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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.

This report addresses the activities for the quarterly period of January 1, 2005 through March 31, 2005. During this time period efforts were directed to 1) solicit nominations for the Executive Council, 2) hold the Executive Council Election, and 3) host the Proposal Selection meeting.

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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.

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

This report addresses the activities for the quarterly period of January 1, 2005 through March 31, 2005. During this time period efforts were directed to 1) solicit nominations for the Executive Council, 2) hold the Executive Council Election, and 3) host the Proposal Selection meeting.

In January 2005, the GSTC began to solicit nominations for four members to serve on the Executive Council for the 2005-2006 term. The Consortium received twelve nominations and the election was held with a response deadline of January 26, 2005.

On January 27, 2005 the Executive Council election votes were tallied. The four newly elected Executive Council members are: Stephen Bergin (ONEOK Gas Storage, LLC), Stephen Foh (Gas Technology Institute), Ray Harris (National Fuel Gas), and James Philo (Consumers Energy). These four Council members will join the 2004-2005 term Council members Charles Chabannes (Duke Energy Gas Transmission), Andrew Theodos (Columbia Gas Transmission Corp.), Larry Kennedy, Jr. (El Paso Corp.), L.G. Chorn (Colorado School of Mines), and Karen Benson (Panhandle Energy), in the efforts of the Consortium.

The GSTC organized and hosted a proposal meeting at the Wyndham Greenspoint on February 2-3, 2005 in Houston, TX (agenda on Appendix A). The meeting was dedicated to project update presentations of the four projects selected for GSTC funding in 2004 and reviewing the proposals that were submitted to the GSTC for funding in 2005. The Principal Investigators of the proposed projects provided the membership with a 20-minute presentation, followed by a 5-minute question and answer session.

Of the 12 proposals received, the Executive Council recommended 5 projects for a total of $689,186 in funding. Table 1 summarizes the projects that were approved for co-funding. Appendix B contains a one page executive summary for these projects. The program breakdown for the approved projects is as follows:

Total Project Value: $1,161,677

Amount Approved for DOE Co-Funding: $689,186

% Cost Share: 41%

CONLUSIONS

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During this time period the GSTC solicited nominations for the 2005-2006 Executive Council term, held the Executive Council election, and hosted a Proposal Selection meeting in Houston, Texas on February 2-3, 2005.

REFERENCES

There are no references to include with this report.

APPENDIX A

MEETING AGENDA

Wyndham Greenspoint Hotel
Houston, Texas

February 2, 2005	
8:00 – 9:00	**Buffet Breakfast and Meeting Registration (Salon 11)**
9:00 – 9:15	**Welcoming Comments**
	Technology Transfer Workshop (Salon 11)
9:15 – 9:45	**Gas Storage Field Deliverability Enhancement and Maintenance: An Intelligent Portfolio** *Presenter: Shahab Mohaghegh*
9:45 – 10:15	**Compact Separators for Gas Storage Field Applications – Phase I** *Presenter: Jeffrey Savidge*
10:15 – 10:30	**Break**
10:30 – 11:00	**Real-time Wellbore Integrity Modeling** *Presenter: L.G. Chorn*
11:00 – 11:30	**Renovation of Produced Waters from Underground Natural Gas Storage Facilities** *Presenter: John Rodgers*
	Proposal Presentations
11:30 – 11:55	**Cement Evaluation in Gas Filled Borehole** *Presenter: Greg Barolak*
11:55 - 1:15	**GSTC Luncheon (Alfresco Room)**
1:15 – 1:40	**Real-time Wellbore Flow Monitoring, Phase II** *Presenter: L.G. Chorn*
1:40 – 2:05	**Low-cost Enhanced Storage Well Completions Using High Power Lasers** *Presenter: Brian Gahan*

2:05 – 2:30	**Temperature Effects on Threaded Couplings in Caverns** *Presenter: Kerry DeVries*
2:30 – 2:55	**Scale Remediation Using Sonication: Development of Operating, Performance and Economic Data** *Presenter: Donald Johnson*
2:55 – 3:20	**Using Chemicals to Improve Gas Deliverability** *Presenter: Bill Weiss*
3:20 – 3:35	**Break**
3:35 – 4:00	**Wellbore Cement Bond Integrity** *Presenter: K.E. Gray*
4:00 – 4:25	**Demonstration-scale Constructed Wetland System for Treatment of Produced Waters from Underground Gas Storage** *Presenter: Jim Castle*
4:25 – 4:30	***Closing Comments***
4:30 – 7:30	**GSTC Reception (Campobello Room)**

February 3, 2005	
8:00 – 9:00	**Buffet Breakfast and Meeting Registration (Salon 11)**
9:00 – 9:25	**Real-time Inventory and Deliverability Assessment Using Low Frequency Electronic Flow Measurement Data** *Presenter: Ken Brown*
9:25 – 9:50	**Testing and Preliminary Field Evaluation of the Tragen™** *Presenter: Dennis Coleman*
9:50 – 10:15	**Cost-effective XRF Nanotool for Real-time Identification and Location of Scale and Precipitates in Underground Gas Storage Well Bores** *Presenter: Ram Sivaraman*
10:15 – 10:45	**Break**
10:45 – 11:10	**New Comprehensive Inventory Analysis Tool** *Presenter: Ken Brown*
11:10 – 11:20	**Closing Comments/Meeting Adjourned**
11:20 – 12:20	**GSTC Luncheon (Alfresco Room)**

The GSTC Executive Council Meeting will begin immediately following the proposal meeting on February 3, 2005.

APPENDIX B

CEMENT EVALUATION IN GAS FILLED BOREHOLE

Lead Organization:	Baker Atlas. Baker Hughes, Inc
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GSTC Co-funding:	$117,000

The process of cementing wellbore casing in place provides two major benefits in gas storage wells. First, cement provides zonal isolation, preventing gas migration up the well bore between the formation and the casing. Second, cement transfers stress from the casing to the formation, increasing the effective strength and working pressure of the casing. Unfortunately, reliable cement evaluation data does not exist on many wells in use for gas storage today.

Current cement evaluation techniques are designed to operate in fluid filled holes typically on newly drilled but uncompleted wells. These techniques typically use an acoustic wave generated and then received by a logging tool within the wellbore to detect cement placed outside the casing and quantify several simple properties of this cement. A major restriction of all these services with respect to the gas storage industry, however, is their inability to operate in gas filled boreholes.

Baker Atlas is currently doing research into the use of new acoustic techniques for evaluation of highly modified, light-weight cements. As 100% of the current market for cement bond measurements is in fluid filled boreholes, these experiments are currently limited to these conditions. This proposal requests funding to expand this work to gas filled boreholes. The best candidate transducer or transducers for such a service would be identified and differences in the response of the new measurement between gas and liquid filled boreholes would be investigated.

The ultimate benefit to the Gas Storage industry of a cement evaluation service capable of operating in a gas filled borehole is large. First, it could provide direct proof of cement placement and zonal isolation in older gas wells. (Today, such a determination requires filling the well with fluid before logging.) Second, the presence of cement between casing and the formation provides a method of transferring pressure induced stress from the casing to the formation, greatly increasing the effective burst strength of the casing. Verification of cement placement should allow more realistic assessment of remaining casing burst strength, eliminating significant cost associated with unneeded workovers.

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Smart Gas: Using Chemicals to Improve Gas Deliverability

Each year, more than 17,000 gas storage wells in the United States lose from 3–5% of storage capacity and deliverability. The gas storage industry spends $80–100 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 imbibe 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. Similarly, 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.

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 using 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 cost of current stimulation treatments will be determined The candidate fields will include sandstone, carbonate, and dolomite reservoirs in dry gas fields, depleted oil fields, and water aquifers.

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. Because 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.

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.

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 reporting requirements and has successfully completed several Department of Energy-funded projects.

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Temperature Effects on Threaded Couplings in Caverns

RESPEC, an engineering consulting and services firm, and their subcontractor, C-FER Technologies, have developed a research plan to address well integrity for reservoir and salt cavern wells that have final cemented casings constructed with threaded couplings. The research proposed would investigate the potential for failure of threaded couplings in natural gas storage wells as a result of cyclic fatigue caused by thermal cycling.

When natural gas is injected or withdrawn from storage, the temperature of the gas flowing through the production casing is almost never in equilibrium with the casing components or the rock mass. As a result, the production casing expands and contracts in response to the temperature fluctuations associated with operation. This cyclic behavior may be having deleterious effects on the integrity of cemented casings constructed with threaded couplings. If casing failures and/or separations of the tubular couplings occur, these failures could result in an environmental disaster or even loss of human life. Prevention of an accident might be possible if the failure mechanisms are understood.

This work will consist of comprehensive structural analyses of typical API threaded couplings in different casing sizes subject to pressure, temperature, and load conditions typical of withdrawal and injection cycles in gas storage wells. The proposed effort addresses the loads associated with restrained thermal expansion, subsidence, salt creep, and initial loads induced in the casing during well completion. By considering all of the loads and displacements on the casing, the relative contribution of each load to the total load can be evaluated. Recommendations for remedial action or future well construction practices will be made, depending on the relative contributions of each source of casing load.

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New Comprehensive Inventory Analysis Tool

Inventory analysis is critical to proper management of gas storage facilities. Often, basic inventory analysis plots (e.g., P/Z vs Inventory) are updated and reviewed once or twice a year, with additional scrutiny being applied if several cycles' worth of data suggest possible inventory problems.

There are over a dozen useful diagnostic plots and techniques available for monitoring inventory and identifying potential causes of lost gas in storage reservoirs. However, many operators have given more and more responsibilities to fewer and fewer personnel in recent years, making truly comprehensive inventory analyses more difficult to accomplish in a reasonable timeframe. In addition, as new storage engineers enter the market to replace the graying retirees, unfamiliarity with the underlying assumptions and limitation inherent in the less known analysis techniques may cause undue hesitation to implement these techniques.

We are proposing development of a user-friendly software package developed using off-the-shelf software that would: 1) readily accept all inventory data available for a given field, 2) automatically generate and interactively interpret all diagnostic plots possible with existing data, 3) have available on-line help screens summarizing the technical assumptions of each analysis technique, the applicability of the techniques to various types of storage reservoir (dry gas, aquifer, etc), the inherent dangers of each technique, and example plots of each technique would prove to be an invaluable tool to the practicing storage engineer. We are proposing development of this tool for the storage industry to improve the quality of inventory monitoring and verification as well as aid the resolution of gas loss issues when they occur.

The proposed work is in line with GSTC's mission to "…assist in the development, demonstration, and commercialization of technologies to improve the integrity, flexibility, deliverability, and cost-effectiveness of the nations UGS facilities…" Specifically, the proposed work addresses several items delineated in the Research Focus Area section of the RFP, including investigations that address reservoir characterization and develop new approaches to inventory verification.

The objectives of this work include 1) development and field test a software tool that readily accepts all inventory data available for a given field and automatically generates and interactively interpret all diagnostic plots possible with existing data, 2) Development of on-line help tools within the software that summarizes the technical reference(s) on which the analysis technique is based, the technical assumptions inherent in each analysis technique, the applicability of each techniques to various types of storage reservoir (dry gas, aquifer, etc), the inherent dangers of each technique, and provides example "type curve" plots for each technique showing the characteristic shapes indicative of gas losses, growing bubble size, etc.

This tool will significantly improve operators' ability to effectively monitor inventory and resolve gas loss issues by making inventory analysis processes much more automated and much more comprehensive. It will also enhance the analysis process by guiding the engineer to the appropriate analysis techniques and away from the inappropriate analysis techniques via the on-line help tools.

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Wellbore Cement Bond Integrity

Technical, economic, environmental, and safety considerations underscore the pressing need by gas storage operators to understand the ways in which elements of a well bore and cement sheath interact during drilling, completion, and production operations. Research proposed here is designed to develop a better understanding of cement hardening, cement adhesion, and the effects of cyclic pressure and temperature-related stresses on these processes. It is our belief that this understanding will assist in the development of improvements in cement/casing/formation seals, and of better techniques for assessments of seal quality with down- hole logging tools.

The components of a well-bore are physically coupled. While pressures inside the casing are easily measured and mechanical behavior of casing is well documented, little is known about the stresses, displacements, and behavioral features of the casing/cement interface outward through the cement, mud cake, plastic zone, and formation. Interface stresses, displacements, and coupling conditions change continually as well-bore pressures, pore pressures, and temperatures fluctuate. An understanding of the 3-D, time-dependent changes through all of the system components is necessary for addressing the well-bore cement bond integrity problem, especially in gas storage operations.

The first step in the investigation will be a detailed survey of available information about cement quality, cementing casing, and tools used to monitor bond quality. Next, suites of laboratory tests will be carried out to quantify what happens, when, where, and in what magnitudes and orientations, during casing, cement, and formation interactions. Testing will be carried out in bench-top simulations of well-bores in blocks of reservoir rock, as well as in sophisticated test chambers designed to realistically simulate the down-hole environment. These tests will investigate behavior in cement slurry during set up, assessments of temperature and pressure variations on cement-casing bonding, effects of cyclic differential thermal and pressureinduced stresses on cement-casing adhesion, and direct assessments of axial wave amplitudes and their correlation to cement bond integrity. Acoustic signatures across fluid- filled gaps between cement and casing will be measured directly by the amplitude of transmitted p-waves.
Fluids used for the gap will include air, water, contemporary drilling muds, and high-viscosity resins. These measurements will provide a data base of the effects of fluid properties and geometric factors (in particular, the gap between cement and casing) on acoustic energy loss.

The research proposed here will be in concert with an ongoing research consortium, Life-Of-Well Rock, Fluid, and Stress Systems. This collaboration will provide considerable leveraging of funds, coordination of research with industrial needs, access to state-of-the art developments in cementing and well logging techniques, and recipes for cement formulations in current use. Following this one-year research program, proposals will be submitted for investigations of improvements of techniques for down-hole assessments of cement-bond integrity with downhole logging tools, with direct collaboration of industrial partners. In addition, coordinated development of analytical and numerical simulators, which have the capability and versatility to honor processes and parameters from the above testing activities, will be carried out. These will include finite element models (FEM) and three-dimensional discrete element models (DEM). FEM simulations are very useful for characterizing borehole behavior, but they cannot capture the discontinuous microscopic processes such as micro-fracture, grain-boundary sliding, and cementation in a granular material. DEM simulations are designed specifically for this purpose. In either case, the utility and reliability of simulated behavior relies on accurate input data, and an important component of the proposed study will be a careful measurement of mechanical properties and interactions of the various borehole elements.