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**BARTLESVILLE PROJECT OFFICE
FY 1990 ANNUAL REPORT**

APRIL 1991

Prepared for
U.S. Department of Energy
Assistant Secretary for Fossil Energy

Prepared by
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TABLE OF CONTENTS

	<u>Page</u>
BARTLESVILLE PROJECT OFFICE	v
ABBREVIATIONS	vi
1.0 INTRODUCTION	1
1.1 BPO Mission	1
1.2 Organization	1
1.3 Program Funding	2
2.0 PROGRAM FOCUS AND DIRECTION	5
2.1 Program Focus	5
2.2 Program Direction: Strategy for the Nineties	8
3.0 RESEARCH ACTIVITIES AND ACHIEVEMENTS	11
3.1 EOR Subprogram	11
3.1.1 Geoscience	12
3.1.2 Chemical Flooding	14
3.1.3 Gas Flooding	15
3.1.4 Thermal Recovery	16
3.1.5 Novel Recovery Technology	19
3.1.6 Microbial EOR	20
3.2 AEPT Subprogram	20
3.2.1 Fundamental Geoscience & Extraction Research	20
3.2.2 Supporting Technology & Environmental Research	22
3.2.3 University Geoscience Research	22
3.3 Tertiary Oil Recovery Information System (TORIS)	23
4.0 TECHNOLOGY TRANSFER	27
4.1 Publications Program	27
4.2 Conferences	27
4.3 Contracts with Independent Oil Operators	29
5.0 SIGNIFICANT EVENTS	31

	<u>Page</u>
5.1 Oil Recovery Technology Partnership	31
5.2 Federal/State Joint Efforts	31
5.3 International Cooperation	32
5.4 Environmental Protection	32
5.5 Other Highlights	33

TABLES

1. Project Funding Categories	1
2. Program Funding	3
3. 1989 EOR Production in the United States	11
4. Major TORIS Projects Completed in FY90	24
5. BPO Technology Transfer Distribution Activities, FY84-90	28

FIGURES

1. BPO Organizational Structure	3
2. Organization Supporting Petroleum R&D	3
3. BPO Budget Summary, FY82-91	4
4. Evolution of National Oil Research Program	6
5. National Oil Research Program for Maximizing Productivity	8
6. Work Breakdown Structure of EOR Research Subprogram	13
7. Logic Flow Diagram of EOR Research Subprogram	13
8. Work Breakdown Structure of AEPT Research Subprogram	21

APPENDICES

Appendix A Research Projects Performed in FY90	35
Appendix B Technical Reports Issued in FY90	43

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ABBREVIATIONS

AEPT	Advanced Extraction and Process Technology (Subprogram)
BEG	(Texas) Bureau of Economic Geology
BPD	Barrels per day
BPO	Bartlesville Project Office, DOE
CT	Computerized tomography
E/EM	Electric/electromagnetic
EOR	Enhanced Oil Recovery (Subprogram)
FE	Office of Fossil Energy, U.S. Department of Energy
ERAB	Energy Research Advisory Board
IEA	International Energy Agency, Paris
IOCC	Interstate Oil Compact Commission
LANL	Los Alamos National Laboratory
LBL	Lawrence Berkeley Laboratory, University of California
LLNL	Lawrence Livermore National Laboratory
MEOR	Microbial enhanced oil recovery
MOU	Memorandum of Understanding
MSO	Metairie Site Office, DOE
NAS	National Academy of Science
NIPER	National Institute for Petroleum and Energy Research
NMR	Nuclear magnetic resonance
NPC	National Petroleum Council
NPR	Naval Petroleum Reserves
NMIMT	New Mexico Institute of Mining & Technology
OER	Office of Energy Research, DOE
OGR	Office of Geoscience Research, DOE
ORTP	Oil Recovery Technology Partnership
OSTI	Office of Scientific and Technical Information
PRDA	Program Research and Development Announcement
RD&D	Research, Development and Demonstration
SEG	Society of Exploration Geophysicists
SGP	Supplemental Government Program
SNL	Sandia National Laboratory
SPE	Society of Petroleum Engineers
SPR	Strategic Petroleum Reserve
SUPRI	Stanford University Petroleum Research Institute
TORIS	Tertiary Oil Recovery Information System
UCG	Underground coal gasification
UNITAR	United Nations Institute for Training and Research
UNDP	United Nations Development Program
VSP	Vertical seismic profile

1.0 INTRODUCTION

1.1 BPO MISSION

The Bartlesville Project Office (BPO) was established in 1983 to succeed the Bartlesville Energy Technology Center (BETC). Its lead mission from the Office of Fossil Energy (FE) of the U.S. Department of Energy is to plan and implement research in the Enhanced Oil Recovery (EOR) and Advanced Extraction and Process Technology (AEPT) subprograms of the Petroleum Program. As such, BPO oversees some 160 research projects falling within these two broad subprograms and support activities. These projects, listed in Appendix A, form the major portion of DOE's National Petroleum Research Program, the critical aim of which is to arrest the decline of domestic oil production and to maximize economic recovery. The project contractual categories are given in Table 1.

Table 1: Project Funding Categories

TYPE OF PROJECT	NO. OF PROJECTS	PERCENT
Grants	38	23
Contracts	42	25
FWP's (Pass thru to National Labs)	20	12
PRDA/RFP	2	1
NIPER	49	29
SBIR	8	5
International	8	5
TOTAL	167	100

ABBREVIATIONS

FWP – Field Work Proposals
 PRDA – Program Research and Development Announcement
 RFP – Request for Proposal
 NIPER – National Institute for Petroleum and Energy Research
 SBIR – Small Business Innovation Research

BPO's responsibilities under this lead mission are to:

- Assist Headquarters (HQ) in program formulation
- Develop and execute implementation plans to reduce the level of well abandonments and thus preserve access to the known resource

- Develop and execute implementation plans to perform RD&D to maximize economic recovery of oil using advanced technologies
- Develop and execute implementation plans which advance oil production technology for the currently unrecoverable petroleum resource base
- Implement cross-cutting geoscience research along with other fundamental chemical, physical, and thermodynamic studies
- Implement EOR/AEPT technology transfer to the scientific and technical user community, especially the independent petroleum operators.

The EOR subprogram consists of two research categories: Light Oil and Heavy Oil. These two categories include research activities in: (1) geoscience and reservoir characterization, (2) chemical flooding (3) gas flooding, (4) thermal recovery, (5) novel technology, and (6) microbial EOR.

The AEPT subprogram includes research activities in (1) fundamental geoscience and extraction research, (2) supporting technology and environmental research, and (3) university geoscience research.

1.2 ORGANIZATION

As shown in the BPO organization chart (Figure 1), three program coordinators and seven project managers assist the BPO Director. In carrying out BPO's national research responsibilities, the Director reports to the Assistant Secretary for Fossil Energy. In executing BPO's lead mission in EOR and AEPT, the Director coordinates the programmatic activities with the Deputy Assistant Secretary for Oil, Gas, Shale and Special Technologies and the Deputy Assistant Secretary for Management, Fundamental Research and Cooperative Development (Figure 2).

BPO implements and coordinates its mission through management of research projects performed by:

BPO ORGANIZATIONAL STRUCTURE

Figure 1

- The National Institute for Petroleum and Energy Research (NIPER), which uses the DOE facilities and laboratory equipment at Bartlesville, Oklahoma
- Energy technology centers and national laboratories
- University and industrial research laboratories
- Joint research projects under cooperative agreements with foreign governments and international organizations.
- Joint research projects with oil-producing states, executed under Memoranda of Understanding (MOUs) by universities and/or state geological surveys.

In September 1990 BPO transferred technical management of selected projects to the Metairie Site Office (MSO). According to the MOU between the two offices, MSO will coordinate procurement actions

through BPO and provide support to BPO as agreed between the office directors.

1.3 PROGRAM FUNDING

The BPO budget for FY82-91 is shown in Figure 3. The sharp reduction in 1983 reflected the general shift of emphasis away from oil and gas research by the government and coincided with the defederalization of BETC and the advent of BPO and NIPER. The sharpest increases were between FY88 and FY89 (\$22.4 to \$29.6 million) and again between FY90 and FY91 (\$35.3 to \$41.8 million). The distributions among the three research areas for FY89-91 are as shown in Table 2.

ORGANIZATION SUPPORTING PETROLEUM R&D

* J. Batchelor until September 30, 1990

Figure 2

Table 2: Program Funding

Program	FY89	FY90	FY91
Light Oil	16,738	24,030	24,678
Heavy Oil	4,245	4,014	4,104
AEPT	3,674	2,663	10,077
Sub-total	24,657	30,707	38,859
Other Programs and Admin	4,913	3,637	2,977
Total	29,567	35,344	41,836

The increase in budget and programs has not been accompanied by a corresponding increase in the number of project managers. BPO manages the expanded program with the same personnel ceiling allocation as in 1983, with each project manager responsible for 18 projects, on average.

FY82-91

Figure 3

2.0 PROGRAM FOCUS & DIRECTION

2.1 PROGRAM FOCUS

The National Petroleum Research Program has evolved over the last 15 years, as illustrated in Figure 4. Since the last major revision of the EOR plan in the early eighties, the U.S. oil situation has changed significantly. These changes may be summarized as follows:

2.1.1 Domestic and World Oil Markets

Oil prices collapsed in early 1986 (nominally, from about \$27 to \$10 per barrel), but recovered to the \$14-22 range in the following three years. Since the Iraqi invasion of Kuwait on 2 August 1990, prices jumped to \$30-40 per barrel, then subsided to about \$20. With U.S. oil production still declining and oil demand rising, oil imports were increasing rapidly until August. In 1990 imports averaged 8.09 million barrels per day (BPD), accounting for 48% of the U.S. oil demand of 17.04 million BPD (Oil & Gas Journal, 28 Jan 1991). The domestic production decline has been accompanied by the plugging and abandonment of large numbers of marginal wells (16,100 wells in 1989), thus denying economic access to an increasingly significant portion of the remaining oil in place.

2.1.2 State of the Art

The following concepts have evolved over the last few years and now form the basis of the R&D program.

- Recognition of unrecovered mobile oil (UMO) as a major target (estimated 99 billion bbl) along with immobile residual oil left in the formation after waterflooding (estimated 242 million bbl)¹
- Understanding of reservoir heterogeneity as key in designing UMO or EOR projects
- Site-specific focus as key to integrating application-oriented R&D
- Hypothesis that reservoirs of similar geologic classes should have similar heterogeneities, and are thus expected to show similar response to a given recovery process.

2.1.3 Strategy

The Department of Energy has developed and just published the new National Energy Strategy (February 1991). The strategy confirms the recently evolved concepts of near-, mid- and long-term objectives, and emphasizes technology transfer and environmental protection. It also recognizes the urgency to avoid loss of economic access to the resource from premature abandonment of marginal wells.

In the last two years emphasis has been shifting from long-term high-risk R&D to maximizing productivity of the remaining oil in place (Figure 5). The refocusing of goals and objectives was supported by recommendations of three DOE studies:

1. Geoscience Research for Energy Security (1987), by the Energy Research Advisory Board.
2. Enhanced Domestic Oil Production Initiative (August 1988), by Fossil Energy.
3. Hydrocarbon Geoscience Research Strategy (June 1989), by the Hydrocarbon Geoscience Coordinating Committee.

These initiatives were discussed widely with industry and academia and led to the development of the Oil Research Program Implementation Plan (April 1990), by the Office of Fossil Energy. This plan, developed for the EOR subprogram, will henceforth be referred to as the Implementation Plan in this report.

The overall goal of the Implementation Plan is to maximize the economic producibility of the domestic oil resource. Its basic strategy is to support a prioritized, integrated, and interdisciplinary research, development and engineering program focused on the huge amount of oil left behind in reservoirs after conventional technologies have reached their economic limit.

These three objectives are to be pursued simultaneously; it is the expected timing of the results that differentiates them.

¹ As of 12-31-87. Source: BPO (TORIS) 1989, API/AGA 1980, EIA 1987.

1974: EOR RESEARCH PROGRAM ESTABLISHED

1974: EOR RESEARCH PROGRAM ESTABLISHED

1974

- Immediately after the oil embargo of 1973-74, federal EOR research was initiated under the belief that the technology need only to be demonstrated to be applied.
- A total of 27 demonstration projects were cost-shared with industry to prove the technology options -- with mixed results. Due to limited technical understanding of a very complex interaction between reservoir and process, the reasons for the successes and failures experienced in the field could not be adequately explained.
- Limited engineering research focused on the properties of residual, immobile oil and fundamental EOR extraction mechanisms.

1976-1980

- With the world oil price rise and shortages of 1979-80, EOR was again seen as a major domestic oil potential, requiring only economic incentives.
- The Tertiary Incentive Program granted price relief to over 400 projects designed to increase oil production.
- Resource analysis was initiated to identify the most promising types of reservoirs and to estimate overall EOR potential.

1976-80: RESOURCE ANALYSIS ADDED

Figure 4 – Evolution of National Oil Research

1981-89: TARGET AND SCOPE EXPANDED

1981-89: TARGET AND SCOPE EXPANDED

1981-1989

- As both cost-shared and incentive projects failed to produce significant oil, demonstrations were discontinued.
- Recognition that inadequate understanding of reservoir properties and fluid flow paths contributed greatly to project failures. This resulted in new reservoir characterization research.
- Discrepancy analysis, comparing predicted to actual project results, became central to technology assessment. Resource analysis was expanded in conjunction with the NPC study of the potential of EOR.
- Extraction research retained its long-range fundamental orientation toward immobile oil and EOR.

1989-1991

- Recognition of the potential of unrecovered mobile oil (UMO) and its recovery by infill drilling and advanced secondary techniques.
- The Oil Research Program Implementation Plan issued after peer review by industry and academia. The plan calls for field-testing of the geological similarity hypothesis (Sec. 2.1.2).

1989-91: RESERVOIR CLASSIFICATION EMPHASIZED

1990: RESERVOIR CLASSIFICATION EMPHASIZED

RD&D - RESEARCH, DEVELOPMENT AND DEMONSTRATION
D&E - DEVELOPMENT AND ENGINEERING

Figure 4 continued

Figure 5 – National Oil Research Program

2.2 PROGRAM DIRECTION: STRATEGY FOR THE NINETIES

The strategy of the National Petroleum Research Program in the seventies and eighties was to cost-share EOR demonstration projects with industry, and to conduct long-term, high-risk research. However, in the late eighties it became obvious that DOE/FE would have to shift its emphasis to near- and mid-term research, if only to preserve access to the remaining petroleum for applying advanced recovery methods.

The Fossil Energy strategy for the nineties, is contained in the Hydrocarbon Geoscience Research Strategy (June 1989) and the Oil Research Program Implementation Plan (April 1990).

DOE will implement this highly targeted research, development, and demonstration (RD&D) plan in collaboration with the states, industry, national laboratories, NIPER, and the academic community. The

program is focused on reducing the technical and economic constraints on producibility to realize the enormous potential of the resource remaining in known domestic reservoirs. Three time-specific, strategic objectives address this goal and the constraints on attaining it:

- *In the near term (within five years), preserve access to reservoirs with high oil recovery potential which are rapidly approaching their economic limits.* This objective poses three requirements:
 - a) Identification and selection, on a national basis, of the highest priority classes of reservoirs, i.e., those with greatest ultimate potential for recovery and greatest urgency due to well and field abandonments.
 - b) Identification of *currently available, economic* technologies that have proven effective in extending well life and their broader application to sustain production.
 - c) Development of a sound environmental program that addresses oil field operational problems in

such areas as waste disposal, injection practices, air quality, and other issues that may affect future productivity. The environmental program will also evaluate the potential of economically reversible well plugging techniques for situations where current production is uneconomic, but where the well may be an important access point for future production.

- *In the mid term (within ten years), develop, test, and transfer the best, currently defined, advanced technologies to operators of the reservoirs with the greatest potential for incremental recovery. This will require an integrated, interdisciplinary approach to field work, research, and technology transfer.*
- *In the long term, develop sufficient fundamental understanding to define new recovery techniques for the oil left after the most advanced, currently defined mid-term processes, and for major classes of reservoirs for which no advanced technologies are anticipated to be available in the mid term. The program will continue to support universities in the performance of this research to sustain the Federal Government's ongoing commitment to education.*

Pursuit of these strategic objectives entails a tightly integrated and focused RD&D approach that is guided by five basic tenets:

- a) *Be selective.*
- b) *Conduct field RD&D on the selected classes.*
- c) *Support field RD&D with targeted and discipline-oriented RD&D.*

d) *Exploit the available interdependencies and synergies.*

e) *Focus technology transfer activities.*

The objective, strategy, and management tactics of the program are described in the Implementation Plan. However, certain aspects of the Plan are preliminary in nature, such as the work in heavy oil, where the basic analysis required to identify the urgent issues affecting this resource has just started. Only a portion (about 40%) of the known U.S. resource has undergone the detailed assessment, classification, and analysis which is required for program planning. Classification and analysis of the full U.S. oil resource is expected to be complete by October 1992. Because of the abandonment urgency, work may be proposed in at least some of the priority classes as soon as they are identified, but before all of the classification work has been completed.

Finally, the field RD&D activities and supporting R&D projects are purposely non-specific in this Plan, because they must be detailed in response to the problems that will be identified as work begins with the states and industry on *specific reservoir classes*. The FY91 budget includes funds to begin work on the first two high priority reservoir classes to be identified as a result of the current national reservoir classification effort. The Implementation Plan will be revised annually, and more elements will become more explicit as the work proceeds.

In FY90 R&D was continued according to previous plans. FY91 is a transition year to the Implementation Plan, which should be well in place by FY92.

3.0 RESEARCH ACTIVITIES AND ACHIEVEMENTS

BPO is responsible to the DOE Office of Fossil Energy for the management of over 160 research projects conducted at NIPER, METC, national laboratories, universities and industry, and for overseeing joint projects with other countries under international agreements. This research effort falls into two broad subprograms:

1. Enhanced Oil Recovery (EOR) subprogram, executed under the Light Oil and Heavy Oil Enhanced Recovery Program Implementation Plans (PIPs).
2. Advanced Extraction and Process Technology (AEPT) subprogram, executed under the AEPT Program Implementation Plan (PIP).

Common elements of both subprograms are:

- Emphasis on geoscience research and reservoir characterization
- Tertiary Oil Recovery Information System (TORIS) analytical capabilities for resource assessment
- Technology transfer to industry

3.1 EOR SUBPROGRAM

The work breakdown structure and the logic of the EOR research program are shown in Figures 6 and 7. In FY90 BPO:

- Continued cooperative research projects in reservoir characterization, mainly through state Memoranda of Understanding (MOUs).
- Continued and expanded the Oil Recovery Technology Partnership between national laboratories (Sandia and Los Alamos) and industry.

- Supported field-project research in horizontal wells in California and Oklahoma, in measuring wellbore heat losses during steamflooding in California, and in expanding the MEOR field test in Oklahoma.
- Provided direction for fundamental research in geoscience and EOR processes.

Significant achievements of research activities in FY90 are summarized under each of six EOR activities: geoscience and reservoir characterization, chemical flooding, gas flooding, thermal recovery, novel technology and microbial EOR.

For many years, DOE supported R&D and field testing of miscible CO₂ flooding in light-oil reservoirs and steam flooding in heavy-oil reservoirs. Both techniques are now applied in the field as commercial processes. Thus, oil companies are now conducting only applied research in these two processes, mainly to solve field problems as they arise. DOE has continued to fund R&D in reservoir characterization, aimed at improving sweep efficiency, and hence oil recovery. Research in chemical flooding, for which there is an enormous oil potential, was funded at a high level by both industry and DOE for many years. Since 1986, however, oil companies have severely curtailed research activity in this area, leaving the government as the main source of funding.

In 1989 EOR production in the United States was about 708,000 BPD, or 9.3% of total crude oil production (7,631,000 BPD). The contribution of the different EOR processes are as shown in Table 3.

It is clear from Table 3 that steam injection is still the dominant EOR method, accounting for 70% of the total. For light oil, CO₂ injection is the largest contributor, increasing to 13.5% of the total. Altogether, production due to gas flooding has steadily increased over the last decade. Production by chemical flooding peaked in 1987; record production by thermal methods was set in 1988.

Table 3:
1989 EOR Production in the United States

Process	EOR Production	
	BPD	% of Total EOR Production
Thermal		
Steam	495,600	70.0
In situ combustion	6,100	0.9
Hot water	4,000	0.6
	505,700	71.5
Chemical Flooding		
Polymer	11,200	1.6
Micellar-polymer	600	0.1
	11,800	1.7
Gas Flooding		
Miscible CO ₂	95,600	13.5
Hydrocarbon gases	55,400	7.8
Nitrogen	22,300	3.1
Flue gases	17,300	2.4
	190,600	26.8
Total	708,100	100.0

Source: Figures based largely on the Oil & Gas Journal 1990 EOR Survey (April 23, 1990, p. 52), except for steam injection. The OGJ attributes 444,000 BPD to this process, but the California Department of Conservation 1989 report shows 498,500 BPD thermal recovery for California alone. After allowing for California production due to hot water and in situ combustion, the reconciled data are as shown.

3.1.1 Geoscience and Reservoir Characterization

Within the EOR subprogram, geoscience research is focused on improving the understanding of reservoir rock properties that constrain production and effectiveness of EOR processes. Rock heterogeneities that impact production occur at all scales, from within single pores (microns to millimeters) to between fields (tens of kilometers). A significant portion of the geoscience activity is focused at the interwell scale (hundreds of meters) in known fields. This research has the potential to increase production of mobile oil, at oil prices in the \$15-20/bbl range in the near to mid term, through targeted infill drilling and more efficient waterflood and EOR technologies.

The objectives of this activity are to:

- Apply currently available technology to characterize known reservoirs for increased recovery (near-term research)
- Improve understanding of reservoir heterogeneities and their effect on fluid flow in the reservoir, especially at the interwell scale (mid-term research)
- Develop instrumentation for measuring reservoir rock and fluid properties, and develop analytical and modeling techniques to design and interpret the measurements (mid-term research)

- Improve fundamental understanding of reservoir phenomena applicable to improved hydrocarbon recovery (long-term research)

In December 1989 BPO selected 18 proposals from the geoscience (13) and MEOR (5) research solicitation (PRDA). The projects range from general studies of reservoir architecture to the use of luminescent bacteria as "tracers" in studying the flow of fluids through oil-bearing formations. The selected organizations, representing universities and small companies in six states, will contribute \$3.28 million of the project funding over three years. DOE's share will amount to \$8.14 million.

Proposals from the Small Business Innovation Research (SBIR) program also complemented the geoscience initiative. Five Phase I grants of nearly \$50,000 each were awarded in enhanced recovery and geoscience research, and two were extended as Phase II projects, with funding of nearly \$500,000 each.

The following five research projects (from a total of 37 projects listed in Appendix A) illustrate the progress in geoscience in FY90.

3.1.1.1 Resistivity Measurements in Cased Wells

Contractor: ParaMagnetic Logging, Inc.

A resistivity logging device has been designed and built to measure the electrical resistivity of geologic formations behind the well casing. The measurement is equivalent in accuracy to the conventional, open-hole laterolog. The tool can be used for interpreting the presence of water or oil in old wells, and for locating by-passed oil. ParaMagnetic has completed testing the tool at depth stations in a test well, and is developing a "measure-while-moving" version. Final design and fabrication of the moving version are under way. The apparatus and technique were demonstrated to representatives from BPO, Arco, British Petroleum and Mobil.

This tool could have an important role in DOE's initiative to maintain production from domestic reservoirs. By providing industry with a fast, efficient method of identifying bypassed oil and gas in fields with cased wells, the tool could help avoid premature well abandonment and expensive redrilling.

3.1.1.2 Predicting Reservoir Variation

Contractor: National Institute for Petroleum and Energy Research (NIPER)

The methodology developed for integrated characterization of barrier-island reservoirs was used to complete the study of one reservoir (Bell Creek, Wyoming) and to start another (Patrick Draw, Wyoming). The objective of this comprehensive methodology is to predict oil saturations at interwell scales and flow patterns of injected and produced fluids.

Figure 6 – Work Breakdown Structure, EOR Subprogram

Figure 7 – Logic Flow Diagram of EOR Research Subprogram

After data review of many shoreline-barrier reservoirs, NIPER studied four candidate reservoirs and selected the Patrick Draw field which produces from the Almond formation. Although similar to Bell Creek in many aspects (both Cretaceous sandstone reservoirs deposited in barrier-sandplain setting) they also have differences. Detailed characterization of the Almond formation, which comprises study of both subsurface and outcrop data, is under way. Characteristics are being compared with those of the Muddy formation in Bell Creek.

Publications: Two DOE reports, three papers and three SPE presentations

3.1.1.3 Characterization of Carbonate Reservoir Heterogeneity

Contractor: Geological Survey of Alabama

This is a comprehensive characterization study of the Jurassic Smackover formation in southwest Alabama. The work has included detailed analysis of cores from 19 fields, logs from 70 fields, and thin sections from seven fields. Reservoir heterogeneities were recognized and used to produce maps, cross sections, etc. to aid in interpreting geologic parameters that affect reservoir performance. Ten fields were selected to represent the range of geologic diversity of the 70 Smackover reservoirs in the study area. An equation for heterogeneity ranking was developed, leading to a rating system of candidates for infill drilling or EOR projects.

Publications: One report

3.1.1.4 In-situ Stress and Fracture Permeability

Contractor: Sandia National Laboratory (SNL)

In this cooperative project between Phillips Petroleum and SNL the objective is to quantify the influence of stress (net overburden pressure) on permeability and fractures of a naturally fractured reservoir. Oil and gas production from the Ekofisk field, operated by Phillips in the North Sea, over the last 20 years has caused reservoir compaction and subsidence due to pressure depletion.

SNL conducted stress measurements on cores and Phillips obtained stress and fracture data from the field. The laboratory and field data are being integrated. A radial stress pattern was identified.

Several companies have contacted SNL for similar work on a U.S. reservoir.

Publications: Seven papers presented at 11 symposia

3.1.1.5 Application of Multitracer Technology to Reservoir Studies

Contractor: Brookhaven National Laboratory

In this project perfluorocarbon tracers (PFC) are used to label gas or water injected into a reservoir, to

aid in elucidating reservoir rock properties and accessibility of the remaining oil. Laboratory and field studies are being conducted by both Brookhaven and the Norwegian Institute for Energy Technology under the DOE/Norway MOU.

Sampling techniques have been developed and enhanced following studies in the Gullfaks field in the North Sea. A technique for tagging sea water with PFT was tested at the Ekofisk and Gullfaks fields.

Discussions are under way with NPR-1 (Elk Hills, CA) to apply the multitracer techniques in monitoring waterflood performance.

Publications: Two reports

3.1.2 Chemical Flooding

Vast amounts of immobile oil left in most reservoirs after waterflooding are prime candidates for recovery by surfactants, if economic surfactant formulations can be found for various reservoir conditions. The goals of this activity are to:

- Extend the application range of chemical flooding methods to reservoirs with higher water salinity and hardness, temperature and oil viscosity.
- Increase understanding of the mechanisms and effectiveness of injected fluids to overcome viscous and capillary forces that retain immobile oil.
- Develop methods to increase the productive life of marginal wells, and assess the economics of field-scale applications.

This activity comprised 10 projects in FY90 (Appendix A).

The following are some of the significant accomplishments.

3.1.2.1 Improved Alkaline Flooding

Contractor: NIPER

Over 50 alkaline flooding projects have been implemented in U.S. oil fields. Although alkaline agents have worked in the laboratory in mobilizing residual oil, field results have been disappointing. The biennial surveys of EOR projects published in the *Oil & Gas Journal* show virtually no oil produced by this process.

Research over the last few years at NIPER and elsewhere can now explain the failure of the field tests. NIPER has found that low pH, surfactant-alkaline formulations will have a better chance of success in the field, for the following reasons:

- Reaction kinetics between strong alkalis, e.g. caustic soda (NaOH), and minerals are overwhelming, with excessive consumption of alkali by interaction with the rock.
- Weaker alkaline agents, e.g. sodium bicarbonate (NaHCO_3), react with acidic oils to produce sur-

factants in situ. However, the amount of surfactants extracted from the oil is smaller than for stronger alkaline agents, and the interfacial tension (IFT) reduction is smaller. By adding very low concentrations of synthetic surfactant, the IFT is reduced sharply and more oil is mobilized.

- NaHCO_3 protects the surfactant against divalent cations, and reduces adsorption of surfactant and polymer on the reservoir rock.

Results of this research are being used to design a field pilot test of surfactant-enhanced alkaline flooding in a deltaic reservoir in Kansas. This project will be cost-shared with an oil producer and chemical companies.

Publications: One DOE Report

3.1.2.2 Modeling and Scale-up of Chemical Flooding

Contractor: University of Texas at Austin

This integrated, interdisciplinary research program included significant components of laboratory experiments, physical property modeling, scale-up theory, and numerical analysis. The UTCHEM simulator was used to help understand basic process mechanisms, develop better methods of chemical flooding and help select the best chemicals, process design and process parameters for given reservoir characteristics. UTCHEM was improved to include tracers, polymers, polymer gels, surfactants, and alkaline agents. Improvements made in both the physical-chemical and numerical aspects of UTCHEM enhanced its versatility, accuracy and speed. Supporting experimental studies included relative permeability and trapping of microemulsions, tracer flow studies, oil recovery in cores using alcohol-free surfactant slugs and viscosity measurements of microemulsions. The research performed has added significantly to the knowledge of chemical flooding. The simulator was validated using field data from Conoco and Sun Oil companies.

Publications: One DOE Report

3.1.2.3 Sweep Improvement with Chemical Gels

Contractor: New Mexico R&D Institute

Polymer gels and other types of chemical gels are being investigated as diverting agents of injected fluids (water or gas) from high-permeability paths to unswept regions of the reservoir. The objectives are to identify the diverting mechanisms and to determine where and how gel treatments are best applied. A resorcinol-formaldehyde gel was studied extensively. It was found that gelation was very sensitive to pH, the residual resistance factor decreasing from about 1000 at pH of 7 to about 1 at pH 6. Other gels were investigated and a

mathematical study was performed to characterize gel placement in producing wells.

Publications: Eight reports and three papers

3.1.2 Gas Flooding

In 1989 gas flooding, excluding gas injected strictly for pressure maintenance, contributed 190,600 BPD of oil production. Of this, miscible CO_2 injection accounted for 95,600 BPD, making it the principal EOR method for light oil (Table 3).

The main objective of this research activity is to improve volumetric sweep efficiency or reservoir conformance. A specific objective is to increase understanding and effectiveness of agents (foams and gels) and processes that reduce permeability contrast and/or control mobility of injected fluids. Seven projects were performed in this activity (Appendix A).

3.1.3.1 Scale-up of Miscible Flood Processes

Contractor: Stanford University

The objective of this project is to quantify the relative importance of viscous instability (viscous fingering), reservoir heterogeneity and gravity segregation to the behavior of miscible floods. Reservoir simulations of process performance can then focus on the most important factors that control reservoir-scale displacement performance. The research is divided into three areas: (1) phase behavior, (2) patterns and scales of nonuniform flow, and (3) interactions of nonuniform flow, cross flow and phase behavior. In one facet of this research, detailed comparisons were made between measured finger patterns and particle-tracking simulations. The agreement obtained indicates that the simulator captures the essential physical mechanisms of viscous fingering. This project is supported by 13 oil companies.

Publications: One report and eight papers.

3.1.3.2 CO_2 Sweep Improvement with Foams

Contractor: University of Texas at Austin

The tendency of less viscous CO_2 to by-pass large volumes of oil diminishes the economic viability of EOR projects using CO_2 injection. Foams formed in situ represent a possible means for controlling CO_2 mobility, but the process is complex. One area of research is to maintain water wettability of the rock so that foam could form. Work in FY90 was focused on the stability of thin aqueous films and liquid lamella at pore throats. The main results relate to the theoretical method used in determining stability and implementing the method. Future work will stress the practical implications of this result.

3.1.3.3 Cyclic CO₂ Injection for Light Oil Recovery

Contractor: Louisiana State University

Laboratory corefloods and field tests have shown that oil recovery by cyclic (huff-n-puff) CO₂ injection to be technically feasible, environmentally safe and economically attractive. In FY90 corefloods were performed to determine the effects of gravity segregation, oil saturation and the presence of a gas cap. The laboratory results were matched using a compositional simulator. Results indicate that gravity segregation, the presence of a gas cap and higher oil saturation improve process performance.

Five well sites were considered and one was selected for testing. Meetings were held with oil operators to disseminate technical information, and project personnel have assisted independent oil producers in planning field projects.

Publications: One paper, presented to 1990 SPE annual meeting

3.1.4 Thermal Recovery

In 1989 U.S. oil production by thermal methods was about 505,700 BPD. Some heavy oil is also produced by primary recovery and by waterflooding. Total heavy oil production in the United States is about 900,000 BPD, mostly from California. By far the main thermal recovery method is steam injection (both steamflooding and steam cycling), accounting for about 495,600 BPD in 1989, compared with only 6,100 BPD by in situ combustion (Table 3).

The primary objective of the Heavy Oil Enhanced Recovery category is to maximize the economic producibility of the U.S. heavy oil resource by overcoming technical and economic constraints on production. Specific objectives are to:

- Increase predictability of reservoir performance of heavy oil processes through improved understanding of fundamental recovery mechanisms at reservoir conditions and through improved reservoir description.
- Improve the recovery efficiency of thermal-recovery processes by determining the most suitable recovery mechanisms for each set of reservoir properties and the range of application of chemical additives for increasing mobility control and volumetric sweep efficiency.
- Extend the range of application of thermal processes to thinner, deeper, and more heterogeneous reservoirs.
- Assess the technical viability for additional economic recovery of heavy oil by novel and other processes not presently in extensive use in heavy oil recovery.

The following are some of the more significant research accomplishments in FY90. The 13 projects performed are listed in Appendix A.

3.1.4.1 Recovery Mechanisms in Heavy Oil Reservoirs

Contractor: Stanford University Petroleum Research Institute

This project represents the broadest fundamental research directed toward increasing recovery from heavy-oil reservoirs, and covers five areas: (1) flow properties, (2) in situ combustion, (3) steam additives to improve mobility control, (4) reservoir description, and (5) field support services. The research program is cost-shared by DOE and 13 oil companies. Some highlights are:

- CT scanning was used to determine 2-phase saturations in a variety of experimental conditions and to characterize fractures.
- Multiphase flow with temperature changes was described mathematically.
- Effect of metal additives on performance of in situ combustion was studied in tube experiments.
- The effect of foaming agents on steamflooding was examined using a variety of laboratory (physical) models. One is a 2-dimensional micromodel (silica wafer bonded to a glass plate) connected to a videodigitizer. A 3-dimensional model was built in aluminum to be used under CT-scan.

SUPRI continues to be a leader in technology transfer through its many publications.

Publications: Twelve DOE reports and five papers.

3.1.4.2 Chemical Additives to Steam

Contractor: University of Southern California

In FY90 emphasis was placed on experimental aspects of foam generation and propagation. Corefloods were conducted at fixed surfactant and brine concentrations. Variables studied included liquid and gas rates and the use of "pre-foamer" before steam injection. It was found that without a pre-foamer it took a long time for the injected gas and surfactant solution to form a strong foam. This "incubation" period decreased with increasing flow rates.

New features regarding 3-phase relative permeabilities, phase behavior and vertical equilibrium were added to the steam-chemical simulator

The use of foams to improve vertical sweep efficiency, by reducing steam override, is of direct practical interest in thermal EOR.

Publications: Four DOE reports and four papers on this study and others under the research project, "Modification of Chemical and Physical Factors in Steamfloods to Increase Heavy Oil Recovery."

Co₂ flooding laboratory. University of Texas at Austin.

Steam foam 1-dimensional model.
Stanford University Petroleum Research Institute.

Monitoring 2-dimensional steamflood experiment that will measure the gravity override effects and resulting residual oil saturation for a crude oil in a sandpack. National Institute for Petroleum and Energy Research.

A core sample moves through the CT scanner. National Institute for Petroleum and Energy Research.

3.1.4.3 Sensing Methods for Thermal EOR

Contractor: Lawrence Livermore National Laboratory (LLNL)

The purpose of this ongoing research project (since 1984) is to develop and employ field techniques for monitoring in situ changes in electrical conductivity (or resistivity) of oil-bearing strata during EOR operations. Cross-borehole electromagnetic induction (EM) is used to monitor the front of injected steam or chemical or water as it propagates from the injection wells. This research is being supported by industry through a consortium of LLNL/UC/Industry at Berkeley.

In cooperation with Lawrence Berkeley Lab and UC Berkeley, LLNL developed a powerful crosswell EM field system. This is capable of operating at depths up to 1500 m (5000 ft) and well spacings over 200 m (660 ft), compared with the 1989 prototype which was limited to 100 m (330 ft).

The new system was tested during FY90 at the Richmond Field Station, California during waterflooding, at a waterflood in the BP/SOHIO Devine Field, Texas, and in a special test at Mobil's South Belridge field, California to test surface-to-borehole measurements. The system will be used at a Mobil steamflood site in the Lost Hills field, California in 1991. The data obtained indicate that the EM system is applicable to low-temperature (waterflooding) environment. The data that will be gathered at the steamflood site will determine if the system is also applicable to the high-temperature environment of steamfloods and firefloods.

Publications: One DOE report and one paper.

3.1.4.4 Feasibility Study of Heavy Oil Recovery in the Mid-Continent

Contractor: NIPER

By far most of the U.S. heavy oil production is from California. The purpose of this study is to determine: (1) the heavy oil resource of the Mid-Continent region (Oklahoma, Kansas and Missouri), (2) if EOR processes can be applied to establish a viable heavy oil industry in the Mid-Continent, and (3) the capabilities of local refineries to process heavy oil. The reservoir database established shows that most of the heavy oil is contained in small reservoirs of less than 20 million barrels each. These reservoirs are amenable to steaming by independent oil operators. The report being compiled will help independents to determine the applicability of steam injection in their leases.

3.1.4.5 Measuring Wellbore Heat Losses

Contractor: Kawasaki Thermal Systems

This research was undertaken to obtain heat-loss

data from an active steam injection well. The data were used in validating a comprehensive PC-program to compute wellbore heat losses. The program is particularly suitable for use by independent oil operators. Major oil companies will also have a body of valid heat-loss data.

A well was drilled and completed in Texaco's Kern River Field, California specifically for this study. Six tests, covering the entire spectrum of insulation methods, were conducted during steam injection.

Publications: Paper presented at the SPE Thermal Operations Symposium in Feb 1991.

3.1.5 Novel Recovery Technology

The R&D objectives of this activity are to:

- Identify and assess the feasibility of novel extraction technologies by literature search, laboratory tests, numerical simulation, and by soliciting proposals from industry and the research community.
- Demonstrate technology applications and assess process economics and environmental acceptability through cost-shared field test.
- Transfer the technology to industry.

Five projects were carried out in FY90 (Appendix A).

3.1.5.1 Horizontal Drilling

Contractor: Rougeot Oil & Gas Company

In this cost-shared project with an independent oil operator, a medium-radius horizontal well was drilled in the Bartlesville sand of the North Flatrock field, Oklahoma. This low-permeability reservoir is underlain by an aquifer and has not been waterflooded. The well was completed at a depth of 1400 ft with a horizontal portion of 1053 ft. Production since June has averaged 7 BOPD and 1 BWPD, compared to an offset, unstimulated, vertical well producing 1.5 to 5 BOPD and 10 BWPD. The operator plans to stimulate the horizontal well.

Publications: One report

3.1.5.2 Innovative Drilling for Steam Injection

Contractor: Petrolphysics, Inc.

The purpose of this project was to demonstrate a drilling-completion system with multiple, short laterals drilled from a vertical well, to alleviate steam override in steamflooded reservoirs. In March 1990 a well was drilled on a Unocal lease in the Midway-Sunset field in California. Four radial holes (71 to 106 ft long) were placed in the Potter C sand at a depth of about 880 ft and completed with gravel-packed liners. The well has produced since July at rates exceeding 50 BOPD, compared with an average of 30 BOPD for nearby vertical wells.

3.1.6 Microbial EOR

The objectives of the microbial EOR (MEOR) activity are to:

- Identify and develop microbial extraction concepts and technology requirements
- Examine metabolic and biochemical characteristics of microbes for:
 - In-situ generation of surfactants, polymers and solvents
 - Selective permeability alteration
 - Wettability alteration
 - Other rock/fluid modifications
 - Reducing production of H_2S dissolved in the reservoir oil
- Conduct controlled field tests to determine incremental recovery due to the MEOR process, and to assess the process efficiency, economics and environmental impact.

Laboratory and field research demonstrated the use of microorganisms to recover more oil from depleted reservoirs. Gases, surfactants, polymers, acids and alcohols are products of microbial metabolism. Improved recovery is attributed to some of these products and to their interactions with reservoir rocks and fluids. Field tests have mostly been single-well stimulation treatments, and a few microbial-enhanced waterfloods. MEOR has had a long history of use in mature oil fields where improved production is difficult to document. As a result of this lack of scientific rigor, the ability of MEOR to recover incremental oil has not been quantitatively demonstrated. Therefore, recent emphasis has been on designing microbial systems and documenting their actual behavior to understand the processes that result in increased oil production.

In FY90 five contracts were awarded for MEOR research as a result of a competitive solicitation (PRDA). These should expand the potential applicability of MEOR to carbonate reservoirs, and will include use of indigenous bacteria and use of bioluminescent bacteria as tracers. Altogether this activity included 11 projects in FY90 (Appendix A).

3.1.6.1 MEOR Waterflood Field Test

Contractor: NIPER

The National Institute for Petroleum and Energy Research (NIPER) is expanding its field project in Nowata County, Oklahoma to a full-field test. The initial phase of the project, testing the feasibility of improving oil recovery in an ongoing waterflood using microorganisms, was concluded in December 1989. Results from the test in a four-well section of the Mink Unit in Nowata County showed an overall 13% increase in oil production.

NIPER is conducting a larger demonstration project to assess full-scale field economics of MEOR in a 520-acre site in the Rogers County Chelsea-Alluwe field that includes 19 injection wells and 47 production wells. Interwell fluid flow communication was tested in early June 1990 using fluorescein tracer, and injection of NIPER's microbial formulation was initiated later in the month. Nutrient is being continuously injected. As a result, production decline has been arrested, the average monthly oil production increasing from 800 bbl in Jan-Apr 1990 to 880 bbl in Jul-Oct 1990.

Publications: Two presented at the 1990 International Conference on MEOR, four other presentations and seven reports.

3.2 AEPT SUBPROGRAM

Figure 8 shows the work breakdown structure of the Advanced Extraction and Process Technology (AEPT) research subprogram. The objectives of the AEPT subprogram are to:

- Ensure that fundamental R&D needs of oil, gas, oil shale, tar sands and underground coal gasification (UGC) are appropriately addressed in an environmentally acceptable manner.
- Perform cross-cutting geoscience research to develop technology to quantify reservoir parameters and to evaluate extraction processes. A further objective is to transfer this technology as it is developed to petroleum producers.
- Perform R&D to develop: (1) procedures for characterizing alternative feedstocks to produce high-quality fuels, and (2) thermodynamic data essential to fuel production.
- Perform R&D toward developing new extraction technologies.

Significant achievements of research activities in FY90 are summarized under each of three activities: (1) fundamental geoscience and extraction research, (2) supporting technology and environmental research, and (3) university geoscience research.

3.2.1 Fundamental Geoscience and Extraction Research

This activity focused on the development of advanced instrumentation for reservoir property measurements and characterization, and included four projects (Appendix A).

Figure 8 – Work Breakdown Structure, AEPT Subprogram

3.2.1.1 Reservoir Imaging: Pore Structure Analysis of Reservoir Rock

Contractor: NIPER

In FY90 NIPER developed methods to compute porosity, permeability and saturation distributions in cores from CT scans and thin-section image analysis, and increased resolution of the NMR imaging system. A multi-scale approach was taken by using CT, NMRI, micromodels and thin sections.

Observations were made of the influence of both low- and high-permeability layers on oil and water distribution during and after drainage and imbibition. It was found that when capillary forces dominate, rock heterogeneities have a more pronounced effect on the initial oil saturation than on the residual oil saturation after waterflooding.

Publications: Five DOE reports and two presentations to the SPE and Society of Core Analysis annual meetings.

3.2.1.2 Crosswell Seismic Surveys

Contractor: Sandia and Los Alamos National Laboratories (Oil Recovery Technology Partnership)

This was the first collaborative project of the Oil Recovery Technology Partnership, launched in FY89. The Crosswell Seismic Forum now consists of representatives from 23 companies. In crosswell surveys a seismic signal is generated in a well and response is monitored by receivers placed in adjacent wells. A detailed tomographic image of the reservoir is produced. Sandia, together with two subcontractors, is developing a multi-station, 3-component seismic receiver for more effective crosswell surveys. A single-station prototype receiver, to operate at 200 °C and 10,000 psi (69 MPa), has been fabricated. This is a small, clamped receiver developed following an extensive mechanical design effort.

Six borehole seismic sources were tested at Texaco's test site in Humble, Texas. These were Sandia's pneu-

matic vibrator, Chevron's hydraulic vibrator, two Bolt Technology borehole airguns, Exxon's multi-level explosive and Teledyne's sparker.

In a parallel effort, Los Alamos worked with three major oil companies and Stanford University to apply crosswell seismic technology to image a fault in the Potter sand (heavy oil reservoir) of the McKittrick field in California. Two sets of surveys were made using three wells. High-quality signals were acquired from 576 propagation paths encompassing the fault zone.

Publications: Two papers, one DOE report and a presentation to the SEG annual meeting.

3.2.2 Supporting Technology and Environmental Research

Cross-cutting research was continued in petroleum chemistry, focusing on structural characterization of heavy crudes, intermediate process streams and products.

This activity consisted of four projects in FY90 (Appendix A).

3.2.2.1 Analytical Methodology for Heavy Crudes

Contractor: NIPER

Information from a 10-year program to develop new methodology, to analyze and characterize heavy crude oils, was accumulated and published as a two-volume book. This information is now being used by industrial and academic scientists. The fundamental heavy petroleum study continues with emphasis on structural reasons for pre-coking and the nature of the undesirable metallic compounds in crude oils.

Publications: Two-volume DOE report and others.

3.2.2.2 Thermochemical and Thermophysical Properties of Organic Nitrogen and Diheteroatom Compounds

Contractor: NIPER

The measurement of precise thermochemical and thermophysical properties of selected "key" organic nitrogen compounds, found in heavy petroleum, shale oil and coal liquids, was continued. These data are being assembled into a database which is nearing completion. Preliminary analysis of the available data indicates that commercial nitrogen-removal processes are being operated under inefficient conditions that produce uneconomic results.

Publications: Five reports

3.2.3 University Geoscience Research

This activity comprised 10 projects in FY90, as listed in Appendix A.

3.2.3.1 Facies and Permeability Patterns in Carbonate Reservoirs

Contractor: University of Texas/Bureau of Economic Geology

The objective is to characterize the facies and permeability patterns in the outcrops of the Permian San Andres formation. In FY90 regional and detailed-sequence stratigraphic frameworks were established for the Irabane Tank Study area where this formation outcrops. Several hundred whole cores, core plugs, and their thin sections were analyzed, and a petrographic/petrophysical database was set up. A comparable database of subsurface data was obtained from the Seminole San Andres Unit. A major review meeting was held in September 1990 with 65 representatives of the ten sponsoring companies, academia and DOE.

Publications: Two papers and two presentations at the SPE Forum in Colorado and the IEA-EOR workshop in Paris.

3.2.3.2 Analysis of Reservoir Heterogeneities

Contractor: University of Alaska

The objective is to develop generic interpretations of depositional environments that can be applied to carbonate reservoirs through the study of the Lisburne Group which outcrops in NE Alaska. A computerized database was developed for petrographic and biostratigraphic data. A geological field study in the Arctic National Wildlife Refuge was completed. The location of the Pennsylvanian-Mississippian boundary in the Wahoo formation was determined from biostratigraphic studies. A major review meeting for industry sponsors was held in February 1990.

Publication: Four papers

3.2.3.3 Demonstration of High-Resolution Inverse VSP

Contractor: Southwest Research Institute (SwRI)

The objective of this study is to eliminate the detrimental effects of the weathered zone on seismic signals. Downhole-sensor planting techniques and instrumentation were developed and evaluated under controlled field conditions for high-resolution inverse VSP measurements. In FY90 SwRI: (1) modified a commercial 3-component VSP tool to contain sensitive high-frequency accelerometer sensors, (2) constructed pneumatically clamped 3-component detector with shielded circuits in the conductor cable, (3) recorded 3-component seismic data using an experimental, high-frequency, inverse VSP system, and (4) selected a British Petroleum field site near San Antonio, Texas.

3.2.3.4 Characterization and Modification of Fluid Conductivity in Heterogeneous Reservoirs

Contractor: University of Michigan

Work accomplished has demonstrated the ability of neutron radiography to characterize flow heterogeneities in reservoir rocks. Four successful techniques, to divert injected fluids into lower permeability rock, were also achieved. These were: (1) particulate injection, (2) in-situ precipitation, (3) bacterial plugging, and (4) stabilized foam.

Publications: Annual report and one paper

3.3 TERTIARY OIL RECOVERY INFORMATION SYSTEM (TORIS)

The Tertiary Oil Recovery Information System (TORIS) is the most comprehensive analytical system of EOR experience in the United States. It includes three databases and several models for predicting oil recovery and economics:

- Databases
 - EOR project database, a file of previous and current EOR projects
 - Reservoir/geological information of major U.S. oil fields
 - Comprehensive database of crude oil properties
- Reservoir Modeling
 - BOAST II, a 3-dimensional 3-phase (black oil) simulator
 - EOR predictive models, including economic analysis
 - Horizontal/slanted lateral well model

The National Petroleum Council (NPC) evaluated and updated the reservoir database in its 1982-84 study. BPO has since added and updated production data needed to analyze decline curves, oil reserves, stripper well status, etc. Working with the Interstate Oil Compact Commission (IOCC) and state agencies, BPO completed the reservoir database for New Mexico,

Oklahoma and Texas. The database is being expanded to 22 other states, including Kansas, Louisiana, Alabama and Mississippi. New geologic data are being added to analyze reservoir heterogeneities and upswept mobile oil. When complete, TORIS will be the only reservoir database capable of examining the entire U.S. oil resource.

The reservoir models are distributed to industry free of charge. BOAST II, in mainframe and PC versions, is used to simulate reservoir performance under primary or secondary (waterflooding or gas injection) recovery. The EOR predictive models are simple, mechanistic models, designed for a PC or a mainframe computer. These models generate a projected oil rate vs. time curve for the reservoir (actually for a single well pattern). This predicted production profile is then entered into the economic analysis program to compute discounted cash flow and various profitability indicators. Predictive models are available for steam-flooding, in situ combustion, polymer, surfactant and CO₂ miscible floods. Predictive models for infill drilling and permeability profile modification are being developed.

DOE continued its use of TORIS in analytical activities during FY90, as summarized in Table 4. There were seven resource assessment projects related to TORIS (Appendix A).

There were two peer reviews of TORIS in FY90. In October 1989 the IOCC Subcommittee on Residual Oil Saturation, meeting in San Antonio, discussed the systematically high estimates of OOIP in TORIS, according to some IOCC members and other industry specialists. The subcommittee concluded that the 1984 NPC estimates, which form the basis of the TORIS data, were essentially correct.

A TORIS peer review by industry representatives was undertaken between October 1989 and July 1990. This included a 2-day workshop in Houston in November 1989, attended by experts from Shell, Chevron, Conoco, Texaco, University of Kansas, Oklahoma Geological Survey and consultants. They recognized the value of TORIS to the industry and the nation and endorsed its basic structure and direction. They also recommended changes which have been incorporated following the meeting.

TABLE 4
MAJOR TORIS PROJECTS COMPLETED IN FY90

PROJECT	START DATE	END DATE	PERFORMED FOR	NO. OF OIL PRICES	RANGE OF OIL PRICES	TECHNOLOGY LEVEL ANALYZED	SCOPE OF ANALYSIS
Preliminary analysis of EOR and UMO potential in Texas	Nov 88	Dec 89	IOCC	7	\$12-\$36	IMP/ADV*	-NPC fields only -EOR and UMO processes -Base tax structure -State severance tax incentives
Evaluation of remaining oil resources in Texas	Apr 89	Jan 90	IOCC	7	-----	IMP/ADV	-EOR and UMO -Tax incentives
Preliminary assessment of EPA oil and gas waste management regulations	Apr 89	ongoing	DOE	4	\$14-\$32	IMP	-EOR and UMO resources in TX, OK and NM -Up to 10 regulatory scenarios
Analysis of federal policy options to increase oil recovery from domestic reservoirs	May 89	ongoing	DOE	7	\$12-\$36	IMP/ADV	-EOR & UMO processes -Fields in TX, OK & NM -Base tax structure -Up to 3 federal tax incentive options -State tax incentives -Combined state/federal tax incentives

* IMP Implemented Technology

ADV Advanced Technology

PROJECT	START DATE	END DATE	PER-FORMED FOR	NO. OF OIL PRICES	RANGE OF OIL PRICES	TECH-NOLOGY LEVEL ANALYZED	SCOPE OF ANALYSIS
TORIS Peer Review: Industry review of all modifications to the TORIS models	Oct 89	Aug 90	BPO/ Industry	--	-----	-----	Review of: -Infill drilling methodology -Economic upgrades of the EOR models -Other technical modifications
Cumulative impact of environmental legislation on domestic EOR production	Nov 89	Feb 90	DOE	4	-----	IMP/ADV	-EOR and UMO -Clean Water Act -RCRA -Clear Air Act
Assessment of environmental regulations on U.S. oil production and reserves	Jan 90	Mar 90	DOE/OPE	4	\$16-\$30	IMP/ADV	-2500 reservoirs -UMO/EOR processes -Conventional recovery using decline curve analysis
Potential impact of state tax incentives in New Mexico	Mar 90	Apr 90	State of New Mexico	4	-----	IMP	-CO ₂ flooding -Reducing severance tax rate by half until project payback
Multi-state Project: Evaluation of recovery potential of remaining mobile and immobile oil in 25 states	Apr 90	ongoing	IOCC	7	\$12-\$36	IMP/ADV	-Development of geological classification system -Collection of geologic data for 1400 reservoirs in 22 states -Evaluation of recovery potential (EOR, UMO)

4.0 TECHNOLOGY TRANSFER

The Bartlesville Project Office (BPO) continues to be recognized worldwide as a major resource of petroleum information, economic and technical analyses, software, and technical reports.

Long-term research activities dominated the petroleum program through FY88, and thus technology transfer was largely confined to research laboratories of major oil companies and universities. With the increasing emphasis on near- and mid-term research starting in FY89, BPO has concentrated its technology transfer effort on the independent oil companies. This concentration continued in FY90.

4.1 PUBLICATIONS PROGRAM

In FY's 89 and 90, the number of publications available to the industry increased as a result of the many R&D activities managed by BPO. There was also a greater demand for reports, software, and technical assistance. A summary of "Report Distribution Activities FY 84-90" is given in Table 5, which shows that the total number of reports distributed was about the same in both years, over 36,000. BPO published 68 technical reports in FY90 (listed in Appendix B) compared with 87 reports in FY89.

Identifying the users is as useful to the technology transfer process as is the information itself. Thirteen user categories of scientific and technical information (STI) have been identified. In FY90, the five largest users were: (1) U.S. academia 2570, (2) research institutes 2306, (3) DOE 2302, (4) independent oil producers 2053, and (5) consultants 1326. The highest demand for STI was for the following four areas: (1) special publications 2704, (2) geoscience 1991, (3) chemical flooding 1856, and (4) resource assessment 1525.

As the DOE depository of STI, the Office of Scientific and Technical Information (OSTI) in Oak Ridge, Tennessee works closely with the individual DOE

offices to coordinate program distribution of all DOE publications. In FY90, OSTI distributed 4374 copies of reports published by BPO to DOE personnel, contractors, and other activities identified by BPO as appropriate recipients of the information.

For the past 16 years, BPO has assisted the petroleum community in keeping abreast of current research efforts by publishing the quarterly status report on EOR, *Contracts for Field Projects and Supporting Research on Enhanced Oil Recovery*. In FY90 alone, BPO distributed 8161 copies of this technical report on EOR to scientists and researchers.

BPO announces the availability of new reports each quarter in the BPO Publications List. Abstracts summarize research results of petroleum R&D projects in chemical flooding, gas flooding, thermal processes, fundamental petroleum chemistry, MEOR, environmental technology, geoscience, and resource assessment. During FY90 BPO distributed 9437 copies of this publication.

BPO, in cooperation with the FE Office of Communications, released one "DOE News" item in FY90: "New Heavy Crude Analysis by DOE," February 1990. This concerned a major technical report that will help the U.S. refining industry to process heavy crude oils more efficiently. The report, which has received strong industry interest and commendation, is the culmination of a multi-year cooperative research effort between DOE and Venezuela to assist in implementing the upgrading techniques needed to produce quality transportation fuels from the Western Hemisphere's vast reserves of heavy crude oil.

4.2 CONFERENCES

As a means of transferring technology to industry, the Bartlesville Project Office continued its series of co-sponsored conferences and symposia in FY90. BPO also participated in other technical meetings with

Table 5: BPO Technology Transfer Distribution Activities, FY84-90

REPORTS	FY84	FY85	FY86	FY87	FY88	FY89	FY90
Total No. of Reports Distributed*	60,478	46,703	45,308	33,464	30,993	36,827	36,378
Total Individual Requests	10,264	9,379	5,511	7,198	4,418	13,558	15,248
No. Orders Received	4,864	3,015	1,556	1,661	1,227	2,427	2,271
Av. No. of Requests per Order	2.11	3.11	3.54	4.33	3.0	5.77	6.71
Total No. Reports Published	50	49	53	67	56	87	78

* Include reports distributed by OSTI

SOFTWARE

BOAST	Tape	39	31	23
	PC	-	375	226
Predictive Models	Tape	15	8	14
	PC	67	226	169
Horizontal Well Model	Tape	-	78	43
Oil Analysis Data Bank	Tape	3	7	21
Miscellaneous	Tapes	-	-	7
		124	725	503

representatives of industry, universities, national laboratories and federal and state agencies. Examples are:

- Oct 89 — M. Ray gave a presentation on TORIS to the Dallas Section of SPE on "Evaluation of Policy Alternatives to Encourage EOR in the U.S."
- Feb 90 — BPO co-sponsored with the University of Oklahoma a two-day conference on "Source Rocks, Generation and Migration of Hydrocarbons and Other Fluids in the Southern Mid-Continent." This third annual event attracted about 200 participants.
- Apr 90 — DOE co-sponsored, with the Society of Petroleum Engineers, the 7th SPE-DOE Symposium on EOR in Tulsa, Oklahoma on Apr 21-25. DOE officials from Bartlesville, Morgantown and HQ participated in the biennial event, and Mr. Michael McElwrath, Acting ASFE, addressed the Plenary Session. E. Allison and J. Casteel chaired technical sessions. DOE's reservoir simulator BOAST II and

the EOR predictive models were demonstrated at the DOE exhibit booth.

Drs. Joseph Taber and John Heller, both active in DOE-supported research at the New Mexico Institute of Mining and Technology, were honored as EOR pioneers at the symposium.

- May 90 — M. Ray and C. Nautiyal participated in the SPE Micro-computer Group meeting in Houston, Texas. They discussed uses for TORIS and demonstrated applications of the EOR predictive models and BOAST II.
- May 90 — BPO co-sponsored, with the University of Oklahoma, the 1990 MEOR International Conference in Norman, Oklahoma on May 27-31. Over 100 scientists from 16 countries participated.
- Jul 90 — T. Wesson participated, with over 250 petroleum industry executives and government officials, in examining the economics and politics of EOR at the Emerging Technologies Conference in

Houston, Texas. This SPE/University of Houston conference, held on July 5-7, was in advance of the G-7 economic summit meeting (of the heads of government of the U.S., Japan, Germany, U.K., France, Italy and Canada).

- Aug 90 — T. Reid participated in the SPE Forum on EOR operations in low-price environment in Crested Butte, CO.

4.3 CONTACTS WITH INDEPENDENT OIL OPERATORS

BPO conducted technology transfer activities tailored mainly for the benefit of small independent oil companies. It contacted the publications executives of petroleum operators associations to make their members aware of DOE technology that can be applied in marginal oil fields.

During the third quarter of FY90 (April-June) BPO reviewed over a dozen enquiries from independent oil

operators about horizontal drilling in the Bartlesville sand. This followed interest generated by the DOE/Rougeot Oil & Gas Corporation cost-shared project.

- Nov 89 — The value of the DOE oil research program was the focus of a talk by M. Ray to the annual meeting of the Illinois Oil & Gas Association in Mount Vernon, Illinois.
- Feb 90 — Two independent operators visited BPO to discuss horizontal drilling and a third obtained information on techniques to reduce water production from oil wells.
- Mar 90 — T. Wesson, BPO Director and D. Juckett, Director of the Office of Geoscience Research, had a productive exchange with oil operators attending the West Central Texas Oil & Gas Association meeting at Abilene, Texas.
- May 90 — M. Ray presented a paper on the "Effect of Well Abandonments on Domestic EOR Activity" to the Oil & Gas Recovery Committee of the IPAA mid-year meeting in Boston, Massachusetts.
- Jun 90 — H. Tiedemann explained the EOR Technology Transfer Program to independent operators attending the Eastern Oil & Gas Equipment Show in Charleston, West Virginia.

5.0 SIGNIFICANT EVENTS

Significant events other than those discussed in Section 4.0 may be grouped under the following headings:

- Oil Recovery Technology Partnership
- Federal/state Joint Efforts
- International Cooperation
- Environmental Protection
- Other Highlights

5.1 OIL RECOVERY TECHNOLOGY PARTNERSHIP

In FY89 DOE launched the Oil Recovery Technology Partnership between two national laboratories and the petroleum industry. The objective of this partnership is to stimulate, facilitate and coordinate technology development and transfer, for increasing domestic oil production. The concept is focused to use and foster technologies largely derived from DOE-funded weapons and energy research.

Sandia and Los Alamos National Laboratories (SNL, LANL), a dozen companies and BPO make up the Partnership at present. BPO provides guidance to the Partnership as an integral part of DOE's Petroleum Research Program. The Partnership has a policy-making steering committee and a review panel of industry representatives who evaluate projects proposed for funding. Partnership projects are discussed in Section 3.2.1.3.

Co-chairman R.J. Hanold (LANL) and D.A. Northrop (SNL) gave several presentations on Partnership activities to DOE and industry visitors to their laboratories. They also reviewed progress with BPO in visits to Bartlesville. They and their staff met and exchanged ideas with oil companies, service companies, state geological surveys, etc.

- Nov 89 — "The Partnership at the End of its First Year" was the theme of a press release by SNL appearing in about 15 newspapers and journals.

- Dec 89 — Sixteen companies were represented at the third meeting of the Crosswell Seismic Forum at DFW airport on December 12. There was strong support to continue the multi-station receiver project and conduct additional field experiments.
- Jan 90 — The DOE Fossil Energy presentation of the Federal Petroleum Research Program in Washington, DC included two projects being conducted by the Partnership. Messrs Moore (Deputy Secretary of Energy) and McElwrath (Deputy ASFE) considered the micro-seismic fracture monitoring and crosswell seismic projects as excellent examples of DOE/industry collaboration.
- May 90 — The fourth meeting of the Crosswell Seismic Forum, held at the DFW airport on May 21-22, focused on borehole seismic-source technology. There were 54 participants from 25 companies. Ten operators gave an excellent survey of the technology.

5.2 FEDERAL/STATE JOINT EFFORTS

- Oct 89 — M. Ray presented a developmental history of TORIS to the IOCC Subcommittee on Residual Oil Saturation held in San Antonio, Texas.
- Dec 89 — BPO participated in the IOCC annual meeting held in Tulsa, Oklahoma, together with state governors, Sen. Domenici (NM), and federal, state and industry officials. Attendants reviewed the Enhanced Oil and Gas Recovery Tax Act of 1989, legal aspects of oil spills, environmental regulations, and wetlands development.

M. Ray spoke to the Enhanced Recovery Committee on the rate of oil well abandonment in New Mexico and its effect on CO₂ flooding operations. He also discussed the role of data studies in DOE's future program direction before the Oil & Gas Information and Database Management Committee.

- Sep 90 — Extending the life of oil fields by improving oil reservoir management was the focus of a presentation by staff from the Kansas University Tertiary Oil Recovery Project (TORP) at BPO. BPO outlined current DOE Oil Plan activities.
- Sep 90 — Researchers from the Texas Bureau of Economic Geology reviewed DOE/industry-sponsored reservoir characterization research before 65 representatives from 10 companies. The one-day meeting in Carlsbad, New Mexico was followed by a two-day field trip to examine the San Andres carbonate outcrops in southeast New Mexico.
- Aug 90 — E. Allison presented a poster session on DOE oil research activities at the International SPE Forum on formation evaluation and reservoir characterization in Crested Butte, Colorado on Jul 29-Aug 3.
- Aug 90 — The DOE/Venezuela MOU Joint Steering Committee on petroleum research met in Bakersfield, California and discussed focusing more research on utilizing the extensive heavy oil resources of the Western Hemisphere.
- Sep 90 — F. Burtch chaired a session of the First International Symposium on Evaluation of Reservoir Wettability held on Sep 18-21 at the New Mexico Institute of Mining and Technology in Socorro.

5.3 INTERNATIONAL COOPERATION

Oct 89 — INTEVEP representatives visited BPO to complete action on several annexes recommended by the U.S./Venezuela Joint Steering Committee, and to discuss possible new annexes. They also visited the nearby microbial EOR field pilot test operated by NIPER and two small business participants.

- Oct 89 — INTEVEP representatives visited SUPRI to discuss with BPO and its contractors (SUPRI, LLNL, and NIPER) the latest research conducted under Annex IV (Thermal Recovery Processes) of the Venezuelan MOU.
- Nov 89 — Dr Edo Nyland, Professor of Geophysics at the University of Alberta, visited BPO and discussed his work in monitoring steamfloods, using buried seismic sensing devices. Preliminary field testing in Canada has been encouraging.
- Mar 90 — Following a visit to the Strategic Petroleum Reserve (SPR), five representatives of the Japan National Oil Co. visited NIPER/BPO to review research and analytical services provided to SPR.
- Mar 90 — BPO participated in the biannual Joint Steering Committee meeting of the DOE/Venezuela MOU in Caracas, Venezuela. Progress of joint research projects was reviewed, and amendments to annexes were considered.
- Mar 90 — BPO representatives and contractors (SUPRI, LLNL, and NIPER) visited INTEVEP to discuss the latest research conducted under Annex IV (Thermal Recovery Processes) of the Venezuelan MOU.
- May 90 — Twenty-three U.S. and Venezuela scientists, representing nine research organizations, reviewed progress in cooperative MEOR research prior to the MEOR International Conference in Norman, Oklahoma.

5.4 ENVIRONMENTAL PROTECTION

- Oct 89 — T. Reid surveyed the pre-project environmental aspects of two heavy oil projects in Bakersfield, California:
 1. Texaco Kern River site of the Kawasaki Thermal System project to measure wellbore heat losses.
 2. Unocal Midway-Sunset site of the Petrophysics innovative drilling/completion project.
- Oct 89 — The DOE Office of NEPA Project Assistance gave a one-day workshop to staff from BPO, NIPER and the Metairie Site Office. The NEPA staff reviewed environmental regulations relevant to petroleum R&D projects, and examined the various levels of environmental assessment.
- Jan 90 — A. Crawley assisted HQ representatives with a peer review of the Kansas Corporation Commission underground injection practices.
- Mar 90 — T. Reid visited the Petrophysics/Unocal project at Midway-Sunset Field, California and completed an environmental site assessment. The project involves the drilling of an innovative combination of vertical and lateral wellbores for steam injection.
- Mar 90 — W. Peters attended the annual National Conference on Octane Quality and Reformulated Gasoline in San Antonio, Texas. More than 450 participants discussed the effect of the Clean Air Bill on the automobile and refining industries.
- Mar 90 — Researchers from Brookhaven National Lab (BNL) visited BPO and discussed the field tracer project, a cooperative effort with Chevron, Bechtel (operator of NPR-1, Elk Hills) and the Norwegian Institute for Energy Technology.

- Aug 90 — BPO submitted Action Description Memoranda (ADM) to FE on three field projects. FE determined that the information contained in the ADMs based on site visits by the Project Manager, complied with NEPA requirements, and issued Memos to File (MTFs) accordingly.
- Sep 90 — A. Crawley represented BPO at the First International Symposium on Oil and Gas Waste Management Practices held in New Orleans, Louisiana on Sep 11-13. The DOE poster session exhibit drew considerable interest from the 700+ attendees.
- Jan 90 — T. Wesson and M. Ray attended Deputy Secretary W. Henson Moore's review of the proposed National Energy Strategy.
- Feb 90 — Staff members from BPO and NIPER participated in the Bartlesville Science Fair as coaches and judges.
- Mar 90 — T. Wesson and M. Ray visited the Elk Hills oilfield in California and discussed with NPR-1 management cooperative activities in testing and applying advanced recovery techniques.

5.5 OTHER HIGHLIGHTS

- Oct 89 — Several industrial sponsors showed interest in DOE-funded research in novel water-soluble polymers at the University of Southern Mississippi.
- Oct 89 — Staff from BPO and NIPER taught science classes during the Bartlesville Energy Awareness Week.
- Dec 89 — BPO selected 12 organizations, from 40 responses to a Program R&D Announcement (PRDA) for research in geoscience and MEOR, to conduct 18 projects.
- Jan 90 — The Program Guidance Committee for NIPER met in Washington under chairmanship of Acting ASFE Michael McElwrath. Director T. Wesson represented BPO.
- Apr 90 — Mr. McElwrath and other FE officials visited BPO and toured the NIPER research laboratories, in conjunction with attendance at the EOR symposium in Tulsa, Oklahoma.
- Jun 90 — Maximizing efficiency of research on electric/electromagnetic (E/EM) methods for diagnosing EOR processes was the theme of a workshop in Albuquerque, New Mexico. Thirty participants from DOE HQ, BPO, four national laboratories and three universities established a Research Coordination Group among researchers in this field.
- Aug 90 — The E/EM Research Coordination Group met and prepared a paper describing the state-of-the-art potential applications and a program plan for developing the necessary technology in concert with industry.
- Aug 90 — Robert Gentile, ASFE and Robert Kripowicz, staff member of House Appropriations Subcommittee, visited BPO for an update on BPO administered programs, BPO staffing, and R&D opportunities at the NPR oilfields.

APPENDIX A

Research Projects Performed in FY90

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
1. Geoscience & Reservoir Characterization		
1.1 Reservoir Characterization and EOR - Annex II	Texas Bureau Econ. Geo. BC14403	W. Fisher
1.2 Characterization of Carbonate Reservoir Heterogeneity - Annex I	Alabama Geol. Survey BC14425	E. Mancini
1.3 Characterization of Sandstone Reservoir Heterogeneity - Annex II	Alabama Geol. Survey BC14448	E. Mancini
1.4 Depositional Sequence Analysis in Pennsylvanian Reservoirs - Annex I	Kansas Geol. Survey BC14434	L. Watney
1.5 Evaluation of Interwell Seismic Logging Techniques	SW Research Inst. BC14649	J. Parra
1.6 Application of Multitracer Technology to Reservoir Studies	Brookhaven NL AS-217-ECD	R. Dietz
1.7 New Microorganisms and Processes for MEOR	Injectech, Inc. BC14663	G. Sperl
1.8 Bacterial Transport and Retention in Porous Media	U. Michigan BC14664	S. Fogler
1.9 MEOR of Indigenous Microorganisms	Mississippi State U. BC14665	L. Brown
1.10 Development of Luminescent Bacteria as Tracers for Reservoir Characterization	Fairleigh Dickinson Labs - BC14666	J. King
1.11 Reservoir Characterization and EOR - Annex II	U. Texas BC14251	L. Lake
1.12 Field Laboratory for Improved Oil Recovery - Annex III	U. Houston BC14443	A. Hildebrandt
1.13 Oil Recovery Enhancement from Fractured, Low- permeability Reservoirs - Annex IV	Texas A&M BC14444	S. Poston
1.14 Development of NMRI Spectroscopy for Improved Petroleum Recovery	Texas A&M BC14446	M. Sharma
1.15 Resistivity Measurements in Cased Wells	ParaMagnetic Logging Inc. - BC14617	B. Vail

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
1.16 A Novel Approach to Modeling Unstable EOR Displacements	U. Texas BC14650	E. Peters
1.17 Reservoir Characterization of Pennsylvanian Sandstones	U. Tulsa BC14651	B. Kelkar
1.18 Investigation of Dispersivity as a Reservoir Rock Characteristic	U. Oklahoma BC14652	D. Menzie
1.19 Description of Reservoir Heterogeneities Using Tracers	U. Texas BC14653	G. Pope & K. Sepehrooni
1.20 Effect of Fracture Closure on Performance of Naturally Fractured Reservoirs	K&A Energy Consultants BC14654	D. Daubin
1.21 Trace Authigenic Components as Indicators during Hydrocarbon Maturation and Migration	Texas A&M BC14656	T. Tieh
1.22 Predictability of Formation Damage	U. Oklahoma BC14658	F. Civan
1.23 Characterization of Non-Darcy Multiphase Flow	U. Oklahoma BC14659	R. Evans
1.24 Oil Recovery Improvement through Profile Modification by Thermal Precipitation	U. Texas BC146660	J. Reis
1.25 Reservoir Assessment and Characterization	NIPER BE1	M. Honarpour
1.26 Three-phase Relative Permeability	NIPER BE9	D. Maloney
1.27 Reservoir Characterization Conference	NIPER SGP 24	V. Foreman
1.28 Methods for Mapping Clay Distribution in Reservoirs	NIPER SGP42	B. Sharma & M. Madden
1.29 Characterization of a Fractured Dolomite Reservoir	Los Alamos NL/Murphy Operating Corp FEW PG12 (ORTP)	R. Hanold
1.30 Improved Recovery from the Bone Springs Formation, NM	Sandia NL/Harvey Yates - FEW 2266 (ORTP)	D. Northrop
1.31 Reservoir Characterization - Annex I	Louisiana State U. ID 12842	T. Bourgoyne
1.32 Improved Oil Recovery Field Laboratory	NM Research Dev. Inst. ID 12872	P. Rodriguez & R. Medina

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
1.33 Geodiagnostics for Reservoir Heterogeneities and Process Mapping	Sandia NL FEW 0772/0214	D. Northrop
1.34 Petroleum Geochemistry - Integrated Basin Analysis	LLNL FEW 6042	A. Burnham
1.35 Advanced Seismic Geodiagnostics - Borehole Acoustic Source	LANL FEW A053	R. Hanold & J. Albright
1.36 In-situ Stress and Fracture Permeability	Sandia NL FEW 1863	L. Teufel
1.37 Oil Recovery Technology R&D Center	SNL & LLNL FEW A054/PG11	D. Northrop & R. Hanold
2. Chemical Flooding		
2.1 Mechanisms of EOR C	U. Minnesota BC10842	H. Davis & L. Scriven
2.2 Structurally Modified Surfactants C	Columbia U. BC14432	P. Somasundaron
2.3 Sweep Improvement with Chemical Gels	New Mexico R&D Inst. BC14447	J. Heller
2.4 Surfactant-assisted Waterflooding C	U. Oklahoma BC14449	J. Scaimehorn
2.5 Improved Surfactant Flooding	NIPER BE4A	L. Noll
2.6. Improved Mobility Control Methods	NIPER BE4C	T. French
2.7 Modeling and Optimizing Surfactant Structure C	U. Texas BC10841	R. Schechter
2.8 Modeling and Scale-up of Chemical Flooding C	U. Texas BC10846	G. Pope
2.9 Gelled Polymer Systems C	U. Kansas ID 12846	P. Willhite
2.10 EOR by In-situ Generated Surfactants C Augmented by Chemical Injection	Illinois Inst. Tech. BC10847	D. Wasan
3. Gas Flooding		
3.1 Statistical Study of Variables in CO ₂ C Equation of State	Johns Hopkins U. BC14200	M. Donohue
3.2 Miscible Gas Flooding	NIPER BE5A	F. Chung

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
3.3 Improved Gas Displacement Methodology	NIPER BE5B	F. Chung & C. Raible
3.4 CO ₂ Flooding Processes	METC 9-891	J. Ammer & D. Smith
3.5 Scale-up of Miscible Flood Processes	Stanford U. MC26253	F. Orr
3.6 CO ₂ Sweep Improvement with Foams - Annex II, Task 3	U. Texas BC14251	R. Schechter
3.7 Cyclic CO ₂ Injection for Light Oil Recovery C	Louisiana State U. BC14204	Z. Bassiouni
4. Thermal Recovery		
4.1 Steam Front Monitoring with Seismometer Arrays	LLNL FEW 6044	P. Harben
4.2 Remote Sensing Methods for Thermal EOR C	LLNL FEW 6038	M. Wilt
4.3 EM Field Test at BP Well Site	LLNL FEW 6039	M. Wilt
4.4 Chemical Additives to Steam	LBL/U. California FEW 4680	C. Radke
4.5 Controlling Premature Oxygen Breakthrough C	Union Carbide BC 14201	R. Drnevich
4.6 International Conference on Heavy Oil & Tar Sands	UNITAR/UNDP BC14259/66	
4.7 Measuring Wellbore Heat Losses C	Kawasaki Thermal Systems BC14260	B. Traynor
4.8 Recovery Mechanisms in Heavy Oil Reservoirs	SUPRI BC14600	H. Ramey & K. Aziz
4.9 Modification of Chemical and Physical Factors in Steamfloods	USC BC14600 (Sub)	Y. Yortsos
4.10 Surfactant-Enhanced Alkaline Flooding	NIPER BE4B	T. French
4.11 Thermal Processes for Light Oil Recovery	NIPER BE11A	D. Olsen
4.12 Thermal Processes for Heavy Oil Recovery	NIPER BE11B	D. Olsen

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
4.13 Feasibility Study of Heavy Oil Recovery in the Mid-Continent	NIPER SGP 37	A. Strycker
5. Novel Recovery Technology		
5.1 Innovative Drilling/Completion System for Steam Injection	Petrolphysics BC14203	W. Dickinson
5.2 Horizontal Drilling	Rougeot O&G Corp. BC14458	J. Rougeot
5.3 Inflow Performance Relationship (IPR) for Slanted/Horizontal Wells under Solution Gas Drive	NIPER SG 27	A. Cheng
5.4 IPR for Slanted/Horizontal Wells with Heterogeneous Systems	NIPER SG 40	A. Cheng
5.5 Surfactant-Enhanced Alkaline Field Test	NIPER SG 41	T. Burchfield
6. Microbial EOR		
6.1 Lab/Field Demonstration of Alpha MEOR Processes	Alpha Environmental BC14205	E. Douglas
6.2 Microbial Field Pilot Study	U. Oklahoma/Sullivan & Co. - BC14246	R. Knapp
6.3 International MEOR Conference	U. Oklahoma BC14437	E. Donaldson
6.4 Development of MEOR Processes for Field Applications	NIPER BE 3	R. Bryant
6.5 Microbial-Enhanced Waterflood Field Test	NIPER SG 13	R. Bryant
6.6 MEOR in Carbonate Reservoirs	U. Oklahoma BC14202	R. Tanner
6.7 MEOR Research - Annex V	U. Texas BC 14445	M. Sharma & G. Georgiou
6.8 Quantification of Microbial Products and their Effect in EOR	U. Oklahoma BC14662	M. McInerney
6.9 MEOR of Indigenous Microorganisms	Mississippi State U. BC14665	L. Brown
6.10 Effect of Thermophilic Microorganisms on Crude Oil	Brookhaven NL AS-219-EDC	E. Premuzic

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
6.11 MEOR and Applied Geoscience Research	EG&G Idaho 5AC3	C. Thomas
7. Fundamental Geoscience & Extraction Research		
7.1 Reservoir Imaging	NIPER BE 12	L. Tomutsa
7.2 Geodiagnostics for Fossil Energy Recovery	Sandia NL FEW 1581	R. Hommert
7.3 Development of Multi-station Borehole Seismic Receiver	Sandia NL FEW 2333 (ORPT)	P. Hommert
7.4 Fault Imaging in McKittrick Field, CA	LANL/Texaco/Chevron FEW PG18 (ORPT)	R. Hanold & J. Albright
8. Supporting Technology & Environmental Research		
8.1 Analytical Methodology for Analysis of Heavy Crudes	NIPER BFR2	J. Green
8.2 Thermochemical and Thermophysical Properties of Heteroatom Organic Compounds	NIPER BFR3	W. Steele
8.3 Strategic Petroleum Reserve Supporting Research	NIPER SGP 07	R. Anderson
8.4 Thermochemistry of Key Organic Compounds	NIPER SGP 10	D. Ripley
9. University Geoscience Research		
9.1 Facies and Permeability Patterns in Carbonate Reservoirs	U. Texas/BEG BC14470	C. Kerans
9.2 Analysis of Reservoir Heterogeneities	U. Alaska BC14471	K. Watts
9.3 Gravity Drainage Phenomena	Western Res. Inst. BC14472	P. Vaughn
9.4 Demonstration of High-Resolution Inverse VSP	SW Res. Inst. BC14473	J. Parra
9.5 Characterization & Modification of Fluid Conductivity	U. Michigan BC14474	S. Folger
9.6 Geophysical and Transport Properties of Reservoir Rocks	UC Berkeley BC14475	N. Cook
9.7 Reservoir Characterization by Transient EM Methods	Blackhawk Gesociences Inc. BC14476	P. Hoekstra

PROJECT	CONTRACTOR/PROJECT NUMBER	PRINCIPAL INVESTIGATOR
9.8 Correlating Recovery Efficiency to Reservoir Properties	Penn State U. BC14477	T. Ertekin
9.9 Borehole Seismic Imaging Techniques	Colorado S. Mines BC14478	A. Balch
9.10 Chemically Assisted In-Situ Recovery of Shale Oil	U. Colorado BC14479	F. Ramirez
10. Resource Assessment (TORIS)		
10.1 Texas Study	IOCC/ICF/BEG BC14230	T. Dowd, A. Becker & N. Tyler
10.2 Improved Oil Recovery in Illinois through Reservoir Characterization	Illinois Geol. Survey BC14250	D. Oltz
10.3 Evaluation of the Domestic Oil Resource and the Economic Recovery of Mobile and Immobile Oil	IOCC/ICF BC14431	T. Dowd A. Becker
10.4 Natural Resources Information System (NRIS)	U. Oklahoma/Okla Geol Survey BC14483	C. Mankin
10.5 TORIS Research Support	NIPER BE 2	J. Pautz
10.6 Developing a Reservoir Data Base	NIPER SGP 28	J. Pautz
10.7 EOR Incentive Database Update	NIPER SGP 30	J. Pautz

Abbreviations:

- U. - (of) University
- NL - National Laboratory
- C - Project completed

APPENDIX B

Technical Reports Issued in FY90

REPORT NUMBER	TITLE	ISSUING ORGANIZATION	DATE	NTIS ORDER NUMBER
<u>GENERAL RESEARCH</u>				
DOE/BC-89/3/SP	Handbook for Personal Computer Version of BOAST II: A Three-Dimensional, Three-Phase Black Oil Applied Simulation Tool.	BPO	Dec 89	DE89000759
NIPER-420	FY90 Annual Research Plan.	NIPER	Jan 90	DE90000210
DOE/BC/14285-1	Technology Transfer to U.S. Oil Producers: A Policy Tool to Sustain or Increase Oil Production.	IOCC	Mar 90	DE90000221
<u>CHEMICAL FLOODING</u>				
NIPER-417	Use of Amine Oxide Surfactants for Chemical Flooding EOR.	NIPER	Nov 89	DE89000773
NIPER-447	Use of Sacrificial Agents to Reduce Carboxymethylated Ethoxylated Surfactant Loss During Chemical Flooding.	NIPER	Dec 89	DE90000203
DOE/BC/10845-15	Surfactant Enhanced Volumetric Sweep Efficiency. Final Report.	Univ of Oklahoma	Oct 89	DE89000770
DOE/BC/10847-15	Enhanced Oil Recovery Through In-Situ Generated Surfactants Augmented by Chemical Injection. Annual Report for 1987-1988.	Illinois Institute of Technology	Oct 89	DE89000772
NIPER-432	Crosslinked, Flexible, Low-Molecular-Weight Polyacrylamide Gels for Mobility Control.	NIPER	Dec 89	DE90000202
NIPER-388	A Three-Dimensional, Three-Phase Simulator for Permeability Modification Treatments using Gelled Polymers.	NIPER	Mar 90	DE90000227
NIPER-446	Design and Optimization of Phosphate-Containing Alkaline Flooding Formulations.	NIPER	Feb 90	DE90000217
NIPER-449	Selection and Design of Ethoxylated Carbonates of Chemical Flooding.	NIPER	Jan 90	DE90000213
DOE/BC/10843-15	Investigation of Application of Gelled Polymer Systems for Permeability Modification in Petroleum Reservoirs. Final Report for Oct 87 - Sep 88.	Univ of Kansas	Mar 90	DE90000229
DOE/BC/10846-15	Modelling and Scale-up of Chemical Flooding. Final Report.	Univ of Texas @ Austin	Mar 90	DE90000226
DOE/BC/10841-15	Modeling and Optimizing Surfactant Structure to Improve Oil Recovery by Chemical Flooding at the University of Texas. Final Report.	Univ of Texas	Apr 90	DE90000230
DOE/BC/10842-10	Flow in Porous Media, Phase Behavior and Ultralow Interfacial Tensions: Mechanisms of Enhanced Petroleum Recovery. Annual Report for Oct 86 -	Univ of Minnesota	May 90	DE90000238

REPORT NUMBER	TITLE	ISSUING ORGANIZATION	DATE	NTIS ORDER NUMBER
	Sep 87.			
DOE/BC/10842-15	Flow in Porous Media, Phase Behavior and Ultralow Interfacial Tensions: Mechanisms of Enhanced Petroleum Recovery. Annual Report for Oct 87 - Sep 88.	Univ of Minnesota	May 90	DE90000239
DOE/BC/10844-20	Polymers for Mobility Control in Enhanced Oil Recovery. Final Report.	Univ of Southern Mississippi	Jun 90	DE90000243
DOE/BC/10847-20	Enhanced Oil Recovery Through In-Situ Generated Surfactants Augmented by Chemical Injection. Final Report.	Illinois Institute of Technology	Aug 90	DE90000253
DOE/BC/14449-2	A Study of Surfactant-Assisted Water-flooding. Final Report.	Univ of Oklahoma	Sep 90	DE90000261
<u>THERMAL RECOVERY</u>				
DOE/SF/00098-T14	The Influence of Texture on Steady Foam Flow in Berea Sandstone.	Univ of California	Oct 89	DE89000771
DOE/BC/14126-11	Pressure Transient Analysis for Composite Systems. SUPRI TR 68.	SUPRI	Oct 89	DE89000768
DOE/BC/14126-12	Devices and Methods for In-Situ Combustion Ignition. SUPRI TR 69.	SUPRI	Oct 89	DE89000766
DOE/BC/14126-13	Phase Change in Binary Systems in Porous Media: Application to Solution Gas-Drive.	Univ of Southern California	Oct 89	DE89000767
NIPER-458	Development of an Inflow Performance Relationship (IPR) for a Slanted/Horizontal Well. Final Report.	NIPER	Mar 90	DE90000224
DOE/BC/14126-14	Modification of Chemical and Physical Factors in Steamflood to Increase Heavy Oil Recovery. Annual Report for Oct 88 - Sep 89.	Univ of Southern California	Feb 90	DE90000214
DOE/BC/14126-15	A Study of Steady-State Steam-Water Counterflow in Porous Media.	Univ of Southern California	Feb 90	DE90000215
DOE/BC-90/1/SP	Supporting Technology for Enhanced Oil Recovery -- EOR Thermal Processes.	Venezuela Ministry of Energy/U.S. DOE	Dec 89	DE90000207
DOE/BC/14126-18	A Comparison of Relative Permeability from Centrifuging Versus Coreflooding. SUPRI TR 72.	SUPRI	May 90	DE90000234
DOE/BC/14126-19	Characterization of Steam Foam Surfactants Through One-Dimensional Sandpack Experiments. SUPRI TR 73.	SUPRI	May 90	DE90000235
DOE/BC/14126-21	A Semianalytical Model for Linear Steam Drive. SUPRI TR 75.	SUPRI	May 90	DE90000237
DOE/BC/14126-23	Modification of Buckley-Leverett and JBN Methods for Power-Law Fluids.	Univ of Southern California	May 90	DE90000240
DOE/BC/14126-24	Steady-State, Vapor-Liquid Concurrent	Univ of Southern	Jun 90	DE90000242

REPORT NUMBER	TITLE	ISSUING ORGANIZATION	DATE	NTIS ORDER NUMBER
	Flow: Relative Permeabilities and End Effects.	California		
DOE/BC/14126-16	A Study of Newton Related Nonlinear Methods in Well Test Analysis, Production Schedule Optimization and Reservoir Simulation. SUPRI TR 70.	SUPRI	Aug 90	DE90000249
DOE/BC/14126-20	The Accurate Measurements of Heat Flux Using Thin Film Heat Flux Sensors with Application to Petroleum Engineering. SUPRI TR 74.	SUPRI	Jul 90	DE90000236
DOE/BC/14126-22	SUPRI Heavy Oil Research Program. Thirteenth Annual Report. SUPRI TR 76.	SUPRI	Aug 90	DE90000250
DOE/BC/14126-26	Effect of Metallic Additives on In Situ Combustion of Huntington Beach Crude Experiments. SUPRI TR 78.	SUPRI	Aug 90	DE90000259
DOE/BC/14126-27	Characterization of Surfactants as Steamflood Additives. SUPRI TR 79.	SUPRI	Sep 90	DE90000263
DOE/SF/00098-T16	A Dual-Gas Tracer Technique for Determining Trapped Gas Saturation During Steady Foam Flow in Porous Media.	Univ of California	Sep 90	DE90000260
<u>CARBON DIOXIDE FLOODING</u>				
DOE/MC/22042-15	Reservoir Characterization for the CO2 Enhanced Oil Recovery Process. Final Report.	SUPRI	Nov 89	DE89000774
DOE/FE/61114-2	Development of Effective Gas Solvents Including Carbon Dioxide for the Improved Recovery of West Sak Oil. Final Report.	Univ of Alaska Fairbanks	Jun 90	DE90000241
DOE/MC/21136-24	Improvement of CO2 Flood Performance. Annual Report for Oct 88 - Sep 89.	NMINT	Aug 90	DE90000254
<u>GAS FLOODING</u>				
NIPER-431	Gas Miscible Displacement. Foams for Mobility Control and Improvement in Gas Sweep Efficiency.	NIPER	Dec 89	DE90000205
<u>GEOSCIENCE</u>				
DOE/BC/10851-15	Dispersivity as an Oil Reservoir Rock Characteristic. Final Report.	Univ of Oklahoma	Dec 89	DE90000209
NIPER-434	In Situ Hydrogenation.	NIPER	Dec 89	DE90000208
NIPER-444	Using Image Analysis to Determine Petrophysical Properties of Reservoir Rocks.	NIPER	Mar 90	DE90000222
NIPER-441	The Effects of Rock Characteristics on Relative Permeability.	NIPER	Jan 90	DE90000212

REPORT NUMBER	TITLE	ISSUING ORGANIZATION	DATE	NTIS ORDER NUMBER
NIPER-439	Integrated Methodology for Constructing a Quantified Hydrodynamic Model for Application to Clastic Petroleum Reservoirs.	NIPER	Jan 90	DE90000211
NIPER-448	Fluid Flow Behavior Through Rock-Slab Micromodels in Relation to Other Micromodels.	NIPER	Jun 90	DE90000244
<u>MICROBIAL EOR</u>				
NIPER-442	Effects of Chemical Additives on Microbial Enhanced Oil Recovery Processes.	NIPER	Dec 89	DE90000204
DOE/BC/10302-46	Genetic, Physiological and Nutritional Studies on Clostridium Strains Isolated and Screened for Characteristics Useful in Enhanced Oil Recovery, with Special Reference to High Salt Tolerance. Final Report.	Oklahoma State Univ	Mar 90	DE90000228
BNL 43788	Effects of Selected Thermophillic Microorganisms on Crude Oils at Elevated Temperatures and Pressures. 1989 Annual Report.	Brookhaven National Lab	May 90	
<u>RESOURCE ASSESSMENT</u>				
DOE/BC/10849-15	Systematic Procedure for Reservoir Characterization. Final Report.	Univ of Texas @ Austin	Oct 89	DE89000765
NIPER-461	Review of EOR Project Trends and Thermal EOR Technology.	NIPER	Mar 90	DE90000225
DOE/BC/14000-2	Producing Unrecovered Mobile Oil: Evaluation of Potential Economically Recoverable Reserves in Texas, Oklahoma, and New Mexico.	ICF Resources Inc, & The Bureau of Economic Geology, Univ of Texas	May 90	DE90000232
DOE/BC/14000-3	Production of Potential of Unrecovered Mobile Oil Through Infield Development: Integrated Geologic and Engineering Studies -- Overview.	ICF Resources Inc, & The Bureau of Economic Geology, Univ of Texas	Aug 90	DE90000255
DOE/BC/14000-4	An Assessment of the Reserve Growth Potential of the San Andres/Grayburg Carbonate (South Central Basin Platform) Play in Texas.	ICF Resources Inc, & The Bureau of Economic Geology, Univ of Texas	Aug 90	DE90000256
DOE/BC/14000-5	An Assessment of the Reserve Growth Potential of the Clear Fork Platform Carbonate Play in Texas.	ICF Resources Inc, & The Bureau of Economic Geology, Univ of Texas	Aug 90	DE90000257
DOE/BC/14000-6	An Assessment of the Reserve Growth Potential of the Frio Barrier-Strand-plain Play in Texas.	ICF Resources Inc, & The Bureau of Economic Geology, Univ of Texas	Aug 90	DE90000258
BNL 43811R	A Perfluorocarbon Tracer Transport and Dispersion Experiment in the North Sea Ekofisk Oil Field.	Brookhaven National Lab	Jul 90	DE90000248

REPORT NUMBER	TITLE	ISSUING ORGANIZATION	DATE	NTIS ORDER NUMBER
<u>ENVIRONMENTAL TECHNOLOGY</u>				
NIPER-450	Application of Natural Isotopes in Groundwater for Solving Environmental Problems. Final Report.	NIPER	Mar 90	DE90000223
<u>FUNDAMENTAL PETROLEUM CHEMISTRY</u>				
NIPER-322	Analysis of Heavy Oils: Method Development and Application to Cerro Negro Heavy Petroleum Detailed Separation and Analysis of Acidic Compounds.	NIPER	Oct 89	DE90000769
NIPER-452 (Vol 1)	Analysis of Heavy Oils: Method Development and Application to Cerro Negro Heavy Petroleum. Final Report.	NIPER	Dec 89	DE90000200
NIPER-452 (Vol 2)	Analysis of Heavy Oils: Method Development and Application to Cerro Negro Heavy Petroleum. Final Report.	NIPER	Dec 89	DE90000201
NIPER-457	Thermodynamics and the Hydrodeoxygenation of 2, 3-Benzofuran.	NIPER	Feb 90	DE90000218
NIPER-459	The Thermodynamic Properties of 2-Methylaniline and Trans-(R,S)-Dehydroquinoline.	NIPER	Feb 90	DE90000216
NIPER-468	Thermodynamics of the Hydrodenitrogenation of Quinoline.	NIPER	Jun 90	DE90000245
NIPER-469	Critical Property and High-Temperature Heat-Capacity Measurements on Quinoline and 5,6,7,8-Tetrahydroquinoline.	NIPER	Jun 90	DE90000246
NIPER-422	Determination of Ideal-Gas Enthalpies of Formation of Key Compounds--The 1988 Project Results.	NIPER	Jul 90	DE90000247

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