RPPR submitted to the US DOE NETL
DE-FE0010799

Small Molecular Associative Carbon Dioxide (CO_2) Thickeners for Improved Mobility Control

Quarterly Research Performance Progress Report
Start date: 10/1/13
End date: 12/31/13

Principal Authors: Robert Enick PI
Bayer Professor of Chemical and Petroleum Engineering
(412)624-9649 or (412)277-0154

January 7, 2013

DUNS Number DUNS: 00-451-4360

Department of Chemical and Petroleum Engineering
1249 Benedum Engineering Hall
University of Pittsburgh, Pittsburgh PA 15261

EXECUTIVE SUMMARY

The objective of this project is to promote the application of a CO_2 thickener for CO_2 EOR, and to then test the thickener in a single injection well pilot test. During Phase 1 – the current and initial phase of this project - various CO_2 EOR operators will be contacted by email, phone, and during in-person meetings in an attempt to establish a relationship that will facilitate such a field trial should the thickener be successfully developed. The field test would be conducted during Phase 2 of this NETL award.

The design, synthesis, purification and initial assessments of CO_2 solubility and (for compounds that dissolve in CO_2) viscosity enhancement are underway under separate ARPA-E funding. In all cases the thickeners are designed to be relatively small molecules that aggregate in solution to induce large increases in viscosity at low concentration. Ultrahigh molecular weight polymers are not being considered because our prior research has shown that only the prohibitive expensive and environmentally persistent fluoroacrylate-functionalized polymer can thicken CO_2 at reservoir conditions. Our team has begun the synthesis of Type 1, Type 2, and Type 3 small associative molecules under separate ARPA-E funding. Type 1 refers to molecules with CO_2-philic cores and aromatic associating groups at each end of the molecule. Type 2 refers to molecules with CO_2-philic cores and CO_2-reactive amine groups at each end of the molecule. Type 3 thickeners, which are two-component systems composed of a CO_2-philic compound with a pendent electron donating group (component 1) or a pendent electron-receiving group (component 2).

During this quarter we have received two letters of commitment for this project from two major CO_2 EOR operators; Denbury Resources and Kinder Morgan. Our contacts for obtaining these letters were David D'Souza, principal technical advisor for reservoir engineering at Denbury Resources; and Lanny Schoeling, VP of Engineering and Technical Development at Kinder Morgan CO_2 Company. The letters were signed by David D'Souza of Denbury and Walt True, Director of Reservoir Technologies at Kinder Morgan. We are continuing our discussions with David Smith, Conformance Engineering Advisor for Enhanced Reservoir Technology at ConocoPhillips. Further, Dr. Enick attended the 2013 CO_2 Conference in Midland Texas and had the opportunity to meet with two other CO_2 EOR operators; Rickey Coon, production Supervisor of Hess Corporation and Tracy Evans, Chief operating Officer of Tabula Rasa. Both companies are currently considering providing letters of support.

As noted previously, Denbury Resources appears to be particularly interested in this project because their CO_2 flooding strategy is focused on gas cycling (not WAG). Therefore Denbury Resources is particularly interested in CO_2-soluble additives such as surfactants (the objective of a separate NETL RUA project) and CO_2-thickeners (this NETL-funded project).

Dr. Enick and Beckman will continue to approach ConocoPhillips, Hess Corporation, and Tabula Rasa for similar letters.

2. ACCOMPLISHMENTS

Major goals:

The major goal of this project is to establish a relationship with several CO_2 EOR operators that will allow for the rapid and effective assessment of a CO_2 thickener in lab-scale tests that would provide enough information to give the operators confidence to conduct a pilot test of the thickener in the field. Therefore we intend to foster these relationships and to employ field data and fluid and rock samples from patterns in which CO_2 mobility control with a CO_2 thickener would be attractive to these operators.

The most important accomplishment during this quarter was obtaining two letters of commitment; one from Denbury Resources and one from Kinder Morgan.

The other accomplishment of this quarter was Dr. Enick's attendance at the 2013 CO2 EOR Conference in Midland where he had the opportunity to discuss this project with numerous companies, two of which (Hess and tabula Rasa) seem to have strong interest in the CO2 thickener.

Accomplishments under these goals

Task 1 – Project Management, Planning, and Reporting

The PMP has been provided to NETL, and was sent along with this quarterly to verify its submission.

Task 2 – Letters of commitment, Field Site Data and Samples

During this quarter we received two letters of commitment.

Task 3 – Approaches for Laboratory Testing of Thickened CO_2

We have no changes to our previously submitted lab testing plan. This outline has already been presented to David D'Souza of Denbury Resources, and is found below.

- Conducting the core floods at or near reservoir temperature and pressure that is commensurate with the fields that may be used in future field tests.
- The core shall be waterflooded and oil-flooded to emulate geologic history, and then waterflooded to emulate decades of waterflooding that often precedes CO_2 flooding (unless, of course, the field under consideration was not waterflooded prior to CO_2 injection).
- Three core flooding experiments: (1) The baseline or "control" core flood shall employ continuous CO_2 injection. (2) The second run shall use a water-alternating-pure CO_2 WAG injection strategy at a 1:1 ratio. (3) Finally, thickened CO_2 shall be continuously injected.
- Repeating each test to verify the reproducibility of the results.
- Conducting a displacement that accounts for the heterogeneity of most formations by using (a) a very heterogeneous core, or (b) a co-axial "core-within-a-core", or (c) a core

with longitudinal, irregular, rough-walled fracture(s) extending the length of the core, (d) or two fairly homogeneous parallel cores with different permeabilites.

- Use of a slug (fraction of a pore volume) of CO_2 thickener followed by CO_2. Check dispersion of the thickener in the CO_2.
- Use of the newly developed DOE-CO_2 simulator by U. T. Austin (or other simulator) for simulation of core floods with thickened CO_2. Add visualization (from CT scanner experiments and simulator results) to convince other operators that the injection of thickened CO_2 is a better option that the prolonged injection of pure CO_2 or WAG for the recovery of oil.

The plans shall be reviewed and agreed upon by the Recipient, the CO_2 EOR Operator(s) and NETL.

Task 4 – Technical Status of APRA-E Research

Our team has now synthesized several dozen Type 1, Type 2, and Type 3 small associative molecules thickeners. About half of the ARPA-E funding supports our collaborators at GE Global Research in Niskayuna NY. Type 1 refers to molecules with CO_2-philic cores and aromatic associating groups at each end of the molecule. Type 2 refers to molecules with CO_2-philic cores and CO_2-reactive amine groups at each end of the molecule. Type 3 thickeners, which are two-component systems composed of a CO_2-philic compound with a pendent electron donating group (component 1) or a pendent electron-receiving group (component 2).

Type 1 molecules made to date include triphenoxymethanes, simple organogelators, silicone oligomers with aromatic end groups, and polyether (specifically polypropylene glycol, PPG) oligomers with aromatic end groups. We have begun working on the "universal gelator" molecule bis-(R,β-dihydroxy ester (an oxygenated hydrocarbon molecule with two hydroxyls and an isopropyl group on each end) which is capable of thickening an incredibly diverse set of solvents (2H,3H-perfluoropentane (HPFP) and 1H,1H-heptafluorobutanol (HFB), water, toluene, cyclohexane, a 10:1 hexane-chloroform-hexane mixture, dichloromethane, water, and even lager and wine! These solvents were gelled with less than 1wt% of the universal gelator, with the exception of the dichloromethane, which required about 5wt%.

Type 2 molecules made to date include silicone oil oligomers with terminal primary and/or secondary amines, PPG oligomers with terminal primary and/or secondary amines, and silicone oil oligomers terminated with amide groups leading to aromatic groups.

Type 3 thickeners have been made solely with silicone oil based A and silicon oil based B compounds. About a dozen A + B combinations have been made to date.

We have begun the testing of CO_2 solubility and viscosity enhancement of these compounds. We are achieving success in CO2-solubility, but to date have not been able to simultaneously achieve self-assembly in solution that leads to viscosity enhancement.

Training and professional development

Dr. Enick spoke with numerous CO2 EOR operators in Midland about this project and the implementation of a CO_2 thickener in the field.

Dissemination of results

As described in the accomplishment section, we have made five companies aware of our three-pronged (Types 1,2 and 3) approach for development of a CO_2 thickener.

We gave a presentation on our work at the AIChE conference in San Francisco.

We submitted an abstract of our ARPA-E + NETL funded work on CO_2 thickeners for the 2014 IOR conference in Tulsa, which has been accepted for presentation (the SPE paper is due Fen 10 2014).

Plans for next quarter

We intend to keep making CO_2 thickener candidate molecules under ARPA-E funding.
We intend to obtain a third letter of commitment.
We intend to visit one company (Denbury) during the next quarter.

3. PRODUCTS

Our presentation at AIChE National Meeting was:

The CO_2-Solubility and Viscosity Enhancing Potential of CO_2-Philes Functionalized With Aromatic Groups, has been accepted for presentation at the 2013 AIChE Annual Meeting in San Francisco, CA. Date: **Wednesday, November 6, 2013**

Wednesday, November 6, 2013: 8:30 AM
Union Square 14 (Hilton)

Jason J. Lee[1], **Stephen Cummings**[1], Robert J. Perry[2], Eric J. Beckman[1] and **Robert Enick**[3], (1)Chemical Engineering, University of Pittsburgh, Pittsburgh, PA, (2)Global Research, General Electric, Niskayuna, NY, (3)University of Pittsburgh, Department of Chemical and Petroleum Engineering, Pittsburgh, PA

The low viscosity of CO_2 at typical enhanced oil recovery (EOR) conditions is responsible for a poor mobility ratio that causes viscous fingering and poor sweep efficiency, leading to reduced efficiency and yield. To overcome this problem, there is a need to develop CO_2-soluble additives that will increase the effective viscosity of CO_2 without the use of a co-solvent. The only known polymeric direct thickener poly(fluoroacrylate-co-styrene) (polyFAST) has been shown to significantly increase the viscosity measured by falling cylinder viscometry and Berea sandstone core mobility experiments. The proposed mechanism of aggregation responsible for this viscosity enhancement is believed to be π-π stacking between aromatic rings. However, high molecular weight polymers like polyFAST require significant amounts of expensive fluorinated moieties in order to impart solubility. In addition to their cost, fluorinated compounds have undesirable environmental impacts. Therefore, this work focuses on the development of less expensive and safer hydrocarbon-based CO_2 thickeners. Because our prior studies have demonstrated that unacceptably high pressures are required to dissolve non-fluorous polymers, this study entails the use of small, associating compounds to create a thermodynamic illusion of a polymer. Each CO_2 thickening candidate consists of at least one non-fluorous CO_2-philic segments and at least two slightly CO_2-phobic functionalities that promote intermolecular aggregation (e.g. aromatic groups). Solubilities of a range of newly synthesized molecules in CO_2 and their associated viscosity enhancing abilities will be presented. Preliminary results indicate that it is possible to design such novel CO_2-thickening candidates that are up to 1wt% soluble in CO_2 at pressures commensurate with EOR.

The PI (Dr. Enick) completed a chapter on CO_2 EOR state-of-the-art for The Catalyst Group newsletter. This report, which includes a highlight the thickener developments, was distributed to the subscribers of the newsletter.

The abstract for the April 2014 SPE IOR meeting in Tulsa was accepted

Development of Small Molecule Thickeners for CO_2 EOR and CO_2 Fracturing

The only known CO_2 thickener (a compound that dissolves in CO_2 and increases it viscosity significantly when present in dilute concentration) is a fluoroacrylate-styrene random copolymer that is probably too expensive for commercial application. High pressure CO_2 has also been thickened via the dissolution of high molecular weight polydimethylsiloxane (PDMS, silicone oil) or polyvinyl acetate (PVAc), but this strategy requires several wt% of the polymer and the addition of large concentrations of an organic solvent (e.g. 20% toluene + 80% CO_2), which is also impractical for commercial use. Because the utilization of high molecular weight polymers no longer appears to be a viable strategy for affordably thickening CO_2 at EOR conditions, we are assessing the use of novel small molecules that self-assemble into viscosity-enhancing supramolecular structures in dense CO_2. Small molecules can actually increase fluid viscosity just as effectively as high molecular weight polymers when compared at similar concentrations. For example, tributyltin fluoride and hydroxyaluminum di(2-ethyl hexanoate) are remarkable thickeners of light hydrocarbons even when present at concentrations well below 1wt%. In this presentation, three types of novel CO_2 thickening candidates are designed, synthesized and assessed for solubility in CO_2 and viscosity-increasing capabilities. Each small molecule possesses a "CO_2-philic" segment that promotes dissolution in CO_2; the CO_2-philic segments are low-cost oligomeric versions of CO_2-soluble polymers. Three different types of slightly "CO_2-phobic" functional groups known to promote intermolecular associations in hydrocarbon and/or aqueous systems are also included in the thickener structure. The foremost challenge in the molecular design is selecting the appropriate type and number of associating groups needed to enhance viscosity, while not rendering the compound insoluble in CO_2. A variety of prospective CO_2 thickeners have been synthesized and the solubility of these candidates in CO_2, and their ability to thicken CO_2, will be presented.

4. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

Dr. Eric Beckman and Dr. Enick are supported by this NETL project.

Collaborators solely related to thickener development (funded by ARPA-E) include Steven Cummings (post doc at Pitt), Jason Lee (PhD student at Pitt), Aman Dhuwe (PhD student) Robert Perry, Michael O'Brien and Mark Doherty (GE chemists).

Informal collaborations have also been made with engineers at Denbury, Kinder Morgan, ConocoPhillips, Hess and Tabula Rasa.

Collaborations with SCAL (core flooding) will not commence until Phase 2 of this project.

Name:	Robert Enick
Project Role:	PI
Nearest person month worked:	1
Contribution to Project:	Leading the project, contacting companies..
Funding Support:	NETL (this award) and ARPA-E
Collaborated with individual in foreign country:	No
Country(ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	N/A

Name:	Eric Beckman
Project Role:	PI
Nearest person month worked:	1
Contribution to Project:	Thickener development and strategies for introducing thickeners into CO_2 for lab- and field-tests.
Funding Support:	NETL (this award) and ARPA-E
Collaborated with individual in foreign country:	No
Country(ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	N/A

Name:	Jason Lee
Project Role:	PhD
Nearest person month worked:	6
Contribution to Project:	Thickener synthesis and testing
Funding Support:	ARPA-E
Collaborated with individual in foreign country:	No
Country(ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	N/A

Name:	Aman Dhuwe

Project Role: PhD
Nearest person month worked: 6
Contribution to Project: Thickener synthesis and testing
Funding Support: ARPA-E
Collaborated with individual
in foreign country: No
Country(ies) of foreign collaborator: No
Travelled to foreign country: No
If traveled to foreign country(ies),
duration of stay: N/A

Name: Steve Cummings
Project Role: PhD
Nearest person month worked: 6
Contribution to Project: Thickener synthesis and testing
Funding Support: ARPA-E
Collaborated with individual
in foreign country: No
Country(ies) of foreign collaborator: No
Travelled to foreign country: No
If traveled to foreign country(ies),
duration of stay: Visited his family in Great Britain for vacation

Name: Robert Perry
Project Role: Chemist at GE
Nearest person month worked: 6
Contribution to Project: Thickener synthesis and testing
Funding Support: ARPA-E
Collaborated with individual
in foreign country: No
Country(ies) of foreign collaborator: No
Travelled to foreign country: No
If traveled to foreign country(ies),
duration of stay: N/A

Name: Michael O'Brien
Project Role: Chemist at GE
Nearest person month worked: 6
Contribution to Project: Thickener synthesis and testing
Funding Support: ARPA-E
Collaborated with individual
in foreign country: No
Country(ies) of foreign collaborator: No
Travelled to foreign country: No
If traveled to foreign country(ies),

duration of stay:	N/A
Name:	Mark Doherty
Project Role:	Chemist at GE
Nearest person month worked:	6
Contribution to Project:	Thickener synthesis and testing
Funding Support:	ARPA-E
Collaborated with individual in foreign country:	No
Country(ies) of foreign collaborator:	No
Travelled to foreign country:	No
If traveled to foreign country(ies), duration of stay:	N/A

5. IMPACT
The most obvious impact of this work will be the improved rate of oil recovery and increased amount of recoverable oil should a thickener be designed.

This work, along with the PI's recent NETL-sponsored review of mobility control and up-coming review of CO_2 EOR (including thickeners), has helped to re-invigorate interest in CO_2 mobility control. Specifically, this project is providing a springboard for the introduction of a research product into a rapid field application.

This project combines basic research, chemistry, chemical engineering, and petroleum engineering, and is an excellent example of how a team consisting of chemists, chemical engineers and petroleum engineers can address energy-related problems.

6. CHANGES/PROBLEMS
None to date.

7. SPECIAL REPORTING REQUIREMENTS
Under the ACCOMPLISHMENTS section we have reported on our progression the ARPA-E sponsored project related to the synthesis of a thickener.

8. BUDGETARY INFORMATION

Cost Plan Status
DE-FE0010799

	OND 12	JFM 13	AMJ 13	JAS 13	OND 13	JFM 14	AMJ 14	JAS 14	OND 14	JFM 15	AMJ 15	JAS 15
Projected Spending	FY13Q1 **Quarter 1**	FY13Q2 **Quarter 2**	FY13Q3 **Quarter 3**	FY13Q4 **Quarter 4**	FY14Q1 **Quarter 1**	FY14Q2 **Quarter 2**	FY14Q3 **Quarter 3**	FY14Q4 **Quarter 4**	FY15Q1 **Quarter 1**	FY15Q2 **Quarter 2**	FY15Q3 **Quarter 3**	FY15Q4 **Quarter 4**
Federal amount	$18,750.00	$18,750.00	$18,750.00	$18,750.00	$18,750.00	$18,750.00	$18,750.00	$18,750.00	$0.00	$0.00	$0.00	$0.00
Federal budget cumulative	$18,750.00	$37,500.00	$56,250.00	$75,000.00	$93,750.00	$112,500.00	$131,250.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00	$150,000.00
Cost Share	$16,830.00	$16,830.00	$16,830.00	$16,830.00	$16,830.00	$16,830.00	$16,830.00	$16,830.00	$0.00	$0.00	$0.00	$0.00
Cost Share budget cum.	$16,830.00	$33,660.00	$50,490.00	$67,320.00	$84,150.00	$100,980.00	$117,810.00	$134,640.00	$134,640.00	$134,640.00	$134,640.00	$134,640.00
Project Total	$35,580.00	$35,580.00	$35,580.00	$35,580.00	$35,580.00	$35,580.00	$35,580.00	$35,580.00	$0.00	$0.00	$0.00	$0.00
Project Cumulative Budget	$35,580.00	$71,160.00	$106,740.00	$142,320.00	$177,900.00	$213,480.00	$249,060.00	$284,640.00	$284,640.00	$284,640.00	$284,640.00	$284,640.00
Actual Spending	FY13Q1 **Quarter 1**	FY13Q2 **Quarter 2**	FY13Q3 **Quarter 3**	FY13Q4 **Quarter 4**	FY14Q1 **Quarter 1**	FY14Q2 **Quarter 2**	FY14Q3 **Quarter 3**	FY14Q4 **Quarter 4**	FY15Q1 **Quarter 1**	FY15Q2 **Quarter 2**	FY15Q3 **Quarter 3**	FY15Q4 **Quarter 4**
Federal amount	$0.00	$0.00	$0.00	$43,481.05	$10,787.60	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Federal actual cumulative	$0.00	$0.00	$0.00	$43,481.05	$54,268.65	$54,268.65	$54,268.65	$54,268.65	$54,268.65	$54,268.65	$54,268.65	$54,268.65
Cost Share	$0.00	$19,735.03	$19,735.03	$19,735.24	$19,735.24	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Cost Share actual cum.	$0.00	$19,735.03	$39,470.06	$59,205.30	$78,940.54	$78,940.54	$78,940.54	$78,940.54	$78,940.54	$78,940.54	$78,940.54	$78,940.54
Project Total	$0.00	$19,735.03	$19,735.03	$63,216.29	$30,522.84	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Project Cumulative Actuals	$0.00	$19,735.03	$39,470.06	$102,686.35	$133,209.19	$133,209.19	$133,209.19	$133,209.19	$133,209.19	$133,209.19	$133,209.19	$133,209.19
Variance	FY13Q1 **Quarter 1**	FY13Q2 **Quarter 2**	FY13Q3 **Quarter 3**	FY13Q4 **Quarter 4**	FY14Q1 **Quarter 1**	FY14Q2 **Quarter 2**	FY14Q3 **Quarter 3**	FY14Q4 **Quarter 4**	FY15Q1 **Quarter 1**	FY15Q2 **Quarter 2**	FY15Q3 **Quarter 3**	FY15Q4 **Quarter 4**
Federal amount	$18,750.00	$18,750.00	$18,750.00	-$24,731.05	$7,962.40	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Federal actual cumulative	$18,750.00	$37,500.00	$56,250.00	$31,518.95	$39,481.35	$39,481.35	$39,481.35	$39,481.35	$39,481.35	$39,481.35	$39,481.35	$39,481.35
Cost Share	$16,830.00	-$2,905.03	-$2,905.03	-$2,905.24	-$2,905.24	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Cost Share cumulative	$16,830.00	$13,924.97	$11,019.94	$8,114.70	$5,209.46	$5,209.46	$5,209.46	$5,209.46	$5,209.46	$5,209.46	$5,209.46	$5,209.46
Project Total	$35,580.00	$15,844.97	$15,844.97	-$27,636.29	$5,057.16	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Project Variance Cumulative	$35,580.00	$51,424.97	$67,269.94	$39,633.65	$44,690.81	$44,690.81	$44,690.81	$44,690.81	$44,690.81	$44,690.81	$44,690.81	$44,690.81

Denbury

Date: 1/7/2014

Dr. Robert Enick
Dept. of Chemical and Petroleum Eng.
University of Pittsburgh
1249 Benedum Hall
Pittsburgh PA 15261
rme@pitt.edu

Dear Prof. Enick:

It is my understanding that you are researching small molecule CO2 thickener for improved CO2 mobility control, with funding from ARPA-e (for the design of the molecule itself) and NETL (for lab-scale testing and core studies to demonstrate viability in porous media). In order for your NETL-sponsored lab tests to closely replicate meaningful field conditions, we would be interested in providing you with the following items related to a pattern in one of our CO2 floods (West Heidelberg or other) with mobility control problems.

The reservoir temperature
The CO2 Injection well – wellhead & flowing bottomhole pressure
The producing well bottomhole pressure
The MMP for the oil
Samples of 1" diameter and 2" diameters horizontal plugs form an oil-rich zone, *or*
Samples of 4" diameter vertical cores form an oil-rich zone
1 gallon of crude oil, 1 gallon of produced brine
A brief history of the pattern's production

It is my understanding that you would use this materials and information to conduct lab-scale tests that would demonstrate whether the CO2 thickener would be a viable candidate for a single injection well field test.

This letter does not constitute any obligation on Denbury's part, but merely a strong interest in the CO2 viscosifier project. Further, if the data above is provided to you, Denbury's agreement and permission would be required prior to publication of any data, information or results regarding its fields. A contract and confidentiality agreement would be executed prior to any data being provided to you for the project.

If the lab testing is successful, we would be very interested in testing the CO2 thickener in the field.

Sincerely,

Walt S. True,
Director of Reservoir Technologies
5320 Legacy Drive
Plano, TX 75024
Phone: 972-673-2505

KINDER MORGAN
CO2 COMPANY, L.P.

2 January 2014

Robert Enick
Dept. of Chemical and Petroleum Eng.
University of Pittsburgh
1249 Benedum Hall
Pittsburgh PA 15261

Dear Prof. Enick:
It is my understanding that you are researching small molecule CO2 thickener for improved CO2 mobility control, with funding from ARPA-e (for the design of the molecule itself) and NETL (for lab-scale testing and core studies to demonstrate viability in porous media). In order for your NETL-sponsored lab tests to closely replicate meaningful field conditions, I would be able to provide you with the following items related to a pattern in a field with mobility control problems.
SACROC
The reservoir temperature
The CO2 pressure at the injector wellhead
The CO2 injection well flowing bottomhole pressure
The producing well bottomhole pressure
The MMP for the oil
Samples of 1" diameter and 2" diameters horizontal plugs form an oil-rich zone, *or (if available)*
Samples of 4" diameter vertical cores form an oil-rich zone (if available)
1 gallon of crude oil
1 gallon of produced brine
A brief history of the pattern's production

It is my understanding that you would use this materials and information to conduct lab-scale tests that would demonstrate whether the CO2 thickener would be a viable candidate for a single injection well field test.

Sincerely,

Dr. Lanny Schoeling, P.E.
VP of Engineering and Technical Development
Kinder Morgan CO2 Company