The *Class* Act

DOE's Reservoir Class Program

July 1995

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The *Class* Act is a quarterly newsletter devoted to providing information about DOE's Reservoir Class Program and presenting results from specific field demonstration projects. The newsletter is produced by BDM-Oklahoma, who manages the National Oil Program for the Department of Energy (DOE) and operates the National Institute for Petroleum and Energy Research (NIPER), a DOE petroleum research laboratory in Bartlesville, Oklahoma.

This first issue focuses on Class 1 activities and results, highlighting the technologies used, the profit potential from applying technology, and results of two specific field demonstration projects.

For further information about the Class Program or any specific project, please contact DOE's Bartlesville Project Office (BPO):

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The Reservoir Class Program

DOE's Oil Recovery Field Demonstration Program is funding industry cost-shared field demonstration projects in geologically defined reservoir classes. Part of the National Oil Program, the Class Program is based on the premise that geologically similar reservoirs have similar reservoir characteristics and production problems. As operators successfully demonstrate existing and new technologies in field projects, other operators can take advantage of the technologies in their reservoir projects.

Classification

DOE classified domestic reservoirs in the Tertiary Oil Recovery Information System (TORIS) into geologically defined reservoir classes: 16 clastic and 6 carbonate classes. Geological classes were ranked on the basis of original oil in place (OOIP), remaining oil in place (ROIP), abandonment risk and future recovery potential. Figure 1 shows the ROIP and cumulative production from the first four classes.

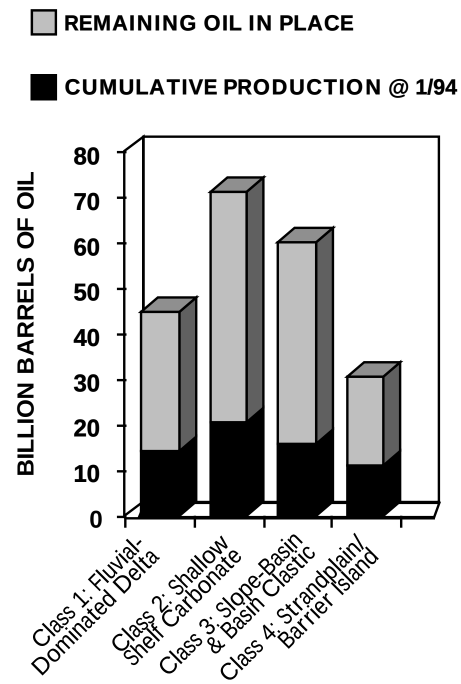

Figure 1 Opportunity by Class

Status of Projects

Fourteen Class 1 (fluvial-dominated delta) projects and ten Class 2 (shallow shelf carbonate) projects have been awarded. Nine Class 3 (slope basin and basin clastic) projects have been selected. Contracts for four of the nine projects have been awarded, with other

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awards anticipated by the year end (see Fig. 2 for project locations). Three Class 1 projects and one Class 2 project are currently inactive. The competitive solicitation for projects in Class 4 (strandplain/barrier island reservoirs) is in progress and will be managed by BDM-Oklahoma/NIPER in Bartlesville, OK. Classes 5, 6, and 7 have been identified, and initial work for Class 5 is underway.

Of the estimated $275.1 million investment in the projects, industry is providing 57% of the funding. Table 1 lists funding levels and contributions from DOE and industry for the first three reservoir classes.

Table 1 Class Project Funding

Class	# of Projects	Millions of Dollars DOE	Millions of Dollars Industry
1	14	43.3	54.7
2	10	38.2	50.6
3	9	38.1	50.4
Total	33	119.5	155.6

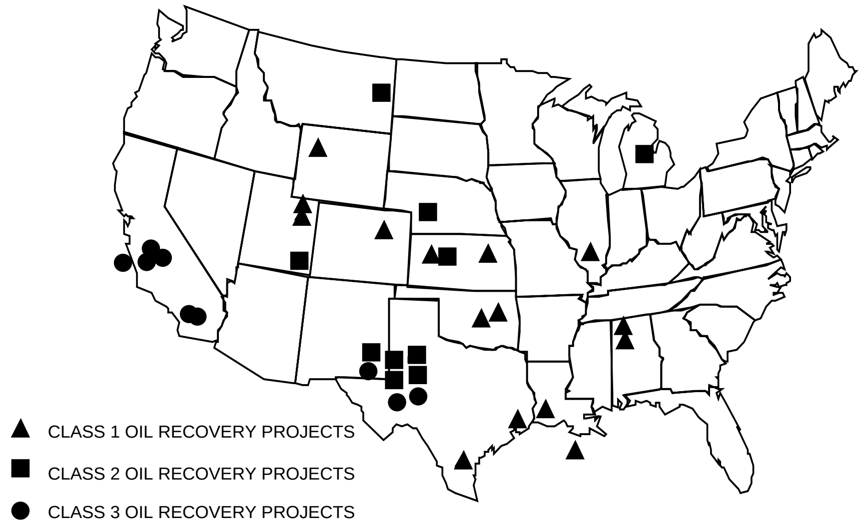

Figure 2 Location of Field Demonstration Projects

PRELIMINARY RESULTS

The program is in its infancy. Only eight field demonstration projects in Class 1 reservoirs have been operating for more than two years, but benefits are already being realized. Operating costs are being lowered, oil recovery is being increased, and technology is spreading. Although results are necessarily preliminary, the urgency of potential abandonment in Class 1 and many other domestic reservoirs dictates that field demonstration projects be examined now for immediately applicable results. Figure 3 shows the locations, field names and organizations for the Class 1 projects. The technologies used, the profit potential from the technologies, and specific project results are discussed in the following sections.

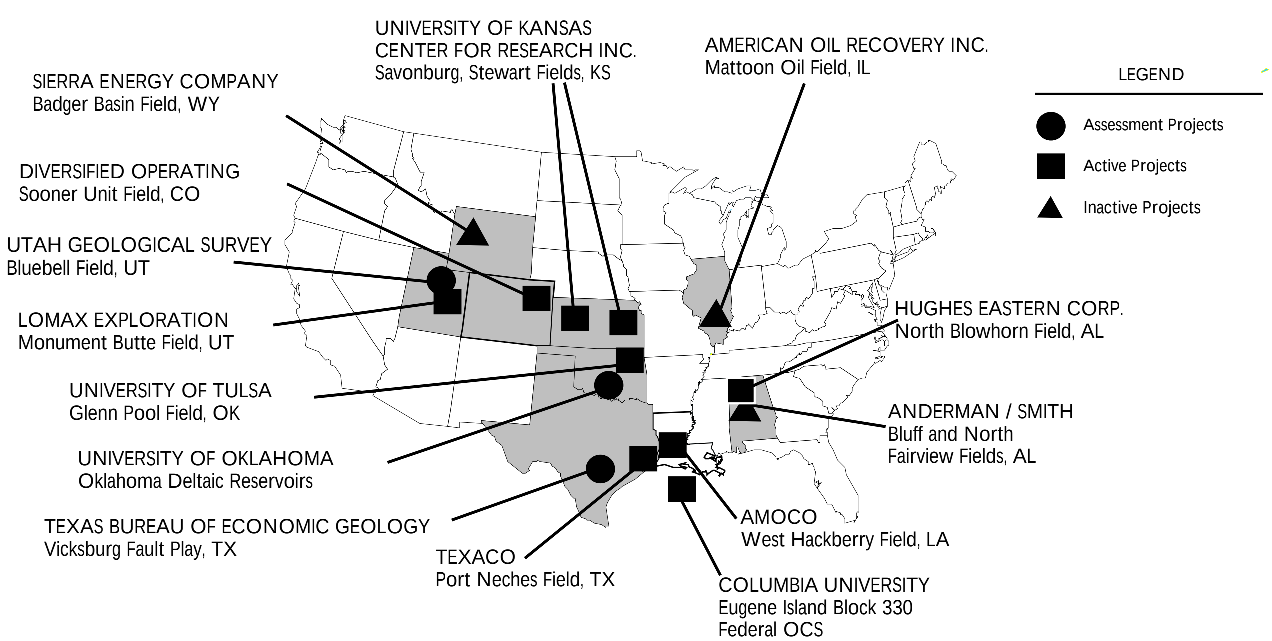

Figure 3 Location, Field Name, and Organization of Class 1 Projects

Technologies Used in Class 1 Projects

A review of the technologies targeted in the Class 1 project Statements of Work reveals that reservoir characterization is a key component in most projects. Table 2 shows the technologies being addressed by each Class 1 project. Data for reservoir characterization are obtained from core and outcrop analysis, seismic interpretation, advanced logging measurements, and well tests. The data are entered into digital databases for reservoir modeling, geostatistics, numerical simulation, and reservoir management planning. Interpretations of the detailed information help operators identify techniques that enhance production and improve oil recovery. Infill drilling and waterflood techniques are widely used; directional drilling, CO_2 injection, microbial, and polymer flooding techniques also are demonstrated in various field projects.

Near-Term Projects

Diversified Operating Corporation is currently applying core analysis, 3D seismic interpretation, and well tests to identify infill drilling and waterflood potential in the Muddy D Sand, Sooner Unit, in the Denver basin. **Lomax Exploration Company** is using core analysis, tracer tests, and numerical simulation to understand the waterflood recovery mechanism in high-paraffin oil reservoirs of the Green River Formation in the Monument Butte Unit and waterflooding potential in other similar reservoirs in the Uinta basin. The **University of Kansas** is performing reservoir characterization, infill drilling, and injection water treatment techniques to improve sweep efficiency, and to evaluate polymer-improved waterflooding potential in the Stewart and Savonburg fields, KS.

The **University of Tulsa** is employing cross borehole tomography, imaging logs, and simulation to evaluate various reservoir management approaches, including horizontal injection wells in the Bartlesville Sand in northeast Oklahoma's Glenn Pool field. The **Utah Geological Survey** is performing geological and engineering characterization and computer simulation of the Green River and Wasatch formations in the Bluebell field of the Uinta basin. Reservoir heterogeneities related to fractures and depositional trends will be identified and used to determine improved completion techniques.

Mid-Term Projects

These four projects are demonstrating enhanced oil recovery processes. **Amoco** is using fluid geochemistry, well tests, and modeling to demonstrate the double displacement process (air injection and gravity drainage) in southern Louisiana. **Columbia University** is applying advanced reservoir characterization, 4D seismic imaging, and reservoir modeling to identify the production potential from overpressured fault zones in the Gulf of Mexico. **Hughes Eastern** is using core and fluid analysis, infill drilling, and the growth of indigenous microbes to improve sweep efficiency in the Black Warrior basin. **Texaco** is using reservoir characterization, modeling, and horizontal CO_2 injection wells to improve production along the southeast Texas Gulf Coast.

Table 2 Technologies Addressed in Class 1 Projects*

	RESERVOIR DATA						ANALYSIS METHODS					PRODUCTION ENHANCEMENT								
	Core/Fluid Analysis	Outcrop Analysis	Biostratigraphy	Seismic	Advanced Logging	Well Tests	Digital Database	Reservoir Modeling	Geostatistics	Num Simulation	Reservoir Mgt	Recompletion	Paraffin Control	Infill Drilling	Directional Drilling	Waterflood	Gravity/Air Injection	CO_2	Microbial	Polymer
American Oil Recovery	●					●		●	●			●		●				●		
Anderman/Smith						●		●		●		●		●		●				
Diversified Operating	●			●		●		●		●	●			●		●				
Lomax Exploration	●				●	●		●		●			●	●		●				
Sierra Energy	●			●											●					
Univ. of Kansas	●					●	●			●	●			●		●				●
Univ. of Oklahoma							●		●	●										
Univ. of Texas	●	●		●			●	●	●			●		●						
Univ. of Tulsa	●	●		●	●	●		●	●	●	●				●	●				
Utah Geological Survey	●	●	●		●		●		●	●		●	●	●						
Amoco Production	●					●		●			●	●					●			
Columbia University	●		●	●	●	●	●	●		●				●						
Hughes Eastern	●		●											●		●			●	
Texaco E&P	●		●			●		●		●		●		●	●			●		

* Table 2 and text discussion are based on technology descriptions in project statements of work. As projects mature, moderate changes in response to project results are occurring (and can be expected to continue).

Make Money with Technology

Productive intervals worth millions of dollars often are overlooked because the resources were not allocated to available technology.

Many of DOE's Class 1 Field Demonstration projects illustrate that applying science and technology can lead to increased profitability and additional reserves for producers.

Making More Money

An operator can add reserves and increase profits in three ways: purchase, explore, or develop existing acreage. Each approach has advantages and disadvantages.

According to the *Oil and Gas Journal* (May 1994), adding reserves by acquisition costs from $3.86 per barrel of oil (BO) to $4.50 per barrel of oil equivalent (BOE) for gas-dominated reservoirs.

Merrill Lynch reported 1993 average exploration costs for the top 10 U.S. independents to be $4.30/BOE. The finding cost for the majority of industry was higher. The figures mentioned did not include other expenses such as salaries, operating costs, and other company overhead.

Impact of Technology

By performing simple calculations similar to Merrill Lynch's to determine the cost of adding reserves, the impacts of applied science and technology can be seen in the Class 1 demonstration projects.

The costs of adding reserves by field development methods were calculated by dividing the total cost (DOE plus operator cost) by the amount of incremental oil recovered. Table 3 presents the costs calculated for the Class 1 projects that had available recovery data. Like the Merrill Lynch calculations, these figures do not include overhead and other costs.

Table 3 Costs To Add Reserves

Project	Reserve Addition (MMBO)	Costs/BOE $
Stewart (KS)	3.73	0.70
Glenn Pool (OK)	0.39	3.33
Sooner Unit (CO)	0.90	1.75
Mon. Butte (UT)	1.68	1.90

The average cost to recover additional reserves from the fields listed in Table 3 is about $1.92/BOE. Drilling in the Sooner unit is predicted to encounter and test new reservoirs with the possibility of additional reserves. This would, accordingly, lower the average finding costs.

Comparing the recovery costs in the Class projects with the industry averages indicates that they are much better than exploring for or purchasing additional reserves. Of course, overhead, royalties, and other expenses must be factored in to determine project payout. But, at the costs shown, a prudent operator using these technologies should have a chance for an adequate return on investment, providing operating costs are low enough.

Technology Transfer

Another important aspect of the field demonstration projects is the technology "spin off," or transfer of the technologies developed in the projects and their economic impact.

The best example of technology transfer is the Monument Butte Unit waterflood project operated by **Lomax Exploration Company**. Lomax successfully demonstrated the waterflooding technology in the Green River Formation of Utah, a formation with primary recovery efficiencies of 5% OOIP. Unconventional waterflooding techniques in this heterogeneous, high-paraffin oil reservoir yielded an additional 5% OOIP with projected recoveries of 25% OOIP. The details of this project and subsequent waterfloods inspired by the demonstration project are discussed on page 6 of this newsletter.

Adding Reserves

Projects that involve regional assessments of oil potential are another approach to adding reserves. These projects compile information to aid exploration and production efforts. **The University of Oklahoma, Utah Geological Survey,** and the **University of Texas/Bureau of Economic Geology** in Texas are performing regional assessment projects. These assessments are similar to basin analysis or regional trend analysis studies performed in exploration so an exact monetary value is hard to quantify. However, one can infer some value by examining one of the projects.

Regional Assessments

The **University of Texas/Bureau of Economic Geology** project is an assessment of the prolific Frio Formation.

In this project, the Frio Sandstone in south Texas has been identified as a reservoir interval in danger of premature abandonment. This particular play has been active since the 1930s and has been considered mature since the 1950s and 1960s. Many independent and major companies have drilled Frio fields.

The Frio fields of south Texas have produced nearly 1 BBbl of oil, but still contain more than 1.5 BBbl of potentially recoverable oil. Because of the compartmentalization of the reservoirs, it is difficult to adequately drain a field, leaving a considerable amount of bypassed oil. More than 70 Frio reservoirs have been abandoned leaving large amounts of oil in place.

By compiling and analyzing reservoir information, it may be possible to identify bypassed reservoir intervals that have high potential. This information will be provided to operators to assist them in drilling new wells in prospective areas.

If this project results in recovering an additional 3% of the OOIP, it will produce 48 MMBbl. Calculate the potential of this project at $18/bbl!

This project only addresses the Frio in the Vicksburg Fault zone of south Texas, but the Frio trend extends east along the Texas Gulf coast into Louisiana. If this project is successful, similar projects could be conducted along the trend. In addition, the same methodology may be applicable in the deeper Yegua or Wilcox sands.

From an explorationist's point of view, these projects are value-added parts of the Class Program.

The **University of Oklahoma** is performing a similar project for all fluvial deltaic reservoirs in the state of Oklahoma. The **Utah Geological Survey** is doing a project in the Bluebell-Altamont field complex that focuses on the identification of improved completion techniques for reservoirs in the Uinta basin. These projects offer significant opportunity for operators by compiling and analyzing large amounts of data and identifying areas of opportunity for increased production.

Opportunity

In the United States, it is estimated that there are more than 37.1 BBbl OOIP in domestic fluvial deltaic reservoirs. About 11.4 BBbl have been produced and 0.6 BBbl of proven reserves remain. That leaves 25 BBbl still in the ground. If 16.3 BBbl of the remaining OOIP is immobile with present technology, then 8.8 BBbl remain. If only 1% of that oil can be recovered, that would be 88 MMBbl! The objective of the Class Program is to demonstrate technologies that can be used to recover that oil.

The Class 1 field demonstration projects show that it is possible to economically obtain reserves from mature fields. A prudent operator must apply science, technology, and make an investment. The science and technology used are not always novel or unique. Many of the technologies are off the shelf and are available from contractors or consulting companies. If an operation is cost-efficient, the operator can profitably add more reserves.

Find DOE's Oil Program Home Page on the World Wide Web

- Technology transfer activities
- Information on major DOE procurements

- Updates to project data
- Calendar of events
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Spreading Technology

Lomax Exploration's Class 1 Project in Utah's Uinta Basin

Lomax Exploration's Green River Formation Waterflood Demonstration Project in Utah's Uinta basin is successfully demonstrating waterflooding in the highly paraffinic, highly heterogeneous Green River Formation. Historically, the oil and reservoir characteristics have discouraged waterflooding. Lomax's successful waterflood demonstration in the Monument Butte Unit and surrounding area has, however, jump-started secondary recovery activity. Seven waterfloods have been started within a 10-mile radius of the Monument Butte Unit, with two more proposed projects (see Fig. 4). More than 300 wells ultimately will be waterflooded, including 83 new wells planned for 1995.

Successful Waterfloods

Early waterfloods, profitable with current conditions, had been conducted in the Greater Red Wash Area (Red Wash, Wonsits Valley, and Walker Hollow fields) some 30 miles away from Lomax's Monument Butte Unit. Having determined that the Monument Butte Unit had similar geological and reservoir characteristics, hydrocarbon composition, primary decline curves and reservoir pressures, Lomax began waterflooding in the Monument Butte Unit in 1987 against conventional wisdom and advice. The 22-well (8 injectors and 14 producers) waterflood has been surprisingly successful. Production has increased from 30 to 300 B/D. Secondary recovery has increased the 4.5% OOIP primary production to over 10% OOIP with a projected recovery of 25%–30%. Based on this success, Lomax proposed a Class 1 field demonstration project to evaluate the success of the Monument Butte Unit and to extend waterflooding to nearby Travis and Boundary Unit areas.

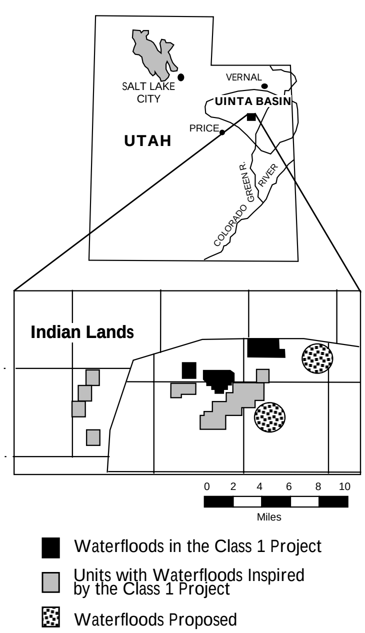

Figure 4 Regional Waterfloods

Reservoir Model

Reservoir characterization methods used in the project included analysis and description of core, petrographic studies, and log analysis. Formation micro-imaging (FMI)™ logs were used to characterize fracture distribution and orientation, thin bed evaluation and interpretation of the depositional environment. Magnetic resonance imaging (MRI) logs provided data concerning effective permeability of the near wellbore reservoir and the type and mobility of the fluid. The new data were integrated with log and stratigraphic section analysis in developing a geologic model. This data and compositional and PVT data for Monument Butte oils were integrated for reservoir simulation studies. Acceptable matches on an individual well and total reservoir basis confirmed the reservoir model. Thermal wellbore modeling indicates a strong possibility of paraffin deposition near the wellbore due to cooler injection water. Potential solutions to this production problem are being studied.

Unique Characteristics

Lomax's experience in applying waterflooding in the nearby Travis and Boundary Units illustrates that each reservoir may have unique characteristics. Waterflooding in the nearby Travis Unit appears to be dominated by natural or induced fractures. FMI logs indicated extensive fracturing of the Lower Douglas Creek, and water channeling problems have been experienced. For this unit, a dual-porosity, dual-permeability fractured reservoir model best matched performance. In the nearby Boundary Unit, a new well did not intersect producing sand layers. Despite the uniqueness of each reservoir and its risks, Lomax estimates the combined effect of all new activity in the area to ultimately be 31 MMBbl of added reserves. With development cost of $72 million, reserve development cost is $2.32/bbl.

Improving Injection Water

University of Kansas/Russell Petroleum CLASS 1 Project

The **University of Kansas** and **James E. Russell Petroleum, Inc.** are conducting a Class 1 near-term project to demonstrate reservoir management and improved waterflooding in Russell Petroleum's Nelson lease in the N.E. Savonburg field in southeast Kansas.

History

First production from the shallow (700 ft) Chelsea Sandstone of the Cherokee group occurred in 1970. Waterflooding began in the early 1980s with the lease being fully developed with over 100 wells by 1985. Cumulative oil production through June 1994 was 371,000 bbl, with 132,000 bbl considered to be primary production. As is typical of fluvial-dominated deltaic reservoirs, cumulative volumes from individual wells are highly variable. Production increases from gel polymer treatments performed in 1986 were not sustained due to wellbore plugging from poor water quality. Production at the start of the Class 1 project had declined to about 20 B/D—near the economic limit.

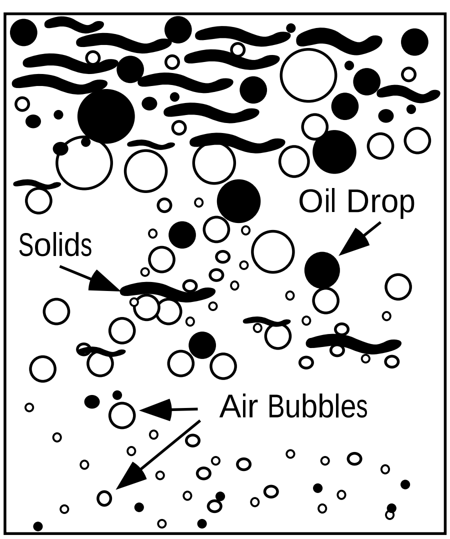

Figure 5 Flotation of Solids & Oil by Air Bubbles

Activities

Project activities have focused on reservoir characterization, identification of unrecovered mobile oil, and operational problems. Reservoir characterization has benefited greatly from closely examining abundant core data (physical cores from 23 wells, description and analyses from additional cores) and applying emerging sedimentologic and stratigraphic principles, especially sequence stratigraphy. Areas with potentially high volumes of mobile oil have been determined by comparing pattern volumetrics with streamtube waterflood simulation results. Engineering estimates place the potentially recoverable oil with improved operations at 363,000 bbl, although it is recognized that this full potential will be difficult to achieve.

Injection Control

Past waterflooding activities were plagued by poor water quality from high solids levels. Factors essential to improved recovery from waterflooding are cleaning the injection wellbores, improving injection water quality, and placing injection water in the desired intervals. Injection wellbores were cleaned by injecting acid and surfactant with a coiled tubing unit. The coiled tubing unit was less expensive and more efficient than using a workover rig. Gel polymer treatments have been performed in three wells to improve injection distribution.

Injection water quality was so poor that the high solids levels would rapidly plug 75 µ filters. An air flotation unit was used to improve the water quality. Although air flotation is an off-the-shelf technology, it has not been extensively applied in the oil field. With the air flotation process, air is bubbled through the water and the air-oil-solids mixture floats off the top (see Fig. 5). The unit operation is still being optimized, but the water quality has been significantly improved, and the required filter mesh has been reduced to 10 µ. Fewer injection wellbore cleanouts are anticipated as the project progresses.

The Bottom Line

Water treating costs per barrel of water have been reduced significantly from $0.09 to $0.05/bbl. Reduced costs indicate that a three-year payout of the air flotation equipment can be achieved. The real payout, increased oil recovery from improved sweep efficiency, remains to be demonstrated as the project matures.

C A L E N D A R

JULY

July 13, Houston, TX; ***TIPRO/Texas BEG,*** Half-day workshop using material from Texas BEG "Revitalizing Mature Oil Plays in Frio Reservoirs of South Texas" Class 1 project; ph (512) 477-4452 for Amy Carmen or Terry Ramsey.

July 14 & July 28, Corpus Christi, TX; ***TIPRO/Texas BEG,*** two half-day workshops using material from Texas BEG "Revitalizing Mature Oil Plays in Frio Reservoirs of South Texas" Class 1 project, ph (512) 477-4452 for Amy Carmen or Terry Ramsey.

July 16–19, Reno, NV; 1995 ***AAPG Rocky Mountain Section Meeting*** (will include presentations by Utah Geological Survey on Bluebell Field, Class 1 project).

July 24, Billings, MT; ***7th Annual International Williston Basin Symposium*** (will include two papers on Luff Exploration's Class 2 project).

AUGUST

August 31, Okmulgee, OK; ***FDD Workshop:*** The Booch Play; University of Oklahoma Class 1 project; ph (800) 330-3996 for Michelle Summers.

Summer 1995 (date to be determined), Allen County Community College, in Iola, Kansas; ***Reducing Operating Costs in the Oilfield;*** by University of Kansas PTTC North Mid-Continent RLO (outgrowth of Class 1 project work); ph (913) 864-7398 for Dr. Lanny Schoeling.

SEPTEMBER

Aug/Sept. (being planned), Midland, TX; ***3D Seismic Data Use for Reservoir Characterization;*** half-day workshop being planned by University of Texas Permian basin (may include discussion of tomography in Oxy, USA Class 2 project).

Fall 1995 (location and date to be determined); ***3D Seismic Seminar for Independents;*** being planned by Diversified Operating Company (Operator of Sooner Unit, Colorado, Class 1 project).

Fall 1995 (location and date to be determined); Two general workshops on Sooner Unit Class 1 Project; being planned by Diversified Operating Company (Operator of Sooner Unit, Colorado, Class 1 project).

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