible displacement has a good future, and it will increase oil recovery greatly in many instances. But field projects involving these processes will require the utmost in planning to become consistently successful and economically attractive.

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Waterflood Performance In Stratified Reservoirs*

By R. V. HIGGINS and
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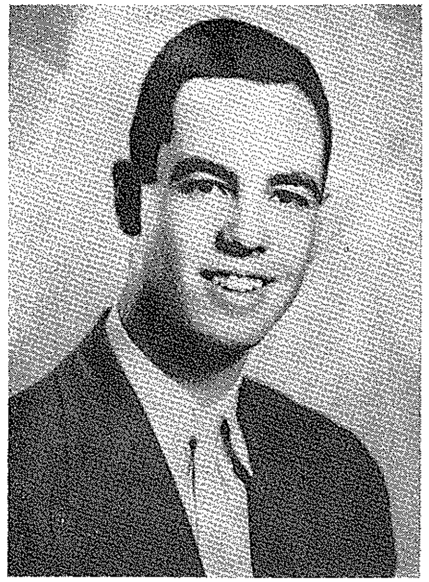

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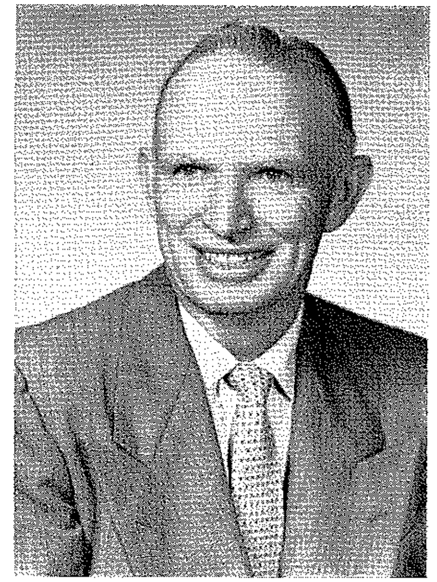

RALPH V. HIGGINS

Introduction and Summary

Because of the difference in permeability of the layers in reservoir sand, the more permeable layers are depleted of oil long before those less permeable. In some reservoir sand the depleted layers may contribute so much water to the combined production from all layers that the flood may have to be abandoned earlier than anticipated owing to an excessive water-oil ratio. Under these conditions, the recovery of oil is low because of the oil remaining in the less permeable layers. The purpose of this study is to evaluate as thoroughly as possible the effect of layers of different permeability on recovery as a function of the water-oil ratio to ascertain ahead of time the potential oil recovery. The changes with time in the saturation distribution in each layer, combined with its effect on the effective permeability, are used in the calculations.

As water enters and moves through a single layer of reservoir rock, the permeability to oil and water and the oil saturation change continuously. Related changes of different values take place in other layers of the same reservoir sand. The combined effect of all these changes influences the recovery of oil from the reservoir.

A method for calculating oil recovery that takes into account all these changes in saturation and permeability and other variables, such as pressure, time, length, and rates, is presented in the report. Because of the number of computations involved, the method was programmed and was run on the high-speed digital computer. Although the computer has made this analysis a practical operation, much thought and effort has been used to keep the number of procedures to a minimum in order that the computer cost will not be a deterrent to the use of the method. Moreover, the authors have made every effort to minimize the complexity of the techniques so as to encourage general acceptance of the method by reservoir engineers.

In the programing procedure for the computer the reservoir was divided into cells, and the quantity of oil and water flowing from each cell during a short interval of time was determined from the saturation and the permeability relations existing in each cell. The injection of water into the first cell and the flow of oil and water from cell to cell and out the last cell result in a change in saturation in each cell. The permeability corresponding to the changed saturation is averaged with the permeability before the change. From the average permeability and the pressure drop across the cell, the average rate of flow of oil and water from each cell for an increment of time is determined. This results in a new saturation. Progressively, the oil saturation of the reservoir is lowered, and the water-oil ratio of the effluxing liquids is increased.

Where the effective permeability-saturation relationships of the layers of the reservoir rock differ only by a multiple from that of the calculated layer, all the information necessary to calculate the combined recovery at a definite water-oil ratio can be determined from the calculated layer by use of dimensionless ratios. Otherwise, each layer has to be calculated individually.

Dimensionless ratios may be used also to calculate the performance of single layers that differ in absolute permeability, length, width, and pressure drop where the effective permeabilities to oil and water for the same water saturation differ by a constant multiplier from that of the model. Under this condition the preceding variables are either directly or inversely proportional to the performance of the model.

The electronic-computer calculation procedure results in an average water saturation at breakthrough which is virtually the same as that obtained by the Welge[7]** and Buckley and Leverett[2] methods.

This report presents the oil and water rates, water-oil ratio, and recovery as a function of time and permeability for a natural, or augmented natural, water drive in a single-layer reservoir rock containing an oil having a 2-centipoise viscosity.

The details for a 10-layer reservoir and a curve for a 20-layer reservoir also are given. The procedure is the same for any number of layers because the performances of the individual layers are summed. The results also are given for a natural water-drive reservoir containing an oil having a viscosity of 20 centipoises. Included also are the results of a waterflood of reservoir rock after fill-up, that is, after pores containing gas are filled with water to a saturation of 0.4.

In the examples of multiple layers, permeability variation of the layers was chosen to be about 0.6, according to the Standing, Lindblad, and Parsons[5] scale.

The effect on recovery of multiple layers of different permeability in a linear flood have been treated by Stiles[6] and by Dykstra and Parsons[3]. In their methods they assume a constant saturation of the displacing phase after the passage of the oil bank. They also assume no production of oil from a layer after the oil bank has reached the outlet face. As the procedures given in this report take into account the effect of the continuously changing saturations and permeabilities, also the contribution to recovery of the oil flowing after the breakthrough of the oil bank, the computations required are correspondingly greater. Nevertheless, the maximum computation time required on a high-speed digital computer for complete evaluation with a minimum of "printout" was 10 minutes.

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Nomenclature

C_1, C_2, C_3 = Constants in water-relative-permeability-saturation equation.

D_1, D_2, D_3 = Constants in oil-relative-permeability-saturation equation.

h = Thickness of "pay."

K_a = Absolute permeability of reservoir rock.

k_o = Relative permeability to oil.

k_w = Relative permeability to water.

L = Distance between input and output wells.

P = Pressure.

Q_o = Oil-flow rate.

S_w = Water saturation.

t = Time used in model relationships.

w = Width of layer (distance between adjacent input or output wells).

General Principles—Single Layer

The term "single layer" as used in this report signifies a layer of reservoir rock of uniform thickness whose permeability-saturation relation to oil and water is represented by only one set of curves throughout the layer.

The effect of capillarity is not considered, because Blair, Douglas, and Wagner[1] and Rapoport and Leas[4] have shown that capillary factors may be neglected when the distance between the incoming water and the outgoing oil is as long as the distance between wells in field reservoirs.

Only linear flow is considered. Linear flow has been and still is being used to approximate either the performance of a line-drive or peripheral water-flood or the performance of a natural or augmented water drive.

For analysis the single-layer reservoir is divided into linear segments and each segment into cells. A previously specified quantity of water enters the first cell for an interval of time. From the effective permeability-saturation relations the quantity of water and oil leaving each cell during entry of water into the first cell is calculated. For material balance the combined volume of oil and water leaving each cell equals the volume of water entering the first cell. The resulting volume changes of each cell, owing to the volume of oil and water entering and leaving the cell, are calculated. From the new saturations new permeabilities are calculated. New and old permeabilities are averaged. The average rates of oil and water flow are determined for each cell from the average permeabilities, the quantity of water entering the first cell, and the total pressure drop. Then calculations are made for the entry of another specified quantity of water. During each step the elapsed time, accumulative time, quantity of oil and water leaving each cell, accumulative production, and quantity of oil remaining are determined.

Example Calculations

In the following calculation of oil recovery for one layer from a natural water encroachment or a stimulated natural water drive, the distance between wells in the line-drive pattern is 600 feet, the thickness of the "pay" is 100 feet, and the pressure drop between the line of input and output wells is adequate to produce initially 1,100 barrels of oil per day per well. In these studies a constant pressure drop is maintained across the layer during a flow history. The layer for these examples is divided into 40 cells. Viscosities of the oil and water are 2 and 1 centerpoises, and initial water and oil saturations are 0.2 and 0.8, respectively. Interstitial water saturation is 0.2 and irreducible oil saturation 0.2. Relative permeability relations as a function of saturation used for the examples are:

$$k_o = \frac{0.200\ (0.8 - S_w)}{1 - 1.3333(0.8 - S_w)}$$

and

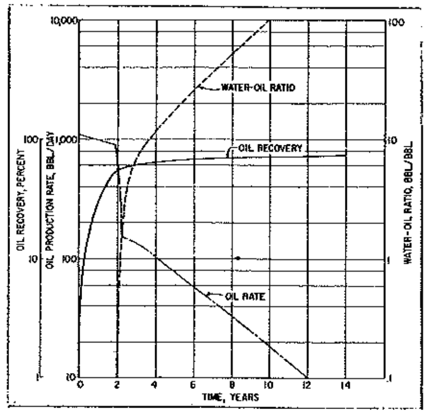
$$k_w = \frac{0.200\ (S_w - 0.2)}{1 - 1.3333(S_w - 0.2)}\ .$$

Most of the pressure drop in a line drive occurs near the input and output wells. This loss is usually considered an energy loss and not a recovery loss. In most of the reservoir, calculations will show that only a small pressure drop is required to produce 1,100 barrels of oil per day per well when the spacing between wells is 600 feet and the "pay" thickness 100 feet. In linear flow, this drop takes place through an area of 600 by 100 square feet and along a distance of 600 feet. The pressure drop is 33 p.s.i. for a 2-centipoise oil in a reservoir sand having an effective permeability to oil of 600 millidarcys (md.).

In *Figure 1* are plotted data from the "print-out" tables from the computer, showing the oil rate, water-oil ratio, and the percentage recovery as functions of the time. These data are of chief interest to the reservoir engineer.

* This article, RI Bureau of Mines Report of Investigations 5618, has been condensed especially for The MINES Magazine by the authors.

** Superior numbers refer to items in the bibliography at the end of this report.



▼ **Figure 1. Oil Rate, Water-Oil Ratio, and Percentage Recovery Versus Time From a Well 600 Feet From an Active Edgewater. (Thickness of Pay, 100 Feet, Single Layer; Initial Production of Oil, 1,100 Barrels Per Day; Initial Oil and Water Saturation, 0.8 and 0.2, Respectively; and Viscosity of Oil in Place, 2 Centipoises.)**

Model Properties

Although the data in *Figure 1* were obtained from a specific example, they can be used as a model. For instance, the oil rate would be doubled for a reservoir twice as thick. If the pressure were doubled, the flow rate also would be doubled. If the effective permeability-saturation relations were multiples of 2 (same rock properties but different permeabilities to air), the time scale would be shifted by the reciprocal of 2 or by ½; that is, where 1.0 is the time it would become 0.5, and the remaining time changes would be proportional. These proportions can be generalized by the use of dimensionless ratios.

When the model is generalized, the ordinate and abscissa values remain the same and the new values are obtained as follows:

$$Q_{o(new)} = Q_{o(model)} \times \frac{P}{P_{(model)}} \times \frac{L_{(model)}}{L} \times \frac{h}{h_{(model)}} \times \frac{w}{w_{(model)}} \times \frac{K_a}{K_{a(model)}}$$

Water rate has the same relationship as the oil rate. When the effective permeability-saturation relations of two rock layers are in the same ratio as the air permeabilities of the two rocks, the abscissa for the oil rate, water-oil ratio, and recovery curves can be represented by:

$$t_{(new)} = t_{(model)} \times \frac{K_{a(model)}}{K_a} \times \frac{L}{L_{(model)}} \times \frac{P_{(model)}}{P}$$

Multiple Layer Reservoir

Many reservoirs, especially in California, have pay thicknesses greater than the well spacing and in geological time were laid down in what is conveniently termed "layers of different permeabilities." These layers have led to the "layer principle" to aid in approximating the performance of reservoirs. This approach is more scientific than a guess at a permeability that will represent the average performance of all layers.

Where the effective permeability-saturation relationships of these layers are multiples, the model relationships presented in the section on "Model Properties" make it relatively easy and inexpensive to calculate the performance of the reservoir. Recovery and oil and water rates are computed for each layer for a given time and added to give the reservoir recovery and oil and water rates. The quotient of the total water and oil rates is the water-oil ratio. If the relationships are not multiples it is still relatively easy but costs more, as each layer would have to be evaluated separately by the computer for each set of permeability-saturation curves.

Example Calculations

Several specific examples have been worked to show the effect on the recovery of oil from hypothetical reservoirs having layers of reservoir sand whose permeability-saturation relationships are multiples of K_a.

Table 1 gives K_a for the 10- and 20-layer examples. These K_a distributions were chosen to give a factor of 0.6, using the scale of Standing, Lindblad, and Parsons. The average permeability of the layers is made equal to that of the model so that the conductivity to oil and water of the layers will equal that of the model at the initial stage. Thus, a comparison can be made of the effect of a permeability variation factor of 0.6 on the recovery of oil by natural water drive.

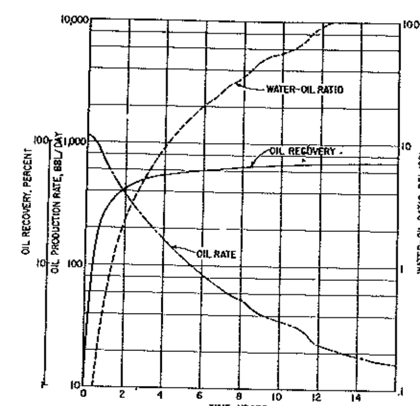
For the examples in which the reservoir rock contains 2-centipoise oil, the effect of layers of different permeability is not as pronounced as it would be in a reservoir containing a more viscous oil, owing to the relatively high recovery at breakthrough for a nonviscous oil. Nevertheless, a comparison of the calculated performance of reservoirs with and without layers of different permeabilities *(Figs. 1 and 2)*, but having the same gross initial conductivity to water and oil, shows the expected trend. The recovery of oil is higher in the life of the flood and stays higher for the same water-oil ratio compared with the reservoir with multiple layers of different permeabilities.

The waves in the oil rate and water-oil ratio in *Figure 1* are due to the sudden drop in oil production, because the breakthrough of water has occurred for one of the layers. The oil rate at this time in the life of the field is low and therefore sensitive to the contributions from the layers.

Figures 2 and 3 show that an increase from 10 to 20 layers does not change appreciably the oil rate, recovery, or water-oil ratio, when the viscosity of the oil is 2 centipoises and the permeability relations are those used for this example.

Recovery of 20-Centipoise Oil

Figure 4 shows the calculated oil recovery, oil rate, and water-oil ratio as functions of time when the viscosity of the oil is 20 centipoises instead of 2. The starting conditions are identical to those shown in *Figure 1*; the only difference is the tenfold increase in viscosity. The oil rate in *Figure 4* followed the normal trend. It was low at the beginning because of the resistance offered by the viscous oil. As the water saturation behind the advancing oil bank increases, the overall resistance is lowered and the oilrate increases. After breakthrough the oil rate does not decline as rapidly as does the oil rate for the 2-centipoise oil. This slower decline is to be expected, as breakthrough occurs at a lower water saturation, and the contribution to recovery after breakthrough is substantial—long subordinate phase.



▼ **Figure 2. Production History From a 20-Layer Reservoir, of Which Each Layer Has a Different Effective Permeability to Oil and Water. (Oil Rate, Water-Oil Ratio, and Percentage Recovery From a Well 600 Feet From Edgewater. Pay Is Composed of Twenty 5-Foot Layers, and Effective Permeability to Oil and Water to Each Layer Is Different, but Initial Gross Conductivity to Oil and Water Is the Same As That for the Single Layer Shown in Fig. 1.)**

TABLE 1.—Permeability of layers of 10- and 20- layer reservoirs

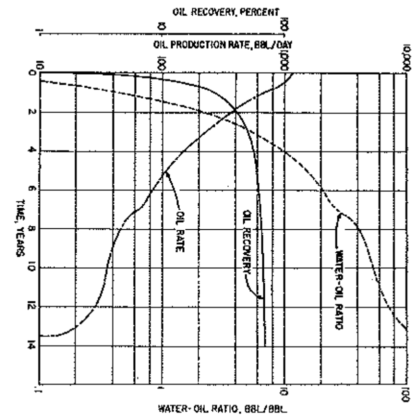
Layer No.	Absolute permeability, md. 10-layer reservoir	20-layer reservoir
1	3,190	3,950
2	1,800	2,600
3	1,300	1,920
4	990	1,630
5	780	1,420
6	620	1,200
7	500	1,020
8	380	960
9	280	820
10	160	720
11		640
12		560
13		520
14		450
15		410
16		350
17		290
18		240
19		180
20		120
Average	1,000	1,000

After breakthrough the water-oil ratio remained relatively flat during the subordinate phase. The accumulative oil recovery for the 20-centipoise oil was much less for the same elapsed time than that of the reservoir containing the 2-centipoise oil. These results show that the computations give saturation distributions that virtually reproduce those obtainable by frontal advanced techniques.

Recovery After "Fill-Up"

Many reservoirs having no natural water drive are potential projects for waterflooding after part of the oil has been recovered by the expansion of dissolved gas. To aid in evaluating the reservoir performance of potential waterfloods with this history, the space occupied in the pores by the free gas is considered to be filled first with injected water. Then the potential recovery of oil by waterflooding is calculated. The data in *Figure 5* pertain to such a reservoir evaluation. The only difference between the starting conditions in *Figures 1 and 5* is the water saturation used for "fill-up." In *Figure 5* a starting interstitial water saturation of 40 per cent was used instead of 20 per cent as in *Figure 1*. In other words, 20 per cent of the pores was considered to have been produced, first by expansion of dissolved gas then by filling with injected water.

The oil rate and other data shown in *Figure 5* follow the trend required by reservoir engineering concepts. The oil rate increases until the "bank of oil" passes through the outlet face. Then the oil rate drops rapidly because the recovery of a 2-centipoise oil occurs rapidly.

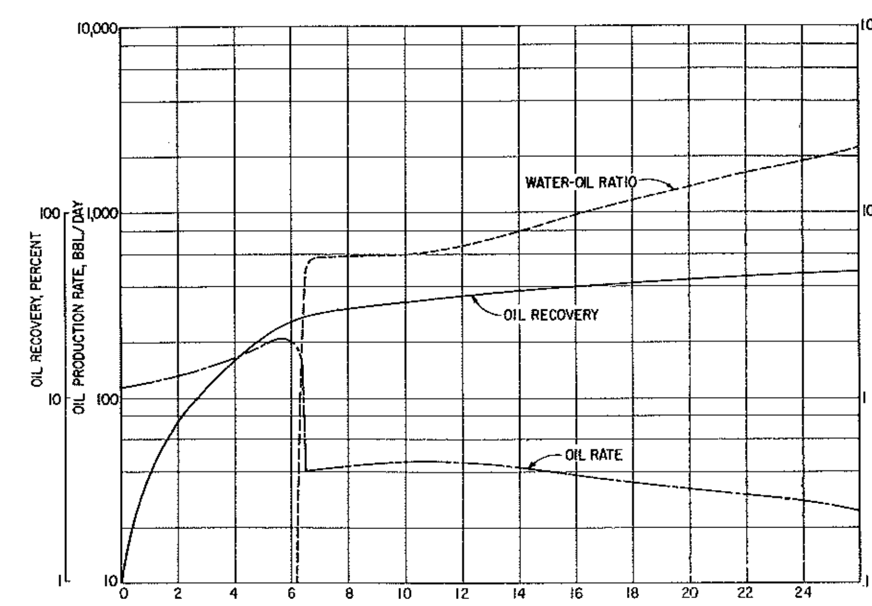


▼ **Figure 3. Production History for a 10-Layer Reservoir, of Which Each Layer Has a Different Effective Permeability to Oil and Water. (Pay Is Composed of Ten 10-Foot Layers.)**

The water-oil ratio curve is flat until the breakthrough of the bank of oil.

Recovery and Water-Oil Ratio

The water-oil ratio is one of the indices used to determine the economic life of a flood. The oil rate also is an index. For example, a thick sand yielding 5 barrels of oil and 250 barrels of water per well per day can be economic when the



▼ **Figure 4. Production History for a Single-Layer Reservoir Having an Oil With a Viscosity of 20 Centipoises.**

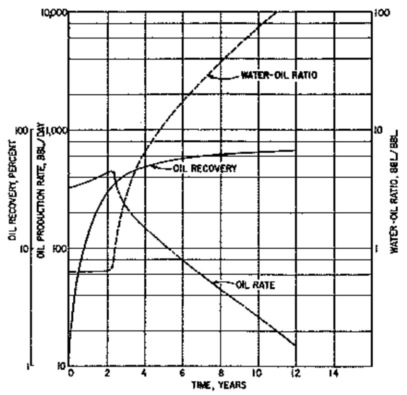


Figure 5. Effect on Recovery of a Waterflood in Single Layer After Fill-Up. (Oil Rate, Water-Oil Ratio, and Percentage Recovery Versus Time From a Well 600 Feet From an Augmented Edgewater, Thickness of Pay, 100 Feet; Initial Oil and Water Saturations After Fill-Up, 0.6 and 0.4, Respectively; and Viscosity of Oil in Place, 2 Centipoises.)

water-oil ratio is 50, but a well yielding only ½ barrel of oil a day with less than a 50 water-oil ratio may not be economic. Accordingly, a thick "pay" has a longer economic life. However, for sand layers of the same thickness, the curves of water-oil ratio as a function of percentage of oil recovery are good comparative indices. Such curves are shown in *Figure 6.* The curves show the expected trend. The highest recovery of oil for the same water-oil ratio is from the single layer containing a nonviscous oil having a viscosity of 2 centipoises.

The recovery from the 10-layer group having an initial combined conductivity equal to that of the single layer is less than that of the single layer for the same water-oil ratio, because the more permeable layers are "watered out" long before the less permeable layers are depleted of oil. The watered-out layers account for the high water-oil ratio.

The percentage recovery for the same water-oil ratio for the single layer containing the 20-centipoise oil is less than that for the 2-centipoise oil. The difference in recovery is of the right order for a tenfold increase in viscosity.

The recovery after fill-up for the same water-oil ratio is low compared with that from the fully oil-saturated layer, because the starting low initial oil saturation results in the production of only a small bank of oil. Recovery for this layer is based on the percentage of oil in place just after fill-up.

The water-oil ratio curves for the 10-layer and single-layer reservoirs containing the 20-centipoise oil have a similar relationship to the corresponding water-oil ratio curves for the reservoirs containing the 2-centipoise oil; that is, the water-oil ratio for the 10-layer reservoir is higher for the same recovery than for a single-layer reservoir. This results from the bank of oil moving more rapidly through the more permeable layers, causing them to become partly depleted sooner than the other layers. Therefore, these partly depleted layers contribute considerable water to the combined production of water and oil.

The water-oil ratio curve for the 10-layer reservoir containing 20-centipoise oil shows less recovery for the same water-oil ratio than the 10-layer reservoir containing the 2-centipoise oil. This expectancy is normal; that is, the higher the viscosity the lower the recovery.

Commentary

At the start of each flood the saturation of the pores to oil and water in each cell was made the same for convenience. With a few changes in the computer program each cell can begin with a different saturation and even have a different set of permeability curves. This could represent the conditions in some reservoirs.

For convenience each cell also had the same size and shape. With a few changes in the computer program each cell can have a different size and shape. This has been done for a five-spot pattern.

Conclusions

A method is presented to calculate performance of (1) natural or augmented natural water drives and (2) waterfloods of reservoirs after fill-up of the pore space voided by the oil that was produced by expansion of the dissolved gas. The method is applicable where the geometry of these floods can be represented by the linear flow of oil and water. A procedure also is given to evaluate the performance of waterfloods when the conductivities of multiple layers in the reservoir differ from one another. In the calculations, changing oil saturation and changing permeabilities with saturation at any time and in every part of reservoir layers are thoroughly used in evaluating the flood performance.

Where the effective permeability-saturation relationships of the layers are the same or differ by a constant multiplier, the computer calculations for one layer can be used as a model to obtain the rates, recoveries, water-oil ratios, and elapsed time for other layers, even though the length and pressures are different. Rates and recoveries of the individual layers were totaled to obtain the performance of multiple-layer reservoirs.

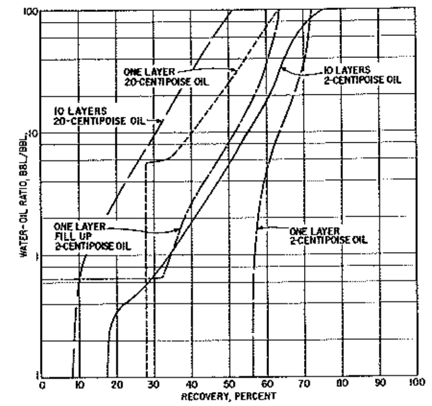


Figure 6. Recovery of Oil and Water-Oil Ratio As Influenced by Viscosity and Layers of Different Permeability.

The authors minimized the mathematical and physical concepts required to make the calculations so as to save computer time and encourage adoption of the method. Nevertheless, the authors believe that the performance of waterfloods has been thoroughly evaluated.

The trend of the result of all calculations fulfills the physical and mathematical concepts of reservoir engineering.

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AND NOW— Complete Automation In Water Flooding*

By E. E. CLARK

E. E. CLARK

The North Burbank Unit is a cooperative water-flooding enterprise of 15 oil companies and individuals. Phillips Petroleum Co. is the operator of the project.

At the beginning of the pilot flood of the North Burbank Unit in 1951, Phillips designed and constructed a raw-water supply system with a capacity of 300,000 bbl. per day. Water is obtained from seven gravel-packed wells located in the alluvium along the Arkansas River in Osage County, Okla. Deep-well turbine pumps, driven through right-angle gears by single-cylinder engines, on these wells maintain a constant level in a 44,000-bbl. surge tank. Control devices in the tank regulate the speed of the engines. From the tank, water is boosted by four 450-hp Ingersoll-Rand engines and 2-stage centrifugal pumps to maintain a constant discharge pressure of 180 psi. The raw water is distributed through seven miles of 30-in. line to one of the largest water-flood areas of the world, involving six major water-flood projects.

This water system, termed the "Ark-Burbank" water system, is also operated by Phillips' North Burbank Unit personnel. It is completely automatic. One operator spends four hours per day cleaning and checking the entire equipment; it operates unattended for 20 hours per day. A telephone signal alarm system from the plant is tied into the overall NBU signal network, and a trouble-identification board facilitates repairs to malfunctioned equipment.

From the ordinary equipment used in 1951 to inject water and to produce and sell the oil, the North Burbank Unit has grown into a mechanical giant that now produces and processes more than 23,000 bbl. of oil and 165,000 bbl. of water per day. It injects 250,000 bbl. of water daily.

During the past year, the major gaps have been closed in automatic tank-battery operations, so as to permit the operation of the project to continue essentially unattended, except for preventive maintenance, equipment failures, or drastic changes in conditions. We say that an enterprise operating in this manner works automatically. The term "automatic" has always been subject to changes in meaning. As generally considered in present everyday conversation, it is applied to machines, or combinations of mechanical contrivances which, after certain conditions have been fulfilled, continue to operate until such time as the conditions materially change. Thus, automation may be said to be a matter of degree.

The equipment in the 1959 water-flood extension of the North Burbank Unit satisfies the foregoing definition—and does even more. The equipment actually adjusts itself automatically to most changes in conditions, such as those caused by:

1. Variations in the sediments produced in the water-oil emulsions requiring special treating compounds.
2. Mixing water of changing incompatibility.
3. Rapid and unpredictable well stimulation caused both by flooding itself and by sand-fracture treatments.
4. Wide fluctuations in water-oil ratios, gas-oil ratios, and crude-oil gravities.

Water flooding is further com-

THE AUTHOR

Since his graduation in 1942 from the New Mexico School of Mines, E. E. Clark has been employed by Phillips Petroleum Co.—natural gas department for one and one-half years, remainder of time in the production department with operations in Oklahoma, Montana, Kansas and California. Of this time, 12 years have been in active secondary recovery areas—mostly waterflooding in East Kansas and Northern Oklahoma. Since writing this paper, Mr. Clark has been promoted and transferred from Shidler, Okla. to the company's California District.

Mr. Clark writes that when he was a member of the Phillips 66er Basketball Team, he used to practice in 1943 at the Colorado School of Mines so he feels well acquainted with the School. He also has supervised a number of young Mines graduates, the most recent of whom were Jim Ault and Bob Martin, now employed at the North Burbank Unit in Shidler.

* Paper presented at the spring meeting of the Rocky Mountain District, Division of Production, American Petroleum Institute, in Casper, Wyo., April 20-22, 1960.

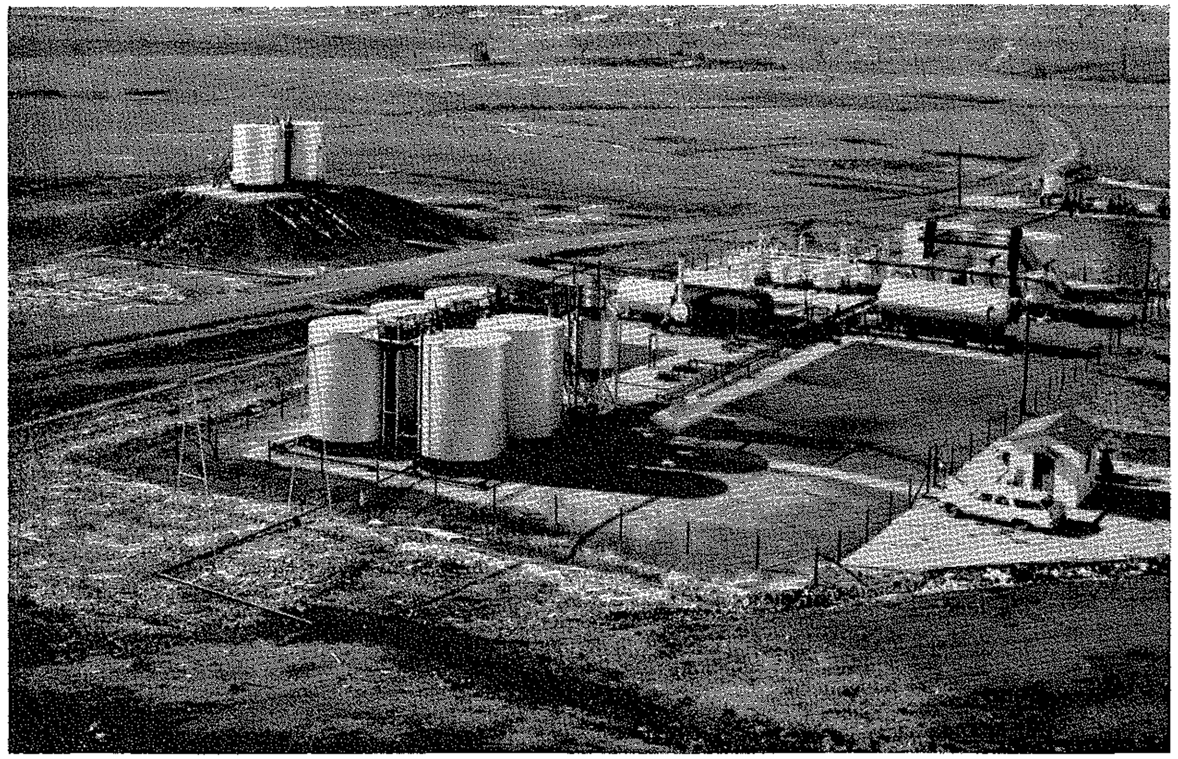


Figure 1. North Burbank Unit automatic tank battery.

plicated by the unpredictable left-overs of the earlier surgeons of primary production. Uncontrolled flooding, sparse records, poor well completions, salt-water disposal, damaged casing, casing and liners that are corroded and leaking, improperly plugged wells, old shot holes, junk left in wells—all these contribute their share to condition changes.

Automation in water flooding is thus contrasted with the operation of an automobile plant or a refinery where all the operations are confined to a relatively small area, where the nature of raw materials are known, and where the changes in the production line and the processes can be accurately predicted.

Evidence of the degree of automation is found when the required operating labor is examined. In the new area developed, one lease foreman and sub-foreman supervise 4,000 acres of water-flood production, involving four automatic tank batteries (operated by one battery pumper), and 217 producers and 181 water-injection wells (operated by four well pumpers, or approximately 100 total wells each). Preventive maintenance and scheduled equipment checking is performed bi-monthly by a field mechanic crew (mechanic and helper) and monthly by a well tester.

At peak production the foregoing group may be responsible for the handling of 16,000 bbl. of oil per day and 110,000 bbl. of water per day, and for the clarification and injection of 120,000 bbl. of water per day. Most all of the unscheduled maintenance is handled by a centralized maintenance group, serving all foremen areas.

Water flooding can be broken down into systems and sub-systems. The various systems may work independently of one another, or they may share equipment. At the North Burbank Unit, all of them have certain common design features:

1. Almost all equipment fails safely; i.e., its failure will not cause damage to other equipment; will not shut down the production of oil; and will not cause waste or pollution. Emergency storage of both oil and water is provided until equipment malfunctions can be corrected and normal operations restored.

2. Equipment failures and major condition changes are signalled immediately to the operator and identification devices are provided to locate quickly the area of trouble.

3. Protection is provided automatically against winter freezing by either draining stagnant water lines and pumps or by filling them with warm, clean oil during idle periods.

Automatic Tank Batteries

When producing wells are stimulated and water production occurs, the production system and the water-injection system must then be married at the tank batteries. The tank batteries are the heart of the water flood. It is here that the operation ends in the sale of the recovered water flood oil to the pipeline companies. At the North Burbank Unit there are three pipeline companies, all of which may be connected to take oil from a single tank battery.

For purposes of discussion, the automatic tank batteries may be subdivided into seven smaller systems:

1. Oil treating (including chemical-proportioning unit).
2. Lease automatic custody transfer.
3. Trouble signal and identification.
4. Gas venting and sales.
5. Water clarification.
6. Relief and oil skimming.
7. Water injection.

Oil Treating

In addition to the usual free-water knockouts and heater-treaters, it is necessary to add treating compounds to break emulsions.

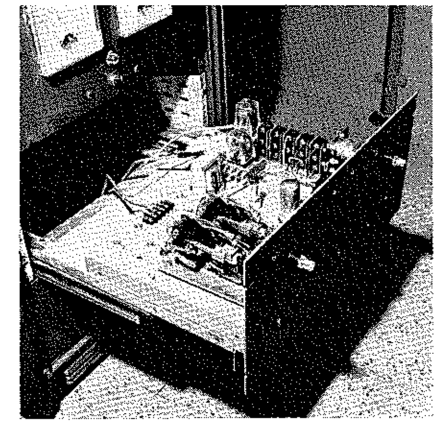


Figure 2. Chemical proportioning unit (bottom drawer of instrument console).

The chemical-proportioning unit *(Fig. 2)*, which performs this function, is a recent Phillips addition to automation at the North Burbank Unit. At 12-min. intervals, the output of the BS&W monitor cell, which is policing the oil from the heater-treater, is used to reset resistors in a stepping switch located in a panel rack inside the pumper's doghouse. The current from this switch is then relayed to a Swarthout pressure transducer *(Fig. 3)*, located near the heater-treater. Here the current is converted into gas pressure, which is piped to diaphragm valves located near gas-operated chemical pumps on the incoming trunk lead lines at both sides of the tank battery.

It follows that chemical is added only when and as required to maintain the BS&W of the oil being sold at the desired percentage. Experience has shown that the BS&W percentage can be maintained with ±0.1 percent, provided the emulsions to be treated are sufficiently sensitive to the treating compound being used.

The significance of "controlling" the BS&W content of the sale oil so as to offset any "automatic" 0.2 per cent BS&W deduction by the pipeline, (when the oil may be essentially clean) will be recognized—especially by the producers.

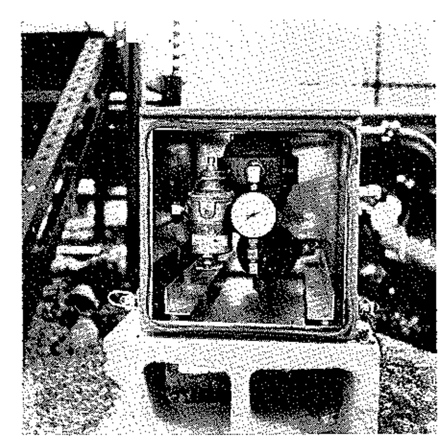


Figure 3. Swarthout pressure transducer.

The results of this automatic system are rather amazing and may well eliminate the oil treater. The unit is so new that we have it installed at only one automatic battery. This gives us an opportunity to compare it with two otherwise identical batteries installed at the same time. By controlling the BS&W percentage and injecting the compound only as needed, the one battery treats at a ratio of 2,100 bbl. of oil per gallon of chemical. By manually setting the treating ratio using conventional bottle tests at the other two batteries, the treating ratio averages about 700 bbl. of oil per gallon of chemical. The payout of this $450 additional installation cost is obvious.

Lease Automatic Custody Transfer

To date, the North Burbank Unit has sold 15,000,000 bbl. of oil through eight LACT systems.

Much has been said and written about the Phillips LACT system†[2]. It will be reviewed very briefly since it makes up a vital part of automation in water flooding.

The Phillips Unit uses the basic weir system. Oil from the heater-treater enters a 500-bbl. surge tank and the monitor pump starts as soon as the refill level is reached. The monitor pump then runs continuously. Its purpose is to circulate oil through the monitor cell and assure policing of the BS&W content of the oil while the surge tank refills and the sales unit is at rest. Any time the oil quality becomes less than pre-set values (usually 0.8 per cent BS&W), no transfer can take place. The LACT circulating pump then starts and circulates oil back from surge tank to heater-treater until merchantable oil is again seen by the monitor. The pump continues to run for 10 min. after sale has resumed—just to make sure that the oil is clean.

Sales commence when oil reaches the transfer level in the surge tank. Oil is transferred to the 95-bbl. meter tank. Instruments prevent the meter tank from starting to fill unless sufficient oil is available in the surge tank to make a complete run. The meter tank is filled, the overflow switch shuts down the transfer pump, and the read-out instruments process the temperature and gravity data. The BS&W content of all the oil was accumulated while the oil was being transferred. After the read-out instruments gather the data, the tank is released for sale. The run valve opens and the oil is dumped in the sump tank.

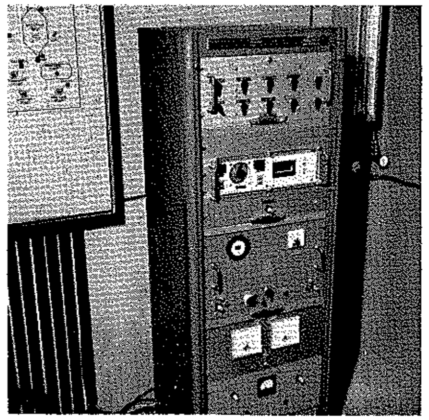
The sump tank has a 64-bbl. capacity. It is primarily for the benefit of the pipeline company. It permits their pump to operate continuously while the meter tank is being refilled and new data accumulated. The capacity of the LACT system is determined by: 1 how fast the pipeline pump can empty the sump tank; and 2 the ability of the transfer pump to refill the meter tank and read-out the data by the time the sump tank is emptied. The pipeline pump is operated by a float switch in the sump tank. The complete LACT system is at rest when the last full meter tank is processed and the sump becomes empty.

The LACT package-type instrumentation is assembled in the console located inside the doghouse *(Fig. 4)*. Three of the drawers in this unit have been adequately covered in a previous publication.[2] They are the data read-out programmer, the combination integrator-temperature transducer, and the Phillips-designed BS&W monitor. The function of these three units will be reviewed very briefly, as they are a part of the overall LACT system.

The data read-out programmer has counters which accumulate quantities of gravity, temperature, meter-tank dumps, BS&W, and time. It permits time-sharing of the gravity and temperature-sensing devices with the integrator. The BS&W of the oil being sold is accumulated on a register during the time in minutes required to transfer the oil, as accumulated on the time counter. The accumulated BS&W divided by time is used to obtain the average BS&W content of the oil sold.

The programmer takes over and runs the show when the weir level in the meter tank is reached. First, the integrator is used to convert oil temperature to pulse rates and the pulses are accumulated for exactly one minute on the programmer's temperature counter. The accumulated temperature divided by the number of dumps, gives the average temperature of the oil sold. Next, the output of the gravity instrument is programmed to the in-

† References are at the end of the paper.



▼Figure 4. LACT control panel and instrument console.

tegrator, which similarly converts the d-c voltage to pulses. These are passed through the one-minute gating timer and accumulated on the gravity register. After the oil is released for sale and the oil level at the weir drops away, a zero check is made of the gravity instrument and deducted on the register, so as to make sure that no drift in electronics has occurred. The net gravity pulses manually divided by the total tank dumps is used to obtain the API gravity of the oil sold.

The read-out programmer provides all the basic data required to run tickets for any desired period of time. At present, the pipeline companies are visiting the batteries from a daily to a three-times-per-week basis. Obviously, consideration is being given to extending these visits—as, for example, once per month.

The sharing of equipment by use of the programmer suggests wider application of this equipment, Phillips is now planning LACT units that will share common LACT facilities with a number of small leases.

The BS&W monitor is the heart of the LACT system. It works because the capacitance cell, located on the meter-tank inlet, accurately senses the change in the crude-oil dielectric constant, caused by the presence of water or water-coated B.S. The monitor d-c voltage output is utilized in two ways:

a. To read directly the BS&W and to police not only the oil being transferred for sale, but also the oil being produced while the LACT system is at rest in its "refill" cycle; and

b. During actual sale, the voltage is converted to a pulse rate by the integrator so that the actual BS&W content of all the oil can be accumulated by the data read-out programmer during the time it is being transferred.

The integrator converts all signals from the BS&W, temperature and gravity-sensing devices into pulse rates so as to permit quantitative determinations. It also teams with the BS&W monitor and monitor cell to supply the proper setting of the chemical-proportioning unit, previously discussed.

Trouble Signal and Identification

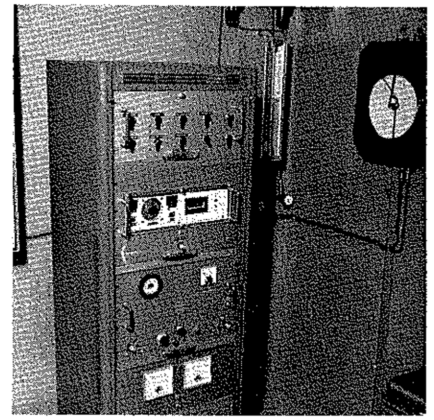
The signal system was used at earlier conventional NBU tank batteries. The transmitter has been enlarged and conveniently located in the top drawer of the panel rack. Any one of several switches located at strategic points in the tank battery will cause the trouble light to come on and a coded signal to be received at a 24-hour attended telephone switchboard. The telephone operator then notifies the appropriate foreman that trouble exists at the particular battery.

Upon arrival, the trouble is pinpointed by determining which of the labeled toggle switches turns out the light.

Gas Venting and Sales

The sale of low-pressure gas from the tank batteries has been possible because of the availability of a gasoline plant. To make deliveries into the plant's vacuum system, several new automatic devices were needed. The opening and closing of thief hatches needed to be eliminated so as to prevent contamination and waste of the gas, and a positive full-volume safety relief valve was required. The vent-system pressure is controlled by a conventional back-pressure regulating valve located at the entry to the vacuum system.

A surge-tank level-control device *(Fig. 5)* was designed by Phillips to provide direct reading of the volume of oil in the surge tank, thereby eliminating hand gaging and the need for opening thief hatches. To determine daily production, the operator merely adds or subtracts the change in surge-tank volume to the total oil sold through the LACT system. A special temperature-correction table is provided the pumper for quickly determining actual production at 60 F. so as to rule out the volume differences caused by ambient temperature changes and the transfer of warm oil. This is important in making production checks for operating purposes on large tank batteries.



▼Figure 5. Surge tank level control with dry-gas bubblers.

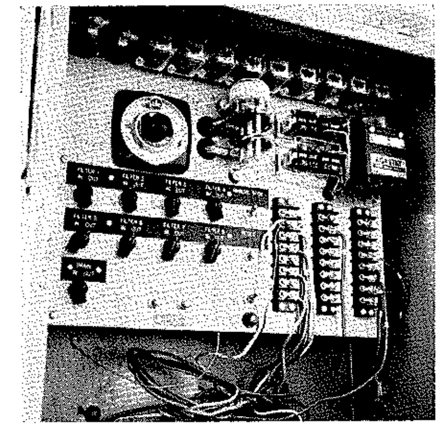
The device is a simple manometer system. The mercury column continually reflects exactly the level of oil in the surge tank. The vent-system pressure and the oil level in the surge tank may also be read directly on pressure gages located on the tank walk. A dry-gas bubble system insures that the gas-pressure transmission lines, especially a down pipe in the surge tank, are purged of liquids so as to reflect accurate pressures.

The surge-tank level control also shares functions with the LACT and signal systems. A Marlex‡-coated magnet floats on the mercury column and causes small adjustable reed-type switches to make and break as the magnet moves up and down. These switches serve not only as the "refill" and transfer controls for the LACT unit but also as the hi-level overflow in the signal system.

By eliminating the need for opening the surge-tank thief hatch and eliminating oxygen contamination, the rich vapors became much desired by gasoline plants. This gas yields eight gal. of liquid hydrocarbons per Mcf. The average volume of gas produced per barrel of Burbank crude oil sold is 32 cu. ft. per bbl. Thus, gas production from a 4,000 bbl. of oil per day tank battery will be 128 Mcf., which will yield 24 bbl. of liquid products.

The new venting system required a safety relief valve that would not only be leakproof, but also would relieve at full volume in the event of failure in the vacuum gas-gathering system. An Enardo separator blowdown valve was modified to give very satisfactory service. It

‡ A trademark for Phillips' family of olefin polymers.



▼Figure 6. Automatic backwash control panel.

will also function as an in-line vent valve, if required.

Water Clarification

Water is first separated at the free-water knockouts. Cathodic protection, utilizing purchased power and long-lasting carbon snodes, is used. At the low power rate enjoyed by the North Burbank Unit, the corrosion protection costs one cent per day per vessel. One rectifier serves two vessels.

The operating pressures of the water knockouts are used to deliver all the produced water to elevated skimming tanks where several services are performed:

a. All solution gas is released when pressure is dropped to atmospheric. This promotes better filter operation and prevents station pumps from gas locking.

b. Oil is automatically skimmed. In addition to the salvaged oil value, this minimizes filter contamination.

c. Incompatible make-up waters and produced waters are mixed. Chemical reactions take place before filtering so that the filtered water is clear and stable.

d. Important hydrostatic pressure head for pump station suction, taken directly through filters, is accomplished by gravity alone.

The filters are backwashed automatically *(Fig. 6)*. A patent was issued to Phillips on Feb. 23 this year on the system utilized. The key part of the procedure is to keep the backwash tanks full so as to permit maximum settling time for solids. At regular intervals, the clear water is drained from the backwash tanks, after which they are refilled immediately with new water and sediments from a new backwash cycle.

The system is triggered by pairs of "dogs" on a 24-hour disc of a time clock. The clock activates a solenoid pilot on a gas-operated dump valve, which permits the settled clear water from the previous backwashing to flow by gravity to a multi-purpose sump tank located at the pump station. Here a float-controlled entry valve throttles the water into the sump tank so as to prevent overflowing.

The water-return pump at the sump tank then starts and transfers the water to the skimming tank as make-up water. Appropriate automatic valves and controls at the skimming tank prevents overflows and permits this water to take preference, as make-up water, over the raw water available under pressure from the Ark-Burbank water system.

When the backwash tank is drained down to the low level—just above the settled solids—a diaphragm pressure switch on the backwash tank signals the dump valve to close, opens the pressured raw-water valve, and causes the valves on the first filter to reverse their normal position *(Fig. 7)*.

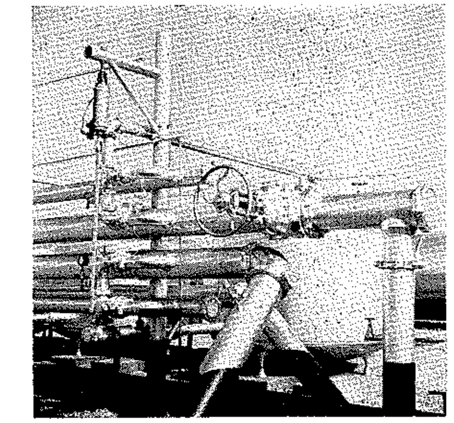
The time desired for backwashing each filter is selected on a timer located in the control panel. The sequence of reversing valves and returning them to normal continues until all filters have backwashed and the backwash tank is again full.

All dead water is drained automatically in winter. This is accomplished by connecting a backside lever to the raw-water supply valve operator which opens a series of drain valves when the supply valve is closed and vice versa.

Relief and Oil Skimming

The need for emergency storage occurs most often when pump-station difficulties occur and relief is needed for produced water which overflows from the skimming tanks. By using oil-water interface float controls for make-up water valves, the large overflow line to the relief tanks also serves as an oil-skimming line. All primary relief lines from heater-treaters, water knockouts, backwash tanks, etc., are connected to this main relief line.

Emergency storage capacity consists of 1,500 bbl., or three tanks, for both the oil and water. This represents three hours storage at a 6,000 bbl. of oil per day production rate, and 1½ hours storage at a 24,000 bbl. per day water-production rate. Although this may not



▼Figure 7. Vertical backwash header and valve operator.

appear to allow much time to signal the operator, and to identify and correct the trouble, almost four years experience and 15 million barrels of automatic tank-battery oil sales has demonstrated that ample time is provided.

All emergency fluids and the skimmed oil enter the bottom of the first relief tank. When the skimmed oil or relief water reaches the two-ft. start level, the utility pump starts and continues to run until the relief tank is emptied. In this manner, temporary relief requirements caused by filter plugging, valve malfunctions, etc., may be handled automatically without manual attention.

Automatic winter protection for the relief systems is accomplished by a small solenoid-operated valve located near the utility pump, which permits the pump and all the essential lines to be filled with warm, clean oil from the heater-treater just prior to shutting down.

Water Injection

Static suction and discharge pressures from the pump station are piped through buried lines into the doghouse and are continuously recorded on weekly charts. Since no housing is provided for either the pump station or water-clarification system, this feature prevents their freezing and permits close checking of both the water-clarification and water-injection systems by the operator. From the discharge-pressure record large leaks or breaks in the water distribution system can be detected. An experienced operator can even audibly detect valve trouble in the pumps. The station suction pressure gives the operator an excellent record of filter operation and backwash cycles. It will indicate any tendencies for filter plugging and the need for more frequent backwashing.

The pump and engines at the pump station represent the only equipment which are not set on portable concrete blocks. Portable concrete is used for setting all individual pumping units and all tank-battery vessels and equipment.

Rubber suction and discharge hoses are utilized to minimize vibrations and to assist in control of pressure surges. A single automatic oil level-trol maintains a constant level of oil in all engine lubricators.

Frost boxes are used where required. They are made of outside-type plywood and lined with insulation. They are light and easily removable in much the same manner as a drawer.

No buildings are required, except for the pumper's doghouse.

No unsightly sediment or waste pits are required in the operation of the tank battery. Accumulations of sediments in the backwash tanks and the vessel-cleaning tank are removed by a vacuum tank truck, after the settlings have been stirred by a special high-pressure tank-washing system.

Conclusion

The major gaps are believed to have been closed in the automatic operation of the North Burbank Unit. One then wonders, "Where to from here?" The course is clear. The major effort must now be placed in improving equipment and procedures. Full advantage must be taken of the equipment already in service. A certain amount of time is always required for education and catching up.

In 1960, following are some of the advancements in equipment and procedures being planned by Phillips at the North Burbank Unit:

1. Improved stuffing-box equipment on producing wells, so as to extend time between visits.

2. Application of Phillips manometer-type controls to tank-battery relief-tank operations and trouble-alarm signals.

3. Improved tank-cleaning devices and procedures.

4. Improvement of LACT instrumentation and controls through use of transistorized circuits and improved materials.

5. Improvement and expansion of automatic chemical-proportioning devices for treating crude oil. Continued optimism and close cooperation of both the pipeline companies and the producers are needed to realize the progress that is indicated by present trend of times.

References

1. Hebard, G. C.: "Installation and Operation Experience on Automatic Lease Custody Transfer Battery," presented at AIEE Conference, Sept. 17-19, 1956.

2. Kuntz, L. E.: "New LACT Instrumentation," *Oil and Gas Journal*, Vol. 57, No. 42, 177, Oct. 12 (1959).

CLASS NOTES

(Continued from page 14)

QUENTIN T. McGLOTHLIN is employed in the Research and Development Division, Humble Oil & Refining Co. with mailing address P. O. Box 3950, Baytown, Texas.

RODERICK J. MORRELL, an engineer with Peter Kiewit Sons Co., has moved from Englewood to 187 S. Ingalls, Lakewood, Colo.

ALBERT E. MILLER is living in Ames, Iowa, where he is graduate assistant, Department of Chemistry, Iowa State University.

JOSEPH W. REESE asks to have his mail sent to his home address: 388 West Ave., Stamford, Conn. until he notifies us of his OCS Navy address.

MERL L. REDHAIR's new address is 11342 Colima Rd., Whittier, Calif.

RALPH N. ROCKWELL has moved from Stamford, Conn., to 2212 Ford, Apt. 12, Golden, Colo. However, he will soon be joining the Army at Ft. Leonard Wood, Mo.

DAVID M. ROPCHAN's address is 175 N. Grove Ave., Oak Park, Ill.

GEORGE M. VENABLE, Jr., has left Golden, Colo. for Ellerslie, Ga.

GARY E. WARNER, formerly of Gering, Nebr., has a new address: Route 1, Walters, Okla.

AUGUSTINE J. SLANOVICH is junior engineer for Howard, Needles, Tammen & Bergendoff, Kansas City, Mo. His mailing address is 529 W. Grant, Pueblo, Colo.

ROBERT A. SULTZBACH may be addressed c/o Bear Creek Mining Co., 2601 N. First Ave., Tucson, Ariz.

BERNARD J. C. TURPIN recently joined the Alumni Association. His address is 94 Avenue Victor Hugo, Paris 16, France.

LETTERS TO THE EDITOR

G. S. PETER BERGEN, Geol. E. '58, writes that his new address is 140 Claremont Ave., New York 27, N. Y., and that he is still at Columbia University Law School where he is specializing in the law of water resources and the law of oil and gas.

Addressing himself to Colonel Fertig, he comments: "Your articles in The MINES Magazine on 'Engineering Education' have been interesting. My feelings are that you should first stress education, then engineering, then mining (or what have you) in the CSM curriculum, rather than the other way around."

* * *

DONALD M. MORRISON, '35, 19204 Frazier Dr., Rocky River 16, Ohio, writes: "I have just completed a test using natural gas in blast furnace operation. It lasted for about eight weeks and was held in the Detroit area. It was an interesting and enjoyable experience.

"If the door is still open I will produce an article for your consideration, by January. It will probably be confined to recent blast furnace developments."

(Editor's Note: Thanks Don for your letter and particularly the list of names of the other Miners who are in steel-making and the production of its raw materials.)

* * *

With reference to the recent editorial in *The Mining World*, which was reprinted in *The MINES Magazine*, concerning the program of developing scholarships for Filipino students, at the Colorado School of Mines, GEORGE ARGALL, editor of *The Mining World*, wrote just recently, "Jesus Cabarrus (one of the Mining leaders in the Philippines) was here in San Francisco yesterday and he told me that President Garcia, of the Philippines, had asked him about this matter. . . . gold miners in the islands are having a very tough time now that de-control and revaluation of the peso is under way.

"I am enclosing a picture of the dinner given by the Manila Section while I was in the Philippines a few months ago."

* * *

WILLIAM D. BAKER, '49, general superintendent A. S. & R. Co., Apt. 85, Parral, Chih, Mexico, writes: "Still in Mexico at the same old stand with Asarco. Have been on crutches for the past 14 months with a cast above the knee since a burro (long-eared Mexican jackass) stepped on my leg and broke it. After four operations, the last two at Mayo Clinic, I might be walking by Christmas, I hope.

"The Magazine improves with each issue. If only more Miners, including me, would shake up a little energy and write more articles, your job wouldn't be so tough. Congratulations and best regards."

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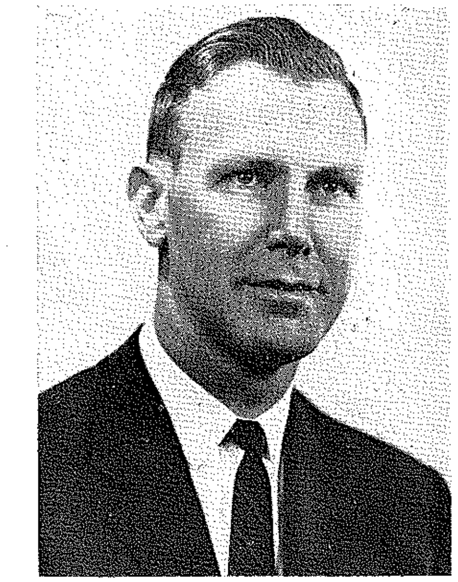
The Engineering Aspects of Pressure Maintenance and Secondary Recovery Operations*

By SHOFNER SMITH



SHOFNER SMITH

THE AUTHOR

Shofner Smith has been employed since June 1953 as chief petroleum engineer of the Production Department, Phillips Petroleum Co., Bartlesville, Okla.

Born May 2, 1919 Mr. Smith received his elementary school education in Durant, Okla. and graduated in 1941 with a B.S. degree in chemical engineering from Oklahoma State University. In 1941 he was employed by Phillips Petroleum Co. as an engineering trainee in the North Burbank Field in Osage County, Okla. The next year he was transferred to the company's Research Department where he was engaged in process development work relating to the manufacture of synthetic rubber.

Mr. Smith served on active duty with the U. S. Navy from October 1942 to June 1946 in the South Pacific. During service with the Navy he did post-graduate work in engineering at Harvard University and M.I.T.

From June 1946 to June 1947 he was employed by Phillips' Research Department on problems relating to crude oil production. In May 1947 he returned to the company's Production Department as a supervising petroleum engineer for the Permian Basin Area.

He returned to the Navy to serve from May 1951 to April 1952 in the Navy Department, Bureau of Ordnance, and in the Office of the Secretary of Defense, Munitions Board, Office of Petroleum Programs.

Leaving the Navy he was employed by Phillips until June 1953 as assistant division superintendent, Production Department, Central Division in Oklahoma City, Okla.

Introduction

Engineering consists of the economic application of the physical properties of matter to the service of mankind. This definition reveals that the engineering aspects of an operation encompass consideration of both the physical and economic aspects of the operation.

The primary production, or pressure depletion, oil recovery process is inherently inefficient in that only 10 to 30 per cent of the oil can be recovered from most oil producing reservoirs by utilization of the natural energy available in the reservoir. The characteristic inefficiency of the primary oil production process in most reservoirs is the basic justification for supplementing natural energy available for production of oil by injection of extraneous fluids. Such injection can be either "pressure maintenance" or "secondary recovery" operation.

No attempt will be made in this paper to set forth criteria and conditions requisite to successful application of pressure maintenance and secondary recovery operations to oil producing reservoirs. It should be clearly understood that the factors which determine whether a reservoir is susceptible to pressure maintenance or secondary recovery operation, and if so, which of the various forms of operation is most profitable, involve many complex physical and economic analyses. Decisions of this nature must be made on an individual project basis after detailed and thorough analysis by qualified personnel.

The purpose of this paper is to make readily available that background information, relating to the physical and economic aspects of oil recovery processes, which will aid the promotion and adoption of technologically superior oil producing techniques that are economically sound and result in the effective conservation of oil and gas, an irreplaceable natural resource.

Pressure Maintenance and Secondary Recovery

Pressure maintenance and secondary recovery are fluid injection operations conducted for the purpose of increasing the ultimate economic oil recovery from underground reservoirs. The distinction between pressure maintenance operation and secondary recovery operation relates to the physical difference in reservoir pressure, and other related differences of degree rather than kind, existing at the time fluid injection is initiated. Pressure maintenance refers to fluid injection operations which are initiated during the course of primary oil production, at reservoir pressures somewhat in excess of the reservoir abandonment pressure, in order to increase ultimate oil recovery by one of two methods. The first is that of maintaining or increasing

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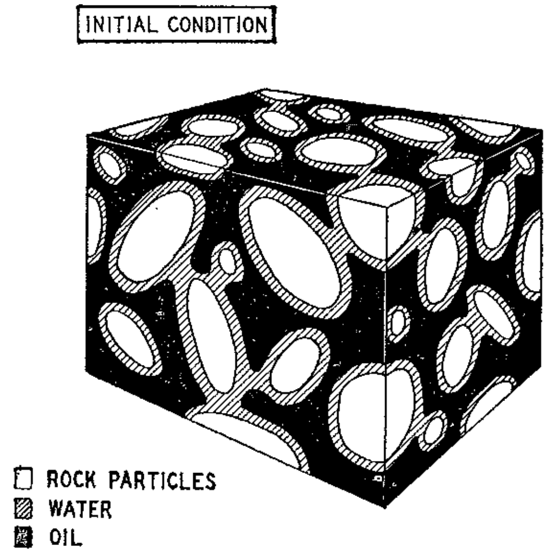
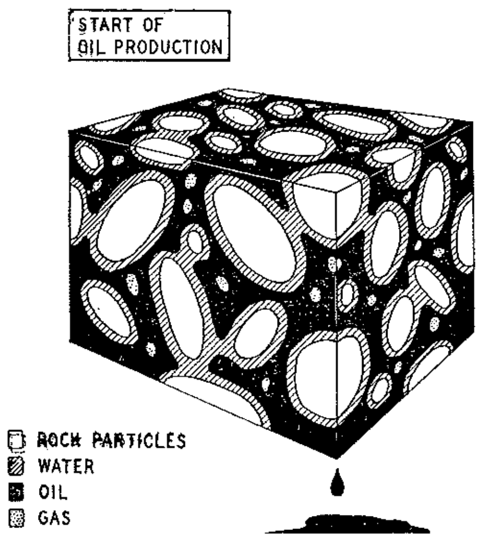
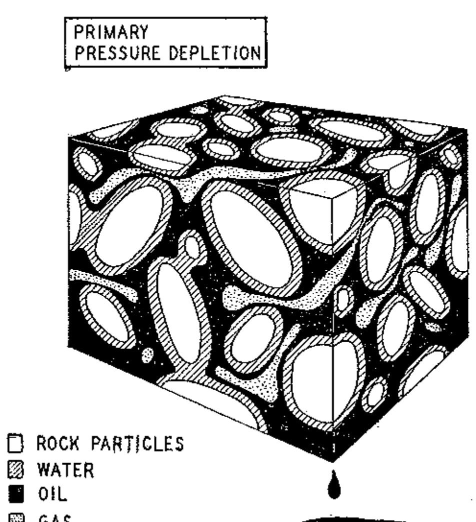


▾ Figure 1. Schematic Reservoir Fluid Distribution—Initial Condition.



▾ Figure 2. Schematic Reservoir Fluid Distribution—Start of Production.



▾ Figure 3. Schematic Reservoir Fluid Distribution—Primary Pressure Depletion.

reservoir pressure. The second, and more commonly applied method, is that of retarding the rate of pressure decline in the reservoir. Secondary recovery refers to fluid injection operations which are undertaken when reservoir pressure is at, or very near, abandonment pressure. Secondary recovery operation may properly be considered as the ultimate form of delayed pressure maintenance operation.

Secondary recovery has been of great economic importance to the oil industry in the past, and will have continued application in the future. Such operation is of decreasing relative importance because: first, a substantial portion of the older pressure depleted fields, including most of the larger ones, to which such operations are applicable have already been subjected to secondary recovery operation; and second, a significant proportion of the more recently developed fields are being subjected to pressure maintenance operation. Fluid injection at comparatively high reservoir pressure is gaining broader acceptance because the physical principles governing production of oil and gas show that pressure maintenance operation of a reservoir can usually be expected to recover more oil, at greater profit, than can secondary recovery operation.

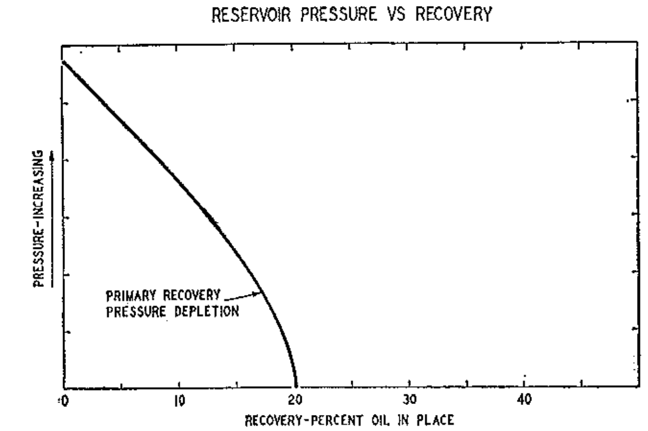
Comparison of Conventional Recovery Processes

A review of the distribution of oil, gas, and water in an oil reservoir and the changes which occur in this arrangement of fluids during the producing life, together with an examination of the accompanying changes in reservoir pressure and oil producing rates, is essential to full understanding of the need and justification for pressure maintenance and secondary recovery operations.

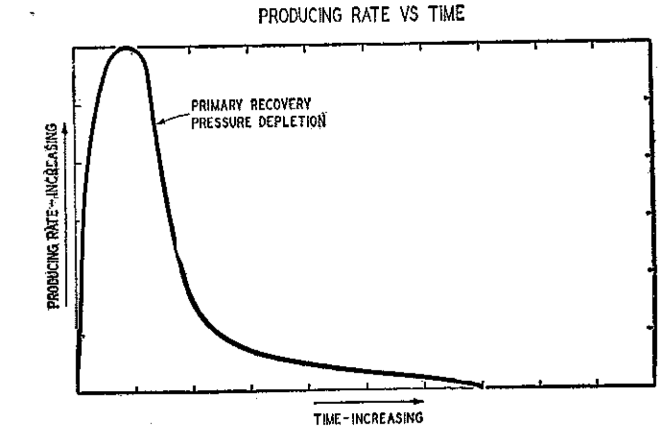
Initial Conditions

Figure 1 is a schematic diagram of the distribution of oil, gas, and water in oil-bearing rock prior to production from the reservoir. Oil with gas in solution is contained in the pore spaces of the rock. A portion of the pore space is occupied by water adhering to the surface of the sand grains or limestone material in the formation and is generally called "connate water." Water was present in the formation before the oil entered, and was only partially displaced by oil because capillary forces held a portion of the water locked in place in the formation. Oil with gas in solution occupies that portion of the pore space in the formation which is not filled with water. These initial conditions of fluid distribution hold for all pressures above the "bubble point" pressure. The bubble point is the pressure below which gas is released from solution with oil. Original reservoir pressures higher than the bubble point pressure of the reservoir oil are not uncommon.

The principal natural source of energy for production of oil from most reservoirs is the energy associated with gas in solution with oil at initial reservoir pressure. Such reservoirs are referred to as "solution gas drive reservoirs." It is in reservoirs of this type that pressure maintenance or secondary recovery operation will bring about the greatest increase in ultimate oil recovery. In some reservoirs nature placed an extensive body of water-bearing rock in contact with the oil-bearing portion of the reservoir. As oil is removed from such formations, water moves in and replaces the oil thereby maintaining pressure in the oil-bearing portion of the formation. This producing mechanism is referred to as "water drive." The natural energy in water drive reservoirs is usually sufficient to recover 50 to 60 per cent of the oil originally in place. Conventional pressure



▾ Figure 4. Reservoir Pressure Versus Oil Recovery During Primary Recovery Pressure Depletion.



▾ Figure 5. Producing Rate During Primary Recovery of Pressure Depletion.

maintenance and secondary recovery methods of operation will usually effect no increase in ultimate oil recovery from such reservoirs.

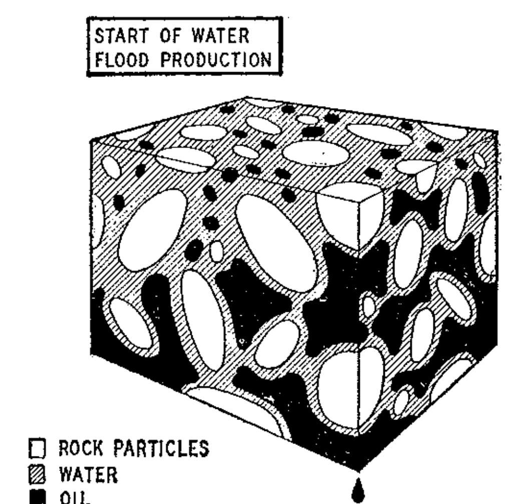
Primary Depletion

At or shortly following the commencement of oil production from a reservoir, a distinct change occurs in reservoir fluid distribution. This change is illustrated by *Figure 2* which shows that small bubbles of gas have formed within the oil in the pore spaces. Gas is released from solution with reservoir oil when the reservoir pressure is reduced to a level below the bubble point pressure. Continued oil production results in the further release of gas from solution with oil and a corresponding enlargement or increase in number and size of gas bubbles in the formation.

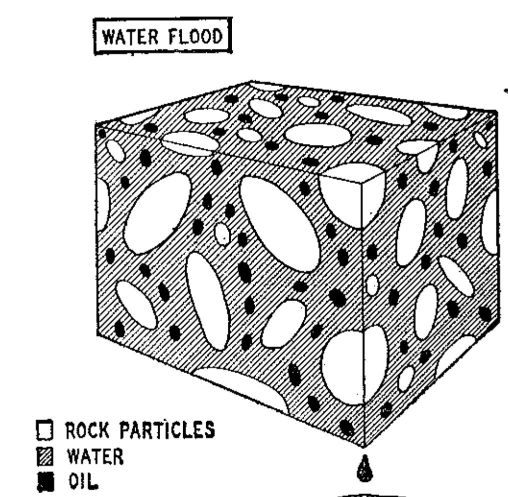
Figure 3 is a schematic representation of reservoir fluid distribution following depletion of pressure to abandonment levels. A significant quantity of oil remains in the reservoir, and the gas bubbles have enlarged and interconnected to form continuous gas saturated flow paths through the formation. Inasmuch as gas has a considerably lower viscosity than the oil, the gas tends to move through the formation with greater ease. The primary pressure depletion production process just described is commonly referred to as "solution gas drive." It is the natural functioning of the physical properties of reservoir oil, when reservoir pressure declines, which permits the preferential flow of gas through the oil-bearing formation and renders the primary pressure depletion process inherently inefficient.

Figure 4 is a plot of reservoir pressure versus oil recovery expressed as per cent of oil originally in place. This figure shows that production from a typical solution gas drive reservoir causes a continuous decline in reservoir pressure, until substantially all pressure has been dissipated, with an attendant representative oil recovery equal to only 20 per cent of the oil initially in place. Although only one-fifth of the oil has been recovered, production ceases because there is no longer energy available for moving oil into the well bore.

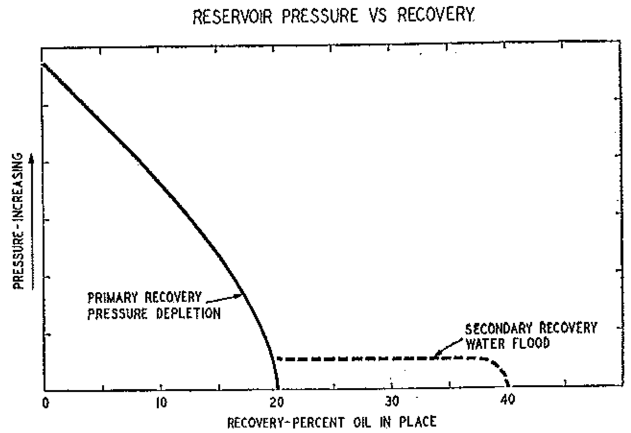
Figure 5 is a plot of oil producing rate in the absence of producing rate restrictions, for a solution gas drive reservoir as compared to time. Producing rates increase rapidly while wells are being drilled and completed. Maximum oil producing rates are generally achieved in the first one or two years of a reservoir's producing life. Subsequently, the producing rate declines until revenue from sale of produced oil equals the cost of operation of the wells. At this point secondary recovery operations must be commenced, or the wells will be plugged and abandoned.



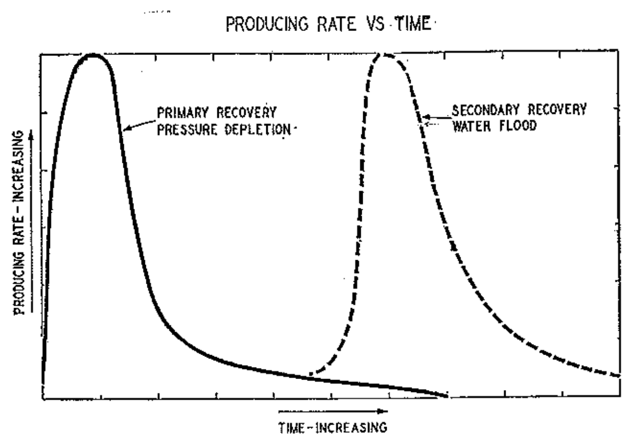
▾ Figure 6. Schematic Reservoir Fluid Distribution—Start of Waterflood Production.



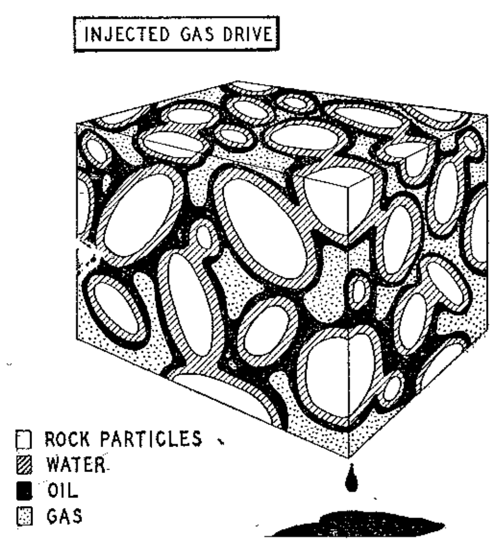
▾ Figure 7. Schematic Reservoir Fluid Distribution Following Waterflood.



▼ Figure 8. Reservoir Pressure Versus Recovery During Secondary Recovery Waterflood.



▼ Figure 9. Producing Rate During Secondary Recovery Waterflood.



▼ Figure 10. Schematic Reservoir Fluid Distribution at Conclusion of Injected Gas Drive.

Secondary Recovery—Waterflood

Water injection into reservoirs which have been depleted by solution gas drive or by injected gas drive will generally bring about a further increase in oil recovery. *Figure 6* is a schematic representation of fluid distribution in the reservoir at the beginning of waterflood production. No significant waterflood oil is produced until sufficient water has been injected to fill substantially all free gas space that may have been created by prior production from the reservoir.

Figure 7 is a schematic representation of the fluid distribution in the reservoir following depletion by secondary recovery waterflood operation. A considerable quantity of oil has been trapped in the formation behind the advancing water front. Ultimate oil recovery as a result of primary pressure depletion and secondary recovery waterflood operations will generally not exceed 40 per cent of the oil in place in the reservoir.

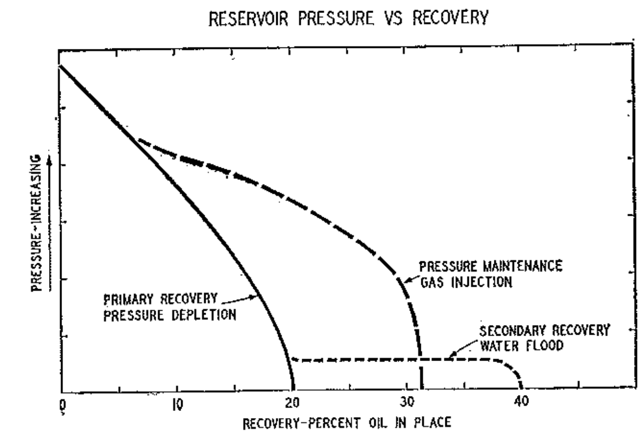
Figure 8 is a pressure versus recovery plot which shows pressure distribution in the reservoir during secondary recovery waterflood operation as well as pressure history during primary production. It will be noted that reservoir pressure during secondary recovery waterflood remains at a comparatively low level but somewhat above reservoir abandonment pressure by primary pressure depletion methods.

Figure 9 is a plot of producing rate versus time which shows the relationship between primary recovery producing rates and secondary recovery waterflood producing rates. Producing rate during waterflood operation generally follows the production rate history of the reservoir during primary recovery operation. On occasions the maximum oil producing rate during waterflood operation will exceed the maximum rate achieved during the primary recovery life of the field. Primary pressure depletion followed by secondary recovery waterflooding has the disadvantage of extending the operating life of the reservoir over a large number of years, with correspondingly greater total operating cost during the reservoir producing life.

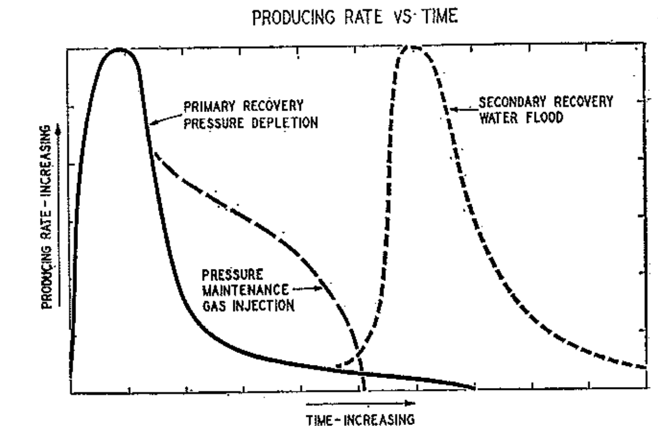
Pressure Maintenance—Conventional Gas Injection

Pressure maintenance by conventional gas injection has been utilized to increase ultimate oil recovery from reservoirs. Conventional gas injection refers to the injection of part or all of the gas produced with the oil, or in addition, injection of make-up gas, at reservoir pressures below those required to achieve miscibility of injected gas and reservoir oil. Conventional gas injection is declining in usage because of increased income available to operators from sale of gas as it is produced, and the ability of other forms of pressure maintenance to produce more oil at less cost.

Figure 10 is a schematic representation of the fluid distribution within a reservoir following depletion by conventional gas injection. The portion of the pore space occupied by gas is greater after conventional gas injection than after primary depletion. *Figure 11* is a reservoir pressure versus recovery plot showing pressure history typical of pressure-maintenance gas-injection operation, as well as pressure history for primary depletion and secondary recovery waterflood. The return of gas to the reservoir decreases the rate of decline of reservoir pressure and results in the recovery of substantially more oil than could be recovered without supplementing natural reservoir energy. Recovery of oil by conventional gas injection, although greater than by primary pressure depletion, generally will not exceed 30 to 35 per cent of the oil originally in place in the reservoir. *Figure 12* is a plot of reservoir oil producing rate versus time showing the producing rate typical of pressure-maintenance gas-injection operations. This curve illustrates one of the principal advantages of pressure maintenance operation, which is recovery of ultimate oil production from the reservoir in a lesser period of time, with correspondingly lower total operating cost during the reservoir producing life.



▼ Figure 11. Reservoir Pressure Versus Recovery During Maintenance Gas Injection.



▼ Figure 12. Producing Rate During Pressure Maintenance Gas Injection.

Although conventional gas injection generally results in a lesser ultimate oil recovery than water-injection pressure-maintenance, it will continue to be economically attractive in reservoirs where: first, connate water saturation (*i.e.*, water in place with oil in the reservoir) is sufficiently high to preclude, or render doubtful, the successful application of water injection operations; second, bottom water (*i.e.*, water segregated from and underlying the oil accumulation in the same porous and permeable reservoir) is present, which would render water injection ineffectual as a means of increasing oil recovery; third, steeply dipping and highly permeable reservoirs permit the force of gravity, as aided by updip conventional gas injection, to produce more oil than could be recovered by down-dip water injection; and fourth, lack of a market for produced gas renders the return of gas to the reservoir for storage, future production, and sale, economically attractive.

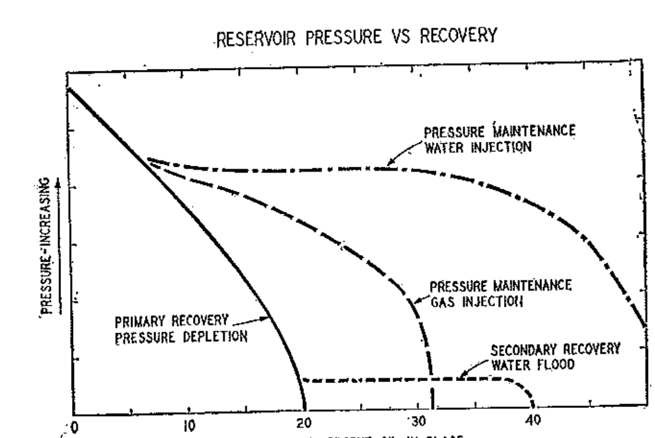
Pressure Maintenance—Water Injection

Figure 13 is a reservoir pressure versus recovery plot showing the pressure history typical of a field operated by water-injection pressure-maintenance, as well as pressure history of the forms of operation previously mentioned. Oil recovery by this method of operation will generally exceed 50 per cent of the oil in place. Fluid distribution in the reservoir following this type operation is similar to that following secondary recovery waterflood operation, the only difference being that a lesser quantity of oil remains unrecovered in the reservoir. *Figure 14* is a production rate versus time plot showing the producing rate history of water-injection pressure-maintenance as compared to the other forms of operation previously mentioned. It will be noted that the time required to recover the greater amount of oil by water-injection pressure-maintenance is less than the total time required for primary depletion and waterflood operations. This demonstrates one of the principal economic advantages of water-injection pressure-maintenance operation in that it shows greater oil recovery in a lesser period of time. This means more revenue and less operating cost.

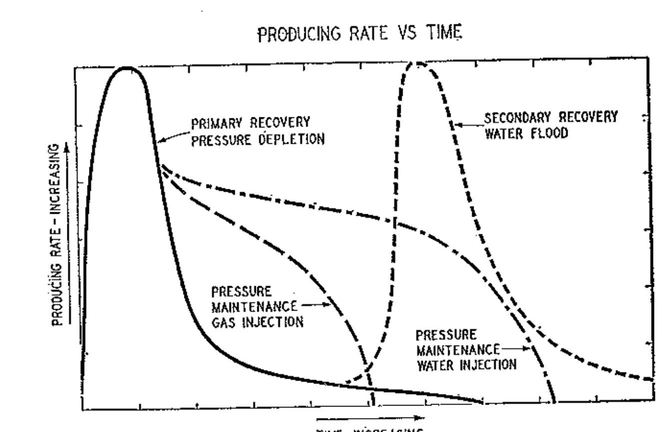
New Recovery Processes

The oil industry is acutely aware of the necessity, from both the economic and conservation points of view, of developing oil recovery processes that will produce a substantial portion of the 40 to 60 per cent of original oil in place in a reservoir which remains unproduced following the most successful application of heretofore conventional forms of pressure maintenance and secondary recovery operations. The research effort within the oil producing industry has brought about development of several new oil recovery processes, some of which are now in practice in a limited number of fields. These processes will recover substantially all of the oil initially in place in the reservoir, within the area swept by injected fluids.

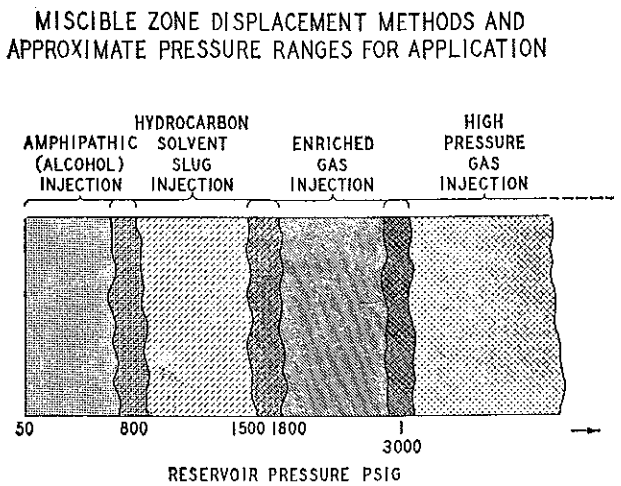
The high pressure gas injection, enriched gas injection, hydrocarbon solvent slug injection, and amphi-



▼ Figure 13. Reservoir Pressure Versus Recovery During Pressure Maintenance Water Injection.



▼ Figure 14. Producing Rate During Water Injection Pressure Maintenance.



▼ **Figure 15. Range of Pressures for Miscible Zone Displacement Methods.**

pathic slug injection processes have in common the characteristic of eliminating or substantially reducing interfacial tension, or the boundary between reservoir oil and injected fluids. It is this factor that renders these processes capable of increasing oil recovery from a reservoir to values approaching the initial oil in place. The investment and operating cost involved in all these methods require that owners of rights to production from a reservoir combine their interests by unitization to prevent loss of reservoir oil and injected fluids because of migration to properties not participating in the project. *Figure 15* is a graphic portrayal of the range of pressures generally suitable or required for application of these recovery processes.

High Pressure Gas Injection

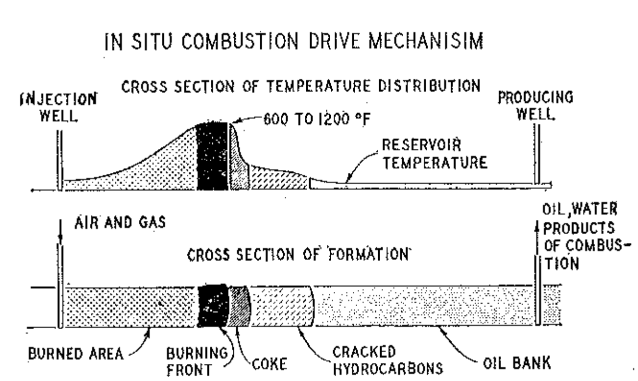
The high pressure gas injection oil recovery process involves injection of gas, in quantities exceeding the volumes produced, in order to maintain reservoir pressure at or above that level necessary to achieve miscibility, a single phase state, between injected gas and reservoir oil. In the miscible state, oil and gas become one material, as does water and antifreeze when mixed in an automobile cooling system. Successful application of this process requires that the reservoir oil contain comparatively high proportions of the intermediate hydrocarbon such as propane, butanes, and pentanes. The reservoir pressure must be maintained at a level such that the comparatively dry injected gas, after being enriched with intermediate hydrocarbon components by contact with oil in the vicinity of the injection well bore, combines with oil, at a position further from the injection well bore, to form a single phase mixture. Under these conditions there is no longer a boundary or interface between the injected gas and the reservoir oil. A mass exchange of components between the gas and oil has resulted in their transformation into a single material. This transformation from a gas phase and a liquid phase into a single liquid or gaseous phase is referred to as "miscibility." Oil is displaced ahead of the miscible zone to producing wells at near 100 per cent efficiency because forces of interfacial tension which hold oil in the pore spaces have been eliminated. It is these same forces that cause low oil recovery by ordinary methods of production.

Reservoir pressures required for the high pressure gas injection process to function properly are generally in excess of 3000 psi. Gas injection operations must be commenced early in the producing life of the pool, or production from the pool must be drastically curtailed until sufficient gas has been injected to restore reservoir pressure to a level which will allow the process to function properly. The process cannot be applied to the shallower reservoirs where the formation pressures required would balance the weight of the overburden formations and create fractures in the oil bearing rock. High pressure gas injection requires participation of all owners of rights to production from a reservoir in the program; or highly effective segregation of the project area from the remainder of the reservoir. Further requirements are: substantial investment in facilities, or high compression charges, to obtain gas at the 4000 to 6000 psi wellhead injection pressures required; and purchase of large quantities of make-up gas, over and above all gas produced. These factors, when considered with producing rate restrictions imposed in some states, make high pressure gas injection projects difficult to form as well as difficult to justify economically. Nonetheless, a few such projects are in operation. The most noteworthy of these is the Block 31 Devonian Unit located in Crane County, Texas. This high pressure gas injection project has been in operation for eight years and shows every indication of achieving the ultimate oil recovery predicted.

Enriched Gas Injection

Enriched gas injection, which is also referred to as condensing gas drive, is similar in its operation to high pressure gas injection in that miscibility must be obtained between injected gas and reservoir oil. Principal differences are: reservoir oil may contain lesser quantities of the intermediate hydrocarbons; the process can be successfully applied at reservoir pressures as low as approximately 1500 psi; and the gas injected must be rich in intermediate hydrocarbons in its natural state or enriched by addition of propane, butanes, or pentanes to the gas stream on the surface or in the well bore as gas is injected. Enriched gas injection is more flexible in its application than high pressure gas injection in that miscibility between injected gas and reservoir oil can be obtained at lower pressure. A greater decline in initial reservoir pressure can be experienced prior to commencing injection operations. Miscibility pressure can be varied by altering the degree of enrichment of the injected gas with intermediate hydrocarbons. Enriched gas injection requires a smaller investment in facilities, or lesser compression charge for gas, than does high pressure gas injection; but does require purchase of intermediate hydrocarbons, usually propane and/or butane, to enrich the injection gas stream early in the

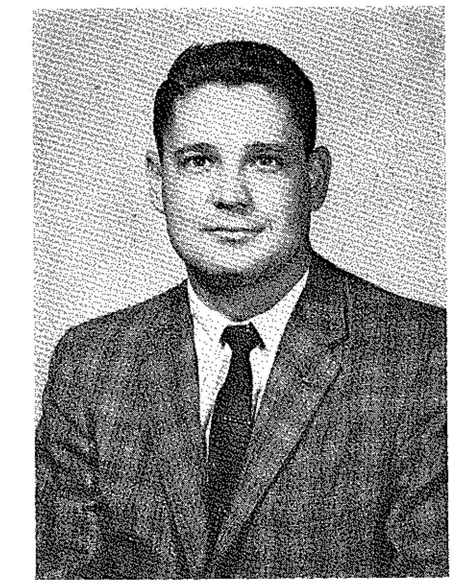
(Continued on page 73)



▼ **Figure 16. Schematic Representation of In Situ Combustion Recovery Process.**

Our Stake In Percentage Depletion

By GEORGE E. TARBOX, '52



GEORGE E. TARBOX

In this, a presidential election year, we seem beset on all sides with thorny political issues. Many of these issues are seized by politicians from both parties as vehicles upon which they can ride to election—or re-election. And of course there are many innuendoes and half-truths that surround a political campaign which often distort or conceal the objective facts about the issues.

One of these issues is the so-called "tax loophole" of the percentage depletion allowance for the extractive industries, with that of petroleum in particular. Now that the election is over and the dust is beginning to settle, let's look at the objective facts about percentage depletion. They are the same facts that have always existed (and, in fact, this article is being written before the election), but somehow this same information never seems to filter through the maze of political implications to the average voter. Indeed, many of the persons employed by the affected companies do not realize the importance of the depletion allowance.

Like most readers of this magazine, I am an engineer in the mineral industries. And as we know, domestic and foreign petroleum exploration alike are in a very vulnerable position because of the depressed state of the industry; this also applies to certain phases of the mining industry. One thing that is keeping us going is percentage depletion, and it has become such a political football that we are in increasing danger of losing it. It has reached the stage where the general public has a distorted view of it, and it is time for you and me to do everything possible to get the *facts* out in the open. That is, unless we want to play guessing games about whether our company will further reduce its operations (and us with it) in the years ahead.

"But what can I do?" you ask? Shall we let the public relations boys in the head office defend us against these attacks on depletion? No! It's not enough to do the job. If we want to survive in domestic exploration, we must realize that it is *our* responsibility to learn the facts and preach them—loudly.

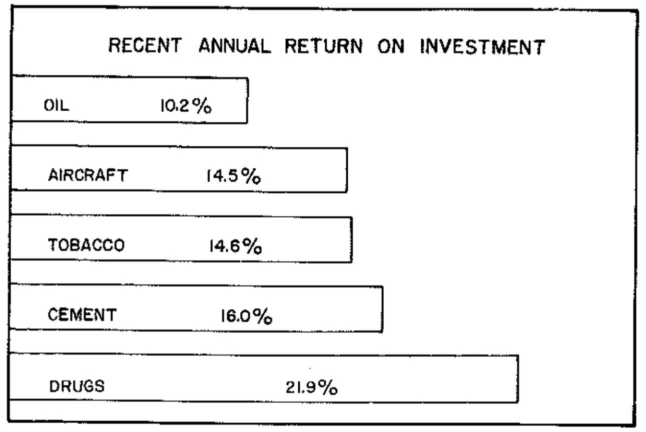
We are continually on the defensive on this issue, and unnecessarily so. Remember the recent Denver Post editorial cartoon showing the oil companies as a big hog wallowing in the "27½% depletion tax allowance"? Or Jack Steele (Scripps-Howard newspapers) stating that depletion was "one of the biggest windfalls and tax-avoidance gimmicks of all"? Or Senator Proxmire of Wisconsin proclaiming on the senate floor that it is the "number one example of unfairness, inequity and injustice in our tax system"? This is typical of the very effective propaganda campaign carried on by those who *do not know* or *will not state the facts.* Such attacks contain many innuendoes but few facts—yet many of the voters

THE AUTHOR

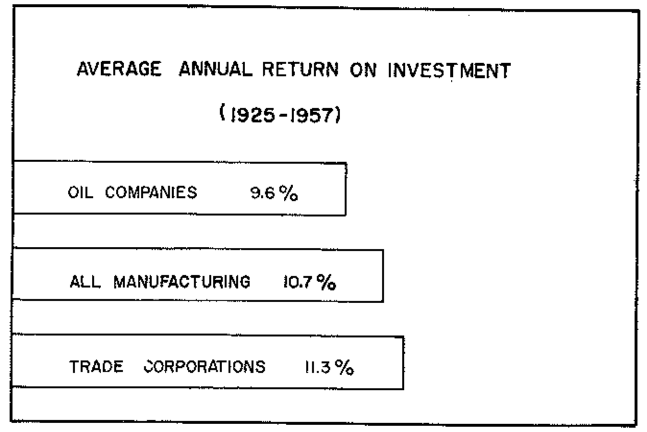
George E. Tarbox, a 1952 graduate of Colorado School of Mines in geophysical engineering, has been employed by Pan American Petroleum Corp. since that time. During the Korean War, Mr. Tarbox served as an engineering officer and pilot of fixed wing aircraft and helicopters in Alaska and Hawaii for the Army Engineers. He is still active as a captain in the Engineers as inspector-advisor to reserve units.

Mr. Tarbox has worked in geophysical exploration in Oklahoma, Kansas, Mississippi and Texas, and is now located in Pan American's Lubbock, Texas office as district geophysicist. As community programs chairman for 18 counties for Texas Mid-Continent Oil & Gas Assn., he is well aware of the importance of the depletion allowance to the petroleum industry. The statements in the following article, however, are his own and do not necessarily reflect the policies of Pan American Petroleum Corp.

Other publications by Mr. Tarbox include "Radio Surveying Applied to Geophysics" (MINES Magazine, May 1952), "The Helicopter—New Tool of the Petroleum Industry" (The Petroleum Engr., June 1956), "Recent Developments in Airborne Minerals Exploration" (MINES Magazine, January 1957), "Bibliography of Graduate Theses on Geophysics in U.S. and Canadian Institutions" (MINES Quarterly, January 1958), and several others.



▼Figure 1. Recent annual return shows oil lagging in many industries in spite of depletion allowance.



▼Figure 2. During the above period the present percentage depletion provision was active in influencing oil company operations.

swallow the catch-phrases and believe them. It is not necessary for us to be defensive about the issue at all, and certainly the critics would not gain support if the public could see the facts for themselves.

Let us examine the pertinent questions involved:

(1) What is percentage depletion? Is it necessary and legally sound? Or is it a tax loophole?

(2) Is the depletion percentage too low or too high? What if it were stopped? Or just reduced?

(3) Does depletion affect me, a salaried engineer? And what can I do about it?

To answer the first question completely would involve volumes of legal discussion and explanation. But we can look at a few of the basic points. For more complete reading, there appears at the end of this article a short list of material on depletion and where it may be obtained.

In the first place, the supporters of the critics do not seem to realize the difference between selling a barrel of oil (or a ton of coal) and selling a pair of shoes. But if the shoe factory sold a small portion of the factory *along with* the shoes, its capacity to make other shoes would soon be gone. The basic problem, then, is that of being able to reinvest that capital into a new oil well (or shoe factory). Not only that, but the shoe manufacturer need not build nine or ten factories before he has one that will produce.

Congress recognized this problem long ago as did the Constitution of the United States; in the Sixteenth Amendment of the Constitution, congress was empowered to tax *income* from capital but *not* capital itself. But a troublesome question arose for the extractive industries in that it was (and is) extremely difficult to estimate what percentage of a barrel of oil or ton of ore is returning as capital and what percentage is income. If only there was a simple method of doing this, there would be no uproar over depletion.

Cost Depletion

The initial method proposed to compensate for the fact that a portion of the product was a sale of a capital asset (and tax-exempt) was cost depletion. This system, in general, allows you to deduct your original investment, or cost, in that particular oil well from the gross income from the well. This, however, did not alleviate several problems, i.e., the risks involved and the tremendous amount of capital spent in drilling the many holes which fail to produce. Some allowance was needed to provide for these risks and some allowance given for the capital spent on dry holes. Cost depletion, which was initiated in 1909, then gave way to discovery value depletion.

Depletion vs Depreciation

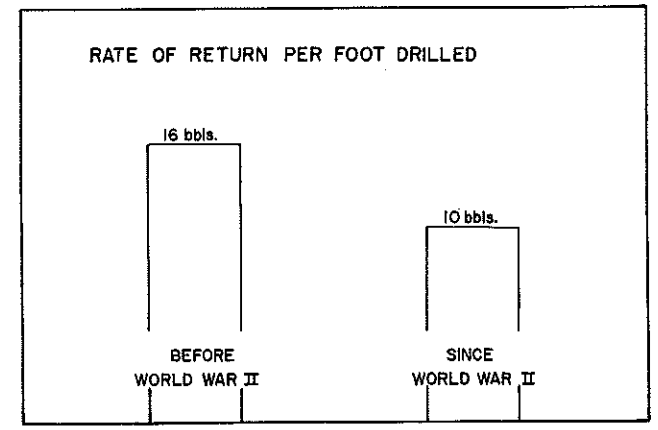
But before going further, let us note the difference between "depletion" and "depreciation." Most businessmen are very familiar with depreciation, which has the same principal for its justification insofar as tax-exemption goes. With depreciation, however, it is considerably more simple in that you buy a piece of equipment and immediately can plan your business with the following facts in mind: (1) the exact, fixed cost of the equipment needed, (2) how much the equipment can produce or how it can be expected to perform, including maintenance, (3) the exact life of that equipment, at least for purposes of taxation, and therefore (4) the rate of tax deduction for wasting away of a capital asset, or *depreciation*, that you will obtain for a given period.

The miner and oilman, on the other hand, cannot make such precise advance analyses of costs, what materials are needed, and rates of production. They cannot estimate with any accuracy what their deductions should be. This fixed cost depreciation was not the answer. Thus "depreciation," which in principle is used in almost all phases of business, is hard to apply to the extractive industries for these reasons and the *concept of depletion allowances* necessarily (and justly) substituted. Depletion, in its various forms, is the attempt to give the same type of return of protection of capital values as depreciation does to industries with more fixed and tangible risks.

Discovery Value Depletion

The Revenue Act of 1918 instituted a broadening of cost definitions to include other development costs and further stated that if the fair market value of the discovery was disproportionate to the cost, then the depletion tax allowance would be based on the fair market value on the date of discovery or within 30 days thereafter. This was termed "discovery value depletion" and was used in various forms until the passage of the Revenue Act of 1926 which can be said to have introduced the concept of "percentage depletion."

The 1926 law was formulated partly as a result of investigations by the House Ways and Means Committee and a Select Senate Committee known as the Couzens Committee. These investigations pointed out and attacked several weaknesses in the discovery value method, such as the difficulties involved with placing a value on a mineral discovery before it has been recovered. As anyone who estimates total reserve values knows only too well, this is impossible to establish with accuracy and would necessarily be constantly amended as new veins or pay sections or new production techniques (such as secondary recovery) are developed.



▼Figure 3. Crude reserves proven per foot drilled has been dropping steadily.

Percentage Depletion

The concept of percentage depletion, then, was the result of years of legislative effort to find an equitable method of allowance for loss of capital assets and taxing only that portion of the sale of the oil (or ore) that can be called income. We in the extractive industries should not feel defensive about this, for it merely attempts to put us on an equal footing with manufacturers who utilize depreciation for the same purpose.

Basically, the percentage depletion deduction allows that, for oil and gas, 27½ per cent of the *gross* income may be deducted but is limited to an amount not to exceed 50 per cent of the *net* income from the property. Thus on inefficient production, "stripper" wells and others with high operating costs, 50 per cent of the net income can be much less than 27½ per cent of the gross income.

The preceding remarks have, I hope, answered our first question: percentage depletion is both legally and ethically sound and just. It might even be argued that not to allow it is in violation of our Constitution. It most certainly is *not* a tax loophole.

Our second question needs no other discussion than a resume of a few facts. Percentage depletion, it is noted, varies from 27½ per cent for oil and gas wells to 23 per cent for sulphur, uranium and (if from U.S. deposits) bauxite, mica, lead, nickel, zinc and many other ores. Limestone, feldspars, granites, bentonites, and many clays receive 15 per cent. Coal and common sodium chloride get 10 per cent and even sand, shale and gravel receive a 5 per cent deduction. The percentages vary, in general, with what the legislators felt was the degree of risk of capital required to develop new reserves of these materials, and *every mineral known is covered by such allowances.*

Why, incidentally, is the allowance applied to *gross* income while the limitation applies to 50 per cent of *net* income? Senator Reed, a member of the Senate Finance Committee during the 1926 debate, answers this point:

"So we are trying, by the finance committee amendment, to get away from those uncertainties and to adopt a rule of thumb which will do approximate justice to both the government and the taxpayers.

"We find, then, that probably the best way to do it is to provide that an arbitrary percentage on the gross value of each year's yield be chalked off for depletion. We figure it on gross income instead of net income, because the net income from oil wells varies greatly. When the first flush production comes, the operating cost of the well is very low per barrel, but as the well trails down and finally comes to produce a small quantity of oil, the cost increases. Up in my state we have many wells working which average less than a quarter of a barrel of oil per day. Obviously, the operating costs of those wells is pretty high, and in many cases production gets down to the point where there is practically no net income, and yet the oil keeps flowing. There is a reduction of capital going on, and if we based the depletion on net income we would not always reflect it."[(1)]

Returning to our second question, then, is the 27½ per cent allowed to oil and gas too high? Look at the earnings reports of oil companies and the answer is clear. Of course the last couple of years have been poor ones as far as earnings are concerned, so in order to be more objective a longer period should be used.

The period 1925 to 1957 suggests itself, because before 1925 we operated under discovery value depletion. During this 32-year period, oil companies earned an average of 9.6 per cent on their invested capital (with the aid of percentage depletion); this is compared with 10.7 per cent for all manufacturing companies and 11.3 per cent for trade corporations. In addition, oil was seventeenth in earnings among 33 industries surveyed between 1947-1955. It would not appear then, that the oil companies are making any "excess profits" (if the meaning of that term can be described) as a result of the depletion deduction. Further, the *actual* deduction averages only about 23 per cent instead of 27½ per cent because of the limitation to 50 per cent of net income; this is never brought out by the critics, possibly because they are not that familiar with the industry they are attacking.

Effect of Cut in Depletion

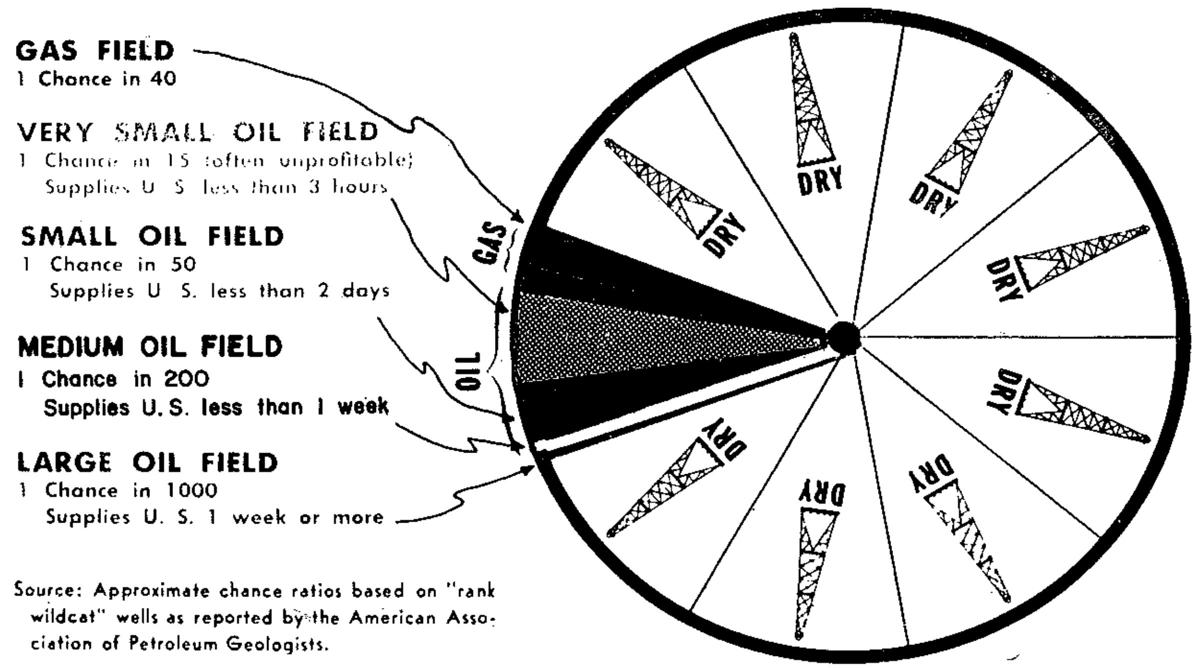
What, then, if the depletion deduction were not allowed? Or cut to a lesser percentage? Again let us examine the statistics ignored by the critics. Using the current discovery rate, if we lost depletion, a 30 per cent price increase of crude oil would be needed to compensate for it. Or, if that entire load were borne by gasoline, the price would have to increase some 5 cents per gallon.

In Texas alone, almost 4.5 billion gallons of petroleum fuel are used each year. Using this figure, loss of depletion would cost Texas motorists $225 million annually and farm operations alone would rise $25 million per year. Again using Texas as an example of an oil-producing state, loss of depletion would also mean:[(2)]

(1) 44 Congressional Record 3761-62, 69th Congress, 1st Session.
(2) Based on a recent survey by Texas Mid-Continent Oil and Gas Association.

RISK ELEMENT IN HUNTING FOR OIL

1 CHANCE IN 9 AT AN AVERAGE COST OF $90,000



▼Figure 4. Above chart illustrates need for attracting venture capital in drilling of wildcat wells.

(1) $275 million less spent on drilling;
(2) $55 million less for pipe and equipment;
(3) $110 million less for services (logging, cementing, surveying);
(4) $65 million less in payrolls (12,000 jobs, perhaps yours and mine);
(5) $60 million less in farmer and rancher income from leasing.

Loss of depletion would mean approximately 5000 less wells drilled in Texas alone, resulting in a 200 million barrel decrease in reserves. Aside from the above effects due to this decreased activity, this would mean a loss of $44 million in tax revenues to state and local governments and $88 million yearly to the federal government.

It becomes obvious, then, that if depletion were stopped, the "closing" of such a "tax loophole" would ultimately reduce oil company income (and therefore reduce revenue from income taxes) as well as reduce the general economy and employment situation in every oil producing state.

What, then, of a cut in the allowance to about 15 per cent? For the immediate future, of course, the government would receive approximately $390 million more in tax revenues. The U.S. Treasury Department admits, however, that income taxes from oil companies would drop some $65 million and that the indirect effects such as those itemized above would certainly reduce Treasury income substantially and have a widespread effect.

Again, let us take Texas as an example.[3] 1958 saw the seriousness of the present "oil recession," yet oil and gas producers paid $198 million to the *state* (in addition to federal taxes), *not including* the gasoline taxes paid by the public. That $198 million represents two-thirds of all business and property taxes collected and therefore paid two-thirds of the Farm-to-Market Road Program, Teacher Retirement, Old Age Assistance, Foundation School Fund, and many others.

But in that same year, 3287 fewer wells were drilled in Texas than in 1957. Crude production was off 134 million barrels (13 per cent) which caused a $19 million loss to Texas in production taxes. The Texas Employment Commission states that there were 10,000 fewer workers in the state's petroleum industry in 1958 than in 1957. From 1958 to 1960 is an even sadder story, and from present oil income in the state, Texas may be in financial difficulties very soon. Yet the favorite cry of the legislators is to get more money from the "rich" oil companies. They never read the fable of the goose that laid the golden eggs, it would seem!

Another factor to consider is that approximately 80 per cent of Texas wildcats are drilled by small firms (there are about 6500 oil producing firms in the state). In the face of reduced depletion this operator would disappear. Such small firms, in order to share risks in drilling, must attract outside investment capital to stay in business, an impossible situation if investors were not allowed the depletion deduction. For those with reserves in the ground, it would become much more attractive to sell out for a maximum 25 per cent capital gains tax than to produce and pay straight income tax on their own capital assets.

Would a "sliding scale" reduction in the allowance help this small producer, then? It may sound better when first said, but it possesses the same attributes as the graduated income tax: it penalizes successful growth. In addition, it would have a direct effect on the larger companies that would seek to become smaller and more numerous with resultant loss in efficiency and service to the public.

To even reduce depletion, then, would most certainly backfire on the entire nation in the form of a crippled and unprofitable oil industry—this at a time when we estimate that our present 3.25 billion barrel consumption will increase to over 6 billion barrels by 1975. There is also the very real problem of keeping and increasing adequate domestic reserves and a healthy oil industry in the midst of growing international tensions.

The last question—"What can I, an engineer, do about it?"—must be answered by the individual himself. The primary item, of course, is to learn the facts—those above are but a few. Certainly, if we want to remain a part of a healthy and growing industry, we cannot and *must not remain silent* in the face of unwarranted attacks. The arguments against the percentage depletion allowance are in actuality very weak and unsound, and yet they grow for lack of opposition.

When we see or hear such innuendoes as "tax loophole," let us speak up and ask for *facts* . . . and, further, *give facts* to the press in letters, or in communications to our elected representatives, and to everyone who will listen objectively. If we are not that interested, then we, and the extractive industries, will lose by default.

(3) Based on a survey by Texas Mid-Continent Oil and Gas Association.

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Biography of An Oil Well*

Winkler County, Texas, abutting the sharp right angle of the New Mexico border, is a sparsley settled land of sagebrush, tumbleweed, bear grass and jack-rabbits. Average rainfall is less than fifteen inches, and vegetation is enough to nourish only a dozen or 15 head of cattle to a square-mile section of land. Generations of ranchers have persevered in running livestock on this part of the western range, but real riches lie far far beneath the surface. Today oil rather than cattle provides the major crop.

The presence of oil in the area has brought prosperity to many individuals, but this has been achieved only through a combination of luck, persistent effort and substantial investments. The story of one oil well in Winkler County serves to illustrate the risks involved and, perhaps of equal interest, the scientific techniques that have raised oil-field production. These methods indicate that there are more ways than one of getting oil out of the ground today.

The first settlers to arrive in West Texas, years ago, were not dreaming of underground wealth. One such was R. E. Cleveland, who received a homestead grant of 640 acres in Winkler County, north of the town of Kermit, in 1907. Years of drought and struggle followed, and the section of land changed hands five times in five years. In 1912 the owner deeded it to J. F. Howe, a banker in Ionia, Mo., in exchange for 26 mares.

Mr. Howe took no particular interest in his Texas acreage, except to pay the yearly taxes of $24, until 1926. In that year oil was discovered not many miles away, and Humble Oil & Refining Co. took a mineral lease on half of Howe's section. In 1929 Mr. Howe disposed of five-eighths of his royalty interest for $20,500, retaining three-eighths of the landowner's share of any oil or gas that might be discovered.

In December, 1935, a Humble company drilling rig arrived by rail from East Texas. With it came the drilling crews and their families, who settled down for a stay in a typical western boom town. It took nearly three weeks to set up the equipment, and drilling began Dec. 30. When the New Year arrived, the hole was 78 feet deep.

Drilling was not easy. Rock formations were encountered, so hard that 16 drilling bits were worn out in 14 days of operation. Each time a bit was changed the drill pipe had to be pulled to the surface, the new bit threaded to the bottom section and the pipe lowered back into the hole. By the time the bit was 2,700 feet down, it took most of a day to make such a "round trip." Twice the drill pipe separated and the lower section had to be fished out of the hole.

But there were also good days when the drill bored 300 or more feet. The best day of all came on Jan. 25, 1936, when the pipe reached 2,985 feet and found oil.

* This article is published in The MINES Magazine through the courtesy of THE LAMP (Standard Oil Co. of N. J.), Vol. 42, No. 3.

Well Produced 1,178 Barrels a Day

Officially designated "J. F. Howe No. 1," the well on test produced at the rate of 1,178 barrels a day. The Texas Railroad Commission, which regulates all wells in the state, fixed its allowable production at 74 barrels a day. Soon 23 other wells were drilled on the lease and, as expected, the flow from Howe No. 1 tapered off. In 1938 production dropped to 24 barrels a day, and in 1941 it went down to nine barrels daily. In June of that year pumping equipment was installed, and daily production rose to 20 barrels. Again there was a gradual decline. In 1945 Howe No. 1 was capable of producing only four barrels a day.

Howe No. 1 was now operating at a loss to the Humble company, and a request to abandon was granted by the state authorities. The recommendation of the company's district superintendent was to "salvage as much equipment as possible and permanently plug and abandon the well." The division geologist and the petroleum engineering department concurred. Although Howe No. 1 had produced nearly 44,000 barrels of oil in 10 years, its life was apparently at an end.

Howe No. 1 Plugged and Abandoned

It had taken almost a month to drill the well, but plugging took only two days. Gravel and cement were poured into the bottom of the hole. A charge of nitroglycerin was lowered to a depth of 1,000 feet, and the explosion broke the steel casing in two so that the top 990 feet could be salvaged. The well was then capped with another 20 sacks of cement. In Humble offices a line was drawn through the black dot on the map that was J. F. Howe No. 1, indicating that a well had been abandoned. Six other wells on the property were also sealed.

Seventeen wells on the Howe lease were still pumping a few barrels of oil a day, but it appeared that the entire lease might be given up as no longer profitable. Even though more than a million barrels of oil had been recovered, the net loss to the company amounted to about $130,000.

Secondary Recovery Undertaken

At this point Humble decided to undertake what petroleum engineers refer to as "secondary recovery," in an effort to bring more oil out of the Kermit field. Certain wells were to be flooded with water so that the pressure would force oil still trapped below ground to flow up through other wells. The technique, then still relatively new in West Texas, had proved successful elsewhere in the area. Five wells were converted for water injection in the spring of 1949, and by early the following year production began to increase. Within two years it had doubled, and a regular program of flooding was begun throughout the lease.

For the second time a drilling rig was moved to the site of J. F. Howe No. 1, now dead for more than six years. This time the drill bit bored through cement.

When the old depth was reached—nearly 3,000 feet—pumping equipment was installed. In February, 1952, the well began to deliver oil once more, at a rate of 21 barrels daily.

More and more water was forced underground through the surrounding wells, and by May, 1955, the Howe lease was producing 462 barrels of oil a day. By fall, however, production from Howe No. 1 had dropped to nine barrels a day, and geologists and engineers made plans for applying another new technique. Oil mixed with sand was pumped into the well under pressure, in order to "fracture" the formation. The sand provided a new and highly permeable channel for the flow of oil.

At Howe No. 1 three different zones beneath the surface were fractured, and the production curve began to rise once more. Soon the nine-barrels-a-day average climbed to 85 barrels. Water was now being produced with the oil, and this increased volume of fluids called for larger tubing. In November, 1955, the tubing was changed, and since that date Howe No. 1 has continued to produce. Today a pumping unit nods its head above the well, delivering 50 to 60 barrels of oil a day. In the eight years since it was reopened, the well has produced more than 200,000 barrels of oil, or four and one-half times as much as it produced in its first ten years of life.

New Methods of Production Studied

Petroleum engineers estimate that under primary methods of recovery about 5,000 barrels of oil per acre were recovered from the Howe lease. Waterflooding and fracturing are expected to recover an equal amount.

Other new methods of production are being studied to determine their value in fields such as Kermit. Scale models have been constructed so that electronic computers, using complex mathematical formulas, can help to predict the behavior of wells. Radioactive tracers may be introduced into the injected water in order to determine its flow pattern through the oil-bearing rock strata. Such modern techniques are expected to keep J. F. Howe No. 1 producing for several more years.

Primary recovery from the Howe lease was much lower than average, although it was normal for this West Texas area where rock formations are hard and of low permeability.

The average primary recovery from oil fields in the United States has been on the order of 25 per cent, and scientific methods of conservation are raising this figure to about 35 or 40 per cent. Engineers are developing even more advanced techniques with which they expect to recover a far greater proportion of the oil in a reservoir. These methods should greatly increase the reserves of oil available for future use.

The heirs of Mr. J. F. Howe continue to receive royalty payments on an investment made 48 years ago. They have perhaps learned that, although the life span of oil wells is never easy to forecast, petroleum science has done much to increase their longevity and productivity.

SECONDARY RECOVERY OPERATIONS

(Continued from page 66)

life of the project. An example of this type operation is the Seeligson Field in South Texas.

Hydrocarbon Solvent Slug Injection

Hydrocarbon solvent slug injection consists of obtaining miscibility between reservoir oil and injected fluids by first injecting a slug of intermediate hydrocarbons, usually propane and/or butane, into injection wells, and following the slug with gas injected into the same wells. This process may be applied in a range of reservoir pressures from approximately 800 to 1800 psi, depending on the composition and characteristics of the reservoir fluids. Application of the process requires the purchase of large quantities of liquefied petroleum gases to form the miscible solvent slug, as well as gas in addition to produced gas for injection behind the solvent slug. Substantial investment or amortization charges are required for compression facilities for injection of gas following the miscible slug. Several projects employing the hydrocarbon solvent slug injection process are now in operation.

Amphipathic (Alcohol) Slug Injection

Amphipathic (alcohol) slug injection consists of the injection of a slug of alcohol or other fluid miscible with both water and oil into injection wells followed by water injection. This process has no practical economic application at the present time, but could become most significant should it become possible to obtain alcohol or other suitable substances at a small fraction of today's prevailing prices. The process can be employed in a pressure range of from near zero to any economically practical upper limit.

In Situ Combustion Drive

The ability of heat to increase oil recovery from a reservoir has been recognized for many years. The U. S. Bureau of Mines made use of this knowledge in some of its work shortly following the turn of the century. It may be erroneous to classify combustion drive as a new oil recovery technique in that United States patents were issued on the process in 1923; and field experiments were conducted in the Soviet Union utilizing the principle of underground combustion in the late 1930's. Developments of the process, of such significance as to give it new potential, have been made in the United States since World War II.

Figure 16 is a schematic representation of the in situ combustion recovery process. Air is injected into input wells and combustion is initiated either spontaneously or by introduction of outside heat into the injection well bore. Following ignition, the burning front moves radially outward from the injection well toward the producing wells. Several distinct zones develop in the vicinity of the combustion front. These zones may be divided as follows: the burned out portion of the reservoir, from which newly injected air transfers heat into the combustion zone; the combustion zone, where coke is oxidized or burned by injected air to produce heat; a zone containing coke, which is the residue left after oil is subjected to the available heat; a zone containing cracked gases, resulting from the heating of residual oil to the 600 to 1200 degree Fahrenheit temperatures; and the oil zone immediately ahead of the cracked gases.

In situ combustion drive results in removal of all oil from the portion of the reservoir swept by the combustion front. Oil consumed as fuel is approximately 10 to 20 per cent of the oil in place in the reservoir. Many technical difficulties remain to be solved before this process can have widespread application. Even then, it is unlikely that application will be broad because of economic limitations imposed by the cost of compressing air for injection. Air required ranges from 200 to 400 cubic feet for each cubic foot of formation burned clean.

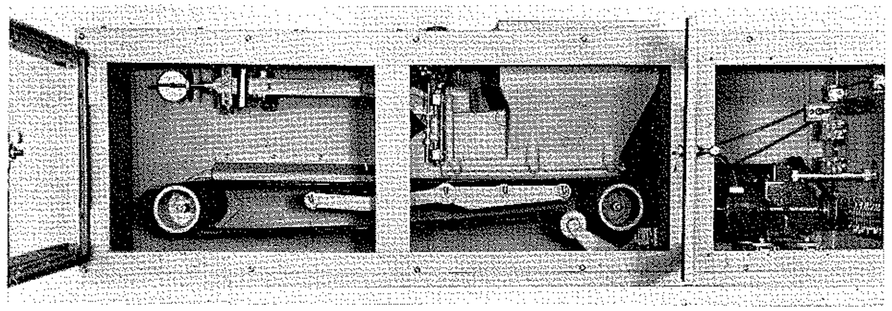
(Editor's note. This article will be continued in the December, 1960 issue of the MINES Magazine.)

WITH THE MANUFACTURERS

Equipment News

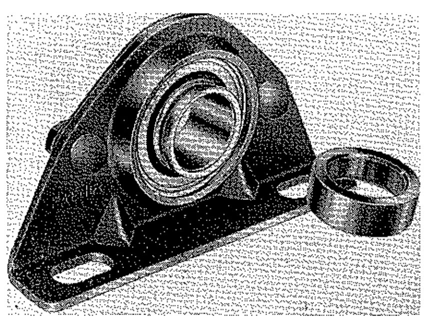
In these columns the latest in equipment of interest to our readers is reviewed. Many readers request additional information and prices. For their convenience each article is numbered. Fill in the number on the coupon at the bottom of the page and mail your request to Mines Magazine, checking information requested.

"G" Type Chemical Feeder (1000)



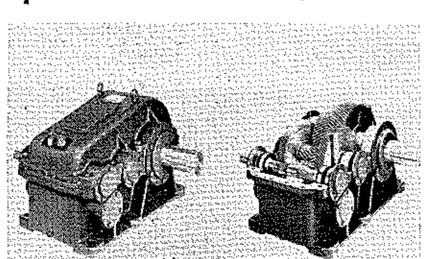
The mechanism and operating principles of the new type "G" Gravimetric chemical feeder are discussed in the new Bulletin 260 issued by INFILCO Incorporated, Tucson, Ariz. The Type "G" feeder is a general purpose feeder because it handles all dry chemicals normally used in water and waste treatment, whether the chemicals are in powder, granule or lump form up to ¾" in diameter. Its finely balanced weighing mechanism gives an accuracy of plus or minus 1% of the set rate over an operating range of 20:1.

Pillow Block Unit (1001)



A new low-cost pillow block unit which incorporates high quality bearings has been announced by The Fafnir Bearing Co. of New Britain, Conn. A principal feature of the device is that it is no longer necessary to sacrifice bearing quality because of the cost of housings, as in previous low-cost pillow block installations. The design permits the use of standard Fafnir rubber contact seal bearings with self-locking collars, which have proved themselves by long periods of satisfactory service under a wide variety of operating conditions.

Speed Reducers (1002)



Link-Belt Co. has introduced a redesigned and expanded line of "balance design" parallel shaft speed reducers available in 57 sizes.

With 23 new sizes added to the line, drive selections can now be matched more closely to horsepower requirements with a resultant saving in drive costs. Single, double and triple reduction units are available in capacities up to 2,800 h.p. at high or low output speeds and ratios up to 292:1. Shafts can be arranged to suit specific drive requirements, and unique design permits assembly with single shaft projections in either direction or with double shaft projections.

Fracturing Pump (1003)

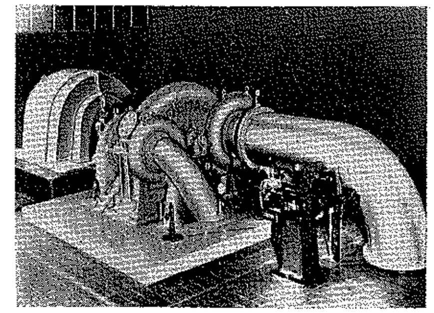
A powerful gas turbine engine-driven fracturing pump is being readied for operations which will give new life to tired oil wells, it was announced by Solar Aircraft Co., manufacturer of the 1100 hp Saturn T-1000 gas turbine engine.

Hydraulic horsepower in the range of 1000 to 3000 is needed for most fracturing operations. The Solar Saturn T-1000 engine and Western pump will deliver 1000 hydraulic horsepower per unit over a wide range of volume-pressure ratios—approximately twice that of former diesel units. This reduces by nearly 50 per cent the number of truck-mounted units needed for most operations.

Reduced operating costs are forecast in the decrease in equipment and personnel required for each operation. In addition, the capability of the turbine to operate at full power within seconds and without warmup is expected to minimize fuel requirements.

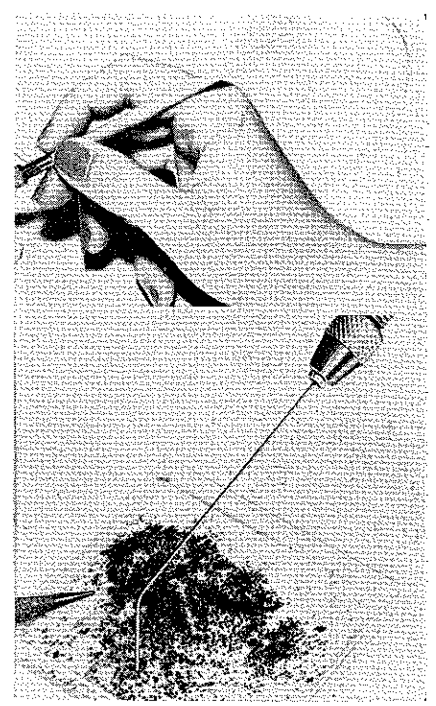
The Solar T-1000 gas turbine engine weighs approximately 1200 pounds, and occupies less than 51 cubic feet. The simple design of the unit, with all moving parts rotating, minimizes vibration and eliminates the need for elaborate foundations. The engine can easily be mounted on a light truck.

Centrifugal Compressor (1004)



The integral gear design of this 4-stage integral gear centrifugal compressor (manufactured by Worthington Corp., Harrison, N. J.) allows direct coupling to a low speed motor driver. This minimizes installation problems and reduces installation costs. It eliminates all the disadvantages associated with erection and alignment of a high speed compressor with separate speed increasing gears and a high speed coupling. It also eliminates possible vibration problems which may occur if this extra installation and erection work is not perfectly accomplished.

Vacuum Pencil (1005)



The amazing new K & S Vacuum Pencil (Kulicke & Soffa Mfg. Co.) has just been developed for the simple and efficient handling of miniature pieces of metal.

MINES MAGAZINE,
Golden, Colorado

Refering to Equipment News, please send as checked:

No. ______ Prices ☐, Bulletins ☐; No. ______ Prices ☐, Bulletins ☐;
No. ______ Prices ☐, Bulletins ☐; No. ______ Prices ☐, Bulletins ☐.

Please have copies mailed to:

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PLANT NEWS

New Torch Cuts Through Metal 30 Inches Thick

A natural gas cutting torch that can slice through 30-in. of metal in a single pass has been introduced by Linde Co., division of Union Carbide Corp. The new Oxweld C-66 Cutting Torch has the largest gas flow—up to 3000 cfh of oxygen and 250 cfh of natural gas—and the widest cutting range—from sheet metal to large risers—of any existing natural gas hand cutting torch.

It will handle every manual cutting job encountered in factories, foundries, steel mills, fabricating shops, and scrap yards. It is ideal for removing large risers. Special applications such as gouging, rivet piercing, and pad and fin washing are also handled with ease with the new torch.

All types of cutting jobs can be handled faster and easier with the C-66 because of its tremendous preheat capacity and large cutting oxygen flows. Extensive field testing has proved that operating costs of the C-66 are 15 per cent lower than other natural gas torches because of faster starts and quicker cutting made possible by its large capacity.

For additional information write to Linde Co., Division of Union Carbide Corp., 270 Park Ave., New York 17, N. Y.

Joy Manufacturing Co. Promotions Announced

Joy Manufacturing Co., producer of mining, air handling, construction and oil field machinery, announces the appointment of C. A. Patten as works manager of its New Philadelphia, Ohio plant and the appointment of Clair C. Ballard as Seattle District manager of both the Industrial and the Mining and Construction Divisions.

George R. Fox, works manager of Joy plants in Franklin, Pa. since 1953, has been elected vice president of manufacturing, Joy International, S. A., a wholly-owned subsidiary which guides the company's overseas operations from headquarters in Monaco.

Crucible Will Market All Around Tool Steel

Crucible Steel Co. of America, world's largest producer of tool and high speed steels, has announced the availability of a low temperature air-hardening die steel which will be marketed under the trade name ORBIT. In addition to its free-machining qualities, this all around tool steel (AISI grade A-6) combines many of the advantages of air-hardening grades with the low hardening temperature of oil hardening grades.

Link-Belt Co. Appoints Three General Managers

Link-Belt Co. has announced general managers for three of its plants. T. Webster Matchett, former manager of the Caldwell plant in Chicago, has been appointed general manager of the Pershing Road plant in Chicago. He is succeeded at the Caldwell plant by George Ramsden, general manager of the North Central Division in Minneapolis. Ramsden is succeeded in Minneapolis by Gerald A. Stone, district manager of the Dallas office and factory branch store. The appointments were effective Sept. 15.

The announcement was made by Robert C. Becherer, president of Link-Belt Co., manufacturer of materials handling and mechanical power transmission equipment.

CF&I Gets Right to Prospect In Apache Indian Land, Ariz.

Colorado Fuel and Iron Corp. has announced the successful conclusion of permit and option negotiations with the White Mountain Apache Tribe granting the Co. an exclusive prospecting permit and option to lease Apache Indian land in Arizona.

The permit covers 188 square miles in the northwestern section of the Fort Apache Indian Reservation and gives CF&I the right to prospect for all minerals except oil and gas. The permit is for two years, with the right to extend it for an additional two years if desired.

The presence of iron ore deposits has been known for many years. CF&I plans to continue the prospecting work previously done by the U. S. Bureau of Mines and the U. S. Geological Survey, which have indicated reserves of about 10 million tons of iron ore, according to R. R. Williams, Jr. '29, manager of mines for CF&I.

The company also plans to investigate reports of deposits of asbestos, manganese and coal in the area.

Conveyor Systems, Inc., Buys A. B. Farquhar Division

Purchase of Oliver's A. B. Farquhar Division by Conveyor Systems, Inc., Morton Grove, Ill. on April 1, offers a new combination line of standard and custom conveyor equipment for industry. The A. B. Farquhar Division manufactures a complete line of standard conveyors for bulk and package handling and its new parent company, Conveyor Systems, Inc., is a specialist in custom conveyor engineering and constructions; including trolley conveyors, slat conveyors and other types of materials handling equipment.

According to Marvin H. Coleman, president of Conveyor Systems, Inc., the sales efforts of these two companies will be integrated to provide service as complete as any now existing in the materials handling field.

All operations of Farquhar, located in York, Penn., were formally moved to Morton Grove, Ill. on Aug. 15 and manufacturing operations began about Aug. 25 in the newly-enlarged plant of Conveyor Systems, Inc.

Michigan Chemical Doubles Capacity of Bromine Plant

Michigan Chemical Corp.'s new bromine plant expansion at El Dorado, Ark., is now completed and in operation. This doubles the capacity of this facility which is a joint venture with Murphy Corp. of El Dorado.

This added capacity, along with Michigan Chemical's bromide-producing plants at Saint Louis and Manistee, Mich. provides the chemical industry with three dependable sources of high-quality chemical grade bromine for use in fumigants, fungicides, nematocides, refrigeration, nuclear viewing windows, pharmaceuticals, dyes, water purification uses, fire-proofing compounds, extinguishments, and a growing list of other chemical process and fine chemicals applications.

A-C Appointments

The appointment of Will Mitchell, Jr., as acting director, Research Division, Allis-Chalmers Manufacturing Co., has been announced by R. S. Stevenson, president. Mitchell, previously was associate director of the company's Research Division. He succeeds the late Dr. H. K. Ihrig, director of research and vice president of the company, who died Aug. 22.

Allis-Chalmers Centrifugal Pump Department, West Allis Works, has announced the following appointments:

Joseph J. Jacobs, chief engineer; C. L. Babb, senior staff engineer, and W. W. Weltmer, senior development engineer.

CATALOGS and TRADE PUBLICATIONS

FOR YOUR CONVENIENCE

Send your publication to The MINES Magazine, Golden, Colo., for review in these columns. Readers will please mention MINES Magazine when requesting publications from the manufacturer. Readers may order publications from this office by giving index number. These publications are FREE.

(1037) EASTCO INTERCOM. September 1960, by Eastman Oil Well Survey Co., 1450 Speer Blvd., Denver 1, Colo., contains 8 pages of articles describing the new organizational setup and biographies of key personnel.

(1038) PROGRESS NEWS. October 1960, by Gates Rubber Co., Denver 17, Colo., is a 32-page magazine about the company's operations, activities, personnel and general news features and articles. Of interest is an article entitled "Be Alert to Poor Thinking," showing how pessimistic, selfish attitudes can produce illness, depression, moods, nervous breakdown.

(1039) WATER BILL U.S.A. A 16-page booklet just released by Caterpillar Tractor Co., Peoria, Ill. The booklet, listed as Form D041, tells the story of water and the huge money outlay necessary to pay our annual water bill each year. Waste is the largest single threat to our water resources and with demand growing greater each year as our population and industries expand, it is a luxury we can ill afford.

(1040) ARAMCO WORLD. October 1960, by Arabian American Oil Co., 505 Park Ave., New York 22, N. Y., contains 24 pages of illustrated articles, some of which are: "At War with Trachoma," "How Come the Rainbow?" "College Days in Colonial Times," "Pipe Art," "Bring on the Clowns!" "Those Other Precious Stones," "The First 4 out of 7," and "The Versatile Kernel."

(1041) PARALLEL SHAFT SPEED REDUCERS. A new 36-page book, Book No. 2719, by Link-Belt Co., Dept. PR, Prudential Plaza, Chicago 1, Ill., which describes the complete line of Link-Belt's redesigned and expanded line of parallel shaft reducers in 57 sizes, including 23 new sizes. It includes full information for selecting the correct drive for every application. Sixteen pages of rating tables contain thermal and mechanical horsepower rating for each input and output speed.

(1042) NO. 6 CONCENTRATING TABLE. A four-page Bulletin No. 118-O by The Deister Concentrator Co., Inc., 901-935 Glasgow Ave., Fort Wayne, Ind., describing with illustrations the Super Duty Diagonal-Deck No. 6 Concentrating Table. Features are: cannot be equalled for low costs in operation and maintenance; offers higher capacity; surpasses in recovery; requires only 2 H.P. to start and operates at substantially ½ H.P. under continuous operation; offers a time-tested record making head motion.

(1043) RE: PORTER. August 1960, by H. K. Porter Company, Inc., Pittsburgh, Pa., contains 12 pages of short illustrated articles covering activities of the various companies associated with the H. K. Porter Co. Featured is a pictorial article entitled "Freedomland Visitors Ride on Connors Rail." The railroad is one of the major attractions at Freedomland U.S.A., the world's largest and newest amusement center, located in the Bronx (New York City).

(1044) MONEY SAVED BY THERMAL DRYING. A four-page Technical Reprint No. 7060, by Dorr-Oliver Inc., Stamford, Conn., describing the increased output and reduced cost resulting from the installation of a single D-O FluoSolids dryer at a coal preparation plant. The reprint describes the process, equipment, plant operation and control, and operating results obtained at the Price, Ky., plant of Inland Steel Corp.

(1045) WELDING ALLOY CATALOG. A new 56-page welding, brazing and soldering alloy and flux Catalog & Instruction Manual, by All-State Welding Alloys Co., Inc., White Plains, N. Y. describes the physical properties, major uses, detailed application instructions and the latest techniques for welding, brazing, soldering, cutting and hard-facing. Helpful charts and tables summarize alloy selection and properties; products are indexed by major metal use. The manual is designed for the advanced welder or engineer as well as the beginner. The Manual is a must for maintenance or production welders, design, maintenance and production welding engineers and foremen, trade school instructors and purchasing agents.

(1046) ELECTROLYTIC HYGROMETER CELL. A two-page Application Data Sheet, EH 5033, by Scientific and Process Instruments Division of Beckman Instruments, Inc., Fullerton, Calif., describes the new Beckman Electrolytic Hygrometer Cell which makes it possible to measure the moisture content in hydrogen streams.

(1047) REX WORLD. Vol. 26, No. 2, by Chain Belt Co., 4677 W. Greenfield Ave., Milwaukee 1, Wis., contains such features as "Progress in Action," "Cement with a Western Accent," "Hole-Drilling Humdingers," "Did You Know," "Problem and Solution," and "Taking Shape . . . New Look in Missile Launchers."

(1048) POLYDYNE DRIVES. GEA-6806, 16 pages, two color, by General Electric Co., Schenectady 5, N. Y. describes the new ¼ to 25 horsepower line of Polydyne mechanical adjustable speed drives. Bulletin discusses principles of operation, configurations and features, and includes mounting positions, rating tables, and description of available accessories. Also discussed: the benefits of mechanical adjustable speed drives, and how to select and specify Polydyne units.

(1049) MINING CHEMICALS IN THE COAL FIELD. A new booklet by American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N. Y., which discusses methods of solving stream pollution problems and the simultaneous possibilities of profitable recovery of fines now lost in breaker effluent. It outlines methods of coal recovery by flocculation and froth flotation and also gives practical information on the chemicals required.

(1050) EXPLOSIVES & REAGENT NEWS. A four-page pamphlet by American Cyanamid Co., 30 Rockefeller Plaza, New York 20, N. Y. presenting some of the Cyanamid chemicals and suggested uses and featuring the "Do's and Don'ts to Prevent Accidents in the Use of Explosives."

(1051) CONSTRUCTION AND HANDLING EQUIPMENT. By Clark Equipment Co., Benton Harbor, Mich. Bulletin 150A is a four-color catalog describing the complete line of Michigan construction and bulk materials handling equipment. The catalog contains descriptions and full-color illustrations of Michigan tractor shovels, tractor dozers, tractor scrapers, tractor loggers, and excavator cranes. New on-the-job photographs show Michigan equipment in action on projects ranging from interstate highway construction to logging operations. Cover design of the catalog emphasizes the mobility of Michigan rubber tired equipment. One section of the catalog describes the Clark power train basic to all Michigan machines. Components pictured are the torque converter, four-speed power-shift transmission, and steering and non-steering axles.

(1052) DECO TREFOIL. Vol. 24, No. 4, a 24-page publication by Denver Equipment Co., 1400 17th St., Denver 17, Colo., featuring "The Reynolds Mining Corporation's Fluorspar Mill at Eagle Pass, Texas. Also included in this issue is ACD Says, The Original Wonder Drug, Denver Equipment News, What's New—"Tru-Glandless" SRL Pump, Decography (Orvis E. Bowers), Operating Notes, Flowsheet Study—Pyrite Recovery From Tailings, Laboratory Notes, Stock Index, Metal Prices, Froth, and How the Seal Works on Denver SRL Pumps.

(1053) ALL-METAL FLEXIBLE HOSE. By Universal Metal Hose Co. 2133 S. Kedzie Ave., Chicago 23, Ill. A completely new 20-page catalog, No. ID-100D, pictorially describing Universal All-Metal Flexible Hose to convey gases, solids and fluids; for vibration control; and to compensate for motion or misalignment under high temperature, pressure, vacuum or abrasive conditions. Application-use photographs covering a wide variety of industrial applications prove the extreme versatility of Universal quality factory assembled and tested all-metal flexible hose products.

(1054) THE AMSCO BULLETIN. No. 2, 1960, a 16-page publication by American Manganese Steel Division of American Brake Shoe Co., features the following material: Biggest Collection of BIG Shovels, Three Mile Pump, Roadbuilding on the Run, They'll Tackle Anything, and Amsco Ferrous Alloy Castings.

(1055) LABORATORY EQUIPMENT. By Denver Fire Clay Co., 3033 Blake St., Denver, Colo. The General Catalog has been planned to serve as a ready reference for the laboratory man, the purchasing agent, the plant superintendent, the engineer, or the manager. The Denver Fire Clay Co. offers a complete line of refractories, industrial burners, industrial furnaces, combustion control equipment, and other industrial equipment. Laboratory equipment described on pages F-1 through F-27 include annealing cups, various types of crucibles, laboratory crushers, DFC crushers and crusher parts, cupels, cylcaps, clay funnels, moulds, muffles, semi-muffles, muffle plates and hearths, pulverizers, retorts, ore samplers, scorifiers.

(1056) CONTINUOUS VACUUM DISC FILTERS. Bulletin 404 is a 4-page publication by Filtration Engineers Division, American Machine & Metals Inc., East Moline, Ill., which describes and presents features of the FEinc Disc Filter. These filters offer high capacity, trouble-free agitation, minimum floor area, and sizes to 2500 sq. ft.

(1057) LOCOMOTIVE. Bulletin 1295 by Atlas Car & Mfg. Co., dealer: A. J. Philpott Co., 1816 California St., Denver, Colo. This bulletin presents specifications and optional features of the Atlas Type Q 3 ton storage battery Locomotive with rigid cab. Spur gear drive, low maintenance cost, anti-friction bearings, and totally enclosed drive are features of the Atlas locomotive.

(1058) ABOUT FLOTATION. Bulletin No. F5-B32, by Western Machinery Co., San Francisco, Calif., describes the principle of the flotation process for selectively separating finely divided mineral particles, as well as the design, construction and operating characteristics of WEMCO Fagergren Flotation Cells.

(1059) BELT SLINGS. By Wire Rope Division of Jones & Laughlin Steel Corp., Muncy, Pa. A multi-color brochure describing a new line of safety weave synthetic web belt slings. The brochure contains useful information about both nylon and dacron slings, including data showing the resistance to all common agents; charts listing dimensions and capacities of synthetic slings in vertical, choker and basket applications and available aluminum and steel fittings for nylon and dacron slings of varying dimensions and capacities.

(1060) DIHEDRAL SPINDLE COUPLINGS. By Ajax Flexible Coupling Co., Inc., Westfield, N. Y. A 12-page Catalog No. 70 giving engineering, application, capacity and dimensional data on Ajax Dihedral Spindle Couplings as well as Series D-100 and D-3000 Dihedral gear type flexible couplings. A wide variety of Ajax Dihedral couplings for use on mills and allied equipment throughout the ferrous and non-ferrous metal, paper, rubber, chemical, food and other industries is illustrated. Included is a two-page Question, Answer and Sketch sheet to facilitate outlining individual requirements.

MINES MAGAZINE
Golden, Colorado

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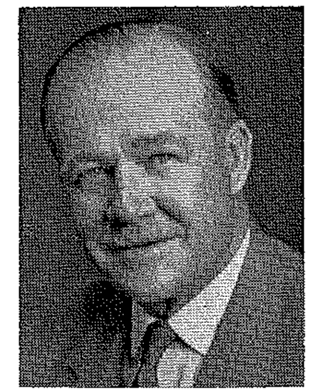
FROM THE EXECUTIVE MANAGER'S DESK



COL. WENDELL W. FERTIG

By this time you have received the proxy mailed with your ballot. If you have not already signed and returned it, I suggest you read the detailed explanation of the proposal to amend the certificate of Incorporation of the CSM Alumni Association, Inc. so that we can enjoy tax exempt status without the question being raised by the Bureau of Internal Revenue. Be sure to sign the Proxy with the same signature as typed on your dues card. Return it at once. The approval of this proposal will simplify several of the problems involved in operating your Alumni Association.

Be sure and vote for your favorite candidate, but the ballots must be in our hands not later than January 20, 1961, if they are to be counted.

Both the Proxy and the ballot have been mailed to those members who have paid their dues for the year 1960.

* * *

Advertising

The recent campaign to increase the amount of advertising has shown some results, but we should not consider that more than just a start. It will require continued pressure from each of you to sell as much advertising as we need to publish a MINES Magazine of which you can be proud. Frank Bowman has done a fine job, but as I have mentioned before, it is not a one-man job, but can only be done successfully by a team effort.

Mr. Otto Highfield is now settled in Phoenix and will represent The MINES Magazine as advertising manager, Pacific Division & Special Accounts. He attended the American Mining Congress in Las Vegas and made many useful contacts. With his new assignment, we hope to increase the amount of advertising available in the West Coast states as well as export accounts. Good luck, Otto.

The MINES Magazine has been listed for the past two months in Standard Rate and Data Catalog. In talking with your company or other prospective clients, emphasize the fact that The MINES Magazine is so listed. At present The MINES Magazine is listed only under Mining Engineering, but by January, 1961, we should be listed under Geological Engineering, Petroleum Engineering and Metallurgical Engineering.

* * *

Membership Benefits

In the October Magazine, I listed six benefits, realizing that there were probably many more that I had not considered. Sure enough, the next mail brought this letter from a loyal and active alumnus. He said, "I would like to add one more benefit, and that is the assistance which alumni can give one another while traveling. For example, every time I make a trip, I take my ALUMNI Directory with me, and regardless of what town I am in, usually I can find an alumnus who can help me with an introduction to an oil company official or with data on local producing properties, etc."

I can second that statement from personal experience. If you find another MINER, you will find someone who is willing to give you a hand.

Yes, all of these seven benefits are tangible and available whether you are an active member or not. But they cost money, and so we appeal to you to only pay your own dues, then persuade your buddy, if he is not a member, to do likewise. Then if persuasion does not work, why not give a membership as a Christmas present. It will be appreciated and will bring him into closer contact with his friends.

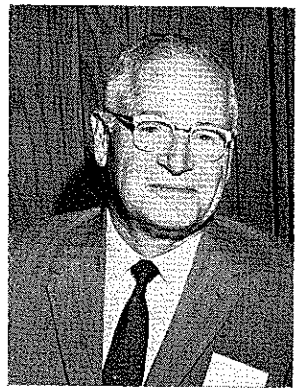
There are always a few who will go along for a free ride, never becoming an active member until times are tough or they need a helping hand. If they had been active and kept up with our activities, they need not have waited until the last moment to turn to us.

Recently, I have been told, "I don't owe the Alumni or the School of Mines a thing. I graduated through my own efforts, I paid my tuition, and I don't owe anyone anything." How short-sighted can you be? Didn't you associate with other students, ask an occasional extra bit of help from a prof., absorb some small amount of the purpose of mutual helpfulness that is such a part of the MINES education. If you can answer all these questions affirmatively, and still repeat "I don't owe anyone anything," I might possibly, just possibly believe it.

I didn't mean to preach, but I just can't understand how anyone can believe that he can stand alone. Someone is always helping without expectation of reward. We are not that altruistic; we expect that the assistance shall be mutual at least, although we would not complain if we do more than our share. Next time the question comes up, why not phrase it this way, "What have I done for the Alumni Association, or the School, or other MINERS?"

IN MEMORIAM

Kuno Doerr, Jr.



KUNO DOERR, JR.

Kuno Doerr, Jr., a 1927 metallurgical engineering graduate of the Colorado School of Mines, died Oct. 13 in a Lima, Peru hospital after a heart attack. He had served since 1958 as president, director and general manager of Southern Peru Copper Corp., Toquepala, Peru. Long an active member of the CSM Alumni Association, Mr. Doerr was one of five Mines alumni to receive the Distinguished Achievement Medals at the School's May 22, 1959 Commencement exercises in Golden, Colo.

Mr. Doerr was born May 3, 1904 in Aguas Calientes, Mexico, and after his graduation from Mines became a chemist at the American Smelting & Refining Co.'s Garfield, Utah smelter. Later he occupied a position as metallurgist with the company and then became assistant superintendent at Garfield.

In 1941 Mr. Doerr came to Salt Lake City as assistant manager of the Utah Department of AS&R Co. From 1947-1955 he was manager of the East Helena plant, and in January 1955 he returned to Utah as manager of the Garfield smelter. At the end of that year, he was given the added job of president of the Garfield Chemical and Manufacturing Co., serving in executive capacities until his election in 1958 as president of Southern Peru Copper Corp. (Asarco is the parent company of Southern Peru Copper Corp.)

Survivors include his widow, Mrs. Gwendolyn M. Doerr, of Toquepala, Peru; a daughter, Mrs. R. N. (Jane Elizabeth) Totten, Spokane, Wash.; a son, Kuno Doerr, III, 1604 Garfield Ave. (1870 South) Salt Lake City, Utah; a granddaughter, his parents and brothers, Alfred, South Pasadena, Calif., and Phil, Torreon, Mexico.

Thomas M. Straney

THOMAS M. STRANEY

Thomas M. Straney, a 1928 mining engineering graduate of the Colorado School of Mines, died Sept. 12 in Mexico City after a short illness. He was born Jan. 2, 1907 in Hoboken, N. J.

Mr. Straney was employed by Nevada Consolidated Copper Co. at Ray, Ariz., and subsequently by Moctezuma Copper Co. at Sonora, Mexico. He also worked for San Francisco Mines of Mexico and for Braden Copper Co. in Chile, South America.

In 1934 Mr. Straney joined the American Smelting & Refining Co. as mining engineer in Parral, Chih., Mexico. He was promoted and transferred to various properties of the company until 1954 when he became general superintendent of the company's Charcas Unit, San Luis Potosi, Mexico, which position he held until his death.

Survivors include his wife, Elizabeth, and four children.

James A. Peck

James A. Peck, a 1923 mining engineering graduate of the Colorado School of Mines, died recently at his home in Colorado Springs.

A native of Colorado, he obtained his elementary and secondary education in Colorado Springs. During World War I he was with Headquarters Co., 148th Battalion, 66th Field Artillery Brigade in five major battles and then with the army of occupation. In World War II Major Peck was Pueblo Air Base ordinance officer for two years and later transportation officer at Headquarters, Air Force Base in Colorado Springs.

Survivors include his wife Marjorie Gilligan Peck, 3 Winfield Ave. Colorado Springs, Colo.; four sons, two daughters, and 15 grandchildren.

Roy B. Munroe

ROY B. MUNROE

Roy B. Munroe, who graduated from the Colorado School of Mines in 1929 with a petroleum engineering degree, died Sept. 7 when a shotgun he was examining in his home discharged accidentally, killing him instantly. The gun was to have been a birthday gift to his 17-year-old son, James.

Mr. Munroe, an employee of the Peoples Gas & Coke Co. of Chicago, Ill. for 27 years, was assistant to the vice-president in charge of sales.

Born Oct. 17, 1908 in Denver, Colo., Mr. Munroe attended both Manual Training and East Denver high schools. He was an honor student at Mines and was awarded the Wolf Medal for scholarship. After his graduation from Mines, he entered the Doherty Junior Engineering School at Bartlesville, Okla. During the succeeding four years, he worked with the Union Public Service Co. and the Kansas City Gas Co., handling industrial engineering work and also doing direct selling. He joined the Peoples Gas Light and Coke Co. in 1933 as sales supervisor and house heating engineer. Three years later he was appointed sales director.

Active in civic activities, Mr. Munroe was an elder in St. Paul's Union Church, a member of the Kiwanis, and a member of the Illinois Athletic Club and the Ridge Country Club.

Survivors include his widow, Mrs. Allison Platt Munroe of 1955 W. 91st St., Chicago 20, Ill.; a son, James, and a daughter, Mrs. Marilyn McKinney, both of Chicago; his father, two sisters, and a brother.

Reginald P. Oliveros

Reginald P. Oliveros, who received his mining engineering degree in 1917 from the Colorado School of Mines, died April 8 at his home, Summons Bluff Road, Yonges Island, S. C. Mr. Oliveros was southeast district representative of Semet Solvay Engineering Corp.

ALUMNI BUSINESS

General Membership Will Vote On Proposal to Amend Certificate of Incorporation

One of the most important matters to come before the general membership of the Association for many years is the proposal to amend the Certificate of Incorporation of the Colorado School of Mines Alumni Association. Since this requires approval by two-thirds of the active members, a proxy statement has been included with the ballott for election of officers for 1961. This proxy should be signed and returned with your completed ballot (a self-addressed, postage-paid envelope is enclosed for this purpose) if you favor the amended certificate. Failure to return the proxy, if you do not plan on attending the annual meeting to be held at the Lakewood Country Club on Thursday evening, Jan. 26, 1961, will effectively cast your vote as being against the proposed amended certificate.

The full text of the proposal follows:

AMENDMENT OF CERTIFICATE OF INCORPORATION OF COLORADO SCHOOL OF MINES ALUMNI ASSOCIATION

We, the undersigned members of the Executive Committee of the Colorado School of Mines Alumni Association, a non-profit corporation under the laws of the State of Colorado, do hereby certify that at a meeting of the members of said corporation duly called and held in the City and County of Denver on the .... day of ...., 1960, at which meeting a resolution as hereinafter set forth, was adopted by a two-thirds vote of the membership.

RESOLVED that the Preamble and Articles I through V, inclusive, of the Certificate of Incorporation of the Colorado School of Mines Alumni Association be and the same are hereby amended to read as follows:

Know All Men By These Presents: That we, C. Lorimer Colburn, Hugh M. Connors, and Malcolm E. Collier, all residents of the City and County of Denver and State of Colorado, and citizens of the United States, have associated ourselves together for the purpose of becoming a body corporate not for pecuniary profit pursuant to the provisions of Subdivision XII, Chapter 38, Compiled Laws of Colorado, as amended by Section 22, Chapter 70, Session Laws of Colorado of 1931, and do hereby make, execute and acknowledge this certificate in writing of our intention so to become a body corporate under said laws.

I

The corporate name shall be: Colorado School of Mines Alumni Association, Inc., hereinafter sometimes referred to as the Association.

II

The Association is organized and shall be operated exclusively for charitable and educational purposes designed to promote the interest and welfare of the Colorado School of Mines and the fraternity and professional excellence of its graduates. To effect these purposes, the Association shall have the power: 1) To publish a magazine dedicated to the growth of a dynamic mineral industry and to the continued attainment of professional excellence among the graduates of the Colorado School of Mines.

2) To acquire by gift, bequest, devise, endowment or purchase, property, real, personal or mixed; to own, manage, convey, lease, exchange, dispose, or encumber such property.

3) To invest in, acquire, hold, mortgage, pledge, hypothecate, resell, exchange, transfer or otherwise dispose of securities of any nature and exercise all the rights, powers and privileges of ownership thereof.

4) To borrow and lend money on such terms as the Board of Directors may determine.

5) To make and execute contracts for any lawful purpose with any person, firm, association, or corporation, or body politic of whatsoever kind or nature.

6) To exercise any and all powers which may be conferred by law or which may be necessary, incidental or convenient to the attainment of the objects and purposes above mentioned.

III

The business of the Association shall be managed and controlled by a Board of seven Directors consisting of the officers of the Association, as hereafter named, and three elected members. The Board shall be assisted in the management and control of the business of the Association by an Executive Secretary, who shall be selected and hired by the Board and shall perform such duties and have such powers as the By-Laws of the Association may provide.

Those persons presently constituting the members of the Executive Committee of the Association shall serve as the Board of Directors until their successors shall be duly determined, elected and qualified.

The officers of the Association shall be: A President, a Vice-President, a Secretary, and a Treasurer.

IV

The principal office of the Association shall be at the Colorado School of Mines, Golden, Colorado.

V

The Board of Directors shall have the power: To make, amend and repeal By-laws for the management and conduct of the business of the Association; and to delegate to one or more officers of the Association the right to convey or encumber all or any part of the property of the Association.

VI

The members of the Association shall be all active, associate, junior, honorary, and life members as defined in the By-laws of the Association. The Association shall not issue capital stock but may issue membership certificates to its members.

VII

No officer, director or member of the Association shall receive any pecuniary profit from the Association, provided, however, that compensation may be paid for any services rendered to the Association by any officer, director, member, agent, or employee or any other person or corporation pursuant to authorization by the Board of Directors.

VIII

These Articles of Incorporation may be amended at any time and in any respect if so authorized by the vote of at least two-thirds of the members present, in person or by ballot, at any meeting called for the purpose of considering such proposed amendment, upon written notice served upon such voting members of the Association, as provided for in the By-laws.

IN WITNESS WHEREOF, we have hereunto set our hands and corporate seal this ....day of ...., 1960.

In order to particularize the changes involved, they are considered separately:

Section I—No change except to add "hereinafter sometimes referred to as the Association."

Section II—In the original charter, this section read: "The object for which our said corporation is formed and incorporated shall be the cultivation of friendship, acquaintance and mutual aid among our members, and the elevation of the reputation and standard of the Colorado School of Mines."

There is some question by the Bureau of Internal Revenue whether this stated object would qualify the Alumni Association as a non-profit organization under the amended income tax laws now in effect. The proposed amendment meets these objections and assures that the Alumni Association does qualify as a non-profit organization. Gifts made to the Alumni Endowment (Trust) Fund are assured of being tax deductible if the amendment is approved.

Section III—The change here is in nomenclature only. The Executive Committee is to be known as the Board of Directors, and the Executive Manager would be known as Executive Secretary. This change is proposed merely to bring the name of our governing body into accord with modern practice.

Section IV—Restates the content of the original.

Section V—The proposed amended certificate restates the original Section V by deleting the reference to the Constitution of the association.

Sections VI, VII, and VIII are taken from the present constitution and represent all of that document that will be preserved in the amended certificate. All other powers contained in the constitution are more properly placed in the By-Laws of the association.

If there are any questions concerning this matter, you should write the Executive Manager at once, so that your questions can be answered in time to allow you to act on the proposal.

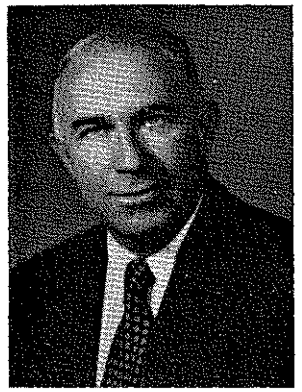
Nominating Committee Members

Members of the Nominating Committee are Edward F. Kingman, '34, chairman; A. B. Manning, '40; Robert H. Waterman, '28, and Anthony F. Corbetta, '48.

ALUMNI NEWS

V. N. Burnhart, '32, Elected E. J. Longyear Co. President

Vincent N. Burnhart, a 1932 graduate of the Colorado School of Mines, has been elected president of the E. J. Longyear Co., Minneapolis, Minn. He succeeds Donald M. Davidson who died Sept. 15.



VINCENT N. BURNHART

Mr. Burnhart, who graduated from Mines in 1932 with a degree in mining engineering, was associated until 1942 with American Metals Climax. Between 1942 and 1946 he commanded a battalion in the Corps of Engineers, serving in China, India and Burma.

Joining the Longyear Co. in 1946, Mr. Burnhart became manager of the Contract Drilling Division in 1947. He was named general manager in April of 1957 and became vice president in January 1958.

He is a director of the E. J. Longyear Co. and of Canadian Longyear Limited, North Bay, Ontario. He also is president of the Diamond Core Drill Manufacturers Assoc., an organization made up of leading U. S. core drilling equipment producers.

As president, Burnhart will direct the operations of a company which manufactures diamond core drilling equipment and supplies, does exploration drilling on contract, and offers geological consultation and mining engineering services. Subsidiary companies are located in Canada, Holland, France, Mexico and Japan. Sales representatives are located throughout the world.

Baroch, '54, Accepts Position with Battelle

Charles J. Baroch, a 1954 metallurgical engineering graduate of the Colorado School of Mines, has accepted a position as senior engineer in Frank Stephens' ('42) Extractive Metallurgy Division at Battelle Memorial Institute. His address is 770 Harley Dr., Columbus, Ohio. Before joining Battelle, Mr. Baroch was senior metallurgist, Army Reactors, USAEC, at Germantown, Md.

Prior to leaving the Commission, Mr. Baroch prepared a paper, "A Comparison of Stainless Steel and Zirconium for Use in Pressurized Water Reactors," which he has offered for publication in The MINES Magazine.

94 Mines Men Attend Luncheon at AMC Meeting

On Oct. 11 ninety-four Miners from all over met for an informal luncheon in the Gourmet Room of the Tropicana Hotel, Las Vegas, Nev., during the American Mining Congress meeting held in that city Oct. 10-13. They were:

Arthur C. Terrill, '05; Frank Briber, '16; Blair Burwell, '19; Myron L. Sisson, '20; Jack Bonardi, William McKenna and I. M. Charles, '21; "Bunny" Livingstone, x-'21; Pitt W. Hyde, Louis C. Rhodes, '22; Lute J. Parkinson, Edward McGlone, '23; R. W. Persons, x-'23; Manuel F. Quiroga, Dewitt C. Deringer, '24; Donald M. Ray, M. H. Salsbury, Norman Whitmore, Gaylord Weaver, '26; E. H. Crabtree, M. Edward Chapman, '27; Salvador del Rio, '28; Robert R. Williams, '29; Wm. Page Morris, '30; H. R. Nye, J. L. Robinson, Robert L. Stark, '31; James Boyd, V. N. Burnhart, Robert J. Dalton, G. W. Heim, A. George Setter, '32; Frank Coolbaugh, Neil O. Johnson, '33; W. G. Rinker, x-'33; Charles E. Golson, Edward Matsen, H. David Squibb, N. F. Wetzel, '34; C. Wilbur Gustafson, x-'34.

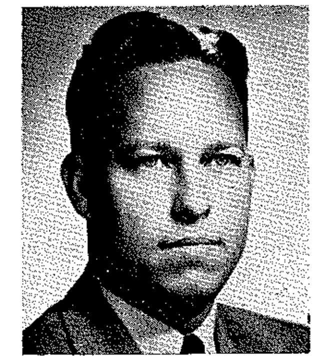
George O. Argall, Jr., C. H. Carlton, Albert M. Keenan, E. Keith Staley, '35; F. E. Love, E. F. White, G. W. Wunder, '36; James A. Appleton, '37; T. G. Swartz, '39; Donald H. Dowlin, W. E. Heinrichs, Jr., Howard K. Schmuck, '40; Charles S. Burriss, x-'40; Robert P. Comstock, W. L. Crow, L. S. Helms, W. E. Janakka, '41; Richard L. Scott, '42; H. C. Bishop, Jr., David F. Coolbaugh, Alec Jamieson, Richard F. Moe, '43; T. C. Hedlund, W. D. Lord, Jr., A. M. Simpson, Charles V. Woodard, '44.

John L. Bolles, John A. Brandon, R. C. Cutter, D. S. Galbraith, D. R. Siljestrom, '49; D. M. Cooper, Fred C. Hohne, Jr., '50; V. F. Malone, R. A. Martin; '51; Richard Chojnacki, Richard Franklin, E. D. Smith, '52; Louis A. Gaz, John Lindberg, J. D. Mulryan, Eric Newman, '54; Mervin L. Greenlee, '56; Robert W. Dalton, '57; B. Frank Porter, '60.

▼On Oct. 11th 94 Miners from all over met for an informal luncheon in the Gourmet Room of the Tropicana Hotel, Las Vegas, Nev., during the American Mining Congress meeting held in that city on Oct. 10-13.

Schilthuis, '30, Receives Award at SPE Meeting

Ralph J. Schilthuis, '30, executive vice-president and member of the board of management of the Humble Division of Humble Oil & Refining Co., received the 1960 John Franklin Carll Award presented by the Society of Petroleum Engineers of AIME.



RALPH J. SCHILTHUIS

Schilthuis was honored by the Society at its 35th Annual Fall Meeting held Oct. 2-5 in Denver, Colo. Presentation was made at the Welcoming Luncheon on Monday, Oct. 3.

The award carried the following citation: "In recognition of his important contribution to the technology of petroleum engineering and for his example in applying engineering principles to the problems of industrial management".

The purpose of the Carll Award is to "recognize distinguished achievements in or contributions to petroleum engineering". It was established in 1957 and has previously been awarded to Herbert Comstock Otis, Gen. E. O. Thompson and Eugene A. Stephenson.

Schilthuis joined Humble in 1930 after graduating with a petroleum engineering degree from Colorado School of Mines. During his 30-year tenure with the company, he has served in various capacities in the Production Research Division, Administrative Department, Petroleum Engineering Division, Gas Division, and Production Department. In 1955 he was elected a director, and in 1957, vice-president. He assumed his present position in 1959.

Schilthuis has previously been honored for his engineering achievements when he received the Alfred Noble Prize in 1938 from the founder engineering societies for an outstanding technical paper written by a member no more than 30 years old.

Conventions Scheduled

Nov. 14-16—American Petroleum Institute in Chicago, Ill.

Nov. 18—American Mining Congress Coal Convention Committee meeting in Pittsburgh, Pa., (1961 Coal Show, May 15-18, 1961)

▼In spite of a few serious faces, Miners enjoyed the dinner sponsored by the local Denver Section held Oct. 3rd at the Denver Press Club to honor delegates attending the Fall Meeting of the Society of Petroleum Engineers of AIME.

Gruberth, '55, Analyst With Continental Oil Co.

Fred J. Gruberth, a 1955 geological engineering graduate of the Colorado School of Mines, is now employed by Continental Oil Co. as analyst in the Coordinating and Planning Department. He writes that the new job is extremely interesting and quite different from his previous work. In a philosophical vein he adds that "it is always a challenge to learn new things and the experience should be invaluable in later years."

FRED J. GRUBERTH

Mr. and Mrs. Gruberth and two children—Jill, 5, and Cincy, 3—are nicely settled in Houston, Texas at 9701 Warwana Rd.

After graduating from Mines, Mr. Gruberth was employed as a junior geologist by Superior Oil Co. in Grand Junction, Colo. Three years later he decided to become a student once again and to earn his Master's degree in business administration, which he received from Harvard University in June 1960.

Mr. and Mrs. Mills E. Bunger, '09, Celebrate Their Fiftieth Wedding Anniversary

Mr. and Mrs. Mills E. Bunger of 3850 Harlan St. Wheatridge, Colo. celebrated their 50th wedding anniversary with a dinner at the Holland House in Golden. They were married in Denver Sept. 29th 1910.

Mills graduated from the Colorado School of Mines, class of '09; Mrs. Bunger, formerly Mary Ethel Dale, graduated from Greeley class of '08.

They have a son, David Elwood, of Klamath Falls, Ore., and two daughters, Mrs. Barbara Fagerberg of Powell, Wyo., and Mrs. Dorothy Laipple of Sturgeon Bay, Wis., and six grandchildren.

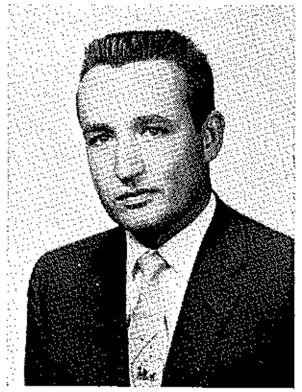
Mills retired from the Foreign Service of the State Department and is now a consultant on water problems.

Metzger, '34, Joins Houston Chemical Corp. As District Sales Manager

Russell E. Metzger, E. M. '34, has left the employ of C. F. & I. where he was general manager of tubular sales and has joined Houston Chemical Corp. as district sales manager with office and residence in Houston. His office address is the Americana Building; home address, 3722 Drummond Dr., Houston 25, Texas, telephone MA 3-2755.

Now constructing a plant in Beaumont, Texas, for the manufacture of tetra ethyl and tetra methyl lead, Houston Chemical is the third largest manufacturer of TEL and TML in the country.

Mitchell, '53, Wins Degree, Gets Married, Tours Europe, And Accepts New Job



GEORGE W. MITCHELL

George W. Mitchell, Jr., who received his E.M. degree from the Colorado School of Mines in 1953, this June earned a Master's degree in business administration from Stanford University, where he had been a graduate student for the past two years.

Soon after graduation he was married to Miss Susan Arnold who had been teaching school for the past few years in Palo Alto, Calif. The happy couple spent its honeymoon touring England and Western Europe this summer. They returned to the Bay Area shortly before Mrs. Mitchell was scheduled to start teaching school.

Mr. Mitchell writes that since he wanted to get a little experience in other types of industries, he recently took a job as assistant to the sales manager of Ultek Corp., an electronics firm engaged in the business of manufacturing and distributing ultra high vacuum ion pumps. He concedes that his new job "is a ltle different from mining but it is a rapidly growing company and very interesting."

Lankenau, '48, Appointed Department Head by Union Carbide Nuclear Co.

Arthur W. Lankenau, a 1948 metallurgical engineering graduate of the Colorado School of Mines, was recently appointed department head of Union Carbide Nuclear Co.'s Experimental and Development Laboratory at Grand Junction, Colo.

Mr. Lankenau has taken graduate work at both Stanford and Columbia Universities—during World War II he studied advanced mechanical engineering in the Army Specialized Training Program, and in 1948-49 he attended mineral engineering graduate school at Columbia University.

His principal work experience has been ore testing engineer for Denver Equipment Co.; mill superintendent, National Lead Co. at Fredericktown, Mo.; research metallurgist for M. A. Hanna Co.; plant superintendent, mill superintendent and department head for Union Carbide Nuclear Co. at Uravan, Colo.

Phillips, '49, Receives Ph.D. from Harvard

JOHN S. PHILLIPS

John S. Phillips, a 1949 geological engineering graduate of the Colorado School of Mines, received his Ph.D. in geology this spring from Harvard University. Since July he has been employed in mining exploration by Montana Phosphate Products Co. at the company's Prescott, Ariz. office. Mr. and Mrs. Phillips and their two children—Margaret Rose, 6, and Hugh Alan, 3—are living at 606 Douglas Ave., Prescott, Ariz.

After graduating from Mines, Mr. Phillips worked as a geologist for New Jersey Zinc Co. at Gilman, Colo. In January 1951, he was called to active duty in the Army Corps of Engineers as a second lieutenant. He served as Battalion supply officer with the 656 Engineer Topographic Battalion at Schwetzinger, Germany. While in Germany, he married Danielle Grace, a British citizen employed by the U. S. Army Engineers.

After completion of his tour of duty, Mr. Phillips returned to work for New Jersey Zinc in Colorado. In September 1954, he entered graduate school at Syracuse University, completing requirements for a M.S. in geology a year later. In the fall of 1955 he continued graduate study at Harvard University, where he took course work for two years. The next year was spent on field work for his dissertation on "Sandstone-Type Copper Deposits of the Western United States" under the direction of Professors H. E. McKinstry and R. M. Garrels. The next two years were devoted to laboratory work and writing of the dissertation and in June 1960 he received his Ph.D. from Harvard.

Courtier, '28, Honored For 25 Years of Service With Phillips Petroleum

William H. Courtier, who in 1928 received a Master's degree in geology from the Colorado School of Mines, was honored recently for 25 years of service with Phillips Petroleum Co. Mr. Courtier, chief geophysicist of Phillips' land and geological department in Bartlesville, Okla., was one of 188 long-service employees from 20 states and two other countries honored at a dinner Oct. 6.

A native of Newark, Ohio, Mr. Courtier has a B.S. degree in civil engineering from Denison University and a Ph.D. in geology from the University of Kansas, in addition to his Master's degree from Mines. He has headed the student's membership committee of the Society of Exploration Geophysicists, and is a member of the H. C. Price Colorado School of Mines scholarship committee.

In 1957 he received the Erasmus Haworth Distinguished Alumni Award in geology from the University of Kansas and in 1959 was honored with a similar citation from Denison University. He is a member of the American Association of Petroleum Geologists, Society of Exploration Geophysicists, Geological Society of America, and Sigma Xi.

J. P. Allen, '57, Awarded Fellowship at Harvard

John P. Allen, a 1957 graduate of the Colorado School of Mines, has been awarded the Mineral Engineering Fellowship for 1960 at the Harvard Business School. He is the seventh Mines graduate to receive the Fellowship since the program was started in 1953. The two-year Harvard course leads to the degree Master in Business Administration.

Allen will receive $1500 annually to support his study and he may select his own method and time schedule in repaying the revolving fellowship fund. Five Mines graduates have already completed the program and are now employed in mineral engineering administration throughout the country.

A native of Pauls Valley, Okla., Allen received a metallurgical engineering degree from Mines. A veteran of the U. S. Army Corps of Engineers, he was student body president at Mines and a three-year letterman in football. Since graduating from Mines he has worked as a mill metallurgist and senior metallurgist for Allegheny Ludlum, and as a department head for Union Carbide.

FROM THE LOCAL SECTIONS

Minutes of Section Meetings should be in the Alumni Office by the 15th of the Month preceding Publication.

ALABAMA

Birmingham Section

Pres.: Joseph Hohl, '25
Sec.: Richard White, '42
249 Flint Dr., Fairfield

ARIZONA

Arizona Section

Pres.: Spencer R. Titley, '51
V. Pres.: Roger R. Nelson, '50
Sec.-Treas.: John H. Bassarear, '50
c/o Pima Mining Co., Box 7187, Tucson
Annual meetings. First Monday in December; 3rd Sunday in May (annual picnic).

Four Corners Section

See New Mexico for officers

CALIFORNIA

Bay Cities Section

Pres.: John D. Noll, '51
V. Pres.: Ralph D. Eakin, '48
Treas.: Herbert D. Torpey, '51
Sec.: Charles G. Bynum, '26
2810 Loyola Ave., Richmond

Southern California Section

Pres.: R. E. "Ray" McGraw, '53
Treas.: J. R. Leonard, '42
Sec.: H. David Squibb, '34
2215 E. Sycamore St., Anaheim

COLORADO

Denver Section

Pres.: Ronald F. Lestina, '50
V. Pres.: Hugh Wallis, '28
Sec.-Treas.: Patrick C. Brennan, '53
1893 S. Leyden, Denver 22
Office: AC 2-2060

Regular luncheon meetings are held the third Tuesday of each month at the Denver Press Club, 1330 Glenarm Pl. During the football season, films of the previous Mines game will be shown at luncheon meetings which will be held every Tuesday during that period.

Four Corners Section

See New Mexico for officers

Grand Junction Section

Pres.: John Emerson, '38
V. Pres.: Tony Corbetta, '48
Sec.-Treas.: Joe Hopkins, Ex-'37
1235 Ouray Ave., Grand Junction

DISTRICT OF COLUMBIA

Washington, D. C., Section

Pres.: Alexander S. Wyner, '25
V. Pres.: Leroy M. Otis, '14
Sec.-Treas.: Horace T. Reno, '48
708 N. Wayne St., Arlington 1, Va.

ILLINOIS

Great Lake Section (Chicago)

Ray Watson, c/o Standard Oil Co., 910 So. Michigan Ave., Chicago 80, Ill.

KANSAS

Kansas Section

Pres.: Francis Page, '39
Sec.: James Daniels, '51, AM 5-0614
205 Brown Bldg., Wichita
Meetings: Called by Sec. Contact Sec. for date of next meeting

LOUISIANA

New Orleans Section

Pres.: George Burgess, '49
V. Pres.: Emory V. Dedman, '50
Sec.-Treas.: Thomas G. Fails, '54
P.O. Box 193, New Orleans 12, La.
Special meetings on call of officers; no regularly scheduled meetings.

MINNESOTA

Iron Range Section

Pres.: Paul Shanklin, '49
V. Pres.: Leon Keller, '43
Sec.-Treas.: James Bingel, '53
50 Garden Dr., Mt. Iron, Minn.
Exec. Com.: Wm. Gasper, '43 and Robert Shipley, '52

MISSOURI

St. Louis Section

Pres.: Earl L. Sackett, '33
Sec.: H. A. Dumont, '29
227 Crane St., Edwardsville, Ill.

MONTANA

Montana Section

Pres.: John Suttie, '42
V. Pres.: John Bolles, '49
Sec.-Treas.: Wm. Catrow, '41
821 W. Silver St., Butte

NEW MEXICO

Four Corners Section

Pres.: Dick Banks, '53
V. Pres.: Tony King, '57
Sec. Treas.: Tom Allen, '41
2104 E. 12th St., Farmington

NEW YORK

New York Section

Pres. & Treas.: Ben F. Zwick, '29
Sec.: H. D. Thornton, '40
Union Carbide Olefins Co.
30 E. 42nd St., New York City

OHIO

Central Ohio Section

Pres.: Roland Fischer, '42
Sec.-Treas.: Frank Stephens, Jr., '42
Battelle Mem. Inst., Columbus

Cleveland Section

Pres.: Charles W. Irish, '50
3811 Merrymound Rd.
No regularly scheduled meetings. Special meetings on call of the president.

Cleveland Section

Charles Irish, '50, president, Cleveland, Ohio, Local Section, writes:

"It's a tremendous task to get Miners together in this area. While we're all Miners and are proud of it, there are few, if any, professional ties that draw us together and help keep us that way. For example: Ted Goudvis in Vermilion, Ohio, operates a concrete block plant, John Hutton is a Manufacturers' representative, and I help General Electric make tungsten for light bulbs. We've had a couple of good flings during the past couple of years and there'll be more. Much as I would like to report weekly meetings, speakers, outings, and professional activities, I must admit I can't, at least to the extent other Sections do. However, we're here and, believe me, some of us still have that terrific Mines spirit. You'll be hearing from us from time to time.

"Give 'em hell, Mines!!"

Pennsylvania-Ohio Section

See Pennsylvania for officers

OKLAHOMA

Bartlesville Section

Pres.: W. K. Shack, '51
V. Pres.: W. H. Courtier, '28
Sec.-Treas.: C. F. Hinrichs, '57
403 Parkview Drive
Bartlesville, Oklahoma
Luncheon meeting every Friday, Bartlesville Y.W.C.A.

Oklahoma City Section

Pres.: Fred E. Rugg, '49
V. Pres.: Lincoln F. Elkins, '40
Sec.-Treas.: C. E. Ramsey, Jr., '58
511 NW 47th St.
Regular meeting first Monday of each month

Tulsa Section

Pres.: Chester H. Westfall, Jr., '52
V. Pres.: Brook Tarbel, '50
Sec.-Treas.: Charles J. Diver, '52
528 S. New Haven, Tulsa 12

PENNSYLVANIA

Eastern Pennsylvania Section

Pres.: Samuel Hochberger, '48
V. Pres., Sec-Treas.: Arthur Most, Jr., '38
91 7th St., Fullerton

Pennslvania-Ohio Section

Pres.: L. M. Hovart, '50
Sec.-Treas.: George Schenck, '52
7130 Thomas Blvd., Pittsburgh
Meetings upon call of the secretary

TEXAS

Houston Section

Pres.: Jack Earl, '53
V. Pres.: John C. Capshaw, '54
Sec.-Treas.: Nick Shiftar, '40
5132 Mimosa St.,
Bellaire, Texas

Houston Section

Nick Shiftar, '40, advises that the Houston Section held its regular monthly luncheon meeting at the Lamar Hotel on Oct. 5. The turnout was very gratifying, with 43 Miners present, many of whom came for the first time.

Dave Johnson, CSM faculty retired and now a member of the CSM

Board of Trustees, was a surprise visitor. He gave an enjoyable report on the recent developments in Golden.

A short discussion was held about some sort of social family event early in December, but nothing definite has been decided.

All Miners who will be attending the API Refinery Division meeting in Houston next year are reminded of a special Mines Alumni luncheon to be held on Tuesday, May 9th, at the Houston Club.

Miners who attended the Oct. 5 luncheon meeting were:

A. G. Wolf, '07; S. A. Merwhirter, '17; C. Don Beeth, '24; Jim Ballard, M. L. Euwer, Don Davis, '25; H. W. Haight, '27; Ed Borrego, x-'27; Jack B. Ferguson, A. C. Stanfield, Ken Bowie, '30; Don Herbert, Frank Linderman, '33; J. D. Perryman, '35; W. Bruce Barbour, '37; S. A. Wickstrom, J. L. Morris, '38; John Biegel, '39; Nick Shiftar, G. E. Crosby, Lynn Ervin, '40; Howard Itten, H. E. Stommel, '41; Dell Redding, Dick Hohlt, '47; Dennis E. Gregg, Jack Warren, J. W. Williams, '50; Duane Coppedge, Larry Forney, '51; C. A. Lehnertz, Jr., Bob Turley, B. W. Barnes, '52; Jack F. Earl, Dale Hieger, George Freeland, '53; John Capshaw, Bob Abercrombie, '54; J. H. Jackson, '56; W. C. Bagby, '58; Robert E. Miller, '59.

North Central Section

V. Pres.: Howard Itten, '41
Sec.-Treas.: Harley Holliday, '42
4505 Arcady Ave., Dallas 5
Sec.-Treas.: John Thornton, '50
609-B Scott St., Wichita Falls

Permian Basin Section

Pres.: William D. Owens, '45
V. Pres.: Thomas M. McLaren, '52
Sec.-Treas.: James F. Rucker, '52
2102 Club Drive, Midland
Luncheon meeting the first Friday of each month at Midland Club.

South Texas Section

Pres.: James Wilkerson, '31
V. Pres.: Edward Warren, '50
Sec.-Treas.: Richard Storm, '53
1007 Milam Bldg., San Antonio

UTAH

Four Corners Section

See New Mexico for officers

Salt Lake City Section

Pres.: Robert B. Ingalls, '48
Vice Pres.: Edwin T. Wood, '48
Sec.-Treas.: Major W. Seery, '56
260 W. 1200 North, Bountiful, Utah
Regular luncheon meeting second Thursday of each month at the Ft. Douglas Club.

WASHINGTON

Pacific Northwest Section

Pres.: Wm. C. Douglas, '11
Sec.-Treas.: C. Ted Robinson, '53
16204 S.E. 8th, Belleview

WYOMING

Central Wyoming Section

Vice Pres.: Martin Hegglund, '41
806 W. 13th St., Casper

▼The Manila Section of the Colorado School of Mines Alumni Association recently held a dinner meeting to honor George O. Argall, Jr., '35, and Horacio B. Ma. Aycardo, '55.

CANADA

Calgary Section

Pres.: Joe S. Irwin, '54
V. Pres.: G. L. Gray, '50
Sec.-Treas.: Hugh Evans, '49
Hudson's Bay Oil & Gas
320 7th Ave. West
Luncheon meetings held 3rd Monday of each month in Calgary Petroleum Club; visiting alumni welcome.

Calgary Section

Hugh Evans, '49 secretary-treasurer of the Calgary Section, writes that the section held its first meeting of the fiscal year in the Calgary Petroleum Club at noon on Sept. 19. Twenty-two fellow Miners were present. This is a fair percentage of the 43 alumni living in Calgary, considering an additional five were out of the city.

Evans adds that several Miners including himself "expressed opinions that the recent issues of The MINES Magazine exhibited a new flavor of humor, organization and style that is most welcome to all of us. Keep up the good work . . ."

PERU

Lima Section

Pres.: Richard Spencer, '34
V. Pres.: Martin Obradovic, '53
Sec.-Treas.: Norman Zehr, '52
Casilla 2261, Lima
Meetings first Friday of each month, 12:30 p.m., Hotel Crillon (April through December), or on call.

PHILIPPINES

Baguio Section

Pres.: Francisco Joaquin, '26
V. Pres.: Claude Fertig, x-'27
Sec.: P. Avelino Suarez
Balatoc Mining Co., Zambales

Manila Section

Pres.: Anselmo Claudio, Jr., '41
V. Pres.: Rolando Espino, '41
Sec.-Treas.: Edgardo Villavicencio, x-'40

Manila Section

The Manila Section of the Colorado School of Mines Alumni Association held a dinner honoring George O. Argall '35, editor of the *Mining World,* and Horacio B. Aycardo, '55, during Mr. Argall's visit to the Philippines last spring. Many of these men are now occupying important positions in the mineral industry of the Philippine Islands. Those who attended the meeting were:

Front row, left to right: Jones R. Castro, E.Met. '39; Anselmo D. Claudio, Jr., E.M. '41, president of the Manila Section; George O. Argall, Jr., E.M. '35, guest of honor; Horacio B. Ma. Aycardo, P.R.E. '55, guest of honor; Edgardo I. Billavicencio, x-'40, secretary of the Manila Section; Ernesto C. Bengzon, E.M. '21.

Standing, left to right: J. C. Quema, E.M. '39; Estanislao Y. Feria, Geol.E. '41; Rolando Gamboa, E.M. '40; Manuel M. Aycardo, Jr., Geol.E. & E.M. '41; David Sycip, E.M. '39; John R. Kuykendall, E.M. '41, and Domingo T. Lim, E.M. '41.

TURKEY

Ankara Section

Alumni visiting Turkey contact:
Ferhan Sanlav, '49, Turkiye Petrolleri A. O. Sakarya Caddesi 24, Ankara; Tel. No. 23144.

VENEZUELA

Caracas Section

Pres.: William A. Austin, Jr., '27
V. Pres.: G. V. Atkinson, '48
Sec.-Treas.: T. E. Johnson, '52
c/o Phillips Petr. Co.
Aptdo 1031
Asst. Sec.-Treas.: R. L. Menk, '51
c/o Creole Petr. Corp.
Aptdo 889

CAMPUS HEADLINES

Department of Petroleum Engineering

By PROF. CLARK F. BARB, '25

Petroleum engineering education at the Colorado School of Mines dates from the fall of 1916 when a course entitled "The Geology of Coal, Oil, and Gas" was offered under Mr. Pynch of the Geology Department for the first time. Hager's "Practical Oil Geology," "Oil and Gas Production" by Johnson and Huntley, and "The American Petroleum Industry" by Bacon and Hamor were used as references by Professor Ziegler who gave the lectures on the subject the next year. The lack of an adequate text led Professor Ziegler to write his "Popular Oil Geology" which was published in 1918 by C. H. Merrifield of Golden. Courses on the geology of oil and gas have been offered continuously since that time.

Dr. V. C. Alderson became president of the school in September, 1917. He was intensely interested in oil shale at that time and the author of a number of articles and bulletins on the subject. His contacts with the oil industry, together with his association with Professor Ziegler and other faculty members, brought the need for subjects in oil technology to his attention. As a result, a number of courses were added to the curricula and these eventually led to the establishment of the Petroleum Engineering Department in 1922.

"Oil and Oil Shale Technology", offered by Prof. C. W. Botkin in 1918, marked the entrance of the Chemistry Department into the subject of petroleum engineering. This course only partially answered the demand for additional work on the subject and led Professor Botkin to give "Oil Shale Analysis," "The Chemistry of Hydrocarbons," "Petroleum Refining," and "The Analysis of Mineral Oils" in 1920. Professor Botkin was succeeded by Professor Franks in 1921 and the courses changed in name, although not materially in content. A course in "Oil Field Development" was added to the curricula during this year by Prof. F. M. Van Tuyl of the Geology Department. Prof. R. B. Baxter took over the work in petroleum chemistry in 1923 and had charge of this phase of petroleum technology for many years.

The need for men who were trained primarily for entrance into the field of petroleum engineering became increasingly apparent and a Department of Petroleum Engineering was organized in 1922. Mr. W. H. Kirby, who had a background of practical experience, was engaged to head the new department. Several courses in production, transportation, and refining were introduced in addition to the petroleum subjects already being given by the Chemistry and Geology Departments.

Professor Kirby was succeeded by Prof. R. C. Beckstrom who came to the school from Oklahoma University in 1923. He organized a strong refining option and gave a few courses in oil production and management. In 1924, Mr. P. H. Shannon of the Continental Oil Co. took over the work on the production phases of oil technology and expanded that portion of the subject. Ten lecture hours of strictly petroleum refining subjects and nine hours of strictly production subjects were being offered by the department by 1926.

Professor Beckstrom left the department in the spring of 1928 and Professor Shannon became head of the department. Professor Shannon left the school in the fall of 1928 and was succeeded by Mr. Byron B. Boatright as head of the department. Professor Boatright resigned in 1937 and Prof. Clark F. Barb was appointed head of the Petroleum Engineering Department which gave the degree of petroleum engineer, production or refining option. At that time there was an effort to make the course work in petroleum engineering comparable to the work in general engineering because of the extremely varied type of problems encountered by engineers in either production or refining. Much of their work was common to both with the production men taking more geology and the refining men taking more chemistry.

In 1938 Prof. J. O. Ball was employed to handle the courses in refining and in 1948 the department of Refining Engineering was set up separately with Professor Ball as head. The Department of Petroleum Engineering was continued with Professor Barb as head. The two departments were accredited separately whereas previously they had been accredited as a single department. The curricula have diverged considerably during the past 10 years with more emphasis on chemical engineering in the refining work and more emphasis on mechanical engineering and geology in the production division.

In 1958-59 there began a change in curriculum with a reduction in total course requirements of all students and a shift from the heavy curriculum of physical science and engineering courses to one liberalized in the direction of humanities, arts and social sciences.

At this time (1960) the curriculum in petroleum engineering is more in line with the curricula of other schools giving work in this field and the rather unique position of Mines in having a very heavy and unbalanced load of science and engineering has changed. It is possible now for students from other areas to find schools near home which offer courses fairly comparable to that now given at Mines. This change in all of the curricula has been the result of accrediting requirements on a national level and is reviewed by inspecting groups from ECPD (Engineering Council for Professional Development). The final accreditation comes from the national offices of ECPD and the purpose is to bring all schools of engineering to the same general level of education.

(Editor's Note—Does this accreditation result in an improvement of mineral engineering education or does it result only in bringing all schools to a norm which may or not represent the finest level of education in the respective areas of the Mineral Industries? Question is asked by the editor and does not represent or reflect the views of the Petroleum Engineering Department or that of the administration of the Colorado School of Mines. wwf.)

The Petroleum Engineering faculty as of 1960 is comprised of Prof. Clark F. Barb, Dr. R. V. Hughes, formerly of Stanford University and the Gulf Oil Corp., and Dr. H. K. van Poollen, presently with Ohio Oil Co. Research Division and special lecturer in reservoir engineering. Graduate students are doing some part-time work in the department. All course work in the sciences and general engineering is handled by the particular departments involved and this type work is not given in the Department of Petroleum

Engineering as is the case in some schools. The Petroleum Department simply indicates where such background knowledge may be used in the development and operation of oil fields.

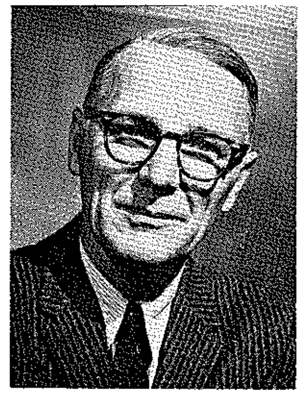
PROF. CLARK F. BARB

CLARK F. BARB, who has been professor and head of the Department of Petroleum Engineering at the Colorado School of Mines since 1936, received P.E. and M.Sc. degrees (1925 and 1928) from Mines. He also attended Kansas State Agricultural College in 1915-16 and worked as a part-time student on a Ph.D. degree from 1942-44 at the University of Colorado.

Professor Barb's professional experience began in 1916, when he was employed as a rodman in the Engineering Department of the Santa Fe Railroad in Kansas. During the 44 years that followed, Professor Barb has been active as a professor of petroleum engineering (at Mines and for a few years at Pennsylvania State College) and as a petroleum engineering consultant for many government agencies and private corporations.

During World War II, Professor Barb acted as consultant to the Petroleum Administration for War in the Reserves Division. From 1945 to 1948 he was in charge of the Colorado Industrial Research program and was consultant to the Colorado Oil & Gas Commission. From 1951 to 1954 he served as a commissioner on the Colorado Oil & Gas Conservation Commission. During the past 10 years he has been a member of various committees of the Interstate Oil Compact Commission, the Research Committee, the Secondary Recovery Committee, and was regional chairman of the special committee on Underground Storage of Petroleum for the National Defense Council.

The author or co-author of numerous articles for technical publications and of innumerable reports to governmental agencies and operating companies, Professor Barb is a member of Tau Beta Pi, AIME, Rocky Mountain Assn. of Petroleum Geologists, Petroleum Engineers Club of Denver, Colorado Scientific Society, Sigma Gamma Epsilon, Sigma Xi, Scabbard and Blade, American Chemical Society, and American Society of Civil Engineers.



PROF. R. V. HUGHES

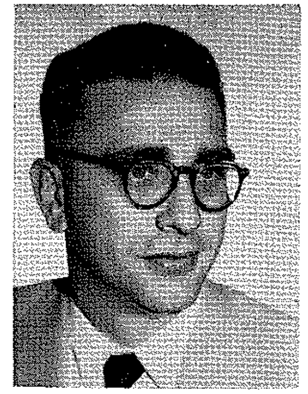
RICHARD V. HUGHES joined Mines as a professor of petroleum engineering in November 1958. He is an engineering graduate of the University of Nebraska, class of 1925. Following graduation, he spent three years in Venezuela in oil exploration and development work and then entered The Johns Hopkins University from which he received a Ph.D. degree in geology in 1933. The years 1935-1941 were spent with the Tropical Oil Co. (Standard) in Colombia as geologist, assistant chief geologist, and chief geologist.

The period 1941-49 was spent in Washington, D. C., as chief of the development unit, Petroleum Administration for War, and as director of secondary recovery of oil research for the Pennsylvania Grade Crude Oil Assn., Bradford, Pa.

He taught petroleum engineering at Stanford University, 1949 to 1953, becoming head of the department in 1951, and worked part time at the Stanford Research Institute on oil production research. He resigned from Stanford in 1953 to become technical advisor to the Vice President of Production, Gulf Oil Corp., Houston, Texas.

Professor Hughes teaches the senior courses in oil production, reservoir engineering, and oil property valuation. He is responsible for the graduate instruction in petroleum engineering and teaches the graduate courses in drilling and secondary oil recovery.

HANK K. van POOLLEN is a research engineer for The Ohio Oil Co., Denver Research Center, Littleton, Colo.



DR. H. K. VAN POOLLEN

He is a native of the Netherlands and studied at the University of Delft, where he received his Bachelor's degree in Mining Engineering in 1948. He then studied at the Colorado School of Mines and received a Master's degree in mining engineering in the Mining Department in 1950.

Following his graduation, Dr. van Poollen returned to the Netherlands to serve in the Dutch Army until 1951, at which time he joined the Standard Vacuum Petroleum Maatschappij, Sumatra, as a reservoir engineer.

In 1954, he returned to the Colorado School of Mines to receive his D.Sc. degree in Mining Engineering in 1955.

Subsequently, he was employed with Halliburton Oil Well Cementing Co. in Duncan, Okla., as a reservoir engineering section leader. In 1958, he joined the Ohio Oil Co.

Starting in the fall of 1960, Dr. van Poollen became a special lecturer in reservoir engineering at the Colorado School of Mines on a part-time basis.

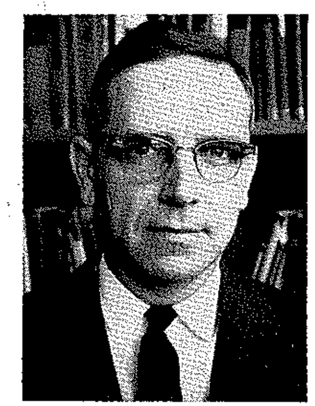
He has published several articles in technical journals in the areas of well stimulation and drill stem testing. The course he teaches at the Colorado School of Mines is PE-605, Advanced Reservoir Engineering.

Dr. van Poollen is married and has five children. He now lives at 4913 S. Fox, Englewood, Colo.

Department of Petroleum Refining Engineering

BY DR. JAMES H. GARY

During the past few years some rather drastic changes have been made in the various curricula of the School of Mines and the Department of Petroleum Refining Engineering was no exception to these changes. The reasons these changes were made and the effects they will have upon the qualifications of our graduates will be discussed after the faculty of the Department is introduced to you.

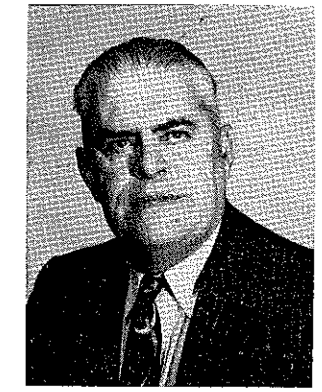


DR. JAMES H. GARY

DR. JAMES H. GARY joined Mines as professor and head of the Department of Petroleum-Refining Engineering in July, 1960. He received his B.S. and M.S. degrees in chemical engineering from the Virginia Polytechnic Institute and the Ph.D. degree from the University of Florida. He spent six years in the Technical Service Division of The Standard Oil Co. (Ohio), starting as a junior engineer in the catalytic cracking section and rising to the position of group engineer in charge of pilot plant development.

After leaving industry, Dr. Gary taught for four years at the University of Virginia where he held the rank of assistant professor of chemical engineering and research director in the Engineering Experiment Station. He was then an associate professor for three years and professor of chemical engineering for one year at the University of Alabama and was in charge of the Engineering Radioisotope Laboratory there before coming to Mines this summer.

Dr. Gary has been employed as consultant to the Allen-Sherman-Hoff Co., International Paper Co., Cities Service Research and Development Co., and the U. S. Bureau of Mines. He is a registered professional engineer in Ohio and Alabama, holds patents, and has published articles in several technical magazines.



PROF. GEORGE W. LeMAIRE

GEORGE W. LeMAIRE, Mines '26, joined the Mines faculty in April, 1946, as assistant professor. Professor LeMaire served as associate professor and was promoted to professor and acting head of the Petroleum-Refining Engineering Department in 1959-60.

He was employed by the Standard Oil Co. (New Jersey) for two years in the Crude Oil Evaluation and Economics Section. This was followed by five years with Humble Oil Co. where he worked on the development of a process for the manufacture of alcohol from light hydrocarbons and served in the Technical Service Department. From 1933 to 1944 he designed and was engineer in charge of the treating processes of the Aruba Refinery in the Netherlands West Indies. From 1944 to 1946 Professor LeMaire was technical supervisor of the alkylation, isomerization and treating operations for the Cheyenne refinery of Frontier Refining Co.

Professor LeMaire has contributed articles to The MINES Magazine and has written four School of Mines Quarterlies. He has devoted much time to the development and application of counseling techniques primarily to assist graduating students select a job area (sales, research, etc.) at the start of their industrial careers and also to assist undergraduates select a course of study.

Professor LeMaire is a registered professional engineer in Colorado.

DR. L. W. MORGAN

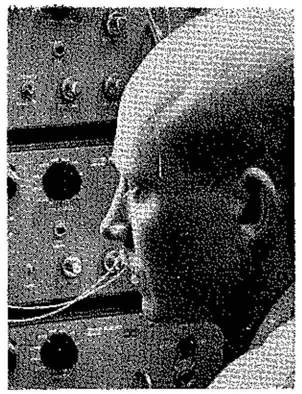
DR. LYMAN W. MORGAN came to the staff as associate professor in 1958. A graduate of the Massachusetts Institute of Technology with a B.S. in chemical engineering, he went on to graduate work at the Georgia Institute of Technology and received both the M.S. and the Ph.D. degrees there.

Upon graduation from Georgia Tech, Dr. Morgan joined Phillips Petroleum Co. and became group leader of the Systems Analysis Group in Research and Development. While with Phillips, he did theoretical analyses of research, pilot plant, and full scale plant data and designed automatic optimalizing control units for plant application.

Dr. Morgan is the holder of patents in the systems analysis field and has contributed to technical magazines. He specializes in process engineering and systems analysis and this year initiated a new course which introduces the engineering science of transport phenomena at the Junior level. He is also consultant to the Humble Oil & Refining Co. in the field of process systems engineering.

JOHN C. THOMAS joined the Petroleum Refining Engineering Department in January 1960 as laboratory assistant in charge of designing and installing a process systems engineering laboratory suitable for both graduate and undergraduate use. He is a graduate in chemical engineering from Texas Agricultural and Mechanical College.

After graduation, he worked with Phillips Chemical Co. as a developmental research engineer and later transferred to the Phillips Petroleum Co. as an instrument development en-



JOHN C. THOMAS

gineer in their Research and Development Department. Mr. Thomas has several instrument and process patents pending as a result of his work on the system dynamics and reaction parameters of chemical processes and the development of on-stream and laboratory analytical instrumentation for Phillips.

He is a registered professional engineer in the state of Texas and is a consultant in the field of process systems engineering.

The curriculum of the Department of Petroleum-Refining Engineering is approved and accredited by the ECPD (Engineers' Council for Professional Development) on the basis of chemical engineering. This means that while by the title of the degree we are preparing students for that phase of the chemical industry devoted to the refining of crude oil and the manufacture of products derived from it, the graduate from Mines in Petroleum Refining is competitive in basic and fundamental engineering training with chemical engineering graduates across the country.

This is a decided advantage to the student with respect to his application and association in the field and his professional achievement. It is also advantageous to the faculty in the department since the teaching material, objectives and teaching philosophy can be strengthened by comparison with and utilization of the experience of chemical engineering departments in other colleges and universities.

In conjunction with departmental curriculum changes, the over-all curricula of all options in the school has been revised considerably after more than two years of study by the Curricula Committee of the Faculty. This was the result of a number of factors some of which include suggestions by accrediting groups, changes in engineering requirements in industry, progress in the development and application of electronics and computers in the areas of process control, statistics and analysis, and the opinion of the teaching staff.

At the lower class level these changes include the introduction of an organized orientation program for which academic credits are given which together with time provided for humanities electives provides for 19 hours in this area.

Physics has been built up to three semesters to strengthen training in this basic science and to permit time for the introduction of principles of modern physics.

Four semesters of chemistry are integrated to provide a sequence of chemical knowledge which includes principles in general chemistry, and emphasizes physical chemistry and thermodynamics.

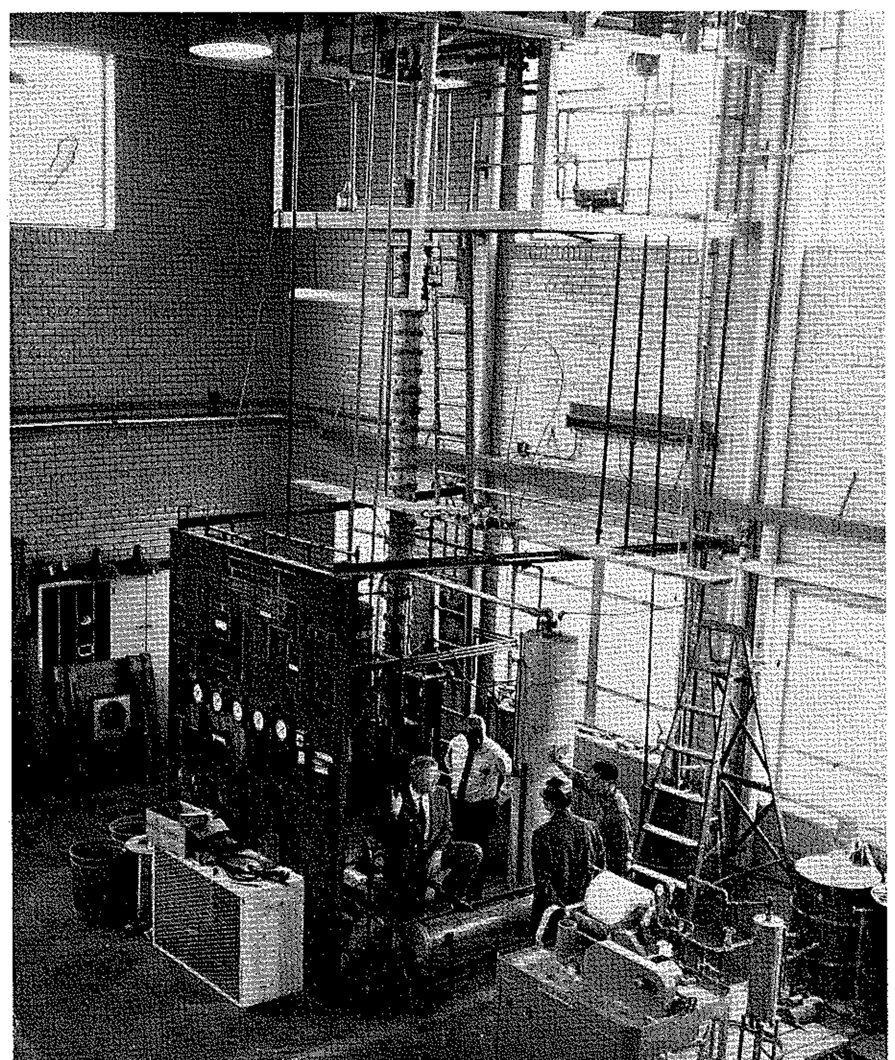
At the upper level, changes which directly affect the option include the following:

Two semesters of a new course in mathematics were introduced in the Junior curricula called Engineering Mathematics. In these courses, the application of advanced mathematics to engineering and research situations is stressed including a further study of ordinary differentials, partial differentation, introduction to the Fourier series and LaPlace transform, vector analysis, complex variables, probability and statistics.

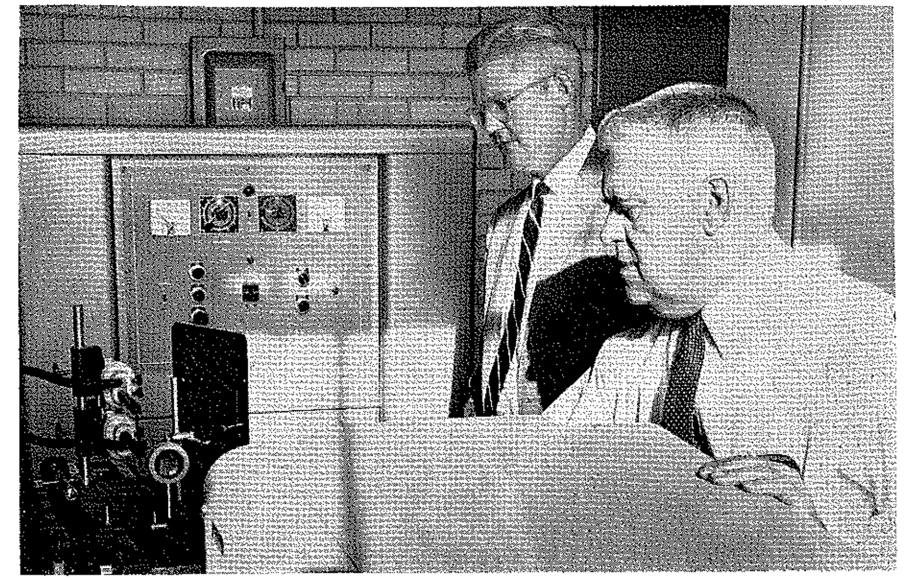
The math courses are taken concurrently with revised material in Unit Operations to permit the study of diffusional processes of momentum, heat and mass transport. The applied physics of the operations are taught in terms of their differential equations.

To strengthen the application of thermodynamic principles to process design, mechanical and chemical thermodynamics follow each other consecutively in the Junior curricula.

Emphasis in two semesters of organic chemistry is placed on the relations of chemical and physical properties to chemical structure and reaction mechanisms involving bond type and structural effects.



▾The Petroleum Refining Department staff—Dr. J. H. Gary, Prof. G. W. LeMaire, Dr. C. W. Morgan—and graduate student discussing operation of a fractionating unit. Also visible is a continuous rotary filter.



▾Prof. G. W. LeMaire and Dr. L. W. Morgan discussing the operation of the emission spectroscope.

Within the Petroleum-Refining Engineering Department, the laboratory course in Chemical Engineering Unit Operations has been developed into a six weeks' Summer Field Course to follow the introductory material on transport phenomena and simple process equipment design given during the Junior year. Topics of practical importance are taken up which are not included in the more theoretical material of the regular Junior year. The propagation of experimental error is emphasized as a guide to the design of bench scale and pilot plant experimentation.

The prime need of the Senior year is to bring together into a coherent relationship the five general areas of chemical process engineering, namely properties and structure of matter, laws of conservation (e.g. energy balances), thermodynamics, physical and chemical kinetics, and process control. To accomplish this purpose it is necessary to develop the concepts of control and instrumentation to a greater degree than has been the practice in the past.

A new course in Fluid Dynamics is offered during the first semester to provide the necessary emphasis in process control. It presents both theoretical and laboratory work in process measurement, dynamics, and control. Experimental transient and sinusoidal testing, used to analyze the dynamics of both processes and instruments, lead to the design of a simple process control system by the end of the course. The new Engineering Mathematics course provides the necessary background in operational calculus.

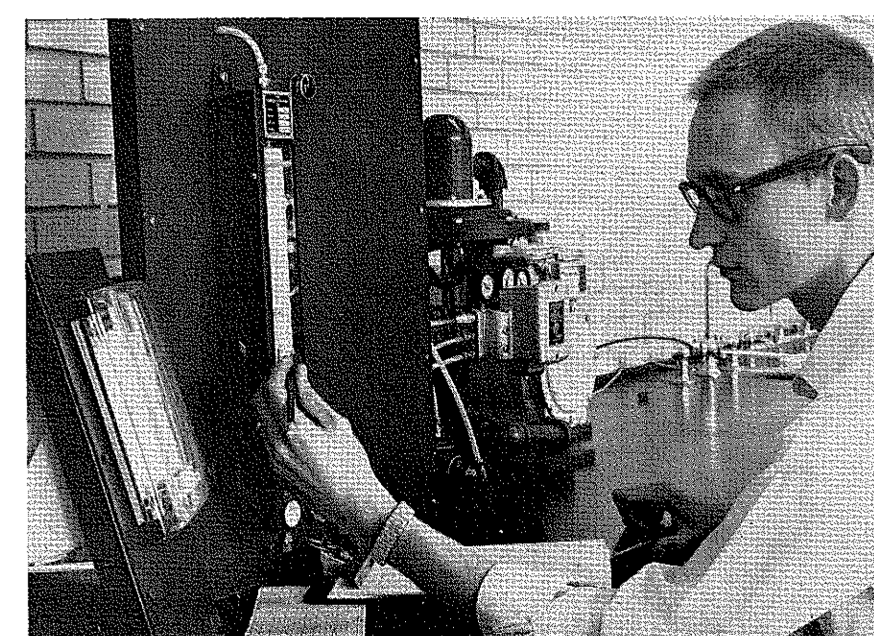
A new course in Chemical Instrumentation is included in the same semester to complete the necessary introduction to process control. Consisting of both theory and laboratory experiments, the roles of the various chemical analyzers in chemical process control are brought out.

Chemical Process Engineering is scheduled for the second semester to actually bring together the necessary areas of competence. This is done by making a rational approach to the computer control of chemical processing plants. It is necessary to work out a mathematical model of the plant and this, in turn, requires all of the five areas. This three hour course leans toward petro-chemical processing for its examples and uses the processing difficulties of colloidal and amorphous materials as practical problems. Methods of obtaining and organizing data for the solution of problems supplemented by testing, analysis and experimentation are included. Process control then, important in itself for practical reasons, also serves as a framework on which to build a coherent course of instruction in chemical process engineering.

By such means the departmental faculty feels that individual interests and abilities of students can be aided and directed to areas that will be of maximum benefit to them and will better equip the graduate to become associated with job selection in any phase of chemical engineering.

The faculty has the combination of practical experience, education, and teaching experience necessary to give the student a firm background in fundamentals and then to show him how to apply these theoretical concepts to practical problems. In service, these men represent 35 years of plant experience and 26 years of teaching. Individual interests cover a wide variety of subjects which together provide the basis for a well-rounded training in all phases of refining and petro-chemical engineering.

This faculty, together with the excellent facilities available, should result in progressive improvement in the quality of the graduates bearing the degree of Petroleum Refining Engineering.



▾Robert Sims, graduate student, studies dynamic characteristics of an automatic valve.

JOHN C. THOMAS

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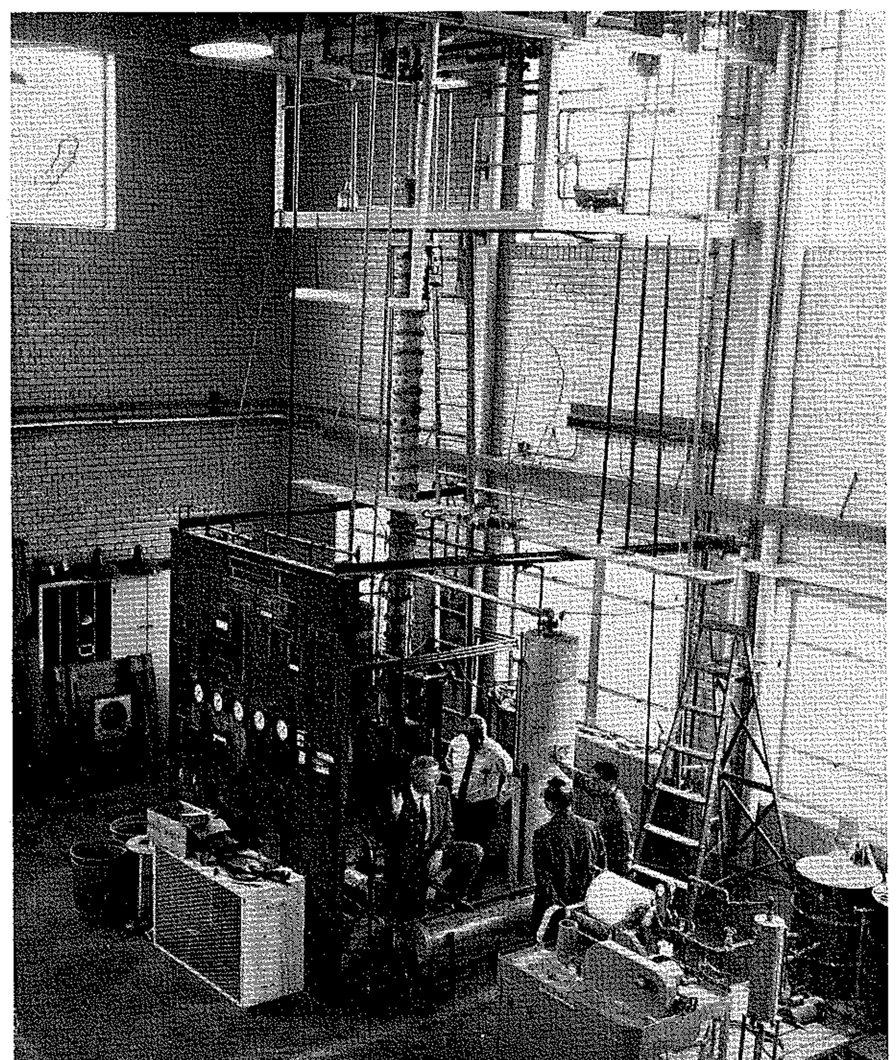
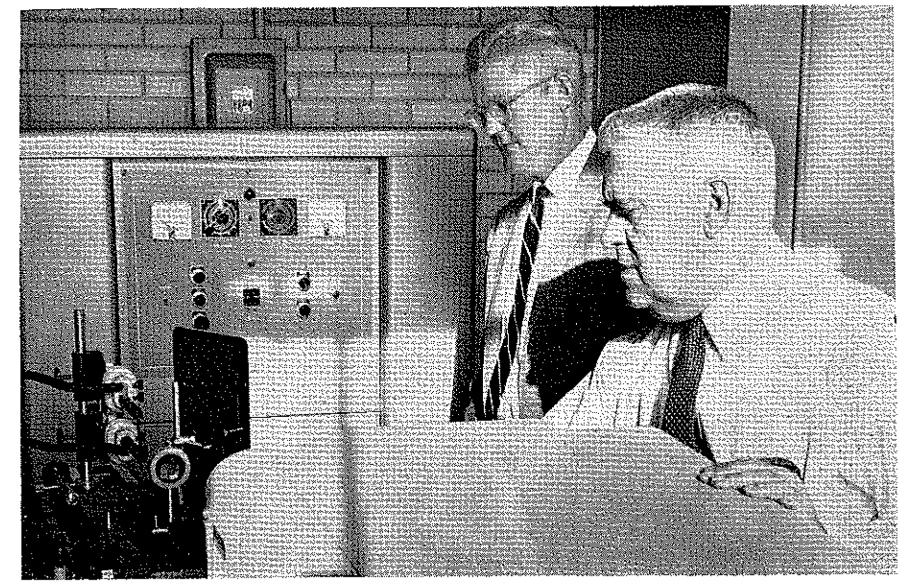


▼The Petroleum Refining Department staff—Dr. J. H. Gary, Prof. G. W. LeMaire, Dr. C. W. Morgan—and graduate student discussing operation of a fractionating unit. Also visible is a continuous rotary filter.



▼Prof. G. W. LeMaire and Dr. L. W. Morgan discussing the operation of the emission spectroscope.

Within the Petroleum-Refining Engineering Department, the laboratory course in Chemical Engineering Unit Operations has been developed into a six weeks' Summer Field Course to follow the introductory material on transport phenomena and simple process equipment design given during the Junior year. Topics of practical importance are taken up which are not included in the more theoretical material of the regular Junior year. The propagation of experimental error is emphasized as a guide to the design of bench scale and pilot plant experimentation.

The prime need of the Senior year is to bring together into a coherent relationship the five general areas of chemical process engineering, namely properties and structure of matter, laws of conservation (e.g. energy balances), thermodynamics, physical and chemical kinetics, and process control. To accomplish this purpose it is necessary to develop the concepts of control and instrumentation to a greater degree than has been the practice in the past.

A new course in Fluid Dynamics is offered during the first semester to provide the necessary emphasis in process control. It presents both theoretical and laboratory work in process measurement, dynamics, and control. Experimental transient and sinusoidal testing, used to analyze the dynamics of both processes and instruments, lead to the design of a simple process control system by the end of the course. The new Engineering Mathematics course provides the necessary background in operational calculus.

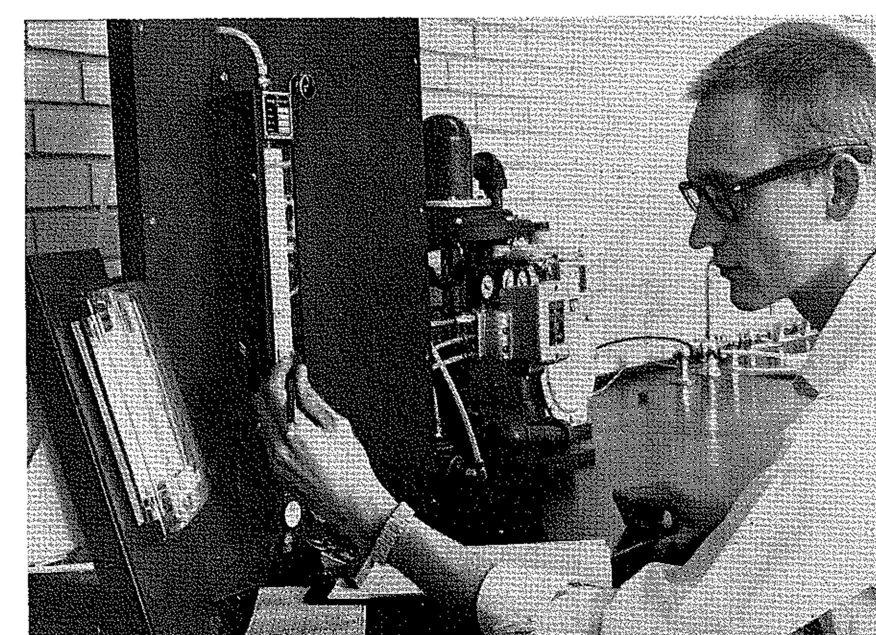
A new course in Chemical Instrumentation is included in the same semester to complete the necessary introduction to process control. Consisting of both theory and laboratory experiments, the roles of the various chemical analyzers in chemical process control are brought out.

Chemical Process Engineering is scheduled for the second semester to actually bring together the necessary areas of competence. This is done by making a rational approach to the computer control of chemical processing plants. It is necessary to work out a mathematical model of the plant and this, in turn, requires all of the five areas. This three hour course leans toward petro-chemical processing for its examples and uses the processing difficulties of colloidal and amorphous materials as practical problems. Methods of obtaining and organizing data for the solution of problems supplemented by testing, analysis and experimentation are included. Process control then, important in itself for practical reasons, also serves as a framework on which to build a coherent course of instruction in chemical process engineering.

By such means the departmental faculty feels that individual interests and abilities of students can be aided and directed to areas that will be of maximum benefit to them and will better equip the graduate to become associated with job selection in any phase of chemical engineering.

The faculty has the combination of practical experience, education, and teaching experience necessary to give the student a firm background in fundamentals and then to show him how to apply these theoretical concepts to practical problems. In service, these men represent 35 years of plant experience and 26 years of teaching. Individual interests cover a wide variety of subjects which together provide the basis for a well-rounded training in all phases of refining and petro-chemical engineering.

This faculty, together with the excellent facilities available, should result in progressive improvement in the quality of the graduates bearing the degree of Petroleum Refining Engineering.



▼Robert Sims, graduate student, studies dynamic characteristics of an automatic valve.

Mines to Be in USIA Film Depicting Higher Education In the United States

The Colorado School of Mines has been selected as one of six colleges and universities to represent this nation's program of higher education in a large-budget movie film.

The film, "Higher Education in the United States," is sponsored by the United States Information Agency, and was written by Gene Wyckoff, writer for the former TV series "Wide, Wide World."

The film, a half-hour sound and color production, is intended by USIA to answer a series of films produced by the University of Moscow, describing the education opportunities of the Russian university.

Six schools were selected from the more than 1800 colleges and universities in the country. The other five schools are Harvard, Pittsburgh, Caltech, Goucher and Wittenberg. Each will have a five minute segment in the film.

Film shooting crews from Baltimore, Md., will visit the campus before Christmas to shoot the Mines portion of the film.

Mines and CU Start Geology Teacher Exchange

The Colorado School of Mines and the University of Colorado have started a geology teacher exchange program this fall. The program is designed to supplement course offerings in geology at no additional cost to either institution.

This fall Dr. Robert Weimer, associate professor at Mines, is conducting a CU graduate seminar in "Principles in Stratigraphy" one afternoon a week.

Next spring the University of Colorado will send Dr. William C. Bradley, an assistant professor, to Golden for a seminar on "Glacial Geology."

Both institutions have planned compensatory adjustments in slight teaching load reductions for each professor when he is teaching at the other institution.

"This is a reciprocal agreement by which we both can profit," Dr. Warren O. Thompson, CU geology department head, declared. "Each school can offer its own special talents to fill in for the fields not covered at the other school."

Dr. L. W. LeRoy, Mines geology department head, agreed "wholeheartedly with the exchange. I think it certainly is going to be advantageous to both departments, and I hope we can continue to do something along this line in the future."

Both department heads stated the program was a good idea in which to utilize special talents cooperatively.

Both participating professors have advanced degrees from Stanford University. Weimer, who earned his bachelor's degree at the University of Wyoming and is beginning his fourth year at Mines, has a broad background in stratigraphy and geological structure in the Rocky Mountain region.

This summer Weimer presented a paper co-authored with Dr. John D. Haun of Mines at the International Geological Congress in Copenhagen, Denmark.

Bradley has done research in sedimentation and geomorphology and has had several papers published. He has an A.B. degree from the University of Wisconsin and belongs to Sigma Xi and Phi Kappa Phi societies. He is in his fifth year of teaching at CU.

The exchange program is part of the inter-institutional cooperative program arranged by the Association of State Institutions of Higher Education in Colorado.

SPORTS

Orediggers Win 3, Lose 2 at Football

As of Oct. 23 the Miners have won three and lost two on the football field. Oredigger victories were chalked up over Omaha University 28-20 (Oct. 1), over Colorado College 16-12 (Oct. 8), over Westminster 20-13 (Oct. 15). The Miners lost to Highlands University 14-6 (Sept. 27) and to Colorado State College 20-12 (Oct. 22).

The Oredigger reports that the win over Omaha was due to the Miners taking advantage of Indian miscues. Three Mines touchdowns came following two fumbles and one Indian pass interception. The final score: 28-20 in favor of Mines.

The Mines victory, 16-12, over Colorado College was a Rocky Mountain Conference football thriller. Mines used single wing power plays and took advantage of CC errors to score one touchdown. An intercepted pass and a wild center snap on an intended punt set up two of the Mines scores, and a safety in the final 27 seconds provided the icing.

Although the Miners were outrushed 147-87 yards, alert defensive play and a few breaks gave them the game over the hard-fighting Westminster Parsons, 20-13. Led by the fine passing of Bruce Henry, the Orediggers opened the scoring in the first quarter. In the second quarter Westminster roared back and Suttles scored from the one-yard line, but the kick failed and the score was tied 6-6. Later in the same quarter, Mike McCutchan dashed over for the second Mines score, but a 7-yard pass from Westminster's Hill to Armstrong tied the score at half time 13-13. The final blow came in the fourth period when the Orediggers drove 50 yards for a touchdown, making the final score 20-13.

Two pass interceptions and a recovered fumble were used by the Colorado State College Bears to down Mines 20-12. Bob Schmidt picked off a Kay White pass and ran 80 yards for the Bears first touchdown in the second period. Two similar breaks produced two touchdowns and erased a 12-6 deficit in the fourth quarter. Leroy Wretlind scored both Mines touchdowns on passes from White.

Miners defeated Idaho State 7-0 to win Homecoming victory on Oct. 29th.

MINERAL INDUSTRIES

(Continued from page 19)

Ohio Oil Contributions Total $400,000 in 1960

The Ohio Oil Co. will make contributions totaling more than $400,000 in aid to education and in support of community health, welfare and youth programs in 1960. The financial assistance is given chiefly through the Ohio Oil Company Foundation.

J. C. Donnell II, president, said that the current budget exceeds Ohio Oil's 1959 contributions by about $75,000.

Grants this year furthering higher education account for over half of the total program, or $226,000. More than 240 colleges and universities in all parts of the nation will benefit from unrestricted grants and donations for expansion projects. Numerous schools from which Ohio Oil draws substantial numbers of employees are included.

Airborne Geophysical Data Released by Surinam

Geological and airborne geophysical data for most of Surinam is being released to interested individuals and to mining companies by the government of Surinam. According to Dr. Ir. F. E. Essed, minister of Development of Surinam, the data is being published as rapidly as the reports and map compilations are completed. Over 100 isomagnetic map sheets are now available.

A photo-geological survey was completed last July, to guide airborne geophysical reconnaissance of approximately 105,000 sq. kms. of Surinam. The survey, flown by Aero Service Corp., Philadelphia, and Canadian Aero Service Ltd., Ottawa, was made with the Gulf airborne magnetometer and scintillation counter. Flight altitude was 150 meters, and the gridded flight lines were spaced at 1 km. intervals. Doppler Radan guided the survey aircraft over the dense "sea of trees," covered by KLM's aerial photography of Surinam.

The airborne data are being compiled in magnetic maps at a scale of 1:40,000, at a 20 gamma contour interval. Geophysical interpretation will follow.

The remaining 160 magnetic map sheets were completed for the government of Surinam by Sept. 30, 1960, according to Aero Service Corp.

Changes in Minerals Eligible For Exploration Assistance

The Department of the Interior has announced a proposal to make additional types of asbestos and beryllium ores eligible for federal exploration assistance.

Under present regulations only beryl and the strategic type of asbestos are eligible. Two other changes in the regulations (30 CFR 301) are proposed also to clarify the language in section 301.5 concerning the filing of applications and in section 301.15, title to and disposition of property. Interested parties have 30 days in which to comment on these proposed changes before they become effective.

Frank E. Johnson, a 1922 Mines graduate and acting director of the Office of Minerals Exploration, said that this change will permit the federal government to extend exploration assistance to other ores not previously considered as eligible.

Since the inception of the federal exploration assistance program in 1951 under the Defense Minerals Exploration Administration (predecessor to the Office of Minerals Exploration), considerable interest has been shown in exploration for these two mineral commodities.

Sixty applications were received for asbestos exploration projects. Nineteen of these resulted in contracts having a total value of $616,000 with Government participation of $553,000. Five of these contracts were certified as discoveries or developments. Applications for beryl and beryl-mica exploration assistance numbered 100, of which 21 became contracts having a total value of $228,000 with Government participation of $203,000. Eight of these were certified as discoveries or developments.

Exploration assistance is available through the OME to qualified operators who wish to explore for any one or more of the 32 mineral commodities listed in the OME regulations.

Application forms and additional information about the program may be obtained from the following offices:

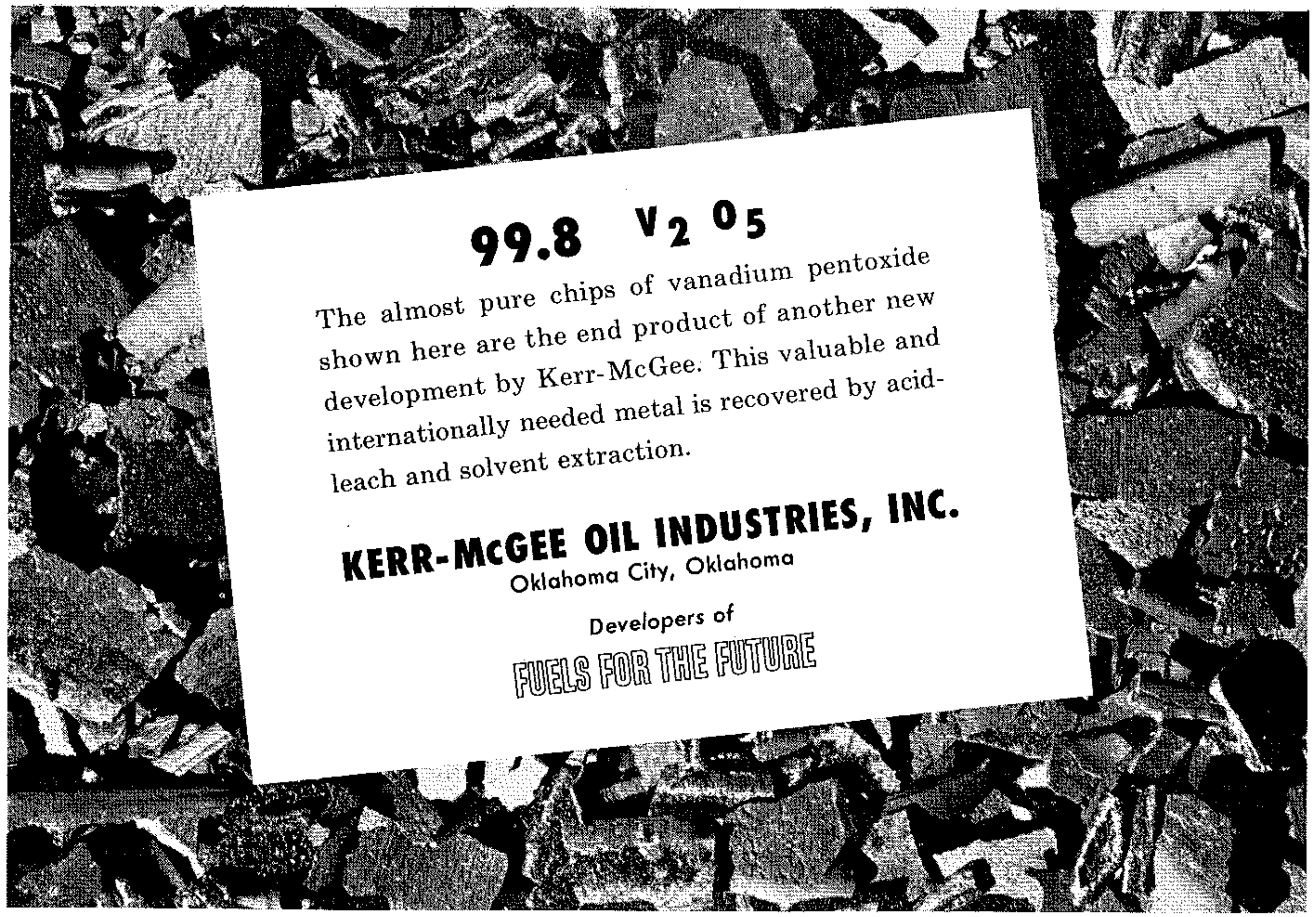
The Office of Minerals Exploration, Department of the Interior, Washington 25, D. C.

OME—Region I—South 157 Howard St., Spokane 4, Wash.

OME—Region II—420 Custom House, 555 Battery St., San Francisco 11, Calif.

OME—Region III—Building 20, Denver Federal Center, Denver 25, Colo.

OME—Region IV—Room 11, Post Office Bldg., Knoxville 2, Tenn.



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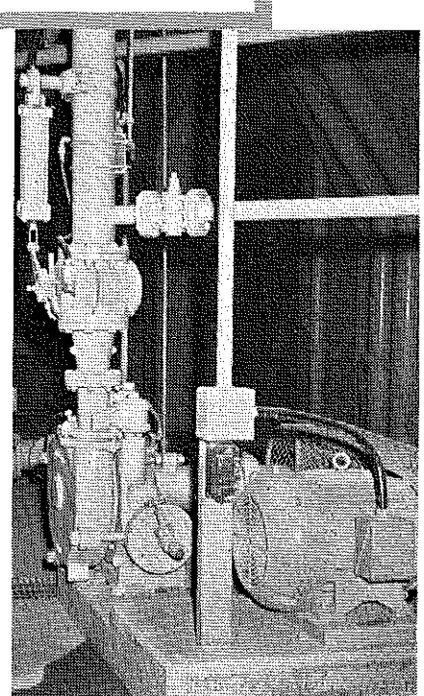

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