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**ASSIST IN THE RECOVERY OF BYPASSED OIL FROM
RESERVOIRS IN THE GULF OF MEXICO**

Contract Number: DE-AC22-92BC14831

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Department of Petroleum Engineering
Baton Rouge, LA 70803-6417**

**Contract Date: February 18, 1992
Anticipated Completion Date: March 18, 1994
Total Government Award: \$2,025,755**

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Quarterly Status Report (Draft): Covering Jan. 1, 1993 - March 30, 1993

Report Date: April 30, 1993

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Executive Summary

To collect data from MMS in the most efficient and accurate manner, efforts were keyed on 208 sands in 46 fields which contained 1,289 reservoirs. This represents 60% of the original oil in place (OOIP) for the entire offshore Gulf of Mexico. If time and resources permit, additional reservoirs will be included to increase the coverage to 70% (plus) OOIP. The most efficient target for an accurate description of the bypassed oil in the Gulf of Mexico is from 208 sands and 60% OOIP.

LSU and BDM began analysis of data obtained from Taylor Energy on the South Marsh Island (SMI) Block 73 field in the Gulf of Mexico. Specifically, the process of developing a detailed data set for simulating the B-35 K Sand and B-65 Sand reservoirs began. This included the review and analysis of the geology of the reservoirs to define reasonable grid configurations for use in the simulator.

Both the SMI 73 B-35 K and B-65 Sand reservoirs are excellent examples of steeply dipping salt dome related oil reservoirs. These reservoirs provide an opportunity to simulate attic gas injection, because numerous gas injection cycles were conducted. The operator intends to conduct additional cycles so that the simulation can be utilized to help define the optimum injection rate and volume, an anticipated shut-in time necessary for optimum gas migration and a more accurate estimate of the up-dip oil volumes.

At present, modifications to BOAST II for radial grid systems are producing believable results in a reasonable, though long, period of time. Attempts to reproduce the results of small-scale experiments conducted in the Department of Petroleum Engineering are currently underway. The results appear to compare favorably with the experimental data, but more rigorous comparisons will need to be performed. Also, difficulties are being experienced with the inclusion of gravity in the model, however the problems are minor, and several ideas have been considered to resolve the difficulties.

BDM has modified the MASTER reservoir simulation model for use in simulating miscible gas injection processes in steeply dipping reservoirs. The simulation code has been modified to include the dip feature, and the program has been successfully installed and operated on in-house PCs. BDM began the process of verifying the model by comparing model output to published model results for an attic gas injection process in a steeply dipping reservoir.

INTRODUCTION

Much of the remaining oil offshore is trapped in formations that are extremely complex due to intrusions of salt domes. Conventional seismic processing techniques cannot clearly image either these traps or the full extent of oil-bearing segments near the salt domes; therefore, substantial volumes of oil may have remained uncontacted by previous drilling.

Recently, however, significant innovations have been made in seismic processing and mathematical migration of seismic signal. In addition, significant advances have been made in deviated and horizontal drilling technologies and applications. These technology advances make it possible to reprocess existing seismic data to identify non-contacted portions of the reservoirs, which can then be contacted using advanced drilling technologies to kick out new wells from existing wells. Effective application of these technologies, along with improved recovery methods, offers opportunities to significantly increase Gulf of Mexico production, delay platform abandonments, and preserve access to a substantial remaining oil target for enhanced recovery and other advanced recovery processes.

During this reporting period, data collection continued from the Minerals Management Service (MMS) and several operators. Modifications to BOAST II and MASTER reservoir simulators for the integration of radial grid systems and for use in simulating miscible gas injection processes in steeply dipping reservoirs continued. The building of the experimental apparatus designed for studying the recovery of attic oil also continued. Analysis of data obtained from Taylor Energy in South Marsh 73 field began.

Project Description

The objective of this research is to assist the recovery of non contacted oil from known reservoirs on the Outer Continental Shelf in the Gulf of Mexico. Mature offshore reservoirs, declining oil reserves, declining production, and other natural forces are accelerating the abandonment of offshore oil resources and production platforms. As these offshore wells are plugged and the platforms are abandoned, an enormous volume of remaining oil will be permanently abandoned. Significant quantities of this oil could be recovered using advanced technologies now available if the resource can be identified.

This project will proceed under three broad phases:

Analysis -- TORIS level data will be collected on the major fields located in the piercement salt dome province of the Gulf of Mexico Outer Continental Shelf. Representative reservoirs will be studied in detail in order to evaluate undeveloped and attic oil reserve potential. These detailed investigations will be used to calibrate the TORIS level predictive models. The recovery potential of advanced secondary and enhanced oil recovery processes and the exploitation of undeveloped and attic oil zones for salt dome reservoirs in the Gulf of Mexico will be assessed.

Supporting Research -- Supporting research will focus on the modification of public domain reservoir simulation models to accurately simulate the conditions encountered in the piercement salt dome province of the Gulf of Mexico. Laboratory research will focus on the development of fluid relationships that will be used in the simulation of miscible and immiscible processes in the project area.

Technology Transfer -- A significant effort is planned to transfer the results of this project to potential users of the technology. Technology transfer activities will also provide feedback channels that will help keep the analysis and supporting research focused on the most important problems associated with this project.

Project Status and Planned Activities

Data Collection

To collect data from MMS in the most efficient and accurate manner, efforts were shifted from keying on the 118 reservoirs which had >2.5 MMBBLS reserves and >60% produced to date (i.e. large, incorrectly mapped reservoirs) to 208 sands in 46 fields which contained 1,289 reservoirs. This represents 60% of the original oil in place (OOIP) for the entire offshore Gulf of Mexico. If time and resources permit, additional reservoirs will be included to increase the coverage to 70% (plus) OOIP. Figure 1 illustrates the distribution of the OOIP in piercement salt dome fields by sand horizon. The most efficient target for an accurate description of the bypassed oil in the Gulf of Mexico in 208 sands and 60% OOIP.

FIGURE 1

ICF personnel concentrated on data pertinent to Bay Marchand 2 field since this is the largest and most prolific field in the offshore Gulf Coast. Upon completion of the data collection on Bay Marchand 2 field, personnel began collecting data on South Marsh 73 field and other pertinent fields. Taylor Energy Co., the main operator of South Marsh 73 field, has agreed to provide a substantial amount of data for the project. Therefore, efforts at MMS will be coordinated with the Taylor data collection efforts. Figure 2 shows the unit of analysis and scope of data collected for the sands. MMS will provide, through DOE, the content of FRRE Database for the 1,289 reservoirs. ICF's on-site personnel will compile measurements of fault blocks from maps, data elements from MER and other hard copy files, and key reservoir properties from hard copy files for the purpose of cross-checking the FRRE Database.

LSU is collecting the Taylor data. LSU is also continuing the collection of data from other operators. ARCO Oil and Gas Co. has provided some excellent data on the South Pass 60 and 61 field areas. Several other companies have indicated a desire to assist. Also, Amoco has agreed to provide an information package for sands in Eugene Island 208 pending approval from their partner, Texaco. Mobil Exploration has also agreed, in principle, to provide information and assistance. An initial meeting is scheduled with Mobil in April.

FIGURE 2

Data Analysis

LSU and BDM began analysis of data obtained from Taylor Energy on the South Marsh Island (SMI) Block 73 field in the Gulf of Mexico. Specifically, the process of developing a detailed data set for simulating the B-35 K Sand and B-65 Sand reservoirs began. This included the review and analysis of the geology of the reservoirs to define reasonable grid configurations for use in the simulator. Review of well histories, including production, gas injection, and pressure data also began. BDM concentrated on the B-35 K Sand, and LSU concentrated on the B-65 Sand.

Both the SMI 73 B-35 K and the B-65 Sand reservoirs are excellent examples of steeply dipping salt dome related oil reservoirs. Initial efforts have been placed primarily on the B-35 K Sand reservoir for several reasons. Production from the B-35 K Sand reservoir has exceeded the mapped reserves as a result of poor definition of either the up-dip limit or the original oil/water contact, or both. Recovery to date from the B-35 K Sand represents 86% of the initially

defined original oil in place. Volumetric analysis of this additional potential will be performed as the study progresses to define a reservoir volume that results in a reasonable percentage recovery. This reservoir also provides an opportunity to simulate attic gas injection, since numerous gas injection cycles were conducted. The operator intends to conduct additional cycles so that the simulation can be utilized to help define the following: optimum injection rate and volume, an anticipated shut-in time necessary for optimum gas migration, and a more accurate estimate of the up-dip oil volumes.

Predictive Modeling Phase

The determination of the methodology for the predictive modeling phase of the project is about 50% complete. The design of the blueprint began in February 1993, and the computer coding began in March 1993.

Critical Process Parameter Laboratory Experiments

The apparatus for the study of attic oil recovery techniques is continuing to be built.

BOAST II Modification

Personnel from the LSU computer science department worked on the simulation of two-phase flow of slightly compressible fluids in a three-dimensional porous medium. Progress to date has included the construction of a FORTRAN program that uses 3-D finite elements to approximate the governing equations. Although the solutions show numerical stability, minor oscillations inherent in the transient finite element methods were discovered. The fact that the equations are highly nonlinear, along with the fact that the model typically contains a sharp front (or discontinuity), magnifies these problems so that the resulting solutions are sometimes unsatisfactory. Problems of oscillations are traditionally resolved by refining the mesh, as in finite-difference methods. However, to obtain acceptable answers, the refinement would have to be to such a degree that it would result in unacceptable memory and time requirements. Through further investigation, it is believed that the use of a better time integration scheme such as either Crank-Nicholson, Pade Approximate, or Predictor-Corrector should significantly reduce the oscillations. This is the current focus of efforts.

To determine the source of the oscillation problem, considerable improvements were added to the program, and the code was scrutinized so that confidence of its correctness could be achieved. In addition, extensive information was gathered concerning Darcy-flow simulations when they are discretized with finite element techniques. It is believed that an acceptable solution with the model is obtainable and will be reached with one of these time integration schemes. There is a high degree of confidence that these techniques will be easily extended to a large collection of simulation problems.

The existing finite element code was adapted so that virtually any type of element may be easily incorporated into the solution scheme. This gives increased flexibility and makes it possible to utilize the mesh refinement techniques.

Additionally, code was created that will refine and unrefine arbitrary elements in a mesh of bilinear quadrilateral elements. This code has been tested and appears to be robust. The next step was to incorporate this mesh refinement code into the finite element program to provide a tool that dynamically constructs small elements in regions of activity and coarse elements elsewhere.

At present, the software is producing "believable" results in a reasonable, though long, period of time. Attempts to reproduce the results of small-scale experiments conducted in the Department of Petroleum Engineering are currently underway. The results appear to compare favorably with the experimental data, but more rigorous comparisons will need to be performed. Also, difficulties with the inclusion of gravity in the model are being experienced; however, the problems are minor, and several ideas have been considered to resolve the difficulties.

Future work will include the resolution of our problem with the gravity term, followed by a quantitative comparison of our results with the experimental data. This will be followed by the construction of an adaptive finite element program for full three-dimensional modeling. Although the solution methods will

be similar to those used in two-dimensional problems, emphasis will be placed on efforts to produce efficient code for reducing the computational resources needed for a simulation.

MASTER Modification

BDM has modified the MASTER reservoir simulation model for use in simulating miscible gas injection processes in steeply dipping reservoirs. The simulation code has been modified to include the dip feature, and the program has been successfully installed and operated on in-house PCs. BDM began the process of verifying the model by comparing of model output to published model results for an attic gas injection process in a steeply dipping reservoir. In addition, BDM is in the process of installing a post-processing package on the MASTER model that will greatly enhance the capability for plotting and mapping simulation output data.

Summary

During this reporting period, ICF Resources Incorporated (ICF), a subcontractor for the project, continued to collect data from Minerals Management Service (MMS) and LSU continued to collect data from several operators. LSU also continued to modify BOAST II for the integration of radial grid systems and the building of the experimental apparatus for studying the recovery of attic oil. BDM Federal, Inc. (name changed from BDM International, Inc.) (BDM), a subcontractor for the project, began modifying the MASTER reservoir simulation model for use in simulating miscible gas injection processes in steeply dipping reservoirs. LSU and BDM Federal. Inc. began analyzing data obtained from Taylor Energy in South Marsh 73 field.

References

There were no references for this report.

Publications

There were no publications during this reporting period.

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