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Quarterly Reports

DOE/BC-94/1 **Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery. Progress Review No. 77. Quarter ending December 31, 1993. 117 pp. Order No. DE94000200.** Status reports are given for various enhanced oil recovery and gas recovery projects sponsored by the Department of Energy. The field tests and supporting research on enhanced oil recovery include chemical flooding, gas displacement, thermal/heavy oil, resource assessment, geoscience technology, microbial technology, field demonstrations in high-priority reservoir classes, novel technology, and environmental technology.

DOE/BC-94/2 **Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery. Progress Review No. 78. Quarter ending March 1994. May 1995. 105 pp. Order No. DE95000126.** Status reports are given for various enhanced oil recovery and gas recovery projects sponsored by the Department of Energy. The field tests and supporting research on enhanced oil recovery include chemical flooding, gas displacement, thermal/heavy oil, resource assessment, geoscience technology, microbial technology, field demonstrations in high-priority reservoir classes, novel technology, and environmental technology.

Chemical Flooding

DOE/BC/14882-10 **Responsive Copolymers for Enhanced Petroleum Recovery. Second Annual Report. University of Southern Mississippi. May 1995. 200 pp. Order No. DE95000143.** Advanced copolymer and terpolymer systems are being studied under a coordinated research program in the Polymer Science Laboratories at the University of Southern Mississippi. This report describes second year efforts in synthesis, characterization, and rheology to develop polymers with significantly improved efficiency in mobility control and conformance as compared to conventional systems. Key features of these microstructurally tailored systems allow triggered response to environmental stimuli including pH, ionic strength, electrolyte concentration, and shear. Ampholytic and/or hydrophobic interactions between polymer chains can be designed for desired rheological response. The polymers have potential to circumvent problems inherent in traditional EOR polymers where molecular weight must be compromised to allow sufficient permeation without plugging of the porous reservoir network. Most conventional polymers fail in high calcium, barium, or sodium concentrations, precluding use in high salinity fields or offshore. By contrast, these advanced polymer systems would maintain high viscosities or behave as virtual gels under low shear conditions and at elevated electrolyte concentrations. At high fluid shear rates, associates would deaggregate yielding low viscosity solutions, reducing problems of shear degradation or face plugging during injection. Other promising polymer systems developed during the past year are polymeric surfactants with potential for use in higher salt, higher temperature reservoirs for mobilization of entrapped oil.

DOE/BC/14886-9 **Investigation of Oil Recovery Improvement by Coupling an Interfacial Tension Agent and a Mobility Control Agent in Light Oil Reservoirs. Second Annual Report for October 1993-September 1994. Surtek, Inc. April 1995. 68 pp. Order No. DE95000138.** A study is underway of two major areas concerning co-injecting an interfacial tension reduction agent(s) and a mobility control agent. The first area defines the interactions of alkaline agents, surfactants, and polymers on a fluid-fluid and a fluid-rock basis. The second area concerns the economic improvement of the combined technology. This report continues the fluid-fluid interaction evaluations and begins the fluid-rock studies. Fluid-fluid interfacial tension work determined that replacing sodium ion with either potassium or ammonium ion in solutions with interfacial tension reduction up to 19,600 fold was detrimental and had little or no effect on alkali-surfactant solutions with interfacial tension reduction of 100 to 200-fold. Reservoir brine increases interfacial tension between crude oil and alkaline-surfactant solutions. Na_2CO_3-surfactant solutions maintained ultralow and low interfacial tension values better than NaOH-surfactant solutions. The initial phase of the fluid-rock investigations was adsorption studies. Surfactant adsorption is reduced when co-dissolved with alkali. Na_2CO_3 and Na_3PO_4 are more efficient at reducing surfactant adsorption than NaOH. When polymer is added to the surfactant solution, surfactant adsorption is reduced as well. When both polymer and alkali are added, polymer is the dominate component, reducing the Na_2CO_3 and NaOH effect on adsorption. Substituting sodium ion with potassium or ammonium ion increased or decreased surfactant adsorption depending on surfactant structure with alkali having a less significant effect. No consistent change of surfactant adsorption with increasing salinity was observed in the presence or absence of alkali or polymer. The importance of the fluid-rock

nteraction in oil recovery was demonstrated by performing radial orefloods with three alkaline-surfactant-polymer solutions, all with ltra low interfacial tension values. Incremental oil recovery varied from to 20% of the initial oil saturation.

DOE/BC/14880-10 **Improved Techniques for Fluid Diversion in Oil Recovery. Second Annual Report for October 1993-September 1994. New Mexico Institute of Mining and Technology. March 1995. 244 pp. Order No. DE95000131.** This project is directed at reducing water production and ncreasing oil recovery efficiency. In the United States, more than 20 billion barrels of water are produced each year during oil field operations. An average of 7 barrels of water are produced for each barrel of oil. Today, the cost of water disposal is typically between $0.25 and $0.50 per bbl. Therefore, there is a tremendous economic incentive to reduce water production if that can be accomplished without sacrificing hydrocarbon production. Environmental considerations also provide a significant ncentive to reduce water production during oil field operations. This three-year project has two technical objectives. The first objective is to compare the effectiveness of gels in fluid diversion (water shutoff) with those of other types of processes. Several different types of fluid-diversion processes are being compared, including those using gels, foams, emulsions, and particulates. The second objective of the project is to identify the mechanisms by which materials (particularly gels) selectively reduce permeability to water more than to oil. A capacity to reduce water permeability much more than oil or gas permeability is critical to the success of gel treatments in production wells if zones cannot be isolated during gel placement. Topics covered in this report include (1) comparisons of the use of gels, foams, emulsions, and particulates as blocking agents, (2) propagation of aluminum-citrate-HPAM gels through porous rock, (3) gel properties in fractured systems, (4) gel placement in unfractured anisotropic flow systems, and (5) an investigation of why some gels can reduce water permeability more than oil permeability.

DOE/BC/14860-9 **Detailed Evaluation of the West Kiehl Alkaline-Surfactant-Polymer Field Project and Its Application to Mature Minnelusa Waterfloods. Final Report. Surtek, Inc. March 1995. 132 pp. Order No. DE95008922.** The combination of an interfacial tension agent and a mobility control agent has the potential to produce additional oil beyond a waterflood. The West Kiehl alkaline-surfactant-polymer project is the first application of this chemical enhanced oil recovery technique. The West Kiehl alkaline-surfactant-polymer flood was initiated in September 1987 as a secondary application after primary recovery. The following analysis of the West Kiehl alkaline-surfactant-polymer flood indicates that incremental oil greater than waterflooding was produced at a cost of less than $2.00 per incremental barrel. An analysis of approximately 120 Minnelusa oil fields in the Powder River Basin indicates that the total original stock tank oil in place exceeds one billion barrels. If the enhanced oil recovery technology implemented at West Kiehl field could be successfully applied to these fields, the potential incremental oil recovery would approach 130 million barrels. The goals of this project are to evaluate both the field performance of the alkaline-surfactant-polymer enhanced oil recovery technology as well as its potential application to other Minnelusa oil fields. After studying 72 fields in a 275 square mile area around the West Kiehl, Prairie Creek South and Simpson Ranch were selected as waterflood and polymer flood analogs. Prairie Creek South numerical simulation predictions of the waterflood is 790,000 barrels of oil or 39.4% OOIP. Classical engineering prediction for the ultimate waterflood recovery is 764,900 to 814,900 barrels of oil or 38.1 to 40.6% OOIP. Alkaline-surfactant-polymer injection is predicted to produce 1,100,000 barrels for 310,000 barrels of incremental oil. A mobility control polymer flood estimated recovery is 919,000 barrels of oil. If an alkaline-surfactant-polymer project was implemented after a waterflood in the West Kiehl, Simpson Ranch and Prairie Creek South fields the incremental oil recovery predicted by the numerical simulator is 321,000, 323,000, and 272,000 barrels, respectively. The West Kiehl total production by alkaline-surfactant-polymer flood forecast was greater after a waterflood because the Kottabra 25-15 well was on production for the entire alkaline-surfactant-polymer injection period, rather than 6 months. Actual incremental cost per barrel of oil was less than $1.60. If 1994 prices are applied to the incremental oil recovery potential indicated by the numerical simulation for West Kiehl, Prairie Creek South, and Simpson Ranch, alkaline-surfactant-polymer incremental oil is produced for less than $3.00 per barrel. Incremental oil recovery potential is 130 million barrels of oil in the Minnelusa trend.

DOE/BC/14883-10 **Surfactant-Enhanced Alkaline Flooding for Light Oil Recovery. 1993-1994. Illinois Institute of Technology. March 1995. 112 pp. Order No. DE95000135.** This report presents the results of experimental and theoretical studies in surfactant-enhanced alkaline flooding for light oil recovery. The overall objective of this work is to develop a very cost-effective method for formulating a successful surfactant-enhanced alkaline flood by appropriately choosing mixed alkalis which form inexpensive buffers to obtain the desired pH (between 8.5 and 12.0) for ultimate spontaneous emulsification and ultralow interfacial tension. In addition, this study (1) investigates the effect of surfactant on the equilibrium and transient interfacial tension, (2) investigates the kinetics of oil removal from a silica surface, and (3) develops a theoretical interfacial activity model for determining equilibrium interfacial tension.

Thermal Recovery

DOE/BC/95000144 **Reservoir Characterization and Process Monitoring with EM Methods. 1994 Annual Report. Lawrence Livermore National Laboratory. May 1995. 16 pp. Order No. DE95000144.** The objective of this study is to apply surface and borehole EM methods for oil- field characterization and process monitoring and to improve the knowledge of oil field structure and secondary recovery processes by providing the electrical resistivity distribution in the region between wells. During FY94 Lawrence Livermore National Laboratory (LLNL) conducted its largest field test to date. They applied crosshole and surface-to-borehole EM techniques to reservoir characterization at the Lost Hills No. 3 oilfield making three sets of measurements during the initial phase of the steam drive. From these data they were able to determine the resistivity and configuration of the oil sands, between their observation wells, and provide an image of the subsurface resistivity changes because of the steam drive. In addition to the steamflood monitoring in FY94 they also conducted a waterflood experiment at our Richmond Field Station facility using the borehole-to-surface EM technique. For this test they injected a small quantity of saltwater, and applied the EM technique to monitor the progress of the injected plume. Data collection for this experiment is complete but the results are yet to be interpreted. Their preliminary analysis indicates that they were able to detect the saltwater plume and distinguish its orientation. The field data were also observed to be much noisier than corresponding crosshole measurements because of the influence of surface cultural features and external noise.

DOE/BC/14899-20 **A Study of Dykstra-Parsons Curves. SUPRI TR 29. Stanford University. February 1995. 32 pp. Order No. DE95000124.** The Dykstra-Parsons method for prediction of oil recovery by waterflooding is a well-known technique which has been used by the petroleum industry since 1945. The present work carries their study further, solving the same problem of calculating coverage for certain values of permeability variation having water-oil-ratio and mobility ratio as fixed parameters. The work herein, instead of using 50 layers, uses 200. Also a more precise theoretical

approach to the problem is given. Because of these differences the resulting curves are slightly modified. The second part of this study deals with empirical simplifications with considerable success. The idea was to collapse the data and curves obtained in the first part into a single curve which covers most of the range of variables commonly seen in reservoir displacements.

DOE/BC/14861-6 (Vol. 1) **Horizontal Oil Well Applications and Oil Recovery Assessment. Volume I: Success of Horizontal Well Technology. Final Report. Maurer Engineering Inc. March 1995. 132 pp. Order No. DE95000133.** Horizontal technology has been applied in over 110 formations in the U.S.A. Volume I of this study addresses the overall success of horizontal technology, especially in less-publicized formations, i.e., other than the Austin Chalk, Bakken, and Niobrara. Operators in the U.S.A. and Canada were surveyed on a formation-by-formation basis by means of a questionnaire. Response data were received describing horizontal well projects in 58 formations in the U.S.A. and 88 in Canada. Operators' responses were analyzed for trends in technical and economic success based on lithology (clastics and carbonates) and resource type (light oil, heavy oil, and gas). The potential impact of horizontal technology on reserves was also estimated. A forecast of horizontal drilling activity over the next decade was developed.

DOE/BC/14861-6 (Vol. 2) **Horizontal Oil Well Applications and Oil Recovery Assessment. Volume II: Applications Overview. Final Report. Maurer Engineering Inc. March 1995. 168 pp. Order No. DE95000134.** Horizontal technology has been applied in a wide variety of applications and reservoir settings. Much information has been published on drilling, completion, and workover systems, tools and techniques for these wells, especially for the most active formations. Little has been presented describing overall production and economic success of the technology in the wider range of formation types. In Volume II of this study, numerous case studies and analyses are presented of horizontal technology projects in each major application and resource type. Field location, geology, production and economic success, reserves increases, and production problems are described for each project. Chapters are presented assessing horizontal applications in light-oil, heavy-oil, and gas reservoirs. To broaden the base of formation types, especially with respect to heavy-oil and gas reservoirs, Canadian operations are highlighted in the study along with those in the U.S.A. Additional objectives of the study include an assessment of the technical and economic limits of horizontal technology.

Resource Assessment Technology

DOE/BC-95/2/SP **Supporting Technology for Advanced Oil Recovery: Infill Drilling Predictive Model. Venezuela-Mem/USA-DOE Fossil Energy Report III-7. February 1995. 576 pp. Order No. DE95000119.** The Infill Drilling Predictive Model (IDPM) is in a style similar to previous Enhanced Oil Recovery Predictive Models which were developed for and in conjunction with the Chemical Task Group of the National Petroleum Council (NPC) for use in the 1982-1984 NPC study on enhanced oil recovery (EOR) potential. The model is designed to conform to the methodology and structure of the suite of models used in that study. This insures that all models calculate and report predicted oil recovery and economics in an identical manner. As do the other models, the IDPM contains an extensive set of default equations to calculate non-critical reservoir properties, flood properties, and economic criteria. The Department of Energy, Bartlesville Project Office, supported the NPC and has maintained the models since the NPC study was completed.

Geoscience Technology

DOE/BC/95000129 **Predicting the Transport Properties of Sedimentary Rocks from Microgeometry. University of California. February 1995. 96 pp. Order No. DE95000129.** This study investigates through analysis and experiment how pore geometry, topology, and the physics and chemistry of mineral-fluid and fluid-fluid interactions affect the flow of fluids through consolidated/partially consolidated porous media. Their approach is to measure fluid permeability and electrical conductivity of rock samples using single and multiple fluid phases that can be frozen in place (wetting and nonwetting) over a range of pore pressures. These experiments are analyzed in terms of the microphysics and microchemistry of the processes involved to provide a theoretical basis for the macroscopic constitutive relationships between fluid-flow and geophysical properties that are developed. The purpose of these experiments and their analyses is to advance the understanding of the mechanisms and factors that control fluid transport in porous media. This understanding is important in characterizing porous media properties and heterogeneities before simulating and monitoring the progress of complex flow processes at the field scale in permeable media.

DOE/BC/14892-5 **Visual Display of Reservoir Parameters Affecting Enhanced Oil Recovery. FY 1994 Annual Report. Michigan Technological University. June 1995. 44 pp. Order No. DE95000148.** Evaluation of oil and gas properties for enhanced oil recovery (EOR) involves a high degree of risk, especially when the fields are old and well past their prime. The purpose of this project is to provide the small-to-medium size oil field operator with the tools necessary to do an EOR evaluation of the same quality and sophistication that only large international oil companies have been able to afford to date. This approach utilizes readily available, affordable computer software and analytical services. This project will provide a detailed example, based on a field trial, of how to evaluate a field for EOR operations utilizing data typically available in a field which has undergone primary development. Michigan Technological University decided that the most effective way to provide a user-friendly, state-of-the-art package to the independent producers who are their primary clients is to link the best modules from four different systems: a commercial database, a wireline log analysis program, a mapping program, and a 2D and 3D visualization program, into a flexible, user-friendly unit. Microsoft Access was chosen for the database management platform. Currently all digitized log data is being read into, corrected, analyzed, and archived in the Crocker Data Management Petrolog Program at DPI.

DOE/BC/14893-6 **Integration of Advanced Geoscience and Engineering Techniques to Quantify Interwell Heterogeneity in Reservoir Models. First Annual Report for September 29, 1993-September 30, 1994. New Mexico Institute of Mining and Technology. May 1995. 24 pp. Order No. DE95000147.** The goal of this project is to provide a more quantitative definition of reservoir heterogeneity. This objective will be accomplished through the integration of geologic, geophysical, and engineering databases into a multidisciplinary understanding of reservoir architecture and associated fluid-rock and fluid-fluid interactions. The intent is to obtain a quantitative reservoir description incorporating outcrop, field, well-to-well, and laboratory core and fluid data of widely varying scales. This interdisciplinary effort will integrate geological and geophysical data with engineering and petrophysical results through reservoir simulation to quantify reservoir architecture and the dynamics of fluid-rock and fluid-fluid interactions. A more accurate reservoir description will allow greater accuracy and confidence during simulation and modeling as steps toward gaining greater recovery efficiency from existing reservoirs. A field laboratory, the Sulimar Queen Unit, is

ilable for the field research activities that will be conducted. Pecos roleum Engineering Inc. in Roswell, NM, was retained as the field agent. Preliminary work for the outcrop phase of this study included ecting aerial photos, geologic and topographic maps of the area, and ving the roads in the area to identify Queen outcrops that may be use- for the study. Queen outcrops containing rocks most closely resem- g those seen in the Sulimar Queen core were chosen for further rk. Emphasis is being placed on outcrops having the potential for mination in three dimensions, particularly those with great areal osure. Several trips were made to the field area, and a few promising crops were located. A report on the diagenesis in the cored interval Well 1-16 was prepared. Examination of this core demonstrates quite rly the combination of depositional and diagenetic effects that ved to create a hydrocarbon reservoir in the Sulimar Queen Field.

DE/BC/14471-19 **Results and Synthesis of Integrated Geologic Studies of the Carboniferous Lisburne Group of Northeastern Alaska. Final Report. University of Alaska, Fairbanks. May 1995. 452 pp. Order No. DE95000123.** The mary objective of this project was to develop an integrated database haracterize reservoir heterogeneities resulting from numerous small- le shallowing-upward cycles (parasequences) comprising the Penn- vanian Wahoo Limestone. The Wahoo Limestone is the upper part of extensive carbonate platform sequence of the Carboniferous Lis- ne Group which is widely exposed in the Brooks Range and is a despread hydrocarbon reservoir unit in the subsurface of the North pe of Alaska. A leading goal is to determine lateral and vertical vari- ons in the complex mosaic of carbonate facies comprising the Wahoo. order to understand the overall basin history and its relationship to stratigraphic and structural framework, aspects of rock units adja- t to the Wahoo, the underlying Endicott Group and Alapah Lime- ne and overlying Echooka Formation are also discussed. This report sents the results of research accomplished by a team of specialists in bonate petrology, biostratigraphy, and diagenesis. It includes an erview of the regional geological framework; a discussion of biostrati- phic results; a summary of diagenetic studies; and preliminary ults of comparative studies of a cored well in the Lisburne oil field. A nputerized database system (the Wahoo database) was developed d is explained in a users manual.

s Displacement

DE/BC/14661-10 **Oil Recovery From Naturally Fractured Reservoirs by Steam ection Methods. Final Report. The University of Texas at Austin. y 1995. 244 pp. Order No. DE95000140.** The United States of America s naturally fractured reservoirs containing many tens of billions of rrels of oil. When secondary and enhanced recovery methods are plied, fractures tend to channel injected fluids through the reservoir production wells, resulting in much of the oil in the matrix blocks ng bypassed and not recovered. This results in a low recovery effi- ncy from fractured reservoirs. Because of the large size of this ource, any new technology that improves recovery efficiency from turally fractured reservoirs by as little as a few percent could result in ignificant increase in overall oil production from existing petroleum rmations. The objectives of this research program are to quantify the nount of oil expelled by these recovery mechanisms and to develop a merical model for predicting oil recovery in naturally fractured reser- irs during steam injection. The experimental study consists of con- ucting and operating several apparatuses to isolate each of these echanisms. The first measures thermal expansion and capillary imbi- ion rates at relatively low temperature, but for various lithologies and trix block shapes. The second apparatus measures the same parame- s, but at high temperatures and for only one shape. A third experi- ental apparatus measures the maximum gas saturations that could build up within a matrix block. A fourth apparatus measures thermal conductivity and diffusivity of porous media. The numerical study consists of developing transfer functions for oil expulsion from matrix blocks to fractures at high temperatures and incorporating them, along with the energy equation, into a dual porosity thermal reservoir simulator. This simulator can be utilized to make predictions for steam injection processes in naturally-fractured reservoirs. Analytical models for capillary imbibition have also been developed.

DOE/BC/14852-10 **Scale-Up of Miscible Flood Processes for Heterogeneous Reservoirs. Second Annual Report. Stanford University. March 1995. 144 pp. Order No. DE95000132.** Progress is reported for a comprehensive investigation of the scaling behavior of gas injection processes in heterogeneous reservoirs. The interplay of phase behavior, viscous fingering, gravity segregation, capillary imbibition and drainage, and reservoir heterogeneity is examined in a series of simulations and experiments. Use of streamtube to model multiphase flow is demonstrated to be a fast and accurate approach for displacements that are dominated by reservoir heterogeneity. The streamtube technique is particularly powerful for multiphase compositional displacements because it represents the effects of phase behavior with a one-dimensional flow and represents the effects of heterogeneity through the locations of streamtubes. A new approach for fast calculations of critical tie-lines directly from criticality conditions is reported. A global triangular structure solution for four-component flow systems, whose tie-lies meet at the edge of a quantern-ary phase diagram or lie in planes is presented. Also demonstrated is the extension of this solution to multicomponent systems under the same assumptions. The interplay of gravity, capillary and viscous forces on final residual oil saturation is examined experimentally and theoretically. The analysis of vertical equilibrium conditions for three-phase gravity drainage shows that almost all oil can be recovered from the top part of a reservoir. The prediction of spreading and stability of thin film is performed to investigate three-phase gravity drainage mechanisms. Finally, experimental results from gravity drainage of crude oil in the presence of CO_2 suggest that gravity drainage could be an efficient oil recovery process for vertically fractured reservoirs.

Reservoir Class Demonstration Projects

DOE/BC/14951-10 **Integrated Approach Towards the Application of Horizontal Wells to Improve Waterflooding Performance. Annual Report. The University of Tulsa. May 1995. 140 pp. Order No. DE95000146.** This annual report describes the progress during the second year of the project on Integrated Approach Towards the Application of Horizontal Wells to Improve Waterflooding Performance. This project is funded under the Department of Energy's Class I program which is targeted towards improving the reservoir performance of mature oil fields located in fluvial-dominated deltaic deposits. The project involves an integrated approach to characterize the reservoir followed by the drilling of horizontal injection wells to improve production performance. The type of data integrated includes cross borehole seismic surveys, geological interpretation based on logs and cores, and engineering information. This report covers the second phase of the project which includes a detailed reservoir description of the field by integrating all the available information, followed by flow simulation of the Self Unit under various operating conditions. Based on an examination of the various operating parameters, the best possible solution to improve the Self Unit performance is to recomplete and stimulate most of the wells followed by an increase in the water injection rate. Drilling of horizontal injection well, although helpful in improving the performance, was not found to be economically feasible. The proposed reservoir management plan will be implemented shortly.

DOE/BC/14986-3 **CO_2 Huff-n-Puff Process in a Light Oil Shallow Shelf Carbonate Reservoir. 1994 Annual Report. Texaco Exploration & Production Inc. May 1995. 44 pp. Order No. DE95000142.** Texaco E & P Inc. and the U.S. Department of Energy have teamed up in an attempt to develop the CO_2 Huff-n-Puff process in a light oil, shallow shelf carbonate reservoir within the Permian Basin. This cost-shared effort is intended to demonstrate the viability of this underutilized technology in a specific class of domestic reservoirs that are considered to be at risk of abandonment. The selected site for the demonstration project is the Central Vacuum Unit waterflood in Lea County, New Mexico. The CO_2 Huff-n-Puff process is a proven enhanced oil recovery technology in Louisiana-Texas gulf coast sandstone reservoirs. Application seems to mostly confine itself to low pressure sandstone reservoirs. The process has even been shown to be moderately effective in conjunction with steam on heavy California crude oils. A review of earlier literature provides an excellent discussion on the theory, mechanics of the process, and several case histories. Although the technology is proven in light oil sandstones, it continues to be a very underutilized enhanced recovery option for carbonates. It is anticipated that this project will show that the application of the CO2 Huff-n-Puff process in shallow shelf carbonates can be economically implemented to recover appreciable volumes of light oil. The goals of the project are the development of guidelines for cost-effective selection of candidate reservoirs and wells, along with estimating recovery potential. Work is nearing completion on the reservoir characterization components of the project.

DOE/BC/14960-7 **Post Waterflood CO_2 Miscible Flood in Light Oil, Fluvial-Dominated Deltaic Reservoir. FY1993 Annual Report. Texaco Exploration and Production Inc. March 1995. 168 pp. Order No. DE95000120.** The "Post Waterflood CO_2 Miscible Flood in Light Oil Fluvial Dominated Deltaic Reservoir" is a Class I DOE-sponsored field demonstration project of a CO_2 miscible flood project at the Port Neches Field in Orange County, Texas. The project will determine the recovery efficiency of CO_2 flooding a waterflooded and a partial waterdrive sandstone reservoir at a depth of 5800'. The project will also evaluate the use of a horizontal CO_2 injection well placed at the original oil-water contact of the waterflooded reservoir. A PC-based reservoir screening model will be developed by Texaco's research lab in Houston and Louisiana State University will assist in the development of a database of fluvial-dominated deltaic reservoirs where CO_2 flooding may be applicable. This technology will be transferred throughout the oil industry through a series of technical papers and industry open forums. Major work necessary to establish results from the project have been accomplished, with the initiation of CO_2 injection into the waterflooded fault having began on September 22, 1993. Six producing wells and four CO_2 injection wells have been worked over and made ready for CO_2 operations.

DOE/BC/14952-10 **Secondary Oil Recovery from Selected Carter Sandstone Oilfields--Black Warrior Basin, Alabama. Final Report. Anderman/Smith Operating Company. February 1995. 40 pp. Order No. DE95000125.** In this Class I PON, Anderman/Smith Operating Company targeted three Carter sandstone oilfields (Black Warrior Basin) for secondary recovery. Waterfloods are currently under way in two of the areas - Central Bluff and North Fairview units. For the third area, South Bluff, unitization efforts have been suspended and will not be addressed in this final report.

Microbial Technology

DOE/BC/14664-12 **Polysaccharides and Bacterial Plugging. Final Report for 1992-1993. The University of Michigan. February 1995. 124 pp. Order No. DE95000127.** In situ core plugging experiments and transport experiments, using the model bacteria Leuconostoc m., have been conducted. Results demonstrated that cellular polysaccharide production increases cell distribution in porous media and causes an overall decrease in media permeability. Further, a parallel core plugging experiment was conducted and showed the feasibility of this system to divert injection fluid from high permeability zones into low permeability zones within porous media as is needed for profile modification. To implement this type of application, however, controlled placement of cells and rates of polymer production are needed. Therefore, kinetic studies were performed. A kinetic model, i.e. the modeling of the production of cells and polysaccharides, was subsequently developed for Leuconostoc m. bacteria. This model is based on data generated from batch growth experiments and allows for the prediction of saccharide utilization, cell generation, and dextran production. These predictions can be used to develop injection strategies for field implementation. Transport and in situ growth micromodel experiments have shown how dextran allow cells to remain as clusters after cell division which enhanced cell capture and retention in porous media. In situ growth in porous media results in three injection pressure regimes: 1) initially no measurable change in injection pressure, 2) dramatic increase in injection pressure, and 3) injection pressure oscillations. These regimes coincide with the development of the internal biofilm that initially does not restrict flow until its thickness becomes significant. At a critical point, the biofilm undergoes sloughing which produces cell and dextran aggregates that are transported and recaptured. Pressure oscillations are observed during this phase.

DOE/BC/14662-15 **Quantitation of Microbial Products and Their Effectiveness in Enhanced Oil Recovery. Final Report. University of Oklahoma. February 1995. 168 pp. Order No. DE95000121.** A three-dimensional, three-phase, multiple-component numerical simulator was developed to investigate transport and growth of microorganisms in porous media and the impacts of microbial activities on oil recovery. The microbial activities modeled in this study included: (1) growth, retention, chemotaxis, and end product inhibition of growth, (2) the formation of metabolic products, and (3) the consumption of nutrients. Major mechanisms for microbial enhanced oil recovery (MEOR) processes were modeled as follows: (1) improvement in sweep efficiency of a displacement process because of in situ plugging of highly-permeable production zones by cell mass or because of improved mobility control achieved by increasing the viscosity of the displacing fluid with a biopolymer, and (2) solubilization and mobilization of residual oil in porous media because of the reduction of the interfacial tension between oleic and aqueous phases by the production of a biosurfactant. The numerical solutions for mathematical models involved two steps. The distributions of pressure and phase saturations were solved from continuity equations and Darcy flow velocities for the aqueous phase were computed. This was followed by the solution of convection-dispersion equations for individual components. Numerical solutions from the proposed model were compared to results obtained from analytical equations, commercial simulators, and laboratory experiments. The comparison indicated that the model accurately quantified microbial transport and metabolism in porous media, and predicted additional crude oil recovery because of microbial processes.

Environmental

DOE/MT/91004-1 **Analysis of Environmental Constraints on Expanding Reserves in Current and Future Reservoirs in Wetlands. Final Report. Louisiana State University. March 1995. 204 pp. Order No. DE95000136.** Louisiana wetlands require careful management to allow exploitation of nonrenewable resources without destroying renewable resources. Current regulatory requirements have been moderately successful in meeting

this goal by restricting development in wetland habitats. Continuing public emphasis on reducing environmental impacts of resource development is causing regulators to reassess their regulations and operators to rethink their compliance strategies. The regulatory system was examined and it was found that reducing the number of applications required by going to a single application process and having a coherent map of the steps required for operations in wetland areas would reduce regulatory burdens. Incremental changes can be made to regulations to allow one agency to be the lead for wetland permitting at minimal cost to operators. Operators need cost effective means of access that will reduce environmental impacts, decrease permitting time, and limit future liability. Current wetland practices were examined and those practices comparing environmental versus economic costs were evaluated. A method was created for ranking the practices. Possible alternative access methods were examined for wetland access and it was found that while currently cost prohibitive, these methods would provide significant environmental benefits. .

Reservoir Characterization

DOE/BC/14652-15 **Dispersion Measurement as a Method of Quantifying Geologic Characterization and Defining Reservoir Heterogeneity. Final Report. The University of Oklahoma. May 1995. 156 pp. Order No. DE95000141.** The main objective of this research project is to investigate dispersion as a method of quantifying geological characterization and defining reservoir heterogeneity in order to enhance crude oil recovery. The dispersion of flow of a reservoir rock (dispersion coefficient and dispersivity) was identified as one of the physical properties of a reservoir rock by measuring the mixing of two miscible fluids, one displacing the other in a porous medium. A rock was 100% saturated with a resident fluid and displaced by a miscible fluid of equal viscosity and equal density. Some specific experiments were performed with unequal densities. Produced fluid was analyzed by refractometer, nuclear reaction, electrical conductivity and X-ray scan. Several physical and flow characteristics were measured on the sand rock sample in order to establish correlations with the measured dispersion property. Absolute permeability, effective porosity, relative permeability, capillary pressure, the heterogeneity factor and electrical conductivity were used to better understand the flow system. Linear, transverse, 2-D and 3-D dispersions were measured and used to characterize the rock heterogeneity of the flow system. A new system of measuring dispersion was developed using a gas displacing gas system in a porous medium. An attempt was also made to determine the dispersion property of an actual reservoir from present day well log data on a producing well.

DOE/BC/14651-20 **Reservoir Characterization of Pennsylvanian Sandstone Reservoirs. Final Report. University of Tulsa. February 1995. 380 pp. Order No. DE95000122.** This final report summarizes the progress during the three years of a project on Reservoir Characterization of Pennsylvanian Sandstone Reservoirs. The report is divided into three sections: (1) reservoir description, (2) scale-up procedures, and (3) outcrop investigation. The first section describes the methods by which a reservoir can be described in three dimensions. In this section the technique of simulated annealing to incorporate dynamic information is applied. Dynamic information includes any information which is a result of flow performance of the reservoir. The two types of dynamic information included are well test data and production data. To include the dynamic data more efficiently, the information was first converted into equivalent static information. For well test data, it is shown that, using an analytical solution for radial geometry and combining it with the Cartesian coordinate system, reservoir description can be generated which honors the well test pressure data as well as the pressure derivative data. The technique is also extended to include the porosity heterogeneities as well as permeability anisotropy. The next step in reservoir description is to scale up reservoir properties for flow simulation. The second section addresses the issue of scale-up of reservoir properties once the spatial descriptions of properties are created. A new analytical method is proposed to estimate a permeability tensor based on small scale.

DOE/BC/14474-17 **Characterization and Modification of Fluid Conductivity in Heterogeneous Reservoirs to Improve Sweep Efficiency. Final Report. The University of Michigan. February 1995. 196 pp. Order No. DE95000128.** The main objectives of this project were to develop new treatment strategies that would improve the efficiency of oil production, and stimulation procedures. Strategies were developed to treat injection well matrix heterogeneities, production well matrix or saturation heterogeneities, and fractured wells. The treatment strategies investigated included a particulate system, and a foamed gel for injection well profile modification, a foam/acid injection strategy for improving acidization of carbonates, an acid reactive gel for controlling acid leak-off into fractures, and a water reactive gel for water shut-off at production wells. The research focused on discovering the principles governing the performance of the treatment strategies to provide a fundamental basis for further development of these techniques. Other goals of this project were to demonstrate the use of Neutron Imaging for real time imaging of fluid flow through heterogeneous porous media and develop a kinetic model to simulate the effect of diagenetic processes on reservoir porosity and permeability.

DISCLAIMER

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For your convenience in requesting information, the technical staff at the Bartlesville Project Office (BPO) and their areas of professional expertise are listed below.

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The 5th International Conference on Microbial Enhanced Oil Recovery and Related Biotechnology for Solving Environmental Problems

The U. S. Department of Energy, BDM-Oklahoma and the Center for Environmental Research and Technology of the University of Tulsa will jointly sponsor the 5th International Conference on Microbial Enhancement of Oil Recovery and Related Biotechnology for Solving Environmental Problems September 11 - 14, 1995, at the Harvey Hotel in Plano, Texas. The conference will feature a one-day workshop on the microbial enhancement of oil recovery (MEOR) for the independent producer. The workshop will acquaint operators with cost-effective MEOR techniques and the resources available for their implementation. Following the workshop will be three days of technical sessions on the state of the art in the use of microbial systems for improving oil recovery, treating petroleum production fluids and solving related environmental problems. These sessions will be organized to be of interest to both the independent producers and to the academic and industrial researchers who are working to develop and field test MEOR and environmental technologies.

CONFERENCE AGENDA

September 11	MEOR Workshop for Independent Producers
	Exhibits
September 12	Plenary sessions (State-of-the-art Lectures)
	MEOR Field Tests
	Poster Session (evening)
September 13	Control of Souring and Treatment of Sour Production Fluids
	MEOR from the Laboratory to the Field
September 14	Biotechnology for Solving Petroleum Environmental Problems
	Characterization and Behavior of Microbial Systems for MEOR

CONFERENCE FEES

The conference fee is $50.00 per day. This daily fee applies to any day or any combination of days in attendance at the conference.

1 day	$50.00
2 days	$100.00
3 days	$150.00
4 days	$200.00
Student Registration (with letter from department chair)	$25.00 per day

For more information about this conference, contact one of the co-chairs:

Rebecca Bryant
BDM - Oklahoma
(918) 337-4328

Kerry Sublette
Center for Environmental Research & Technology
The University of Tulsa
(918) 631-3085

I am interested in attending the 5th International Conference on Microbial Enhanced Oil Recovery and Related Biotechnology for Solving Environmental Problems and want to receive future mailings about the conference.

Name: _____

Company: _____

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Please tell us which days you are interested in attending:

September 11 _____ September 12 _____ September 13 _____ September 14 _____

Return completed form to: Helen Bresson, BDM-Oklahoma, Inc., 220 NW Virginia Avenue, Bartlesville, OK 74003