AIIM

**Association for Information and Image Management**

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910

301/587-8202

Centimeter

Inches

MANUFACTURED TO AIIM STANDARDS
BY APPLIED IMAGE, INC.

DOE/BC/14880--8

RECEIVED
USDOE/PETC
94 JUL -1 AM 11:16
ACQUISITION & ASSISTANCE DIV.

RECEIVED
SEP 20 1994
OSTI

Quarterly Technical Progress Report

# IMPROVED TECHNIQUES FOR FLUID DIVERSION IN OIL RECOVERY

Contract Number: DE-AC22-92BC14880

New Mexico Petroleum Recovery Research Center
New Mexico Institute of Mining and Technology
Socorro, New Mexico

Date of Report: July 1, 1994

Contract Date: September 17, 1992

Anticipated Completion Date: September 30, 1995

Program Manager: Randall S. Seright

Principal Investigator: Randall S. Seright

Contracting Officer's Representative: Jerry F. Casteel

Reporting Period: April 1, 1994 through June 30, 1994

Contributors: John Hagstrom, Jenn-Tai Liang,
Hassan Nimir, Richard Schrader, Mei Ye

PRRC Report 94-31

## OBJECTIVES

This three-year project has two general objectives. The first objective is to compare the effectiveness of gels in fluid diversion with those of other types of processes. Several different types of fluid-diversion processes will be compared, including those using gels, foams, emulsions, and particulates. The ultimate goals of these comparisons are to (1) establish which of these processes are most effective in a given application and (2) determine whether aspects of one process can be combined with those of other processes to improve performance. Analyses will be performed to assess where the various diverting agents will be most effective (e.g., in fractured vs. unfractured wells, deep vs. near-wellbore applications, reservoirs with vs. without crossflow, or injection wells vs. production wells). Experiments will be performed to verify which materials are the most effective in entering and blocking high-permeability zones. Another objective of the project is to identify the mechanisms by which materials (particularly gels) selectively reduce permeability to water more than to oil. In addition to establishing why this occurs, our research will attempt to identify materials and conditions that maximize this phenomenon.

## SUMMARY OF TECHNICAL PROGRESS

**Use of Foams as Blocking Agents.** A report (PRRC Report 94-22) has been prepared that examines the use of foams as blocking agents. In concept, several phenomena could allow foams to be superior to gels as blocking agents, however, only in certain circumstances. At present, these circumstances are hypothetical; very few conditions have been verified experimentally or in field applications. Two phenomena (the limiting capillary pressure and the minimum pressure gradient for foam generation) could allow low-mobility foams to form in high-permeability zones but not in low-permeability zones. Exploiting these phenomena during foam placement requires that (1) under given reservoir conditions, a gas/liquid composition must be identified that will foam in high-permeability zones but not in low-permeability zones, (2) the foam must not easily collapse or wash out from the high-permeability zones, and (3) the aqueous phase must not contain a gelant or other reactive blocking agent.

The following is a list of several other ideas where foams, foamed polymers, or foamed gels could have advantages over gels as blocking agents. However, all of these concepts require further development and experimental verification.

1. When oil wells are returned to production after foam injection, foams could collapse more rapidly in oil zones than in water zones. Foam washout from the water zones could be reduced by incorporating a polymer or gel into the foam. If a gelant is used, the foam must be produced from the oil zones before gelation occurs; otherwise, the oil zones could be damaged.

2. Pre-formed foamed gels may be effective blocking agents for plugging fractures. Because gelation occurs before injection, leakoff from fractures could be minimized using foamed gels. Because they are foams, foamed gels may propagate through fractures more effectively than pre-formed gels (i.e., foamed gels may be less likely to screen out or develop excessively high pressure gradients during injection).

3. Because of their high gas content, foamed gels formed using "strong" gels may allow more control in achieving low or intermediate residual resistance factors.

4. In cyclic steam projects, foam placement could be aided by gravity effects combined with very large mobility contrasts between the foam and the displaced oil.

5. For foams, residual resistance factors for gas can increase with increasing permeability. This behavior could be exploited when using foam as a gas blocking agent. A similar phenomenon has not been observed for water residual resistance factors in the presence of foam. Gels and foams are known to show different permeability reductions for different phases. Experimental work is needed to establish the permeability reduction properties of foamed polymers and foamed gels.

**Use of Emulsions as Blocking Agents.** Another report (PRRC Report 94-25) has been prepared that examines the use of emulsions as blocking agents to improve reservoir sweep efficiency. Although several features of emulsion flow through porous media remain unanswered, our analysis of the literature indicates that emulsions or emulsion/gel combinations will not perform significantly better than gels as blocking agents, particularly in the areas of placement characteristics and permeability-reduction properties.

**Use of Particulates as Blocking Agents.** A third report (PRRC Report 94-30) has been prepared that examines the use of particulates as blocking agents. Petroleum and patent literature was surveyed to investigate whether particulates have potential advantages over gels for use as blocking agents. Most of the literature surveyed made unsubstantiated claims that particulates can selectively plug high-permeability thief zones without damaging oil productivity. Critical analyses of these claims reveal that most of the proposed schemes suffer from the same placement limitations that gels experience. Particulates small enough to penetrate into the formation can cause significant damage to the formation permeability. The degree of permeability reduction increases with decreasing formation permeability.

We developed a theoretical model to examine the feasibility of using particulates to prevent gelant penetration into low-permeability zones. Our theoretical analyses revealed that, when used in conjunction with gels, mono-disperse particulates could prevent gelant leakoff into the rock matrix during the placement process. To achieve selective placement, the size of the particulates must be small enough to penetrate readily into high-permeability zones but large enough not to enter low-permeability zones.

For economic and technical reasons, particulates used in field applications usually have a size distribution. To achieve selective placement using particulates with a normal size distribution, a maximum standard deviation exists that should not be exceeded for a given permeability contrast. The maximum standard deviation for selective placement decreases with decreasing permeability contrast. For a given standard deviation, maximum selectivity is achieved by choosing the average of the critical particle sizes of the high- and low-permeability zones as the mean particle size.

**Propagation of an Aluminum-Citrate-HPAM "Colloidal-Dispersion" Gel Through Berea Sandstone.** Another report (PRRC Report 94-29) has been prepared that examines the ability of an aluminum-citrate-HPAM "colloidal-dispersion" gel to propagate through Berea sandstone. Our experimental results indicate that this formulation basically behaves like other gels and gelants. Early in the gelation process, it propagates through sandstone like a polymer solution without crosslinker. After some point (presumably when gel aggregates grow to the size of pore throats), gel propagation is extremely slow or negligible. Although we observed an unusual behavior during the second day of gelant injection, we do not expect aluminum-citrate-HPAM formulations to propagate through porous rock like a "super polymer" after gel formation.

An objective analysis of the literature supports these findings. Claims to the contrary were based largely on field results that assumed the wells were not fractured. The field and laboratory results can be explained if the injection wells are assumed to be fractured.

# DATE FILMED

10/11/94

# END