Characterization of Potential Sites for Near Miscible CO2 Applications to Improve Oil Recovery in Arbuckle Reservoirs

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PROJECT MANAGEMENT PLAN

SCOPE OF WORK

Defined Effort Objectives

Due to the lack of coring, modern well logging, and well testing in the past, Arbuckle reservoirs have not been well characterized. Current understanding of the Arbuckle is based on a conceptual model with limited petrophysical, drill stem test and pressure build up data. The uncertainty of reservoir properties places a challenge for an IOR application in Arbuckle reservoirs as the nature of flow is affected by reservoir properties and heterogeneity.

In order to ultimately predict improved oil recovery in a future CO₂ flood, an evaluation plan is designed to seek data that pertain to the pressure, residual oil saturation, reservoir properties and the nature of the flow from well to well. The evaluation methods include single well transient pressure tests, multiple well interference tests, single well tracer tests, and interwell tracer tests. All tests will be designed to determine the nature of the flow paths and average properties in the reservoir, to assess the effect of geology on process performance, to calibrate a reservoir simulation model, and to identify operational issues and concerns for future IOR applications.

I. Tasks:

The proposed work will be conducted by the Tertiary Oil Recovery Project (TORP) at the University of Kansas at a selected oil filed producing from Arbuckle formation. The participating consortiums include University of Kansas Center for Research, Inc., TORP, University of Kansas, Kansas Geological Survey and small producer, Carmen Schmitt, Inc.

This is a field-based research project in which primary tasks 4-7 will be conducted at Ogallah unit located at Trego County in Kansas. Task 4 will utilize single well pressure build up tests to examine the pressure distribution in the field test. Task 5 will utilize well to well interference test to determine kh between wells. Task 6 will utilize well to well tracer technology to determine reservoir properties and continuity between wells. Task 7 will utilize single well tracer technology to measure the residual oil saturation remaining in the reservoir for CO₂ application. Task 8 will utilize all the
data collected from other tasks to design flooding pattern for future CO₂ injection with the simulation conducted at TORP, University of Kansas. With improved reservoir characterization as a result of this proposed approach, a first near miscible CO₂ application based upon a better description of the reservoir system could be field tested to prove the technology leading to additional oil recovery from Arbuckle reservoirs in Kansas. The potential benefits will be significant with an increase in the resource base for CO₂ flooding and an expanded opportunity for small producers to apply CO₂ flooding.

**Task 1 Project Management Plan**

In conjunction with the RPSEA Project Officer, the Project Management Plan will be modified and updated as necessary. The revised plan will be submitted within 30 calendar days of project kick-off. The RPSEA Contracts/Procurement Manager will have 20 calendar days from receipt of the Project Management Plan to review and provide comments to us. Within 15 calendar days after receipt of the RPSEA’s comments, we will submit a final Project Management Plan to the RPSEA Contracts/Procurement Manager for review and approval.

**Task 2 Technology Status Assessment**

A Technology Status Assessment will be completed and submitted to RPSEA within 30 calendar days of project kick-off.

**Task 3 Technology Transfer**

We will designate 2.5% of the amount of the award for funding technology transfer activities. Throughout the project, we will work with RPSEA to develop and implement an effective Technology Transfer Program at both the project and program level. Technology Transfer activities will consist of both project and program level activities amounting to not less than 2.5% of the total cost of the project. The total cost of the project is the value of funds provided by RPSEA plus the value of our cost share. We will nominate work/activities for 1.5% of the total cost for project level technology transfer activities. This work/activities may typically include writing technical papers and, as appropriate, participation in agreed to conferences and workshops. RPSEA will reserve 1% of the total cost for program level technology transfer activities. Project level Technology Transfer Plans will be submitted to RPSEA within 30 calendar days of
project kick-off. Technology transfer activities will also be detailed in the Project Management Plan. We will report the cost associated with project level technology transfer activities on each monthly report.

We will provide information requested by RPSEA to support DOE’s quantitative estimation of program benefits for the purposes of evaluating the benefits of the program and for review of Project Summary Sheets, newsletter articles and project status and successes.

The technology developed during this project will also be transferred to the oil and gas industry through 1) distribution of quarterly and annual reports, 2) annual project reviews, 3) presentation of papers at professional meetings and subsequent publications, 4) active participation in regional workshops, and 5) regular interaction with research counterparts in industry, government, and academic institutions.

The deliverables relevant to technology transfer are summarized as follows:

1. University of Kansas will submit a project-level Technology Transfer Plan within 30 calendar days of project kickoff.
2. University of Kansas will construct a website within 6 months of the project kick-off and maintain this web site with information about the project, progress reports, and any pertinent material derived from this study.
3. University of Kansas will work with regional PTTC or other appropriate producer organization to present at least two talks or papers on study results at meetings or workshops that target the regional producers.
4. University of Kansas will publish at least one relevant article in a trade journal that specifically targets producers.
5. University of Kansas will prepare/present at least one technical article for SPE or similar peer-reviewed journal.

**Task 4 Pressure Test for Flow Characteristics**

Task 4 consists of a well testing study to determine the potential operational pressure and flow capacity, wellbore conditions and other pertinent information. New pressure build up tests will be performed on wells without well test pressure data. The entire well test data developed from this program will be collected and analyzed. Specific subtasks are: 1) pressure build up tests, and 2) well test data interpretation.
**Task 4.1 Pressure Build Up Test**

Simple pressure build up tests will be performed. The selected producers will be shut-in and the fluid level will be shot for a period of time. The pressure data will be collected for interpretation.

**Task 4.2 Well Test Data Interpretation**

Commercial software will be used to interpret the test data. The flow geometry for the area affected by the test as well as the initial reservoir pressure will be determined. The flow capacity, area of drainage and other pertinent properties will be used in the reservoir description for reservoir modeling.

Completion of Task 4 allows us to examine the pressure distribution in the field and use the data with results from other tasks to select the sites for CO₂ injection.

**Task 5 Well-to-Well Interference Test**

Interference tests will be conducted to determine whether there is the presence or lack of communication between the test wells and surrounding wells and the kh between wells. Pulse testing will be used in this study. Before the start of pulse testing, all the test wells are shut-in until the pressures stabilize. The active well is then allowed to produce at a constant rate and the pressure response in the observation well(s) is observed and recorded. The pressure data responding to the production of the active well depend on the properties of rock and fluid and can be analyzed by commercial well test software to determine kh property between wells.

Completion of this task allows us to determine kh and communication between wells which is valuable and complimentary to the well-to-well tracer tests to characterize the flow path between wells.

**Task 6 Well-to-Well Tracer Test**

Inter-well tracer tests will be performed to gather information on flood patterns within the reservoir such that the uncertainty about flow paths and reservoir continuity may be reduced. The tracer program will be designed to 1) select the type of tracer, 2) calculate the tracer volume, 3) select the well to be injected and wells to be monitored, 4) determine the sampling frequency, and 5) specify sampling and detection techniques. The field execution plan will be coordinated with field personnel to implement the tracer injection and sample collection from producers. Finally, the tracer in the samples will be
analyzed and documented to 1) qualitatively derive the information about reservoir continuity and barriers and 2) model tracer transport for validation as necessary.

Completion of this task allows us to complete the characterization of potential sites for future CO₂ injection at near-miscible conditions.

**Task 7 Single Well Tracer Test**

Single well tracer tests will be used for measuring residual oil saturation. The test will be designed such that a reacting partitioning (primary) tracer is injected and produced through the same well following a shut-in period of time. During the shut-in, the primary tracer undergoes hydrolysis to generate a non-partitioning secondary tracer. Once the producer brings back the fluid after the occurrence of hydrolysis, the secondary tracer will arrive at the wellbore earlier than the primary tracer in a volume less than the injected volume. Based on the chromatographic theory, the separation of primary and secondary tracers can be quantitatively related to the residual oil saturation. Special interpretation techniques and design procedures will be considered to cope with tracer response characteristics arising from the double porosity structure of carbonate if it exists. This task will be subcontracted to Chemical Tracers, Inc. for the test.

Completion of this task allows us to determine the residual oil saturation in the reservoir prior to CO₂ injection. The data will be used for economic analysis in the pattern design.

**Task 8 Pattern Design**

A reservoir model as verified and updated with all the data collected from Tasks 4 to 7 will be used to design the flooding pattern. The pattern design will consider the operational issues and economic concerns for the CO₂ injection applications. Simulation will be conducted to evaluate the flooding pattern for optimization of CO₂ injection at near-miscible pressure.

Completion of this task allows us to develop an appropriate plan for field testing of CO₂ displacement processes at near-miscible conditions.

**Deliverables of the Defined Effort**

1. University of Kansas will submit Project Management Plan, Technology Status, Assessment, and Technology Transfer Plan within 30 days of project kick-off.
2. University of Kansas will track both cost share and technology transfer funds monthly and submit monthly report to RPSEA through SharePoint site before the 7th of each month.

3. University of Kansas will construct a website within 6 months of the project kick-off. The website will provide project information, progress reports, and other pertinent information derived from the project and updates as appropriate. The website will be maintained throughout the project period.

4. University of Kansas will provide an annual report detailing results of the data collection and analysis performed in Task 4 and 5.

5. University of Kansas will provide an annual report detailing results of the testing, analysis and simulation performed during the second year of the project.

6. University of Kansas will provide a final report.

7. Technology transfer efforts as defined in Task 3.

II. Schedules

A. Project Schedule/Timeline

![Gantt chart of the project](image)

Figure 1. Gantt chart of the project

B. Milestone Log

Milestones will take the form of specific project deliverables. Substantial progress towards each deliverable will be demonstrated as follows (Table 1):
### Milestone of Task

<table>
<thead>
<tr>
<th>Task Description</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Project Management Plan</td>
<td>30 days</td>
</tr>
<tr>
<td>2. Technology Status Assessment</td>
<td>30 days</td>
</tr>
<tr>
<td>3. Technology Transfer</td>
<td></td>
</tr>
<tr>
<td>1. Technology Transfer Plan</td>
<td>30 days</td>
</tr>
<tr>
<td>2. Other activities</td>
<td>24 months</td>
</tr>
<tr>
<td>4. Individual well pressure build up test</td>
<td></td>
</tr>
<tr>
<td>1. Collection of data</td>
<td>2 months</td>
</tr>
<tr>
<td>2. Build up test</td>
<td>12 months</td>
</tr>
<tr>
<td>3. Data interpretation</td>
<td>12 months</td>
</tr>
<tr>
<td>5. Interference well test</td>
<td>13 months</td>
</tr>
<tr>
<td>6. Well to well tracer test</td>
<td>12 months</td>
</tr>
<tr>
<td>7. Single well tracer test</td>
<td>2 months</td>
</tr>
<tr>
<td>8. Pattern design</td>
<td>12 months</td>
</tr>
</tbody>
</table>

The proposed research program is organized into five general areas that coincide with the tasks outlined in the Statement of Work. The presented Gantt chart in Figure 1 shows the project schedule and milestones. Task 1 and 2 are mandatory required by RPSEA. In Task 3, technology transfer efforts will be made from the start of project by planning how results of the proposed work can be made available to the research community, the target small producers, and to the oil industry. Research baseline cost/schedule/milestone report will be submitted to RPSEA monthly by 7th of every month through the SharePoint site of RPSEA. Task 4 will utilize single well pressure build up tests to examine the pressure distribution in the field test. Task 5 will utilize well to well interference test to determine kh between wells. Task 6 will utilize well to well tracer technology to determine reservoir properties and continuity between wells. Task 7 will utilize single well tracer technology to measure the residual oil saturation remaining in the reservoir for CO₂ application. Task 8 will utilize all the data collected from other tasks to design flooding pattern for future CO₂ injection. As demonstrated from the Ganttt chart in Figure 1, all the experimental tests in the field will be executed sequentially from the early stage of the project. The pattern design and computational
modeling to assess the potential application of CO\textsubscript{2} near-miscible flooding will start when selection of potential sites has been sufficiently established.

Technology transfer will include preparation of required reports such as management summary reports, program/project status reports, quarterly technical reports, annual technical reports and final technical report. These reports will be distributed through the website created and maintained by University of Kansas throughout this project. Technical papers will be prepared for presentation at appropriate technical meetings and for consideration for publication in Society of Petroleum Engineers’ literature. Presentation of short courses or workshops through the Petroleum Technology Transfer Council (PTTC) will be done as appropriate. Regular interaction with small producer participant and other research counterparts in industry, government, and academic institutions will be followed.

\textbf{C. Success Criteria at Decision Points}

As this is a field research project, the methodology developed is subjected to modification as the project proceeds. The decision points are set at the middle phase of each task where the data collected from pressure test, tracer test are to be analyzed. The reservoir properties as characterized by the proposed technique will be used to verify the existing reservoir model which is based on the geological model with moderate uncertainty. The success of each task depends on the quality of data collected and analysis. Downhole pressure measurement device will be installed if the quality of data in pressure measurement needs to be improved. The tracer sampling and detection on site will be considered if continuous monitoring of tracer are deemed to be necessary. A clear criterion for success at each decision point is to have good quality data developed from the proposed characterization method and validate reservoir modeling for this Arbuckle reservoir. Additional criterion for success in pattern design is completion of a plan for field testing of CO\textsubscript{2} displacement process at near-miscible condition.

\textbf{III. Planned expenditures:}

All the expenditures will be invoiced monthly according to the scheduled tasks performed and submitted to RPSEA monthly by 18\textsuperscript{th} of every month. The allocations of funding for the expenses in each task are described in the following section. The cost share expenditures will be invoiced according to University of Kansas accounting system.
Task 3 Technology Transfer

We will allocate 1.5% of awarded funding from each budget year in this task to conduct all the activities as described in the deliverables of defined efforts throughout this project.

Task 4 Pressure Test for Flow Characteristics

Task 4 starts at the first quarter of the first year of the project. We will allocate 22.3% of the first year and 11.6% of the second year awarded funding in this task to pay student’s salary, tuition, labor cost and equipment rental for pressure build up test.

Task 5 Well-to-Well Interference Test

Task 5 starts at the third quarter of the first year of the project. We will allocate 24.5% of the first year and 18.3% of the second year awarded funding in this task to pay labor cost, well test service and equipment rental for interference test.

Task 6 Well-to-Well Tracer Test

Task 6 starts at the third quarter of the first year of the project. We will allocate 25.3% of the first year and 13.9% of the second year awarded funding for cost of chemical, labor and equipment for field tracer test as well as the laboratory supplies for tracer analysis research.

Task 7 Single Well Tracer Test

Task 7 includes two tracer tests. One test will be conducted during the first budget year and another one during the second budget year. We will allocate 26.4% of the first year and 26.4% of the second year awarded funding for the cost of chemical, labor and service provided by Chemical Tracers, Inc.

Task 8 Pattern Design

Task 8 starts at the first quarter of second year of the project. We will allocate 28.3% of second year awarded funding in this task to pay student’s salary, tuition, computer supply and service for reservoir modeling, pattern design and analysis.