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Date Published—March 1982

For the Period
January–December 1981

Bartlesville Energy Technology Center
U.S. Department of Energy
Bartlesville, Oklahoma 74005



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For the period

January - December 1981

Compiled by
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Technology Transfer Section
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Date Published - March 1982

U.S. DEPARTMENT OF ENERGY

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QUARTERLY PROGRESS REPORTS

DOE/BETC/QPR-80/3. Liquid Fossil Fuel Technology. Quarter ending September 30, 1980. Edited by Bill Linville. February 1981. 64 pp. Progress reports on research, development, and demonstration projects conducted by Bartlesville Energy Technology Center personnel and contractors are given, with emphasis on liquid fossil fuel projects. Reports from BETC's Divisions of Extraction Research, Processing and Thermodynamics Research, Utilization Research, and Project Integration and Technology Transfer are included.

SPECIAL PUBLICATIONS

DOE/BETC/SP-81/1. Alcohol Fuels in Diesel Farm Engines—A Major Research Project to Determine Practical Uses. BETC Staff. February 1981. This brochure describes BETC research work being conducted to determine if ethanol of a lower purity—capable of being produced on the farm—may be practical to use in on-farm diesel engines. This work is investigating the types of diesel engines likely to perform well on ethanol-diesel mixtures, the effects of alcohol proof on diesel engines, what system will best introduce the fuel mixture into the engine, and the effects of the fuel mixture on long-term engine durability.

DOE/BETC/SP-81/3. List of BETC Publications. BETC Staff. March 1981. 72 pp. This report is a compilation of the first 13 BETC publications lists and includes abstracts of all BETC reports published from October 1977 to December 1980.

CONFERENCE PROCEEDINGS

CONF-8004140. International Energy Agency Workshop on Enhanced Oil Recovery, Bartlesville Energy Technology Center, April 24, 1980—Proceedings. U.S. Department of Energy. February 1981. 288 pp. This report includes 14 papers that were presented at the International Energy Agency Workshop, plus a list of attendees. The enhanced oil recovery papers include

such topics as residual oil saturation, surfactant adsorption, wettability effects, and carbon dioxide and micellar-polymer methods of recovering oil.

PETROLEUM PRODUCTS SURVEYS

DOE/BETC/PPS-81/1. Motor Gasolines, Summer 1980. Ella Mae Shelton. February 1981. 69 pp. A total of 2,062 samples of motor gasolines were collected from service stations throughout the country and analyzed in the laboratories of various refiners, motor manufacturers, and chemical companies. The data were submitted to BETC for study, necessary calculation, and compilation under a cooperative agreement between BETC and the American Petroleum Institute (API). The samples represent the products of 48 companies which manufacture and supply gasoline. These data are tabulated by groups according to brands (unlabeled) and grades for 17 marketing districts. A map included in the report shows marketing areas, districts, and sampling locations. The report includes charts indicating the trends of selected properties of motor fuels since 1949. Twelve octane distribution percent charts for unleaded, regular, and premium grades of gasoline are presented. The antiknock (octane) index averages of gasolines sold in this country were 87.8 for unleaded below 90.0, 91.6 for unleaded 90.0 and above, 88.9 for regular, and 92.8 for premium grades.

DOE/BETC/PPS-81/2. Aviation Turbine Fuels, 1980. Ella Mae Shelton. March 1981. 16 pp. Properties of some aviation turbine fuels marketed in the U.S. during 1980 are presented. The samples are typical 1980 production and were analyzed in the laboratories of 17 manufacturers of aviation turbine (jet) fuels. The data were submitted for study, calculation, and compilation under a cooperative agreement between BETC and the American Petroleum Institute (API). Results for the properties of 98 samples of aviation turbine fuels for military grades JP-4 and JP-5 and commercial type Jet A are included in the report.

EOR PROGRESS REVIEWS

DOE/BETC-80/4. Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery and Improved Drilling Technology. Progress Review No. 24, Quarter ending September 30, 1980. Edited by Bill Linville. February 1981. 182 pp. Status reports are given of various enhanced oil and gas recovery projects sponsored by the Department of Energy. The field projects and supporting research on enhanced oil recovery include chemical flooding, carbon dioxide injection, thermal/heavy oil recovery, microbial recovery, and residual oil determination. Other research includes extraction research and improved drilling methods.

REPORTS BY CONTRACTORS

DOE/BC/10027-12. Experimental Evaluation of Reservoir Pretreatment in Chemical Flooding, Final Report. Exoil Services. February 1981. 51 pp. This report presents the results of 56 radial disk floods in Berea sandstone that were completed to evaluate the effect of various reservoir pretreatment systems. From these floods the following effects were identified: (1) In the

absence of other contrary forces, increasing preflush size improves oil recovery; (2) clay alteration as produced by disk firing has a detrimental effect on tertiary oil recovery; (3) various inorganic chemical preflushes were beneficial, and a soft saline preflush is effective in displacing the divalent cations in the connate water; (4) a high monovalent/divalent cation ratio in connate brine generally was beneficial for oil recovery when no preflush was employed; (5) a high frontal velocity leads to low oil recovery, presumably due to bypassing of considerable pore space; and (6) the floods showed an inverse relationship between sulfonate retention and oil recovery.

DOE/BC/10045-12. Fundamental Synthetic Fuel Stability Study, First Annual Report, May 1, 1979-

April 30, 1980. Exxon Research and Engineering Co. February 1981. 96 pp. This report covers the first year of a study on the effects of nitrogen compounds on the storage stability of synthetic fuels derived from oil shale and coal. A variety of organic nitrogen compounds were evaluated for their tendencies to promote sediment in hydrocarbon fuels under accelerated storage conditions. A literature search was performed in order to determine the state-of-the-art of storage stability with synthetic fuels and to identify the most prevalent nitrogen, sulfur, and oxygen compounds found in shale- and coal-derived middle distillate fuels. The effects of nitrogen compounds on sediment formation, observed previously in pure hydrocarbon systems, were confirmed in broad range fuels. The most deleterious species to fuel stability were found to be alkylated heterocyclic nitrogen compounds. The most reactive compounds were those with two or more alkyl groups, at least one of which was situated on a carbon adjacent to the nitrogen. Dissolved oxygen was found to promote sediment formation to a significant degree. During the course of this work a modified storage stability test was developed which significantly improved the accuracy of sediment determinations.

DOE/BC/10069-10. The Mechanism of Oil Bank Formation, Coalescence in Porous Media and Emulsion Stability, Annual Report, June 1979-May 1980. Illinois Institute of Technology. February 1981. 224 pp.

This report presents results of a basic study of coalescence phenomena, emulsion formation and stability, and dynamic interfacial properties when crude oil and pure hydrocarbons are contacted with aqueous solutions of surfactant/polymer and alkaline agents. These measurements are correlated with each other and with observations on oil bank formation and displacement and recovery efficiency by chemical flooding in microwave monitored laboratory core flooding experiments. The scope of this work includes three tasks: (1) caustic flooding of heavy crude, (2) surfactant/polymer flooding, and (3) thin liquid films: drainage and stability of foam and emulsion films.

DOE/BC/10070-1. Project Tracking System (PTS) User's Manual. Advanced Technology, Inc. March 1981. 190 pp.

The BETC Project Tracking System is a computerized information system developed to generate automatic updates to other Department of Energy systems such as the Business Management Information System, as well as to aid in the in-house tracking of the cost, schedule, and manpower status of the approximately 200 BETC contracts. The PTS data base contains administrative and limited technical information on planned, active, and terminated contracts.

DOE/BC/10079-18. Determination of Optimum Air (Gas) Injection Rate in Aerated Drilling Operations, Annual Report, May 1, 1979-April 30, 1980. University of Tulsa, January 1981. 52 pp.

There have been several attempts to calculate the minimum volumetric requirements for aerated fluid drilling. The results of these studies are valid only over limited ranges of drilling rates because many variables are involved in an air drilling situation. This report describes a method that will permit the driller to determine optimum fluid injection rates while in the field, eliminating the need for complicated flow calculations used to predict volumetric air requirements. The method is based on the principle of minimum bottomhole pressure and thus maximum differential pressure into the hole. It allows changes in volume

requirements to be made as drilling conditions change, and can be put in nomograph form for easy, rapid, and accurate calculation in the field.

DOE/BETC/OR-11. Chemicals for Enhanced Oil Recovery, Biennial Report, April 1978-March 1980.

Oak Ridge National Laboratory. March 1981. 157 pp. Manufacturer's bench tests were performed on Crane and Rexnord microscreens ranging between 1 and 60 μm aperture, in both stainless steel and dacron polyester. Microscreens compare favorably in installed cost and operating energy to diatomaceous earth (DE) filtration and centrifugation for gross biomass removal. Seven fungi from genera other than *Sclerotium*, *Helotium*, or *Stromatinia* were tested as potential biopolymer producers. Batch and continuous methods for the enzymatic hydrolysis of scleroglucan and xanthan were developed to increase the flux of these materials through porous media without decreasing their viscosity. Coagent alcohols and alcohol-ketone mixtures were readily produced from weak acid sulfite liquor, condenser effluent, and thermomechanical effluent streams. Weak acid sulfite liquor appeared the most promising because of concentration, lower toxicity, and availability. Earlier failure to find conditions under which sodium oleate affected interfacial tension of the millidyne/cm order arose from the limited range of compositions studied. On extending the range, conditions giving ultralow tensions with sodium oleate and with tall oils were found. Commercial ethoxylated fatty acids of different hydrophilic/hydrophobic ratios were evaluated, both alone and in conjunction with a petroleum sulfonate surfactant. Combinations of neutral and anionic surfactants cause occurrence of a larger volume of third phase than with the anionic component alone. Conditions giving low aqueous/hydrocarbon interfacial tensions were found. Waste and low-valued byproducts from pulping of wood are being evaluated as competitive adsorbates to decrease loss of surfactants by adsorption on minerals. Of the agents tried, caustic extract from the bleaching of kraft pulp and the spent digestion solution from kraft pulping, weak black liquor, appear most promising.

DOE/ET/12047-52. Alkaline Waterflooding Demonstration Project, Ranger Zone, Long Beach Unit, Wilmington Field, California, Fourth Annual Report, June 1979-May 1980. Volumes 1, 2, and 3. City of Long Beach and THUMS Long Beach Co. March 1981. Vol. 1: 108 pp. Vol. 2: 466 pp. Vol. 3: 287 pp.

An alkaline-enhanced waterflooding pilot test is being conducted in the Ranger Reservoir of the Long Beach Unit. An alkaline flood process is being used to increase recovery efficiency. The reservoir is an alternating sand-shale sequence comprising a gross thickness of 850 feet and a net sand thickness of 305 feet. Comparative core flood testing of preserved core rock samples and sand pack alkaline flood tests gave new insights on *in situ* alkaline consumption. Dehydration of sodium orthosilicate water-produced water-crude oil systems does not appear to create any operational problems. The alkaline injection facilities were completed and placed in operation. The preflush injection, which was composed of 11.5 million barrels of softened fresh water with an average salt content of 0.96 percent, was completed at that time. The total preflush amounted to approximately 10 pore volume percent. The 0.4 percent sodium orthosilicate-1.0 percent salt/soft, fresh water injection started at the end of the preflush. A loss of injectivity began at the same time as alkaline injection, which is attributed to divalent ions in the salt brine. Preparations are underway for making the alkaline flood simulator performance prediction for the pilot.

DOE/ET/12056-10. Laboratory Combustion Tube Studies—Part II. Stanford University Petroleum Research Institute. March 1981. 29 pp.

To promote a better understanding of the problems and mechanisms involved in dry *in situ* combustion of crude oils in porous media, three laboratory combustion tube studies were made with unconsolidated core material and Lombardi Zone crude oil from the San Ardo Field, Calif. The tube runs were designed so that a wide variety of conditions could be observed. The variables in the course of these runs were oil saturation, water saturation, air flux porosity, and amount of clay in sand. The experiment consisted of (1) preparation of oil

and sand test pack, (2) the combustion run, and (3) analysis of products and results. These results are presented in tables and graphs included in the report.

DOE/ET/12056-17. Further Results Determining Permeability and Thickness for a Multi-Layer Five Spot Tracer Test. Stanford University Petroleum Research Institute. February 1981. 32 pp. This report presents further results obtained using a computer algorithm which gives an indication of the heterogeneity among the layers of a reservoir. This algorithm accurately describes the shape of tracer data for multi-layer systems by choosing the peak values. Permeability and height can be found for each layer. The algorithm works best when the spread between peaks is great, for as the peaks approach one another, interference causes a shift in the generated peak values. The final match using 10 layers to depict the tracer breakthrough curve is about as accurate as is possible to match these tracer data. A current listing of this program is included at the end of this report.

DOE/ET/12056-19. Determining the End of Infinite-Acting Behavior for Producing Wells in Closed Rectangles. Stanford University Petroleum Research Institute. February 1981. 26 pp. During a pressure drawdown test, all wells behave as if they are in an infinite reservoir for a brief period (termed the infinite-acting time). In an attempt to better determine this time for well locations in closed rectangular shapes, this report presents computer and hand calculator programs as well as contour graphs that yield the dimensionless time (in terms of area), t_{DA} , which defines the end of the infinite-acting period.

DOE/ET/12056-20. Estimation of Oil Recovery by *In Situ* Combustion in the Jobo Field of Eastern Venezuela. Stanford University Petroleum Research Institute. March 1981. 36 pp. The purpose of this project was to obtain laboratory data to evaluate the applicability of the *in situ* combustion process to the Jobo Field, Eastern Venezuela, and to predict the field recovery. Laboratory data needed to evaluate the combustion process include: the amount of air injection required per barrel of oil recovered, minimum injection rate which will sustain combustion, rate of advancement of the combustion zone, air required per unit volume of reservoir burned, amount of oil recovered, and amount of oil consumed as fuel. These data were obtained from experiments simulating *in situ* combustion in a small cylindrical tube packed with sand and utilizing core material from the Jobo Field. The data obtained from this experiment can be used for an approximate estimation of recovery for a pilot project in the Jobo Field.

DOE/ET/12059-4. The "200" Sand Steamflood Demonstration Project, Fourth Annual Report, June 1979-June 1980. Santa Fe Energy Co.—Chanslor Division. February 1981. 48 pp. This project was begun to test an enhanced steamflooding technique in the Midway-Sunset Field, Kern County, Calif. The "200" Sand Pool contains approximately 50 million barrels of oil-in-place in a structure that lies between 400 and 700 feet in depth. The reservoir produced very little primary production and responded poorly to cyclic steam stimulation. Therefore, this project was initiated to demonstrate the operational, recovery, and economic aspects of steamflooding a typical heavy oil reservoir that had unfavorable response to cyclic steam stimulation. A pilot test was conducted in four 2.35 acre inverted seven-spot steam drive patterns that were not fully developed with producers. As a result of the response shown by the pilot, work began to expand the pilot area to a total of 14 fully developed 2.35 acre inverted seven-spot patterns. Expansion to a full-scale steamflood test will consist of drilling and completing 30 producing wells and 10 steam injection wells. The report details the project performance to date and outlines the pilot expansion program and the economics of the project.

DOE/ET/12075-2. Scaled Physical Model Studies of the Steam Drive Process, Second Annual Report, September 1978-September 1979. University of Southern California. February 1981. 81 pp. A scaled physical model was operated

to simulate steam drive operations in five-spot patterns with reservoir and operational parameters similar to those encountered in California reservoirs. The goal of this study was to define the role of two controllable parameters, steam injection rate and steam quality, and to explore the role of oil viscosity and reservoir permeability on the performance of steam drive. The influence of bottom water and a basal permeable layer were also investigated. The experiments demonstrated that there is an optimum injection rate; that in the vicinity of this optimum an increased quantity results in improved oil/steam ratios; that the viscosity of the oil at steam temperature, raised to the fractional power 0.5, appears to correlate with oil production; that permeabilities in the darcy range have little effect on performance, but an increasing one with low viscosity oil; and that bottom water results in poorer early performance, but one which eventually rivals the oil/steam ratio of a uniform reservoir at a somewhat higher recovery of original oil-in-place.

DOE/ET/12380-1. Heavy Oil Reservoirs Recoverable by Thermal Technology, Annual Report. Volumes 1, 2, and 3. Science Applications, Inc. February 1981. Vol. 1: 176 pp. Vol. 2: 527 pp. Vol. 3: 337 pp. This report is a compilation of data on reservoirs containing heavy oil in 8 to 25° API gravity range, containing at least 10 million barrels of oil currently in place, and which are non-carbonate in lithology. The reservoirs within these constraints were then analyzed in light of applicable recovery technology, either steam drive or *in situ* combustion, and then ranked hierarchically as candidate reservoirs. The study is presented in three volumes. Volume 1 presents the project background and approach, the screening analysis, ranking criteria, and listing of candidate reservoirs. The economic and environmental aspects of heavy oil recovery are included in appendices in this volume. Volume 2 presents the data for reservoirs less than 2,500 feet deep susceptible to steam drive and those susceptible to *in situ* combustion. Volume 3 presents the data on reservoirs equal to or greater than 2,500 feet deep which are potentially recoverable by steam drive. Both of these volumes also contain a complete listing of operators and projects, as well as a bibliography of source material.

DOE/ET/14033-1. Chemical Flood Progress Evaluation Test, South Pass Block 27 Field, Plaquemines Parish, Louisiana, Final Report, Sept. 28, 1979-May 16, 1980. Shell Oil Co. February 1981. 27 pp. The first step in starting this surfactant flooding pilot in a 170°F temperature, high salinity, offshore reservoir was to drill, core, and log the first pattern well at a depth of about 8,000 feet. The well was designed for residual oil saturation evaluation and as the first injection well in the chemical flood pilot. The resulting ROS measurements are less than the 20-25 percent value required for continuation of the pilot at the planned "N₄" sand location in this field. Oil saturation data from cores reported here are believed to be minimum values because of blowdown and viscous stripping. Differences between core and log-inject-log results were not resolved. The core data (with about 20 percent correction for blowdown and viscous stripping) are believed to be more representative of *in situ* residual oil saturation values for this high permeability sand. Other experiences in this geologic area indicate that the ROS values will be varied, but generally the average will be about 25 percent.

DOE/MC/5532-7. Determination of the Effects of Sulfur Dioxide on Recovery Systems for CO₂, Final Report, 1977-1980. West Virginia University. January 1981. 68 pp. This study was initiated to investigate the problems associated with the recovery of CO₂ from flue gases for enhanced oil recovery. The results indicate that in gases containing ammonia, ammonium sulfate is quickly formed to render that portion of the absorbent inactive. In MEA, amine sulfite and amine sulfate are the dominant impurities formed. However, higher oxidized forms of the amines and thiosulfates were found in very small quantities. In amine-activated potassium carbonate solutions, only sulfite and sulfate ions were found, without higher oxidation products. No nitrogen-oxide species were found in any solution. The impurity levels obtained in the present experiments indicated no limit on

contaminant build-up. The sulfate levels in a commercial system could be expected to increase until the capacity for absorbing either CO₂ or SO₂ is exhausted. Corrosion in the absorption systems will be similar to that observed in CO₂ absorption systems from reducing gas streams; however, corrosion will be slightly higher in the absorption tower than in present commercial plants. Several alternative absorption systems were examined in a preliminary cost evaluation, and recommendations based on cost are included in the report.

DOE/MC/05301-62. Rock Creek Carbon Dioxide Pilot Project, Annual Report, July 1979-June 1980.

Pennzoil Co. January 1981. 51 pp. This project is designed to demonstrate the feasibility of miscible carbon dioxide oil recovery in the Rock Creek Big Injun Field, Roane County, W. Va. The pilot consists of two contiguous five-spot patterns encompassing a total of 19.65 acres. These dual five-spots are surrounded by 13 backup injection wells for containing injected carbon dioxide. Once miscible reservoir conditions were obtained and certain mechanical difficulties resolved, carbon dioxide injection began. The total effective volume of liquid carbon dioxide to be injected approximately equals 25 percent of the hydrocarbon pore volume in the pilot area. Upon completion of the carbon dioxide injection, a water slug will be injected as long as necessary to evaluate the full recovery of the process. The progress of the project and the corresponding cash outlay are presented pictorially in the report. The total production of the center two wells credited to the waterflood process was 10,403 BO or 529 BOPAc. To date, production credited to carbon dioxide injection is 3,152 BO or 160 BOPAc. Substantially higher recoveries are anticipated.

DOE/MC/10689-5. Development of Mobility Control Methods to Improve Oil Recovery by CO₂,

First Annual Report, Oct. 1, 1979-Sept. 30, 1980. New Mexico Institute of Mining and Technology. March 1981. 32 pp. The objective of this project is to improve the efficiency of carbon dioxide flooding as an enhanced oil recovery process. This aim is to be pursued by the development of techniques and additives for mobility control. Suggested methods will control those non-uniformities in frontal displacement which are due to or aggravated by the unfavorable mobility ratios between the carbon dioxide-containing displacing fluid and the displaced oil and water. Phase 1 of this project has been to collect, study, and assess information about the former and continuing efforts of other researchers. To date, most Phase 2 activity has consisted of planning and designing laboratory work. This effort has been directed at preparing a series of experiments which will supply information on mobility control in CO₂ floods.

OUTSIDE PUBLICATIONS

Note: Outside publications are listed for reference purposes only and are not available from BETC. Individuals interested in these publications should contact the publishers.

BERC/OP-78/24. Thermodynamic Properties of Methyl-Substituted Indans. S. H. Lee-Bechtold,

H. L. Finke, J. F. Messerly, and D. W. Scott. Published in the *Journal of Chemical Thermodynamics*, Volume 13, No. 3. 1981. Pages 213-228. The low-temperature thermal properties of three dimethylindans (1,1; 4,6; and 4,7) and two tetramethylindans (1,1,4,6 and 1,1,4,7) were measured by adiabatic calorimetry from 10 to about 400 K. Properties measured included the heat capacity of the condensed phases at saturation pressure, enthalpy of fusion, triple-point temperature, and purity of sample. The 1,1,4,6-tetramethylindan exhibited a lambda transition with a peak at 191 K. The 1,1,4,7 sample formed a glass when cooled rapidly from the liquid. The glass was studied from 10 K to the transition temperature

(about 160 K). The results were used to calculate the following thermodynamic functions at selected temperature for the condensed phases: $-[G_s(T) - H^{\circ}(0)]/T$, $[H_s(T) - H^{\circ}(0)]/T$, $H_s(T) - H^{\circ}(0)$, S_s , C_s , and the thermodynamic functions for the ideal gas.

BETC/RI-79/7. Predictive Test Method for Coking and Fouling Tendency of Used Lubricating

Oil. G. L. Steele, D. W. Brinkman, and M. L. Whisman. National Bureau of Standards Special Publication 584. November 1980. 12 pp. A short, reliable test has been developed to measure the coking and fouling tendency of used lubricating oils undergoing thermal stress.

DOE/BETC/OP-80/6. Screening of Hydrotreated Coal Liquids for Mutagenic Activity. Dexter Sutterfield,

W. C. Lanning, and R. E. Royer. Published in Volume 1 of the Proceedings of the Second U.S. Department of Energy Environmental Control Symposium, March 17-19, 1980, Reston, Va. January 1981. Pages 649-657. Coordinated by Argonne National Laboratory, 9700 South Cass Ave., Argonne, Ill. 60439. The Ames test was used to screen coal liquids from the SRC-II process for mutagenic activity before and after hydrotreatment. The coal liquid was hydrotreated at 2,000 psig over a commercial catalyst at temperatures ranging from 310° to 400° C. This range of conditions removed more than 90 percent of the sulfur, from 30 to greater than 99 percent of the nitrogen, and from 39 to 99 percent of the oxygen. Hydrogen was increased from 8.4 to 12.4 wt-pct for these conditions. At moderate conditions for this test (325° C), mutagenic activity had been decreased to a level indistinguishable from that of the control sample which had no coal liquid present.

DOE/BETC/OP-80/41. The Department of Energy's Research Program for Enhanced Oil Recovery. Bill

Linville. Published in *Well Servicing*, 6060 North Central Expressway, Suite 538, Dallas, TX 75206. Volume 21, No. 1. January/February 1981. Pages 47-54. The petroleum industry has embarked on an all-out program to maximize ultimate recovery of hydrocarbon liquid. In line with this effort, the Department of Energy has been funding cooperative programs with industry to promote the demonstration and development of enhanced oil recovery techniques. DOE's Cost-Sharing and Tertiary Incentive Crude Oil programs have served as a major stimulus to industry to test "high-risk" recovery techniques. As these programs draw to a close, DOE scientists are examining their results and modifying some on-going projects to obtain more data. Technical information that evolves from this research and development effort will be processed and made available throughout industry.

DOE/BETC/OP-81/25. Maximizing Efficiency of Fuel Production and Utilization. Don E. Koehler and W. F.

Marshall. Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096, SAE Paper 810062. February 1981. Reprinted from SP-481—"Electronic Engine Management and Driveline Control Systems," pages 53-58. An experimental study was undertaken to determine the influence of fuel octane quality, engine compression ratio, and ignition timing adjustment on fuel utilization efficiency. This information, combined with data on refinery energy consumption for producing fuel of various octane qualities, can be used to estimate the potential for improvement in miles traveled per barrel of crude oil consumed. The vehicle selected for this investigation incorporated a closed-loop, air/fuel ratio control system using an oxygen sensor and a three-way catalyst. Ignition timing was adjusted for minimum fuel consumption at each of three compression ratios with the engine operating on fuels of various octane quality. An ignition timing retard system was used for those combinations of compression ratio and fuel quality which precluded use of best ignition timing. Results indicate that a 13 percent improvement in miles traveled per barrel of crude oil consumed is possible.

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Bartlesville Energy Technology Center
HARRY R. JOHNSON, Director

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QUARTERLY PROGRESS REPORTS

DOE/BETC/QPR-80/4. Liquid Fossil Fuel Technology. Quarter ending Dec. 31, 1980. Edited by Bill Linville. May 1981. 74 pp. Progress reports on research, development, and demonstration projects conducted by Bartlesville Energy Technology Center personnel and contractors are given, with emphasis on liquid fossil fuel projects. Reports are included from BETC's Divisions of Extraction Research, Processing and Thermodynamics Research, Utilization Research, and Project Integration and Technology Transfer.

REPORTS OF INVESTIGATIONS

DOE/BETC/RI-80/6. Diesel Exhaust Emissions from Engines for Use in Underground Mines. B. H. Eccleston, D. E. Seizinger, and J. M. Clingenpeel. April 1981. 42 pp. Experimental data were obtained from two medium-duty diesel engines derated to qualify for use in underground mines. Gaseous and particulate emissions from these engines were measured, and results provide information on the effect of exhaust treatment devices on the emissions. The devices in the study were a catalyst, a particulate trap, and an exhaust gas cooler of the water scrubber type. Emission levels of carbon monoxide and hydrocarbons were observed to be very low in comparison with emission levels of comparable engines in full-rated operation. Oxides of nitrogen and benzo(a)pyrene content of the exhaust also were found to be somewhat low in comparison with previous findings. For particulate reduction, the combination of a particulate trap and a scrubber was observed to be the most effective combination tried; in some cases, over 60 percent removal of particulates was effected by the trap-scrubber combination.

DOE/BETC/RI-80/10. A Method for Calculating Strontium Sulfate Solubility. G. E. Fletcher, T. R. French, and A. G. Collins. April 1981. 17 pp. This paper presents a method of predicting the tendency of brines to deposit strontium sulfate scale. Strontium sulfate solubility product constants were determined in the laboratory at temperatures of 50, 75, 122, and 156°F and at ionic strengths of sodium chloride solutions from 0.1 to 5.25. Solid strontium sulfate was prepared and tagged with radioactive sulfur-35. Excess of this strontium

sulfate was added to the sodium chloride solutions and shaken at the various temperatures until equilibrium was reached. The filtrate was analyzed for sulfate ion using a liquid scintillation counter and for strontium ion using an atomic absorption spectrophotometer. The solubility products were expressed graphically as K_{sp} versus ionic strength at various temperatures. A series of synthetic brines containing various amounts of sodium, magnesium, calcium, strontium and chloride ions was prepared. The solubilities of strontium sulfate in these brines were calculated using the known ionic strengths and solubility data obtained from the experiments with the sodium chloride solutions. These calculated values were compared with actual values determined in the same manner as those from the sodium chloride values.

DOE/BETC/RI-80/11. Environmental, Resource Conservation, and Economic Aspects of Used Oil Recycling. D. W. Brinkman, M. L. Whisman, N. J. Weinstein, and H. R. Emerson. April 1981. 59 pp. To provide current and updated information, the case for burning used automotive lubricating oil versus re-refining it has been reevaluated based upon the 1980 American economy and energy conservation posture. The environment is considered within four scenarios ranging from unrestricted burning of used oil without government constraints to complete prohibition of burning, thereby funneling all used automotive lube oils to re-refining. Two other areas have been reevaluated in the context of burning versus re-refining of automotive lube oils in the U.S. These are the material and energy advantages to be realized in terms of resource conservation through either burning or re-refining and an estimation of the economics and profit potential currently available in the disposition of used lube oil. This study shows that the energy required to produce a gallon of lube oil from paraffinic crude oil is greater than that to produce a gallon of lube oil from used lubricating oil. As a result, the re-refining of collectible used automotive lube oil could conserve 43 to 76 trillion Btu's per year, equivalent to 7 to 12 million barrels of imported crude worth up to a half billion dollars. Additionally, this study indicates that new technology such as solvent/distillation re-refining would provide a 26 percent after-tax return on investment based upon 1980 markets and costs.

DOE/BETC/RI-80/12. Polyacrylamide Polymer Viscosity as a Function of Brine Composition. T. R. French, Nathan Stacy, and A. G. Collins. May 1981. 15 pp. A computer model has been developed which predicts the viscosity of polymer and oil field brine mixtures. The polymers used were Amoco Sweepaid 103 and Dow Pusher 500 polyacrylamide polymers. All experiments were conducted at 1,200 ppm polymer concentration. The computer input consists of the ionic strength of the brine in the mixture and the fraction of that ionic strength due to sodium ions. The computer program makes predictions of viscosity by referencing a family of viscosity curves for various mixtures of sodium chloride and calcium chloride in 1,200 ppm polymer solutions. The model has been tested using 59 mixtures of brines and polymers. The ionic strength of the brine in the mixtures varied from 0.0018 to 0.025. The fraction of the brines' total ionic strength due to sodium ions varied from 0.22 to 0.49. The brines consisted predominantly of sodium, potassium, magnesium, calcium, chloride, bicarbonate, and sulfate ions.

DOE/BETC/RI-81/2. Design and Testing of a Procedure for Evaluating Fuel-Efficient Crankcase Lubricants. Ted M. Naman. April 1981. 14 pp. Experiments were conducted at BETC to design a procedure for evaluating the fuel efficiency

characteristics of crankcase lubricants, using the driving cycles of the 1975 Federal Test Procedure and the Highway Fuel Economy Test. Three crankcase lubricants and five oil supplements, plus a baseline lubricant, were used in eight 1980 model-year vehicles of identical make. The vehicles were operated at 75°F. (24°C) in closely controlled chassis dynamometer tests designed to detect small changes in fuel efficiency. Results from these tests showed measurable increases in fuel economy of up to 6 percent with the test lubricants when compared to a common SAE 30 grade oil. These results are not definitive because of lack of quantification of mileage accumulation effects. The test protocol did reduce measurement variability greatly; this procedure can be applied to evaluation of fuel-efficient oils using larger test fleets.

FACT SHEETS

DOE/BETC/FS-81/1. Effects of Low-Proof Alcohol on Internal Combustion Engines. BETC Staff. May 1981. 1 p. A "Research Brief" describes results of a DOE-funded project at Oregon State University. The purpose was to define the lower limit of alcohol proof that can be tolerated in the internal combustion engine. A total of 24 engine tests were done using a 2.3 liter, four-cylinder, overhead cam Ford engine. Results indicate that operating with alcohol less than 160-proof could contaminate the engine oil, leading to possible engine damage.

INFORMATION CIRCULARS

DOE/BETC/IC-80/4. Three-Phase Fluid Flow in Porous Media. E. C. Donaldson and M. B. Kayser. April 1981. 24 pp. In the regions of two-phase flow, with a third phase stationary, the third phase plays an important role in the resulting relative permeability relationships. Wettability has an extremely significant effect on the permeability and flow behavior of the system. This report presents a review of the literature on three-phase relative permeability and a suggested unsteady-state method for finite-difference calculations.

EOR PROGRESS REVIEWS

DOE/BETC-81/1. Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery and Improved Drilling Technology. Progress Review No. 25, Quarter ending Dec. 31, 1980. Edited by Bill Linville. May 1981. 160 pp. Status reports are given of various enhanced oil and gas recovery projects sponsored by the Department of Energy. The field projects and supporting research on enhanced oil recovery include chemical flooding, carbon dioxide injection, thermal/heavy oil recovery, microbial recovery, and residual oil determination. Other research includes extraction research and improved drilling methods.

REPORTS BY CONTRACTORS

DOE/BC/00034-21A. Improved Pressure Coring System, Annual Report, Oct. 1, 1979-Sept. 30, 1980. Sandia National Laboratories. June 1981. 16 pp. Two recent developments have emerged with the potential of significantly improving the present performance of pressure coring. Coring bits utilizing synthetic diamond cutters have demonstrated coring rates of 1 ft per minute while improving core recovery. It is also apparent that cores of a near-unconsolidated nature are more easily recovered. In addition, a special low invasion fluid which is placed in the core retriever has demonstrated reduced core washing by the drilling mud and a decrease in the complexity of preparing cores for analysis. This report describes the design and laboratory and field testing efforts which led to these coring improvements. Also, experience in utilizing these developments while recovering over 200 cores is discussed.

DOE/BC/00042-35. Measurement of Formation Characteristics of Western Tight Sands, Special Core Analysis Report. Institute of Gas Technology. May 1981. 27 pp. This report describes the Institute of Gas Technology's (IGT) research on tight sandstone cores from four wells. Samples from the Dakota Formation of the San Juan Basin well, Canyon Largo No. 256, were selected for comparison with the unpublished measurements of R. D. Thomas of the Bartlesville Energy Technology Center. The second well is the Mobil PCU F31-13G well in the Piceance Basin, which is being tested under a Mobil Oil Co. Department of Energy program. The third well is the Natural Buttes well (Sec. 15, T 10S, R 24E) Uinta Basin. The fourth well is the C-K Geoenergy well DOE-GC1 (Sec. 16, T 17S, R 24E) Uinta Basin. Permeability to gas was measured as a function of pore pressure, confining pressure, and partial water saturation in an attempt to estimate *in situ* permeability of tight sandstones. Permeability to liquid was also measured as a function of net confining pressure, and mercury injection tests were conducted on samples to obtain capillary pressure curves. The permeability of tight sandstones was found to be strongly dependent upon net confining pressure and partial water saturation. Brine permeabilities were found to be lower than gas permeabilities extrapolated to infinite mean pore pressure for the cores studied. Under no confining stress, pore size distributions, measured by mercury injection tests, indicate that the majority of pore entry diameters range from 0.1 to 5 microns.

DOE/BC/00047-13. Development of Improved Mobility Control Agents for Surfactant/Polymer Flooding, Second Annual Report, Oct. 1, 1979-Sept. 30, 1980. New Mexico Institute of Mining & Technology. April 1981. 126 pp. The objective of this laboratory work is to develop improved mobility control agents that are more effective than commercial polymers currently used. During this second year of the project, the baseline testing of commercial products was completed. These baseline tests include studies on mobility control, retention, and shear degradation in Berea cores, the effect of common ions on rheological properties, thermal stability, microbial degradation, and surfactant-polymer interactions. Work was also initiated on the synthesis, characterization, and preliminary screening of new and modified polymers. A number of potential structure-utility relationships have been observed and are outlined in this report.

DOE/BC/10043-25. Optimization of Accelerated Stability Test Techniques for Diesel Fuels, Final Report. Southwest Research Institute. June 1981. 64 pp. The purpose of this 2-year project was to study the formation of deleterious products in middle distillate fuels and to apply the results toward the development of more reliable test methods for fuel stability. During the first year of this program, eight accelerated stability tests were chosen and evaluated using a set of six test fuels. Correlations of accelerated stability test results were then related to test results obtained at a storage temperature of 43°C (110°F), which has generally been regarded as showing good correlation with long-term ambient storage. During the second year's effort, primary emphasis was placed on testing 43°C and 150°C tests which are being cooperatively developed by the American Society for Testing and Materials (ASTM). Testing of eight fuels having a wide range of stabilities provided data which, when mathematically correlated, allowed for a number of observations. Total insolubles, as opposed to total gum values, were judged to be more acceptable for data correlation in that total gum values could not be reliably corrected for initial gum values. In general, test results at 43°C, 80°C, 150°C, and ASTM D 2274 provided directional agreement. Vented versus nonvented storage at 43°C did not provide any evident biases related to test configurations at the 4-, 8-, 12-, 18-, and 24-week test intervals. Based on data generated, no significant bias could be found for bottle configuration in the 43°C test. In an effort to standardize the 43°C and 150°C tests, planning and cooperative testing was provided to ASTM Committee D-2, Technical Division E-V.

DOE/BC/10095-4. Mobility Control and Scaleup for Chemical Flooding, Annual Report, August 1979-July 1980. University of Texas. June 1981. 206 pp. This report

presents the results of first-year research on mobility control and scaleup, including results on these items: (1) simulation development, (2) history matching core floods, (3) transport experiments, (4) oil recovery experiments, and (5) rheology experiments. Both 1-D and 2-D micellar/polymer simulators have been under development. This research involves physical property modeling, model formulation, numerical techniques, coding, testing, and applications. The 1-D simulator has been used to match various core floods. The transport experiments include low-tension, steady-state relative permeabilities and multiphase dispersion. The oil recovery experiments are for history matching purposes. Extensive physical property data were collected to support all of the flow experiments and for use as input to simulators. This integrated program of experiments and simulation, including theoretical analysis, is designed to both enhance the understanding of the process, and to improve the capability to reliably scale it up from the laboratory to the field.

DOE/BC/10311-1. CO₂ Stimulation Process, Final Report. Computer/Bioengineering Institute and Intercomp, Inc. May 1981. 22 pp. Cyclic CO₂ stimulation of a production well, especially in viscous oil reservoirs, is developing as a method of rapidly producing tertiary oil and obtaining valuable data. History matching provides confirmation of CO₂-crude interactions, measured in the laboratory, that can increase the accuracy of CO₂ flood predictions. In the absence of published field data, this study utilized a numerical simulator to predict incremental oil recovery as a function of the various operating and reservoir parameters. Multiple regression analysis was then used to relate the efficacy (STB incremental oil/MCF CO₂ injected) of the CO₂ cyclic stimulation process to six parameters. Under ideal conditions, one extra barrel of stock tank oil is produced for each MCF of CO₂ injected. Efficacy decreases with both number of cycles and volume injected.

DOE/BC/20001-10. Tertiary Oil Recovery Processes Research at the University of Texas, Final Report. University of Texas. June 1981. 127 pp. During the past year the research continued to focus on surfactant adsorption, phase behavior, interfacial tension, and solubilization in the continued belief that these are some of the most significant EOR problem areas. In previous studies, three adsorption problems were considered of paramount importance: (1) the composition of micelles in mixed surfactant systems, which requires determinations of the CMC of mixed micelles, (2) determination of the extent of adsorption from high surfactant concentration microemulsion, which requires rigorous development of analytical techniques, and (3) a better understanding of surfactant chromatography, which requires a better understanding of the composition of mixed hemimicelles. During the past year, emphasis has been on the influence of branching for anionics and molecular weight for non-ionics. In addition, the University of Texas researchers have: (1) related phase behavior to emulsion stability, (2) continued studies on polymeric surfactants, and (3) continued a synthesis and evaluation program for a variety of salinity tolerant surfactants.

DOE/BETC/5603-15. Improved Polymers for Enhanced Oil Recovery—Synthesis and Rheology, Third Annual Report, October 1979–September 1980. University of Southern Mississippi. April 1981. 293 pp. In recent years an increasing number of commercial and experimental water-soluble polymers have become available for use as displacement fluids in enhanced oil recovery. The potential usefulness of these polymers is not easily assessed due to a number of complex interactions experienced during polymer flooding. The goals of this research project are to gain a more complete understanding of the effects of macromolecular structure on aqueous rheological behavior, to develop simple yet meaningful screening tests, to project performance under field conditions, and ultimately to synthesize more efficient polymers.

DOE/ET/10145-64. A Survey of Activity in the Area of Instrumentation for Reservoir Description for Enhanced Oil Recovery, Final Report. Gulf Universities Research Consortium. May 1981. 74 pp. This report reviews the state-of-the-art

and recent progress in the types of instrumentation which can be applied to reservoir description. The traditional sources of reservoir information are cores, wireline logs and well tests. There are, however, new techniques which involve geophysics, geochemistry and tracer testing. For the purposes of enhanced oil recovery, the instrumentation must be capable of measuring smaller-scale effects with greater accuracy than was considered necessary in the past in oil exploration. The report concludes that considerable progress has been made in instrumentation but that greater precision in measurement is needed.

DOE/ET/10145-65. Computerized Procedure for Data Validation and Resource Calculation for Oil Reservoirs, Final Report. Gulf Universities Research Consortium. May 1981. 66 pp. GURC has developed a computerized procedure to aid in data validation and resource calculation using the data in the Petroleum Data System's file. The Petroleum Data System (Univ. of Oklahoma), which is a publicly available source of geologic and engineering data, was recognized as having missing and/or inconsistent data in the Oil and Gas file. The process that was developed identifies missing and/or inconsistent data in the data base system. It uses, when possible, existing data to calculate that which is missing and/or corrects inconsistencies. When data are available, it generates an estimate of remaining oil in place for each reservoir processed.

DOE/ET/10145-66. Chemicals for Chemical Flooding in Enhanced Oil Recovery. Gulf Universities Research Consortium. May 1981. 96 pp. This report contains a variety of information regarding EOR chemicals, with the emphasis on surfactant polymer EOR. Included are supply and demand information, cost and pricing information, various need and use projections, and statements of industry representatives.

DOE/ET/10145-69. A Computer Model for Comparative Economic Analysis of Enhanced Oil Recovery Projects. Gulf Universities Research Consortium. May 1981. 73 pp. A computer model has been developed with the versatility to analyze economic sensitivities for most injection sequences and economic aspects of several different types of EOR processes. Input of economic parameters is in terms of constant value dollars for investments and operating costs. Input of project performance is by specifying cumulative fractional oil recovery versus cumulative pore volumes of material injected. Risk can be appraised by input of three such relations, i.e., "expected," "good," and "poor" performance, each of which can be probability-weighted. Conversion to time-rate of recovery is done internally, either through input transmissibility data or user specified pore volume injection rate for each injection stage. Economic sensitivities to various input parameters are in terms of a new economic parameter, "present value cost per present value barrel." The model is intended primarily for investigation of economic sensitivities to parameters such as: oil in place at project initiation, recovery efficiency, transmissibility, and material-investment-operating costs.

DOE/ET/12056-11. In Situ Combustion Models for the Steam Plateau and for Fieldwide Oil Recovery. Stanford University Petroleum Research Institute. June 1981. 112 pp. Two interrelated parts of the *in situ* combustion oil recovery process have been investigated. The steam plateau region of laboratory combustion tube experiments was studied, and heat transfer modes describing the steam plateau were also studied and evaluated. This part of the study points out some of the design problems and considerations important to the operation of the combustion tube and the interpretation of the results related to the steam plateau. An analytical heat model was developed which describes the movement of the steam plateau axially along a cylinder with heat loss through an annular insulation. The behavior of the solution was studied to determine the interaction of the heat transfer mechanisms in laboratory cores. The results of laboratory combustion tube runs were used to verify the theory set forth by the heat model. The agreement between experimental laboratory temperature

profiles and those computed by model were satisfactory. In the second part of the study, correlations were developed to predict field scale recovery of dry *in situ* combustion processes. Basically, a case history analysis was made on field tests as a first step. The recovery histories of those field systems were studied. A combination of an engineering and a statistical approach was used to develop the correlation. The match between the correlations and field test results was satisfactory.

DOE/ET/12056-12. Numerical Modeling of Thermal Recovery Processes. Stanford University Petroleum Research Institute. June 1981. 121 pp. This work treats a theoretical investigation of forward combustion in a simulated laboratory combustion tube. A mathematical model has been developed that includes the thermal, thermodynamic, and hydrodynamic aspects of the process. In this model, oil is assumed to burn directly, in a fashion similar to Gottfried's assumption. This model is an improvement over the model of Crookston et al. in that the computer program is designed to handle phase disappearance. The model shows a temperature profile that matches combustion tube runs done at Stanford. The model yields spatial distributions of pressure and temperature, and saturations and concentrations of all important components (oil, water, oxygen, inert gas, and steam). It also gives production rates, cumulative production, and instantaneous and cumulative WORs and GORs. Interpretation of the various computed profiles and the associated phenomena is presented, and comparison with other numerical models is included. The model can also simulate other thermal recovery processes, such as hot water flooding and steam injection.

DOE/ET/12063-28. Electrodril System Field Test Program, Final Report for Phase II, Task C-1—Deep Drilling System Demonstration. General Electric Co. April 1981. 69 pp. The Electrodril concept is to provide a method to drill with a downhole electric motor that uses a retrievable power cable and employs a telemetry system which makes downhole measurements of various drilling and safety parameters and transmits them to the surface. The field test demonstrations were aborted in July 1979, due to connector problems. Subsequent post-test analyses concluded that field-replaceable connectors were the probable cause of the problems encountered. The designs of both the male and female connectors, together with their manufacturing processes, were subsequently modified. A total of nine male and nine female connectors were manufactured and delivered during the 2nd Quarter 1980. Exhaustive testing was then conducted on each connector. The report documents the results of the connector qualification test program which was successfully completed Oct. 28, 1980. In general, it was concluded that connector qualification had been achieved, and plans are now in progress to resume the field test demonstration program so that Electrodril System performance predictions and economic viability can be evaluated.

DOE/ET/12065-38. Enhanced Oil Recovery by Improved Waterflooding, Third Annual Report, October 1979–September 1980. Energy Resources Co., Inc. April 1981. 41 pp. Energy Resources Co., Inc. and its subcontractor, Elf-Aquitaine Oil and Gas Co., are conducting a 100-acre pilot polymer flood in the Storms Pool Field near Carmi, in White County, Ill. Preparation for the polymer flood began in September 1977, and the project is scheduled for completion in December 1983. Once highly productive, the Storms Pool Flood has yielded over 12 million barrels of oil from the Waltersburg formation since its discovery in 1939. The field has been waterflooded for over 20 years. Material balance and recent electric logs indicate that there is a substantial volume of movable oil still in place, presumably bypassed by the inefficient waterflood. The polymer flood is intended to improve the sweep efficiency, showing that the engineering, management, and financial resources required for such tertiary techniques can be applied to similar fields that might otherwise be abandoned. This report discusses the final polymer selection, design of the graded polymer banks, results of reservoir pressure tests and plans for continued testing, and completion of basic plant construction.

DOE/ET/12072-2. Economics of Enhanced Oil Recovery, Final Report. Lewin and Associates, Inc. May 1981. 116 pp. During the last several years, costs and revenues associated with enhanced oil recovery have changed significantly. The market price for tertiary oil has more than doubled, but inflation has also increased investment and operating costs. In addition, there have been changes in taxation, such as the addition of the Windfall Profit Tax. These events have markedly changed the economics of enhanced oil recovery. The costs of various EOR techniques were last estimated on a consistent basis in 1978. The purpose of this report is to analyze the economics of five different EOR techniques in mid-1980 dollars under a consistent basis, incorporating experimental results from field tests, as well as an improved understanding of EOR process that has been obtained since 1978. Three separate tasks were undertaken: (1) collect and update cost data to mid-1980, (2) update the recovery models for each EOR technology, and (3) evaluate the economics of each EOR technique. The techniques considered include steam drive, *in situ* combustion, carbon dioxide flooding, surfactant/polymer flooding, and polymer waterflooding.

DOE/ET/12082-9. Displacement of Oil by Carbon Dioxide, Final Report. New Mexico Institute of Mining & Technology. May 1981. 156 pp. Results of a comprehensive research program on factors influencing CO₂ flooding are reported. Equipment constructed for static equilibrium is described. Design of an apparatus used for a variety of displacement tests is also reported. Apparatus and experimental procedures are described for a new experiment in which equilibrium phase compositions can be measured rapidly and continuously. Results of displacements of crude oil from slim tubes, cores and mixing cells are presented and interpreted in terms of detailed measurements of the phase behavior and fluid properties of the CO₂-crude oil mixtures. The complex (liquid-liquid and liquid-liquid-vapor) phase behavior of low temperature CO₂-crude oil mixtures is described and compared with similar behavior for CO₂-alkane mixtures. A simple correlation is offered for the ranges of reservoir temperature and pressure at which liquid-liquid and liquid-liquid-vapor phase behavior should be expected to occur. Direct evidence is presented of the efficiency with which a CO₂-rich liquid phase can extract hydrocarbons from a crude oil. A simple one-dimensional process simulator for CO₂ flooding applications is described. Simulation results are compared with experimental data from slim tube displacements. Factors such as phase behavior, viscous fingering, gravity segregation and core heterogeneity influencing laboratory experiments are reviewed. Uses and limitations of laboratory experimental data to support field scale performance predictions are discussed. Reprints of two papers which provide additional analysis of CO₂-crude oil phase behavior are given in Appendices A and B.

DOE/ET/12366-22. Residual Oil Saturation Technology Test, Bell Creek Field, Montana, Final Report. Gary Energy Corp. June 1981. 137 pp. A field test was conducted to measure residual oil saturation following waterflood secondary oil recovery processes. The test was conducted in a new well drilled solely for that purpose northwest of the Bell Creek micellar-polymer pilot. The area where the test was conducted was originally drilled during 1968, produced by primary until late 1970, and was under line drive waterflood secondary recovery until early 1976, when the area was shut in at waterflood depletion. This report presents the results of tests conducted to determine waterflood residual oil saturation in the Muddy Sandstone reservoir. The engineering techniques used to determine the magnitude and distribution of the remaining oil saturation included both pressure and sidewall cores, conventional well logs, carbon-oxygen logs, dielectric logs, nuclear magnetism log, thermal decay time logs, and a partitioning tracer test.

DOE/ET/13070-63. El Dorado Micellar-Polymer Demonstration Project, Sixth Annual Report, September 1979–August 1980. Cities Service Co. April 1981. 375 pp. The primary objectives of this project are to determine the economic feasibility of improved oil recovery using two micellar-polymer processes and to determine the associated benefits and problems of each process. The El

Dorado Demonstration Project is designed to allow a side-by-side comparison of two distinct micellar-polymer processes in the same field so that the reservoir conditions for the two floods are as similar as possible. Polymer solutions have been injected into both patterns for this entire project year. Severe biodegradation of the north pattern polymer was controlled by the addition of alcohol to the injection fluids. Modifications to the south pattern polymer injection system were made to reduce downtime and maintenance problems and to improve mobility control. Fluid movement at observation wells has been monitored closely. The four producing wells in the north pattern have shown low but positive and steadily increasing levels of secondary-butyl alcohol. None of the producing wells has exhibited any surfactant or measurable oil to date. There have been no significant changes in compositions at any of the production wells. The polymer drive for the north pattern using polyacrylamide following the biopolymer has been developed. Change-over to the new design will be made in the next project year. This design should give better mobility control than that which would be obtained using biopolymer only. Evaluation will continue, along with data documentation and evaluation. Core floods and finite difference chemical flood simulators will be employed to forecast oil breakthrough times.

DOE/ET/13077-49. Commercial Scale Demonstration, Enhanced Oil Recovery by Micellar-Polymer Flood, Annual Report, October 1979-September 1980. Marathon Oil Co. April 1981. 120 pp. This commercial scale test, known as the M-1 Project, is located in Crawford County, Ill. It encompasses 407 acres of Robinson Sand reservoir and covers portions of several waterflood projects that were approaching economic limit. The project includes 248 acres developed on a 2.5-acre five-spot pattern and 159 acres developed on a 5.0-acre five-spot pattern. Development work commenced in late 1974. Micellar solution (slug) injection was initiated on Feb. 10, 1977, and is now completed. After 10 percent of a pore volume of micellar slug was injected, injection of 11 percent pore volume of Dow 700 Pusher polymer was conducted at a concentration of 1,156 ppm. At the end of this reporting period, 625 ppm polymer was being injected into the 2.5-acre pattern and 800 ppm polymer was being injected into the 5.0-acre pattern. The oil cut of the 2.5- and 5.0-acre patterns increased from 8.6 percent and 5.2 percent respectively in September 1979, to 11.0 percent and 5.9 percent in September 1980. The oil cut performance has consistently exceeded that predicted for the project.

DOE/MC/03259-10. Enhanced Oil Recovery by CO₂ Foam Flooding, Second Annual Report. New Mexico State University. June 1981. 84 pp. The objective of this project is to identify commercially available additives which are economically attractive and effective in reducing the mobility of carbon dioxide, thereby improving its efficiency in the recovery of tertiary oil. The fundamental data that have been obtained are providing an excellent base for extending CO₂ mobility control much closer to commercial reality. Correlation work on dynamic foam stability in two-phase flow experiments in a linear sandpack has shown that the most active foaming agents, as identified in static tests, may not be the best choices for mobility control in the field. The Alipal CD-128/Monamid 150-AD system, the leading foam generator in the static test, is slightly inferior to an ethoxylated alcohol, Neodol 23-6.5, which produces only a modest amount of foam in the static test. In the dynamic test, Neodol 23-6.5 lowered gas mobility by about a factor of two greater than the Alipal system. Both systems are outstanding in their performance, and further comparative tests are scheduled.

DOE/MC/10865-6. CO₂ Formation Damage Study, First Annual Report. New Mexico State University. June 1981. 127 pp. This project is researching how to avoid or minimize formation damage due to CO₂ injection processes. The study is determining the types of chemical and physical changes that can occur in carbonate or other reservoirs because of injected carbon dioxide and its chemical additives and the effects on oil recovery due to those changes. During the first year, a well defined experimental plan has been developed. Most of the apparatus has been designed, and assembly of some

systems has been completed. A literature search made at the inception of the project found no documented reports of CO₂ damage to oil reservoirs. The search was then expanded to include studies relating to project's proposed damage mechanisms. Over 100 references were selected, and these are presented with abstracts, author index, and subject category in the report appendix.

DOE/SF/01802-56. Bell Creek Field Micellar-Polymer Flood Demonstration, Fourth Annual Report, October 1979-September 1980. Gary Energy Corp. June 1981. 103 pp. This pilot is being conducted to determine if micellar-polymer flooding is an economically feasible technique to enhance oil recovery from the Bell Creek Field in southeastern Montana. The pilot is a contained 40-acre five-spot located in a representative watered-out portion of the Unit reservoir. The pay is sandstone with an average net pay of 6.4 ft, permeability of 1,050 md, and water TDS of 2,500 ppm. The average remaining oil saturation in the 40-acre pilot area was estimated to be 35 percent at the start of chemical injection. The pilot has four injectors and one producer. The overall micellar-polymer recovery is estimated at 15 percent of the remaining oil at the initiation of the chemical flood. In the fourth contract year, micellar slug injection was completed and injection of the graded mobility buffer began, and a second radioactive/chemical tracer test was begun at the start of the polymer phase.

DOE/SF/10762-1. Field Demonstration of the Conventional Steam Drive Process with Ancillary Materials, First Annual Report, October 1979-October 1980. Chemical Oil Recovery Co., Petro-Lewis Corp. April 1981. 129 pp. The primary goal of the field demonstration is to evaluate the economic merits of ancillary materials to a conventional steam drive to improve sweep efficiencies. The ancillary materials are used to reduce injection in "steep channels" and thus force the injected steam to enter alternate flow paths. By reducing the steam channeling effects, the factors causing steam channeling become less dominant, and improved vertical and areal sweep efficiencies are realized, thus reducing residual oil saturation in areas that would have been unswept without the use of ancillary materials. The demonstration is being conducted in six 10-acre inverted nine-spot steam drive patterns which are fully developed with producers. By the end of the first year, background data has been collected, observation wells have been drilled, four injection well treatments have been designed and started, and comprehensive monitoring of data is underway. Chemical treatments began in January 1980, and by May 1980, all four treatments were underway. Evaluation of production data plotted by injection pattern shows increases in production that can be attributed to the ancillary materials. Estimates of as much as 125 barrels of incremental oil per acre can be made during August 1980, depending upon the method of establishing decline curves.

SPECIAL WATERFLOODING REPRINTS

Due to recent renewed interest in waterflooding technology, the Bartlesville Energy Technology Center has reprinted the following 12 reports published in the 1940s, '50s, and '60s. A limited number are available, and requests will be filled as long as the supply lasts. Only one copy of each report can be provided per individual order.

RI 3728. History of Waterflooding Oil Sands in Oklahoma. D. B. Taliaferro and D. M. Logan. November 1943. 10 pp. This report contains detailed information regarding all waterflooding projects in operation in Oklahoma as of the publication date.

RI 4795. Waterflooding of Oil Sands in Washington County, Oklahoma. C. H. Riggs and W. C. Smith. May 1951. 20 pp. This report presents pertinent data on all active waterflooding projects in Washington County (as of the publication date) and describes in detail the operation and production history of five representative floods.

RI 4831. A Survey of Oil Production in Oklahoma by Waterflooding, Part I—Nowata, Rogers, and Craig Counties. J. P. Powell and K. H. Johnston. February 1952. 160 pp. This report describes waterflooding operations from July 1, 1942, to Dec. 31, 1949, in the three counties.

RI 4832. A Survey of Oil Production in Oklahoma by Waterflooding, Part II—Counties Other Than Nowata, Rogers, and Craig. J. P. Powell and K. H. Johnston. November 1951. 142 pp. This report gives the same information as the one above for all other Oklahoma counties in which waterflooding operations had taken place.

RI 4896. Waterflooding in Nowata County, Okla., Oil Fields. J. P. Powell and J. L. Eakin. June 1952. 53 pp. This report describes four waterflooding projects in detail, presenting a production history of the leases in each project and discussing the methods of operation, the types of equipment used, the methods of water treatment, and the results obtained.

Order by title. Water Flooding in the Burbank Oil Field, Osage County, Oklahoma. C. H. Riggs. May 1954. 23 pp. This report describes three major waterfloods in western Osage County, Okla.: the North Burbank Unit and the South Burbank Unit, operated by Phillips Petroleum Co.; and the Mid-Burbank Unit, operated by Kewanee Oil Co.

RI 5134. Recent Developments in Waterflooding in Nowata County, Okla., Oil Fields, 1954-55. J. L. Eakin. May 1955. 53 pp. A discussion is presented of four full-scale waterflooding projects in the Delaware-Childers Field and one pilot project in the Curl Creek Field, all of which had only been in operation a few months.

IC 7750. Waterflooding of Oil Sands in Butler and Greenwood Counties, Kans. J. P. Powell. May 1956. 46 pp. Four waterflooding projects in this area had recovered about 6.6 million barrels of additional oil from the injection of 84.7 million barrels of water at the time of publication.

IC 7787. Some Recent Developments in Waterflooding in Washington County, Okla., 1956-57. J. P. Powell. May 1957. 39 pp. This report presents a discussion of four waterflooding projects in the Bartlesville-Dewey Field and one in the Hogshooter Field.

IC 7896. Four Waterflooding Projects in Washington and Nowata Counties, Okla., 1959. J. P. Powell. 1959. 39 pp. This report describes four projects in Washington and Nowata Counties, including the first project in this area employing carbonated water.

IC 7969. Four Waterflooding Projects in Greenwood County, Kans., 1960. Kenneth H. Johnston. 1960. 40 pp. Three of these projects produced oil from the Bartlesville sand and one produced from the Cattleman sand.

IC 8038. Developments in Waterflooding and Pressure Maintenance in Osage County, Okla., Oilfields, 1961. K. H. Johnston and J. L. Castagno. 1961. 39 pp. This report describes three waterflooding projects and a pressure-maintenance project. Two of the waterflooding projects and the pressure-maintenance project produced oil from the Burbank sand. The other waterflooding project produced from the Mississippi chat.

OUTSIDE PUBLICATIONS

Note: Outside publications are listed for reference purposes only and are not available from BETC. Individuals interested in these publications should contact the publishers.

DOE/BETC/OP-78/23. Thermodynamic Properties of Cyclopropylamine, Cyclopentylamine, and Methylenechlorobutane. H. L. Finke, J. F. Messerly, and S. H. Lee-Bechtold. *Journal of Chemical Thermodynamics*, 13, 1981, pp. 345-355. A study was made of the thermochemical and thermophysical properties of a number of small ring compounds which have strain energy in the ring and, therefore, may have potential use as building blocks for high-energy fuel components, low-temperature thermal studies of cyclopropylamine, cyclopentylamine, and methylenecyclobutane. The derived results were used to calculate the thermodynamic properties of the condensed phases from 10 K to near their respective boiling temperatures. Third-law entropies of the three compounds in the ideal-gas state at 298.15 K were calculated from these measurements and enthalpies and entropies of vaporization were derived from the vapor-pressure measurements of Osborn and Scott. Enthalpies of formation in the liquid state were combined with the enthalpies of vaporization to derive enthalpies of formation in the ideal-gas state at 298.15 K. Values of the standard Gibbs energy of formation and logarithm of the equilibrium constant of formation at 298.15 K were derived.

DOE/BETC/OP-79/36. Vapor Heat Capacities and Enthalpies of Vaporization of Five Alkane Hydrocarbons. I. A. Hossenlopp and D. W. Scott. *Journal of Chemical Thermodynamics*, 13, 1981, pp. 415-421. In this second of a series of three papers reporting results of vapor-flow calorimetry, measurements are reported for five alkane hydrocarbons: n-pentane, 2,2-dimethylpropane (neopentane), 3,3-dimethylpentane, n-octane, and 2,3,4-trimethylpentane.

DOE/BETC/OP-79/37. Vapor Heat Capacities and Enthalpies of Vaporization of Six Organic Compounds. I. A. Hossenlopp and D. W. Scott. *Journal of Chemical Thermodynamics*, 13, 1981, pp. 405-414. The substances for which measurements by vapor-flow calorimetry are reported in this paper are a miscellany of six organic sulfur, oxygen, nitrogen, and fluorine compounds: cyclohexanethiol (cyclohexylmercaptan), 2-methyl-1-butanethiol (*pri-act*-amyl mercaptan), tetrahydrofuran (tetramethylene oxide), oxetane (trimethylene oxide), 4-methylpyridine (γ -picoline), and hexafluorobenzene.

DOE/BETC/OP-79/38. Vapor Heat Capacities and Enthalpies of Vaporization of Four Aromatic and/or Cycloalkane Hydrocarbons. I. A. Hossenlopp and D. W. Scott. *Journal of Chemical Thermodynamics*, 13, 1981, pp. 423-428. In this third of a series of three papers reporting results of vapor-flow calorimetry, measurements are reported for four aromatic and/or cycloalkane hydrocarbons: 1,4-dimethylbenzene (para-xylene), ethylbenzene, 1-ethyl-1-methylcyclopentane, and indan.

DOE/BETC/OP-79/39. Hydrotreatment and Biological Test of SRC-II Coal Liquid. D. Sutterfield, W. C. Lanning, and R. E. Royer. American Chemical Society Symposium Series, 156, 1981, pp. 145-152. Coal liquid product from the SRC-II process was screened for mutagenic activity by the Ames test before and after hydrotreatment in a bench-scale process unit. The coal liquid was hydrotreated at 2,000 psig over commercial catalyst at 310° to 400°C to remove from 30 to essentially 100 percent of the combined nitrogen. Removal of 65 percent of the nitrogen, accomplished at 325°C, increased the hydrogen content of the liquid from 8.4 to 10.8 wt-pct and decreased mutagenic activity of the liquid product, as measured by the Ames screening test, to a level indistinguishable from background levels. The results are preliminary and must be confirmed by further investigation using mammalian systems.

DOE/BETC/OP-79/40. The Composition of Liquids from Coals of Different Rank. G. P. Sturm, Jr., J. E. Dooley, J. S. Thomson, P. W. Woodward, and J. W. Vogh. American Chemical Society Symposium Series, 156, 1, 1981, 37 pp. Eight coal liquids prepared from six coals of widely differing rank were compared with respect to their suitability as potential feedstocks for production of

refined fuels. The compositions of the liquids were determined by methods adapted from those developed for characterization of petroleum crudes. The coal liquids were prepared and upgraded by hydrogenation in a batch autoclave. The reaction conditions employed were selected to minimize hydrocarbon ring-opening reactions and, at the same time, to produce most of the hydrocarbon liquids potentially available from the coals. The degree of hydrogenation of the raw coal liquids was varied as required to decrease the nitrogen content to about the same level and to provide a predominantly hydrocarbon liquid for analysis. Distilled fractions of the upgraded coal liquids boiling up to 540°C were characterized by a combination of separation and analytical techniques including adsorption chromatography; gel permeation chromatography; separations of acids, bases, and asphaltenes; and high- and low-resolution mass spectrometry. In general, the results show that liquids of comparable suitability as feedstocks for production of refined fuels can be produced from coals of different rank.

DOE/BETC/OP-80/3. Mobile Wellhead Analyzer for the Determination of Unstable Constituents in Oil-Field Waters. S. H. Hoke and A. G. Collins. *Water for Subsurface Injection*, American Society for Testing and Materials STP 735, 1981, pp. 34-38. A brine analyzer was designed that measures pH, redox potential (Eh), oxygen, conductivity, sulfide ion (S^{2-}), HCO_3^- , CO_3^{2-} , and carbon dioxide in oil-field water at the wellhead. When oil-field brine samples are collected in the field and transported to the laboratory for analysis, many of the unstable constituents change in concentration. The amount of change depends on the sampling method, sample storage, ambient conditions, and the amounts of the constituents in the original sample. Thus, an analysis of the brine at the wellhead is necessary to obtain reliable data.

DOE/BETC/OP-80/18. Identification of Sulfur Compounds in Petroleum and Alternative Fossil Fuels. C. J. Thompson. *Organic Sulfur Chemistry*, Pergamon Press, 1981, pp. 189-208—Plenary Lectures of the IX International Symposium on Organic Sulphur Chemistry, Riga, USSR. This report summarizes a systematic 20-year study of the organic sulfur compounds in Wasson, Texas, crude oil and, to a lesser extent, of three other crude oils, that has culminated in some 200 individual sulfur-compound identifications. The development and application of special separation and identification techniques generally suitable for the characterization of sulfur compounds in any crude oil are discussed. This report reviews early literature covering petroleum sulfur compound identifications completed before this study was begun, and cites papers resulting from this work.

DOE/BETC/OP-80/19. Liquid Chromatography on Silica Using Mobile Phases Containing Aliphatic Carboxylic Acids. I. Effects of Carboxylic Acid Chain Length on Separation Efficiency and Selectivity. J. B. Green. *Journal of Chromatography*, 209, 1981, pp. 211-229. The effect of adding aliphatic linear chain carboxylic acids to mobile phases used in separation of solutes of widely varying functionality on microparticulate silica was investigated. Changes in peak shape and retention time of varied solutes as a function of mobile phase acid chain length are described. Peak shape generally improves with increasing acid chain length, especially for acidic solutes. Retention of acidic solutes decreases with decreasing acid chain length; basic solutes exhibit the opposite behavior. These and other effects are discussed in conjunction with a proposed retention mechanism. Potential for application of this type of chromatographic system for rapid assessment of chemical types in complex samples is discussed.

DOE/BETC/OP-80/20. Liquid Chromatography on Silica Using Mobile Phases Containing Aliphatic Carboxylic Acids. II. Applications in Fossil Fuel Characterization. J. B. Green and R. J. Hoff. *Journal of Chromatography*, 209, 1981, pp. 231-250. High-performance liquid chromatographic (HPLC) separations on silica columns using medium polarity mobile phases containing normal chain aliphatic carboxylic acids are applied to characterization of acid and base extracts of fuels. Separations performed on an SRC-II coal

liquid and a Wilmington, Calif., petroleum illustrate the utility of the HPLC method for rapid assessment of functionalities present in acid and base extracts of fuels. The technique is currently limited by the HPLC detectors available; complex samples such as fuels will require more sophisticated detectors. This report includes a discussion of separations of base extracts in hydrocarbon (impurity), pyrrole/phenylamine, aniline/thiazole, and pyridine/dinitrogen types as a function of the chain length of the carboxylic acid in the mobile phase. Similar functional group-type separations of acid extracts are also presented as a function of mobile phase composition. The report presents applications of the technique to assessing purity of fractions obtained from other separation schemes, analyzing high-boiling distillates and residua, and monitoring effects of catalytic hydrogenation.

DOE/BETC/OP-80/21. Chemical Composition of Raw and Upgraded Anthracene Oil and the Chemistry of Coal Liquids Upgrading. S. E. Scheppele, G. J. Greenwood, R. J. Pancirov, and T. R. Ashe. American Chemical Society Symposium Series, 156, 39, 1981, pp. 39-73. Feedstock anthracene oil and the product mixtures obtained from its catalytic hydrogenation/hydrogenolysis at different temperatures and pressures were separated using cation, anion, and complexation chromatography. Carbon-number distributions for the aromatic concentrates were obtained using high- and low-resolution FI/MS and high-resolution 70-eV EI/MS. Specific compounds in the base and hydrocarbon + ether fractions were identified using GC/MS. Both the carbon-number distributions and the GC/MS analysis identified compound types and compounds present in both the feedstock and upgraded liquids. Combination of these results with those obtained from the catalytic reaction of model compounds with hydrogen permits identification of reaction sequences occurring during the upgrading process. Thus, the hydrogenation/hydrogenolysis of nitrogen-, oxygen-, and sulfur-containing aromatic compounds and aromatic hydrocarbons will be considered. The dependence of reactivity on molecular structure and the effect of variation in both catalyst and reaction conditions on product yields will be discussed.

DOE/BETC/OP-80/38. Ideal Gas Thermodynamic Properties of 1,4-Dimethylbenzene. J. A. Draeger and D. W. Scott. *Journal of Chemical Physics*, 74, 1981, pp. 4748-4749. Reliable thermodynamic properties of 1,4-dimethylbenzene in the ideal gas state have been recalculated. Selected values are compared with accurate experimental results. Deductions for free or very nearly free internal rotation of the methyl groups are included in the report.

DOE/BETC/OP-81/4. A Laboratory Study to Determine Physical Characteristics of Heavy Oil After CO₂ Saturation. J. S. Miller and R. A. Jones. Proceedings of the Second Joint SPE/DOE Symposium on Enhanced Oil Recovery, Tulsa, Okla., April 5-8, 1981, pp. 259-268. Petroleum recovery techniques are being developed by laboratory experimentation by personnel at the Bartlesville Energy Technology Center. These techniques are being studied and developed to aid production from shallow, low productivity, heavy oil sand deposits in southeastern Kansas, southwestern Missouri and northeastern Oklahoma. Heavy oil samples ranging from 10 to 17° API gravity (1.000 to 0.953 g/cm³) were tested to determine physical characteristics of heavy oils before and after CO₂ saturation. The experimentation was conducted using a modified PVT apparatus designed and constructed at BETC. Viscosity, density, saturation and swelling factor were determined at temperatures of 75°, 140° and 200°F (24°, 60° and 93°C) and at 11 pressures ranging from 200 to 5,000 psi (1,400 to 34,500 KPa) at each temperature.

DOE/BETC/OP-81/16. Semi-Automated Method for Cation Exchange Capacity Determinations of Reservoir Rocks. B. L. Gall, L. J. Volk, and C. J. Raible. 1981 SPE/DOE Low Permeability Symposium Proceedings, Denver, Colo., May 27-29, 1981. Published by the Society of Petroleum Engineers, 6200 North Central Expressway, Dallas, TX 75206. In the past, CEC measurements

have been difficult and time consuming to obtain. An automated method, however, has been described by A. E. Worthington that avoids many difficulties of other techniques while determining the CECs of many samples at one time. The present work is a modification of the work done by Worthington. Easily assembled commercial equipment instead of the specially built equipment is used to agitate rock samples contained in dialysis membrane bags during ion exchange with barium acetate solution and during washing of the sample to remove excess barium ions. Barium acetate is used as the source of barium ions instead of barium chloride which is used by Worthington, to avoid corrosion of the stainless steel equipment. The amount of barium ions on the rock sample is then determined by conductometric titration with magnesium sulfate. The titration procedure was not automated. In addition, the use of the barium ion method was extended to samples with CEC values an order of magnitude lower than those determined by Worthington. Most measured CECs for the Western Tight Gas Sands ranged from .005 to .10 meq/g.

DOE/BETC/OP-81/20. The Relationship of Permeability to Confining Pressure in Low Permeability

Rock. J. B. Jennings, H. B. Carroll, and C. J. Raible. 1981 SPE/DOE Low Permeability Symposium Proceedings, Denver, Colo., May 27-29, 1981. Published by the Society of Petroleum Engineers, 6200 North Central Expressway, Dallas, TX 75206. Laboratory permeability measurements of low permeability (less than 1 md) reservoir rock is significantly affected by test confining pressure. Knowledge of the confining pressure is required to predict permeability at reservoir conditions. A model is proposed which relates electrical conductivity, permeability, and pore dimensions to confining pressure. The model assumes that rock pores are interconnected by thin cracks and microfractures which can be modeled by rectangular slits. For this model, core permeability is related to confining pressure by a third order polynomial, and electrical conductivity is related to confining pressure by a first order polynomial. Electrical conductivity and permeability versus confining pressure measurements were made on test cores having laboratory Klinkenberg permeabilities from 20 to 200 microdarcys. The experimental measurements were found to be consistent with the slit model theory.

DOE/BETC/OP-81/22. Embedment of High Strength Proppant into Low-Permeability Reservoir Rock.

L. J. Volk, C. J. Raible, H. B. Carroll, and J. Spears. 1981 SPE/DOE Low Permeability Symposium Proceedings, Denver, Colo., May 27-29, 1981. Published by the Society of Petroleum Engineers, 6200 North Central Expressway, Dallas, TX 75206. Embedment of sintered bauxite into Berea, sandstone core, and shale core at closure pressures up to 10,000 psi (69 MPa) is reported. Several variables influencing fracture closure are examined: closure pressure, proppant size and size distribution, proppant concentration (up to a monolayer), formation hardness, and surface roughness. Comparison is made with sand proppant. Empirical equations are derived to describe embedment into sandstones and shale for non-crushing proppants such as sintered bauxite.

DOE/BETC/OP-81/44. Waterflood Residual Oil Saturation Technology Test in a Semi-Consolidated Sand-

stone Reservoir. F. Richard Myal and T. C. Wesson. Proceedings of the Second Joint SPE/DOE Symposium on Enhanced Oil Recovery, Tulsa, Okla., April 5-8, 1981, pp. 389-402. Gary Energy Corp. has conducted for the DOE an evaluation of the technology available to measure residual oil saturation following waterflood secondary oil recovery processes in the Bell Creek Field, Powder River County, Mont. This paper presents the results of 10 stand-alone tests conducted to determine waterflood residual oil saturation. The engineering techniques used in an attempt to determine the magnitude and distribution of the remaining oil saturation included pressure cores, conventional openhole logs, carbon-oxygen logs, dielectric logs, the nuclear magnetism log, thermal decay time logs and a partitioning tracer test.

DOE/BETC/OP-81/45. Calcium Effects in the DOE Surfactant-Polymer Pilot Test. P. B. Lorenz and M. K.

Tham. Proceedings of the Second Joint SPE/DOE Symposium on Enhanced Oil Recovery, Tulsa, Okla., April 5-8, 1981, pp. 577-584. The surfactant and polymer slugs for the chemical recovery pilot test operated by DOE were designed to be effective at the divalent ion concentration of the injection water. Laboratory tests indicated that even if there were no intrusion by the formation brine, the slugs would experience an increase in divalent ion content on contact with the rock. It was found that with calcium present, optimal salinity of the surfactant system was reduced by 4 to 7 times the amount of calcium on an equivalent basis. The minimum IFT was raised 4-fold by 8 eq/m³ (meq/l) of calcium, but the valley was much broader. The distribution of calcium indicated that it occurred primarily in the surfactant phase. Empirical equations were developed for calculating the effect on polymer viscosity of polymer concentration, salinity, and calcium. Over a range of polymer concentrations and salinities, calcium had close to 10 times more effect on viscosity than an equivalent increase in salinity. It was found that calcium from the rock played a major role in surfactant behavior but affected polymer behavior in only a minor way.

PROCEEDINGS OF SECOND JOINT SPE/DOE SYMPOSIUM ON ENHANCED OIL RECOVERY

The Proceedings of this second joint symposium, held in Tulsa April 5-8, 1981, is available for \$18 from the Society of Petroleum Engineers, 6200 North Central Expressway, Dallas, TX 75206, Attn: Book Order Dept. (Texas residents add 5 percent sales tax. Outside Continental U.S. add \$1 for postage.) The document contains pre-prints of the technical papers presented on EOR field and laboratory research that is being conducted by industry and government groups. The papers cover all major EOR processes. Additional information can be obtained by contacting the SPE at the address listed or telephone (214) 361-6601.

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Bartlesville Energy Technology Center
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QUARTERLY PROGRESS REPORTS

DOE/BETC/QPR-81/1. Liquid Fossil Fuel Technology. Quarter ending March 31, 1981. Edited by Bill Linville. August 1981. 68 pp. Progress reports on research, development, and demonstration projects conducted by Bartlesville Energy Technology Center personnel and contractors are given, with emphasis on liquid fossil fuel projects. Reports are included from BETC's Divisions of Extraction Research, Processing and Thermodynamics Research, Utilization Research, and Project Integration and Technology Transfer.

REPORTS OF INVESTIGATIONS

DOE/BETC/RI-81/1. Application of the BETC Re-Refining Technology to Some State-of-the-Art Commercial Lube Oils. Bartlesville Energy Technology Center. July 1981. 11 pp. Five new lubricating oils of the extended drain and/or friction modified-type were charged to vehicles and used. The segregated drainings from each oil were re-refined by the solvent treatment/distillation process developed by BETC. The solvent treatment step of this process failed to de-sludge these oils significantly, indicating high levels of active dispersant additives remaining in the oils because of insufficient use. The overall process was successful, however, in producing re-refined basestocks of apparent high quality from the used oils. Thus, it would appear that direct distillation without pretreatment would have been adequate for these segregated samples.

PETROLEUM PRODUCTS SURVEYS

DOE/BETC/PPS-81/3. Motor Gasolines, Winter 1980-81. Ella Mae Shelton. July 1981. 67 pp. Analytical data for 546 samples of motor gasoline were collected from service stations throughout the country and were analyzed in the laboratories of various refiners, motor manufacturers, and chemical companies. The data were submitted to BETC for study, necessary calculations, and compilation under a cooperative agreement with the American Petroleum Institute. The samples represent the products of 23 companies according

to brands (unlabeled) and grades for 17 U.S. marketing districts. The report includes 16 octane distribution percentage charts for unleaded antiknock index (R+M)/2 below 90.0, unleaded antiknock index (R+M)/2 90.0 and above, leaded antiknock index (R+M)/2 below 93.0, and leaded antiknock index (R+M)/2 93.0 and above grades. The antiknock index (R+M)/2 averages of gasoline sold in this country were 87.6 unleaded below 90.0 octane, 91.4 unleaded 90.0 octane and above, 89.1 leaded below 93.0 octane, and 93.3 leaded 93.0 octane and above.

DOE/BETC/PPS-81/4. Heating Oils, 1981. Ella Mae Shelton. August 1981. 43 pp. Properties of 249 heating oils marketed in the United States were submitted for study and compilation under an agreement between BETC and the American Petroleum Institute. The fuels were manufactured by 28 petroleum refining companies in 92 domestic refineries. The data are tabulated according to six grades of fuel and subdivided into five geographic regions in which the fuels are marketed. Trend charts in the report show average properties of the six grades for the past several years. Summaries of the results of the tests by grade and by region for 1981 are compared with 1980 tests.

EOR PROGRESS REVIEWS

DOE/BETC-81/2. Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery and Improved Drilling Technology. Progress Review No. 26. Quarter ending March 31, 1981. Edited by Bill Linville. July 1981. 160 pp. Status reports are given of various enhanced oil and gas recovery projects sponsored by the Department of Energy. The field projects and supporting research on enhanced oil recovery include chemical flooding, carbon dioxide injection, thermal/heavy oil recovery, microbial recovery, and residual oil determination. Other research includes extraction research and improved drilling methods.

CONFERENCE PROCEEDINGS

CONF-810381. Design Properties of Coal Liquids: Edited Workshop Proceedings, March 2-4, 1981, Fountainhead Lodge, Oklahoma. United States Department of Energy. August 1981. 172 pp. More than 60 representatives of industry, universities, and government attended the 2½ day workshop, which focused on the need for better data on the physical and thermodynamic properties of coal liquids. Particular attention was given to the information required for designing and trouble-shooting large coal liquefaction facilities. The report itself is an edited transcript of the presentations and discussion.

CONF-810718. 1981 Annual Heavy Oil/EOR Contract Reports—Proceedings, Presented July 28-30, 1981, in San Francisco. Fossil Energy Division, San Francisco Operations Office. July 1981. 256 pp. The 1981 Department of Energy Heavy Oil/EOR Meeting for presentations by contractors was the fifth annual presentation by West Coast contractors to the Department of Energy. The meeting program emphasized the recovery of heavy oil, and reports were given on enhanced oil recovery by applications of thermal processes, chemical flooding, and miscible flooding. Reports included field projects, basic research, and environmental studies.

REPORTS BY CONTRACTORS

- DOE/BC/10007-12. Low Interfacial Tension and Miscibility Studies for Surfactant Tertiary Oil Recovery Processes, Annual Report, Dec. 1, 1979–Nov. 30, 1980.** Carnegie-Mellon University. August 1981. 53 pp. The purpose of this project is to develop an improved basic understanding of how ultralow interfacial tensions arise in oil-brine-surfactant systems. Such tensions must be achieved and maintained during enhanced oil recovery processes employing surfactants if these processes are to be successful. Polymer addition to an aqueous surfactant "solution" causes phase separation when the solution is initially a single liquid crystalline phase or a dispersion of liquid crystal in brine, but not when the solution is an isotropic phase containing no liquid crystal. The resistance of randomly coiled polymer molecules to configurational change is the underlying cause of the phase separation. These results provide a basis for understanding and subsequently eliminating phase separation due to polymer-surfactant interactions in micellar-polymer recovery processes. A theory of drop size in microemulsions has been developed which includes an improved model of the surfactant films at the drop surfaces. The first portion of the theory discussed deals with nonionic surfactants. It predicts the effect of oil chain length on drop size and inversion conditions. The theory thus offers good prospects of explaining for the first time the observed alkane carbon number effect on microemulsion behavior.
- DOE/BC/10053-21. Analysis of Potential Used Oil Recovery From Individuals, Final Report.** Market Facts, Inc. July 1981. 128 pp. To assist the Department of Energy in its investigation of methods for recycling used motor oil, Market Facts conducted a telephone survey of individuals who change their own motor oil. A national survey was taken of 4,805 households in the continental United States. The survey identified households with vehicles as well as households where at least one member personally changed the oil in a motor vehicle within the past 12 months. The study examined the amount of oil used, oil change practices, oil disposal methods, and perceptions and attitudes toward used motor oil disposal and oil recycling.
- DOE/BC/10079-26. Experimental Determination of Solids Friction Factors and Minimum Volumetric Requirements in Air or Gas Drilling, Topical Report.** University of Tulsa. August 1981. 217 pp. The many variables involved in an air or gas drilling situation have prevented development of a general correlation to predict appropriate volumetric requirements in the field. The results of previous attempts to calculate minimum volumetric requirements are valid over limited ranges of drilling conditions. This research has developed new empirical correlations for solids-friction factors for sandstone, limestone, and shale. A new and more realistic technique for predicting minimum volumetric requirements is presented. This method includes a complete analysis of pressures throughout the system. It also offers flexibility in the selection of standpipe pressure and air flow rate, and, thus, compressor specifications. The method is primarily graphical so that it can be used at the well site without access to a computer. Results are presented in tabular and graphical forms. These results confirm that existing methods may predict too low or too high a volumetric flow rate.
- DOE/BC/10255-4. Characterization of Fluid Flow in Naturally Fractured Reservoirs, Final Report.** University of Central Florida. August 1981. 63 pp. This report summarizes the results of a 4-month study of the characteristics of multi-phase flow in naturally fractured porous media. After an assessment of the literature, the mathematical models presented in the literature were evaluated. Particular attention was focused upon identifying unique approaches that would lead to the formulation of a general mathematical model of multi-phase/multi-component flow in fractured porous media. A model is presented that can be used to more accurately predict the movement of multi-phase fluids through such formations. Equations of motion are derived for a multi-phase/multi-component fluid that is flowing through a double porosity, double permeability medium consisting of isotropic primary rock matrix blocks and an anisotropic fracture matrix system. A general distribution function, called the fracture matrix function, is introduced to represent the statistical nature of the fractures.
- DOE/BC/10256-1. Initial Assessment of Selected Advanced Lubricating Oil Filters.** Systems Control, Inc. September 1981. 30 pp. This study provides documented evidence that permits an initial assessment of the potential effectiveness of advanced oil filters claimed to re-refine the oil on-board a vehicle or claimed to provide never-drain or extended-drain benefits. The effort included a patent search, literature review, and contacts with manufacturers. Based on the study, it was concluded that so-called re-refining filters do not actually re-refine in-service motor oil nor do they prevent depletion of additives. These advanced filters may remove particles smaller than a standard oil filter removes, but the benefits are questionable. The electric cartridge heater of some advanced filter devices was judged to have little or no value, and the fuel consumed to supply electrical current to the device contained roughly twice the heating value of the lubricating oil that was allegedly saved through extended drain.
- DOE/BETC/OR-19. Ion Exchange Characteristics of Enhanced Oil Recovery Systems (Miscibility Studies), Sesquiannual Report, April 1, 1979–September 30, 1980.** Oak Ridge National Laboratory. July 1981. 60 pp. The objective of this work was to attempt to unravel the complex aqueous/hydrocarbon chemistry underlying micellar floods by investigating phase, interfacial, and adsorption behavior with pure components, and, often, fewer components than the water/surfactant/alcohol/salt/hydrocarbon classes in field systems. This study approached these systems from the low-equivalent-weight side of the surfactant component, starting with compounds ("protosurfactants") below the alkyl content necessary for formation of micellar or liquid-crystal aggregates, which typically occur in micellar floods. During this period, studies of the hydrotropic properties of organic alkylbenzenesulfonates and particularly of alkylbenzenecarboxylates were extended; the effects of several different alcohols on miscibility between aqueous protosurfactant solutions and aliphatic and aromatic alkanes were investigated; hydrotropic properties of an alicyclic carboxylate were determined; the equivalent weight of the organic salts studied was extended into the surfactant range; solubilities of protosurfactants and surfactants in salt solution were measured; and investigations of the adsorption of protosurfactants on minerals as a function of salinity were started.
- DOE/ET/12044-54. Micellar-Polymer Joint Demonstration Project, Wilmington Field, California, Third Annual Report, June 1978–July 1979.** City of Long Beach. August 1981. 39 pp. The micellar-polymer demonstration project to be conducted—through the design phase—in the HXa sand of Wilmington Field is proceeding satisfactorily but has fallen behind schedule because the laboratory sample of the cosurfactant used to formulate the "final" design slug was not representative of the plant product. The cosurfactant received from the manufacturer's plant was blended with the other components of the final slug and core-flood tested. The results showed that recovery efficiencies were much lower than those achieved using the laboratory sample of cosurfactant to prepare the final design slug. Nearly 6 months of reformulating and additional core testing were required to finally achieve satisfactory laboratory results. All surface facilities have been installed; the production and injection wells are completed and in operation in preparation for micellar injection operations.
- DOE/ET/12056-14. The Effectiveness of Foam as a Blocking Agent at Elevated Temperatures Over Extended Periods of Time.** Stanford University Petroleum Research Institute. July 1981. 44 pp. The ability of foaming agents to withstand elevated temperatures over extended periods of time has been studied for their potential use in thermal recovery operations. Thirty-four samples were studied in a preliminary screening apparatus in which foaming ability was observed at the boiling point of water over a 1-week period. The sulfonate samples and some of the cations showed the best results, while the nonionics showed the poorest. A second study involved the injection

of slugs of water or foamer solution into an unconsolidated sandpack, followed by continuous gas injection. Temperatures ranged from room temperatures to 360°F. The slug containing foamer solution decreased gas flow rate through the sandpack significantly more than the water slug. In time the gas flow rate would increase again, but injection of more foamer would cause it to decrease to even lower levels than the previous injection.

DOE/ET/12057-7. Bodcau In Situ Combustion Project, Produced Fluids Analyses, Topical Report. Cities Service Company. July 1981. 68 pp. Produced oil, gas, and water were analyzed seven times from 1976 to 1979 to evaluate the Bodcau Fireflood Project in the Bellevue Field, Bossier Parish, La. The samples analyzed were collected at the wellhead of the various producing wells. The following observations were made: (1) The oil produced during the fireflood was lighter compared to native oil. (2) The sulfur content of the crude oil decreased during the early part of the fireflood and then increased. (3) The crude oil acid number decreased from 5.1 in native oil to 2.9 in May 1979, showing that there is no oxidation of the crude by air. (4) Comparison of oil viscosities with emulsified water to the viscosities after the water is removed shows that the emulsions have higher viscosities. (5) The produced combustion gas was a mixture of nitrogen, carbon dioxide, carbon monoxide, oxygen, hydrogen sulfide, and hydrocarbons; no ammonia or nitrogen oxides were found. (6) The methane concentration alone increased during the wet combustion phase of the fireflood, indicating a reduction of carbon monoxide. (7) The water salinity decreased throughout the project. (8) The water specific gravity is only slightly higher than the oil specific gravity, and the oil and water separate slowly.

DOE/ET/12057-8. Bodcau In Situ Combustion Project, Fourth Annual Report, September 1, 1979-February 28, 1981. Cities Service Company. July 1981. 100 pp. The objective of this project is to demonstrate the technical efficiency and economics of a commercial-scale *in situ* combustion project in a shallow heavy oil reservoir. Five elongated inverted nine-spot patterns were developed for this demonstration on the Bodcau Fee "B" Lease in the Bellevue Field, Bossier Parish, La. The field was discovered in 1921 and consists of a dome-type structure covering approximately 900 productive acres. The Upper Cretaceous Nacatoch Sand is the producing formation at a depth of 300 to 400 ft. The five patterns enclose 19 productive acres and consist of 38 producing, five injection, and five observation wells. This report reviews the history of the project, emphasizing this reporting period, and includes a section on the air system explosion of February 1980 and the results from an evaluation well drilling program.

DOE/MC/03103-6. Investigations of Enhanced Oil Recovery Through Use of Carbon Dioxide, Final Report. Louisiana State University. July 1981. 134 pp. A complete laboratory was designed and constructed to accommodate high pressure carbon dioxide displacements in both unconsolidated sand packs (slim tubes) and Berea sandstone cores. High pressure sample equipment and chromatographic analysis procedures were in routine use to give compositional histories of the produced fluid throughout a transition zone during a miscible displacement, or to give compositions of produced equilibrium fluids if the displacement was not miscible. The slim tubes provided path lengths up to 80 ft and were used for displacement studies where water saturation was not a parameter. Twenty-four displacements were made in sand packs; the majority involved use of a synthetic crude formulated to be similar to a West Texas crude. The presence of methane in the injected carbon dioxide resulted in an approximately linear increase in minimum miscibility pressure over the range of concentrations studied. However, where methane is present in the carbon dioxide, the addition of 5 percent propane to the injection fluid resulted in a decrease in minimum miscibility pressure. All studies relating to the use of carbon dioxide as a tertiary process (high water saturation present) were done in Berea sandstone cores.

DOE/MC/11580-5. Effects of Porosity Type, Pore Geometry, and Diagenetic History on Tertiary Recovery of Petroleum From Carbonate Reservoirs, Final Report, July 1, 1979-Nov. 30, 1980. Rensselaer Polytechnic Institute. September 1981. 227 pp. The Upper Ordovician Red River Formation at Cabin Creek Field, Mont., consists of several carbonate peritidal sequences deposited on a broad, shallow-marine, carbonate bank under arid conditions. Pore geometry of these carbonate reservoirs is a function of depositional environment and diagenetic history. The size, shape, and sorting of pores is related to porosity type. Geometry of pore throats is primarily a function of the size and shape of dolomite crystals composing the matrix of the reservoir rock. Study of petrographic thin sections, mercury capillary-pressure curves, and resin pore casts showed that several different types of pore systems occur, and each is associated with particular depositional environments and diagenetic regimes. An important relationship was established between porosity and pore geometry. Mean pore-throat size, a statistical measure of pore geometry, was found to increase as percentage porosity increases, depending on reservoir rock type. Using this relationship and electric log porosity values, it is possible to predict pore geometry and recovery efficiency if lithofacies distribution, porosity type, and diagenetic history are known for the reservoir. Residual oil saturation caused by capillary forces is strongly dependent on the pore system characteristics of the reservoir rock. This approach to predicting reservoir pore geometry is thus capable of identifying areas of potentially high residual oil saturation which can be targeted for enhanced recovery.

DOE/PO/10879-1. An Evaluation of Alternatives in Downhole Steam Generation. Commercialization Insights. September 1981. 80 pp. Studies have been made of two developing technologies. One is downhole steam generation, being developed by Sandia Laboratories, in which steam is injected into the formation, with or without the combustion gases. The other is downhole oil treatment, being developed by World Energy Systems and Aerospace Research Corporation, in which steam is also generated downhole, but from hydrogen and oxygen. Representatives from six oil companies were interviewed to obtain their views on one or both of these technologies. The interest in downhole steam generation was almost exclusively centered on the high pressure version, which employs the injection of combustion gases into the formation. Economic evaluations of the process were made to include the effects of rate of return on investment (ROI), higher-than-predicted capital cost, and various fuel oil and crude prices. Downhole oil treatment is not so well defined. The hardware for generating hydrogen/steam and oxygen/steam mixtures has been developed, but there is a need for computer simulation supported by laboratory data to explore the technical capabilities of the technology. Because the proposed technology is a considerable departure from current practice, the economic analysis was made assuming that the operator who would consider using it would be looking for a high benefit-to-risk ratio. The required oil yields were higher than any indicated to be required for economically-attractive downhole steam generation. Nevertheless, it is possible to achieve the required oil yields, although the techniques for using the available hydrogen, steam, and oxygen rates to do so have not been studied yet.

OUTSIDE PUBLICATIONS

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DOE/BETC/OP-79/42. Preparative Liquid Chromatography for Fractionation of Petroleum and Synthetic Crude Oils. J. W. Vogh and J. S. Thomson. *Analytical Chemistry*, 53 (1981), pp. 1345-1350. The procedures for routine preparative liquid chromatographic separation of hydrocarbon classes in high boiling petroleum and coal liquid samples have been improved by use of high performance liquid chromatography techniques. Separations were carried out

on alumina and silica gel to produce sample fractions equivalent to those obtained with older methods. The columns are reusable following suitable solvent backwashing, and provide stable performance and good hydrocarbon class resolution over an extended series of runs. The complete operating time, including regeneration to starting conditions, is 80 minutes for the alumina column and 25 minutes for the silica gel column. Capacity ranges from 1 to 6 grams of sample, depending on its composition.

DOE/BETC/OP-80/8. Synfuel Stability: Degradation Mechanisms and Actual Findings. D. W. Brinkman (BETC), J. N. Bowden (Southwest Research Institute), and John Frankenfeld and Bill Taylor (Exxon Research and Engineering). *Oil Shale, Tar Sands, and Related Materials*, ACS Symposium Series, No. 163 (1981), Chap. 20, pp. 297-314. While substantial quantities of only a few experimental synfuels have been generated, those available have demonstrated the degradation problems that were predicted from work with petroleum. The high heteroatom and unsaturate content of syncrudes derived from shale and coal will necessitate closer attention to processing parameters required to produce a commercially viable product. This paper presents basic and applied data that should aid in the tradeoff decisions between further costly processing and product stability.

DOE/BETC/OP-80/43. Chemical Thermodynamic Properties and Internal Rotation of Methylpyridines: III. 4-Methylpyridines. J. A. Draeger and D. W. Scott. *Journal of Chemical Physics*, 75, No. 4 (1981), pp. 2016-2018. The ideal gas state thermodynamic properties of 4-methylpyridine have been calculated based on free internal rotation of the methyl group. Selected values are compared with accurate experimental results.

DOE/BETC/OP-81/4. A Laboratory Study to Determine Physical Characteristics of Heavy Oils after CO₂ Saturation. John S. Miller and Ray A. Jones. *Oil & Gas Journal*, P.O. Box 1260, Tulsa, OK 74101. July 6, 1981, pp. 135-145. Petroleum recovery techniques under development by laboratory experimentation at BETC are being studied and developed to aid production from shallow, low productivity, heavy oil sand deposits in Southeastern Kansas, Southwestern Missouri, and Northeastern Oklahoma. Heavy oil samples ranging from 10 to 17° API gravity (1.000 to 0.953 g/cm³) were tested to determine physical characteristics of heavy oils before and after CO₂ saturation. The experiments were conducted using a modified PVT apparatus designed and constructed at BETC. Viscosity, density, saturation, and swelling factor were determined at temperatures of 75°, 140°, and 200° F and at 11 pressures ranging from 200 to 5,000 psi at each temperature.

DOE/BETC/OP-81/17. Characterization of Cerro Negro Crude. Part I. Physical and Chemical Separations. P. L. Grizzle, J. B. Green, V. Sanchez, E. Murgia, and J. Lubkowitz. American Chemical Society, Division of Petroleum Chemistry, *Preprints*, 26, 4 (1981), pp. 839-850. Detailed compositional analyses of heavy petroleum would be greatly facilitated by separations of these complex liquids into chemically unique fractions. In addition, the compound

class distribution data obtained by such separations could be of major importance in developing processes for the effective utilization of these materials. Attempts are being made to separate a sample of Cerro Negro crude oil from the Venezuelan Orinoco basin into chemically unique fractions, using ion-exchange and liquid-solid chromatography. The crude oil was distilled using a molecular still into five fractions. The four higher-boiling fractions were separated into acids, bases, and hydrocarbons, using non-aqueous ion-exchange chromatography. The hydrocarbon fractions were subsequently separated into group-class concentrates by two methods: classic silica/alumina chromatography and a preparative HPLC method using a dinitroanilinopropyl silica column. Low-voltage, high-resolution mass spectrometry was used to evaluate the two separation methods. The overlap between hydrocarbon classes in both separation methods results from the complexity of this oil and the large quantities of sulfur compounds present. Bases were separated into five fractions of increasing basicity with liquid-solid chromatography on silica using mobile phases containing propanoic acid. Infrared spectroscopy was used to characterize these fractions and similar fractions obtained from separations of the acids.

DOE/BETC/OP-81/18. Characterization of Cerro Negro Crude. Part II. Chemical Analysis. G. P. Sturm, Jr., Q. G. Grindstaff, D. E. Hirsch, S. E. Scheppele, and M. Hazos. American Chemical Society, Division of Petroleum Chemistry, *Preprints*, 26, 4 (1981), p. 851. Mass spectrometry is being used to evaluate the resolution attained in the separation of Cerro Negro crude according to compound class. The 425-550°C distillate was subjected to chromatographic separation using both a silica/alumina substrate with a step gradient and a dinitroanilinopropyl silica substrate with a linear gradient. The fractions obtained across both chromatograms were introduced into the mass spectrometer ion source (300°C) via the all-glass inlet system (325°C). Low-voltage electron-impact mass spectra were acquired at resolutions between 12,000 and 20,000. Compound types were identified from precise molecular ion masses. However, for this range in resolving power, identification and quantification of at least C_nH_{2n+Z} and D_nH_{2n'}+_ZS compounds are difficult when Z(S) - Z(H) = 14m - 4 for m = n - n' - 2 because the elemental analysis of the distillate yields 4 percent sulfur. The functional dependence of the normalized weight percents of specific Z series (compound types) on elution volume and the normalized weight percents of corresponding homologs within specific Z series on elution volume relate to the resolution attained in the separation.

DOE/BETC/OP-81/57. DOE Enhanced Oil Recovery Research Program Progresses. Bill Linville. *Well Servicing*, 6060 North Central Expressway, Suite 538, Dallas, TX 75206. September/October 1981, pp. 76-84. The Department of Energy enhanced oil recovery cost incentives program began in 1979 to help producers offset certain costs related to EOR. The 416 resulting projects are listed in tables showing the enhanced oil recovery techniques used, the companies conducting the projects, and project locations. The information provided in each company's application for the program, along with data from other sources, is being processed for use in a computerized data bank on enhanced oil recovery at BETC.

BETC PUBLICATIONS

Bartlesville Energy Technology Center
HARRY R. JOHNSON, Director

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GENERAL RESEARCH

Quarterly Reports

DOE/BETC/QPR-81/2. Liquid Fossil Fuel Technology. Quarter ending June 30, 1981. Edited by Bill Linville. October 1981. 72 pp. Progress reports on research, development, and demonstration projects conducted by Bartlesville Energy Technology Center personnel and contractors are given, with emphasis on liquid fossil fuel projects. Reports are included from BETC's Divisions of Extraction Research, Processing and Thermodynamics Research, Utilization Research, and Project Integration and Technology Transfer.

EXTRACTION

Enhanced Oil Recovery—General

DOE/BETC-81/3. Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery and Improved Drilling Technology. Progress Review No. 27, Quarter ending June 30, 1981. Edited by Bill Linville. September 1981. 141 pp. Status reports are given of various enhanced oil and gas recovery projects sponsored by the Department of Energy. The field projects and supporting research on enhanced oil recovery include chemical flooding, carbon dioxide injection, thermal/heavy oil recovery, microbial recovery, and residual oil determination. Other research includes resource assessment, extraction research, improved drilling methods, and environmental technology.

DOE/BC/10032-43. BETC Information Management System With Focus on ROS Estimation. Science Applications, Inc. December 1981. 40 pp. A special-purpose information data base system has been designed for BETC to support the technical staff in the areas of enhanced oil recovery and residual oil saturation estimation. The system has been built to combine a series of iterative design steps and pilot software development tasks to produce a unique information retrieval system. Studies of information usage patterns and information perceptions by BETC staff resulted in the development of a

hierarchical arrangement of subject terms emphasizing EOR/ROS. The analysis also revealed that four basic data types were required most often by potential users: (1) numeric files, (2) bibliographic citations and abstracts, (3) project information such as schedules and budgets, and (4) references to persons that were authorities in various relevant topical areas. The system has been designed to permit the retrieval of information by searching the subject taxonomy, selecting a subject term, and determining the appropriate data types in "one-step" searching. To accommodate a diverse user group, the system incorporates a range of man/machine interface features including both menu selection and command language capabilities.

DOE/BETC/3251-12. Measurement and Correlation of Conditions for Entrapment and Mobilization of Residual Oil, Final Report. New Mexico Petroleum Recovery Research Center. October 1981. 114 pp. This report covers a two-year research project with six tasks concerned with factors which affect the entrapment and mobilization of residual oil. Task 1 involved the measurement of relationships between the ratio of viscous to capillary forces and the reduction in normal waterflood residual oil for a variety of rock types. General correlations of results obtained for a variety of sandstones are presented. Task 2 concerned the application of measured capillary number relationships to the problem of flushing as related to determining *in situ* residual oil saturations. Task 3 investigations involved the microscopic structure and distribution of residual oil. A technique involving solidification of the immobile oil phase and subsequent separation has been developed, and electron micrographs were made of the solid blobs. Under task 4, relationships between residual saturation and the ratio of gravity to capillary forces were measured, and the equivalence of gravity and viscous forces on trapping were established. Under task 5, to determine the causes of variation in residual oil saturation, the influence of pore structure on trapping mechanisms was investigated using two-dimensional micromodel systems. Task 6 investigations of the effect of interface velocity at rough surfaces for advancing and receding conditions showed that, for velocities ranging from below to well above typical field flow rates, contact angles at roughened low energy surfaces changed by no more than a few degrees for a wide range of wetting conditions.

DOE/ET/10145-72. A Relational Methodology for Integrating and Analyzing Field Test and Research Data Describing Enhanced Oil Recovery. Gulf Universities Research Consortium. October 1981. 150 pp. This report demonstrates the application of concepts of relational analysis for the integration of two experimental data bases: the Enhanced Oil Recovery Field Test Data Base and the Enhanced Oil Recovery Research Data Base. The relational analysis capabilities described in this report are based on the development of a structured methodology for integrating data from the data bases. The major components of this methodology are a keyword model for elaborating the context of specific EOR research projects and a set of analysis capabilities for the classification and visual display of data relationships. The operational premise for the methodology and its components is organized upon relational data-base management concepts. In practice, the methodology responds to the complex range of issues and tasks required for the surveillance and analysis of EOR research.

Enhanced Oil Recovery—Chemical

DOE/BETC/OR-18. Chemicals for Enhanced Oil Recovery, Semiannual Report, Apr. 1-Sept. 30, 1980.

Oak Ridge National Laboratory. November 1981. 39 pp. The objective of this study is to lower barriers to implementation of the micellar flood approach by decreasing cost and increasing availability of chemicals used in the process. Alternative feedstocks in wastes or low valued organic byproducts are being examined and lower cost production procedures are being developed. Because of the large quantities of waste and low valued byproducts generated by the paper industry, wood pulping streams have received particular attention. Cosurfactants, sequestering agents for the control of hardness, and competitive adsorbates are being studied as well as surfactants and mobility control factors.

DOE/SAN/1556-5. Coalinga Polymer Demonstration Project, Final Report, July 1976-December 1980. Shell Oil Co. December 1981. 260 pp. A field demonstration test of displacement mobility control was conducted in the East Coalinga Field. The test was designed to determine the relative merits of polymer flooding and waterflooding in a medium viscosity reservoir. The pilot injection pattern consisted of four inverted 5-spot patterns and an updip area. Water injection began in June 1976 and continued through April 1978. Polymer was injected continuously in the four pilot injectors from May 1978 to October 1979; water injection was resumed from November 1979 to December 1980. The overall production performance for the pilot was far less than expected. Oil production rate was below the expected primary decline rate when the project was terminated. Though the operation of the polymer injection facilities met or exceeded the specifications required, polymer injectivity was substantially lower than predicted (200 BPD actual versus 1,000 BPD predicted). Final results indicate that polymer flooding is not a viable process in the Zone II Temblor sands in this portion of the East Coalinga Field.

DOE/SF/01424-39. Big Muddy Field Low-Tension Flood Demonstration Project, Third Annual Report, April 1980-March 1981. Conoco, Inc. November 1981. 95 pp. This pilot project was initiated to evaluate a low-tension flood of the Second Wall Creek reservoir. The test area now consists of nine 10-acre five-spots. It was designed to provide data for commercialization of surfactant flooding in the low-permeability freshwater reservoirs typical of eastern Wyoming and Colorado. The test zone is the second bench of the Second Wall Creek formation; this is a high porosity sandstone with a good waterflood history. The pay zone is 3,100 ft deep and about 70 ft thick. It was waterflooded using much wider well spacing than is being used for the surfactant flood. The objectives of this project are to evaluate a commercial-scale field test using cost-optimized chemical slug size and composition, to field test a surfactant system that could be made available in commercial quantities, to demonstrate oil recovery effectiveness in multiple patterns, and to demonstrate the feasibility of applying a low-tension process to low-permeability sands by using propped fractures in injection and producing wells. The preflush injection has been completed, and filter problems have delayed the injection of the surfactant.

Enhanced Oil Recovery—Carbon Dioxide

DOE/MC/08341-31. Target Reservoirs for CO₂ Miscible Flooding, Task Two: Summary of Available Reservoir and Geological Data, Task Two Final Report, Vol. 1: Permian Basin Geological and Reservoir Data. Gruy Federal, Inc. October 1981. Part 1: 133 pp. Part 2: 336 pp. Part 3: 358 pp. Part 4: 319 pp. This report for Task Two summarizes existing reservoir and geological data on carbonate reservoirs located in west Texas, southeast New Mexico, and the Rocky Mountain states. It is contained in two volumes; this volume, in four parts, is a summary of reservoir data for fields in the Permian Basin of west Texas and southeast New Mexico. Part 1 contains the Permian Basin reservoir selection procedure, geology, and reservoir data summary. Data is included on the following fields: Part 2—ADAIR-San Andres through EUNICE MONUMENT-Grayburg/San Andres, Part 3—FARMER-San Andres through NOLLEY-Wolfcamp, Part 4—OCEANIC-Pennsylvania through YATES-Yates Lime.

DOE/MC/08383-26. Well Test Report and CO₂ Injection Plan for the Little Knife Field CO₂ Minitest, Billings County, North Dakota, First Annual Report, September 1979-August 1980. Gulf Oil Exploration and Production Company. November 1981. 95 pp. A field test of the CO₂ miscible displacement process is being conducted in the Mission Canyon Formation, a dolomitized carbonate reservoir currently in the middle stage of primary depletion. The field is located at the approximate center of the Williston Basin. Four wells were drilled in an inverted four-spot configuration within the five-acre minitest. The central well is the injection well surrounded by three non-producing observation wells. Oriented cores were obtained from each well for detailed reservoir characterization and laboratory testing, and pulse and injectivity tests were obtained. Results from these tests were used to upgrade two reservoir simulation models. Various parameters within the models were modified to determine the most efficient injection plan. A WAG-type injection sequence involving alternate slugs of water and CO₂ will be employed. The test is designed to establish the incremental recovery of a miscible CO₂ flood in an oil reservoir.

Enhanced Oil Recovery—Thermal

DOE/ET/12056-25. An Algorithm for Computing In Situ Combustion Oil Recovery Performance. Stanford University Petroleum Research Institute. October 1981. 27 pp. A simple method has been published to consider the frontal displacement, thermally aided gravity drainage, steam distillation, oil swelling and viscosity reduction, and other significant mechanisms of and adjacent to the burning front associated with *in situ* combustion. The method is called the oil-recovery/volume-burned method. This method can be used to make accurate engineering and economic evaluations for the design and monitoring of *in situ* combustion projects. In this paper an algorithm based on this method is presented to provide a quick estimate of the oil recovery, air/oil ratios, oil rates, and economic limits of *in situ* combustion projects.

DOE/ET/12056-27. The Effects of Confining Pressure, Pore Pressure and Temperature on Absolute Permeability. Stanford University Petroleum Research Institute. October 1981. 112 pp. This study investigated absolute permeability of consolidated sandstone and unconsolidated sand cores to distilled water as a function of the confining pressure on the core, the pore pressure of the flowing fluid, and the temperature of the system. Since permeability measurements are usually made in the laboratory under conditions very different from those in the reservoir, it is important to know the effect of various parameters on the measured value of permeability. The results of this study support the theory that the permeability is reduced as confining pressure is increased or pore pressure decreased. The effects of confining pressure and pore-pressure changes on absolute permeability are given explicitly so that measurements made under one set of confining pressure-pore pressure conditions in the laboratory can be extrapolated to conditions more representative of the reservoir.

DOE/ET/12056-30. Determination of the Duration of the Infinite-Acting Period for Interference Testing in Closed Rectangles. Stanford University Petroleum Research Institute. October 1981. 39 pp. During a pressure drawdown test of one well in a closed rectangle, that well and any observation wells will behave as if they are in an infinite reservoir for a brief period. During this time the producing well pressure-time data will follow the storage and skin-type curve while the data for the observation well will follow the line-source solution. The time when the producing well itself deviates from this infinite-acting case has already been studied. This report gives a computer program and contour graphs that yield the dimensionless time in terms of area, which defines the end of the infinite-acting period for observation wells with a producing well located in several positions in various closed rectangles. The reciprocity principle can be used to extend these results.

DOE/ET/12058-5. Williams Holding Lease Steamflood Demonstration Project, Cat Canyon Field, Fourth Progress Report, December 1979–April 1981. Getty Oil Co. October 1981. 56 pp. The objective of this pilot program is to evaluate the efficiency and economics of the steam displacement process for future full-scale development of the Cat Canyon S1-B reservoir and similar heavy-crude-oil reservoirs. Steamflood response occurred over a 10-month period beginning in October 1977 in four of the nine pilot producers. Subsequent attempts to divert steam to the non-responding producers failed. Poor oil production and high water-oil ratios characterized steamflood performance. The injection was temporarily suspended in February 1980. Improvement in oil production and a decrease in the water-oil ratio resulted during the following months. Displacement steam injection was scheduled to resume in August 1981 at a lower rate through insulated tubing. Favorable steamflood production response is anticipated with the resolution of the over-injection and steam-quality problems.

DOE/SF/10761-1. Field Demonstration of the Conventional Steam Drive Process with Ancillary Materials, First Annual Report, Oct. 1, 1979–Sept. 30, 1980. CLD Group, Inc. October 1981. 132 pp. The purpose of this project is to prove the concept that the use of a particular ancillary material—surfactant base foams—can improve the efficiency of conventional steam drive. The initial laboratory testing was aimed at screening foam chemicals for thermal stability and placing the foam systems in porous media. The final bench tests were conducted in a 16-ft sandpack to verify the compatibility of the emplacement techniques and the capacity of the chemical system to achieve a significant measure of mobility control over injected steam. Additional laboratory work will seek to optimize the process following the evaluation of the early field results. This will involve the addition of polymers and other additives to seek greater stability and longevity in mobility reduction. Minitest locations are being chosen in the Midway-Sunset, Cat Canyon, and San Ardo Fields so that the two major reservoir problems that are encountered in steam drive operations can be addressed: the flow of steam through "thief" zones or other channels that exist at the outset of initiating operations, and the progressive increase in channeling of steam through the oil-depleted, steam-swept zone.

Drilling

DOE/BC/00015-28. Low Invasion Fluids for Pressure Coring, Final Report. Sandia National Laboratories. October 1981. 39 pp. A program has been completed to develop improved low invasion fluids for pressure coring applications. This paper compares seven fluids containing different calcium carbonate materials using two different sandstone core samples and two simulated field conditions. The results indicate that the presently used mixture of 10 lb/bbl hydroxyethyl cellulose polymer and 300 lb/bbl CaCO_3 in a CaCl_2 eutectic brine mixture appears to be a very good choice for minimizing invasion of the core sample. Minor improvements in core invasion are achieved by matching the CaCO_3 particle size to the formation pore size. Experimentation or prior experience are necessary for choosing the type of CaCO_3 to be used. At best, the invasion of the core may only be slowed and not stopped completely. Factors which cause relatively large amounts of filtrate intrusion into the core are long exposure times, low fluid viscosities, and low solids content of the fluid. Curves are presented demonstrating the effectiveness of high polymer and CaCO_3 particle concentrations and comparing the core invasion of water, bentonite drilling mud, and the seven low invasion fluids.

DOE/BETC-3000-1. Methods for Determining Vented Volumes During Gas-Condensate and Oil Well Blowouts. Coastal Petroleum Associates, Inc. September 1981. 40 pp. Several methods are presented for determining vented volumes during gas-condensate and oil well blowouts, and each is illustrated with a numerical example. The method of crossplotting formation and flow string resistances is the only one which does not require special measurements and is therefore applicable to cratered wells and underwater

blowouts. The report also includes suggestions for investigations which might lead to better determination methods.

Western Gas Sands

DOE/BC/10106-26. Reservoir Engineering, Transient Pressure Well Testing, and Petrophysical Analyses of Western Gas Sands, Annual Report, July 1978–August 1979. Intercomp Resource Development and Engineering, Inc. November 1981. 170 pp. Improvement in gas deliverability by massive hydraulic fracturing (MHF) of low permeability Western Gas Sands has been generally disappointing. This investigation uses the petrophysical studies, transient pressure analyses of well performance, and parametric studies of various fracture properties to aid in the understanding of the results of several DOE cost-shared MHF treatments. Both the transient pressure analyses and the parametric studies utilize numerical simulation techniques. A generalized approach to pressure buildup analyses of tests with short flow periods was developed. The parametric analyses are focused on those variables of MHF treatments over which the operator and engineer have some control. Improvements in pressure measurement techniques are suggested as well as reasons why MHF treatments have had limited success.

DOE/BC/10038-19. Lightweight Proppants for Deep Gas Well Stimulation, First Annual Report, July 1979–July 1980. Terra Tek, Inc. October 1981. 34 pp. Existing high strength proppants have desirable strength characteristics for propping deep hydraulic fractures, but also have high specific gravities when compared to sand. The high specific gravity necessitates high-viscosity fracturing fluids and/or high pumping rates, along with low proppant concentration, which make fracture control and high conductivity fractures difficult to obtain. Theoretical stress and strength analyses of the proppants suggest that hollow spheres, as well as porous high purity ceramics, offer an alternative to dense bauxite proppants. Several novel ceramics, with specific gravities lower than conventional bauxite, are recommended for further evaluation in massive hydraulic fracturing.

PROCESSING AND THERMODYNAMICS

Characterization

DOE/BETC/PPS-81/5. Diesel Fuel Oils, 1981. E. M. Shelton. December 1981. 36 pp. Properties of diesel fuels produced and marketed in the U.S. during 1981 were submitted for study and compilation under a cooperative agreement between the Department of Energy and the American Petroleum Institute. Tests of 160 samples of diesel fuel oils from 77 refineries were made by 26 petroleum groups according to type of diesel fuel. Each group of analyses is subdivided into five tabulations according to regions of the country where the fuels are marketed. Data from 13 laboratory tests on each sample are listed and arranged by geographic marketing districts in decreasing order of sales volume. Charts are included showing trends of averages of certain properties for the four types of diesel fuels for the years 1960–1981. Summaries of the results of the 1981 survey, compared with similar data from 1980, are given in tables.

PATENTS

Patent No. 4,281,289. Method of Determining Interwell Oil Field Fluid Saturation Distribution. E. C. Donaldson and F. D. Sutterfield. Issued July 28, 1981. A method has been developed for determining the oil and brine saturation distribution in an oil field by taking electrical current and potential measurements among a series of open-hole wells geometrically distributed throughout the oil field. Poisson's equation is utilized to develop fluid saturation distributions from the electrical current and potential measurement. Both signal generating equipment and chemical means are used to develop current flow among the several open-hole wells.

OUTSIDE PUBLICATIONS

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DOE/BETC/OP-79/25. Thermodynamic Property Measurements Made at the Bartlesville Energy Technology Center. B. E. Gammon and W. D. Good. Proceedings of the Workshop on Techniques for Measurement of Thermodynamic Properties, Albany, Oreg., Aug. 23-24, 1979. United States Department of the Interior, Bureau of Mines Information Circular 8853 (1981). The BETC maintains personnel and equipment for determining and/or predicting thermodynamic properties of fossil-fuel-related organic compounds. These measurements are made so that the properties can be specified over the range of temperature and pressure that may be encountered in utilizing such materials. Calorimetric techniques are described for bomb calorimetry, solution calorimetry, condensed-phase heat-capacity calorimetry, and vapor-flow calorimetry. State-property measurements are described for (1) vapor pressures; (2) the pressure, volume, temperature surface; (3) the velocity of sound, temperature, pressure surface; and (4) gas solubilities at high pressures. Techniques for spectroscopic measurements and for statistical mechanical calculations are discussed. The relative region of the thermodynamic surface probed by these methods is identified and discussed.

DOE/BETC/OP-80/22. Consequences of the Mass Spectrometric and Infrared Analysis of Oils and Asphaltenes for the Chemistry of Coal Liquefaction. S. E. Scheppele, P. A. Benson, G. J. Greenwood, Q. G. Grindstaff, T. Aczel, and B. F. Beier. American Chemical Society, Advances in Chemistry Series, Chemistry of Asphaltenes, 195, pp. 53-82. Oils and asphaltenes are generally assumed to be key intermediates in coal liquefaction. Since the application of fundamental chemical/mathematical principles requires compositionally unique fractions, mass spectrometry and infrared spectroscopy were employed to obtain detailed molecular analyses of fractionated coal-liquid-derived oils and asphaltenes. The asphaltenes contain higher-molecular-weight homologs in many specific-Z series and different compound types than do the oils. However, both fractions contain appreciable quantities of compound types equivalent in molecular formula and, hence, assumably in molecular structure. The chemical/physical properties of oils and asphaltenes are not describable in terms of average (hypothetical) molecular structures. The lack of unique oil and asphaltene compositions necessitates detailed molecular analysis as a prerequisite for understanding, assessing, and controlling the chemical/physical phenomena intrinsic to production and processing of coal liquids.

DOE/BETC/OP-80/40. Carbon Isotope Geochemistry of Paleozoic Oils from Big Horn Basin. H. M. Chung, S. W. Brand, and P. L. Grizzle. *Geochimica et Cosmochimica Acta*, 45 (1981), pp. 1803-1815. Twenty crude oils from Paleozoic reservoirs in the Big Horn Basin, Wyo., were fractionated into light hydrocarbons, saturates, monoaromatics, diaromatics, polyaromatics-and-polars, and asphaltenes. Amounts and isotopic composition of each fraction were found to be internally consistent with the degree of maturation of the oil, confirming the established single source origin for these oils. A variation of approximately three per mil in the carbon isotopic composition of the whole oil and individual fraction was explained as being caused by maturation. The isotope-type-curves for these oils, which show the variations in isotopic composition as a function of compound group-type, were not found to be as simple as commonly believed. Other alteration processes, such as migration and deasphalting, might have influenced the pattern of the isotope distributions among fractions. The conservative nature of mass balance and subsequent isotope flows among various fractions of crude oil showed that the maturation of crude oil consists of consecutive processes leading from larger and more polar components into smaller

and less polar components culminating in natural gas. Calculations were made to project the amount of condensates associated with the crude oils and the amount of natural gas which had been generated from crude oils of a given maturity.

DOE/BETC/OP-81/37. Effect of Impurities on Partial Molal Volume and Critical Micelle Concentration of Sodium Dodecylsulfate, Correction of Micelle Aggregation Number. D. A. Doughty. *Journal of Chemical Physics*, 85 (1981), pp. 3545-3546. The partial molal volume (\bar{V}) of sodium dodecylsulfate (SDDS) is shown to vary in a regular manner as a function of sample purity. The change in volume upon micellization and critical micelle concentration (CMC) as determined by density measurements, however, show no significant effect. Using the measured effect of known impurities on \bar{V} , the amount of impurity for several commercial SDDS samples is calculated. The calculated impurity for a commercial SDDS sample used in a previous study of micelle aggregation numbers (N) is used to correct the reported values of N.

DOE/BETC/OP-81/44. Comparison of Methods for Measurement of Oil Saturation. E. C. Donaldson and H. L. Staub. Society of Petroleum Engineers of AIME, 6200 N. Central Expressway, Dallas, Texas 75206. Preprints, 10298. Presented at the 56th Annual Fall Technical Conference and Exhibition of the Society of Petroleum Engineers, Oct. 5-7, 1981, San Antonio, Texas. The City of Long Beach, Calif., in cooperation with the DOE, conducted a program to obtain oil saturation data in the HXa unconsolidated sand of the Wilmington Field after initiation of a micellar-polymer project. A core analysis program was coupled with open-hole and cased-hole logging and the single-well tracer test to obtain a comparative analysis of current commercial methods that are available for the determination of oil saturation. The measurements of oil saturation showed considerable disagreement between methods. Core analysis was impaired by loss of fluids and expansion. Comparison of the vertical profile of log analyses exhibits differences due to limitations of the individual methods; combined analyses of several logs is considered more reliable. The best average formation saturation was obtained from the single-well partition tracer test.

DOE/BETC/OP-81/45. EOR Databank Assembled. R. M. Ray. *Northeast Oil Reporter*, 6525 Busch Blvd., Ste. 203, Columbus, Ohio 43229. October 1981, pp. 83-86. Enhanced oil recovery technology has progressed rapidly in the last few years, and the Bartlesville Energy Technology Center has supported research to survey and collect existing, publicly available data on oil reservoirs to identify those reservoirs amenable to EOR technology. From these programs, BETC is constructing an EOR data base. The types of input to the data base have been EOR-process specific and reservoir specific. This will make the data base useful to most companies associated with EOR—from equipment suppliers to field-project personnel. BETC also is supporting contractual efforts to develop reservoir-process screening models and economic models to predict process performance and EOR economics. The process models will be used in part to determine sensitivities to data elements as applied to EOR processes, and partly to study risks involved in applying EOR technology.

DOE/BETC/OP-81/58. Prospects for Enhanced Oil Recovery in the United States. H. R. Johnson. Presented at the Annual Meeting of the International Petroleum Association of America, Houston, Texas, Oct. 18, 1981, and at the World Oil & Gas Show and Conference, Dallas, Texas, Dec. 14-17, 1981. This paper reviews the potential for enhanced oil recovery, the evolutionary nature of the recovery processes being applied in oilfields today, key parameters that describe the technology state-of-the-art for each of the major oil recovery processes, and the nature and key outputs from the current Department of Energy research program on enhanced oil recovery. The DOE program is focused on the analysis of ongoing tests and on long-range, basic research to support a more thorough understanding of process performance.