Technical Progress Report for the Gas Storage Technology Consortium

3rd Quarterly Report for the Period
4/1/2004 – 6/30/2004

By

Dr. Robert W. Watson
Principal Investigator

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Submitting Organization
The Pennsylvania State University
The Energy Institute
C211 Coal Utilization Lab
University Park, PA 16802

DISCLAIMER

ABSTRACT

Gas storage is a critical element in the natural gas industry. Producers, transmission and distribution companies, marketers, and end users all benefit directly from the load balancing function of storage. The unbundling process has fundamentally changed the way storage is used and valued. As an unbundled service, the value of storage is being recovered at rates that reflect its value. Moreover, the marketplace has differentiated between various types of storage services, and has increasingly rewarded flexibility, safety, and reliability. The size of the natural gas market has increased and is projected to continue to increase towards 30 trillion cubic feet (TCF) over the next 10 to 15 years. Much of this increase is projected to come from electric generation, particularly peaking units. Gas storage, particularly the flexible services that are most suited to electric loads, is critical in meeting the needs of these new markets.

In order to address the gas storage needs of the natural gas industry, an industry-driven consortium was created – the Gas Storage Technology Consortium (GSTC). The objective of the GSTC is to provide a means to accomplish industry-driven research and development designed to enhance operational flexibility and deliverability of the Nation's gas storage system, and provide a cost effective, safe, and reliable supply of natural gas to meet domestic demand. To accomplish this objective, the project is divided into three phases that are managed and directed by the GSTC Coordinator. Base funding for the consortium is provided by the U.S. Department of Energy (DOE). In addition, funding is anticipated from the Gas Technology Institute (GTI).

The first phase, Phase 1A, was initiated on September 30, 2003, and was completed on March 31, 2004. Phase 1A of the project included the creation of the GSTC structure, development and refinement of a technical approach (work plan) for deliverability enhancement and reservoir management. This report deals with Phase 1B and encompasses the period April 1, 2004, through June 30, 2004. During this 3-month period, a Request for Proposals (RFP) was made. A total of 17 proposals were submitted to the GSTC. A proposal selection meeting was held June 9-10, 2004 in Morgantown, West Virginia. Of the 17 proposals, 6 were selected for funding.

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EXECUTIVE SUMMARY

Gas storage is a critical element in the natural gas industry. Producers, transmission and distribution companies, marketers, and end users all benefit directly from the load balancing function of storage. The unbundling process has fundamentally changed the way storage is used and valued. As an unbundled service, the value of storage is being recovered at rates that reflect its value. Moreover, the marketplace has differentiated between various types of storage services, and has increasingly rewarded flexibility, safety, and reliability. The size of the natural gas market has increased and is projected to continue to increase towards 30 trillion cubic feet (TCF) over the next 10 to 15 years. Much of this increase is projected to come from electric generation, particularly peaking units. Gas storage, particularly the flexible services that are most suited to electric loads, is critical in meeting the needs of these new markets.

In order to address the gas storage needs of the natural gas industry, an industry-driven consortium was created – the Gas Storage Technology Consortium (GSTC). The objective of the GSTC is to provide a means to accomplish industry-driven research and development designed to enhance operational flexibility and deliverability of the Nation's gas storage system, and provide a cost effective, safe, and reliable supply of natural gas to meet domestic demand. To accomplish this objective, the project is divided into three phases that are managed and directed by the GSTC Coordinator. Base funding for the consortium is provided by the U.S. Department of Energy (DOE). In addition, funding is anticipated from the Gas Technology Institute (GTI).

The first phase, Phase 1A, was initiated on September 30, 2003, and was completed on March 31, 2004. Phase 1A of the project included the creation of the GSTC structure, development and refinement of a technical approach (work plan) for deliverability enhancement and reservoir management. This report deals with Phase 1B and encompasses the period April 1, 2004, through June 30, 2004. During this 3-month period, a Request for Proposals (RFP) was made. A total of 17 proposals were submitted to the GSTC. A proposal selection meeting was held June 9-10, 2004 in Morgantown, West Virginia. Of the 17 proposals, 6 were selected for funding.

EXPERIMENTAL

This project is a consortium between industries, academia, and the U.S. Department of Energy. As a consortium, there are no experimental results to report.

RESULTS and DISCUSSION

On September 30, 2003, the first phase, Phase 1-A, was initiated to create a consortium to address the gas storage needs of the natural gas industry. During this first phase, the Gas Storage Technology Consortium (GSTC) was formed. The formation of the GSTC included developing a constitution (by-laws) for the consortium, and the election of a 9 member Executive Council (EC). Phase 1-A successfully ended on March 31, 2004.

With the completion of Phase 1A, Phase 1B began on April 1, 2004. This report deals with the activities during the first three months of this phase, from April 1, 2004 thru June 30, 2004. The first order of business was to issue a Request for Proposals (RFP). The RFP due date was May 27, 2004 at 4PM EST. The result of the RFP was the submission of 17 proposals. A proposal selection meeting was held June 9-10, 2004 at the Radisson Hotel, Morgantown, West Virginia. The meeting agenda is attached in Appendix 1. During the first day, each proposal presenter was given 20 minutes to explain to the GSTC members and the executive council the details of their proposed project that was requesting funding. 45 GSTC members attended this meeting. The attendee list can be found in Appendix 2.

On the morning of the second day, the executive council, with consultation of the DOE and the Consortium Director, met to discuss which proposals would be awarded funding. A total of 17 projects were proposed to the executive council, the previous day, with requested funding from the GSTC totaling $2.4M. Details of the requested funding and cost share for each project are listed in Appendix 3. From this list, 6 projects were selected. However, only one was chosen as proposed. The others selected required modifications as per the Executive Council's recommendations. The selected projects are as follows:

1) "Smart Gas: Using Chemicals to Improve Gas Deliverability," Correlations Company

2) "Gas Storage Field Deliverability Enhancement and Maintenance: An Intelligent Portfolio Management Approach," West Virginia University
3) "New and Improved Deliverability Enhancement Methodology for Gas Storage Wells," Kinder-Morgan
4) "Evaluation of Compact Separators for Gas Storage Field Fluid Control," Colorado Engineering Experiment Station, Inc.
5) "Real Time Well Bore Integrity Modeling," Colorado School of Mines
6) "Renovations of Produced Waters from Underground Natural Gas Storage Facilities: A Feasibility Study Using Hybrid Constructed Wetland Technology," Clemson University

A summary of these chosen projects along with the GSTC committed funding level are shown in Appendix 4. Appendix 5 includes the Executive Summary for these 6 project proposals as they were originally submitted.

The next meeting of the consortium has been scheduled for February 2-3, 2005 at the Wyndham Hotel, Houston Texas. This meeting will serve as both a technology transfer session and project proposal presentation and selection for the second round of funding. The RFP due date for this round of funding has tentatively been set as January 14, 2005. The Executive Council is currently working on an addendum to the RFP that will spell-out in more specific terms, research areas that are of particular interest to storage operators.

CONCLUSIONS

In order to address the gas storage needs of the natural gas industry, an industry-driven consortium has been created – the Gas Storage Technology Consortium (GSTC). The objective of the GSTC is to provide a means to accomplish industry-driven research and development designed to enhance operational flexibility and deliverability of the Nation's gas storage system, and to provide a cost effective, safe, and reliable supply of natural gas to meet domestic demand. To accomplish this objective, the project is divided into three phases that are managed and directed by the GSTC Coordinator. Base funding for the consortium is provided by the U.S. Department of Energy (DOE). In

addition, funding has been anticipated from the Gas Technology Institute (GTI). However, as of June 30, 2004 the GTI money had not yet been received by Penn State.

The first phase of the consortium, Phase 1-A, was initiated on September 30, 2003, and was completed on March 31, 2004. Phase 1-A of the project included the creation of the GSTC structure, development and refinement of the constitution (by-laws), and election of the 9 member Executive Council.

The second phase, Phase 1-B, began on April 1, 2004. A Request for Proposals (RFP) was issued with a due date of May 27, 2004. The result of the RFP was the submission of 17 proposals. A proposal selection meeting was held June 9-10, 2004 at the Radisson Hotel, Morgantown, West Virginia. 45 GSTC members attended this meeting. The executive council, with consultation with the DOE and the Consortium Director, selected 6 proposals for funding. However, only one was chosen as proposed. The others selected required modifications as per the Executive Council's recommendations.

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REFERENCES

There are no references at this time for this report.

APPENDIX 1: Meeting Agenda for Proposal Selection, June 9-10, 2004

MEETING AGENDA

Radisson Hotel at Waterfront Place
Morgantown, West Virginia

June 9, 2004	
7:30 – 8:30	**Buffet Breakfast (Salon AB)**
8:30 – 9:00	**Meeting Registration**
9:00 – 9:20	**Welcoming Comments (Salon FGH)**
9:20 – 9:40	**Hydrate Formation for Natural Gas Storage** *Presenter: West Virginia University*
9:40 – 10:00	**Pressure Transient Analysis to Identify Behind Pipe Gas Storage Horizon Gas Losses** *Presenter: NITEC, LLC*
10:00 – 10:20	**Optimizing Investments in Existing Underground Storage Reservoirs to Improve Withdrawal Capacity** *Presenter: Colorado School of Mines*
10:20 – 10:40	**Break**
10:40 – 11:00	**Smart Gas: Using Chemicals to Improve Gas Deliverability** *Presenter: Correlations Company*
11:00 – 11:20	**Correlation Analysis as a Simple Predictive Tool for Gas Storage Field Operations** *Presenter: NITEC LLC*
11:20 – 11:40	**Gas Storage Field Deliverability Enhancement and Maintenance: An Intelligent Portfolio Management Approach** *Presenter: West Virginia University*
11:40 – 12:00	**Best Practices for Handling H2S Contaminated Storage Gas** *Presenter: Gas Technology Institute*
12:00 - 1:00	**GSTC Luncheon (Waterfront Meet Room AB)**

1:00 – 1:20	**An Integrated Forecasting Model for Natural Gas Storage Management** *Presenter: The Pennsylvania State University*
1:20 – 1:40	**Expansion of GTI Damage Monitoring Database** *Presenter: Schlumberger-Holditch*
1:40 – 2:00	**New and Improved Deliverability Enhancement Methodology for Gas Storage Wells** *Presenter: Kinder-Morgan*
2:00 – 2:20	**Evaluation of Compact Separators for Gas Storage Field Fluid Control** *Presenter: Colorado Engineering Experiment Station, Inc.*
2:20 – 2:40	**Real Time Well Bore Integrity Modeling** *Presenter: Colorado School of Mines*
2:40 – 3:00	**Real Time Inventory and Deliverability Assessment Using Low-Frequency Electronic Flow Measurement Data** *Presenter: Schlumberger-Holditch*
3:00 – 3:20	**Break**
3:20 – 3:40	**Cyclic Fatigue Effects on Mechanical Properties of Salt** *Presenter: RESPEC*
3:40 – 4:00	**Development of a Real Time Underground Gas Storage Reservoir Management System** *Presenter: Gemini Solutions, Inc.*
4:00 – 4:20	**Evaluation of Multi-phase/Wet Gas Metering for Gas Storage Field Storage Applications** *Presenter: Colorado Engineering Experiment Station, Inc.*
4:20 – 4:40	**Renovation of Produced Waters from Underground Natural Gas Storage Facilities: A Feasibility Study Using Hybrid Constructed Wetland Technology** *Presenter: Clemson University*
4:40 – 5:00	**Closing Remarks**
5:30 – 7:30	**GSTC Reception (Waterfront Meet Room AB)**

June 10, 2004	
8:00 - 1:00	GSTC Executive Council Meeting (Puskar Boardroom)

APPENDIX 2: Attendee List, June 9-10, 2004, Morgantown, WV

COMPANY	FIRST NAME	LAST NAME	ADDRESS	CITY	STATE	ZIP CODE	PHONE	FAX	EMAIL ADDRESS
Panhandle Energy	Karen	Benson	5444 Westheimer Rd WT-422	Houston	TX	77056	713-989-7483	713-989-7483	kgbenson@panhandleenergy.com
Isotech Laboratories, Inc.	Jerry	Benson	1308 Parkland Court	Champaign	IL	61821-1826	217-398-3490		benson@isotechlabs.com
ONEOK Field Services	Stephen	Bergin	100 West Fifth St	Tulsa	OK	74103	918-588-7674	918-588-7980	sbergin@oneok.com
CEMR - West Virginia University	H. Ilkin	Bilgesu	MRB 345 C PO Box 6070	Morgantown	WV	26505	304-293-7682 x3403		bilgesu@cemr.wvu.edu
Schlumberger Data and Consulting Svcs	Kenneth	Brown	1310 Commerce Dr Park Ridge 1	Pittsburgh	PA	15275	412-787-5403	412-787-2906	kbrown2@pittsburgh.oilfield.slb.com
Ameren Corporation	Allen	Bues	607 East Adams				217-535-5334	217-535-5091	adbues@ameren.com
Clemson University Dept of Geo Sciences	Jim	Castle	Box 340919	Clemson	SC	29634-0919	864-656-5015	864-656-1041	jcastle@clemson.edu
Gemini Solutions, Inc.	Randy	Cazenave	11301 Richmond Ave, Suite 110	Houston	TX	77082	281-759-4200	281-759-7773	randyc@geminisi.com
Duke Energy Transmission Corp.	Charles	Chabannes	5400 Westheimer Ct.	Houston	TX	77056	713-627-5743	713-627-5658	cchabannes@duke-energy.com
Colorado School of Mines	L.G.	Chorn	1500 Illinois	Golden	CO	80401-1887	303-273-3903	303-273-3189	lchorn@mines.edu
American Gas Association	Kimberly	Denbow	400 N. Capitol Street NW	Washington	DC	20001	202-824-7334	202-824-9184	kdenbow@aga.org
RESPEC	Kerry	DeVries	3824 Jet Drive PO Box 725	Rapid City	SD	57709-0725	605-394-6400		kerry.devries@respec.com
DOE-NETL	Dan	Driscoll	PO Box 880	Morgantown	WV	26507-0880	304-285-4717		daniel.driscoll@netl.doe.gov
El Paso Corporation	Doug	Elenbaas	Two North Nevada Ave. PO Box 1087	Colorado Springs	CO	80944	719-520-4287	719-520-4668	doug.elenbaas@elpaso.com
Gas Technology Institute	Steve	Foh	1700 South Mount Prospect Rd	Des Plaines	IL	60018	847-768-0894	847-768-0501	steve.foh@gastechnology.org
Schlumberger Data and Consulting Svcs	Joseph	Frantz, Jr.	1310 Commerce Dr Park Ridge 1	Pittsburgh	PA	15275	412-787-5403	412-787-2906	jfrantz@pittsburgh.oilfield.slb.com
Halliburton Energy Services	John	Guoynes	PO Box 519	Kalkaska	MI	49646	231-258-7022		john.guoynes@halliburton.com
National Fuel Gas Supply Corporation	Ramon	Harris	6363 Main Street	Williamsville	NY	12441-5887	716-857-6884	716-857-7310	harrisr@natfuel.com
Williams Gas Pipeline	Steven	Heath	PO Box 1396	Houston	TX	77251-1396	713-215-2087	713-215-2345	steven_a_heath@williams.com
Kinder Morgan, Inc.	Floyd	Hofstetter	747 E 22nd Street	Lombard	IL	60148	630-691-3660	630-691-3531	Floyd_Hofstetter@kindermorgan.com
Gas Technology Institute	Aqil	Jamal	1700 South Mount Prospect Rd	Des Plaines	IL	60018	847-768-0906	847-919-8415	aqil.jamal@gastechnology.org
Halliburton Energy Services	Dan	Jockel	PO Box 519	Kalkaska	MI	49646	231-258-7022		

The Pennsylvania State University	David	Johnson	411 Academic Activities	University Park	PA	16802	814-863-8899		dkj103@psu.edu
Marathon Ashland Pipe Line LLC	Ann	Justice	539 South Main St Room 731-M	Findlay	OH	45840-3295	419-421-3719		amjustice@mapllc.com
El Paso Corporation	Larry	Kennedy,Jr.	Two North Nevada Ave PO Box 1087	Colorado Springs	CO	80944	719-520-4287	719-520-4668	larry.kennedy@elpaso.com
The Pennsylvania State University	Sue	Lavan	221 Walker Building	University Park	PA	16802	814-865-7650		sal5@psu.edu
Basic Systems, Inc.	Doug	Law	10901 Clay Pike Rd	Derwent	OH	43733	740-685-2155 x302	740-685-5516	
Dominion Transmission, Inc.	F. John	Leeson	445 West Main Street	Clarksburg	WV	26301	304-627-3366	304-627-3390	f_john_leeson@dom.com
Centerpoint Energy	Richard	Mantia	1111 Louisiana St	Houston	TX		314-991-7494	314-991-7512	rich.mantia@centerpointenergy.com
RESPEC	Kirby	Mellegard	3824 Jet Drive PO Box 725	Rapid City	SD	57709-0725	605-394-6400		slbracy@respec.com
DTE Energy	Fred	Metzger	2000 2nd Ave 605	Detroit	MI	48226	313-235-1112		metzgerf@dteenergy.com
West Virginia University	Shahab	Mohaghegh	345E MRB PO Box 6070				304-293-7682	304-293-5708	shahab@wvu.edu
The Pennsylvania State University	Ronald	Nargi	C-211 CUL	University Park	PA	16802	814-863-7381		eihelp@ems.psu.edu
The Pennsylvania State University	Natalie	Novak	C-211 CUL	University Park	PA	16802	814-865-9802		nun1@psu.edu
Consumers Energy	James	Philo	1945 W Parnall Rd	Jackson	MI	49201	517-788-0509	517-788-5884	jdphilo@cmsenergy.com
PRCI	Christina	Sames	1401 Wilson Blvd. Suite 1101	Arlington	VA	22209	703-387-0190 x105	703-387-0192	csames@prci.org
NITEC, LLC.	Bill	Savage	475 17th St.,Ste 850	Denver	CO	80202	303-292-9595	303-292-9585	bsavage@nitecllc.com
CEESI	Jeff	Savidge	4043 WRC	Nunn	CO	80648	970-897-2711		jsavidge@ceesi.com
Basic Systems, Inc.	Tom	Stemmer	10901 Clay Pike Rd	Derwent	OH	43733	740-685-2155	740-685-5516	tstemmer@bsicos.com
Texas Gas Transmission, LLC	Richard	Stocke	3800 Frederica St	Owensboro	KY	42301	270-688-6926		richard.c.stocke@txgt.com
Columbia Gas Transmission Corp	Andrew	Theodos	1700 MacCorkle Ave SE PO Box 1273	Charlestown	WV	25325	304-357-2365	304-357-3585	atheodos@nisource.com
PII North America, Inc.	Scott	Thetford	2707 North Loop West Room 649	Houston	TX	77041	832-295-7630	832-295-7670	scott.thetford@og.ge.com
NW Natural	Todd	Thomas	220 NW Second Ave	Portland	OR	97209	503-226-4211	503-220-2595	tat@nwnatural.com
The Pennsylvania State University	Robert	Watson	119 Hosler Building			16802	814-865-0531		rww1@psu.edu
Correlations Company	Bill	Weiss	PO Box 730 115 Court Street	Socorro	NM	87801	505-838-3876	505-838-3876	bweiss@sdc.org
Buckeye Gulf Coast Pipe Lines	Terrel	Williams	5002 Buckeye Road	Emmaus	PA	18049	832-615-8618	832-615-8601	twilliams@buckeye.com
AOPL C/O Ent Prod.	Joe	Young	7155 Inkster Road	Houston	TX	77008	313-292-9842	313-292-2130	jyoung@sunocologistics.com

APPENDIX 3: Proposed Project List

Number	Title	Project Cost Summary				Lead Organization	Project Participants
		Total	GSTC	Applicant	Cost Share		
1	Hydrate Formation for Natural Gas Storage	$156,067	$93,100	$62,967	40.35	West Virginia University, WV	None
2	Pressure Transient Analysis to Identify Behind Pipe Gas Storage Horizon Gas Losses	$228,879	$183,103	$45,776	20.00	NITEC, LLC., CO	Colorado School of Mines
3	Optimizing Investments in Existing Underground Storage Reservoirs to Improve Withdrawal Capacity	$194,375	$185,575	$8,800	4.53	Colorado School of Mines, CO	NITEC, LLC
4	Smart Gas: Using Chemicals to Improve Gas Deliverability	$163,875	$163,875	$0	0.00	Correlations Company,NM	None
5	Correlation Analysis as a Simple Predictive Tool for Gas Storage Field Operations	$193,484	$154,787	$38,697	20.00	NITEC, LLC,CO	None
6	Gas Storage Field Deliverability Enhancement and Maintenance: and Intelligent Portfolio Management Approach	$183,167	$104,850	$78,317	42.76	West Virginia University,WV	Columbia Gas Transmission Corporation
7	Best Practices for Handling H2S Contaminated Storage Gas	$119,984	$71,984	$48,000	40.01	Gas Technology Institute, IL	Related gas industry JIP managed by GTI
8	An Integrated Forecasting Model for Natural Gas Storage Management	$102,571	$61,103	$41,468	40.43	The Pennsylvania State University, PA	None
9	Expansion of GTI Damage Monitoring Database	$163,820	$77,500	$86,320	52.69	Schlumberger - Holditch, PA	Various UGS operators
10	New and Improved Deliverability Enhancement Methodology for Gas Storage Wells	$645,108	$120,108	$525,000	81.38	Kinder-Morgan, TX	None
11	Evaluation of Compact Separators for Gas Storage Field Fluid Control	$416,418	$249,851	$166,567	40.00	Colorado Engineering Experiment Station, Inc., CO	None
12	Real Time Well Bore Integrity Modeling	$308,998	$172,198	$136,800	44.27	Colorado School of Mines, CO	Well Dynamics
13	Real Time Inventory and Deliverability Assessment Using Low-Frequency Electronic Flow Measurement Data	$269,600	$157,000	$112,600	41.77	Schlumberger - Holditch, PA	Texas A&M and Columbia Gas Transmission
14	Cyclic Fatigue Effects on Mechnical Properties of Salt	$249,217	$149,397	$99,820	40.05	RESPEC,SD	None
15	Development of a Real Time Underground Gas Storage Reservoir Management System	$321,280	$189,168	$132,112	41.12	Gemini Solutions Inc., TX	None
16	Evaluation of Multi-phase/Wet Gas Metering for Gas Storage Field Storage Applications	$416,418	$249,851	$166,567	40.00	Colorado Engineering Experiment Station, Inc., CO	None
17	Renovation of Produced Waters from Underground Natural Gas Storage Facilities: A Feasability Study Using Hybrid Constructed Wetland Technology	$162,449	$97,468	$64,981	40.00	Clemson University, SC	None
	Grand Total	$4,295,710	$2,480,918	$1,814,792	42.25		

APPENDIX 4: GSTC Selected Project List

Number	Title	Project Cost Summary				Committed Funding
		Total	GSTC	Applicant	% Cost Share	
4	Smart Gas: Using Chemicals to Improve Gas Deliverability	$163,875	$163,875	$0	0.00	$163,875
6	Gas Storage Field Deliverability Enhancement and Maintenance: and Intelligent Portfolio Management Approach	$183,167	$104,850	$78,317	42.76	$104,850
10	New and Improved Deliverability Enhancement Methodology for Gas Storage Wells	$645,108	$120,108	$525,000	81.38	$60,000
11	Evaluation of Compact Separators for Gas Storage Field Fluid Control	$416,418	$249,851	$166,567	40.00	$50,000
12	Real Time Well Bore Integrity Modeling	$308,998	$172,198	$136,800	44.27	$172,198
17	Renovation of Produced Waters from Underground Natural Gas Storage Facilities: A Feasability Study Using Hybrid Constructed Wetland Technology	$162,449	$97,468	$64,981	40.00	$97,468
	Grand Total	$1,880,015	$908,350	$971,665	51.68	$648,391

SMART GAS: USING CHEMICALS TO IMPROVE GAS DELIVERABILITY

Lead Organization: Correlations Company
Key Contact: William W. Weiss
(505) 838-3876, bweiss@sdc.org
Total Project Cost: $ 163,875
Level of Funding: $ 163,875

The overall objective of the proposed project is to develop new technology to improve gas deliverability from gas storage wells. The initial effort includes laboratory work with reservoir cores to evaluate surfactant-gas-core systems with the objective of demonstrating that gas deliverability can be greater with certain surfactants than without. In addition, an engineering survey will be conducted to provide an inventory of storage facility reservoirs that are candidates for field testing. The candidate fields will include sandstone, carbonate, and dolomite reservoirs in dry gas fields, depleted oil fields, and water aquifers.

Results from this project will provide the foundation for a continuation project that will focus on field demonstrations of the new technology. Many variables are expected to affect changes in well deliverability. New smart technology based on fuzzy logic and neural networks will be used to analyze the results of the field tests and generate correlations that will optimize commercial applications.

Each year, more than 17,000 gas storage wells in the United States lose from 3 to 5 percent of storage capacity and deliverability. The gas storage industry spends $80 million to $100 million annually to revitalize existing wells with methods such as mechanically removing debris, washing, injecting acids, and creating new perforations in the well pipe. Only limited and temporary improvements are achieved. There is a need to cost effectively increase the deliverability and hence the flexibility of the Nation's underground gas storage facilities.

It is known that water wet porous media imbibes water in a fashion similar to water rising in a glass capillary tube. In the reservoir of a gas storage well, the imbibition force promotes the retention of water in the pore space which curtails the deliverability of gas to the wellbore during periods of high demand. In a similar manner, the injection of gas during the fill cycle is restricted. In addition, the pore space occupied by irreducible water is not available to hold gas.

It is possible that proper chemicals, such as surfactants, can be added in treatment fluids of gas wells to decrease the capillary pressure by decreasing gas/water surface tension and changing the rock surface wettability. Only a limited number of laboratory studies of chemicals that change wettability to less water-wet have been reported. Previous laboratory studies have demonstrated that reducing the water wetness of outcrop cores doubled the deliverability of gas from the cores. Based on similar technology a documented field test demonstrated that oil-well deliverability doubled when the oil-wet formation was made more water-wet. The proposed laboratory work also includes evaluating the compatibility of the surfactants with operating chemicals by observing mixtures for emulsions and precipitates.

Although storage facility costs where gas is bought and sold remain relatively constant, the economic benefits of doubling gas deliverability, while difficult to quantify, are believed to be considerable. While operating economics are frequently proprietary in this competitive industry making a detailed economic analysis difficult, the improved flexibility in the form of greater deliverability should significantly increase profitability.

Correlations Company staff has experience directing both university research programs and the application of laboratory results to commercial oilfield projects. The company has considerable experience with Department of Energy reporting requirements and has successfully completed several DOE-funded projects.

GAS STORAGE FIELD DELIVERABILITY ENHANCEMENT AND MAINTENANCE: AN INTELLIGENT PORTFOLIO MANAGEMENT APPROACH

Lead Organization: West Virginia University
Key Contact: Shahab D. Mohaghegh
(304) 293-7682 x3405, shahab@wvu.edu

Total Project Cost: $ 183,167
Level of Funding: $ 104,850

Portfolio management, a common practice in the financial market, is essentially an optimization problem that attempts to increase return on investment. The objective this project is to apply the state-of-the-art in optimum portfolio management to the gas storage field in order to optimize the return on investment associated with well remedial operations.

Each year gas storage operators spend hundreds of thousands of dollars on workovers, re-completions, and re-stimulations of storage wells in order to battle the decline in deliverability due to well damage with time. A typical storage field has tens if not hundreds of production wells. Each well will respond to a remedial operation in its own unique way that is a function of a set of uncontrollable parameters such as porosity and permeability and a set of controllable parameters such as completion and stimulation practices.

The objective of this project is to identify the combination of best candidate wells for the remedial operations that will result in the most successful program each year, and consequently provide the highest return on investment. The project deliverable is a Windows-based software application that would perform the analysis and provide the list of wells and their corresponding remedial operation for each year base on the budget constraints identified by the user.

The state-of-the-art in intelligent systems application that is currently being used extensively in the Wall Street is the methodology to achieve the objectives of this proposed project. This methodology includes a hybrid form of artificial neural networks, genetic algorithms and fuzzy logic. The principal investigator of this project is a pioneer in application of intelligent systems in the oil and gas industry and has a successful track record in developing intelligent applications for our industry.

Columbia Gas Transmission Corporation will be the industry partner of this project and will cooperate with the research and development team in order to ensure successful completion of the project.

NEW AND IMPROVED DELIVERABILITY ENHANCEMENT METHODOLOGY FOR GAS STORAGE WELLS

Lead Organization: Kinder-Morgan
Key Contact: Russell Frame
(713) 396-9341, Russell_Frqame@kindermorgan.com
Total Project Cost: $ 645,108
Level of Funding: $ 60,000

The replacement of deliverability and injectivity loss in gas storage wells is critical to meeting gas supply demands. The loss is well documented and caused by a variety of reasons, one proving to be near-well-bore skin damage. Skin damage occurs from an assortment of damage mechanisms reducing flow-capacity of the rock in the near-well-bore area. Halliburton has performed damage diagnostic studies for Kinder-Morgan's Natural Gas Pipeline Company, utilizing work performed in GRI-98-0197 study on damage mechanisms, to identify causes and degrees of damage in the North Lansing storage field.

Previous work performed in 1997 on 19 selected wells was successful in recovering deliverability using damage diagnostic evaluation and coil tubing high pressure blasting tools and straddle packers to clean pipe and perforations. Tailored chemical treatments were also employed to remediate near well-bore skin damage. A new streamline process utilizing a fluidic oscillation technology with coil tubing was tested on 2 new wells in North Lansing in early 2004. Preliminary test results indicate this new process may improve prior stimulation methods used in many gas storage fields.

Some existing and new wells in North Lansing, like in many other gas storage fields, are completed with tubing and packers. Previous techniques using blasting tools and straddle packers are more costly and time consuming to remediate skin damage in these types of completions. There is an added cost to pulling pipe and/or packers to successfully treat wells with skin damage and scale problems. Blasting tools are limited by pipe stand-off and straddle packers require a rig or coil tubing to operate. In both cases, Halliburton's history of treating more than 1000 storage wells since the GRI/DOE-98-0197 study has shown that tubing and packers need to be pulled for ample stimulation.

The new fluidic oscillation methodology introduced early this year in the North Lansing pilot allows wells to be effectively stimulated without pulling pipe or compensating for standoff. This proposal will evaluate and compare the effectiveness of fluidic Oscillation technology on 17 additional gas storage wells in the North Lansing storage fields and compare that technology and analysis with the previously treated 19 wells in 1997.

Fluidic-oscillation technology sends out alternating bursts of fluid that creates pulsating pressure waves within the well-bore and formation fluids. These pressure waves help break up near-well-bore damage and restore permeability by carrying the fluid past the well-bore into the formation. The oscillating pressure waves are not affected by standoff as with conventional jetting or velocity tools and are small enough to run through standard size tubing and still effectively clean larger ID's. Kinetic energy in the pressure pulse travels through the well-bore fluid with no appreciable energy loss. The pressure waves expand spherically, providing 360^{o} coverage while the tool is moved through the interval. As the damage is removed, the waves penetrate deeper into the formation creating benefits of matrix chemical treatments.

The new method, incorporating the newly designed fluidic-oscillating tool (FOT) appears to improve cost benefit ratios allowing more efficient re-gained deliverability. This proposal presents a technical description of the new fluidic-oscillating processes and incorporates proven diagnostic engineering analysis to evaluate before and after treatment effects on deliverability and injectivity. Individual well cases with pre-treatment and post-treatment diagnostic analysis will be presented to illustrate effectiveness of the fluidic-oscillation technology.

EVALUATION OF COMPACT SEPARATORS FOR GAS STORAGE FIELD FLUID CONTROL

Lead Organization: Colorado Engineering Experiment Station, Inc.
Key Contact: Jeffrey Savidge
(970) 897-2711, jsavidge@ceesi.com

Total Project Cost: $ 416,418
Level of Funding: $ 249,851

The objective of this project is to provide experimental data on the performance of low cost compact separator designs for gas storage field applications. Reducing the amount of liquid (both hydrocarbon liquid and free water) downstream of the production tree will help to minimize problems induced by the presence of liquids. Some of the problems include hydrate deposits and blockages, scale deposition, and corrosion.

In addition, storage field operations can be improved by removing as much water vapor as possible from locations near the well head. New innovation with the design and construction of compact separators, moisture controllers, and moisture detection instrumentation appear to have the capability to provide some benefit in this area.

CEESI proposes to perform actual testing of compact separators at our laboratory facilities in Colorado. The laboratory test conditions will closely simulate those conditions encountered at gas storage facilities. The style and fabrication of the compact separators will be selected to provide the optimum separation for certain well head flowing conditions.

The CEESI testing facilities can provide high pressure (1400 psi) natural gas testing with gas velocities ranging from 1 to 90 ft/sec and GVF (gas volume fraction) values ranging from 0.7 to 1. The methodology of the test facilities is to measure both the gas and liquid flow that enters the separator and then also measure the amount of liquid captured by the separator. With this type of testing, the efficiency of the separator can be determined as well as “liquid carry-over” and “gas carry-under”.

REAL TIME WELL BORE INTEGRITY MONITORING

Lead Organization: Colorado School of Mines
Key Contact: L.G. Chorn
(303) 273-3903, lchorn@mines.edu
Total Project Cost: $ 308,998
Level of Funding: $ 172,198

Mechanical failures of well bore tubulars in long-lived natural gas storage reservoirs and salt domes represents a safety hazard for the operator's staff as well as local residents. High pressure natural gas can escape into shallower geologic horizons, overpressure them, and find its way to the surface where the potential for explosion and fire is high. The underground natural gas storage industry has an outstanding safety record and is striving to maintain its record by seeking out new, comprehensive methods to monitor tubular integrity.

The petroleum industry has recently experienced dramatic advances in wellbore monitoring and flow control through the linkage of sensors at the reservoir – wellbore interface with remotely actuated valves. These "downhole" sensors have shown longevity and reliability in high temperature, high pressure, and corrosive environments. The ability to observe conditions in the wellbore with relatively inexpensive sensors offers the underground gas storage operator the tool to monitor the integrity of the reservoir-to-surface link and demonstrate system reliability.

We propose to develop a single-phase, transient flow gas well model to predict pressure and temperature profiles between the well perforations and the wellhead under different flow rates. The transient capability of the model will allow the user to predict pressure – temperature profiles in the well when there is a wellbore breach. We will work with WellDynamics technical staff to determine the statistical sensitivities of their sensors. The sensitivities of the sensors will then be compared to the numerical predictions for pressure and temperature under wellbore failure conditions to document the ability of the sensors to detect failures, quantify the magnitude of the losses, and perhaps even predict its location within a few pipe joints. The model results will be transformed to an Excel spreadsheet tool that will allow operators to interpret sensor data and convert it into one of three interpretations: "okay", "requires additional attention" and "wellbore failure." A field-testing program will be proposed for the 2005 GTSC funding review.

RENOVATION OF PRODUCED WATERS FROM UNDERGROUND NATURAL GAS STORAGE FACILITIES: A FEASIBILITY STUDY USING HYBRID CONSTRUCTED WETLAND TECHNOLOGY

Lead Organization: Clemson University
Key Contact: James Castle
(846) 656-5015, jcastle@clemson.edu

Total Project Cost: $ 162,449
Level of Funding: $ 97,468

The goal of the proposed project is to design a hybrid constructed wetland treatment system to effectively and consistently treat waters produced from underground gas storage operations. To efficiently dispose of or to reuse waters produced from gas storage facilities, effective and reliable water treatment systems are needed. Produced waters may be generated in relatively high volumes and contain a variety of constituents that limit disposal or reuse of the water. At the present time, treatment or disposal of produced waters adds substantial operational costs to many gas storage fields. The purpose of the research proposed by Clemson University is to develop a low cost and readily implemented method for testing produced water as part of a system integrated with surface facilities of gas storage fields. The method will be designed for applicability to a range of produced waters, as the composition (including salinity) and volume of water produced from gas storage construction and operations vary greatly among storage fields. The approach involves identifying and confirming targeted constituents, designing constructed wetlands for treatment based on biogeochemistry and macrofeatures (hydroperiod, hydrosoil, and vegetation), conducting carefully designed pilot-scale studies to confirm performance and function, and efficiently and effectively monitoring performance and function of the constructed system.

The investigation will utilize a scaled model constructed wetland treatment system (i.e., wetland mesocosms) to decrease uncertainties and confirm design features for a future full-scale constructed wetland treatment system. The pilot scale, hybrid constructed wetland treatment system will be designed and configured specifically to treat targeted constituents in water produced from gas storage. The proposed hybrid design will contain sequential reactors with the initial reactor focused on salt removal (employing cost effective reverse osmosis or nannofiltration). Based upon prior experience with similar waters, we will employ appropriate experimental design (e.g., replication) and quality assurance and control procedures in the conduct of this investigation. General performance of the system will be determined by comparing inflow to outflow concentrations relative to hydraulic retention time. This initial feasibility and pilot study will serve to confirm the performance of the system and will also evaluate treatment effectiveness during all seasons.

The approach to our proposed investigation is to use sound theory and fundamental principles, such as the Laws of Thermodynamics and basic biogeochemistry, to develop design parameters that would permit installation of an appropriately designed and sized, full-scale constructed wetland system to treat produced water from gas storage fields. A major expected benefit of the proposed investigation is that the results will contribute to reduced cost of water management, which will potentially lead to the expansion of existing storage fields. In addition, new geographic areas may be opened up for the development of gas storage fields because of the anticipated economic advantages.