THE MISSISSIPPI CCS PROJECT

FINAL SCIENTIFIC/TECHNICAL REPORT

Period Start Date: November 16, 2009

Period End Date: September 30, 2010

Principal Author: Doug Cathro, Leucadia Energy, LLC

Report Date: March 5, 2013

DOE Award Number: DE-FE0002260

Leucadia Energy, LLC
315 Park Avenue South
New York, NY
10010-3607

Significant Subcontractors:

Denbury Onshore, LLC
5100 Tennyson Parkway #1200
Plano, TX 75024

Black & Veatch Special Projects Corp.
6601 College Blvd.
Overland Park, KS 66211

Abstract

The Mississippi CCS Project is a proposed large-scale industrial carbon capture and sequestration (CCS) project which would have demonstrated advanced technologies to capture and sequester carbon dioxide (CO_2) emissions from industrial sources into underground formations. Specifically, the Mississippi CCS Project was to accelerate commercialization of large-scale CO_2 storage from industrial sources by leveraging synergy between a proposed petcoke to Substitute Natural Gas (SNG) plant that is selected for a Federal Loan Guarantee and would be the largest integrated anthropogenic CO_2 capture, transport, and monitored sequestration program in the U.S. Gulf Coast Region. The Mississippi CCS Project was to promote the expansion of enhanced oil recovery (EOR) in the Mississippi, Alabama and Louisiana region which would supply greater energy security through increased domestic energy production. The capture, compression, pipeline, injection, and monitoring infrastructure would have continued to sequester CO_2 for many years after the completion of the term of the DOE agreement.

The objectives of this project were expected to be fulfilled through two distinct phases.

The overall objective of Phase 1 was to develop a fully definitive project basis for a competitive Renewal Application process to proceed into *Phase 2 - Design, Construction and Operations*. Phase 1 included the studies attached hereto that establish:

- the engineering design basis for the capture, compression and transportation of CO_2 from the MG SNG Project, and
- the criteria and specifications for a monitoring, verification and accounting (MVA) plan at the Soso oil field in Mississippi.

The overall objective of Phase 2, was to execute design, construction and operations of three capital projects:

- the CO_2 capture and compression equipment,
- the Mississippi CO_2 Pipeline to Denbury's Free State Pipeline, and
- an MVA system at the Soso oil field.

Table of Contents

Appendices

1. Phase 1 SOPO Task 1.5.1.1, Rectisol and CO_2 Compression Optimization Study.
2. Phase 1 SOPO Task 1.5.2.1, Preliminary Engineering of CO_2 Compression Equipment.
3. Phase 1 SOPO Task 1.5.2.2, Preliminary Interconnection Study.
4. Phase 1 SOPO Task 1.5.2.3, Optimization of the CO_2 Compression Equipment Selection.
5. Phase 1 SOPO Task 1.5.3, CO_2 Injection Site Confirmation.
6. Phase 1 SOPO Task 1.5.4.1, Draft Risk Assessment and MVA Plan.
7. Phase 1 SOPO Task 1.5.4.2, Site-Specific MVA Options Evaluation.
8. Phase 1 SOPO Task 1.5.4.3, Final MVA Plan and Detailed Budget.
9. Phase 1 SOPO Task 1.8.1, Technology Cost Data.
10. Programmatic and Technical Prospectus (Fact Sheet)

Executive Summary

Leucadia Energy, LLC signed a Cooperative Agreement with the U.S. Department of Energy (DOE) in November 2009 to complete the first phase of a large scale industrial carbon capture and sequestration (CCS) project. The Mississippi CCS Project was to include the integration of CO_2 capture, transportation/delivery and sequestration with comprehensive monitoring, verification and accounting (MVA). Leucadia Energy teamed with Denbury Onshore, and Black & Veatch to execute Phase 1 of this project.

The Mississippi CCS Project was to receive several CO_2 streams at 20, 40, and/or 60 psia from the Rectisol® units and compress the combined stream to 2,265 psia for injection into the proposed 109 mile Mississippi CO_2 Pipeline. The Mississippi CO_2 Pipeline was to transport the CO_2 to existing oil fields on the Gulf Coast where it was to be used in independent, commercial enhanced oil recovery (EOR) projects. A MVA plan for over 1 million tons per year (tpy) of CO_2 was to be implemented at the Soso oil field to demonstrate the safe and effective storage of CO_2 in the oil bearing geological formations with the additional benefit of enhancing oil recovery in existing oil fields.

Phase 1 of the Mississippi CCS FOA15 project was divided into three components, Capture and Compression, Transportation, and MVA of CO_2 injection at an existing, commercial EOR facility. The focus of the Capture and Compression component included preliminary engineering studies to optimize the combined cost and energy consumption for Rectisol® and CO_2 compression including the startup and shutdown energy requirements from the local grid. Leucadia Energy performed preliminary engineering of the Rectisol® units. Based on the available information, Black & Veatch determined that the Rectisol configuration producing three CO_2 streams would have the lowest cost, highest CO_2 recovery, and lowest specific energy use. The cost of the Rectisol® preliminary engineering was not included in the scope of the Phase 1 award. The second focus of the project was a feasibility study of the most effective route for the 109 mile Mississippi CO_2 Pipeline. The cost of this study was not included in the Phase 1 cost share, however was used in the planning and budgeting of the pipeline that was to be built in Phase 2. The final focus of Phase 1 was the initial review of four oil fields necessary to select the CO2 injection site, the initial risk assessment of the proposed MVA components and the preliminary engineering investigation into the MVA specifications for the proposed location.

This Final Scientific/Technical Report summarizes work completed on the project from November 16, 2009 through September 30, 2010. During this period, all of the tasks identified below in the Phase 1 SOPO were completed.

- C1.1 Project Management and Planning
- C1.2 Environmental Impacts and Permits
- C1.3 Site Arrangements
- C1.4 Teaming Arrangements
- C1.5 Conceptual/Preliminary Design
- C1.6 Phase 2 Project Description and SOPO
- C1.8 Phase 2 Project Costs, Funding and Budget

Weekly, monthly and quarterly reports were submitted through the end of the Phase 1 period. An EIV for the Mississippi CCS project was prepared and attached to the Phase 2 Renewal Application. Firm and binding commitments for the project sites were confirmed. Teaming agreements with key offtakers, licensers, and contractors were developed. Preliminary design of capture, compression, transportation and MVA systems was completed and comprehensive plans for such facilities, including detailed budgets and schedules, have been developed. Attached to this Final Scientific/Technical Report, are the following studies upon which much of this work was based:

- Phase 1 SOPO Task 1.5.1.1, Rectisol and CO_2 Compression Optimization Study.

- Phase 1 SOPO Task 1.5.2.1, Preliminary Engineering of CO_2 Compression Equipment.

- Phase 1 SOPO Task 1.5.2.2, Preliminary Interconnection Study.

- Phase 1 SOPO Task 1.5.2.3, Optimization of the CO_2 Compression Equipment Selection.

- Phase 1 SOPO Task 1.5.3, CO_2 Injection Site Confirmation.

- Phase 1 SOPO Task 1.5.4.1, Draft Risk Assessment and MVA Plan.
- Phase 1 SOPO Task 1.5.4.2, Site-Specific MVA Options Evaluation.
- Phase 1 SOPO Task 1.5.4.3, Final MVA Plan and Detailed Budget.
- Phase 1 SOPO Task 1.8.1, Technology Cost Data.
- Non-Proprietary Programmatic and Technical Prospectus
  (Fact Sheet)

Report Details

The following is a discussion of the SOPO tasks that were completed during Phase 1:

C1.1 Project Management and Planning

C1.1.1 Project Management Plan

- A project management plan in the form of a resource loaded schedule (RLS) was created using Microsoft Project 2007 and submitted to DOE/NETL. Planned costs were loaded as resources to those activities/tasks that were part of the cost share.

C1.1.2 Reporting

- The project team began reporting progress with updates to the RLS on a monthly and a quarterly basis. Quarterly reports were also submitted under ARRA guidelines.

- Weekly status reports were issues and reviewed during weekly update calls with DOE/NETL.

C1.2 Environmental Impacts and Permits

C1.2.1 National Environmental Policy Act (NEPA)

The potential environmental impacts of the proposed Mississippi Gasification (MG) Facility and the proposed Mississippi carbon dioxide (CO2) Pipeline (the "CO2 Pipeline") include impacts to the following resource areas: land use; visual resources; infrastructure and utilities; transportation; climate, air quality, greenhouse gases; noise and vibration; water resources; floodplains and wetlands; geology; soils; biological resources; threatened and endangered species; cultural resources; socioeconomics; environmental justice; waste management; and human health, safety, and accidents.

The Environmental Impact Statement (EIS) for the project is not yet complete, so full information on potential impacts is not yet available. In addition, mitigation for the project would be developed based on the EIS findings as well as final design information, both of which are not yet available. Below is an overview of some of the types of potential impacts and mitigation for the project, based on current information.

The MG Facility

The proposed MG Facility site has a designated industrial use. Minimal site clearing would be required at the beginning of construction. Site preparation activities would include building access roads, clearing, bringing in fill material, leveling and grading the site, bringing in necessary utilities, and undertaking dewatering activities that may be required. Construction of temporary parking, offices, and material storage areas would involve the use of heavy equipment to prepare the site for construction of the plant. Construction activities would disturb approximately 120 acres of the 205-acre site. Once operational, the footprint of disturbed land would be approximately 100 acres (approximately 49 percent of the site). Construction will be conducted pursuant to all applicable federal, state and local regulations, including any necessary wetlands and floodplains approvals.

The area where the main processing units would be located would need to be raised by two feet to minimize the impact of potential flooding. Fill material would be obtained from offsite sources located within 15 miles of the proposed MG Facility. Construction BMPs and controls will be utilized to mitigate impacts of construction activities, including air, noise and water impacts.

In terms of operations, potential impacts include air, water, noise, transportation impacts and waste management. MG would comply with all applicable state and local permit requirements, including air and water permits issued by the state. Water for the project be drawn from several water sources, including the Escatawpa and Pascagoula Rivers. Impacts to surface water would be mitigated through design of the stormwater collection system. The MG Facility would implement appropriate spill prevention and response measures in accordance with the requirements of Occupational Safety and Health Administration (OSHA), Emergency Planning and Community Right-to-Know Act (EPCRA), and CAA provisions.

Mississippi CO2 Pipeline

Denbury would construct the CO2 Pipeline, a total of approximately 109 miles of new pipeline. The total construction right-of-way (ROW) width for the CO2 Pipeline would be 95 feet. The proposed permanent ROW width would be 50 feet. Based on a proposed temporary ROW width of 45-feet and permanent ROW width of 50-feet, the proposed CO2 Pipeline would affect approximately 1,660 acres of land during construction, which includes both temporary and permanent ROWs, additional temporary workspace, aboveground facilities, access roads, and pipe storage yards. Approximately 651 acres of land would be affected during operation of the pipeline on a permanent basis. Of this, the anticipated above ground facilities would require approximately 1.14 acres.

Impact on land use would primarily result from clearing the 95-foot-wide construction ROW for the installation of the new pipeline and from maintaining the 50-foot-wide permanent pipeline ROW. In addition to the construction ROW, construction would require temporary extra work areas near the crossing locations of streams, wetlands, ponds, major rivers, roadways, and railroads; and for topsoil storage in agricultural areas.

Because the CO2 Pipeline would follow existing ROWs, clearing of trees should be minimized. However, any forest clearing during pipeline construction would represent a long-term impact since these areas would be converted to cleared open land. Impacts to agricultural land would include the loss of standing crops within the ROW and the potential loss of future crop productivity, the mixing of topsoil with subsoil, and soil compaction. However, Denbury utilizes double-ditching for segregation of top soil on cultivated lands. Following construction, all temporary construction ROW, extra work areas, contractor yards, and temporary access roads would be allowed to revert to previous land use. Within the permanent ROW, upland forest and some forested wetlands would be permanently converted to a cleared condition as required by most pipeline regulatory schemes.

Temporary construction impacts near residences could include inconvenience caused by noise and dust generated by construction equipment and personnel and from trenching of roads or driveways; ground disturbance of lawns; removal of trees, landscaped shrubs, or other vegetative screening between residences and/or adjacent ROWs; potential damage to existing septic systems or wells; and removal of aboveground structures, such as sheds or trailers, from within the ROW. Homeowners or business owners would be notified in advance of construction activities and any scheduled disruption of utilities.

Disruptions would be minimized to the extent practicable. If project-related work activity in a residential or commercial area would disrupt ingress and egress to the affected property, Denbury would attempt to provide alternative access to the property. Attempts would be made to leave any mature trees and landscaping intact within the construction work areas unless the trees and landscaping interfere with installation techniques or present unsafe working conditions..

The Denbury pipeline will be designed and operated under all applicable federal, state and local regulations. Pre-pipeline construction involves approvals for wetland delineation, habitat evaluations and culture resource studies, along with other environmental and safety statutes. CO2 pipeline safety is regulated by the Office of Pipeline Safety of the DOT under the Hazardous Liquid Pipeline Act of 1979, 49 U.S.C. § 601. Under the Act, DOT regulates the design, construction, operation and maintenance, and spill response planning for CO2 pipelines. 49 C.F.R. § 190, 195-199.

Risks related to the transport and injection of carbon dioxide have been successfully managed for over three decades in commercial EOR operations. In the US, the industry operates thousands of CO2 EOR wells, over 3,500 miles of high pressure CO2 pipelines, and has injected over 600 million tons of CO2.

C1.2.2 Permits and Other Regulatory Authorizations

The status of all necessary permits and authorizations for the Mississippi CCS Project were identified as part of the EIS for each of the capture and compression, pipeline and MVA activities.

The key permit applications that were in the process of being prepared for the MG SNG Plant and those that would need to be prepared for the CO_2 pipeline and the MVA component have been outlined below. Given that the MG SNG Project is located on a brownfield site in the industrial area shown below in figure C1.2.2, and given the level of local and state support for the MG SNG Project, no significant regulatory hurdles were anticipated. The State and local support for the MG project was significant and continuous. The project was originally encouraged by Governor Barbour to locate our facility in Mississippi. The Governor directed his state development agency, MDA, to work with MG to find an appropriate site. MDA recommended Jackson County and we were then introduced to the Jackson County Economic Development Foundation who presented MG with the current site. Governor Barbour allocated $400 million of Katrina bonds to the MG project as proof of the State's support. Since that time, state and local support has been unwavering.

Figure: C1.2.2

- **Resource Conservation and Recovery Act (RCRA)/Hazardous Materials Regulations:** The MG SNG Project did not require a RCRA Permit, as there was no planned storage or treatment of hazardous wastes on site. It was not anticipated that any Toxic Substances Control Act (TSCA) or CERCLA requirements would be applicable to the facility.

- **Clean Air Act Permits**: As discussed more fully in the draft EIS, Title V and Prevention of Significant Deterioration (PSD) Air Permits for emissions associated with the production of substitute natural gas would have needed to be obtained for the MG SNG Project.

- **Water Permits:** The MG SNG Project was seeking a permit to implement zero liquid discharge (ZLD) for the gasification process wastewater. The wastewater generated in the gasification process would have been treated/recycled to achieve ZLD. Filtered solids and dewatered salts would have been disposed of off-site at permitted facilities. Discharge of storm water during construction activities would have required submittal of a Large Construction Notice of Intent (LCNOI) prior to start of construction.

  Two separate water withdrawal permits of 12,000 gpm from the Escatawpa River and 5,000 gpm from the Pascagoula River previously existed for this site. There was the potential that these prior approvals could have been utilized for this Project either through an approved transfer of the permits or contractual arrangements.

  The Clean Water Act (CWA) section 402 (NPDES) would have been administered by the MDEQ as part of the permitting for the proposed CO_2 pipeline. A Large Storm Water Construction General Permit for Land Disturbing activities of 5 acres or greater, The Stormwater Pollution Prevention Plan (SWPPP), a Hydrostatic Test General Permit and a Water Withdrawal Permit would have been filed prior to construction of the proposed pipeline with the MDEQ.

  Applications and Preliminary Assessment Reports (PAR) to the MDEQ would have been prepared for the Ground Water Monitoring Wells one month prior to drilling each of the proposed wells as part of the MVA component of the project.

- **United States Army Corps of Engineers (US COE):** Section 404 permits would have been required for both the capture facility and the pipeline, (Section 404 establishes a program to regulate the discharge of dredged and fill material into waters of the United States, including wetlands), the 404 permits would have been supported by 401 Water Quality Certifications (WQC) issued by the MDEQ for both the capture facility and the pipeline. The 401 Water Quality Certification and Isolated Wetland Permit Section reviews applications regarding projects that would physically impact waters of the state, including streams, lakes and wetlands. A Section 10 permit would have also been required for the MG barge facility. A wetlands delineation was prepared for the capture facility and would have been submitted to the US COE with the 404/Section 10 permit application. The 404 and section 10 permit for the pipeline would have been filed within a month of the draft EIS with the DOE. A section 10 permit issued by the US Army Corps of Engineers is designed to prohibit the obstruction or alteration of navigable waters of the United States.

- **Coast Guard Review**: During the planning and design process, a description and map of the facility, including a letter of intent, would have been sent to the United States Coast Guard (USCG) for its approval and clearance. Coordination with the Coast Guard regarding the US COE permits and construction of the planned structures would have been implemented for this project to ensure that all requirements are satisfied.

- **Endangered Species Act:** Based upon initial survey information, no impacts to rare, threatened or endangered species or critical habitats were anticipated for the proposed capture and compression part of the project. DOE would have been coordinating with the Unites States Fish and Wild Life Service (US FWS) as part of the NEPA process that is underway for the capture and compression project.

  No impacts to threatened or endangered species or critical habitat associated with construction or operation of the pipeline or the MVA activities proposed were anticipated. Informal consultations with the DOE would have been initiated during the development of the EIS with the US FWS, the National Oceanic and Atmospheric Administration's National Marine Fishery Service (NOAA Fisheries) Protected Resources Division, and the National Marine Fisheries Service.

  Land Permits: Special Use Permit applications authorizing pipeline easement through Desoto National Forest and Grand Bay National Wildlife Refuge would have been filed with the Desoto National Forest District office, with the district head serving as the liaison for the U.S. Department of Agriculture – Forest Service and the U. S. Department of Interior – Fish and Wildlife Service. This permit would have been filed within 1 month of filing the EIS with DOE.

  Consultation with the Mississippi Department of Wildlife, Fisheries, and Parks (MDWF&P) would have been consulted regarding the potential impacts to listed fauna species associated with land projects along the pipeline route. This consultation would have been initiated during the EIS development process with the DOE.

- **National Historic Preservation Act:** A Phase I Cultural Resources Survey was performed for this site and a report was issued to the State Historic Preservation Office (SHPO). The SHPO found no objections to the proposed project. The SHPO reviewed this updated information and issued a letter on March 9, 2010 concurring that no known cultural resources listed or eligible for listing on the National Register of Historic Places are likely to be affected by the MG SNG Project.

As part of the pipeline project a Cultural Resources Survey from the pre-existing Destin Pipeline was used to document the potential cultural resources along the proposed CO_2 route. The Mississippi Department of Archives and History, Historic Preservation Division will be consulted during the EIS process to determine any additional cultural resource identification steps necessary.

- **Emergency Management Requirements:** The facility would have been subject to certain emergency management requirements under the Emergency Planning and Community Right-to-Know Act (EPCRA) and Spill Prevention Control and Countermeasure (SPCC) requirements (40 CFR 112). Emergency response procedures would have been developed for the facility in accordance with the requirements of Occupational Safety and Health Administration (OSHA), EPCRA, and CAA provisions. Such procedures were to cover plant evacuation notification to local fire and law enforcement agencies, notification to state and local officials and US EPA. Emergency response procedures would have identified individuals/positions responsible for decision-making and notification and would have included provisions for periodic training of plant management and employees.

- **Oil and Gas Board Permits:** A Form 2 - Applications for Permit to Drill, Workover or Change Operator and a Form 3 – Well Completion or Recompletion Report and Well Log would have been filed for each well with the Mississippi State Oil and Gas Board (MS OGB) prior to construction of each of the wells proposed in the MVA component of the project.

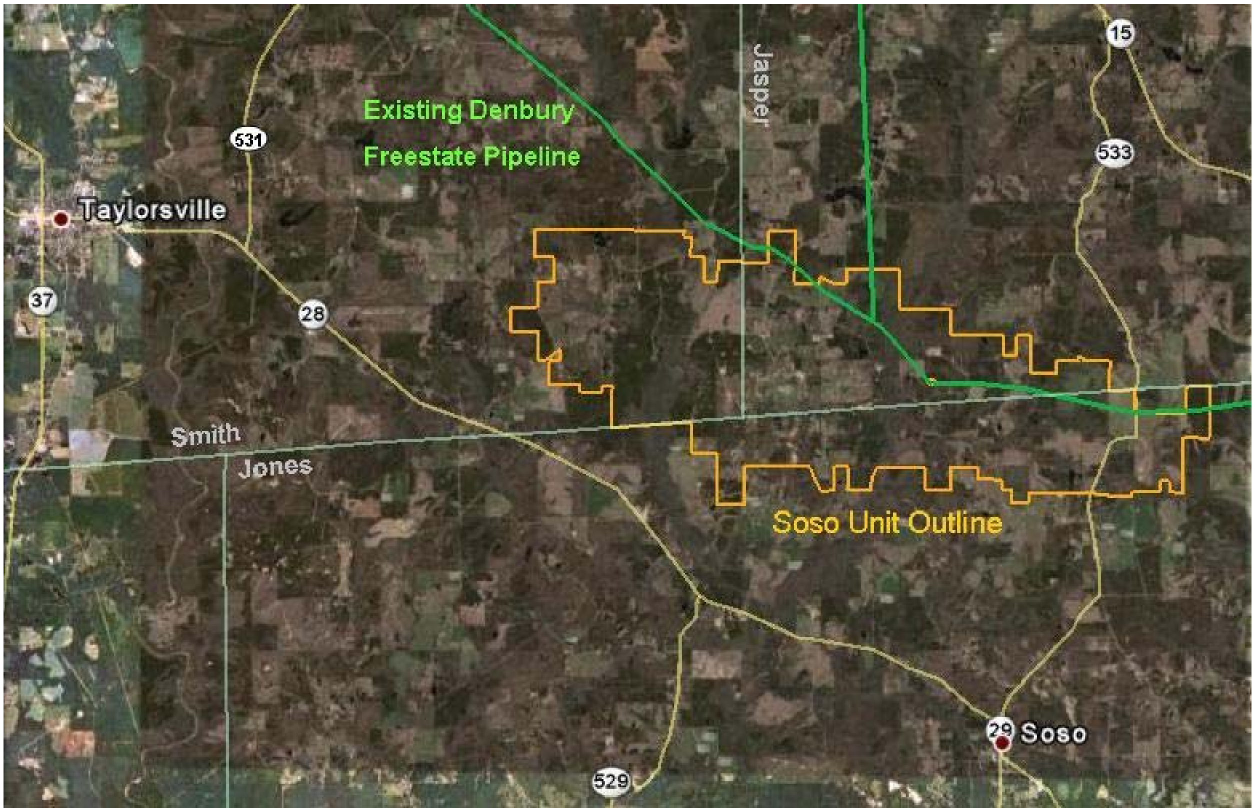
- **Local Permits**: The MG SNG Project was anticipating the need for building permits and a flood zone management permit from local regulators. Coordination on these requirements would have been implemented prior to construction.

C1.3 Site Arrangements

- The MG SNG Project had established site control for the capture and compression facilities through an option to lease the property for an initial term of 50 years with two extensions of 25 and 24 years, respectively. There are two parcels and two lease options:

- Parcel one is approximately 185 acres. This is a brownfield site, formerly owned by International Paper. The site has been remediated to MDEQ standards by the current owner, Jackson County Port Authority, and has been deemed suitable for subsequent development. The site is situated adjacent to the Escatawpa River, which would have been utilized for barge delivery of petcoke and construction modules. The site has ready access to several major interstate natural gas pipelines (for interconnect and delivery of SNG to MG's customers), as well as 115 kV electrical transmission access to Mississippi Power. Fresh water for the site is available through an existing fresh water canal. The site was formerly served by Mississippi Export Railroad via a rail spur which would have been restored/upgraded by MG for alternate delivery of petcoke and export of sulfuric acid. The lease option agreement for this parcel was executed on 12/18/08 between MG and Jackson County Port Authority and had an initial term of 36 months and could have been extended an additional six months at MG's sole option. If the option had been exercised, the subsequent lease would have been for an initial term of 50 years, with options (at MG's sole discretion) for two extensions – one for 25 years and one for 24 years, bringing the total possible lease term to 99 years.

- Parcel two is approximately 20 acres. This parcel is contiguous to parcel one and is currently utilized as a temporary middle school by the Moss Point School District. The students at this school would have been permanently relocated to another school, once repairs were completed from damage caused by Hurricane Katrina. MG planned on utilizing the existing school building for construction offices, initially, and for plant administration once the SNG facility was to be completed. The lease option agreement for this parcel was executed on 3/20/09 between MG and the Moss Point School District and had an initial term of 36 months and could have been extended an additional six months at MG's sole option. If the option had been exercised, the subsequent lease would have been for an initial term of 50 years, with options (at MG's sole discretion) for two extensions – one for 25 years and one for 24 years, bringing the total possible lease term to 99 years.



- The Monitoring Verification and Accounting (MVA) project would have been conducted at a site within the Soso Field, located in Jasper, Jones and Smith counties. Soso Field consists of 6,460 acres of active commercial CO_2 enhanced oil recovery (EOR) field production. Under the rules of the state of Mississippi, Soso Field was unitized in 1957. As the operator of the Soso Field Unit, Denbury has the right to operate the Soso Field Unit for CO_2 EOR operations under the terms of the 1957 Unit Order No. 82-57 of the Mississippi Oil and Gas Board and Unit Operating Parties Agreement dated June 1, 1956.

- The CO_2 injection wells used in the commercial EOR operations are permitted by the Mississippi Oil and Gas Board under primacy from the Underground Injection Control regulations of the US EPA. Its oil and gas operations are regulated by the MS OGB, and the CO_2 pipelines are regulated by various State and Federal agencies. Thus, a complete legal and regulatory framework exists for Denbury to inject CO_2 as part of its commercial CO_2 EOR projects for the Soso Field EOR operation.

C1.4 Teaming Arrangements

Teaming arrangements were established with key offtakers, licensors, and contractors, including the following:

- CO_2 Offtake Agreement between Denbury and Leucadia Energy. The agreement would have been in effect upon first delivery of CO_2.

- Memorandum of Understanding (MOU) between Denbury and Leucadia Energy documenting the conditions under which Phase 2 would have been executed.

- Subcontract between Denbury and UT BEG GCCC for completion of Phase 1 SOPO task 1.5.3, 1.5.4.1, 1.5.4.2, and 1.5.4.3.

- Subcontract between Leucadia Energy and Black & Veatch Special Projects Corporation to perform engineering work necessary to complete Phase 1 SOPO task 1.5.1.1, 1.5.2.1, 1.5.2.2 and 1.5.2.3

- A license agreement between Mississippi Gasification and ConocoPhillips for the E-Gas Gasification Technology (nonexclusive license to practice ConocoPhillips E-Gas Technology related to intellectual property rights, including any patent rights of ConocoPhillips related to E-Gas Technology, and to the use of Technical Information of ConocoPhillips in the production of synthetic fuel gas at the facility).

C1.5 Conceptual/Preliminary Design

- The Rectisol unit was to produce approximately 211 MMSCFD of CO_2 suitable for enhanced oil recovery. The CO_2 concentration would have been about 99 percent by volume. The Rectisol unit would have been designed to produce CO_2 at three different pressures that would have subsequently been forwarded to the CO_2 compression system. A general block flow diagram of the gasification, CO_2 capture, and CO_2 compression system is shown below in figure C1.5

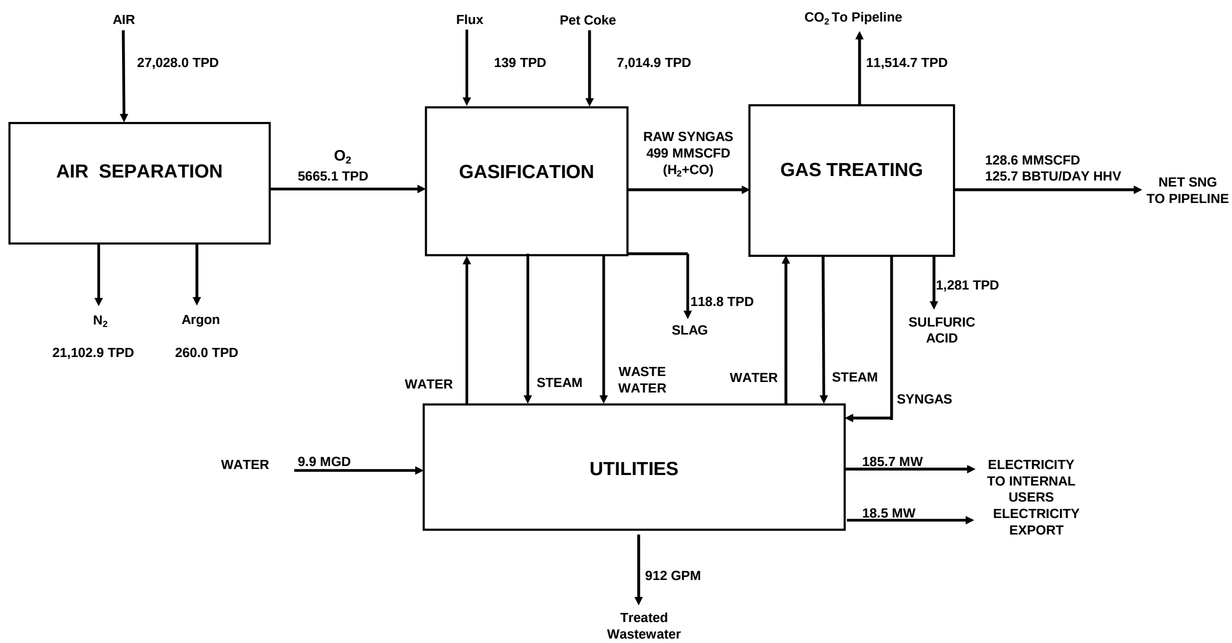


Figure C1.5

C1.5.1.1 Optimization Study of Rectisol® and CO_2 Compression

- At the request of Leucadia Energy, LLC, Black & Veatch performed an optimization study that evaluated potential Rectisol® configuration impacts on the overall cost and energy efficiency of the Mississippi Gasification (MG) SNG Plant. Three Rectisol configurations were evaluated, in which one, two, and three carbon dioxide (CO_2) streams were produced at varying pressures and purities. The one CO_2 stream case included a large vacuum flash compressor, which was to be replaced by additional CO_2 flash equipment in the two and three CO_2 stream cases.
- Based on the available information, Black & Veatch determined that the Rectisol configuration producing three CO_2 streams would have the lowest cost, highest CO_2 recovery, and lowest specific energy use.

C1.5.2.1 Preliminary Engineering of CO_2 Capture and Compression Equipment

- Based upon results of the optimization study, data sheets were issued to compressor vendors for cost and performance data. The CO_2 compression would have required roughly 34.2 MW of power to deliver the 211 MMSCFD of CO_2 to custody transfer metering at a pressure of 2,265 psia. The compressed CO_2 gas was to be cooled to 100º F in the HP CO_2 Aftercooler using cooling water prior to leaving the compressor package battery limits. The combined CO_2 stream purity would have been greater than 99 percent by volume.

C1.5.2.2 Preliminary Transmission Interconnection Assessment

- The integrated gasification and CCS projects were to have a single grid interconnection. The actual interconnection study would have been done as part of the gasification project. There may be an incremental cost associated with the CCS project needs, but it was not included in the Phase 2 funding request. The assessment is attached as Appendix 3.

C1.5.2.3 Optimization of CO_2 Compression Equipment

- Based upon the preliminary engineering and vendor data the type of compressor and the configuration was determined. The preferred configuration was 2 x 50 percent integrally geared multistage centrifugal compressors. The compressor units were to be comprised of a low speed gear and multiple high speed pinions contained within the compressor body. The impellers were to be mounted on the high speed pinions. This would have allowed the selection of impellers operating at different speeds and diameters providing a more optimum aerodynamic selection. Eight impellers (stages) were to be required for the stated pressure ratio with intercooling. The compressor package would have also consisted of all requisite intercoolers and suction scrubbers. There would have been suction scrubbers after the 5th and 6th stages of compression to protect against liquid formation at those conditions. All intercoolers were to use cooling water as the cooling medium.

- The compressors were to be completely packaged by the vendor and includes motor, coupling, compressor, lube oil system, intercoolers, aftercooler and interstage piping.

- CO_2 would have been produced at three different pressure levels in Rectisol®: ~23 psia (LP3), ~40 psia (LP2), and ~60.7 psia (LP3). Each stream was to be supplied to each of the first 3 stages of compression

C1.5.2.4 Capture and Compression Phase 2 Application

- Black and Veatch provided inputs into the development of the Phase 2 application based upon the studies completed under task C1.5.2.1, C1.5.2.2, C1.5.2.3 and the resource loaded schedule prepared under task C1.6.

C1.5.3 Enhanced Oil Recovery /Geologic Sequestration / Injection

A MVA program would have been conducted at a site within Denbury's Soso Field. Soso Field is located in Jasper, Jones and Smith counties Mississippi, located on the northern rim of the Interior Mississippi Salt Dome Basin. Soso was discovered in 1945, has produced over 60 million barrels of oil, 169 billion cubic feet of natural gas and 87 million barrels of saltwater from 110 wells. The Rodessa – 11,180' and the Bailey – 11,701' reservoirs have produced approximately 30 million barrels of oil, or 50% of the oil in the field.

The Soso Field Unit consists of 6,460 acres and has active CO_2 EOR floods in the Rodessa (east side of the field) and the Bailey (west side of the field). The project area for the anthropogenic CO_2 injection and the focus of the MVA project was planned for the future Bailey flood on the east side of the field. The project area would have comprised 988 acres within the unit. When the Bailey flood is completely developed, Denbury anticipates that it will have 9 CO_2 Class II injection wells and 22 producing wells.

At Soso, the target Sligo (Bailey Sand) and Rodessa Formations comprise the approximately 1000’ thick Lower Glen Rose sub-group of the Trinity Group, within the Comanchean Series of the Lower Cretaceous. The Lower Glen Rose has been an exploration target in South Mississippi for almost 60 years, with the Sligo being productive in 50 fields and the Rodessa being productive in 78 fields. The Mooringsport Shale and the Ferry Lake Anhydrite are the overlying 450’ thick hydrocarbon seal.

Whole core analyses show the reservoir quality sands to have an average porosity of 16.8% - 17.4%, an original water saturation of 16.4% - 17.9% and an average permeability of 170.9 – 272.7 millidarcies. The productive limits of the Bailey – 11,701’ Sand are approximately 2648 acres of an unfaulted elongated anticline with gentle 1 degree flank dips. The net pay isopach map of the Bailey – 11,701’ A5 sand demonstrates the sand is well developed and fairly continuous over the entire area. The average oil sand thickness for the Bailey – 11,701’ sand is 33’ and for the Rodessa – 11,180’ sand is 32’. Original reservoir pressure for the Bailey was 5553 psi and for the Rodessa 5075 psi. Due to active CO_2 injection, current reservoir pressure in the Bailey is approximately 6200 psi and in the Rodessa is 5600 psi.

At the Soso Bailey reservoirs, approximately 21 million barrels of oil existed at discovery. By replacing this oil volume with CO_2 with a tertiary recover factor of 17%, 39 BCF or 2.3 million tons of CO_2 can be sequestered into the hydrocarbon pore space.

C1.5.4.1 Draft Risk Assessment and MVA Plan

The Bureau of Economic Geology Gulf Coast Carbon Center at University of Texas (BEG GCCC at UT) prepared a Worksheet for Field and MVA Selection based on a list of site-specific data needs proceeding from previous experience and available site-specific data. The Worksheet for Field and MVA Selection was used as the guiding factor to develop the goals of the MVA plan. The Worksheet and subsequent plan are found in Appendix 6.

The MVA project demonstrated identified risks are not occurring. The project will accomplish this by:

1) Demonstrating that the CO_2 is contained in the designated trap;

2) Demonstrating that well completions have integrity to retain CO_2 over geologic time;
3) Demonstrating that the seal has retained confining capacity after pressure depletion during production and will retain confining capacity after pressure increase during flood;
4) And, interpreting additional observations and activities above and beyond the normal commercial CO_2 EOR operations to access confinement of the CO_2 beyond the operational period.

Prior to injection, Denbury was to create a model of the reservoir using available data to simulate the interaction of injected CO_2 with reservoir fluids as part of its commercial operations. Denbury was to perform a comprehensive review of the model to determine the condition of all flooded wellbores. Once the flood was to begin, Denbury would have tracked CO_2 via well head pressure and routine bottom hole pressures; perform monthly measurement of produced fluids for volumetric balances; and monitor the flood via a collection of other geologic tools as part of the ongoing commercial operations.

The BEG worked with Denbury to develop a site specific MVA plan to augment commercial best practices so that monitoring systems are fit-for-purpose. Significant effort went into the evaluation of the value based on the cost versus benefit of each monitoring tool Had the project advanced to Phase II, the geologic assessment, modeling, and engineering design would have highlighted additional risks to be mitigated along with those risks to storage assurance identified during Phase I.

C1.5.4.2 Site-specific MVA options evaluations

A review team composed of UT BEG GCCC and 16 Denbury staff completed a formal review of the four proposed fields and selected a site within the Soso Field as the location for the MVA project as part of task C.1.5.3.

The proposed MVA program was to include two components: 1) commercial Best Practices for EOR that meet current regulatory requirements and 2) additional MVA activities required in the Cooperative Agreement with DOE and termed ‘research MVA”. The commercial MVA program would have been conducted as part of Denbury’s commercial best practices, in conformance with applicable regulations. Denbury was to document that commercial activities would have been conducted in a manner to lend credence to the MVA project. Applicable data was to be reported to the appropriate state oil and gas regulatory board. BEG was to work with Denbury to disclose to DOE the necessary data to demonstrate permanent sequestration. As part of Denbury’s commercial operations, prior to the flood. For purposes of this MVA study, “Best Practices” means typical oilfield drilling and completion practices in accordance with state regulatory requirements and industry accepted standards utilizing a well injection pattern for CO_2 EOR.

The research MVA program would be designed to provide additional information regarding the effectiveness of sequestration that the commercially Best Practices do not address. MVA options to be evaluated were broken down into three categories: Flood Conformance, Well Integrity and Above-Zone Monitoring. These items were planned to include feasibility tests and risk assessments in Phase 2A; well preparation and baseline testing in Phase 2B; and time lapse testing in 2C. The BEG also proposed predictive reservoir models, prepared in Petrel and GEM, of the CO_2 plume that is injected during the Denbury commercial EOR operations.

A report of the proposed MVA options was prepared and submitted by the BEG GCCC. For additional information, the report is included as Appendix 7 and identifies the field selected and the draft MVA program.

C1.5.4.3 Final MVA plan and detailed budget

The final MVA plan and detailed budget was prepared by BEG GCCC in consultation with Denbury and Sandia Laboratories. The plan included the schedule of activities and the MVA program budget. The budget is broken out by sub-phase, with $3,381,237 proposed for sub-phase 2A, $2,975,284 proposed for sub-phase 2B and $4,016,258 proposed for sub-phase 2C. The 5 year MVA portion of the project totals$10,372,779.

The MVA program includes 2 components: a commercial operations program and an added value research program. The commercial MVA program will be conducted as part of Denbury's commercial best practices, in conformance with applicable regulations. Currently, CO_2 from any source injected for CO_2 enhanced oil recovery (EOR) is regulated under UIC class II. The Mississippi Oil and Gas Board requires a number of monitoring, accounting, and reporting activities to bring a field under flood. Soso Field, located in Jasper, Jones and Smith counties in Mississippi has been under CO_2 flood for several years; containment of the structure is already demonstrated prior to beginning injection of anthropogenic CO_2. Denbury has developed, through a decade of experience with EOR in Mississippi, a number of commercial best practices that are used to control the subsurface movement of CO_2 and manage elevated pressure in order to optimize the performance of the flood and minimize cost and risks. The research program MVA was to be designed to augment the commercial operations monitoring program to the extent that the requirements of the DOE Cooperative Agreement associated with a successful down-select of the project for Phase 2 would be met.

The team of Denbury, BEG and Sandia was also proposed to conduct the MVA program. The schedule of MVA activities was to be coordinated to match the stages of development of the capture facility.

The lead tasks of sub-phase 2A, or the design phase, were to be integration of commercial site characterization data followed by predictive fluid flow and pressure modeling to improve assessment of the viability of CO_2 sequestration. Tests would have been initiated to determine sensitivity and feasibility of proposed soil gas, groundwater, and well-bore integrity methods. BEG had planned re-entry of two idle wells or new drills to a selected above-zone interval to determine the current pressure distribution during this phase.

Sub-phase 2B, or the construction phase, would have started with the preparation for injection of CO_2, as part of Denbury's commercial field development operations. Well workovers, which would have included selecting wells used as access points to monitor and collect baseline data on soil gas. The data that was to be collected from these wells would have been used in a predictive model for further risk analysis.

The demonstration phase, sub-phase 2C would have started with CO_2 injection. The commercial monitoring program would have monitored the CO_2 injected and recycled as well as the performance of the reservoir and wells in retaining CO_2. The research program would have collected time-lapse data and test alternative and possibly high-resolution techniques for demonstrating the CO_2 is sequestered in the injection zone and predicted flood area. It would have also confirmed pressure remained below safe operating conditions. At the end of this phase, BEG in consultation with Denbury, was to prepare a report evaluating results of the MVA program. Included in the report were to have been revised model runs showing model match as well as comparison between the commercial program to the research program demonstrating the effectiveness and permanence of CO_2 sequestration.

The Final MVA Plan and Budget was prepared and submitted by the BEG GCCC and is included as Appendix 8.

C1.6 Phase 2 Project Description and SOPO

The Mississippi CCS Project was to be a unique and highly advanced CO_2 capture and sequestration integrated project. It would have used technology advanced through DOE demonstration initiatives to produce SNG from a refinery waste product in a manner that supports both environmental progress and national energy security objectives. It would have been the first petcoke-to-SNG project in the U.S. The project was to be strategically located to benefit from nearby Gulf Coast petcoke sources and help offset declining natural gas production in the region. It would have been positioned to leverage existing natural gas pipeline infrastructure as well as existing CO2 pipeline infrastructures to supply CO_2 to existing EOR operations. The Mississippi CCS Project would have advanced MVA technology under unique geologic conditions while providing broadly applicable data and techniques that would have supported future CCS initiatives. The three major elements proposed in Phase 2 are: (1) CO2 capture (including purification and compression); (2) transportation and injection of carbon dioxide; and (3) comprehensive monitoring, verification and accounting ("MVA").

Phase 2 tasks were to include program and project management, detailed engineering, procurement, construction, and operation of the Rectisol® unit and CO2 compression equipment, the Mississippi Pipeline, and the MVA facilities.

C1.8 Phase 2 Project Costs, Funding and Budget

- The following chart demonstrates the proposed Phase 2 costs for the project:

Phase II	Total Cost	DOE Share		Leucadia Energy Project Share	
Rectisol	$307,931,177	60.00%	$184,758,706	40.00%	$123,172,471
Compression	$93,787,952	60.00%	$56,272,771	40.00%	$37,515,181
Pipeline	$207,297,290	60.00%	$124,378,374	40.00%	$82,918,916
MVA	$10,372,779	60.00%	$6,223,667	40.00%	$4,149,112
Program Managment	$4,656,390	60.00%	$2,793,834	40.00%	$1,862,556
EIS[1]	$300,000	60.00%	$180,000	40.00%	$120,000
Phase II Total	**$624,345,588**	**60.00%**	**$374,607,353**	**40.00%**	**$249,738,235**

C1.9 Phase 2 Renewal Application

- The Phase 2 Renewal Application was prepared and submitted on April 16, 2010.

List of Abbreviations and Acronyms

ARRA .... American Recovery and Reinvestment Act
BEG .... Bureau of Economic Geology
CCS .... Carbon Capture and Sequestration
CO_2 .... Carbon Dioxide
CO .... Carbon Monoxide
COP .... ConocoPhillips
COS .... Carbonyl Sulfide
DOE .... U.S. Department of Energy
EOR .... Enhanced Oil Recovery
GCCC .... Bureau of Economic Geology Gulf Coast Carbon Center
H_2 .... Hydrogen
H_2SO_4 .... Sulfuric Acid
H_2S .... Hydrogen Sulfide
MG .... Mississippi Gasification
MMSCFD .... Million Standard Cubic Feet Per Day
MP .... Medium-Pressure
MVA .... Monitoring, Verification and Accounting Plan
NETL .... National Energy Technology Laboratory
NO_x .... Nitrogen Oxide
P&A .... Plugged and Abandoned
PSIA .... Pounds Per Square Inch Absolute
PSIG .... Pounds Per Square Inch Gauge
SCFD .... Standard Cubic Feet Per Day
SO_2 .... Sulfur Dioxide
SO_3 .... Sulfur Trioxide
SNG .... Synthetic Natural Gas
SOPO .... Statement of Project Objectives
STPD .... Short Tons Per Day
WSA .... Wet Sulfuric Acid Unit

APPENDIX 1

Phase 1 SOPO Task 1.5.1.1
Rectisol and CO_2 Compression Optimization Study

APPENDIX 1.0 RECTISOL AND CO_2 COMPRESSION OPTIMIZATION STUDY

This appendix provides the results of a CO_2 compression optimization study carried out in order to determine the optimum Rectisol configuration for the Mississippi CCS Project. The details and results of the study are provided in the attached report conducted by Black & Veatch.

MISSISSIPPI CCS PROJECT

PETROLEUM COKE GASIFICATION TO SNG PROJECT

RECTISOL AND CO_2 COMPRESSION OPTIMIZATION STUDY

REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED
B	2/18/2010	Incorporated Leucadia comments	GPG	GPG	RAS
A	2/15/2010	Issued for Review	WLB/MJC/GPG	GPG	RAS

Table of Contents

Tables

Figures

1.0 Summary

At the request of Leucadia Energy, LLC, Black & Veatch performed an optimization study that evaluated potential Rectisol® configuration impacts on the overall cost and energy efficiency of the Mississippi Gasification (MG) SNG Plant. Three Rectisol configurations were evaluated, in which one, two, and three carbon dioxide (CO_2) streams were produced at varying pressures and purities. The one CO_2 stream case includes a large vacuum flash compressor, which is replaced by additional CO_2 flash equipment in the two and three CO_2 stream cases.

Based on the available information, Black & Veatch determined that the Rectisol configuration producing three CO_2 streams would have the lowest cost, highest CO_2 recovery, and lowest specific energy use. The results are summarized in Table 1-1.

Capital cost includes Rectisol, CO_2 compression, and the wet sulfuric acid unit (WSA), which is affected by the volumetric acid gas flow. The WSA nitrogen oxide (NO_x) and sulfur dioxide (SO_2) emissions are proportional to the volumetric acid gas flow; however, the cost impact of higher emissions was not included. The three CO_2 streams case also has the lowest acid gas flow.

The CO_2 purity for the three CO_2 streams case is well within Denbury's specifications for enhanced oil recovery. In the one CO_2 stream case, the CO_2 purity just met the hydrogen sulfide (H_2S) specification; the two CO_2 streams case did not meet the combined H_2S and carbonyl sulfide (COS) specification.

The CO_2 recovery and hydrogen (H_2) and carbon monoxide (CO) loss are essentially the same for the three and one CO_2 stream cases. CO_2 recovery is much closer for the three and one CO_2 stream cases than for the two CO_2 streams case.

The credit for CO_2 recovery dominates the economics such that the three CO_2 streams case is the most economical even though the two CO_2 streams case has slightly lower operating and capital costs.

Table 1-1
Optimization Study Results Summary

Parameter	Units	Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
CO_2 Pressure(s)	psia		29	17.4 48.6	23 40 60.7
CO_2 Purity	%v CO_2	97.0	99.2	98.0	99.1
CO_2 Purity	ppmv H_2S	20	20	7	1
CO_2 Purity	ppmv H_2S+COS	35	33	42	3
CO_2 Recovered (NOC)	stpd CO_2		11,358	10,817	11,397
CO_2 Recovered (NOC)	stpd total		11,396	10,910	11,442
Acid Gas to Wet Sulfuric Acid Unit (WSA)	MMscfd		23.2	31.9	21.9
Acid Gas to WSA	%v CO_2		52.8	67.8	52.7
CO_2 Lost in Acid Gas	%		5.6	10.0	5.3
H_2 and CO Loss to CO_2 and Acid Gas	MMscfd		1.7	3.7	1.8
Electricity Use	MW		1.3	-4.6	Base
Cooling Water Heat Rejection	MBtu/h		-29	-11	Base
Steam Use	MBtu/h		8.1	31.0	Base
Specific Energy Use	MBtu/ton recovered CO_2		0.925	0.977	0.895
Operating Cost at 90% Capacity Factor	$ millions/year		0.93	-0.73	Base
Product Credit at 90% Capacity Factor	$ millions/year		-2.27	-35.46	Base
Capital Cost	$ millions		0.4	-0.4	Base

NOC = Normal Operating Case of 6.6%w S in petroleum coke feed to gasification.

2.0 Background

2.1 Scope of Work and Deliverables

This report fulfills the objectives of Item C1.5.1.1 - Optimization Study of the Statement of Project Objectives (SOPO) in the Cooperative Agreement for the Mississippi CCS Project.

Engineer will perform an optimization study for the combined cost and energy consumption of Rectisol and CO_2 compression. A critical review of the integration between the MG SNG Project Rectisol unit and the CO_2 compression design will be performed to optimize the design between the two facilities. Design configurations will be evaluated regarding reducing CO_2 compression power. Capital and operating costs for several cases will be evaluated to determine the Rectisol design that optimizes the combined costs of Rectisol and CO_2 compression. Cooling and water requirements for the compressors will be integrated with the cooling and water requirements for the synthetic natural gas (SNG) plant.

The deliverable to the Client for this subtask is an engineering report that describes the results of the optimization study. The report will include (1) design recommendations for integration of compression equipment with Rectisol, (2) a discussion of the design elements that minimize the power requirements of the system, (3) a summary of capital and operating cost estimates of the cases evaluated, and (4) an overall design recommendation, including the expected capital and operating costs of the recommended design.

2.2 SNG Production and CCS Project Boundaries

Mississippi Gasification, LLC has been developing a petroleum coke (petcoke) gasification project at Moss Point, Mississippi for several years. The project will produce SNG, sulfuric acid, and argon. The project includes CO_2 capture and compression.

Leucadia Energy, LLC has entered into a Cooperative Agreement (Award No. DE-FE0002260), effective November 16, 2009, with the United States Department of Energy/NETL Pittsburgh Campus for the Mississippi CCS Project. The scope of this agreement is CO_2 capture and sequestration (CCS).

The interface between the SNG production facility and the CCS facility is the CO_2 transfer piping at the Rectisol unit battery limits.

2.3 CCS Project Inputs

Black & Veatch is relying upon data provided by others (including Rectisol data) for the SNG production facility. The work performed on the SNG production facility can be characterized as feasibility level and will be further refined as the project is developed. Lurgi provided Rectisol information for both SNG and H_2 production for the Lake Charles Cogeneration Project, which has been adjusted by Black & Veatch for the different syngas feed to Rectisol composition, flow rate, and pressure of the MG SNG Project.

3.0 Project Configuration

The Mississippi CCS Project will gasify approximately 6,257 short tons per day (stpd) of petcoke to produce 113 million standard cubic feet per day (scfd) of SNG. Byproducts will include sulfuric acid (H_2SO_4), CO_2, argon, and electricity. Sulfuric acid production will range from 625 to 1,428 stpd of 97.5%w sulfuric acid for petcoke sulfur contents of 3.5 to 8%w, dry basis. Normal sulfuric acid production will be 1,178 stpd for 6.6%w sulfur petcoke. CO_2 production will be approximately 11,400 stpd. Argon production will be approximately 373 stpd. The gross electricity production will range from 190 to 208 MW at design SNG production. This electricity will normally be produced from process generated steam in a steam turbine generator. The plant will typically consume approximately 220 MW, which includes 36 MW for CO_2 compression. The net electricity import to the plant will be 10 to 26 MW at design SNG production.

The plant configuration is shown on Figure 3-1 (included at the end of this section). Key aspects are highlighted in this section.

The plant will consist of three ConocoPhillips (COP) gasifiers and two trains of syngas processing, including sour shift conversion, Lurgi Rectisol selective acid gas removal, Haldor Topsoe methanation, and Haldor Topsoe wet sulfuric acid production. At design plant capacity, two COP gasifiers will operate at their design rate, which allows one gasifier to be on hot standby or shut down for maintenance. Gasifiers will be started up using natural gas to minimize SO_2 emissions.

About 75 percent of the raw syngas will flow through two shift conversion trains, where nearly all of the CO will be reacted with water vapor over a catalyst to produce H_2 and CO_2. The flow through shift conversion will be controlled to produce the following required methanol syngas feed stoichiometric ratio:

$$(H_2\text{-}CO_2) / (CO+CO_2) = 2.98$$

H_2S, COS, and CO_2 will be selectively removed from the sour syngas in the Rectisol unit using cold methanol as a physical solvent. The Rectisol unit will produce syngas containing less than 0.1 ppmv total sulfur compounds and 1.9 percent volume (%v) CO_2 for feed to methanation. The sweet syngas from the Rectisol unit will be compressed, combined with recycle syngas, and reacted over a catalyst to produce methanol.

The Rectisol unit will produce an acid gas stream that contains H_2S and COS for feed to the WSA process. The acid gas H_2S and COS concentrations will vary with their concentrations in the sour syngas to the Rectisol unit, which will vary with the petcoke sulfur concentration. The acid gas stream will be combusted to produce SO_2, which will be catalytically oxidized to sulfur trioxide (SO_3) and then reacted with condensing water to produce 97.5%w sulfuric acid.

The Rectisol unit will also produce CO_2 suitable for enhanced oil recovery. The CO_2 concentration will be higher than 98%v. The CO_2 pressure will depend on the Rectisol configuration and can vary from a single stream at 29 pounds per square inch absolute (psia) to multiple streams ranging from 17.4 to 60.4 psia. The CO_2 from the Rectisol unit will be compressed to 2,250 psia.

3.1 Rectisol Selective Acid Gas Removal Process Configurations

The following three Rectisol configurations were evaluated:

1. Single CO_2 stream at 29 psia, with a single reabsorber column with a vacuum flash compressor.
2. Two CO_2 streams at 17.4 and 48.6 psia, with a single reabsorber column without a vacuum flash compressor.
3. Three CO_2 streams at 23, 40, and 60.7 psia, with two reabsorber columns and a hot flash column without a vacuum flash compressor.

The single CO_2 stream Rectisol design has been the most common and typically most if not all of the CO_2 is vented. The two CO_2 stream Rectisol design reduces the total electricity use for Rectisol and compression of all of the CO_2 The three CO_2 stream Rectisol design futher reduces the total electricity use for Rectisol and compression of all of the CO_2 and increases CO_2 recovery and purity. Lurgi developed the three CO_2 stream Rectisol design for the Lake Charles Cogeneration Coke Gasification to SNG Project. The three CO_2 stream pressures were optimized to further minimize the total electricity use for Rectisol and CO_2 compression. Lurgi did not perform an economic assessment including capital cost. So prior to this study the relative overall economic performance of these three Rectisol configurations was unknown.

The Lurgi Rectisol flow diagram for the single CO_2 stream case is shown on Figure 3-2. The gas feed to the Rectisol unit will be chilled to 50° F and passed through an ammonia scrubber. The mixed syngas will then be contacted with CO_2 rich methanol in the prewash section at the bottom of the absorber to remove any remaining ammonia and hydrogen cyanide. After that, H_2S and COS will be removed in the H_2S absorption section of the absorber. CO_2 will then be removed in the CO_2 absorption section of the absorber. The temperature of the methanol to the absorber will be approximately -30° F. This temperature will increase with the heat of absorption, requiring additional methanol chilling at intermediate absorber locations.

CO_2 laden methanol from the absorber will be flashed in the medium-pressure (MP) flash column to remove dissolved hydrogen and CO. The flash gas will then be compressed and recycled back to the feed to the absorber.

The sulfur rich methanol will be flashed in the bottom of the MP stripper to remove dissolve hydrogen and CO. This flash gas will also be compressed and recycled back to the absorber.

The CO_2 rich methanol from the MP flash column will be subcooled in a chiller and then flashed in the reabsorber column(s). The sulfur rich methanol from the MP stripper will be flashed in the reabsorber(s) to remove CO_2. This flash gas will be washed with methanol from the CO_2 flash section at the top of the reabsorber(s) to reabsorb H_2S and COS. The methanol will be flashed to successively lower pressures. The methanol capacity to hold dissolved gas will decrease with decreasing pressure. As the pressure is reduced, the methanol temperature will be decreased by the refrigeration produced from desorption. In the single CO_2 stream case, the methanol will be flashed to a vacuum and the resulting flash gas will be compressed and added back to the higher pressure flash gas in the reabsorber. The two and three CO_2 stream cases do not have the flash gas compressor.

Ammonia and hydrogen cyanide laden methanol from the prewash section of the absorber will be fed to the top of the hot regenerator. Sulfur rich methanol from the reabsorber will be fed to a lower section of the hot regenerator. Methanol at the bottom of the hot regenerator will be indirectly heated to its boiling point by condensing 60 pounds per square inch gauge (psig) steam in reboilers. H_2S, COS, and CO_2 will then be released from the boiling methanol. Methanol removed from the bottom of the hot regenerator will be fully regenerated and returned to the absorber after cooling and chilling. The acid gas from the hot regenerator will be cooled to condense water vapor. The cooled acid gas will be fed to the WSA.

A methanol-water side stream from the hot regenerator will be fed to the methanol water column. Water at the bottom of the methanol water column will be indirectly heated to its boiling point by condensing 140 psig steam. Methanol has a lower vapor pressure than water and will be preferentially vaporized. The methanol vapor will be fed to the hot regenerator. An impure water stream will be taken from the bottom of the methanol water column, where it will be used for coke slurry makeup water. Methanol will also be purged as needed to control ammonia and hydrogen cyanide buildup. The methanol purge stream will be used as fuel in the WSA furnaces.

3.2 CO_2 Compression

The Rectisol CO_2 streams will be compressed to 2,250 psia and cooled to 90° F. At these conditions, CO_2 is a supercritical fluid. The compressed CO_2 will flow through a metering station and will be analyzed before custody transfer to the Denbury pipeline at a minimum pressure of 2,200 psig.

The optiminum number of CO_2 compressors is two each with a capacity of 50% of the total CO_2 flow. This matches the two 50% capacity gas processing trains which is an optimum combination of equipment size, process availability/operating flexibility, and cost. Each gas processing train will be shutdown once a year for preventative maintenance. One of the CO_2 compressors will also be shutdown at the same time for preventative maintenance.

There will be two 50 percent capacity CO_2 compressors. Two types of compressors are commercially available for this service: between bearings and integrally geared multistage centrifugal compressors. Dresser, Elliot, GE-Nuovo Pignone, and MHI offer between the bearings multistage centrifugal compressors, either on one shaft driven by a single motor or with separate motors for the low-pressure and high-pressure casings. These compressors have four stages with three stages of intercooling. MAN and Siemens offer integrally geared multistage centrifugal compressors with eight stages and six stages of intercooling. MAN integrally geared centrifugal compressors have been operating for 10 years in a similar CO_2 compression service at the Great Plains Synfuels Plant.

Black & Veatch recently obtained CO_2 compressor budget pricing and performance data from Dresser, GE-Nuovo Pignone, MAN, MHI, and Siemens for several projects. The polytropic stage efficiencies for the between the bearings compressors ranged from 84 to 64 percent. The polytropic stage efficiencies for the MAN compressors were all 85 percent, which makes it the most efficient machine. The more efficient MAN compressors were also the most economical. Polytropic stage efficiencies of 85 percent were used in this optimization study.

3.3 Optimization Study Results

The Rectisol data supplied by Lurgi for the Lake Charles coke gasification to SNG and H_2 projects were adjusted by Black & Veatch for the different raw syngas flow rate, pressure, and composition for the Mississippi coke gasification to SNG project. Lean methanol solvent rates were estimated by adjusting for CO_2 and H_2S rates and partial pressures in the feed gas to the Rectisol unit. Tower sizes were adjusted to maintain constant superficial gas velocities. Heat duties were adjusted for methanol circulation rates. Pump and compressor horsepower values were estimated for the adjusted liquid and gas rates. The stream rate and composition data and the adjusted equipment size data were used to estimate capital and operating costs.

The Rectisol feed gas study basis is presented in Table 3-1.

A detailed summary of the study process data is presented in Table 3-2. Utilities consumptions for the one and two CO_2 streams cases are listed as the difference from the three CO_2 streams base case.

Energy use is summarized in Table 3-3.

The three CO_2 streams case uses the least electricity and steam energy per ton of CO_2 recovered. The specific energy use of the one CO_2 stream and two CO_2 streams cases are 3.3 percent and 9.2 percent higher than the three CO_2 streams case, respectively.

Table 3-1
Rectisol Feed Gas

Syngas Feed Gas Flow Rate	lb-moles/hr	73,360
Syngas Feed Gas H_2+CO Flow Rate	lb-moles/hr	45,889
Operating Pressure	psia	647
CO_2 Concentration	%vol dry	32.55%
CO_2 Partial Pressure	psia	211
H_2S Concentration	%vol dry	1.36%
COS Concentration	%vol dry	0.03%

Table 3-2
Optimization Study Process Data

Parameter	Units	Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Treated Syngas from Rectisol Unit					
Treated Syngas Flow Rate	lb-moles/hr total		48,912	48,737	48,951
Treated Syngas Flow Rate	lb-moles/hr H_2+CO		45,701	45,483	45,693
CO_2 Concentration	%vol		1.94%	1.94%	1.94%
Operating Pressure	psia		617	617	617
CO_2 Absorbed	lb-moles/hr		22,849	22,852	22,848
Product CO_2 from Rectisol Unit					
CO_2 Pressure(s)	psia		29.0	17.4 48.6	23.0 40.0 60.7
CO_2 Purity	%v CO_2	97.0	99.2	98.0	99.1
CO_2 Purity	ppmv H_2S	20	20	7	1
CO_2 Purity	ppmv H_2S +COS	35	33	42	3
CO_2 Recovered (NOC)	stpd CO_2		11,358	10,817	11,397
CO_2 Recovered (NOC)	stpd total		11,396	10,910	11,442

Table 3-2 (Continued)
Optimization Study Process Data

Parameter	Units	Denbury CO_2 Spec	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Acid Gas from Rectisol Unit					
Acid Gas to WSA	MMscfd		23.2	31.9	21.9
Acid Gas to WSA	%v CO_2		52.8	67.8	52.7
CO_2 Lost in Acid Gas	%		5.5	10.9	5.3
Rectisol General					
Lean Methanol Rate	gpm at 60° F		6,928	7,863	5,600
H_2 & CO Loss to CO_2 & Acid Gas	MMscfd		1.7	3.7	1.8
NOC = Normal Operating Case of 6.6%w S in petcoke feed to gasification.					
Electricity Use					
Pumps	MW		0.1	-1.4	Base
Recycle Gas Comp	MW		0.0	0.0	Base
Flash Vacuum Comp	MW		5.4	0.0	Base
Refrigeration Comp	MW		-7.8	-6.8	Base
CO_2 Compression	MW		2.0	1.9	Base
Cooling Water	MW		-0.1	0.0	Base
Total	MW		1.3	-4.6	Base
Cooling Water Duty					
Rectisol Process	MBtu/h		1.0	18.3	Base
Rectisol Refrigeration	MBtu/h		-36.0	-29.9	Base
CO_2 Compression	MBtu/h		5.8	0.2	Base
Total	MBtu/h		-29.1	-11.4	Base
Steam Use					
140 psig	1,000 lb/h		2.9	10.9	Base
60 psig	1,000 lb/h		5.2	20.1	Base
Total	MBtu/h		8.1	31.0	Base

Table 3-3
Specific Energy Use

Parameter	Units	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams
Electricity and Steam	MBtu/h	438	441	425
CO_2 Recovered	stph CO_2	473	451	475
Specific Energy Use	MBtu/ton recovered CO_2	0.925	0.977	0.895

Capital and operating cost estimates are summarized in Table 3-4 as the differences between the one and two CO_2 streams cases and the three CO_2 streams base case. Capital cost includes Rectisol, CO_2 compression, and the WSA, which is affected by the volumetric acid gas flow. The two CO_2 streams case has the lowest Rectisol capital cost because it uses less equipment, which is why it has lower CO_2 recovery and higher CO and H_2 losses. Lower CO_2 recovery increases the CO_2 level in the acid gas to the WSA, which increases the WSA cost. The WSA NO_x and SO_2 emissions are proportional to the volumetric acid gas flow; however, the cost impact of higher emissions was not included. The three CO_2 streams case also has the lowest acid gas flow.

The three CO_2 streams case has the highest production credits. The two CO_2 streams case has the lowest capital and operating cost, but the capital and operating cost savings are overwhelmed by lower production credits. Overall, the economics for the three CO_2 streams case and the one CO_2 stream case are close, with the three CO_2 streams case being the most economical. The three CO_2 streams case will also be more reliable than the single CO_2 stream case, because it does not have the flash gas compressor.

Table 3-4
Differential Capital and Operating Cost Estimates

Parameter	Units	One CO_2 Stream	Two CO_2 Streams	Three CO_2 Streams	Unit Costs
Capital Costs					
Rectisol	$ millions	-7.1	-16.6	Base	
CO_2 Compression	$ millions	6.1	5.8	Base	
WSA	$ millions	1.4	10.4	Base	
Total	$ millions	0.4	-0.4	Base	
Operating Costs at 90% Capacity Factor					
Electricity	$ millions/yr	0.69	-2.43	Base	$0.067/kWh
140 psig Steam	$ millions/yr	0.26	1.00	Base	$10.00/1,000 lb
60 psig Steam	$ millions/yr	0.20	0.79	Base	$4.50/1,000 lb
Cooling Water	$ millions/yr	-0.23	-0.09	Base	$1/MBtu
Makeup Methanol	$ millions/yr	0.00	0.01	Base	$1/gallon
Total	$ millions/yr	0.93	-0.73	Base	
Production Credits at 90% Capacity Factor					
SNG Production	$ millions/yr	0.04	-1.14	Base	$7.50/MBtu
CO_2 Production	$ millions/yr	-2.32	-34.32	Base	$7.5/ton
Total	$ millions/yr	-2.27	-35.46	Base	

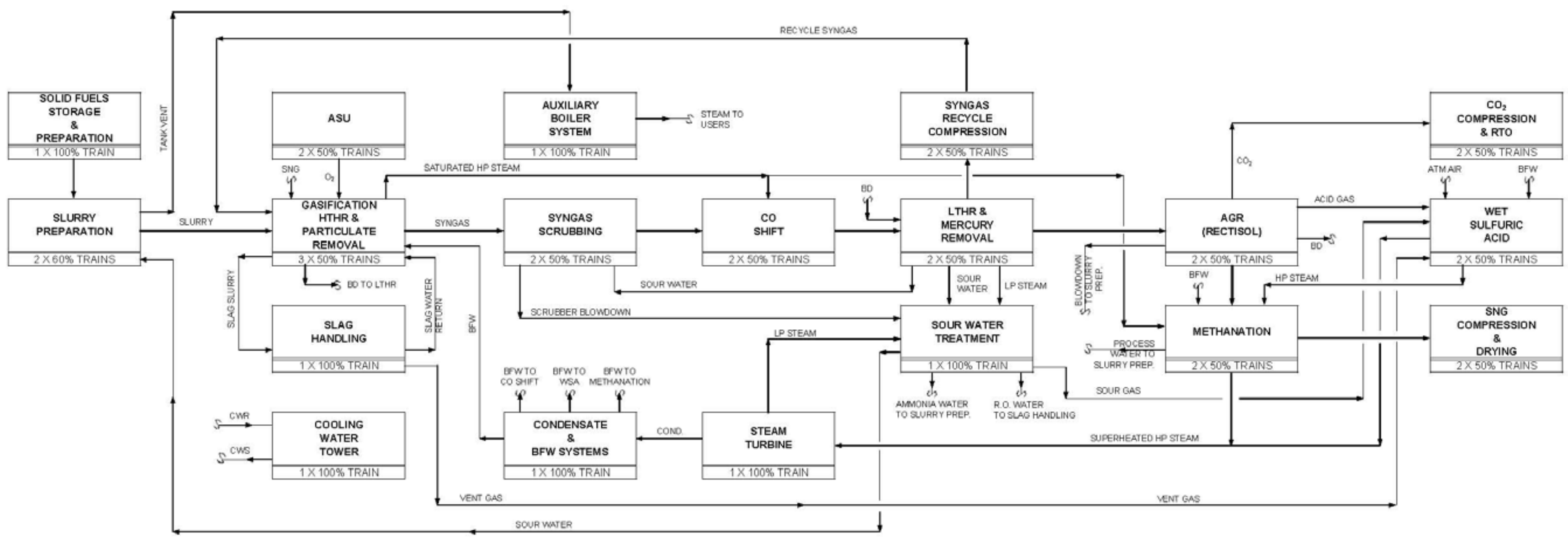


Figure 3-1
Block Flow Diagram

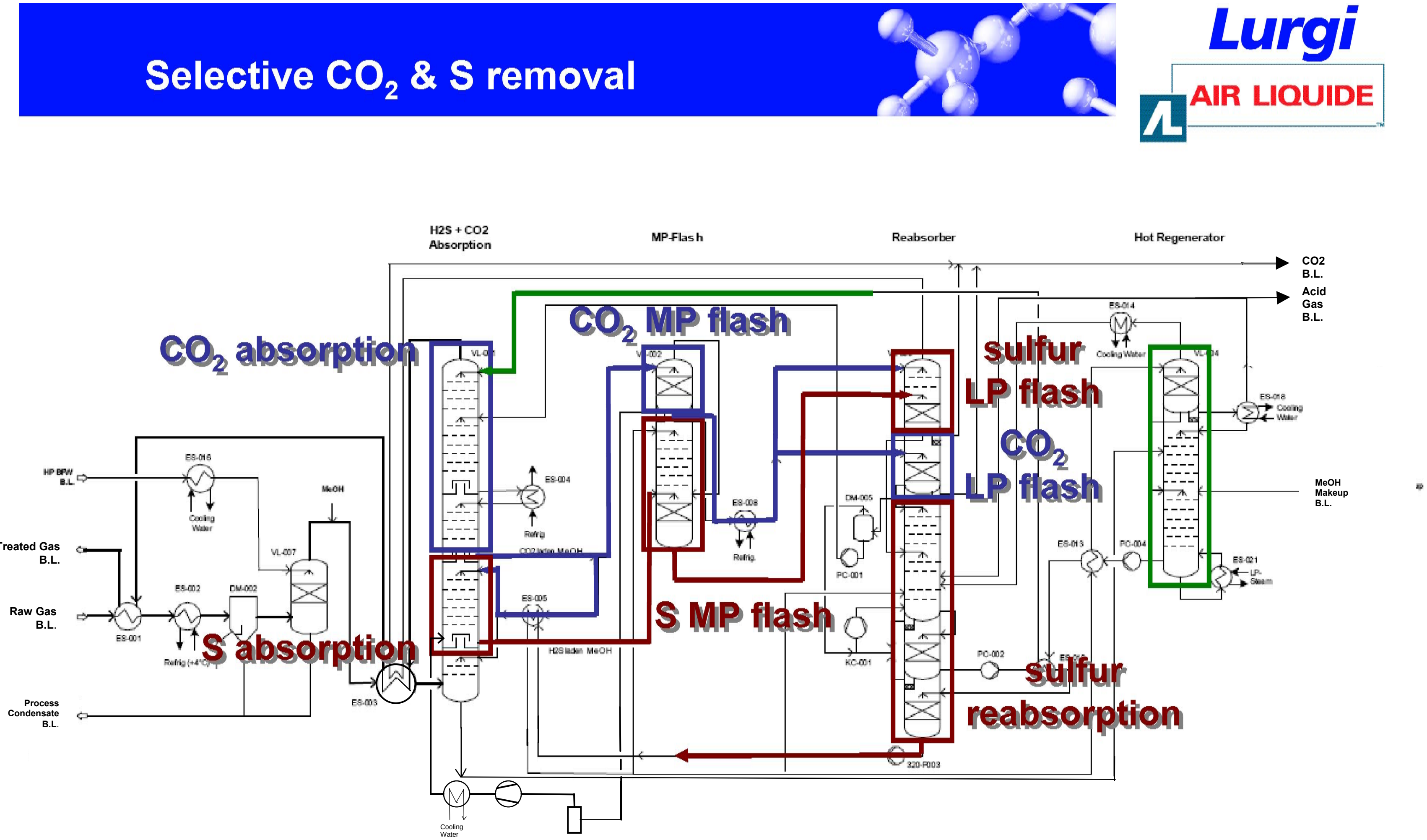


Figure 3-2
Selective CO_2 and Sulfur Removal

4.0 Conclusions

The three CO_2 streams case is optimum because it has the highest incremental revenue minus capital and operating costs, highest CO_2 recovery, and lowest specific energy use per ton of CO_2 recovered. The three CO_2 streams case should be used for inquiring the CO_2 compressors.

APPENDIX 2

Phase 1 SOPO Task 1.5.2.1
CO_2 Capture and Compression Equipment
Preliminary Engineering

APPENDIX 2.0 CO_2 CAPTURE AND COMPRESSION EQUIPMENT PRELIMINARY ENGINEERING

This appendix provides a preliminary plant arrangement, system definition, and material balances for the Mississippi CCS Project's CO_2 capture and compression systems.

2.1 General Project Background

The Mississippi CCS Project will gasify approximately 7,015 short tons per day (stpd) of petcoke to produce approximately 129 million standard cubic feet per day (MMSCFD) of SNG. Byproducts will include sulfuric acid (H_2SO_4), CO_2, argon, and electricity.

The plant will consist of three ConocoPhillips (COP) gasifiers and two trains of syngas processing, including sour shift conversion, Lurgi Rectisol® selective acid gas removal, Haldor Topsoe methanation, and Haldor Topsoe wet sulfuric acid (WSA) production. At design plant capacity, two COP gasifiers will operate at their design rate, which allows one gasifier to be on hot standby or shut down for maintenance.

The Rectisol unit will produce approximately 211 MMSCFD of CO_2 suitable for enhanced oil recovery. The CO_2 concentration will be about 99 percent by volume. The Rectisol unit will produce CO_2 at three different pressures that will subsequently be forwarded to the CO_2 compression system. A general block flow diagram of the gasification, CO_2 capture, and CO_2 compression system is shown on Figure 2-1.

2.2 Plant Arrangement

A conceptual layout of the CO_2 capture and compression equipment is shown on Figure 2-2 and drawing 162651-0010-G1000C.

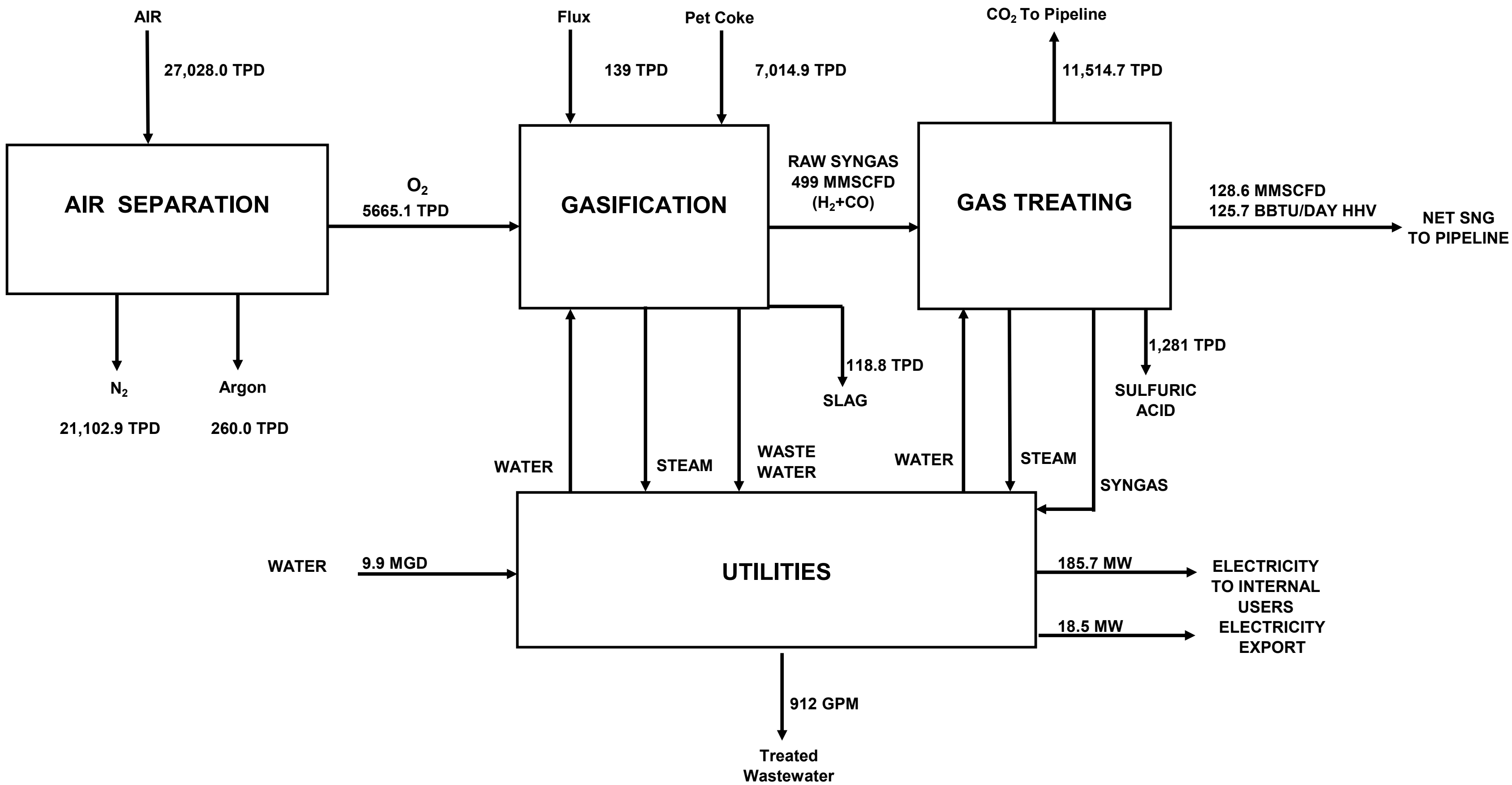


Figure 2-1. Gasification and CO_2 Capture and Compression Block Flow Diagram

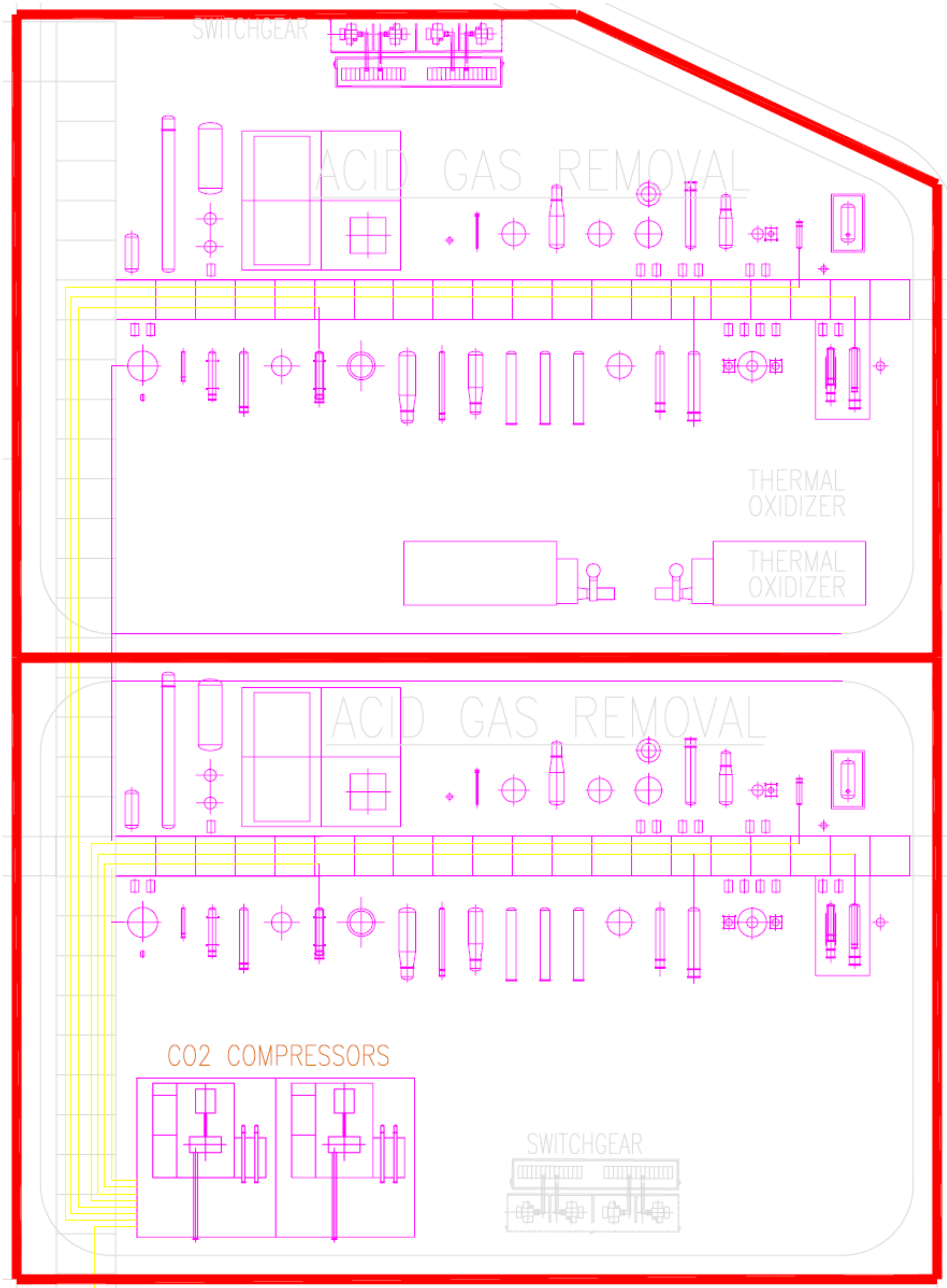
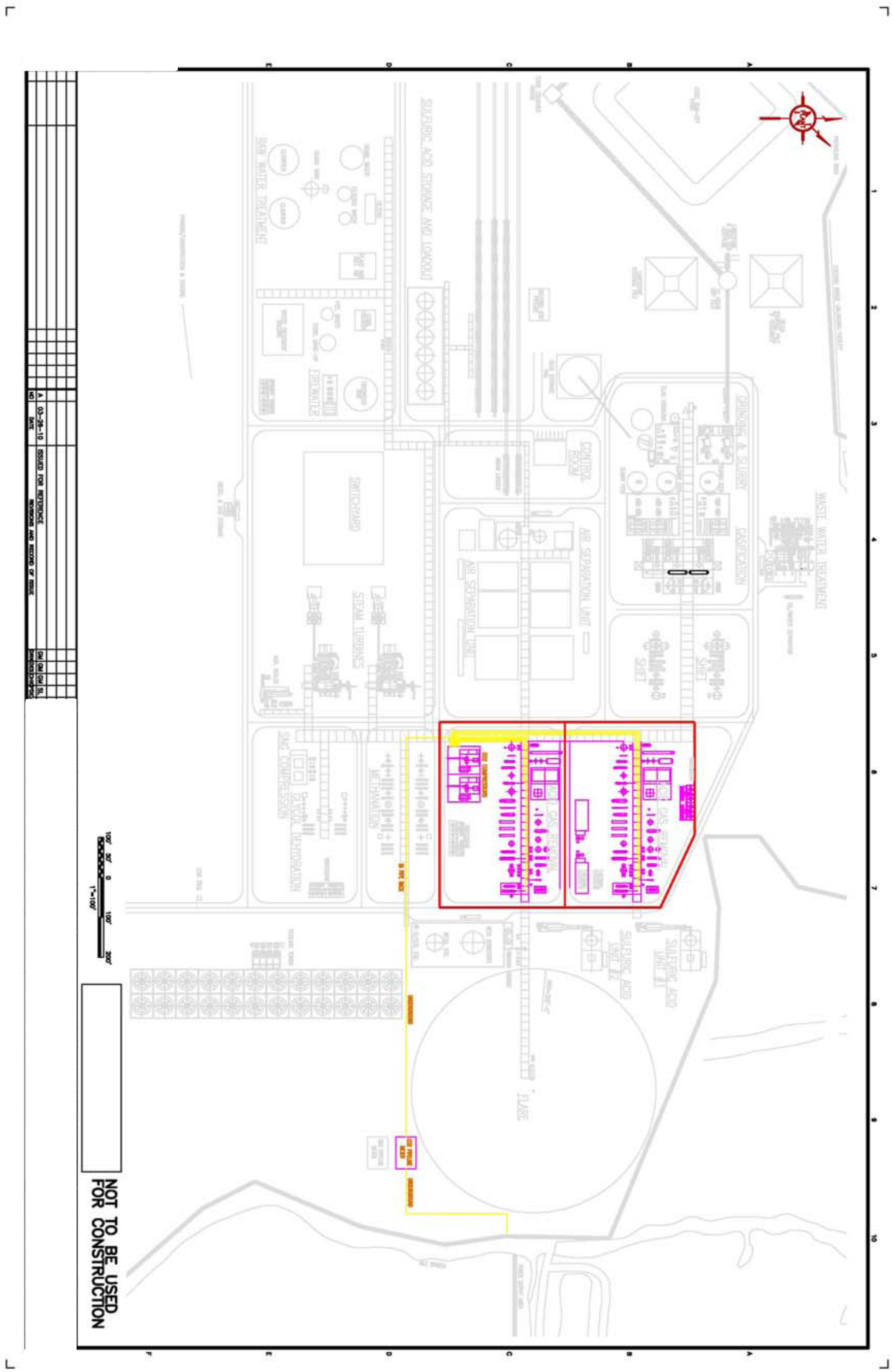


Figure 2-2. CO_2 Capture and Compression Equipment Layout
(Refer to drawing 162651-0010-G1000C for scale)


NOT TO BE USED FOR CONSTRUCTION
SULFURIC ACID STORAGE AND LOADING
RAW WATER TREATMENT
SWITCHYARD
STEAM TURBINES
AIR SEPARATION UNIT
CONTROL ROOM
GRINDING & SLURRY
GASIFICATION
WASTE WATER TREATMENT
SHIFT
SNG COMPRESSION
METHANATION
FLARE
ISSUED FOR REFERENCE

General CO_2 Capture System Definition

Process flow diagrams for single Rectisol train are shown on drawings 042153-0601-P1001 though 042152-0601-P1007. The gas feed to the Rectisol unit will be chilled to 50° F and passed through an ammonia scrubber. The mixed syngas will then be contacted with CO_2 rich methanol in the prewash section at the bottom of the absorber to remove any remaining ammonia and hydrogen cyanide. After that, H_2S and COS will be removed in the H_2S absorption section of the absorber. CO_2 will then be removed in the CO_2 absorption section of the absorber. The temperature of the methanol to the absorber will be approximately -42° F. This temperature will increase with the heat of absorption, requiring additional methanol chilling at intermediate absorber locations.

CO_2 laden methanol from the absorber will be flashed in the medium-pressure (MP) flash column to remove dissolved hydrogen and CO. The flash gas will then be compressed and recycled back to the feed to the absorber.

The sulfur rich methanol will be flashed in the bottom of the MP stripper to remove dissolve hydrogen and CO. This flash gas will also be compressed and recycled back to the absorber.

The CO_2 rich methanol from the MP flash column will be subcooled in a chiller and then flashed in the reabsorber column(s). The sulfur rich methanol from the MP stripper will be flashed in the reabsorber(s) to remove CO_2. This flash gas will be washed with methanol from the CO_2 flash section at the top of the reabsorber(s) to reabsorb H_2S and COS. The methanol will be flashed to successively lower pressures. The methanol capacity to hold dissolved gas will decrease with decreasing pressure. As the pressure is reduced, the methanol temperature will be decreased by the refrigeration produced from desorption.

Ammonia and hydrogen cyanide laden methanol from the prewash section of the absorber will be fed to the top of the hot regenerator. Sulfur rich methanol from the reabsorber will be fed to a lower section of the hot regenerator. Methanol at the bottom of the hot regenerator will be indirectly heated to its boiling point by condensing 70 pounds per square inch gauge (psig) steam in reboilers. H_2S, COS, and CO_2 will then be released from the boiling methanol. Methanol removed from the bottom of the hot regenerator will be fully regenerated and returned to the absorber after cooling and chilling. The acid gas from the hot regenerator will be cooled to condense water vapor. The cooled acid gas will be fed to the WSA.

A methanol-water side stream from the hot regenerator will be fed to the methanol water column. Water at the bottom of the methanol water column will be indirectly heated to its boiling point by condensing 200 psig steam. Methanol has a lower vapor pressure than water and will be preferentially vaporized. The methanol vapor will be fed to the hot regenerator. An impure water stream will be taken from the bottom of the methanol water column, where it will be used for coke slurry makeup water. Methanol will also be purged as needed to control ammonia and hydrogen cyanide buildup. The methanol purge stream will be used as fuel in the WSA furnaces.

The Rectisol unit will require approximately 34.6 MW during normal operation.

2.3 General CO_2 Compression System Definition

The CO_2 Compression System compresses all of the flashed CO_2 from Rectisol unit into a sendout CO_2 pipeline for enhanced oil recovery use. A process flow diagram of a single compressor is shown on drawing 042153-1801-P1001. CO_2 will be produced from two trains of Rectisol and supplied to 2 x 50 percent electric motor driven integrally geared compressors CO_2 compressors at a total rate of approximately 211 MMSCFD.

The compressor units are comprised of a low speed gear and multiple high speed pinions which are contained within the compressor body. The impellers are mounted on the high speed pinions which allow selection of impellers operating at different speeds and diameters which allow for a more optimum aerodynamic selection. Eight impellers (stages) are required for the stated pressure ratio with intercooling as required. The compressor package will also consist of all requisite intercoolers and suction scrubbers. There will be suction scrubbers after the 5th and 6th stages of compression to protect against liquid formation at those conditions. All intercoolers use cooling water as the cooling medium.

The compressors are completely packaged by the vendor and includes motor, coupling, compressor, lube oil system, intercoolers, aftercooler and interstage piping.

CO_2 is produced at three different pressure levels in Rectisol®: ~23 psia (LP3), ~40 psia (LP2), and ~60.7 psia (LP3). Each stream is supplied to each of the first 3 stages of compression as shown on drawing 042153-1801-P1001.

The CO_2 compression will require roughly 34.2 MW of power to deliver the 211 MMSCFD of CO_2 to custody transfer metering at a pressure of 2,265 psia. The compressed CO_2 gas is cooled to 100º F in the HP CO_2 Aftercooler (18-E-0107) using cooling water prior to leaving the compressor package battery limits. The combined CO_2 stream purity will be greater than 99 percent by volume.

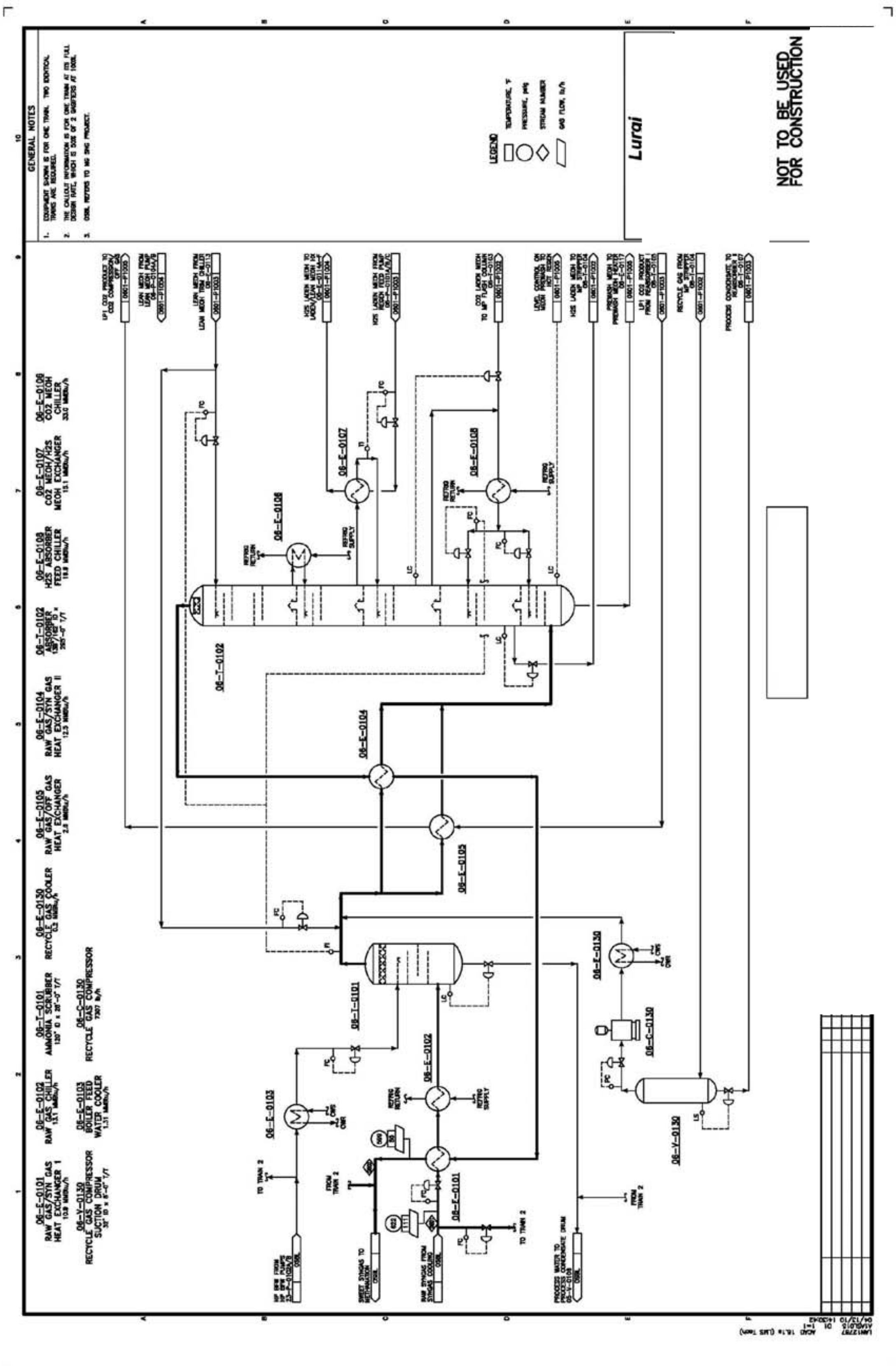
The high pressure CO_2 enters a custody transfer metering station (described below) before leaving the plant battery limit and going into the CO_2 pipeline.

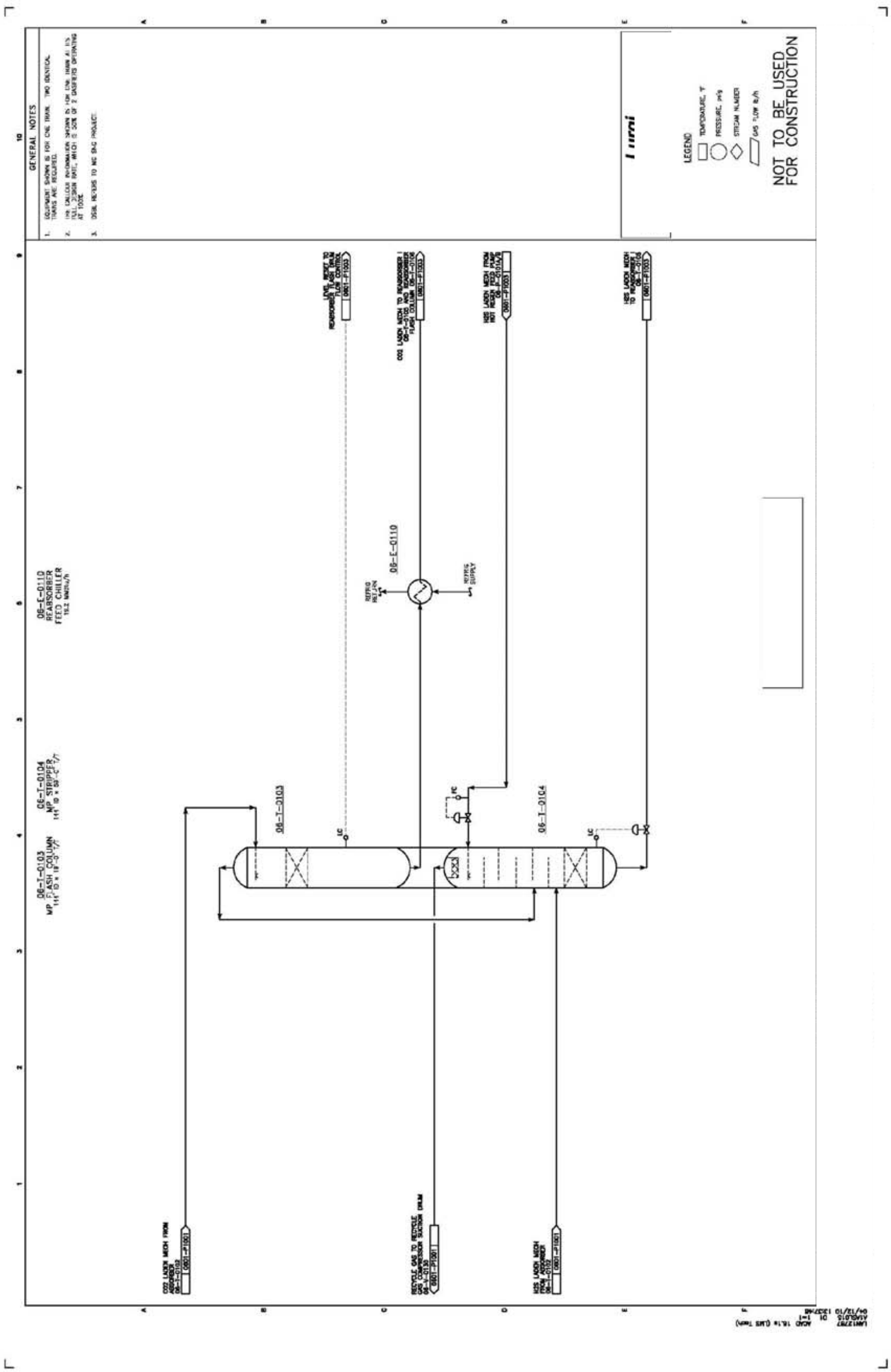
2.3.1 CO_2 Custody Metering

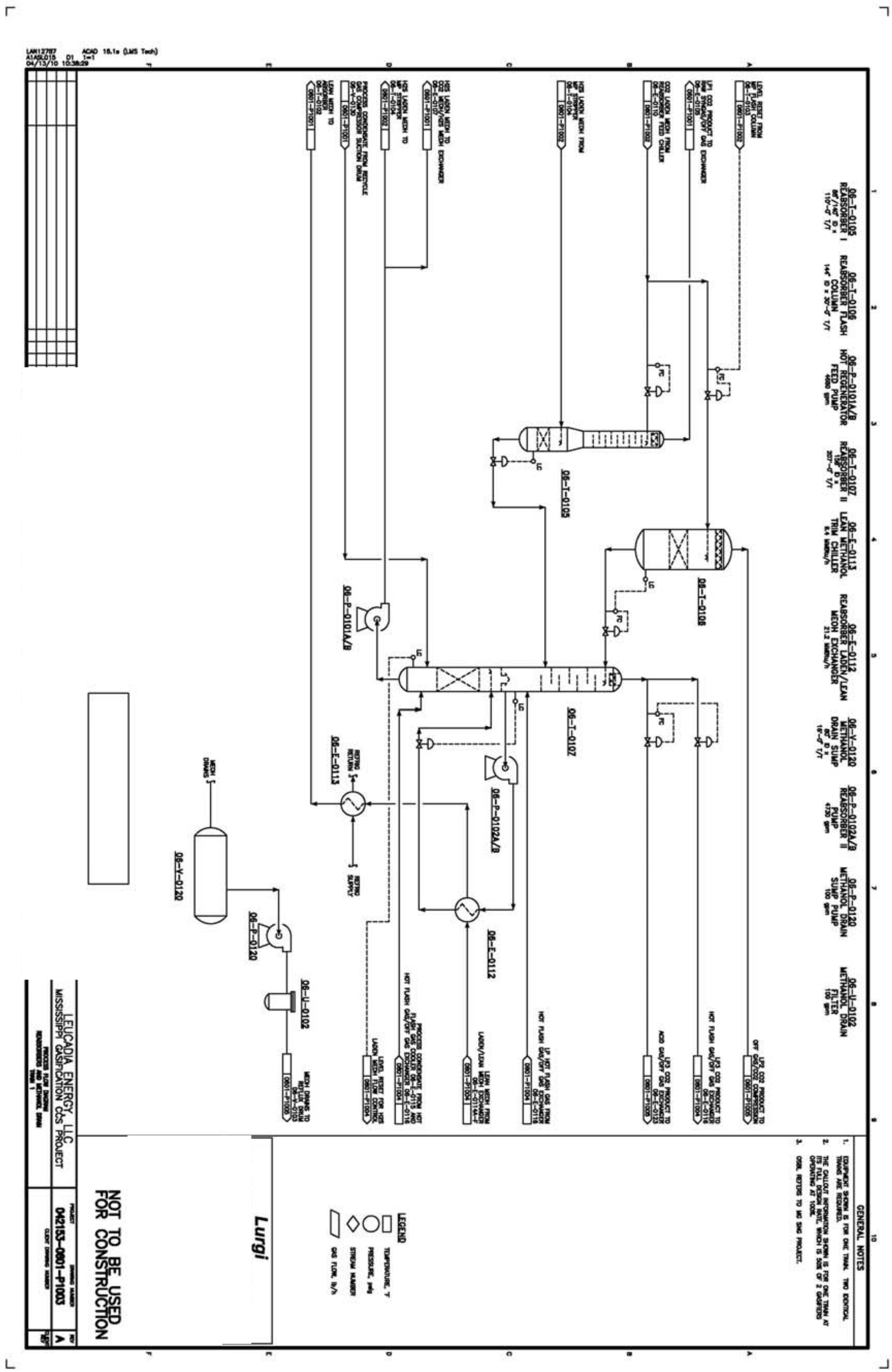
The CO_2 will flow through a two-tube custody meter system as it leaves the plant site. This system shall qualify for custody transfer (volume flow rate accuracy not exceeding +/- 1.0%), consisting of the following components:

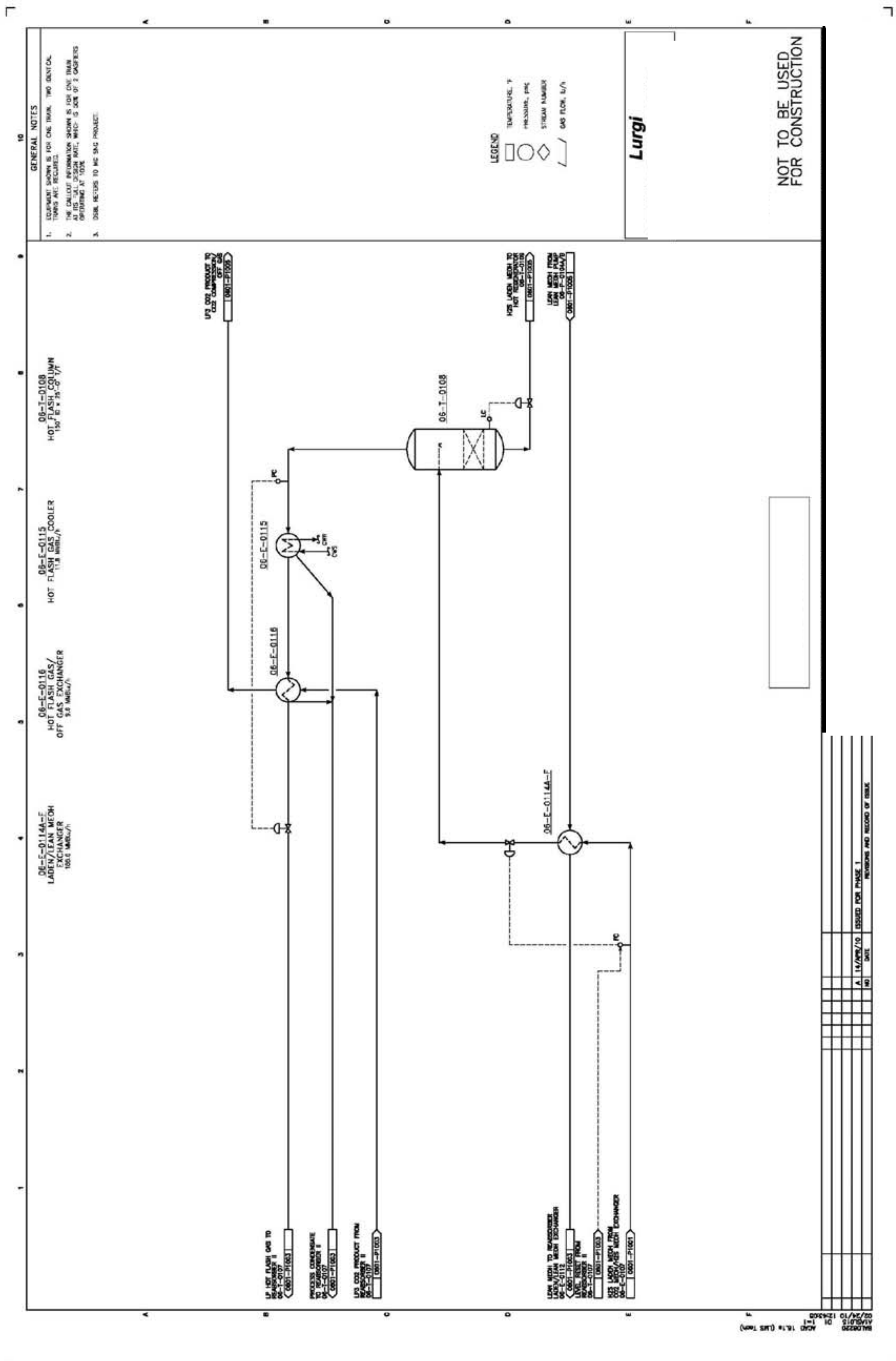
- 2 ea. 12" 2500# meter runs each with switching valves; flow, pressure, and temperature transmitters, and analyzer probes. The 2 meter runs shall be configured in a 1 + 1 configuration, with the second stream used as a spare meter stream.
- 2 ea Multi-path Ultrasonic flow meters, 1 in each run.
- 2 Flow computers (in the Meter house) with serial communication to the DCS. The flow computers correct the flow with pressure and temperature values, and using the gas composition from the chromatograph, calculate volume, mass, and energy flows.
- 2 metering panels (in the Meter house).
- Gas Chromatograph (in the Meter house) with sample probes for each meter run, and sample system and serial communication to the DCS.
- Meter house approved for the Electrical Hazardous Area Classification, including an HVAC and purge system with fresh air intake stack if required.

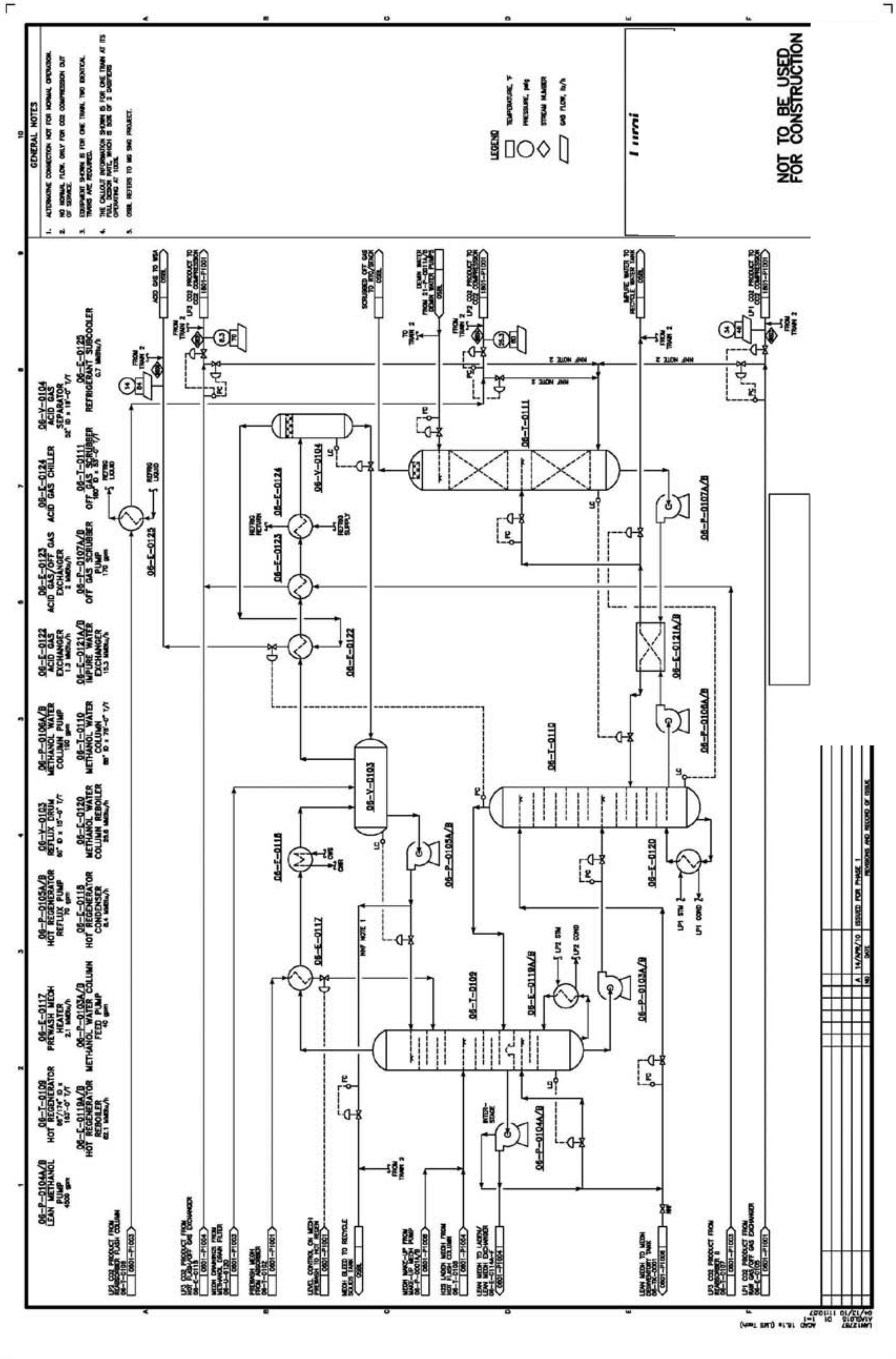
Periodically one of the ultrasonic flow meters will be sent for re-calibration and validation.

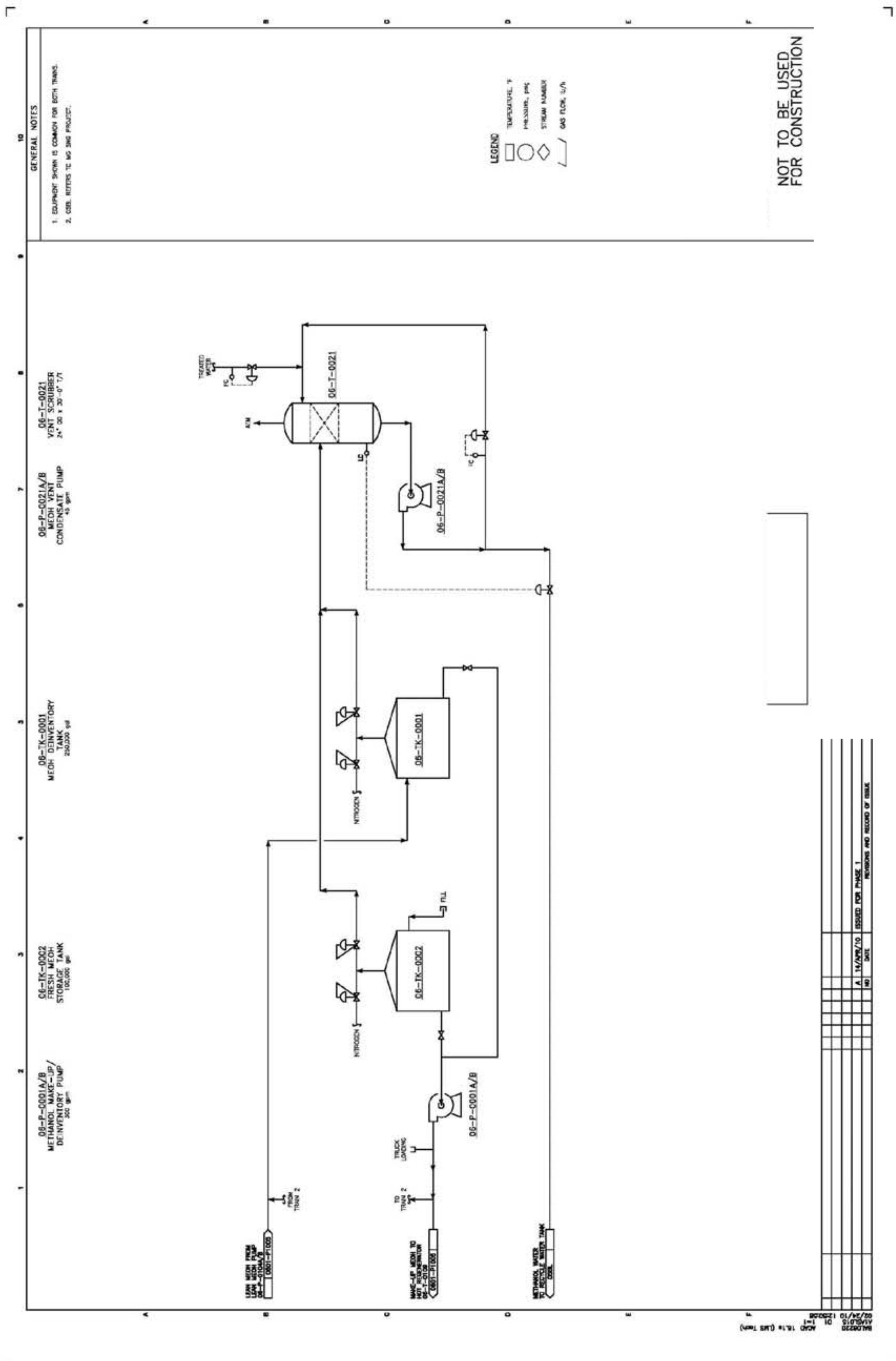

GENERAL NOTES
LEGEND
NOT TO BE USED FOR CONSTRUCTION

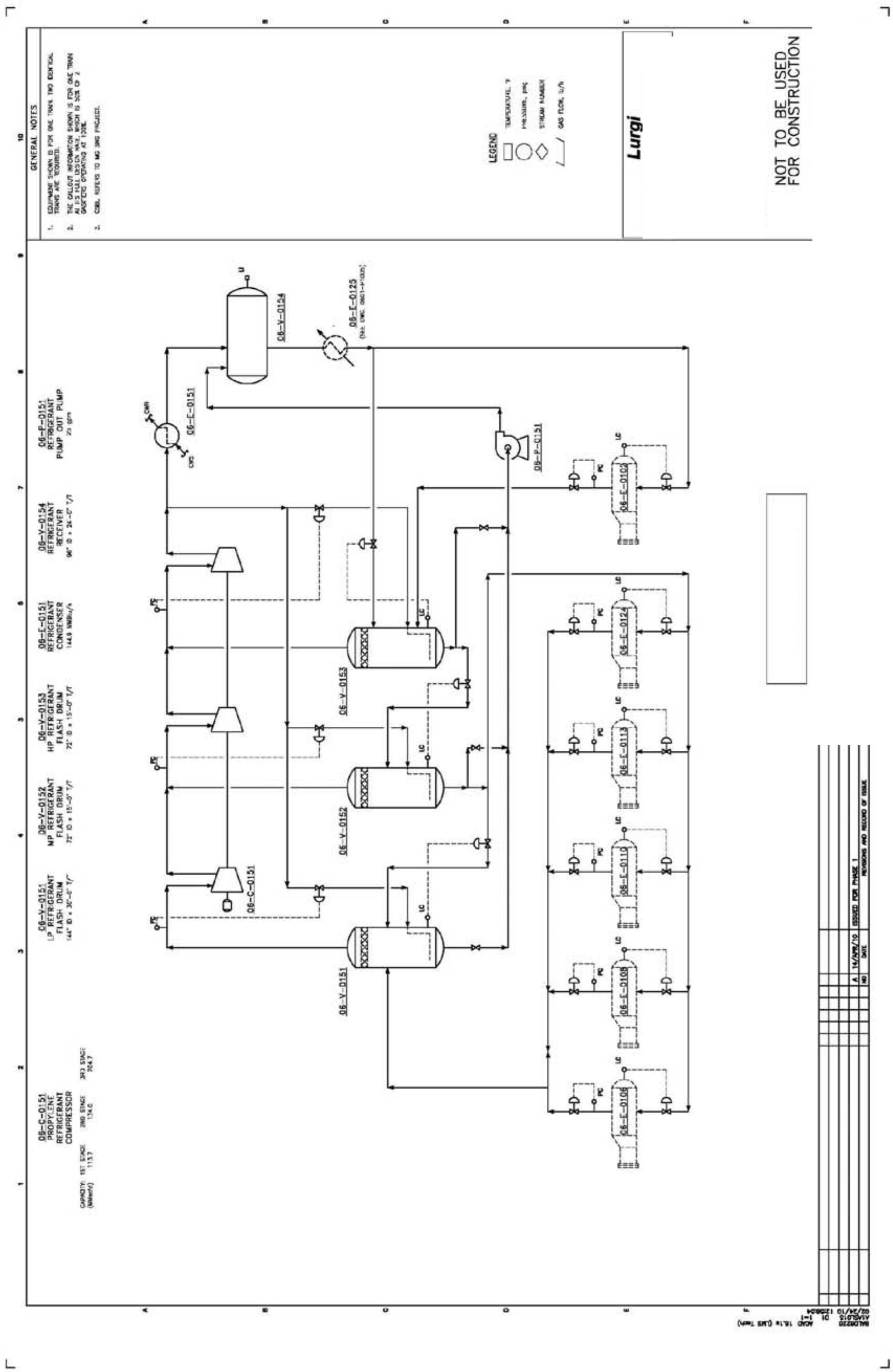

GENERAL NOTES
06-T-0103
MP FLASH COLUMN
06-T-0104
MP STRIPPER
06-E-0110
REABSORBER
FEED CHILLER
LEGEND
NOT TO BE USED
FOR CONSTRUCTION

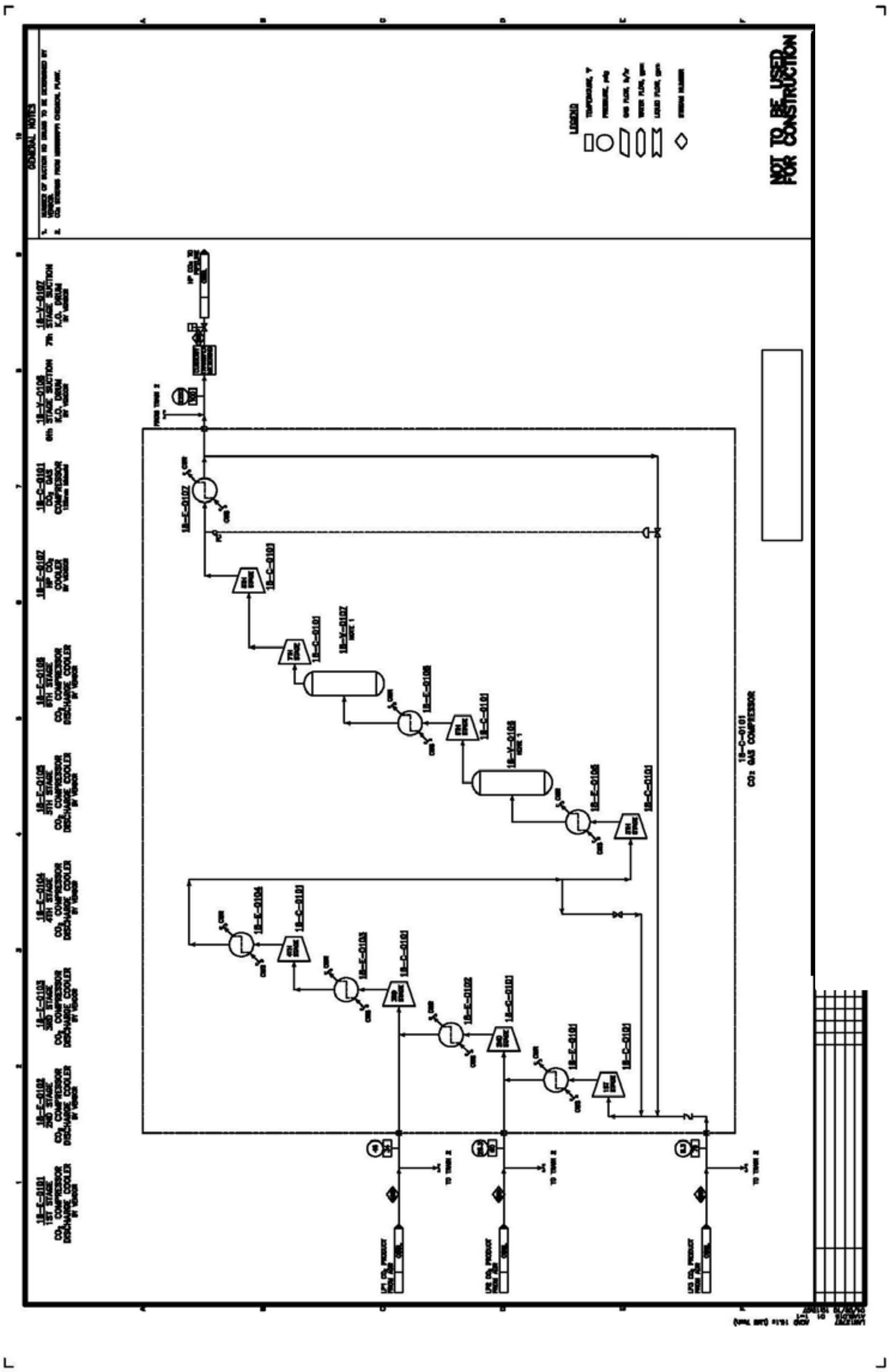

LEUCADIA ENERGY, LLC
MISSISSIPPI GASIFICATION CCS PROJECT
042153-0801-P1003
NOT TO BE USED FOR CONSTRUCTION
Lurgi
GENERAL NOTES
LEGEND


GENERAL NOTES
LEGEND
Lurgi
NOT TO BE USED FOR CONSTRUCTION
06-T-0108
HOT FLASH COLUMN
06-E-0115
HOT FLASH GAS COOLER
06-E-0116
HOT FLASH GAS/ OFF GAS EXCHANGER
06-E-0114A-F
LADEN/LEAN MEOH EXCHANGER


NOT TO BE USED FOR CONSTRUCTION


GENERAL NOTES
LEGEND
NOT TO BE USED
FOR CONSTRUCTION
06-P-0001A/B
METHANOL MAKE-UP/
DEINVENTORY PUMP
06-TK-0002
FRESH MEOH
STORAGE TANK
06-TK-0001
MEOH DEINVENTORY
TANK
06-P-0021A/B
MEOH VENT
CONDENSATE PUMP
06-T-0021
VENT SCRUBBER
NITROGEN
FILL
TRUCK
LOADING
TREATED
WATER
ATM
ISSUED FOR PHASE 1
REVISIONS AND RECORD OF ISSUE


GENERAL NOTES
LEGEND
Lurgi
NOT TO BE USED FOR CONSTRUCTION
06-C-0151 PROPYLENE REFRIGERANT COMPRESSOR
06-V-0151 LP REFRIGERANT FLASH DRUM
06-V-0152 MP REFRIGERANT FLASH DRUM
06-V-0153 HP REFRIGERANT FLASH DRUM
06-E-0151 REFRIGERANT CONDENSER
06-V-0154 REFRIGERANT RECEIVER
06-P-0151 REFRIGERANT PUMP OUT PUMP


NOT TO BE USED FOR CONSTRUCTION

2.4 CO_2 Capture Mass and Energy Balance

A mass and energy balance for the Mississippi CCS Project's CO_2 capture system is provided in Table 2-1 for reference steams shown on the process flow diagrams 042153-0601-P1001 through 042153-0601-P1007.

2.5 CO_2 Compression Mass and Energy Balance

A mass and energy balance for the Mississippi CCS Project's CO_2 compression system is provided in Table 2-2 for reference steams shown on the process flow diagram 042153-1801-P1001.

Table 2-1

CO_2 Capture Mass and Energy Balance

Plant:	Mississippi CCS Project	Material Balance		B&V Project:	042153
Location:	Moss Point, MS	Expected Figures		Date:	April 14, 2010
Case:	COP Gasification, Target Values				

Gas Streams

Stream:		0601	0602	0603	0604	0605	0606
Medium:		SOUR SYNGAS	SWEET SYNGAS	LP1CO2	LP2CO2	LP3CO2	ACID GAS
From:		SYNGAS COOLING	AGR	AGR	AGR	AGR	AGR
To:		AGR	METHANATION	CO2 COMPRESSION	CO2 COMPRESSION	CO2 COMPRESSION	WET SULFURIC ACID
Mole-flow	lbmol/hr	77,952	51,955	6,042	1,400	15,752	2,557
Mass-flow	Mlb/hr	1,612.09	493.01	263.02	59.69	693.10	98.92
Mass-flow	st/hr	806.05	246.51	131.51	29.84	346.55	49.46
Vol.-flow, gas	MMSCFD	709.97	473.19	55.03	12.75	143.46	23.28
Pressure	psia	647	614	60.7	40.0	23	28.7
Temperature	°F	111	86	34	60	70	84
LHV, gas	BTU/scf	212.80	303.86	6.16	16.75	0.23	290.37
LHV, gas	BTU/lb	3,904.90	12,151.75	53.68	149.04	2.01	2,847.74
HHV, gas	BTU/lb	4,405.92	13,737.76	56.86	157.91	2.17	3,096.05
LHV, stream	MMBTU/h	6,295.05	5,990.94	14.12	8.90	1.39	281.69
HHV, stream	MMBTU/h	7,102.75	6,772.86	14.95	9.43	1.51	306.26
Composition							
H2	%mole	47.0869	70.5075	0.6459	1.8866	0.0044	0.2726
CO	%mole	15.4662	22.9437	1.2718	3.4941	0.0279	0.2221
CO2	%mole	32.4398	1.8275	98.0367	94.5496	99.9506	52.6815
CH4	%mole	2.8694	4.0977	0.0095	0.0236	0.0006	4.1773
H2S	%mole	1.3599	0.0000	0.0001	0.0001	0.0001	41.4621
COS	%mole	0.0314	0.0000	0.0003	0.0001	0.0002	0.9551
NH3	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
HCN	%mole	0.0053	0.0010	0.0000	0.0000	0.0000	0.1404
HCL	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AR	%mole	0.0276	0.0412	0.0022	0.0079	0.0000	0.0000
O2	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
N2	%mole	0.3880	0.5813	0.0043	0.0160	0.0000	0.0001
H2O	%mole	0.3256	0.0000	0.0000	0.0000	0.0000	0.0000
SO2	%mole	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Methanol	%mole	0.0000	0.0000	0.0292	0.0220	0.0162	0.0889
Total	%mole	100.0000	100.0000	100.0000	100.0000	100.0000	100.0000
MW							
Molar Flow							
H2	lbmol/h	36,705.27	36,632.17	39.03	26.41	0.69	6.97
CO	lbmol/h	12,056.20	11,920.38	76.85	48.90	4.39	5.68
CO2	lbmol/h	25,287.51	949.50	5,923.86	1,323.33	15,743.98	1,346.84
CH4	lbmol/h	2,236.74	2,128.94	0.57	0.33	0.09	106.80
H2S	lbmol/h	1,060.04	0.01	0.01	0.00	0.02	1,060.01
COS	lbmol/h	24.48	0.01	0.02	0.00	0.03	24.42
NH3	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
HCN	lbmol/h	4.10	0.50	0.00	0.00	0.00	3.59
HCl	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
AR	lbmol/h	21.52	21.43	0.13	0.11	0.00	0.00
O2	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
N2	lbmol/h	302.47	302.02	0.26	0.22	0.00	0.00
H2O	lbmol/h	253.80	0.00	0.00	0.00	0.00	0.00
SO2	lbmol/h	0.00	0.00	0.00	0.00	0.00	0.00
Methanol	lbmol/h	0.00	0.00	1.76	0.31	2.55	2.27
Total	lbmol/h	77,952.13	51,954.97	6,042.49	1,399.61	15,751.77	2,556.58
Mass Flow							
H2	klb/hr	73.994	73.847	0.08	0.05	0.00	0.01
CO	klb/hr	337.69	333.89	2.15	1.37	0.12	0.16
CO2	klb/hr	1112.90	41.79	260.71	58.24	692.89	59.27
CH4	klb/hr	35.88	34.15	0.01	0.01	0.00	1.71
H2S	klb/hr	36.13	0.00	0.00	0.00	0.00	36.12
COS	klb/hr	1.47	0.00	0.00	0.00	0.00	1.47
NH3	klb/hr	0.00	0.00	0.00	0.00	0.00	0.00
HCN	klb/hr	0.11	0.01	0.00	0.00	0.00	0.10
HCl	klb/hr	0.00	0.00	0.00	0.00	0.00	0.00
AR	klb/hr	0.86	0.86	0.01	0.00	0.00	0.00
O2	klb/hr	0.00	0.00	0.00	0.00	0.00	0.00
N2	klb/hr	8.47	8.46	0.01	0.01	0.00	0.00
H2O	klb/hr	4.57	0.00	0.00	0.00	0.00	0.00
SO2	klb/hr	0.00	0.00	0.00	0.00	0.00	0.00
Methanol	klb/hr	0.00	0.00	0.06	0.01	0.08	0.07
Total	klb/hr	1612.09	493.01	263.02	59.69	693.10	98.92

Table 2-2

CO_2 Compression Mass and Energy Balance

Plant	Mississippi CCS Project	Material Balance	B&V Project: 042153
Location:	Moss Point, MS	Expected Figures	Date: April 13, 2010
Case:	COP Gasification, Target Values		

Gas Streams

Stream:		0603	0604	0605	1801
Medium:		LP1CO	LP2CO2	LP3CO2	HPCO2
From:		2 AGR	AG	AG	CO2 COMPRESSION
To:		CO2 COMPRESSION	CO2 COMPRESSION	CO2 COMPRESSION	CO2 PIPELINE
Mole-flow	lbmol/hr	6,042	1,40	15,75	23,194
Mass-flow	Mlb/hr	263.0	59.6	693.1	1,01
Mass-flow	st/hr	131.5	29.8	346.5	507.90
Vol.-flow, gas	MMSCFD	155.03	12.7	143.4	211.24
Pressure	psia	60.7	540.0	6 23	2265
Temperature	°F	34	60	70	100
LHV, gas	BTU/scf	6.16	16.7	0.23	2.77
LHV, gas	BTU/lb	53.68	149.04	2.01	24.0
HHV, gas	BTU/lb	56.86	157.91	2.17	25.4
LHV, stream	MMBTU/h	14.12	8.90	1.39	24.4
HHV, stream	MMBTU/h	14.95	9.43	1.51	25.8
					9
Composition					
H2	%mole	0.645	1.8866	0.004	0.2851
CO	%mole	1.271	3.4941	0.027	0.5611
CO2	%mole	98.0367	94.5496	99.950	99.1261
CH4	%mole	0.009	0.0236	60.000	0.0043
H2S	%mole	0.000	0.0001	0.000	0.0001
COS	%mole	0.000	0.0001	0.000	0.0002
NH3	%mole	0.000	0.0000	0.000	0.0000
HCN	%mole	0.000	0.0000	0.000	0.0000
HCL	%mole	0.000	0.0000	0.000	0.0000
AR	%mole	0.002	0.0079	0.000	0.0010
O2	%mole	0.000	0.0000	0.000	0.0000
N2	%mole	0.004	0.0160	0.000	0.0021
H2O	%mole	0.000	0.0000	0.000	0.0000
SO2	%mole	0.000	0.0000	0.000	0.0000
Methanol	%mole	0.029	0.0220	0.016	0.0199
Total	%mole	100.0000	100.0000	100.0000	100.0000
MW					
Molar Flow					
H2	lbmol/h	39.03	26.4	0.69	66.1
CO	lbmol/h	76.85	48.9	4.39	130.15
CO2	lbmol/h	5923.86	1323.33	15743.98	22991.17
CH4	lbmol/h	0.57	0.3	0.09	1.00
H2S	lbmol/h	0.01	0.0	0.02	0.02
COS	lbmol/h	0.02	0.0	0.03	0.05
NH3	lbmol/h	0.00	0.0	0.00	0.00
HCN	lbmol/h	0.00	0.0	0.00	0.00
HCl	lbmol/h	0.00	0.0	0.00	0.00
AR	lbmol/h	0.13	0.1	0.00	0.24
O2	lbmol/h	0.00	0.0	0.00	0.00
N2	lbmol/h	0.26	0.2	0.00	0.48
H2O	lbmol/h	0.00	0.0	0.00	0.00
SO2	lbmol/h	0.00	0.0	0.00	0.00
Methanol	lbmol/h	1.76	0.3	2.55	4.62
Total	lbmol/h	6042.49	1399.61	15751.77	23193.87
Mass Flow					
H2	klb/hr	0.08	0.05	0.00	0.13
CO	klb/hr	2.15	1.37	0.12	3.65
CO2	klb/hr	260.7	58.2	692.89	1011.84
CH4	klb/hr	1 0.01	40.01	0.00	0.02
H2S	klb/hr	0.00	0.00	0.00	0.00
COS	klb/hr	0.00	0.00	0.00	0.00
NH3	klb/hr	0.00	0.00	0.00	0.00
HCN	klb/hr	0.00	0.00	0.00	0.00
HCl	klb/hr	0.00	0.00	0.00	0.00
AR	klb/hr	0.01	0.00	0.00	0.01
O2	klb/hr	0.00	0.00	0.00	0.00
N2	klb/hr	0.01	0.01	0.01	0.01
H2O	klb/hr	0.00	0.00	0.00	0.00
SO2	klb/hr	0.00	0.00	0.00	0.00
Methanol	klb/hr	0.06	0.01	0.08	0.15
Total	klb/hr	263.0	59.6	693.11	1015.81
		2	9		

APPENDIX 3

Phase 1 SOPO Task 1.5.2.2

Preliminary Transmission Interconnection Assessment

APPENDIX 3.0 PRELIMINARY TRANSMISSION INTERCONNECTION ASSESSMENT

The integrated MG SNG and Mississippi CCS Projects will export an estimated 18.5 MW of electrical capacity. A summary breakdown of the electrical capacities for both projects is provided in Table 3-1 below.

Table 3-1
MG SNG and Mississippi CCS Electrical Load Summary

MG SNG Project	**Value**	
Power Generated by Steam Turbine, MW	204.2	[A]
Balance of Plant Auxiliary Load, MW	116.9	[B]
Mississippi CCS Project		
CO_2 Capture Load (Rectisol), MW	34.6	[C]
CO_2 Compression Load, MW	34.2	[D]
Load Summary		
Net Electrical Power Export to Grid with CO_2 Capture Only, MW	52.7	[A] - [B] - [C]
Net Electrical Power Export to Grid with CO_2 Capture + Compression, MW	18.5	[A] - [B] - [C] - [D]

Power will need to be exported though a grid interconnect.

Key parameters for a preliminary assessment of grid interconnect options include:

- Load flows from and into the grid.
- High voltage level for the interconnect.
- Distance between plant substation/switchyard and the interconnection point.
- Start-up transients for large motors.

The transmission lines in proximity to the sites were reviewed for their capacity and use status. Load flow information is not available in the public domain post 9-11 due to security reasons. A formal request for an interconnection study has to be made to the utility who will put the request in a queue per FERC regulation and who will perform load flow analyses. A short analysis of potential interconnects are as follows:

- Electrical interconnects could potentially be achieved by tapping into the following transmission lines:

- A 115 kV line with a rating of 107 MW is located on the project site. This line is however currently not in use.
- An east-west 230 kV line located to the south of the site (approximately 1 mile) has a rating of 573 MW.
- A north-south 230 kV double circuit line is located approximately 1.25 miles to the west of the site. Each circuit for this double circuit line is rated for 431 MW.

Based on this preliminary assessment, it is expected that the electrical grid within the surrounding vicinity of the site will support the 52.7 MW of electrical capacity generated by the integrated MG SNG and Mississippi CCS Projects. Since the cost of inter connection is substantial at any high voltage level, the CO_2 capture and compression facility would likely have a single high voltage connection through a switchyard/substation and multiple secondary unit substations that would feed loads at 13.8 kV, 4.16 kV and 480 V via transformers, switchgear and motor control centers.

The switchyard/substation will be a design consideration for the MG SNG Project.

A 13.8 kV auxiliary system has been assumed for the Mississippi CCS Project.

APPENDIX 4

Phase 1 SOPO Task 1.5.2.3
Optimization of the CO_2 Compression Equipment Selection

APPENDIX 4.0 OPTIMIZATION OF THE CO_2 COMPRESSION EQUIPMENT SELECTION

This appendix provides the background information to support the compressor configuration and technology selected for the Mississippi CCS Project.

4.1 Background

CO_2 streams captured from the Mississippi CCS Project's Rectisol units will require the CO_2 to be compressed to 2,265 psia and cooled to 100° F. Both reciprocating and centrifugal compressors are commercially available and capable providing the above-mentioned CO_2 stream requirements. The following provides general compressor configuration and technology comparisons that were used to determine the compressor configuration and technology used for the Mississippi CCS CO_2 compression system.

4.2 Compressor Configuration

To determine the optimum compressor configuration to be used for CO_2 compression, order of magnitude capital cost estimates for 2 x 50% (two 50% capacity trains), and 3 x 33% configurations were developed for centrifugal compressors. The order of magnitude installed costs, estimated in first quarter 2010 dollars, are provided below:

	Configuration	
	2 x 50% Trains	**3 x 33% Trains**
Total Installed Cost Estimate, 2010$ million	**84.5**	**107.0**

A 2 x 50% configuration was selected as the preferred arrangement for the Mississippi CCS Project compressors because of the expected capital cost savings compared to a 3 x 33% configuration. This configuration also corresponds to each compressor train compressing CO_2 from an associated Rectisol unit train; allowing one Rectisol unit train to be shut down for maintenance while another one remains in operation.

A 1 x 100% compressor train configuration was not considered since such a configuration would require CO_2 recirculation in the event of a Rectisol train shutdown (e.g. for maintenance); conceding to wasted compression energy and associated compression costs. In addition, CO_2 compression system availability for a 1 x 100%

compressor unit train configuration will be less than a 2 x 50% compressor unit train configuration.

4.3 Compressor Technology

Pressure requirements for screw compressors will be too demanding; as a result, screw compressors are not considered a viable option for the CO_2 compression system.

Because of capacity limitations, the use of reciprocating compressors would require multiple compressor units operating in parallel; hence, based on past experience, capital and operations and maintenance costs for reciprocating compressors are expected to be prohibitively expensive. For these reasons, reciprocating compressors were not considered a viable option for this project.

Centrifugal compressors are considered to be the most viable type of compressor for the CO_2 compression requirements for this project. Two types of centrifugal compressors are commercially available for this service; namely between bearings and integrally geared multistage centrifugal compressors. Dresser, Elliot, GE-Nuovo Pignone, MHI, and Siemens offer between the bearings multistage centrifugal compressors, either on one shaft driven by a single motor or with separate motors for the low-pressure and high-pressure casings. These compressors have four stages with three stages of intercooling. MAN offers integrally geared multistage centrifugal compressors with eight stages of compression and six stages of intercooling. MAN integrally geared centrifugal compressors have been operating for 10 years in a similar CO_2 compression service at the Great Plains Synfuels Plant.

Black & Veatch recently obtained CO_2 compressor budget pricing and performance data from Dresser, GE-Nuovo Pignone, MAN, MHI, and Siemens for several projects. The polytropic stage efficiencies for the Dresser, Elliot, GE-Nuovo Pignone, MHI, and Siemens compressors ranged from 84 to 64 percent. The polytropic stage efficiencies for the MAN compressors were all 85 percent, which makes it the most efficient machine.

To support a centrifugal compressor selection for the Mississippi CCS Project's CO_2 compression system, data sheets (attached to this appendix) were sent to MAN, Dresser-Rand and Elliot for budgetary pricing. The following table summarizes the pricing that was obtained.

Vendor	MANN-TURBO	DRESSER-RAND	ELLIOT
Price	$21,570,000	$30,000,000	$28,600,000

Based on expected efficiencies and costs presented above, MAN integrally geared multistage centrifugal compressors with eight stages of compression and six stages of intercooling were selected as a basis for the Mississippi CCS Project's CO_2 compression system.

BLACK & VEATCH	JOB NO. **166377** ITEM NO. **18-C-0101 / 0201**
	PURCHASE ORDER NO.
CENTRIFUGAL AND AXIAL COMPRESSOR	INQUIRY NO.
DATA SHEET (API 617-7TH Chapter 2)	REVISION NO. **A** DATE **19-Feb-10**
U.S. CUSTOMARY UNITS (1-1.6.5)	PAGE **1** OF **7** BY **CWG**

APPLICABLE TO: ● PROPOSAL ○ PURCHASE ○ AS BUILT ○ STUDY

FOR	**MISSISSIPPI GASIFICATION LLC**	UNIT	**SNG PLANT**
SITE	**MOSS POINT, MISSISSIPPI**	SERIAL NO.	
SERVICE	**CO_2 COMPRESSOR**	NO. REQUIRED	**TWO COMPRESSOR TRAINS**
MANUFACTURER		DRIVER TYPE (1-3.1.1)	**ELECTRIC MOTOR**
MODEL		DRIVER ITEM NO.	

INFORMATION TO BE COMPLETED: ○ BY PURCHASER ☐ BY MANUFACTURER △ MUTUAL AGREEMENT (PRIOR TO PURCHASE)

OPERATING CONDITIONS

(ALL DATA ON PER UNIT BASIS)						
	STREAM 1	**STREAM 2**	**STREAM 3**			
● GAS HANDLED (ALSO SEE PAGE 2)	**CO_2**	**CO_2**	**CO_2**			
△ GAS PROPERTIES (1-2.1.1.4)						
○ MMSCFD/~~SCFM~~ (14.7 PSIA & 60 °F DRY)						
● WEIGHT FLOW, LBM/MIN (WET)	**5,964**	**514**	**2,263**			
INLET CONDITIONS						
● PRESSURE (PSIA)	**22.5**	**39.5**	**60.2**			
● TEMPERATURE (°F)	**70**	**60**	**34**			
○ RELATIVE HUMIDITY %						
● MOLECULAR WEIGHT	**44.00**	**42.65**	**43.53**			
☐ Cp/Cv (K_{AVG})						
☐ COMPRESSIBILITY (Z_1)						
☐ INLET VOLUME, (CFM) (WET / DRY)						
DISCHARGE CONDITIONS						
● PRESSURE (PSIA)		**2265**				
☐ TEMPERATURE (°F)						
☐ Cp/Cv (K_{AVG}) (NOTE 1)						
☐ COMPRESSIBILITY (Z_2)						
☐ GHP REQUIRED						
☐ TRAIN BHP REQUIRED						
☐ BHP REQUIRED AT DRIVER INCL. EXT. LOSSES (GEAR, ETC.)						
☐ SPEED (RPM)						
☐ TURNDOWN (%)						
☐ POLYTROPHIC HEAD (FT-LB / LB)						
☐ POLYTROPHIC EFFICIENCY (%)						
○ CERTIFIED POINT						
○ EXPECTED OPERATION AT EACH CONDITION (%)						
☐ PERFORMANCE CURVE NUMBER						

PROCESS CONTROL (1-3.4.2.1)

METHOD ○ SUCTION THROTTLING FROM ____ PSIA TO ____ PSIA ○ VARIABLE INLET GUIDE VANES (2-2.4.1) ○ SPEED VARIATION FROM ____ % TO ____ % ○ DISCHARGE BLOWOFF TO ____ ○ COOLED BYPASS FROM ____ TO ____

SIGNAL ● SOURCE (1-3.4.2.1)

TYPE ● ELECTRONIC ○ PNEUMATIC ○ OTHER

RANGE ____ MA ____ PSIG

REMARKS:

(1) There are three separate inlet streams each containing dry CO2 gas.

(2) The discharge pressure given is for the total combined flow out of the compressor package.

(3) The number of compressor sections and casing nozzles shall be determined by Supplier based on compression process resulting in balance of lowest installed cost and most efficient compressor operation.

(4) The Supplier shall advise pressure and temperature between the sections. Process intercoolers and, if required, liquid knock-out drums, shall be provided by Purch.

(5) Pressure drop between sections shall be kept to minimum (2-3 psi between low pressure sections, not to exceed 15 psi between any section).

(6) Process gas between sections will be cooled to 100°F.

APPENDIX 5

Phase 1 SOPO Task 1.5.3
CO_2 Injection Site Confirmation

Report to Bureau of Economic Geology on EOR/Geologic Sequestration/Injection at Soso Field for FOA 15

Report Type:	Report and documentation of milestone completion
Report number :	C1.5.3
Report title:	Preliminary CO2 injection site confirmation
Completion Date:	February 26, 2010
Report Issue Date:	April 15, 2010
Submitting Organization:	Steve Upp & Jack Harper Denbury Resources Inc. Plano, Texas

Phase 1 Task C1.5.3

Preliminary CO_2 Injection Site Confirmation – Soso Field

Report by**:**

Denbury Resources

Prepared for:

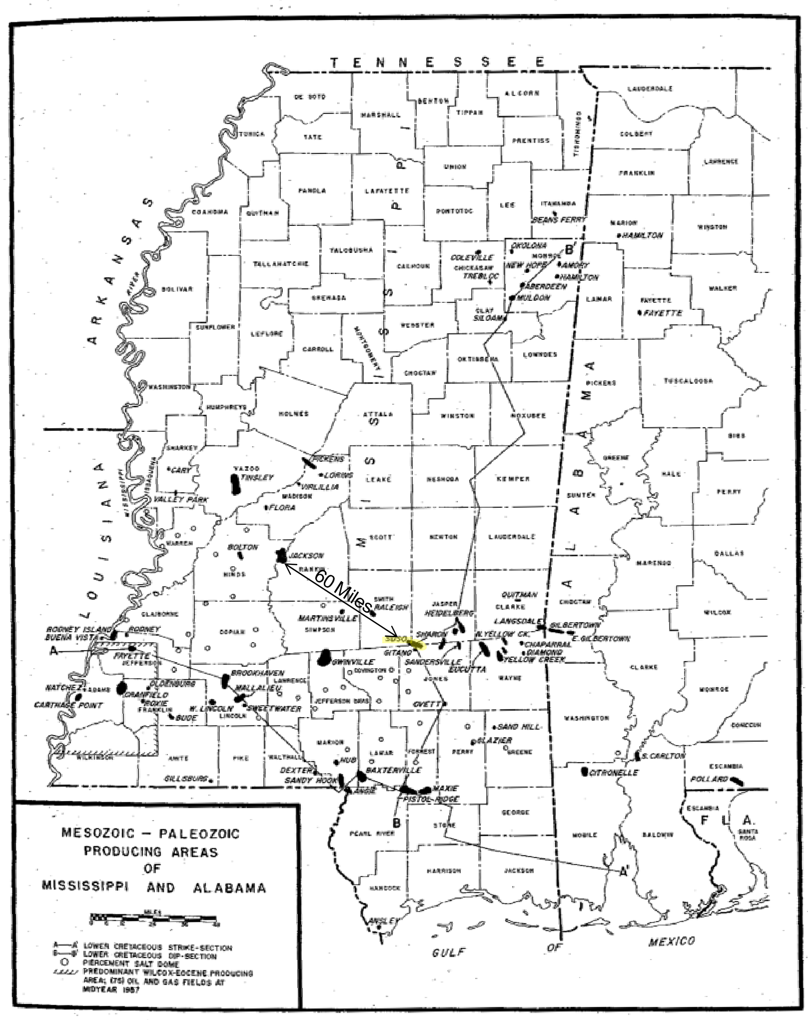
Susuan Hovorka of Gulf Coast Carbon Center

April 15, 2010

Characteristics of the West Soso Bailey injection reservoir

A site within Soso Field, in Jasper, Jones, and Smith counties, Mississippi, located on the northern rim of the Interior Mississippi Salt Dome Basin, is the location for the proposed research MVA program (**Figure1**). Sandstones, shale, and conglomerate comprise most of the Lower Cretaceous in the Interior Mississippi Salt Basin. The sediments were derived mainly from the southern Appalachian region, including the Central Mississippi Uplift. They were deposited in oxidizing coastal plain environments, in large delta systems, and in the shallow, near shore part of an epicontinental sea. The Lower Cretaceous section is approximately 6000' thick at Soso Field (8,450' – 14,450').

Figure 1. Location of Soso field in the Mississippi salt basin



At Soso, the target Sligo (Bailey Sand) and Rodessa Formations comprise the approximately 1000' thick Lower Glen Rose sub-group of the Trinity Group, within the Comanchean Series of the Lower Cretaceous, (**Figure 2**). The Lower Glen Rose has long been an exploration target in South Mississippi after almost 60 years of hydrocarbon production. The Sligo has produced from 50 Mississippi fields, and the Rodessa from 78 fields.

Figure 2. Stratigraphic section

SIGNIFICANT OIL AND GAS POOLS AND FORMATIONS OF MISSISSIPPI

MISSISSIPPI OFFICE OF GEOLOGY

1992

By Rick L. Ericksen and Sandra Douty

(Data current tq 01/01/92)

ERATHEM	SYSTEM	SERIES		GROUP		SIGNIFICANT PRODUCING AND NONPRODUCING FORMATIONS (Number of Fields)	PRODUCING ZONES OR POOLS	RESERVOIR LITHOLOGY	TYPE FIELD
CENOZOIC	QUATERNARY	Holocene					*nonproductive to date*		
		Pleistocene							
	TERTIARY	Pliocene							
		Miocene							
		Oligocene	Upper			Frio (15)	Frio Gas		White Castle
							Frio "C"		Independence
			Lower	Vicksburg			*nonproductive to date*		
		Eocene	Upper	Jackson			*nonproductive to date*		
			Middle	Claiborne		Cockfield (2)	Cockfield		Bruinsburg
						Sparta (26)	Sparta		Stanton
						Zilpha (1)	Zilpha		Kings
			Lower	Wilcox		Wilcox (362)	Wilcox		Cranfield
							numerous localized reservoir names		
		Paleocene		Midway		Clayton (1)	Clayton		Camp Shelby
	CRETACEOUS	Upper	Gulfian	Selma		Selma Chalk (18)	Selma Chalk		Jackson
							Gas Rock Woodruff		Cary Tinsley
				Eutaw		Eutaw (41)	Eutaw		Tinsley
							Brumfield Christmas City Bank Gholar Hiwanee Kirby Masonite McGraw Morrison Perry Powell Stanley Stevens		Tinsley SoSo Sharon Gwinville Chaparral Avera Heidelberg Tinsley Sharon Tinsley Tinsley SoSo Tinsley
						Eagle Ford (2)	Wilburn		Pickens
							Eagleford		Baxterville
				Tuscaloosa		Upper Tuscaloosa (15)	Upper Tuscaloosa		Gwinville
						Middle Tuscaloosa Marine Shale	*nonproductive to date*		
						Lower Tuscaloosa (156)	Lower Tuscaloosa		Cranfield
							Stringer Sands "A" Sand "B" Sand Arrington Case Denkman Dykes Main McComb Pilot Rollins Smith		 Liberty Liberty Brookhaven Brookhaven Little Creek Smithdale Mallalieu McComb Brookhaven Little Creek Brookhaven
							Massive		Brookhaven
MESOZOIC		Lower	Comanchean	Washita – Fredericksburg		Dantzler (5)	Dantzler		W. Pistol Ridge
						Washita – Fredericksburg (42)	Washita–Fredericksburg		Thompson's Crk.
							Cuevas Merit–Kennedy		Ansley Puckett
				Trinity		Paluxy (56)	Paluxy		Bolton
							Dorward Gammill McAlpin		Bolton Pistol Ridge Waveland
					Glen Rose Sub-group	Mooringsport (34)	Mooringsport		Valley Park
						Ferry Lake Anhydrite (1)	Ferry Lake Anhydrite		Merit
						Rodessa (78)	Rodessa		Martinville
							Cox Harrington Peacock Rodessa "A" Rodessa "B" Ware		Merit Verba Merit West Raymond West Raymond Oak Grove
						James (4)	James Ls		W. Oakvale
						Pine Island (7)	Pine Island		Pool Creek
			Coahuilan			Sligo (50)	Sligo		Bolton
							Bailey Barnes Jennings Sullivan		SoSo W. Oakvale Martinville Martinville
						Hosston (81)	Hosston		Diamond
							Booth Diffrient Fleming Forbes Harper Harrington Hatton Ivy Josephine Kelly Lavon Sinclair Steele		Bassfield Holiday Creek Cistercian W. Sandy Hook Cistercian Holiday Creek Newsom Black Creek Magee Seminary Grange Carson Bassfield
	JURASSIC	Upper		Cotton Valley		Cotton Valley (43)	Cotton Valley		SoSo
							Bay Springs Sand		Bay Springs
				Louark		Haynesville (4)	Haynesville		Boykin Church
							"A" Lime		Morton
						Buckner (11)	Buckner (Hardin Lime)		W. Paulding
						Smackover (78)	Smackover		Tinsley
							Smackover A,B,&C Upper Smackover Lower Smackover Smackover Lime Smackover Sand		E. Tallahala Crk. Lake Utopia Lake Utopia Loring Johns
						Norphlet (14)	Norphlet (Denkman)		Pelahatchie
		Lower				Louann Salt	*nonproductive to date*		
	TRIASSIC					Eagle Mills			
PALEOZOIC	PERMIAN (Absent)								
	PENNSYLVANIAN					Pottsville (5)	Nason		Corinne
							Nevins		McKinley Creek
	MISSISSIPPIAN	Chesterian				Parkwood – Pennington (69)	Buskirk		Corinne
							Gilmer		Corinne
							Walker		Maple Branch
							Millerella		Greenwood Springs
							Carter		Amory
							Sanders		Thorn
							Abernathy		Reid
							Rea		Matubby Creek
						Pride Mountain (45)	Evans		Coleville
							Lewis		McKinley Creek
	DEVONIAN			Harriman		Devonian (1)	Devonian Porosity		McKinley Creek
	SILURIAN			Niagaran			*nonproductive to date*		
	ORDOVICIAN			Stones River		Stones River Dolostone (2)	"Knox–Ordovician" (Snow Zone)		Maben New Hope
	CAMBRIAN			Knox			*nonproductive to date*		
PRECAMBRIAN BASEMENT									

KEY – The first production for a particular producing pool is listed first along with the field in which this production was first established. Additional producing zones are listed in alphabetical order.

Note – The above names of producing units have been used in order to complement production reports published by the Mississippi State Oil & Gas Board. In some cases those published names may not agree with the correlations of the Mississippi Office of Geology.

The Sligo and Rodessa formations are composed of a series of river-dominated delta systems, and reworked delta front sandstones. The Rodessa reservoir rocks are sealed by the Upper Glen Rose evaporitic Ferry Lake Anhydrite and the transgressive marine shale of the Mooringsport formations. The Sligo Formation is underlain by the Coahuilan Hosston Formation.

The Soso Field Unit consists of 6,460 acres and has active CO_2 EOR floods in the Rodessa (east side of the field) and Bailey (west side of the field). The project area for anthropogenic injection and the focus of the research MVA project is planned for the future Bailey flood on the east side of the field. The research project area comprises 988 acres within the unit. When the Bailey flood is completely developed, Denbury anticipates that it will have 9 CO_2 Class II injection wells and 22 producing wells.

Soso, discovered in 1945, has produced over 60 million barrels of oil, 169 billion cubic feet of natural gas, and 87 million barrels of saltwater from 110 wells. The Rodessa -11,180' and Bailey -11,701' reservoirs have produced approximately 30 million barrels of oil, or 50% of the oil in the field, (**Figure 3)**. The Mooringsport Shale and the Ferry Lake Anhydrite, **(Figure 4)** are the overlying 450' thick hydrocarbon seal. Whole core analyses document the above reservoir quality sands to possess average porosities of 16.8% – 17.4%, and original water saturations of 16.4% - 17.9%. The core data also indicates average permeabilities ranging from 170.9 millidarcies to 272.7 millidarcies.

Figure 3. Soso type log showing multiple injection zones

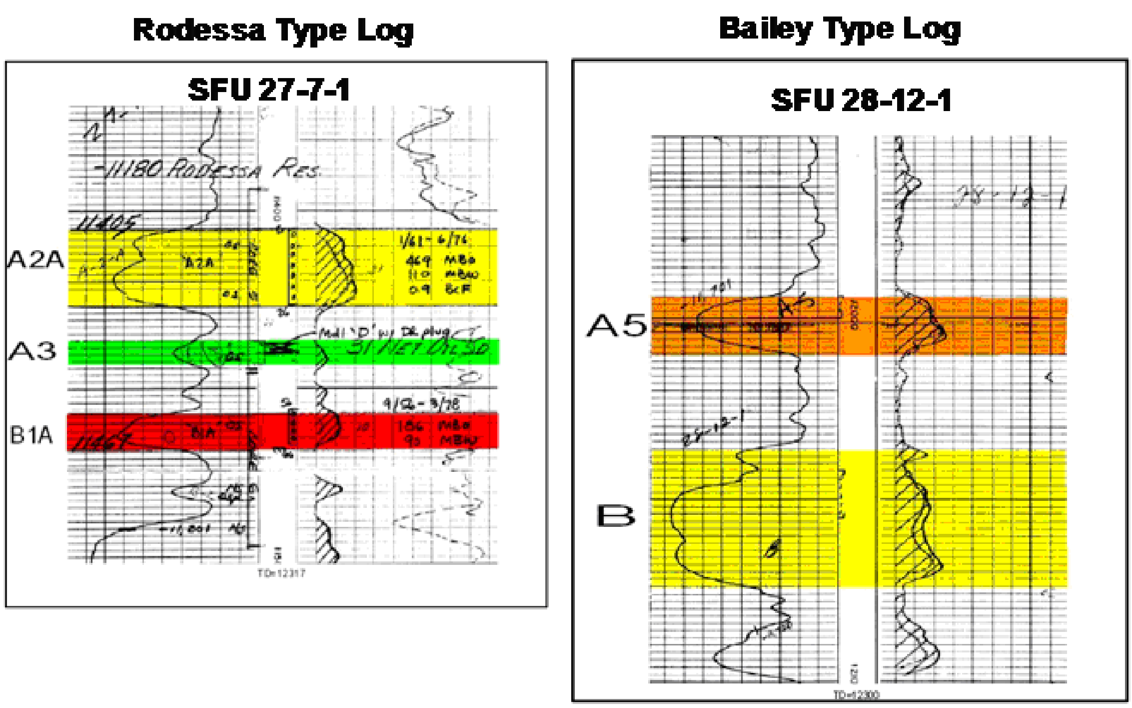
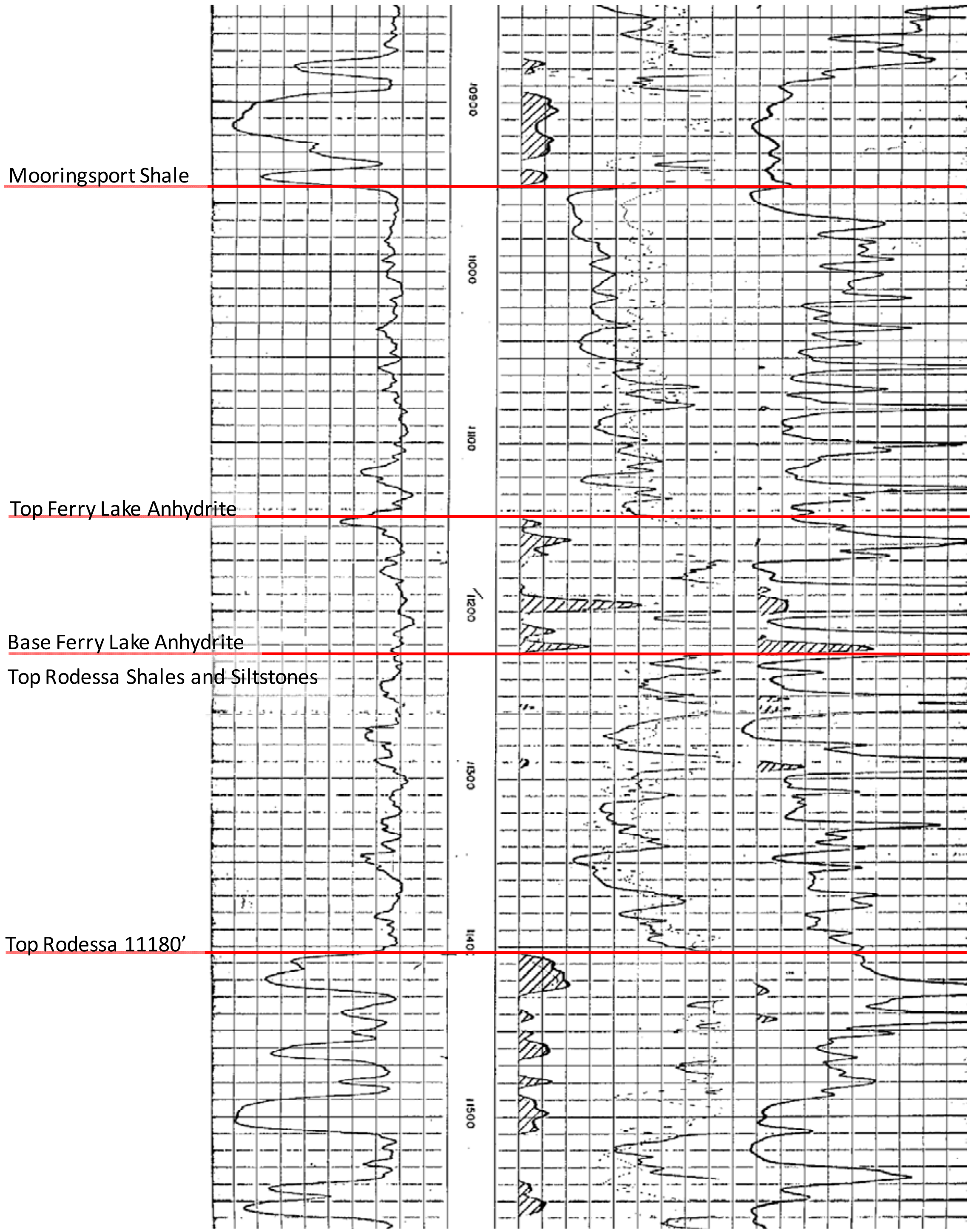


Figure 4. Soso type log showing hydrocarbon Seal

Type Log for Hydrocarbon Seal

SFU 27-7-1



The productive limits of the Bailey -11,701' Sand are approximately 2648 acres. The structure map illustrates an unfaulted, elongated anticline with gentle 1 degree flank dips (**Figure 5**). The major axis, striking in a northwesterly-southeasterly direction, is approximately 6 miles in length, while the minor axis is approximately 2 miles in length. Structural uplift is approximately 110 feet on the Ferry Lake Anhydrite marker. The structure is thought to be underlain by an inter-domal or residual high, surrounded by areas of significant salt withdrawal into adjacent salt domes. This type of sediment-cored anticline is also known as a "turtleback" structure. A net pay isopach (thickness) map of the Bailey -11,701' A5 sand is shown in (**Figure 6**) and demonstrates the sand is well developed and fairly continuous over the entire area. The average oil sand thickness for the Bailey -11,701' sand is 33', and for the Rodessa -11,180' sand is 32'. The original Bailey oil/water contact was estimated at -11701' and the original Rodessa oil/water contact was mapped at -11180'. Original reservoir pressure for the Bailey was 5553 psi and for the Rodessa 5075 psi. Current Bailey reservoir pressure is approximately 6200 psi, and the Rodessa 5600 psi due to active CO_2 injection.

Figure 5. A5 Structure Map Soso Field

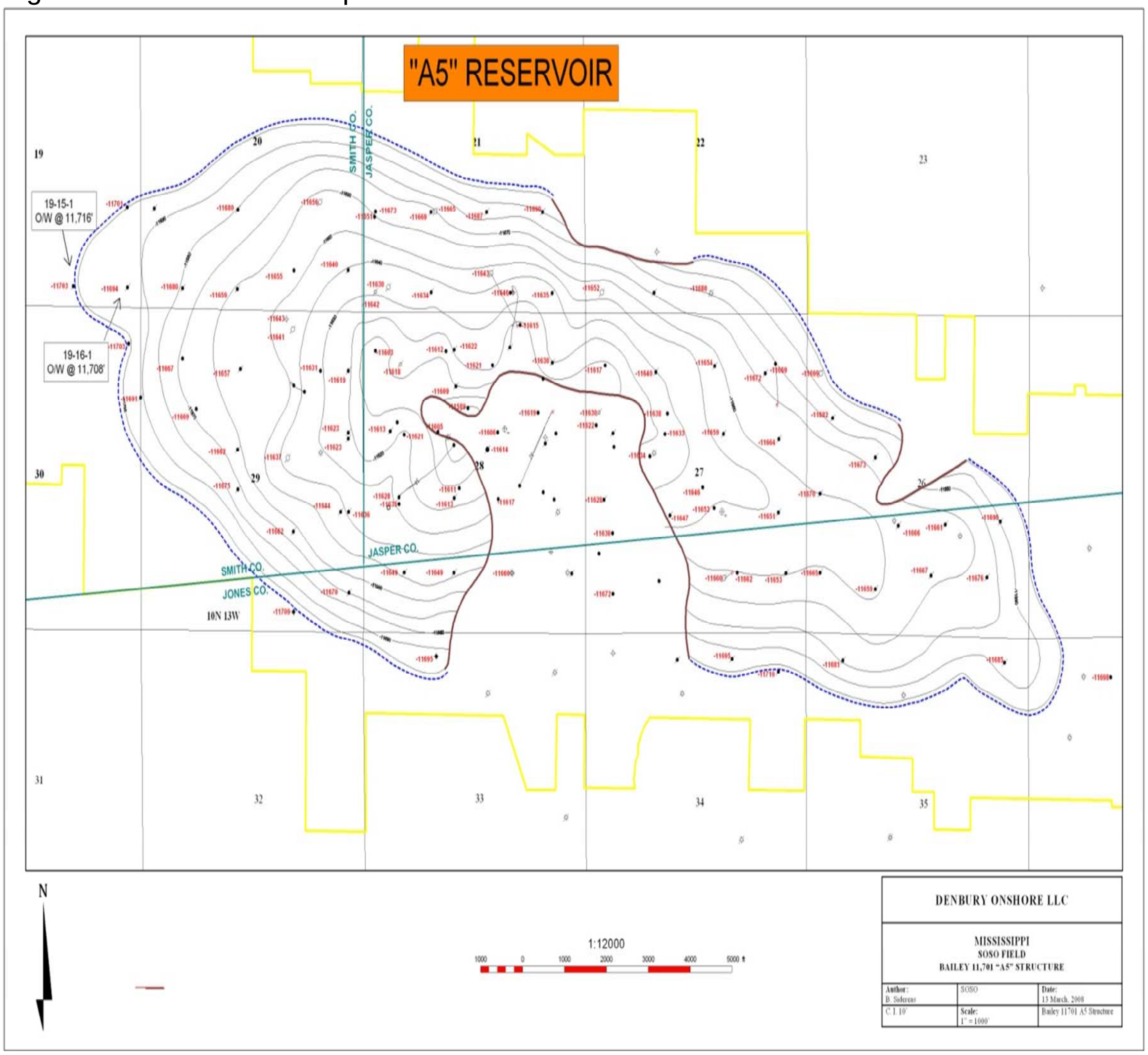
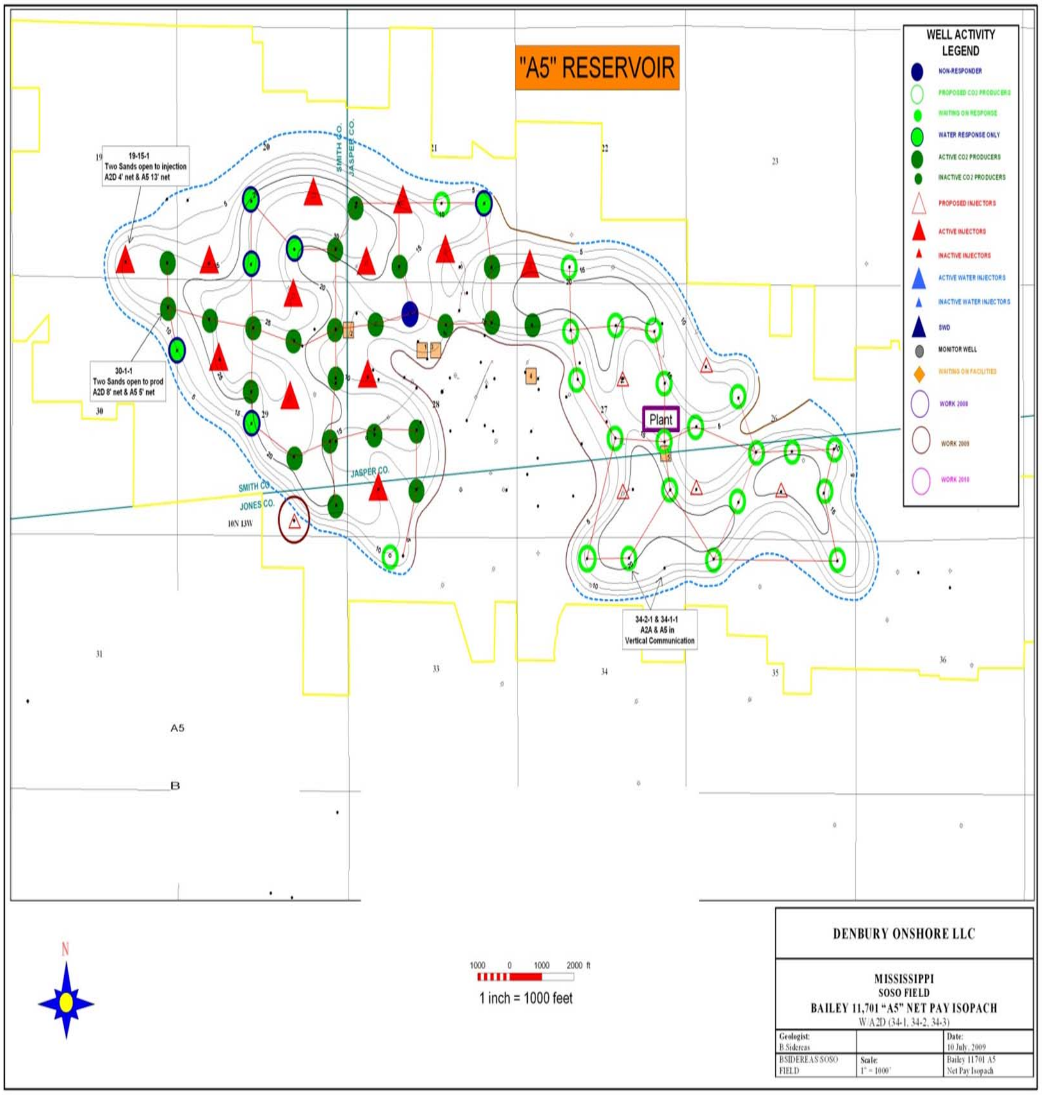


Figure 6. Soso Field Net Isopach of the Bailey – 11,701' A5 Sand



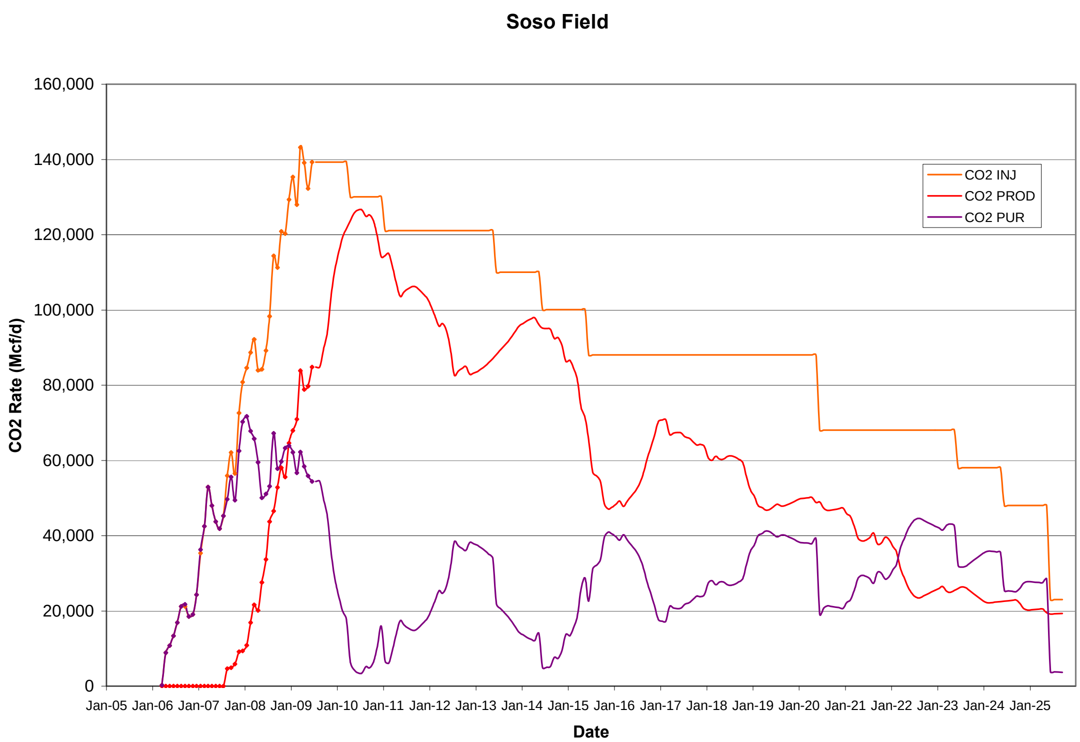
Reservoir drive for both the Bailey and Rodessa sand packages was primarily a weak to moderate water drive. The Bailey was not waterflooded; an attempt to partially waterflood the Rodessa had limited success.

Soso's field limits have been delineated with the drilling of over 110 wells; 86 of these wells drilled through the productive Rodessa and Bailey reservoirs. The total productive ac- ft for these two reservoirs is 107,772 ac-ft.

Expansion of the EOR Project for anthropogenic CO_2

CO_2 is currently being injected into the Rodessa -11,180' and Bailey -11,701' intervals in 22 wells, and began production in March 2007. Currently, 26 CO_2 Class II injection wells are planned for the Soso CO_2 EOR project. The preliminary plans for the CO_2 EOR project will utilize those 26 injectors with an inverted 9 spot pattern configuration. The CO_2 EOR project will involve injecting approximately 160 MMSCFD of CO_2 at a maximum injection pressure 3100 psi to pressure up the Bailey reservoir to approximately 6400 psi, and the Rodessa reservoir to approximately 5800 psi. Current CO_2 injection rates into the 22 Bailey/Rodessa injectors range from 2.0 MMCFGD to 12.0 MMCFGPD with the average rate of 7.1 MMCFGPD. The Soso CO_2 EOR facility is currently capable of injecting up to 160 MMCF/D of CO_2 and processing 132 MMcf/d, 6000 BOPD and 24000 BWPD. **Figure 7** shows the historical oil production and the forecasted remaining production for the field.

Figure 7. Historical injected volumes and the forecasted future CO_2 rates.



With a tertiary recovery factor of 17%, the EOR CO_2 requirement is estimated to be 261 BCF for the field.

Soso – expansion to accommodate CO_2-A

At the time of CO_2 -A arrival, additional injection opportunities into the in the Bailey interval are planned to be available. In the event that other CO_2 EOR sites are more viable when CO_2-A becomes available, Denbury may use such other CO_2 EOR sites for the research MVA project. The preliminary plans for the expansion of the CO_2 EOR project in the Bailey interval will utilize 9 injectors with an inverted 9 spot pattern configuration. The CO_2 EOR project will involve injecting approximately 78 MMSCFD (4 million metric tons) of CO_2 at a maximum injection pressure 3100 psi to pressure up the Bailey reservoir to approximately 6400 psi.

***Injectivity* -** Current CO_2 injection rates into the 16 Bailey injectors (Bailey flood - west side of field) ranges from 3.3 MMCFGD to 13.1 MMCFGPD with the average rate of 8.2 MMCFGPD. The CO_2- A can be accommodated in the expansion area as well as part of Denbury's CO_2 requirements for the current patterns. CO_2-A will be co-mingled with natural CO_2 from Jackson Dome and injected throughout the field. However, the research MVA program will focus on the expansion area.

Storage Capacity

Table 4 shows estimates of original oil-in-place and CO_2 capacity for the Soso Bailey reservoirs. Approximately 21 million barrels oil existed at discovery; by a simple estimate of replacing this oil volume with CO_2, 39 BCF or 2.3 million tons CO_2 can be sequestered into the hydrocarbon pore space. The estimated CO_2 purchase rates by month for the first 3 years of injection into the Bailey are shown in **Table 5**.

Table 4. Original oil-in-place and CO_2 capacity for the Soso Bailey reservoirs

Zone	Area (acre-ft)	Porosity (decimal)	Swi (decimal)	Boi (RB/STB)	OOIP (Mbbls)	CO_2 Capacity (MMcf)
A5	12,837	0.174	0.164	1.328	10,909	20,945
B	11,662	0.174	0.164	1.328	9,910	19,027
Bailey Total	**24,499**				**20,819**	**39,972**

Table 5 is the estimate of CO_2 purchase volumes for the first 3 years of anthropogenic supply. This forecast is dependent upon actual delivery date of the CO_2, capital expenditure levels, and timing for completion of Bailey activities. It is currently assumed that January 1, 2015 will be the date of first CO_2–A delivery. Development activities are estimated to take 2 years from 2015-2016.

Table 5. Estimated of CO_2 purchase volumes for the first 3 years of anthropogenic supply

Month	CO_2 Purchased Volumes (MMcf)	CO_2 Purchased Volumes (MMcf/d)	Cumulative CO_2 Purchased Volumes (MMcf)	Cumulative # injectors
January-15	2,371	78	961	9
February-15	2,351	77	3,313	9
March-15	2,332	77	5,645	9
April-15	2,312	76	7,957	9
May-15	2,293	75	10,250	9
June-15	2,274	75	12,524	9
July-15	2,255	74	14,779	9
August-15	2,236	74	17,015	9
September-15	2,218	73	19,233	9
October-15	2,199	72	21,432	9
November-15	2,181	72	23,613	9
December-15	2,163	71	25,776	9
January-16	2,145	71	27,920	9

February-16	2,127	70	30,047	9
March-16	2,109	69	32,156	9
April-16	2,091	69	34,248	9
May-16	2,074	68	36,322	9
June-16	2,057	68	38,379	9
July-16	2,040	67	40,418	9
August-16	2,023	67	42,441	9
September-16	2,006	66	44,447	9
October-16	1,989	65	46,436	9
November-16	1,972	65	48,408	9
December-16	1,956	64	50,364	9
January-17	1,940	64	52,304	9
February-17	1,924	63	54,228	9
March-17	1,908	63	56,135	9
April-17	1,892	62	58,027	9
May-17	1,876	62	59,903	9
June-17	1,860	61	61,763	9
July-17	1,845	61	63,608	9
August-17	1,829	60	65,437	9
September-17	1,814	60	67,251	9
October-17	1,799	59	69,050	9
November-17	1,784	59	70,834	9
December-17	1,769	58	72,603	9

Equipment for the injection process includes a custody transfer meter to measure the CO_2 delivered to the field, CO_2 booster pumps (multistage horizontal centrifugal pumps), an injection pipeline network, a CO_2 meter to measure the CO_2 being injected at each well and the injection wellhead with the necessary pressure safety devices, shutdowns and relief systems.

Field expansion to accommodate CO_2-A

Two maps (Bailey A5 and B intervals) have been generated showing the status of wells and Denbury's preliminary patterns. Nine (9) patterns are shown for the A5 sand and six (6) patterns for the B sand. A total of 22 producers and 9 injectors are shown. Producer and injectors identified are shown on table 6.

Table 6. Preliminary Concept of Soso Bailey expansion development to accommodate CO2-A

Producers		
No.	**Well**	**Zone**
1	22-14 #1	A5
2	27-3 #1ZB	A5, B
3	27-6 #1	A5, B
4	27-11 #1	B
5	27-14 #1	B
6	27-10 #1	A5, B
7	34-4 #1	A5
8	27-2 #1	A5, B
9	34-2 #1	A5
10	27-1 #1	A5
11	27-8 #1	A5, B
12	27-9 #1	A5, B
13	27-16 #1	A5, B
14	26-12 #1	A5, B
15	26-6 #1	A5
16	26-11 #1	A5
17	26-14 #1	B
18	35-4 #1	A5
19	26-10 #1	A5
20	26-9 #1	A5
21	26-16 #1	A5
22	35-1 #1	A5

Injectors		
No.	**Well**	**Zone**
1	22-13 #1	A5
2	27-5 #1	A5, B
3	27-13 #1	B
4	22-15 #1	A5
5	27-7 #1	A5, B
6	27-15 #1	A5, B
7	26-5 #1	A5, B
8	26-13 #1	A5, B
9	26-15 #1	A5

In addition these injectors and producers, other wells will be used to monitor CO_2 movement in the reservoir. Some wells will monitor the aquifer and others will monitor the freshwater sands inside and outside of the patterns.

Figure 8. Bailey A5 development plan

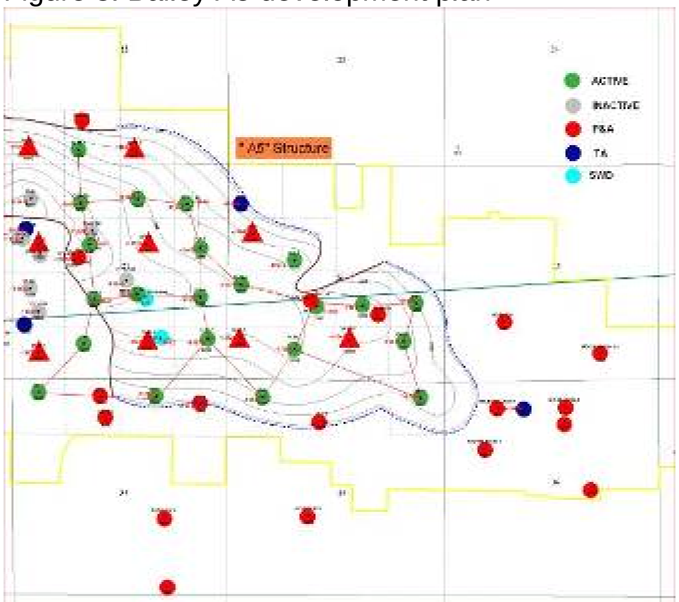
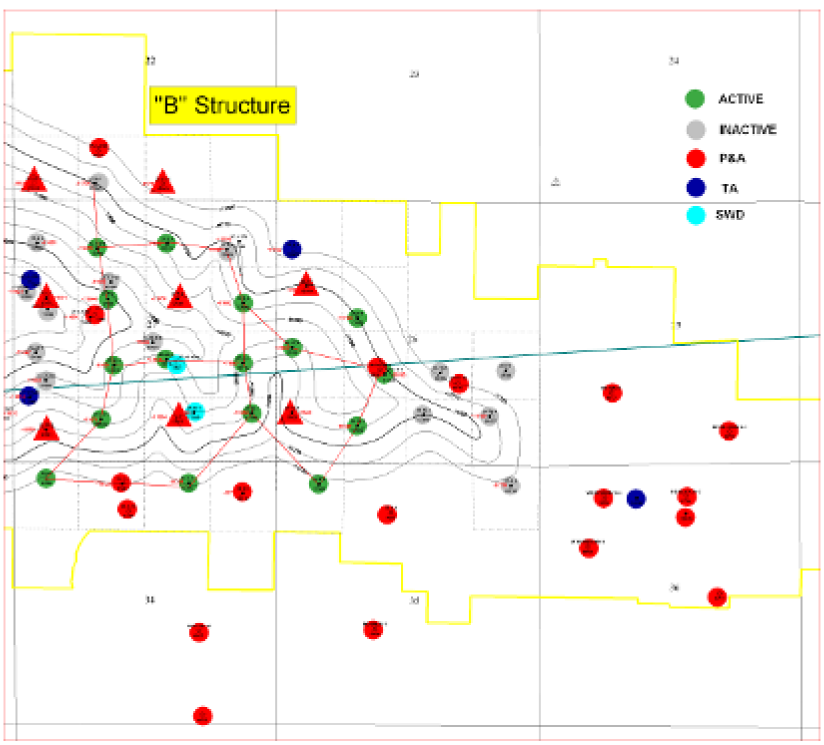


Figure 8 Bailey B development plan



APPENDIX 6

Phase 1 SOPO Task 1.5.4.1
Draft Risk Assessment and MVA Plan

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report Number:	C1.5.4.1
Report Title:	Draft Risk Assessment and MVA plan
Completion Date:	December 15, 2009
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Comment: Draft risk assessment and MVA plan noting site-specific data needs prepared by GCCC based on previous experience and available site-specific data.

Phase 1 Task C1.5.4.1

Draft risk assessment and MVA plan

Prepared for:
Denbury Onshore, LLC

Report by Susan D. Hovorka

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Introduction

This report documents the status of planning and progresses for Task C1.5.4.1, Draft risk assessment and MVA plan. GCCC has prepared a list of site-specific data needs based on previous experience and available site-specific data. This data table describes the data needs needed to design a MVA plan, and requests information from Denbury on data availability for several fields in consideration. It also solicits information on how the MVA needs will be evaluated, and discusses how the data will be used for achieving storage goals.

Goals of a Monitoring, Verification and Accounting Plan (MVA)

A Monitoring, Verification and Accounting (MVA) plan for each sequestration site will focus on demonstrating that identified risks are not occurring. This assurance program includes:

(1) demonstrating that the CO_2 is contained in the designated trap (no spill out of reservoir);
(2) demonstrating that well completions have integrity to retain CO_2 over the 1000 year time frame;
(3) demonstrating that the seal and the faults and fracture systems that cut it retain confining capacity after pressure depletion during production and pressure increase during the flood;
(4) and additional observations and activities above and beyond the normal CO_2 EOR operations that will allow interpretations to be made of confinement of the CO_2 beyond the operational period.

Process for preparing MVA plan

In order to prepare a detailed plan a number of activities will be performed in Phase I of the project. An effective and efficient MVA plan has to be based on the actual field and reservoir in which the sequestration will take place.

Prior to injection, Denbury will construct a geologic model of the reservoir using available wireline logs, core, seismic, and past production data, and simulate the interaction of injected CO_2 with reservoir fluids. Reservoir characterization is undertaken to guide the flood design; this provides essential data to demonstrate that the CO_2 is effectively and efficiently contained within the reservoir (in production terms maximize sweep efficiency and oil contact area).

Well bore integrity is a major reservoir management activity. Denbury has began a comprehensive review to determine the condition of active, idle, and plugged and abandoned (P&A) wells in the area to be flooded. Scout tickets and RRC W-3A P&A records are evaluated to make sure that this process has been properly completed. Denbury will develop a plan to reenter about half of the P&A wells, that will provide an opportunity to evaluate ¾ of the penetrations using a combination of cement bond, temperature, TNT or other wireline tools to determine and remediate, if needed, casing – borehole annular cement integrity prior to or during the flood. The integrity of P&A wells will be determined by (1) comparing the P&A records for wells that were re-entered with the actual condition of the wells, to determine if records are accurate; and (2) a site specific surveillance program using migration indicators in soil and groundwater using both ambient (oil, methane, salinity) and introduced (CO_2, stable isotopic, perfluorocarbon tracers) to verify that individual wells are performing correctly. The operational period for individual wells is >15 years. At the end of useful life Denbury will P&A producers and injectors in accordance with applicable regulations.

As the flood starts, Denbury will track CO_2 via daily to weekly monitoring of well head pressure, monthly measurement of produced fluids from each well using the production test facility, and collection of additional data that are then input into reservoir models to optimize the flood. Denbury will track CO_2 for flood optimization via routine monitoring of bottom hole pressures during the initiation of the flood and routine monitoring of well head pressure to determine when to open and begin to produce the wells into the facility. Once production begins, monthly volumetric balances of produced fluids in conjunction with reservoir pressure measurements and other wireline measurements will be utilized to monitor the flood and location of the CO_2. Surveillance methods may include, flowing and shut-in bottom hole pressure measurements, TNT (neutron) logs, thermal/spinner production logging and other tools that may be developed.

A review of literature and recommendations for MVA activities will be conducted to evaluate what is recommended for each field. There are several existing publications of potential recommended MVA activities such as; IPPC Special Report on Geologic Sequestration, World Resources International CCS guidelines, CCPII's Results from the CO2 Capture Projects Vol. III, and the National Energy Technology Laboratory (NETL) http://www.netl.doe.gov/technologies/carbon_seq/core_rd/mva.html), Interstate Oil and Gas Compact Commission report "Carbon Capture and Storage: A regulatory framework for states.

The Bureau of Economic Geology Gulf Coast Carbon Center (GCCC) will work with Denbury and a number of service companies and research organizations to develop a site specific research MVA plan to augment normal commercial best practices. The MVA plan will include the extent to which normal best practices can provide this confirmation, the extent (if any) to which they need to be augmented and to recommend monitoring systems that are fit- for-purpose.

Criteria that define fit-for-purpose include

(1) definitive data that retention for storage has occurred
(2) predictive data that storage is permanent (<1% migration over 1000 years)
(3) cost effective
(4) compatible with CO_2-EOR practices
(5) durable and robust for monitoring over multi-decade time frame in active CO_2 field environment
(6) quantitative and reportable

Some of the ranges of possibilities that will be considered for the MVA plan are shown in Table 1.

Table 1. Proposed monitoring program options

Goal	MVA techniques to be considered*
Demonstrating that the CO_2 is contained in the designated trap (no spill out of reservoir)	Collection of injection data, pressure data and fluid production. History matching production data using reservoir simulator to document mass balance, pressure conformance, and maximum extent of plume. Additional data collection, such as as PFT Geochemical Tracers to show injector-producer flow and plume thickness, additional permanently installed, wireline or slickline instruments (e.g. thermal, acoustic, pulsed neutron), surface-deployed geophysical techniques including VSP azimuthal and walkaway surveys and time lapse 3-D; conformance control via CO_2 foams or other advanced reservoir management engineering
Demonstrating that well completions and P&A wells have integrity post-closure to retain CO_2 over the 1000 year time frame.	Assessment of historical well completion and P&A reports; reentry of selected wells to test accuracy of historical reports, cement bond and casing integrity logs; deconstruction and analysis of well materials (as done by Schlumberger and CCP); well surveillance during flood (noise, temperature, pressure, fluid migration); above-zone pressure, temperature, geochemical monitoring; emplaced PFT to tag CO_2 to detect above zone or at surface; time lapse 3-D survey looking for change above zone, up-gradient-down gradient groundwater monitoring, soil gas monitoring.
Demonstrating that the seal and faults and fracture systems that cut it retain confining capacity after pressure depletion during production and pressure increase during the flood.	Collection of seal and geomechanical testing and modeling to determine if either pressure drop during production or pressure increase during injection could damage seal, emplaced PFT to tag CO_2 to detect cross-fault, above zone or at surface; geochemical stability with CO_2-water-interation; evaluation of geologic and historical performance of seal and faults during charge and production; cross-faults and above-zone pressure, temperature, or geochemical monitoring; time lapse 3-D survey looking for change above zone; up-gradient-down gradient groundwater monitoring, soil gas monitoring.

* Site specific cost/value/feasibility assessment will be conducted and only a selection of techniques named above will be proposed for the final MVA plan.

As the geologic assessment, modeling, and engineering design advances, it will highlight additional uncertainties or remove potentially eliminate uncertainties that may affect storage assurance. We will use several risk assessment methods, consulting Denbury's in-house expertise, Quintessa FEPS data base (http://www.quintessa.org/CO2fepdb/PHP/frames.php), LBNL-UT certification framework, literature review, interview other current projects doing monitoring (e.g. Otway, Victoria, Australia, Ketzin, Potsdam, Germany, project at ADM plant Dekatur,Il, BP's Insalah Project in Algeria), and expert interviews to formally list all the factors and uncertainties that could lead to failure to attain the expected level of long-term storage. Any significant additions to the list in the table above and a list of monitoring options will be added.

GCCC will invest significant effort into evaluation of the value based on the cost versus benefit of each monitoring tool. Value includes the ability of the tools to make the needed measurements to reach project goals, sensitivity at relevant conditions, durability and cost of maintenance/replacement, frequency of repeat, density of data collection, cost of each repetition, value of information in context of history matching a model or confirming non-detect. This evaluation will make substantive use of GCCC past field monitoring experience (Frio I, Frio II, SECARB Stacked Storage at Cranfield, SECARB Early at Cranfield, and SWP Phase II at SACROC). Each of these test projects has made significant advances in monitoring and provides lessons learned that will be used to meet this project's applied objectives. In addition, the GCCC team has been involved as reviewers and collaborators in many other projects, and will continue aggressive co-ordination with other groups within the Regional Carbon Sequestration Partnerships (RCSP), the US, and worldwide to bring new results to the project. Table 2 shows some of the resources and connections that have been drawn upon to develop the MVA plan. Denbury will review the recommendations of the GCCC evaluation and during working meetings the project team will determine best value tools will be selected for proposal in the final MVA plan.

Table 2. Sources of expertise within the project showing highlights

Expertise	Source	Nature of link
Reservoir characterization	Denbury	Provided to project as in-kind contribution
Storage efficiency –best practice	Denbury	Provided to project as in-kind contribution
Storage efficiency – extended as needed for CCS	GCCC/Denbury	In-zone monitoring experience from Frio test, Phase I Cranfield enhanced reservoir surveillance program, Phase III Cranfield Field test underway. Numerous other CCS specific as well as service company approaches available, contacts through IEA GHGR&D program monitoring working group; RCSP MVA Working Group
Well-bore integrity – best practice	Denbury	Provided to project as in-kind contribution
Well-bore integrity-advanced	GCCC-Sandia Technologies	Expertise via Carbon capture Project (CCP) http://www.CO$_2$captureproject.org/; contacts through IEA GHGR&D program well-bore integrity working group
Above –zone Monitoring	GCCC/Sandia Technologies	Chemical monitoring –Frio, Pressure Monitoring SECARB II and III at Cranfield
Ground water monitoring	GCCC	Experience through recently completed SWP SACROC program, test at Cranfield underway.
Soil gas monitoring	Denbury, GCCC	Baseline underway at Oyster Bayou; GCCC method improvement at Brackenridge field station; Cranfield Phase III. Connection to ZERT, RCSP monitoring working group, numerous vendors

Worksheet for field and MVA selection

The mechanism for accomplishing the site selection and site specific risks will be via an in-person meeting, at which Denbury and GCCC staff will evaluate the candidate field to determine the lowest risk and highest chance of success. The evaluation table is shown in figure 3.

Figure 3. Scoping spreadsheet for field selection and MVA program development

			AL & MS Fields			
Characteristics	**Details**	importance to success of project 5= very important to 1= not at all important	Citronelle	Soso	Eucutta	W Heidelberg
Match of injection area to injection volume						
Number of patterns needed for planned CO_2 A volumes						
Timing/volumes of CO_2A available						
Temporal match of CO_2 available patterns	Will CO_2 be injected in a new area? (no previous CO_2)					
CO_2 accounting						
Quantify and report CO_2 injected, recycled	Who is handing this part of MVA?					
Quantify water, oil, gas volumes extracted						
Handing CO_2 – separator efficacy, line leakage, venting during handing						
Frequency, density, quality of data for CO_2 accounting						
Potential to improve accounting data beyond current practices						
NEPA risks						
Minimum contentious or litigious public						
Wetlands						
No endangered species habitat						

No historical features, parks, residential area problems						
Model reservoir block to account for CO_2 distribution						
3-D seismic						
Cores and core analysis						
Historical production data						
Good PVT data						
Detailed geologic model						
Detailed flow model						
Available MVA data to history match						
Pressure data during flood						
Good access and support for surface monitoring – roads, power, cell coverage						
Can collect repeat 3-D/VSP						
Good well integrity – avoid fields with the most bad well conditions/bad well records						
Good confidence in predicting preflood fluid composition, saturation, pressure						
Minimum complexities of past production – multiple zones produced? Water flood? Past CO_2 flood, other tertiary recovery. Multiple operators in field (e.g. shallower production by another company might raise issues of contamination by CO_2 – not good to monitor and raise these issues						
minimum surface conditions that may limit monitoring options - cropped, uncooperative surface owners, wet or inaccessible, highly complex surface uses (past oil field contamination)						
Suitable probable flood geometry – area to be monitored. reservoir compartmentalization. complexity, number of faults						

Some additional questions and key points to consider as we plan MVA strategy:
Develop MVA approach - Collect data to reduce perception of risk (by CO_2 supplier & DOE)
What are the biggest unknowns? CO_2 use per pattern? Compartmentalization? Miscibility? Pressure? In DOE –speak these would be described as capacity and trapping mechanism
What shall we do to show well integrity?

How do we show faults are sealing especially over geologic time?

Monitoring should be used to confirm a model - who will do this model?

Risk Assessment approach?

How to coordinate monitoring with field development – possible dual use (future injectors/producers used as monitoring wells) to limit cost. Dual use of water make-up wells?
Who are stakeholders and what is process by which they will provide feedback for Phase II proposal?

In Phase II budget -Who will do the monitoring field work – how much done by Denbury or other contractors?

APPENDIX 7

Phase 1 SOPO Task 1.5.4.2
Site-Specific MVA Options Evaluation

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report Number:	C1.5.4.2
Report Title:	C1.5.4.2 Site-specific MVA options evaluation
Completion Date:	February 22, 2010
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Phase 1 Task C1.5.4.2

Site-specific MVA options evaluation

Prepared for:
Denbury Onshore, LLC

Report by Susan D. Hovorka

April 11, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Introduction

This report documents the planning and progresses for Task C1.5.4.2, evaluation if site-specific MVA options. On December 15, 2009, a review team composed of Susan Hovorka, University of Texas, Bureau of Economic Geology (BEG) and sixteen Denbury staff refined the plan for development of the Phase I Storage MVA plan for the Leucadia Mississippi Gasification capture project linked to a storage project proposed under DOE FOA 15. This report recounts the evaluation completed at that meeting, and identifies the field and alternative and MVA options selected for further evaluation. This prepares the way for development of detailed proposals that will be judged competitively for major funding in Phase II.

The review team completed a formal review of four fields nominated in the initial proposal and selected one that seemed to be most competitive in the context of the next round of proposal preparation: Soso - Bailey reservoir. We discussed the separation of monitoring activities into (1) those conducted commercially as part of best practices for an effective EOR flood and/or to meet current regulatory requirements (these are not subject to NEPA) and (2) those geographically and topically limited research-oriented monitoring, verification, and accounting (MVA) activities that will be conducted to further demonstrate the effectiveness of storage. Research MVA will be federally funded and will be subject to NEPA. This report proposes a draft research MVA program. It is intended that this draft discuss a broad scope of all the activities that might be selected for the phase II proposal. This broad scope will help us focus further cost/feasibility/optimization discussion as well as allow preparation of the EIV. For purposes of this MVA study, “best practices” means typical oilfield drilling and completion practices in accordance with state regulatory requirements and industry-accepted standards utilizing a well injection pattern for CO_2 intended to extract additional oil and gas from the reservoir based upon Denbury’s geological (and where appropriate, possibly seismic) and operational studies.

Field Selection – Soso

The four fields proposed in the initial proposal from which one was selected were Citronelle, Heidelberg, Eucutta, and Soso. A list of competitive advantages/possible risks to consider was prepared and jointly reviewed. Issues that were judged to be significant were: temporal and volumetric match between field development and availability of captured CO_2 and possible negative implications of the public aspects of using federal funding, in particular the public information associated with NEPA.

The review team felt that a stronger proposal would result if the field expansion (additional patterns) was approximately matched to the captured CO_2 (assumed to be 1 million tons per site per year during 2014-15). Make-up CO_2 is purchased throughout the life of a field even when recycling dominates, however the possible reviewer confusion about “room for CO_2 when the field is already full” might weaken a competitive proposal. Also in fields which will be relatively mature and into recycle, the purchase volumes needed during the 2014-15 period could not be stated with high confidence in the Phase II proposal. In addition, the possibility of collecting baseline data prior to completion of the development of the flood will allow the MVA program to mirror what the DOE program expects, which will improve its acceptability. The field in which expansions are planned in 2014 timeframe is Soso (downdip Bailey reservoir), and Heidelberg East.

The other factor considered a significant selection parameter is the public comment period triggered by NEPA. Public comment related to NEPA will apply only to federally funded research MVA activities, as Denbury's commercial field operations will be part of the EOR flood whether or not federal funds are applied. Rationally, research MVA activities should provide additional comfort for residents and communities, however where anxiety or hostility are involved, residents may not separate the commercial flood of Denbury from the research MVA of GCCC. Local interest could have possible negative consequences resulting in unnecessary delays for either commercial or research program, or both. We therefore ultimately recommend avoiding locations where the CO_2 enhanced recovery project may impact a larger population.

MVA program

The MVA program proposed will include two components: a commercial operations program and an added value research program. The commercial MVA program will be conducted as part of the EOR Operator's normal best practices, in conformance with applicable regulations. These commercial operations are not subject to NEPA review as they are independent operations which will be conducted whether or not federal funding and anthropogenic CO_2 is acquired for the EOR project. The research program is designed to test with additional rigor and available technology the extent to which a commercial operations monitoring program is adequate to assure that storage is of quality desired to obtain lasting benefit to the atmosphere. In particular the research program will test for conditions where retention of CO_2 is adequate for commercial operations benefit and duration but may not be of standards desired for long-term sequestration. The standards desired for sequestration are not codified at this time, however the IPCC target that a well selected site should retain 99% CO_2 in the reservoir over 1000 years meets DOE's expectations. The research portion of the MVA program will be federally funded and subject to NEPA review.

Commercial operations EOR field monitoring provides assurance to the Operator that the CO_2 flood is performing correctly via reservoir management and its oilfield development pattern. In order to create a credible MVA program, Denbury will document that these commercial activities are conducted in a manner to lend credence to the MVA research project. In some cases the applicable data are reported to the appropriate state oil and gas regulatory board, however, in other cases data is proprietary to the operator and BEG will work with Denbury to disclose that data needed for documentation to demonstrate permanent sequestration. Reservoir management goals and activities are shown in table 1.

Table 1. Commercial MVA program used for reservoir management

Goal	Methods	Remedial action if needed achieve goal
Demonstrate no migration through existing and P&A wells for protection of USDW	Examine well completion records, P&A records prior to flood, run cement bond logs, conduct mechanical integrity tests, during flood daily record of casing pressure at each well (a truly abandoned well may not have pressure recording capability)	Re-entry and workover to repair wells if needed, includes, cement squeezes, installation of casing liners, P&A and redrill if needed.
Surveillance of the flood to demonstrate that injection is balanced (CO_2 is going into the selected area of the selected zone and driving production at selected producers, pressure is not above fracture gradient).	Daily record of tubing pressure on injectors and producers, minimum monthly inventory of fluid volumes produced at each well at test facility, intermittent bottom hole shut-in or flowing well pressures, intermittent production/injection logs.	Shut in wells that do not contribute, increase/decrease injection or production rates, modify perforated interval. Conformance treatments to alter injection and/or production zones.
Predict future performance of reservoir	History match surveillance data to predictions in reservoir model.	Correct model as needed to match history and gain confidence in future predictions

The research MVA program will focus on areas of uncertainty in retention of fluids in the injection zone. As these oil fields have retained oil and gas for geologic time, we consider that it is documented the natural seal is adequate to support a significant CO_2 column with migration occurring possibly only at diffusion rates. Risk assessment and experience indicates that the most probable migration paths are (1) non-sealing well completions; and (2) off-structure or out of compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood. An MVA program is outlined for each of these risk areas and is linked to a mitigation or management process that can be implemented to result in adequate assurance that the CO_2 injected is permanently stored.

Non sealing well completions

Wells that penetrate the seal are potential weak points, especially during injection. This occurs because older wells have been completed under older regulatory schemes. Wells that perform adequately during extraction, when they are pressure sinks, have the possibility of becoming upwardly transmissive during injection when pressure of the reservoir is increased. Wells that are actively producing can be inspected via a logging program, however wells that have been plugged and abandoned (P&A) are prohibitively expensive to reenter to inspect and therefore, do not provide viable candidates for monitoring. The research MVA program is intended extend the commercial operations well integrity program, and test the effectiveness of the commercial operations program.

Activities that will be considered for possible inclusion in the proposal:

(1) Additional logging program (e.g. temperature, radioactive tracers, high end wireline tools)

(2) Above zone pressure monitoring – ambient and introduced fluids

(3) Well deconstruction – possibly associated with workover.

(4) Soil gas, groundwater, or other near-surface monitoring.

Soso has been under flood for 4 or 5 years, the performance of wells can be tested by several possible methods looking for evidence of migration from the injection zones in overlying strata and at surface.

Possible methods for looking for flawed wellbore migration are:

- Thermal anomalies (hot fluids expelled from depth, or cold areas in shallow zones where CO_2 flashes to gas). Can be done though casing
- Noise anomalies - Can be done though casing
- Pressure anomalies - requires perforations
- Geochemical anomalies - requires perforations.
- Soil gas methods near surface (methane, CO_2)
- Augmented soil gas/aquifer surveillance methods (noble gases/isotopes, tracers)

Next actions

(1) BEG estimate sensitivity of these methods for reservoirs in question against the 99% retained over 1000 years standard. Work on concept of proving the container prior to addition of anthropogenic CO_2 – using current perturbation to assess for current migration. Feasibility assessment for which we need basic groundwater including depth to water and soil data.

(2) Discuss with Denbury field staff what wells could be used for above zone assessment - near reservoir depth both during early stages of development and during flood, groundwater wells.

(3) Resolve perspective on the soil gas in these fields.

(4) Develop a detailed “shopping list” request for Sandia to collect needed cost/vendor data.

(5) Finalize plan for proposal.

(6) Finalize budget for proposal.

NEPA activities

This review is provided as the bounding conditions to be considered in NEPA review.

These activities are possible, and not firmly selected.

- Access 1 to 10 existing wells, run various types of wireline wellbore integrity logs (temperature, noise, CBL, USIT, RAT). Select one or more wells not planned for production for plug back/set bridge plug to above-reservoir zone and perforate above zone (presumably in a permeable, "producable" oil, gas or water zone) with a workover rig, produce well with N2 lift to clean formation fluids (several hundred barrels). Completion must allow current geochemical samples and high frequency static fluid pressure. (Surface readout least expensive, downhole certainly possible, but more expensive) Consider simple (pressure transducer to measure fluctuation in static fluid column) and complex, for example Westbay sampler (http://www.slb.com/content/services/additional/water/monitoring/multilevel/westbay_multilevel_well.asp) or Ella G Lees 7 type completions. Record data via data loggers, real time phone system or satellite uplink.
- Soil gas monitoring - numerous (100?) shallow (20 ft deep) boreholes below active soil zone. Install PVC pipes for soil gas wells, install weather station. Define depth the water, may preclude this approach at Hastings. Location inside lease footprint as defined by active and P&A wells. Hastings – Add PFT's to injected CO_2, detect at surface near producers and in oil gas and groundwater wells. This would require several mobilizations because of uncertainty about transport speed.
- Ground water surveillance – access to about 20 existing or new drill (100-200 ft deep) groundwater wells, cemented in PVC casing with surface protection box. Develop wells so that they can produce groundwater (100 barrels). Location inside footprint plus several up-gradient and several down gradient (off pattern) wells. Noble gas, isotope labs.

NEPA activities

We will need to identify labs and do NEPA forms of them also.

NEPA activities

Similar to above, however add well-based geophysics to list of possible techniques. Might need kill fluids, or to plug back existing well as monitoring well (if one is available) above reservoir.

Off-structure or out of compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood

In EOR, injection is mostly balanced by extraction, so that the area of elevated pressure is of limited size, which has not in the past been of much concern. However, the prospect of areas where injection will now be for EOR, or after EOR has ceased (disposal only) has elevated concern within DOE and EPA about management of the size of the CO_2 plume and the size of the area of elevated pressure. It would therefore be wise in a competitive proposal to document the pressure elevation in the reservoir but outside of the flood and the maximum expected extent of CO_2 migration.

Several techniques are possible to document the two areas (elevated pressure and extent of CO_2):

(1) Direct measurement though wells. Repeat measurement of bottom hole pressure under shut in conditions and measurement of fluid saturations via sampling or (in new wells with good open hole logs) logging. This could be done by drilling one

or more future injectors early, and using them as observation wells for most of 2014-15 period before conversion to injection. (these are off structure or away from initial patterns?)

(2) Model –matching, assuring that the ultimate fate of CO_2 over 1000 years is constrained depends on good model-match during early stages of flood. Improve model – collect any needed data such as PVT, end point residual saturation, cap pressure, core porosity and permeability. (Do tar mats, ROZ areas or original water legs have a material impact on the real perm data? BEG needs to define these as part of the model when investigating plume growth beyond the original oil/gas zones)Add data needed to improve history match especially with regard to DOE expectation of tracking injected CO_2 – injection and production profiles, logging program. Update model as needed with observations during flood. (flow model only as good as the static geo model.)

(3) Indirect geophysical measurements - surface deformation via, tilt, GPS and InSAR, downhole tilt, repeat VSP or surface 2-D or 3-D though transects of the plume, to document maximum lateral extent. The choices will be limited because of previous activities, and at Soso by depth.

Next actions

(1) Discuss with Denbury drilling short-term observation wells (future injectors drilled ahead of schedule) Possible? Need to make sure these hit the 2011 or 12 budget ahead of the planned work in 2013 or 2014, best argument is that they are accelerated wells that will be needed anyway.

(2) Discuss model situation with Denbury – What exists? Who will do this work? Ongoing deterministic model in Soso, simplified, being developed by Denbury's Reservoir Simulation group.

(3) Sensitivity/feasibility of using focused geophysics for plume and pressure tracking.
(4) Refine approaches
(5) Look for cost estimates
(6) Final proposed elements
(7) Final costs for budget

APPENDIX 8

Phase 1 SOPO Task 1.5.4.3
Final MVA Plan and Detailed Budget

Gulf Coast Carbon Center – Report to Denbury on MVA Planning for FOA 15

Report Type:	Report and documentation of milestone completion
Report number :	C1.5.4.3
Report title:	Final MVA plan and detailed budget - Soso
Completion Date:	March 22, 2010
Report Issue Date:	April 11, 2010
Submitting Organization:	Susan D. Hovorka, Principle Investigator, Gulf Coast Carbon Center Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Comment: Report presented here is after Denbury review and revision as of April 14, 2010.

Phase 1 Task C1.5.4.3

Final MVA Plan and Detailed Budget - Soso

Prepared for:
Denbury Resources

Report by Susan D. Hovorka

April 15, 2010

Bureau of Economic Geology
John A. and Katherine G. Jackson School of Geosciences
The University of Texas at Austin
Austin, Texas 78713-8924

Proposed Monitoring, Verification and Accounting (MVA) Plan for Anthropogenic CO_2 injected for CO_2 enhanced oil recovery (Soso Field)

Introduction to MVA plan

CO_2 injected for EOR is the best known and therefore lowest risk process available for geologic sequestration. The effectiveness of the seal and trapping structure in confining the fluids (oil and gas) over geologic time has been demonstrated directly by hydrocarbon accumulation. Injectivity and effective capacity have been documented by previous fluid handling during production and water injection. Permitting and negotiation of land and pore space access follow well known processes with low risk. Injection of natural CO_2 into many parts of Soso Field has been underway for several years already; containment of the structure is already demonstrated prior to beginning injection of anthropogenic CO_2 (CO_2-A) injection.

Previous studies focused on sequestration in an EOR context provide precedents for MVA design. These include the Weyburn project conducted at EnCana's flood in Saskatchewan, the BEG-led study as part of the Southwest Regional Carbon Sequestration Partnership (SWP) of the results of more than 30 years of CO_2 injection from EOR at Kinder Morgan's SACROC Field in Scurry County Texas, and the currently underway BEG lead multi-institutional study of large volume (>1 Million ton/year) injection at Denbury's Cranfield Field, Adams-Franklin Counties, Mississippi.

Currently, CO_2 from any source injected for CO_2 enhanced oil recovery (EOR) is regulated under UIC class II. In Mississippi, the Mississippi Oil and Gas Board has primacy and requires a number of monitoring, accounting, and reporting activities to bring the field under flood and which are required periodically during the flood. Protection of groundwater resources (underground sources of drinking water [USDW]) is the main focus of the class II regulations. In addition, Denbury has developed, through a decade of experience with EOR in Mississippi, a number of commercial best practices that are used to control the subsurface movement of CO_2 and manage elevated pressure in order to optimize the performance of the flood and minimize cost and risks. It is unclear if additional monitoring and reporting activities will be required for EOR in the future, or to what the extent of these activities would be. The goals of the research monitoring, verification and accounting (MVA) program proposed here are therefore, based on uniting elements of the existing regulatory monitoring requirements and existing best practices with a number of proposed and suggested processes that are being considered for future application to CO_2 injected under various possible future regulatory or credit trading conditions. Table 1 shows documents with proposed and suggested future MVA processes reviewed during compilation of this research MVA plan.

Table 1. Documents considered in preparation of the research monitoring, verification and accounting (MVA) program

Document	Source	Status
Mississippi Oil and Gas Board rules for EOR	MSOGB Statewide Rules and Regulations Rule 63. Underground Injection Control	in effect
Denbury Commercial Best Practices	Denbury	in effect
EPA Draft Rules	http://www.epa.gov/safewater/uic/wells_sequestration.html Comment Period Closed	Proposed 2008
World Resources Institute CCS Guidelines Report	http://www.wri.org/project/carbon-capture-sequestration	NGO overview document

The current requirements for Class II injection and commercial best practices in managing a CO_2 floods are the foundations of an MVA plan. No federal or state regulatory agency has proposed a change in rules for CO_2 EOR, so that the current regulations that govern injection of anthropogenic CO_2 for EOR are presumed to be those regulating the project injection. It is, however, possible under some scenarios that future rules for handling CO_2 could result in a change of standards for MVA applied to EOR, for example to avoid EOR counting as a source of emissions. The research goals set for this plan, therefore, are (1) to test the extent to which current commercial practices (as required by regulations for fluid injection into productive reservoirs under state law plus commercial best practices) can meet possible future MVA expectations, (2) to test novel MVA approaches to see if they increase confidence and otherwise add value to a EOR + sequestration project, (3) provide adequate budget and flexibility in case regulatory requirements change prior to the end of the project period.

A team comprised of three named groups (Table 2) will conduct the research MVA plan. Each named group will have subcontractors working for them; these subcontractors are not named in the proposal, however costs are based on quotes and extensive past experience with contracting similar services in similar settings. Costs include normal percentage of field work related costs beyond the minimum costs, and also reflect cost uncertainties in labor, fuel, commodities over the project time period.

Table 2 MVA plan responsibilities

Group	Responsibility	Reporting	Budget
Denbury	Conduct commercial MVA activities, remediation in response to any evidence of non-containment	Report results to document the effectiveness of these activities	Commercial and remediation activities are done as part of commercial project, not in proposal budget
Denbury	Support research MVA activities where these activities fit in Denbury's core competency, for example contract geophysical activities, review BEG results prior to submission	Report results through BEG research team	20% Denbury cost 80% Federal cost. Characterization data for reservoir modeling study is provided as in kind (no cash) cost share.
Sandia Technologies LLC	Support research MVA activities where these activities require extensive supervision (e.g. specialized MVA surveys and equipment installation)	Contribute results to research plan through BEG team	20% Denbury cost 80% Federal cost
Bureau of Economic Geology	Develop reservoir and area of elevated pressure for prediction of pressure and fluid evolution during and 1000 years beyond project period, risk assessment, MVA research design, oversight of research data collection, conduct near surface data collection, integration of research results	Report results of modeling and risk assessment, submit updated MVA plans and costs at each phase, report interim results, and at project conclusion report integrated MVA. Results to be reviewed by Denbury and submitted by DOE	20% Denbury cost 80% Federal cost

In the following sections, we define: (1) the schedule of activities, (2) the current state of site characterization and capacity assessment, (3) the current assessment of uncertainties that lead to assessment of risks and guide the research MVA plan, (4) the commercial monitoring activities that provides the standard for the research MVA plan, and (5) the research MVA plan that tests the effectiveness of the commercial plan and several novel approaches that may extend the level of confidence beyond the commercial activities. This is followed by a scope of work detail in the tasks divided by project phase and task number with a reporting plan, a cost justification, experience of key participants, and budget.

Schedule of Phase 2 activities

MVA activities are coordinated to match the stages of development of the capture facility as shown in Table 3.

Table 3 MVA project phases aligned with capture facility phases.

Phase	Capture facility Phase	MVA phase
2A	Design*	Site characterization including current field measurements, predictive fluid flow and pressure modeling, risk assessment, additional tool specification, experience increase as a result of ongoing injection, learning from other projects elsewhere
2Adecision	Go/No Go decision	Revised MVA conceptualization and reallocation of funds as needed to coordinate with revised expansion plan
2B	Capture facility construction	Well workover and new drills in patterns including selected advanced patterns, baseline data on soil gas, groundwater, and subsurface pressure, fluid composition and rock property data collected, baseline geophysics and well logging, input data into predictive model, revised risk assessment.
2B decision		Revised MVA conceptualization and reallocation of funds as needed to coordinate with revised expansion plan
2C	Demonstration CO_2 production from capture facility	Anthropogenic CO_2 injection, time-laps MVA data collection
2C Overview		Evaluation of results of MVA program, revised model runs showing model match, comparing the effectiveness of the commercial program to the research program in documenting effectiveness and permanence of storage. Recommendations for future MVA at EOR settings.

**Commercial proprietary non-funded data utilized to refine fluid flow and pressure modeling may be withheld from public information.*

2A Design phase

The lead tasks of the design phase are integration of commercial site characterization data followed by predictive fluid flow and pressure modeling leading to an improved assessment of risk of non-retention. Denbury is already several years into commercial development of Soso Field for CO_2 EOR flood using natural CO_2 from Jackson Dome. Current injection in Soso is into the Rodessa Formation and parts of the underlying Bailey sandstone; future injection will be into the undeveloped parts of the Bailey. The research MVA project will focus on the Bailey expansion area Denbury's experience in "demonstrating the container" will greatly reduce uncertainties in developing injection patterns to be used in the project area when anthropogenic CO_2 (CO_2-A) is available. Because the Soso Field is in an ongoing EOR operation, it is expected that a NEPA CX or a waiver will be obtained to begin tests to determine sensitivity and feasibility of proposed soil gas, groundwater, and well-bore integrity methods. BEG has planned re-entry of two idle wells or new drills to a selected above-zone interval to determine the current pressure distribution during this phase. Any adjustments needed to match commercial field development to the CO_2-A injection plan(s) will be accommodated. In addition, learning from other projects conducted elsewhere as part of DOE's and international programs, as well as reliance on Denbury's experience in other fields will be part of the design phase. At the end of the phase, BEG, in consultation with Denbury, will prepare a report containing an updated risk assessment, modifications recommended in MVA system, and corresponding adjustments in cost.

2B Construction Phase

In this phase, preparation for injection of CO_2-A into additional patterns in the Bailey will be completed as part of Denbury's commercial field development operations. Modification of injection, production, and monitoring wells will be permitted through the MS OGB. Well workovers including selected wells that will be used as access points to monitor ahead of the active injection, baseline data on soil gas, drilling new groundwater wells and sampling them, and subsurface pressure, and fluid composition will be collected and input into a predictive model, allowing a revised risk assessment. At the end of the phase, BEG in consultation with Denbury will prepare a report containing a revised MVA conceptualization and reallocation of funds as needed to coordinate with revised build out plan.

2C Demonstration

During this phase it is anticipated that CO_2-A will be available from the capture facility. The availability of natural CO_2 will allow flexible staging, as any source of CO_2 can be used to demonstrate containment. As injection starts in the new patterns in the Bailey, the commercial monitoring program will track the CO_2 injected and recycled, and the performance of the reservoir and wells in retaining CO_2. The research program will collect time-lapse data testing alternative and possibly high-resolution techniques for documenting that the CO_2 is retained in the injection zone and in the predicted flood area, and that pressure is below that determined to be safe. At the end of this phase, BEG in consultation with Denbury, will prepare a report evaluating of results of the research MVA program, revised model runs showing model match, comparing the effectiveness of the commercial program to the research program in documenting effectiveness and permanence of storage. Recommendations for future MVA at EOR settings.
The research monitoring program will end at the end of the demonstration phase. The objective of the research MVA program is to increase confidence in commercial monitoring program and in the permanence of CO_2-A storage.

.

Initial characterization and capacity assessment

In this section we review the current state of site characterization and capacity assessment, emphasizing the current assessment of uncertainties that lead to assessment of risks and guide the research MVA plan.

Characteristics of the West Soso Bailey injection reservoir

A site within Soso Field, in Jasper, Jones, and Smith counties, Mississippi, located on the northern rim of the Interior Mississippi Salt Dome Basin, is the location for the proposed research MVA program (**Figure1**). Sandstones, shale, and conglomerate comprise most of the Lower Cretaceous in the Interior Mississippi Salt Basin. The sediments were derived mainly from the southern Appalachian region, including the Central Mississippi Uplift. They were deposited in oxidizing coastal plain environments, in large delta systems, and in the shallow, near shore part of an epicontinental sea. The Lower Cretaceous section is approximately 6000' thick at Soso Field (8,450' – 14,450').

At Soso, the target Sligo (Bailey Sand) and Rodessa Formations comprise the approximately 1000' thick Lower Glen Rose sub-group of the Trinity Group, within the Comanchean Series of the Lower Cretaceous, (**Figure 2**). The Lower Glen Rose has long been an exploration target in South Mississippi after almost 60 years of hydrocarbon production. The Sligo has produced from 50 Mississippi fields, and the Rodessa from 78 fields.

The Sligo and Rodessa formations are composed of a series of river-dominated delta systems, and reworked delta front sandstones. The Rodessa reservoir rocks are sealed by the Upper Glen Rose evaporitic Ferry Lake Anhydrite and the transgressive marine shale of the Mooringsport formations. The Sligo Formation is underlain by the Coahuilan Hosston Formation.

The Soso Field Unit consists of 6,460 acres and has active CO_2 EOR floods in the Rodessa (east side of the field) and Bailey (west side of the field). The project area for anthropogenic injection and the focus of the research MVA project is planned for the future Bailey flood on the east side of the field. The research project area comprises 988 acres within the unit. When the Bailey flood is completely developed, Denbury anticipates that it will have 9 CO_2 Class II injection wells and 22 producing wells.

Soso, discovered in 1945, has produced over 60 million barrels of oil, 169 billion cubic feet of natural gas, and 87 million barrels of saltwater from 110 wells. The Rodessa -11,180' and Bailey -11,701' reservoirs have produced approximately 30 million barrels of oil, or 50% of the oil in the field, (**Figure 3)**. The Mooringsport Shale and the Ferry Lake Anhydrite, **(Figure 4)** are the overlying 450' thick hydrocarbon seal. Whole core analyses document the above reservoir quality sands to possess average porosities of 16.8% – 17.4%, and original water saturations of 16.4% - 17.9%. The core data also indicates average permeabilities ranging from 170.9 millidarcies to 272.7 millidarcies.

The productive limits of the Bailey -11,701' Sand are approximately 2648 acres. The structure map illustrates an unfaulted, elongated anticline with gentle 1 degree flank dips (**Figure 5**). The major axis, striking in a northwesterly-southeasterly direction, is approximately 6 miles in length, while the minor axis is approximately 2 miles in length. Structural uplift is approximately 110 feet on the Ferry Lake Anhydrite marker. The structure is thought to be underlain by an inter-domal or residual high, surrounded by areas of significant salt withdrawal into adjacent salt domes. This type of sediment-cored anticline is also known as a “turtleback” structure. A net pay isopach (thickness) map of the Bailey -11,701’ A5 sand is shown in (**Figure 6**) and demonstrates the sand is well developed and fairly continuous over the entire area. The average oil sand thickness for the Bailey -11,701’ sand is 33‘, and for the Rodessa -11,180’ sand is 32’. The original Bailey oil/water contact was estimated at -11701’ and the original Rodessa oil/water contact was mapped at -11180’. Original reservoir pressure for the Bailey was 5553 psi and for the Rodessa 5075 psi. Current Bailey reservoir pressure is approximately 6200 psi, and the Rodessa 5600 psi due to active CO_2 injection.

Reservoir drive for both the Bailey and Rodessa sand packages was primarily a weak to moderate water drive. The Bailey was not waterflooded; an attempt to partially waterflood the Rodessa had limited success.

Soso’s field limits have been delineated with the drilling of over 110 wells; 86 of these wells drilled through the productive Rodessa and Bailey reservoirs. The total productive ac- ft for these two reservoirs is 107,772 ac-ft.

Expansion of the EOR Project for anthropogenic CO_2

CO_2 is currently being injected into the Rodessa -11,180’ and Bailey -11,701’ intervals in 22 wells, and began production in March 2007. Currently, 26 CO_2 Class II injection wells are planned for the Soso CO_2 EOR project. The preliminary plans for the CO_2 EOR project will utilize those 26 injectors with an inverted 9 spot pattern configuration. The CO_2 EOR project will involve injecting approximately 160 MMSCFD of CO_2 at a maximum injection pressure 3100 psi to pressure up the Bailey reservoir to approximately 6400 psi, and the Rodessa reservoir to approximately 5800 psi. Current CO_2 injection rates into the 22 Bailey/Rodessa injectors range from 2.0 MMCFGD to 12.0 MMCFGPD with the average rate of 7.1 MMCFGPD. The Soso CO_2 EOR facility is currently capable of injecting up to 160 MMCF/D of CO_2 and processing 132 MMcf/d, 6000 BOPD and 24000 BWPD. **Figure 7** shows the historical oil production and the forecasted remaining production for the field.

With a tertiary recovery factor of 17%, the EOR CO_2 requirement is estimated to be 261 BCF for the field.

Soso – expansion to accommodate CO_2-A

At the time of CO_2 -A arrival, additional injection opportunities into the in the Bailey interval are planned to be available. In the event that other CO_2 EOR sites are more viable when CO_2-A becomes available, Denbury may use such other CO_2 EOR sites for the research MVA project. The preliminary plans for the expansion of the CO_2 EOR project in the Bailey interval will utilize 9 injectors with an inverted 9 spot pattern configuration. The CO_2 EOR project will involve injecting approximately 78 MMSCFD (4 million metric tons) of CO_2 at a maximum injection pressure 3100 psi to pressure up the Bailey reservoir to approximately 6400 psi.

***Injectivity* -** Current CO_2 injection rates into the 16 Bailey injectors (Bailey flood - west side of field) ranges from 3.3 MMCFGD to 13.1 MMCFGPD with the average rate of 8.2 MMCFGPD. The CO_2- A can be accommodated in the expansion area as well as part of Denbury's CO_2 requirements for the current patterns. CO_2-A will be co-mingled with natural CO_2 from Jackson Dome and injected throughout the field. However, the research MVA program will focus on the expansion area.

Storage Capacity

Table 4 shows estimates of original oil-in-place and CO_2 capacity for the Soso Bailey reservoirs. Approximately 21 million barrels oil existed at discovery; by a simple estimate of replacing this oil volume with CO_2, 39 BCF or 2.3 million tons CO_2 can be sequestered into the hydrocarbon pore space. The estimated CO_2 purchase rates by month for the first 3 years of injection into the Bailey are shown in **Table 5**.

Table 4. Original oil-in-place and CO_2 capacity for the Soso Bailey reservoirs

Zone	Area (acre-ft)	Porosity (decimal)	Swi (decimal)	Boi (RB/STB)	OOIP (Mbbls)	CO_2 Capacity (MMcf)
A5	12,837	0.174	0.164	1.328	10,909	20,945
B	11,662	0.174	0.164	1.328	9,910	19,027
Bailey Total	**24,499**				**20,819**	**39,972**

Table 5 is the estimate of CO_2 purchase volumes for the first 3 years of anthropogenic supply. This forecast is dependent upon actual delivery date of the CO_2, capital expenditure levels, and timing for completion of Bailey activities. It is currently assumed that January 1, 2015 will be the date of first CO_2–A delivery. Development activities are estimated to take 2 years from 2015-2016.

Table 5. Estimated of CO_2 purchase volumes for the first 3 years of anthropogenic supply

Month	CO_2 Purchased Volumes (MMcf)	CO_2 Purchased Volumes (MMcf/d)	Cumulative CO_2 Purchased Volumes (MMcf)	Cumulative # injectors
January-15	2,371	78	961	9
February-15	2,351	77	3,313	9
March-15	2,332	77	5,645	9
April-15	2,312	76	7,957	9
May-15	2,293	75	10,250	9
June-15	2,274	75	12,524	9
July-15	2,255	74	14,779	9

August-15	2,236	74	17,015	9
September-15	2,218	73	19,233	9
October-15	2,199	72	21,432	9
November-15	2,181	72	23,613	9
December-15	2,163	71	25,776	9
January-16	2,145	71	27,920	9
February-16	2,127	70	30,047	9
March-16	2,109	69	32,156	9
April-16	2,091	69	34,248	9
May-16	2,074	68	36,322	9
June-16	2,057	68	38,379	9
July-16	2,040	67	40,418	9
August-16	2,023	67	42,441	9
September-16	2,006	66	44,447	9
October-16	1,989	65	46,436	9
November-16	1,972	65	48,408	9
December-16	1,956	64	50,364	9
January-17	1,940	64	52,304	9
February-17	1,924	63	54,228	9
March-17	1,908	63	56,135	9
April-17	1,892	62	58,027	9
May-17	1,876	62	59,903	9
June-17	1,860	61	61,763	9
July-17	1,845	61	63,608	9
August-17	1,829	60	65,437	9
September-17	1,814	60	67,251	9
October-17	1,799	59	69,050	9
November-17	1,784	59	70,834	9
December-17	1,769	58	72,603	9

Equipment for the injection process includes a custody transfer meter to measure the CO_2 delivered to the field, CO_2 booster pumps (multistage horizontal centrifugal pumps), an injection pipeline network, a CO_2 meter to measure the CO_2 being injected at each well and the injection wellhead with the necessary pressure safety devices, shutdowns and relief systems.

Figure 1 Location of Soso field in the Mississippi salt basin

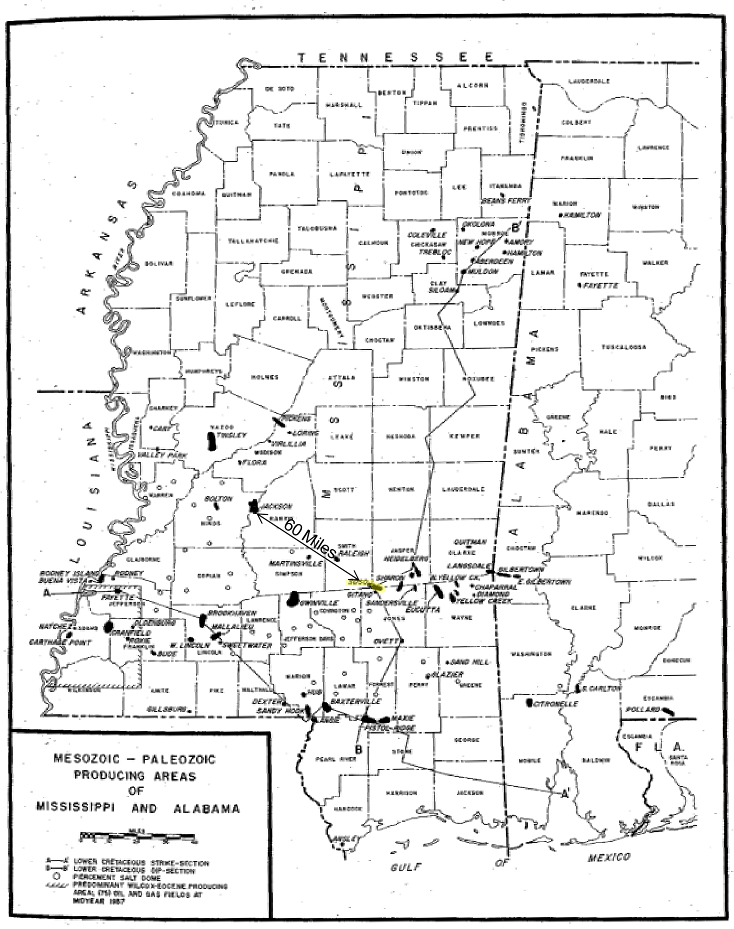

MESOZOIC – PALEOZOIC
PRODUCING AREAS
OF
MISSISSIPPI AND ALABAMA
60 Miles
TENNESSEE
ARKANSAS
LOUISIANA
MISSISSIPPI
ALABAMA
GULF OF MEXICO
FLA.

Figure 2 Stratigraphic section

SIGNIFICANT OIL AND GAS POOLS AND FORMATIONS OF MISSISSIPPI

MISSISSIPPI OFFICE OF GEOLOGY

1992

By Rick L. Ericksen and Sandra Douty

(Data current to 01/01/92)

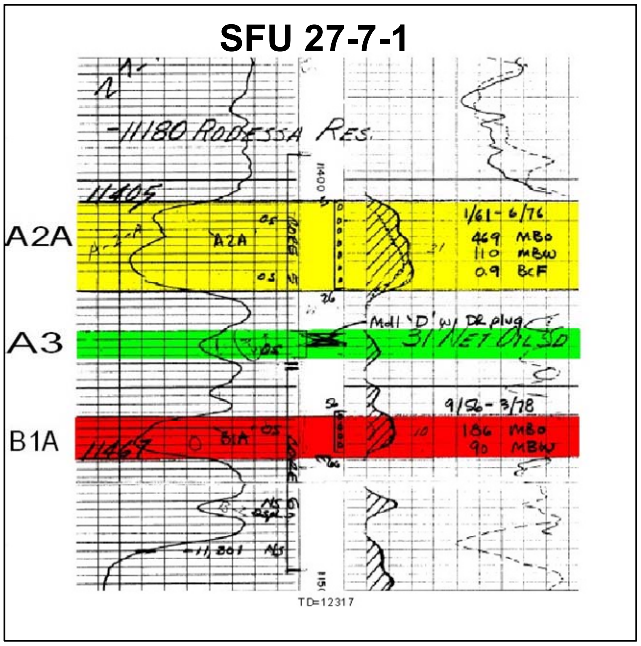
ERATHEM	SYSTEM	SERIES		GROUP	SIGNIFICANT PRODUCING AND NONPRODUCING FORMATIONS (Number of Fields)	PRODUCING ZONES OR POOLS	TYPE FIELD
CENOZOIC	QUATERNARY	Holocene				*nonproductive to date*	
		Pleistocene					
	TERTIARY	Pliocene					
		Miocene					
		Oligocene	Upper		Frio (15)	Frio Gas	White Castle
						Frio "C"	Independence
			Lower	Vicksburg		*nonproductive to date*	
		Eocene	Upper	Jackson		*nonproductive to date*	
			Middle	Claiborne	Cockfield (2)	Cockfield	Bruinsburg
					Sparta (26)	Sparta	Stanton
					Zilpha (1)	Zilpha	Kings
			Lower	Wilcox	Wilcox (362)	Wilcox	Cranfield
						numerous localized reservoir names	
		Paleocene		Midway	Clayton (1)	Clayton	Camp Shelby
	CRETACEOUS	Upper	Gulfian	Selma	Selma Chalk (18)	Selma Chalk	Jackson
						Gas Rock Woodruff	Cary Tinsley
				Eutaw	Eutaw (41)	Eutaw	Tinsley
						Brumfield Christmas City Bank Cholar Hiwanee Kirby Masonite McGraw Morrison Perry Powell Stanley Stevens	Tinsley SoSo Sharon Gwinville Chaparral Avera Heidelberg Tinsley Sharon Tinsley Tinsley SoSo Tinsley
					Eagle Ford (2)	Wilburn	Pickens
						Eagleford	Baxterville
				Tuscaloosa	Upper Tuscaloosa (15)	Upper Tuscaloosa	Gwinville
					Middle Tuscaloosa Marine Shale	*nonproductive to date*	
					Lower Tuscaloosa (156)	Lower Tuscaloosa	Cranfield
						Stringer Sands "A" Sand "B" Sand Arrington Case Denkman Dykes Main McComb Pilot Rollins Smith	 Liberty Liberty Brookhaven Brookhaven Little Creek Smithdale Mallalieu McComb Brookhaven Little Creek Brookhaven
						Massive	Brookhaven
MESOZOIC		Lower	Comanchean	Washita – Fredericksburg	Dantzler (5)	Dantzler	W. Pistol Ridge
					Washita – Fredericksburg (42)	Washita–Fredericksburg	Thompson's Crk.
						Cuevas Merit–Kennedy	Ansley Puckett
				Trinity	Paluxy (56)	Paluxy	Bolton
						Dorward Gammill McAlpin	Bolton Pistol Ridge Waveland
				Trinity – Glen Rose Sub-group	Mooringsport (34)	Mooringsport	Valley Park
					Ferry Lake Anhydrite (1)	Ferry Lake Anhydrite	Merit
					Rodessa (78)	Rodessa	Martinville
						Cox Harrington Peacock Rodessa "A" Rodessa "B" Ware	Merit Verba Merit West Raymond West Raymond Oak Grove
					James (4)	James Ls	W. Oakvale
					Pine Island (7)	Pine Island	Pool Creek
			Coahuilan		Sligo (50)	Sligo	Bolton
						Bailey Barnes Jennings Sullivan	SoSo W. Oakvale Martinville Martinville
					Hosston (81)	Hosston	Diamond
						Booth Diffrient Fleming Forbes Harper Harrington Hatton Ivy Josephine Kelly Lavon Sinclair Steele	Bassfield Holiday Creek Cistercian W. Sandy Hook Cistercian Holiday Creek Newsom Black Creek Magee Seminary Grange Carson Bassfield
	JURASSIC	Upper		Cotton Valley	Cotton Valley (43)	Cotton Valley	SoSo
						Bay Springs Sand	Bay Springs
				Louark	Haynesville (4)	Haynesville	Boykin Church
						"A" Lime	Morton
					Buckner (11)	Buckner (Hardin Lime)	W. Paulding
					Smackover (78)	Smackover	Tinsley
						Smackover A,B,&C Upper Smackover Lower Smackover Smackover Lime Smackover Sand	E. Tallahala Crk. Lake Utopia Lake Utopia Loring Johns
					Norphlet (14)	Norphlet (Denkman)	Pelahatchie
		Lower			Louann Salt	*nonproductive to date*	
	TRIASSIC				Eagle Mills		
PALEOZOIC	PERMIAN (Absent)						
	PENNSYLVANIAN				Pottsville (5)	Nason	Corinne
						Nevins	McKinley Creek
	MISSISSIPPIAN	Chesterian			Parkwood – Pennington (69)	Buskirk	Corinne
						Gilmer	Corinne
						Walker	Maple Branch
						Millerella	Greenwood Springs
						Carter	Amory
						Sanders	Thorn
						Abernathy	Reid
						Rea	Matubby Creek
					Pride Mountain (45)	Evans	Coleville
						Lewis	McKinley Creek
	DEVONIAN			Harriman	Devonian (1)	Devonian Porosity	McKinley Creek
	SILURIAN			Niagaran		*nonproductive to date*	
	ORDOVICIAN			Stones River	Stones River Dolostone (2)	"Knox–Ordovician" (Snow Zone)	Moben New Hope
	CAMBRIAN			Knox		*nonproductive to date*	
PRECAMBRIAN BASEMENT							

KEY – The first production for a particular producing pool is listed first along with the field in which this production was first established. Additional producing zones are listed in alphabetical order.

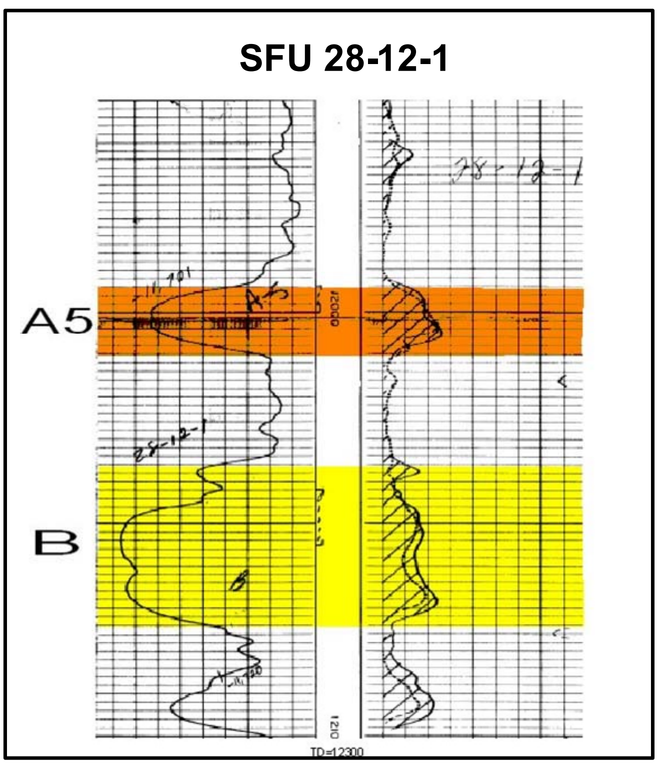
Note – The above names of producing units have been used in order to complement production reports published by the Mississippi State Oil & Gas Board. In some cases those published names may not agree with the correlations of the Mississippi Office of Geology.

Figure 3. Soso type log showing multiple injection zones

Rodessa Type Log

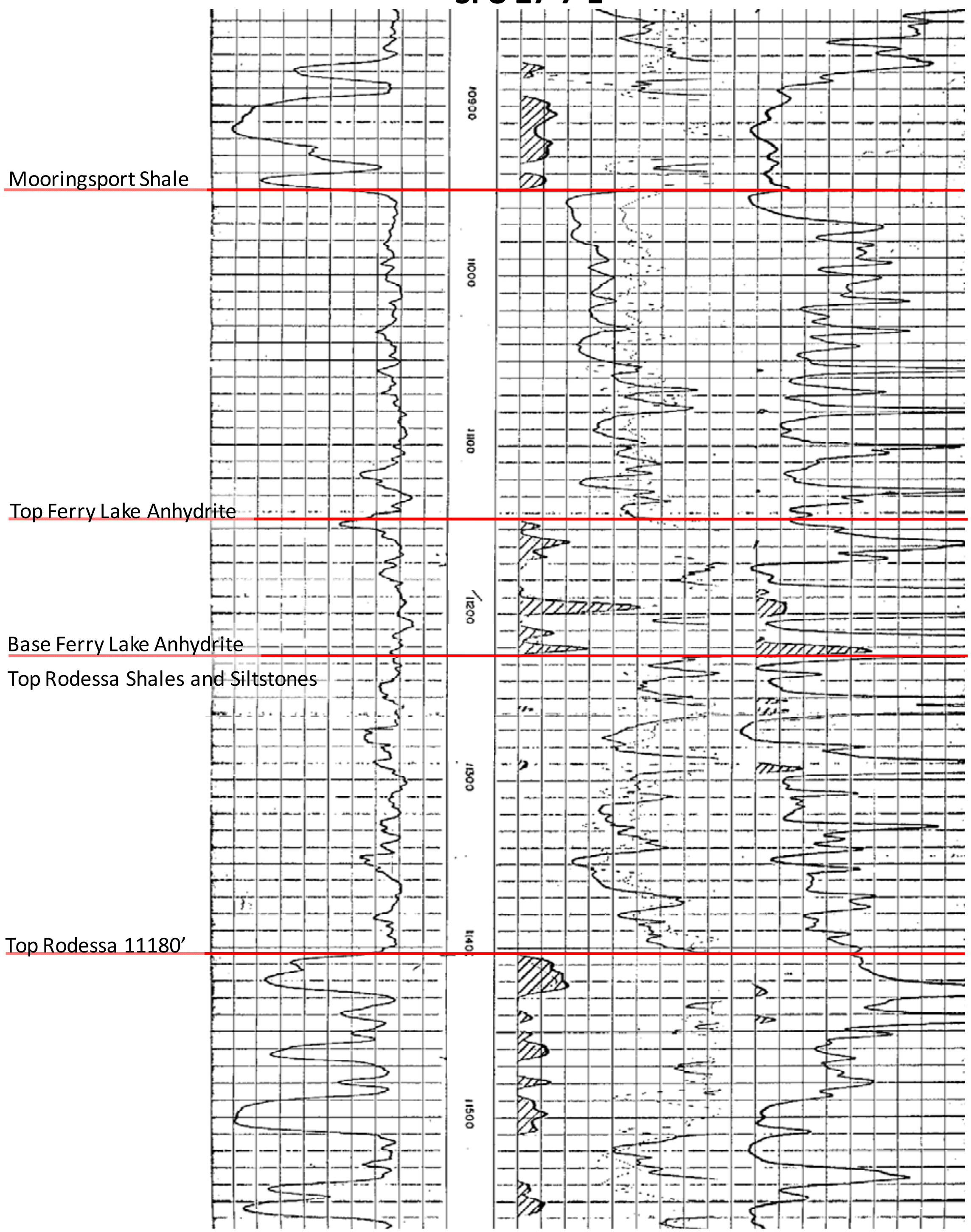


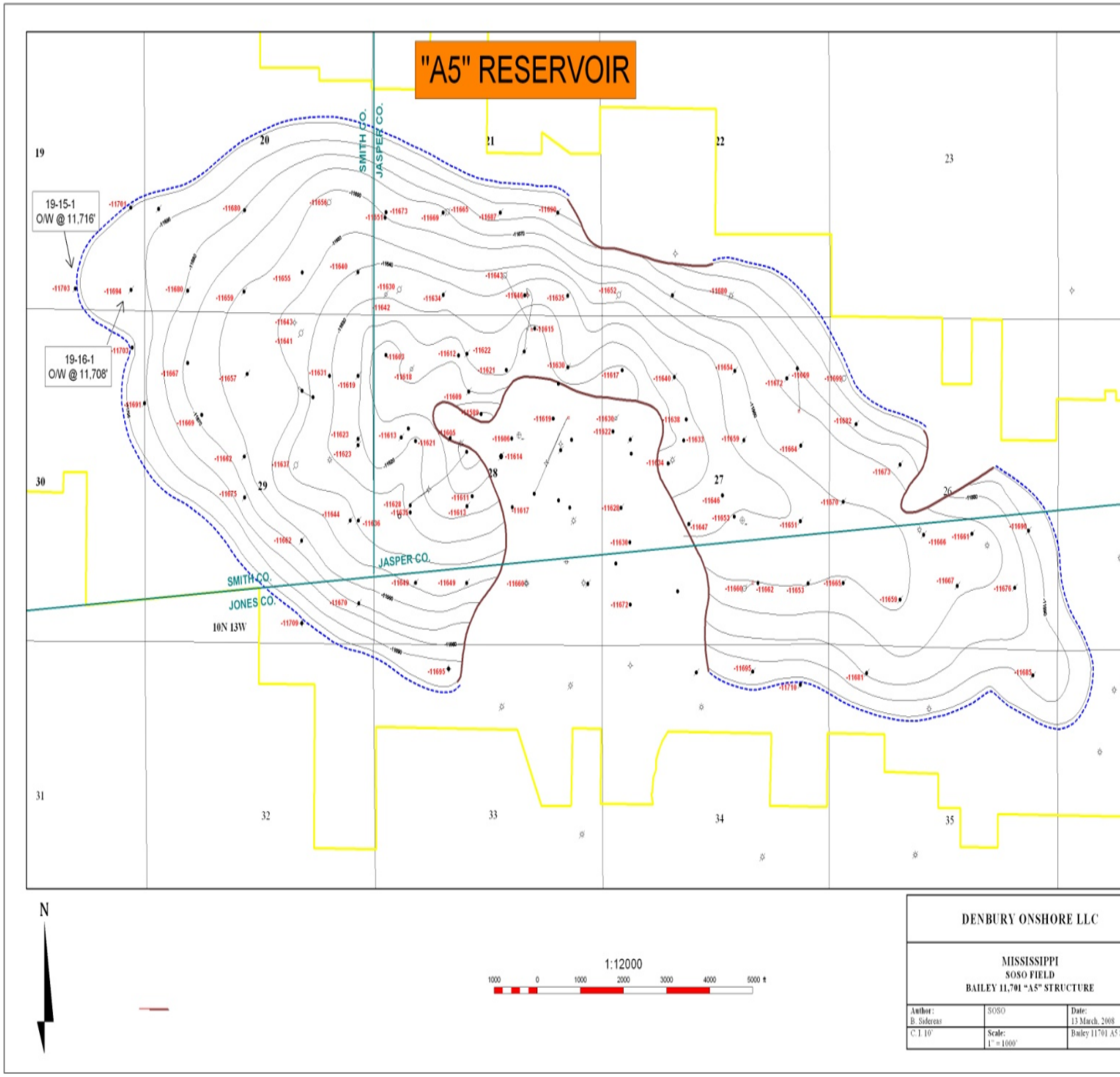
Bailey Type Log



Type Log for Hydrocarbon Seal

SFU 27-7-1




"A5" RESERVOIR
SMITH CO.
JASPER CO.
JONES CO.
19-15-1
O/W @ 11,716'
19-16-1
O/W @ 11,708'
10N 13W
N
1:12000
1000 0 1000 2000 3000 4000 5000 ft
DENBURY ONSHORE LLC
MISSISSIPPI
SOSO FIELD
BAILEY 11,701 "A5" STRUCTURE
Author:
B. Sidereas
SOSO
Date:
13 March, 2008
C.I. 10'
Scale:
1" = 1000'
Bailey 11701 A5

-

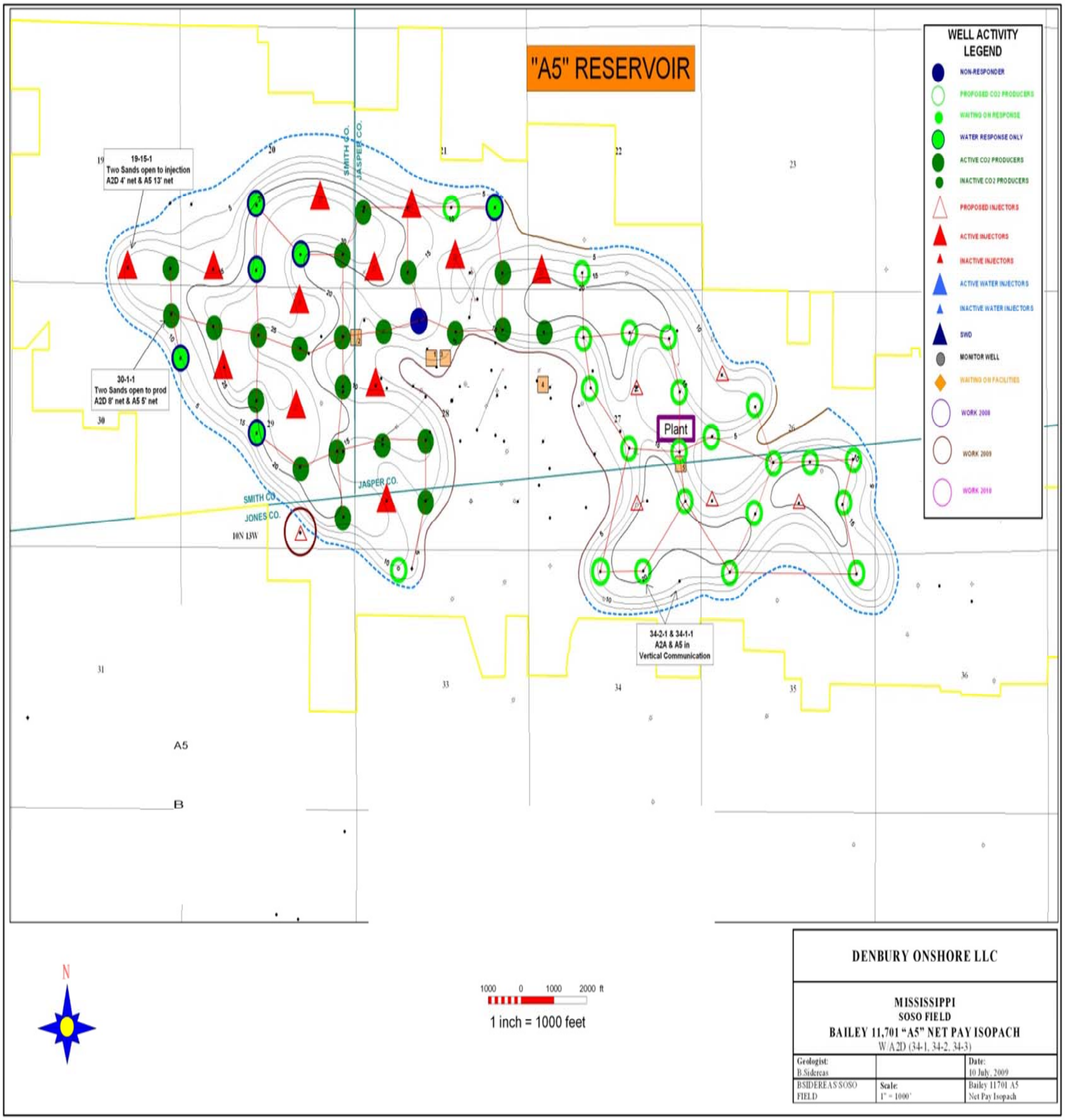
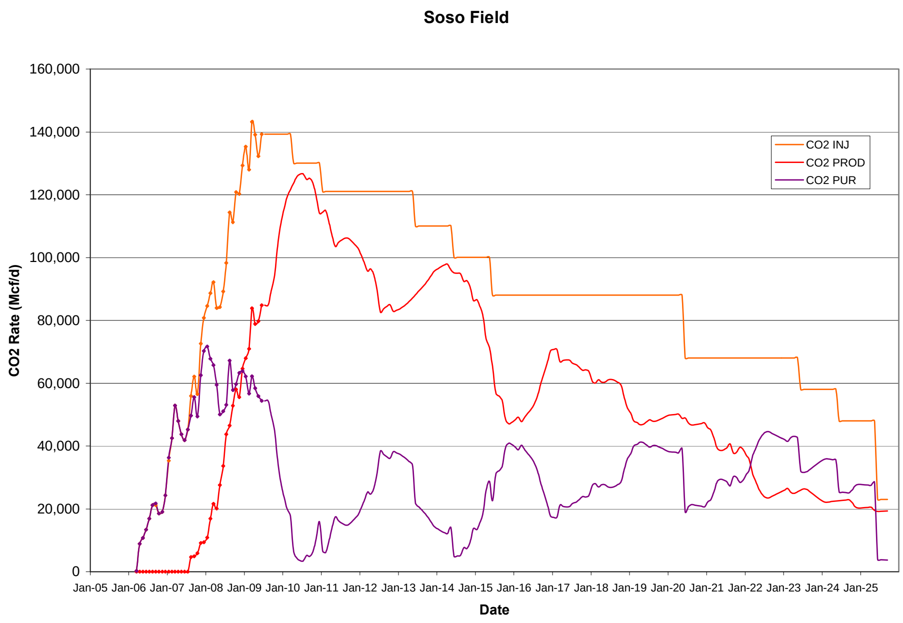

"A5" RESERVOIR
WELL ACTIVITY LEGEND
NON-RESPONDER
PROPOSED CO2 PRODUCERS
WAITING ON RESPONSE
WATER RESPONSE ONLY
ACTIVE CO2 PRODUCERS
INACTIVE CO2 PRODUCERS
PROPOSED INJECTORS
ACTIVE INJECTORS
INACTIVE INJECTORS
ACTIVE WATER INJECTORS
INACTIVE WATER INJECTORS
SWD
MONITOR WELL
WAITING ON FACILITIES
WORK 2008
WORK 2009
WORK 2010
19-15-1
Two Sands open to injection
A2D 4' net & A5 13' net
30-1-1
Two Sands open to prod
A2D 8' net & A5 5' net
34-2-1 & 34-1-1
A2A & A5 in
Vertical Communication
Plant
SMITH CO.
JASPER CO.
JONES CO.
10N 13W
A5
B
N
1000 0 1000 2000 ft
1 inch = 1000 feet
DENBURY ONSHORE LLC
MISSISSIPPI
SOSO FIELD
BAILEY 11,701 "A5" NET PAY ISOPACH
W/A2D (34-1, 34-2, 34-3)
Geologist:
B.Sidereas
Date:
10 July, 2009
BSIDEREAS\SOSO
FIELD
Scale:
1" = 1000'
Bailey 11701 A5
Net Pay Isopach

Figure 7 Historical injected volumes and the forecasted future CO2 rates.



Field expansion to accommodate CO_2-A

Two maps (Bailey A5 and B intervals) have been generated showing the status of wells and Denbury's preliminary patterns. Nine (9) patterns are shown for the A5 sand and six (6) patterns for the B sand. A total of 22 producers and 9 injectors are shown. Producer and injectors identified are shown on table 6.

Table 6 Preliminary Concept of Soso Bailey expansion development to accommodate CO_2-A

Producers

No.	Well	Zone
1	22-14 #1	A5
2	27-3 #1ZB	A5, B
3	27-6 #1	A5, B
4	27-11 #1	B
5	27-14 #1	B
6	27-10 #1	A5, B
7	34-4 #1	A5
8	27-2 #1	A5, B
9	34-2 #1	A5
10	27-1 #1	A5
11	27-8 #1	A5, B
12	27-9 #1	A5, B
13	27-16 #1	A5, B
14	26-12 #1	A5, B
15	26-6 #1	A5

Injectors

No.	Well	Zone
1	22-13 #1	A5
2	27-5 #1	A5, B
3	27-13 #1	B
4	22-15 #1	A5
5	27-7 #1	A5, B
6	27-15 #1	A5, B
7	26-5 #1	A5, B
8	26-13 #1	A5, B
9	26-15 #1	A5

16	26-11 #1	A5
17	26-14 #1	B
18	35-4 #1	A5
19	26-10 #1	A5
20	26-9 #1	A5
21	26-16 #1	A5
22	35-1 #1	A5

In addition these injectors and producers, other wells will be used to monitor CO_2 movement in the reservoir. Some wells will monitor the aquifer and others will monitor the freshwater sands inside and outside of the patterns.

Figure 8 Bailey A5 development plan

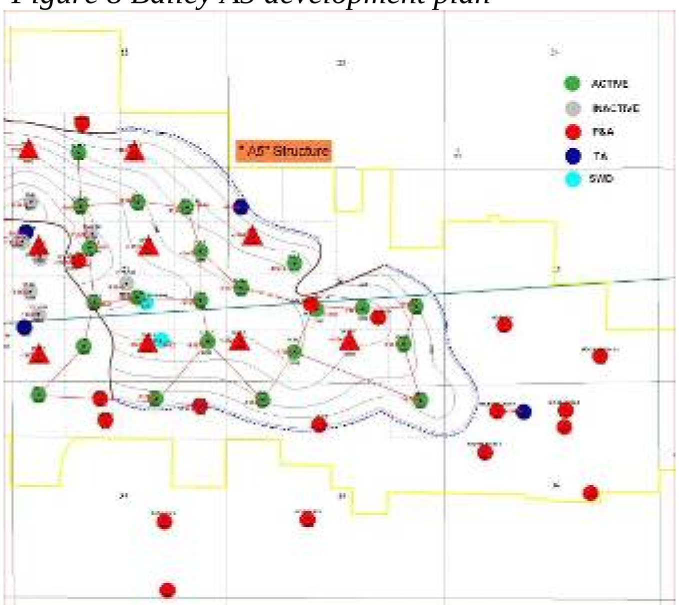
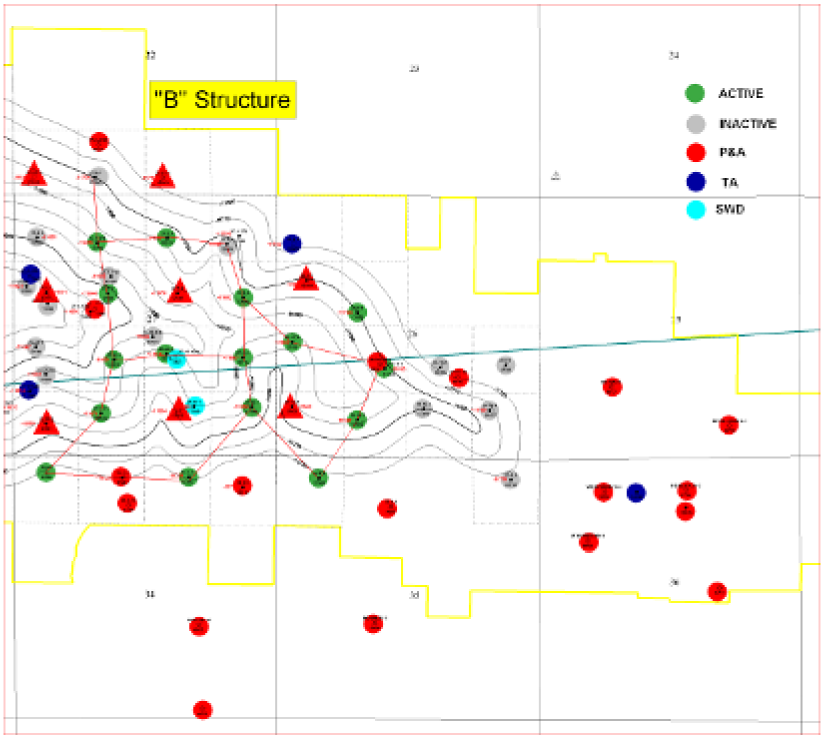


Figure 8 Bailey B development plan



Initial risk Assessment linked to monitoring plans

Over the past 30 years EOR projects have been conducted in the US with essentially no adverse environmental effects. Injection into known traps with well known reservoir properties greatly reduces uncertainties and resulting risk. Active management of pressure via production and operator oversight to optimize the flood also are large risk-reduction measures. CO_2 injected as part of EOR projects is not released to the atmosphere except in instances of equipment upsets or well upsets. Based on review of the data available at this time, there remain areas of uncertainty. For the purposes of this plan, we consider the following possible elements of future MVA expectations that might differ from or exceed the expectations of current Class II and commercial best practices:

(1) Document through characterization the geologic conditions that are expected to retain injected CO_2 for periods long enough to benefit the atmosphere. The standards desired for sequestration are not codified, however the IPCC target that a well selected site should retain 99% CO_2 in the reservoir over 1000 years meets or exceeds DOE's expectations. The atmospheric benefit is not a requirement of the proposed rules of the Mississippi Oil and Gas Board.

(2) Execute a formal assessment of areas of uncertainty through a process such as Risk Assessment. This write up reviews the results of the initial risk assessment.

The research MVA program will focus on areas of uncertainty in retention of fluids in the injection zone. As this oil field has retained oil and gas for geologic time, BEG considers that it is documented the natural seal is adequate to support a significant CO_2 column with migration only at diffusion rates. Risk assessment and experience indicates that the most probable migration paths are (1) non-sealing well completions because of undetected construction flaws or damage and (2) off-structure or out of compartment migration of CO_2 or brine as a result of elevated pressure into areas not controlled as part of the flood. A MVA program is outlined for each of these risk areas and is linked to a mitigation or management process that will document that the CO_2 injected is permanently stored.

Performance of wells

As part of Denbury's commercial operations, prior to the start of the flood, every active, inactive and plugged and abandoned well will have its mechanical status defined prior to the start of the flood. Wells deemed as unable to contain the injected CO_2 in the reservoir will be remediated by Denbury prior to initiating CO_2 injection.

After CO_2 injection starts, both the commercial and research activities defined in the MVA program will be used to monitor the mechanical integrity of each well. The commercial activities of the MVA program include monitoring the surface pressures of injectors and producers frequently, as well as, each inactive well. Wells that have significant changes in surface pressures, will have bottom-hole pressure surveys taken. If the pressure data suggests that a well may have a mechanical integrity problem, a profile survey will be run in the well. A tracer survey and temperature log will be run in an injector. A temperature log, spinner survey and capacitance log will be run in a producer. These surveys will be run in each active well every 6 months regardless of the pressure data to confirm that there is no migration of CO_2 from the reservoir via the wellbore. Surveys will be run in the inactive wells less often. However, as mentioned above, surface pressures will be monitored frequently in these wells.

Injection and production rates will also be monitored as part of commercial activities. Daily rates will be measured for each injector and test rates will be taken for each producer at least once a month. A significant change in rates may indicate a wellbore integrity issue. Logs, as defined above, will be run in a potential problem well. If a problem is identified, then the well will be remediated.

Each pattern will also have IWR's (injection to withdrawal ratios on a reservoir barrel basis) calculated monthly to help define a problem well which requires remediation. The targeted IWR for every pattern is a 1:1 ratio. If a pattern has had such a ratio of several months and the ratio suddenly changes to 2:1 or 3:1 for example, then one of the wells in the pattern has a mechanical integrity issue. The problem well will be identified using the commercial activities described above and remediated.

The task for the research program is to independently test the performance of wells to determine if the commercial approaches are adequate for purposes of storage. The research plan includes surveillance of all wells via monitoring for changes in pressure or chemistry in the above zone monitoring interval (AZMI), monitoring for changes in underground sources of drinking water (USDW – defined as above 2890' per the

MSOGB in the Soso Field), and monitoring for changes in soil gas above plugged and abandoned (P&A) wells.

Non sealing well completions

Wells that penetrate the seal are potential weak points, especially during injection. Wells that perform adequately during extraction, when they are pressure sinks, can become upwardly transmissive during injection when pressure is increased. Wells that are open can be inspected via a logging program, however wells that have been plugged and abandoned (P&A) are prohibitively expensive to reenter to inspect. The research MVA program will extend the commercial well integrity program, and test its'effectiveness.

Activities that have been included in the MVA plan:

(1) Additional logging program (e.g. temperature, tracers, high end wireline tools)

(2) Above zone-pressure monitoring – ambient and introduced fluids

(3) Near-surface soil gas and groundwater monitoring.

In east Soso, some water disposal has occurred at above the productive interval. The extent to which pressure has been elevated and geochemistry perturbed has to be measured. In addition, CO_2 injection is already ongoing in part of the Bailey. The prior water disposal and CO_2 injection can serve as pre- CO_2 injection proof of containment. Methods for assessing well integrity planned are:

1) Thermal anomalies through casing (hot fluids expelled from depth, or cold areas in shallow zones where CO_2 flashes to gas), noise anomalies through casing
2) Pressure and geochemical anomalies that require perforations
3) Augmented soil gas/aquifer surveillance methods (methane, CO_2, noble gases/isotopes, tracers)

Out of pattern migration

In EOR, pressure gradients from injectors to producers generally control most of the flow. Production history, starting with monthly injection/withdrawal ratios (IWR) is a relatively simple method of confirming the correctness of this assumption. For the research program, BEG will collect monitoring data to determine if CO_2 migrates outside the pattern to confirm the relevance of this simple method. Geophysics, VSP array will be used to map the location of the plume edge. Validation data for this site will be attained by preparing producers ahead of schedule, and using them early in the flood as monitoring points. After assumption are validated, these wells will be used for injection into additional patterns.

Monitoring activities

Denbury will conduct current commercial practices and provide nonproprietary results to the research MVA project at no cost to the project. The results of commercial practices provide the standard for the research MVA program. Denbury will provide documentation of the commercial activities described in the Scope of Work throughout the two year MVA monitoring period.

Denbury's typical EOR operation takes 100% of the produced well stream back to the recycle facility where the oil, water and gas are separated and measured. The produced volumes are allocated to each producer based on a monthly test. A sufficient number of test sites are constructed throughout each field to test each producer at least once a month. CO_2 injection is measured by meters located at each injector.

Tubing and casing pressures are measured continuously on the production and injection wells using radio transmitters which communicate back to the SCADA system. The daily CO_2 injection volumes to each injector is also measured using this system, along with wellhead and upstream pressures to the choke. The wellhead and downstream pressures to the choke will also be measured on the producing wells, thus allowing for continuous monitoring of well performance. If downstream pressure builds to high levels, relief valves will be activated to allow for bleed off of line pressure.

Tracer surveys and/or temperature logs will be run be run periodically in injectors to determine where the CO2 is being injected. Temperature logs, spinner surveys and capacitance logs will be run in producers periodically to define from which zone(s) the production is originating from. This data will be used to update the model during the two year research monitoring period. Profile surveys in the injectors and producers are expected to be conducted a minimum of twice per year. If injection and production rates do not change significantly, it can be assumed that the profiles are not changing and the frequency of these surveys can be reduced.

Once reservoir pressure has been raised to the desired operating pressure, injection and production will be balanced so that an injection to voidage ratio of approximately 1:1 is maintained. As described in the "Performance of wells" section above, these calculations will be performed on a monthly basis to show whether the pattern is over or under injecting. Remedial operations such as acidizing, re-perforating and/or other repairs will be performed on wells, if required, to maintain balanced patterns.

Research based monitoring augments the commercial monitoring through an interlocked system of collection of characterization data, modeling and risk assessment. As data is obtained, revisions will be made to our monitoring techniques and reservoir model. By the end of the two year research MVA program, the performance of the container is expected to be proven, greatly increasing confidence in storage permanence.

Scope of Work

Phase 2A, Task 1- Administrative task and subcontracting
Prior to initiation of Phase 2 activities, a number of subtasks will be completed. These are not assigned costs but past experience suggests that they may consume time.

Phase 2A, Task 2- Reservoir Modeling-Initial characterization and modeling Denbury will provide data refined for input into the reservoir model to be constructed by BEG. This data will be used to document that the flood conforms to expected plume area and pressure elevation Table 7 shows the data that will be sought and the source. Reservoir modeling for research MVA differs from commercial monitoring done by Denbury as it (1) approaches from a migration of risk perspective, to identify are uncertainties in the characterization that might lead to risk of CO_2 migrating from the intended injection area, such as unmapped heterogeneities in the reservoir, and (2) although oil is represented in the model as an important part of the system, predicted oil production will not be reported as such results are outside the scope of the study.

Table 7. Data for modeling and likely data source

Data	Source
Field history including historical production drive mechanism, water flood, historical pressures, etc	Denbury + literature search
Reservoir geometry / static model	BEG from task 1
Initial conditions (pressures, saturations, o/w contact…)	Denbury
Boundary conditions	BEG from task 1
Production tests / field tests results	Denbury*
Permeability / porosity measurements	Denbury*
Relative permeability end points	Denbury*
Relative permeability and capillary pressure curves	Denbury* and literature
Oil and gas composition	Denbury*
PVT (viscosity, density) data for oil	Denbury*
Brine composition or at least TDS	Denbury, sampling program
Well locations	Denbury
Perforated intervals for injection and production wells	Denbury
Current injection and production schedule and rates	Denbury
Historical production/injection rates if available	Files, to be allocated
Temperature data	Denbury
Proximity of other oil/gas fields	Denbury + literature search

**Commercial proprietary non-funded data utilized to refine fluid flow and pressure modeling may be withheld from public information.*

BEG, in consultation with Denbury, will prepare a formal report describing model assumptions and outputs, as well as uncertainties that should be considered in the monitoring program. Commercial proprietary data used for input in the model may be withheld by Denbury from the report.

Phase 2A, Task 3- Soil Gas-Feasibility test of surveillance of P&A wells

BEG will undertake an initial assessment of soil gas conditions near representative Soso P&A wells, in consultation with Denbury, to consider complexities that should be considered for soil gas assessment to reduce uncertainties about well integrity in P&A wells. BEG will also include learning from other soil gas tests now underway, for example work at Cranfield, by Denbury at Oyster Bayou, and international projects. This activity will occur after this part of the project has received a CX or under a NEPA waiver. BEG will prepare a letter report recommending future monitoring strategies.

Phase 2A, Task 4- Groundwater monitoring-Feasibility test of surveillance of P&A wells

BEG will sample existing available domestic and other water wells and review Mississippi historic water well records of aquifer properties to obtain information about the range of ground water chemistries and how to best test for rock-CO_2-water interaction in the aquifer should unintended CO_2 migration occur. It will also include learning from other projects underway at BEG and elsewhere to identify criteria that may signal migration. Denbury will review with regard to placement of monitoring wells for next stage of study. Field work will occur after CX or NEPA waiver is obtained. BEG will prepare a letter report recommending future monitoring strategies.

Phase 2A, Task 5-AZMI-Establish current pressure profile via Repeat Formation Test (RFT) on new drill wells

The pressure environment at Soso has been perturbed by oil and brine production, from past years of CO_2 injection, and Wilcox salt water disposal wells. BEG assumes that the simple structure can be properly monitored using two wells.. This test plan will used to characterize the pressure field and if the plan has value, select above zone monitoring interval (AZMI), and wells will then be completed as AZMI wells in Task 15. Several choices will be assessed for best value. Workovers to plug back SSFUZA 26-4#1, SSFUZA 22-15#1 or Soso Field Unit 27-6#1 ZB are possible candidates to use as Mooringsport or Paluxy monitoring wells. Field staff estimate $400,000 each to workover and prepare for AZMI completion, which might save considerable cost compared to new drills. However, cement condition may require costly and possibly unsuccessful remediation. In this budget we planned new drills, which have the advantage of allowing more than one interval to be pressure tested using repeat formation tester (RFT). If workover is selected, additional funds will be transferred to verify good cement and well conditions, and install tubing and packers to maintain casing integrity. This activity will occur after CX or NEPA waiver is received. Denbury will prepare a report with as-build construction and RFT results.

Phase 2A, Task 6- Logging-Feasibility test of surveillance of idle wells

Sandia will subcontract and guide development of a new tool for active temperature stimulation of the reservoir to identify fluid changes and fluid flow. Zones with permeability recover faster from a thermal pulse, and it is hoped that this tool will provide permeability information relevant to migration on faults and fluid changes in AZMI through casing. Denbury will provide initial assess points for testing this tool in up to three wells that are in operation prior to the expansion area flood. Novel tool development is seen as an important part of this project. Sandia will prepare a letter report with as-built tool design and operation, test results and recommendation for further use.

Phase 2A, Task 7- Decision Point, Risk Assessment & Updated MVA plan and cost distribution
BEG in consultation with Denbury, will update the risk assessment and research MVA plan and cost distribution based on the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement commercial operations. BEG will prepare a formal report containing Phase 2B recommendations.

Phase 2B, Task 8- Commercial Flood Monitoring - Well Review and Remediation
Denbury will define the mechanical status of every wellbore within the possible plume area of the injected CO_2. Wells with mechanical problems, which won't allow isolation of the CO_2 within the targeted reservoir being flooded, will be re-plugged or remediated prior to the start of injection. This work will be done as part of commercial field development project, at no cost to the research MVA project. Denbury will prepare a letter report of well status showing compliance with MS O&G Board regulations.

Phase 2B, Task 9- Logging-Baseline Surveillance of idle wells
. Sandia will conduct a survey beyond that conducted by Denbury in Task 8 using an array of tools to critically evaluate condition of wells, especially with regard to potential for natural or anthropogenic fluid migration behind casing. This data will provide a baseline to show any changes that occur as the field is flooded. Sandia, in conjunction with Denbury will select, a sample of representative wells that can be accessed. BEG estimates that 8 may be found in or near the research project area. Sandia will prepare a letter report with methods and results.

Phase 2B, Task 10- Soil Gas-Site & Borehole preparation for surveillance of P&A wells BEG in consultation with Denbury, will select P&A wells to assess using the methods recommended in Phase 2A, Task 3 and develop characterization data such as samples and access tubes, shallow wells or other infrastructure needed. BEG will prepare a letter report with as built construction and field notes.

Phase 2B, Task 12- Soil Gas-Baseline surveillance of P&A wells
BEG will conduct, in consultation with Denbury, data collection on soil gas sites that were developed in Task 10. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepare a letter report of methods and data.

Phase 2B, Task 12- Ground Water Monitoring -Well preparation
Denbury and BEG will select four wells that will be completed in the USDW interval and monitored for CO_2 migration following the methods developed in task 2A-5. Denbury plans to recomplete existing wells. Wells with suitable cemented-in surface casing below 2890 ft have been identified by the Denbury Field team. BEG will prepare a letter report showing as-built construction and field notes.

Phase 2B, Task 13- Ground Water Monitoring -Baseline

BEG will purchase a pump and sample and than analyze the groundwater wells installed in Task 13. Four sets of samples will be collected to established a baseline before CO_2 injection starts. BEG will prepare a letter report including methods, field notes and data table.

Phase 2B, Task 14- Reservoir Modeling-Upgraded
BEG will incorporate data from Task 2A to predict range of plume sizes and magnitude and areas of pressure elevation and provide to Denbury for review. This result will be used to modify and adjust the risk assessment and monitoring strategy as needed. BEG will prepare a letter report showing changes in model parameters, revised predictions on area of CO_2 plume and distribution and magnitude of pressure change.

Phase 2B, Task 15- AZMI-Well Completions
Denbury will complete the two AZMI wells from task M5 in the above zone to keep the perforations open during testing, and install any constructed-in temperature monitoring equipment. Denbury will prepare a letter report containing field notes and as-built construction.

Phase 2B, Task 16- AZMI-Instrument Monitoring Wells
Sandia will install and maintain pressure gauges on monitoring wells completed in Task 15 in AZMI. Completions are designed to be simple, without tubing and packer, and pressure gage hung in the water column. Pressure data will be available via cell phone or data logger. If workover are used, some of the funds saved from well drilling will be used in this task to install tubing and packer, so that well integrity can be monitored. Sandia will prepare a letter report containing field notes..

Phase 2B, Task 17- AZMI- Hydrologic testing and Baseline geochemical sampling Sandia, in consultation with Denbury, will conduct pressure interference test to show hydrologic communication and the area over which the AZMI provides evidence of containment. BEG will collect and analyze pre injection fluids and gases for geochemical samples. Sandia and BEG will prepare a letter Report providing methods and field notes.

Phase 2B, Task 18- VSP-Baseline
Denbury, in coordination BEG, will plan and conduct a baseline VSP survey as an augmented measure of flood conformance. Each proposed 4D-VSP will illuminate an area approximately 1 sqmi. 5 3DVSP's should be planned in the project area to image CO_2 fillup through the reservoir and above/below the reservoir and along faults. With high resolution 3D-VSP seismic data BEG hopes to resolve sand units as thin as 10ft. When these 3D-VSP's are repeated, areas where the reservoir changes based on density and pressure changes in the seismic response will be mapped. Costs for surveys include the surveys, well operations, permitting for seismic sourcing on the surface, and processing. The seismic will require a baseline plus 4 repeats in Phase 2C. Denbury will prepare a letter report providing the details of the field deployment.
.

Phase 2B, Task 19- Measure Out-Of-Pattern Migration (Completion of downdip wells)

As the flood is being developed, two wells outside that phase will be completed by Denbury and used to monitor the possible migration of the CO_2 and elevation of pressure outside the completed patterns. Soso Field Unit 36-2#1 and Soso Field Unit 36-3#1 are two possible choices. Denbury will prepare a letter report including well completion diagrams and daily records of well-head pressure.

Phase 2B, Task 20- Decision Point, Risk Assessment & Updated MVA plan and cost distribution

BEG in consultation with Denbury will update the risk assessment and research MVA plan and cost distribution in consideration of the results of previous data collection efforts, and will make adjustments to the research MVA program to supplement Denbury's commercial field development program. BEG will prepare a formal report containing Phase 2C recommendations.

Phase 2C, Task 21- Commercial Flood Monitoring-Injection and Production Volumes

Denbury will report to the research MVA project the results of commercial flood monitoring, quantifying all injected and produced fluids (including recycle), wellhead pressure, and intermittent injection profiles. This commercial monitoring program will account of purchase and recycle volumes giving the volume of CO_2 in the reservoir and the amount of methane produced and recycled with the CO_2.

This work will be done as part of commercial project but is the most essential monitoring data. BEG wil prepare a monthly report providing details on the distribution of the stored CO_2.

Phase 2C, Task 22- Commercial Flood Monitoring-Best Practice Mitigation

Denbury will provide to the research MVA project information about mitigation for poor well performance to document how conformance is attained commercially. For example if a well will not accept the planned injection rate at field pressure, Denbury may acidize, reperforate, or inject at a higher rate in other parts of pattern. This work will be done as part of the commercial field development project.

Phase 2C, Task 23- Commercial Flood Monitoring-Pressure Maintenance

Denbury will perform normal well surveillance including monitoring casing pressures in both producers and injectors. Denbury will use remediation procedures to repair wells with compromised integrity. Denbury will provide the results of this work done as part of the commercial project.

Phase 2C, Task, 24- Commercial Flood Monitoring-IWR Calculation

Denbury will calculate material balance from data in task M22 for each pattern on a monthly basis to define changes in reservoir performance. Significant changes in IWR identify potential problem wells within the pattern (i.e. mechanical problems with injectors or inactive wells which are causing the loss of CO_2 out of the pattern, or a mechanical problem with the producer(s) within that pattern). The problem wells will be identified and repaired (re-plugged or remediated). This work will be done as part of commercial project.,

Phase 2C, Task 25- Logging-Time lapse surveillance of idle wells
Sandia will conduct a logging and surveillance program on 8 idle wells for which baseline data was collected in Phase 2B, Task 9. This data will be compared to the baseline to show any changes that occur as the field is flooded.. Sandia will prepare a letter report with methods and results will be prepared.

Phase 2C, Task 26- Soil Gas Time lapse surveillance of P&A wells
BEG will follow baseline data collected in Phase2B, Task 11 with repeat data collection over two years on soil gas sites that were developed. Results will be critically assessed to provide information on the value of this approach to documenting well integrity. BEG will prepare aletter report containing data tables and field notes.

Phase 2C, Task 27- Groundwater Monitoring-Time lapse surveillance
BEG will sample and then analyze the groundwater wells for which baseline was collected in Task 13. Samples will be collected to look for changes as CO_2 injection starts. BEG will prepare a etter report containing data tables and field notes.

Phase 2C, Task 28- VSP-Time lapse surveys
Denbury will conduct 4 repeat VSP surveys over the two-year period following the baseline run in Phase 2B Task 18. This data will be used to show that the flood is conforming to the expected patterns, including providing data about out-of zone migration. Denbury will prepare a formal report including methods and results of surveys on annual basis

Phase 2C, Task 29- Real Time BHP-Well Preparation
Sandia will deploy bottom hole pressure gage(s) on a real time read out in one well in the injection interval(s). This type of data has proven valuable at Cranfield to assess the nature of the flood is expected to similarly be valuable at Soso. We have budgeted for an elaborate well-based monitoring array. The detailed plan for the well will be designed in M19. Sandia will prepare a letter report showing as-built well schematics.

Phase 2C, Task 30- Real Time BHP-Sandia
Sandia will maintain and back up data collected in the deployment described in Phase 2C Task 29. Sandia will prepare a letter report containing data tables and field notes.

Phase 2C, Task 31- Logging-Time lapse Surveillance
Denbury will augmented measures of conformance to provide data for match to the model by logging about half the injectors and producers in the patterns every half year focusing on the 31 wells in the expansion area but including 10 wells from other parts of the field. Combination temperature and tracer surveys will be run on injection wells twice per year per well. Producers will have spinner, temperature, and capacitance tools run twice a year per well, assuming a 6 month delay in start up in producing the wells, while

each of the injectors would have a series of four logs run. Testing of additional log types is possible. Denbury will prepare a letter report containing data tables and field notes.

Phase 2C, Task 32- Natural geochemical tracers-Collected at wellhead
BEG will, with the assistance of Denbury, collect wellhead fluid samples from producers that serve as augmented measures of conformance. For example, the fluid chemistry will be evaluated for evidence of dissolution and rock-water interaction. BEG will prepare a letter report containing data tables and field notes.

Phase 2C, Task 33- AZMI-Time lapse geochemical sampling & hydrologic testing
Sandia will conduct a time-lapse hydrologic sampling program of the AZMI wells via pumping. The BEG will collect and analyze fluid samples to look for any geochemical evidence of out of zone migration of CO_2 as part of the above -zone monitoring program. The BEG will prepare a letter report containing data table and field notes.

Phase 2C, Task 34- Measure Out-Of-Pattern Migration
In this task, Denbury will report observation of the wells prepared in Task 19, including first year of pressure change at well heads. This should provide one year of data before beginning of flood near these wells. Denbury will prepare a letter report of pressure data and provide it to BEG for including Phase 2C Task 35 history match of well head pressure.

Phase 2C, Task 35- Reservoir Modeling-Updated
BEG will aggregate data from 2C activities to history match plume size and pressure elevation and test if flood conformance to model expectation was achieved. This will focus on CO_2 and pressure quantification, not oil production. Denbury will review the formal report prepared by the BEG.

Phase 2C, Task 36- Overview and Evaluation report
BEG will prepare and Denbury review a report of the results of this study. BEG and Denbury will determine what, if any, added value the research program added to the commercial program in terms of confidence in the long-term permanence of storage. BEG will recommend any actions that may be informative to future regulations or policies related to storage monitoring at EOR sites. This will be a formal report.

APPENDIX 9

Phase 1 SOPO Task 1.8.1
Technology Cost Data

APPENDIX 9.0 PHASE 1 SOPO TASK 1.8.1, TECHNOLOGY COST DATA

All of the technology cost data and breakdowns identified in Phase 1 SOPO Task 1.8.1 are considered in the Phase 2 Project Management Plan, Appendix C to the Phase 2 Renewal Application, and the Resource-Loaded Schedule included therein.

APPENDIX 10

Non-Proprietary Programmatic and Technical Prospectus (Fact Sheet)

Fact Sheet category identification: **Project Facts**
NETL program/product identification: **Industrial Carbon Capture and Sequestration (ICCS)**

Leucadia Energy, LLC: Mississippi CCS Project

Background

Carbon dioxide (CO_2) emissions from industrial processes have the potential to contribute to global climate change. Advancing development of technologies that capture and store or beneficially reuse CO_2 that would otherwise reside in the atmosphere for extended periods is of great importance. Carbon capture and storage (CCS) technologies offer great potential for reducing CO_2 emissions and mitigating global climate change without adversely influencing energy use or hindering economic growth.

Under the Industrial Carbon Capture and Sequestration (ICCS) program the U.S. Department of Energy (DOE) is partnering with industry to demonstrate the next generation of technologies that will capture CO_2 emissions from industrial sources and either sequester those emissions, or beneficially reuse them. The technologies included in the ICCS program represent advanced CCS projects that are ready for operation at a demonstration scale. Once demonstrated, the technologies can be readily deployed at a commercial scale.

Project Description

The DOE selected Leucadia Energy, LLC to receive ICCS program funding through the American Recovery and Reinvestment Act (ARRA) of 2009, for its Mississippi CCS Project. The project will demonstrate the capture of a minimum of one million tons per year of CO_2 from an industrial facility for use in an independent enhanced oil recovery (EOR) application. The industrial source of CO_2 will be a petcoke-to-substitute natural gas (SNG) plant being developed by Mississippi Gasification, LLC (a Leucadia Energy, LLC affiliate) in Moss Point, Mississippi. Once the CO_2 is captured, it will be purified to remove contaminants, compressed to a pressure suitable for transport by a 110 mile pipeline, and ultimately injected into depleted oil fields in Mississippi for EOR. The project will also implement a comprehensive monitoring, verification, and accounting (MVA) program to confirm the long-term sequestration of injected CO_2.

The project will apply a two-phase approach: During Phase 1, Leucadia Energy, LLC and its team will further define the project, progress through preliminary

CONTACTS

Brad Tomer
Director
Office of Major Demonstrations
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
Phone: (304) 285-4692
brad.tomer@netl.doe.gov

Charles Miller
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
Phone: (412) 386-5745
charles.miller@netl.doe.gov

Hunter Johnston
Participant Project Manager
Leucadia Energy, LLC
New York, NY 10010-3649
Phone: (202) 429-6404
hjohnston@steptoe.com

PROJECT TEAM

Denbury Onshore, LLC
Black & Veatch Corporation
University of Texas Bureau of Economic Geology

PROJECT DURATION (PHASE 1)

Start Date
11/16/2009

End Date
06/16/2010

COST (PHASE 1)

Total Project Value
$904,911

DOE/Non-DOE Share
$542,467 / $362,444

continued funding for the project's construction and early operations. If selected for Phase 2, the project will involve construction of CO_2 compression, pipeline, and monitoring infrastructure followed by the operation of a system to capture, transport, and sequester CO_2 through EOR. A comprehensive MVA program to monitor the injected CO_2 will then be implemented.

Goals/Objectives

The project goal is to advance CCS technologies from the demonstration stage to commercial viability. The project objective is to demonstrate an integrated system of industrial scale CO_2 capture, compression, and sequestration for EOR beneficial reuse.

Benefits

The project will result in the large-scale recovery, purification and compression of more than 4 million tons of CO_2. The sale of CO_2 from the ICCS project for use in independent EOR operations by Denbury affords a cost effective means to increase domestic oil production while using advanced gasification technology to reduce the release of CO_2. On a global scale, petroleum coke currently being exported from the U.S. to regions where little if any environmental controls are required or implemented, will now be used in a domestic chemical project that achieves superior environmental performance and captures CO_2 for beneficial use.

With the completion of the Green Pipeline by Denbury and an affiliate, naturally occurring CO_2 taken from the Jackson Dome in Mississippi will be used for enhanced oil recovery in oil fields in Texas and Louisiana. CO_2 from the project that is compressed and delivered to the Green Pipeline will represent approximately 25 percent of the daily amount of CO_2 that Denbury will use in these oil fields. By using the anthropogenic CO_2 from the Lake Charles plant, Denbury will be able to reduce the amount taken from the Jackson Dome and prolong the life of this naturally occurring source of CO_2 Additionally, a comprehensive MVA program will be implemented in the Hastings and/or Oyster Bayou oil fields that will confirm the long-term sequestration of injected CO_2 in the EOR project application.

The infrastructure developed by the ICCS project could potentially enable other industrial and power plant CO_2 sources in the Lake Charles industrial community to commercially dispose of CO_2 in Gulf Coast EOR operations. Expansion of EOR in the Gulf Region will promote greater energy security by expanding domestic energy supplies. The Lake Charles gasification facility and CCS project alone are expected to provide up to 1,100 construction jobs and 200 permanent operation jobs, as well as millions of dollars in severance taxes and royalties to the States of Louisiana and Texas.

Diagram of the Lake Charles CCS Project