Lake Charles CCS Project
FINAL TECHNICAL REPORT
Phase 2

Reporting Period
November 16, 2009 – June 30, 2015

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Report Issue Date: June 30, 2015

DOE Award Number: DE-FE0002314

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DISCLAIMER

ABSTRACT

In late September 2014 development of the Lake Charles Clean Energy (LCCE) Plant was abandoned resulting in termination of Lake Charles Carbon Capture and Sequestration (CCS) Project which was a subset the LCCE Plant. As a result, the project was only funded through Phase 2A (Design) and did not enter Phase 2B (Construction) or Phase 2C (Operations). This report was prepared relying on information prepared and provided by engineering companies which were engaged by Leucadia Energy, LLC to prepare or review Front End Engineering and Design (FEED) for the Lake Charles Clean Energy Project, which includes the Carbon Capture and Sequestration (CCS) Project in Lake Charles, Louisiana.

The Lake Charles Carbon Capture and Sequestration (CCS) Project was to be a large-scale industrial CCS project intended to demonstrate advanced technologies that capture and sequester carbon dioxide (CO_2) emissions from industrial sources into underground formations. The Scope of work was divided into two discrete sections; 1) Capture and Compression prepared by the Recipient Leucadia Energy, LLC, and 2) Transport and Sequestration prepared by sub-Recipient Denbury Onshore, LLC.

Capture and Compression - The Lake Charles CCS Project Final Technical Report describes the systems and equipment that would be necessary to capture CO_2 generated in a large industrial gasification process and sequester the CO_2 into underground formations. The purpose of each system is defined along with a description of its equipment and operation. Criteria for selection of major equipment are provided and ancillary utilities necessary for safe and reliable operation in compliance with environmental regulations are described. Construction considerations are described including a general arrangement of the CCS process units within the overall gasification project. A cost estimate is provided, delineated by system area with cost breakdown showing equipment, piping and materials, construction labor, engineering, and other costs.

The CCS Project Final Technical Report is based on a Front End Engineering and Design (FEED) study prepared by SK E&C, completed in [June] 2014. Subsequently, Fluor Enterprises completed a FEED validation study in mid-September 2014. The design analyses indicated that the FEED package was sufficient and as expected. However, Fluor considered the construction risk based on a stick-build approach to be unacceptable, but construction risk would be substantially mitigated through utilization of modular construction where site labor and schedule uncertainty is minimized. Fluor's estimate of the overall EPC project cost utilizing the revised construction plan was comparable to SKE&C's value after reflecting Fluor's assessment of project scope and risk characteristic. Development was halted upon conclusion of Phase 2A FEED and the project was not constructed.

Transport and Sequestration – The overall objective of the pipeline project was to construct a pipeline to transport captured CO_2 from the Lake Charles Clean Energy project to the existing Denbury Green Line and then to the Hastings Field in Southeast Texas to demonstrate effective geologic sequestration of captured CO_2 through commercial EOR operations. The overall objective of the MVA portion of the project was to demonstrate effective geologic sequestration of captured CO_2 through commercial Enhanced Oil Recovery (EOR) operations in order to evaluate costs, operational processes and technical performance. The DOE target for the project was to capture and implement a research MVA program to demonstrate the sequestration through EOR of approximately one million tons of CO_2 per year as an integral component of commercial operations.

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CAPTURE AND COMPRESSION

INCLUSION OF COMPLEMENTARY UNITS INFORMATION AS ANCILLARY TO CCS SYSTEMS

The Cooperative Agreement requires that the Technical Report include the description, cost and technical information determined from execution of the scope of work defined in the Carbon Capture and Sequestration (CCS) Design Basis. The areas investigated included the Acid Gas Removal Unit (AGR) for capture of the CO_2; CO_2 Compressor required for transportation of the CO_2 to sequestration; Regenerative Thermal Oxidizer (RTO), an emissions control system destroying hydrocarbons in the CO_2; and certain support components including the propylene compression system (a cooling system necessary for operation of the AGR); the Load Commutated Inverter (LCI), an electrical device necessary for startup of the CO_2 compressor); and the CO_2 meter station to quantify the CO_2 sent to sequestration (together the Base CCS Scope).

The Final Technical Report, however, has been prepared to also include the description, cost and technical information for two complementary systems that are critical to operation of the CCS units and which had been designed in conjunction with the CCS units as part of the overall gasification plant scope but which were not incorporated in the original CCS Design Basis. These are the Wet Sulfuric Acid (WSA) unit and the process cooling system (together the Ancillary Scope). The WSA is an emissions control unit which minimizes SO_2 discharges potentially caused by combustion of acid gases (H_2S and COS) which have been separated from the CO_2 in the AGR. The process cooling system provides cooling necessary for operation of the CO_2 and propylene compressors. Because these systems are necessary for operation of the CCS units in compliance with environmental regulation, LCCE believes the DOE benefits from knowledge of the design and cost of these systems.

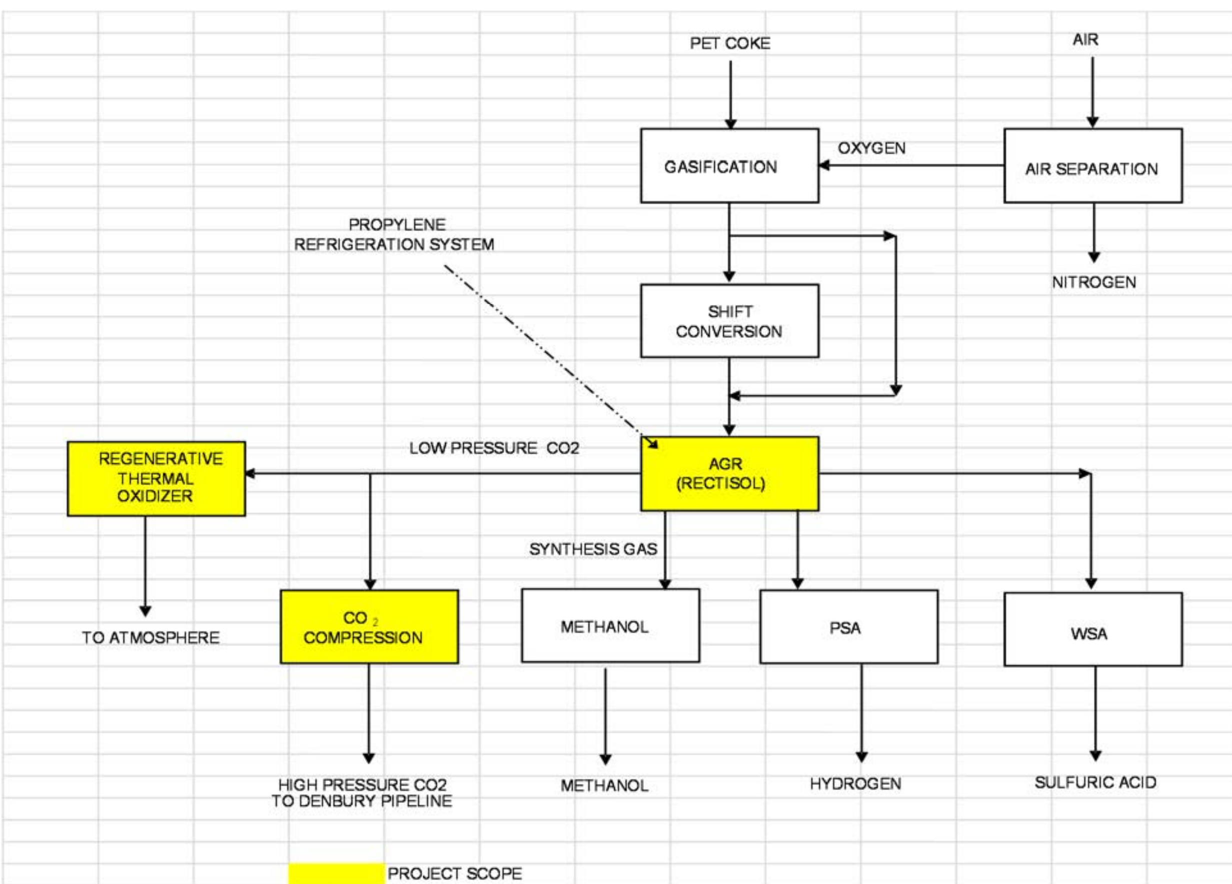
EXECUTIVE SUMMARY

Leucadia Energy, LLC (LEC) was awarded a DOE/NETL grant to design a facility to capture and compress CO_2 from a syngas stream generated by the gasification of petroleum coke. Denbury was to transport this compressed CO_2 via a new 11.7 mile pipeline to the existing Green Line which is connected to a depleted oil reservoir where the CO_2 was to be injected to extract additional oil. The Monitoring, Verification and Analysis (MVA) at the Hastings Field near Houston, TX was to be undertaken by Denbury. Lake Charles Clean Energy, LLC (LCCE) retained SKE&C USA, Inc. to develop a FEED package and cost estimate for CO_2 capture and compression.

The petroleum coke gasification project was located at a site adjacent to the Port of Lake Charles (POLC) material handling facility on the Calcasieu Waterway ("Project"). GE quench type gasifiers were to be used and the syngas generated was to be converted to methanol and hydrogen with co-production of sulfuric acid. The facility was designed to gasify petroleum coke in the presence of 99.65% oxygen, for the production of methanol and hydrogen. LCCE was to lease the approximately 72 acre site from the Port of Lake Charles (POLC). The Project had obtained all necessary permits.

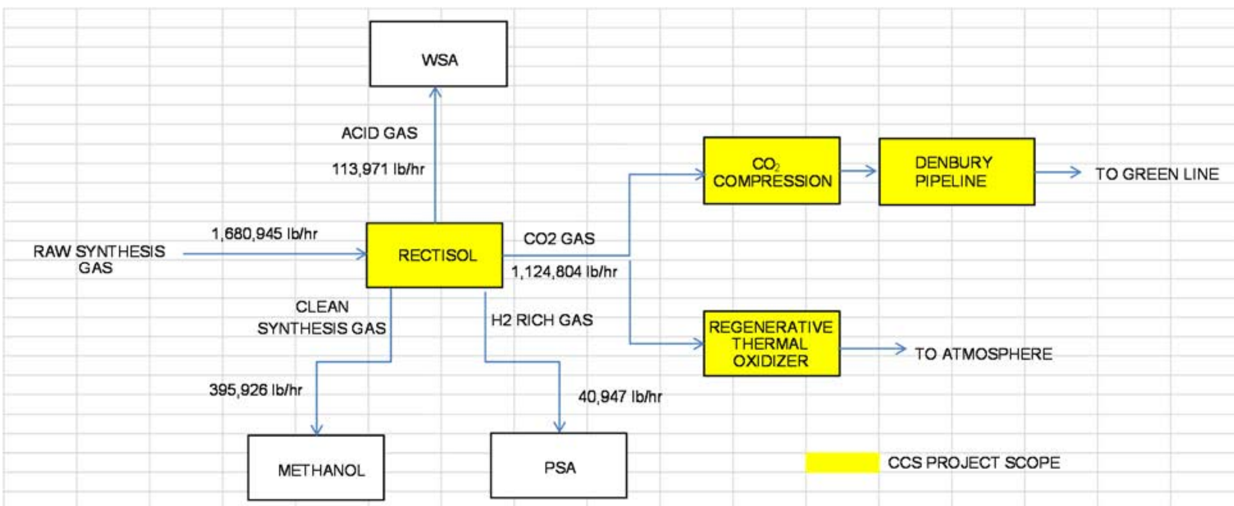
The Project scope is highlighted in yellow below:

Fig. A – CCS and Overall Project Scope



The project scope starts with the shifted and cooled syngas into a Rectisol® Acid Gas Removal (AGR) unit with parallel Absorber trains, one Absorber train for the production of methanol and one for the production of hydrogen. The CO_2 from the Rectisol® system is piped to the CO_2 compressors for compression to approximately 2,250 psig. When the CO_2 transportation system is interrupted, or if the Denbury pipeline cannot accept CO_2, this flow is sent to the Regenerative Thermal Oxidizer (RTO). The RTO destructs all components of the CO_2 stream that exceed emission permit levels. The acid gas from the Rectisol® system is piped to the Wet Sulfuric Acid (WSA), the clean syngas flows to the methanol process and the hydrogen rich gas to the hydrogen process. Fig. B provides an overall balance for the project:

Fig. B – Overall Block Flow Diagram



The CO_2 capture utilizes the Air Liquide/Lurgi licensed Rectisol® process. LCCE licensed this process, which provides for a Process Design Package. This report addresses the engineering coordinated by SKE&C USA for the following areas: Rectisol® (Area 06), Propylene Refrigeration (Area 10), CO_2 Compression (Area 18), Regenerative Thermal Oxidation (Area 16), Wet Sulfuric Acid (Area 12), and Process Cooling Water Loop (Area 26). Engineering deliverables for Area 06 are provided by Air Liquide/Lurgi apart from the propylene refrigeration system which SKE&C USA developed. Engineering deliverables for Area 12 are provided by Haldor Topsoe. All engineering for Areas 16, 18, and 26 are provided by SKE&C USA. The engineering assumed that the utilities and interfaces are provided at the battery limits of the process. The Area numbers (06, 10, 12, 16, 18, and 26) are with reference to the designation used in the overall petroleum coke to methanol and hydrogen project.

Based on the engineering deliverables (sized equipment list, data sheets, P&IDs, etc.) a cost estimate was developed. Request for quotations were issued for the CO_2 compressor, propylene refrigeration compressor, RTO, Cooling Tower and other equipment contained within the scope of these Areas. Bulk material takeoffs were generated for the Piping, Electrical, Instrumentation, Civil, Concrete and Structural Steel within the scope areas by SKE&C USA. All construction labor pricing based on project specific bid packages and pricing for commodities and bulk quantities was developed using data from SKE&C USA. The pricing for instrumentation, electrical equipment and valves used quotes and recent pricing. SKE&C USA developed pricing for the engineering, procurement and management services necessary during the EPC phase.

The capital cost estimate is summarized below:

Table A – Capital Cost Summary

Area Description	Tagged Equipment Cost	Tagged Materials Cost	Construction Hours	(1) Construction Labor Cost	Construction Material Cost	Construction Subcontractor Labor/Mtl Cost	Freight, Taxes and Duties Cost	Spares Cost	Vendor Rep Commission Cost	Sub total	Escalation, Contingency Cost	Totals Cost
Area 06 - AGR	$ 48,374,460	$ 3,072,893	282,933	26,965,722	$ 13,776,432	$ 8,381,158	$ 3,873,850	$ 546,117	$ 627,467	$105,618,100	$ 14,230,939	$ 119,849,039
Area 10 - Propylene Refrigeration	$ 11,045,113	$ 560,026	41,814	4,120,355	$ 1,850,018	$ 590,371	$ 799,145	$ 124,692	$ 143,267	$ 19,232,987	$ 2,591,445	$ 21,824,432
Area 16 - RTO	$ 3,865,720	$ 98,853	17,484	1,812,510	$ 644,325	$ 292,740	$ 273,737	$ 43,642	$ 50,142	$ 7,081,669	$ 954,181	$ 8,035,850
Area 16 - CTS, LCI, utilities	$ 1,867,328	$ 316,761	17,600	2,155,300	$ 1,763,522	$ 2,306,500	$ 234,461	$ 21,081	$ 24,221	$ 8,689,176	$ 1,170,776	$ 9,859,951
Area 18 - CO2 Compression	$ 27,667,751	$ 6,832,650	72,275	6,906,591	$ 3,798,486	$ 352,123	$ 2,274,694	$ 312,352	$ 358,880	$ 48,503,525	$ 6,535,345	$ 55,038,871
Area 12 - WSA	$ 71,086,918	$ 2,550,972	278,920	22,351,018	$ 13,188,289	$ 2,751,454	$ 5,156,885	$ 802,527	$ 922,071	$118,810,135	$ 16,008,429	$ 134,818,564
Area 26 - Process Cooling	$ 9,275,781	$ 340,051	175,162	14,422,035	$ 4,015,750	$ 2,805,107	$ 809,623	$ 104,718	$ 120,317	$ 31,893,382	$ 4,297,301	$ 36,190,683
Interconnecting Piping			117,350	11,324,806	$ 12,272,452	$ 1,173,870	$ 728,900			$ 25,500,027	$ 3,435,863	$ 28,935,891
Project and Construction Mgmt												$ 14,666,684
Home Office, Engineering, EPC fee												$ 90,272,016
TOTALS	**$ 173,183,071**	**$ 13,772,207**	**1,003,537**	**$ 90,058,336**	**$ 51,309,274**	**$ 18,653,324**	**$ 14,151,296**	**$ 1,955,129**	**$ 2,246,365**	**$365,329,002**	**$ 49,224,280**	**$ 519,491,982**

Notes:
1. Includes Construction Indirects

Process performance risk is managed through the licensor specification and guarantee of the syngas quality and quantity through each process unit; construction risks are controlled through management of craft labor availability, modular construction and the ability to transfer work to off-site fabrication facilities; schedule risk is mitigated through agreements from process licensors for timely release of design information and through good procurement practices including expediting to assure timely delivery of vessels, compressors and exchangers.

The technical viability of CCS Capture was validated by SK&EC and Fluor Enterprises. Each confirmed that the licensed technologies employed have been proven successful with a demonstrated history of projects with similar capacity and performance requirements. The composition of the CO2 captured by the Rectisol unit meets the specification for sequestration, its physical characteristics are suitable for compression and the selected compressor has a proven history in similar service. The termination of development of the gasification plant including the CCS portion of the plant was a business decision by Leucadia Energy.

1.0 GENERAL PROJECT DESCRIPTION

SKE&C USA was retained by LCCE to develop a FEED package and cost estimate for the CO_2 capture and compression from a syngas stream generated by gasification of petroleum coke. The project consisted of the following unit operations:

- Area 06 - Removal of sulfur containing compounds and CO_2 from the syngas stream generated by gasification of petroleum coke using the Rectisol® process;
- Area 10 – Propylene refrigeration system for cooling within Area 06;
- Area 12 – Wet sulfuric acid production by oxidation and hydration of sulfur containing compounds removed from the process gas in Area 06;
- Area 16 - Thermal oxidation of the CO_2 stream when the CO_2 compressor is not operational;
- Area 18 - Compression of CO_2 to approximately 2,250 psig including the Custody Transfer station;
- Area 26 – Process cooling water loop servicing cooling loads for the CO_2 compressors, Propylene compressor, the WSA and process units, local electrical distribution including the Load Commutated Inverter (LCI) drive for starting the CO_2 and propylene refrigeration compressor motors;
- Interconnection piping and piperacks for utilities, products and feedstock.

2.0 PROCESS & SYSTEMS

The overall project was identified by areas. The CCS project plus Ancillary Scope consisted of the following areas:

- Area 06 – Acid Gas Removal
- Area 10 – Propylene Refrigeration
- Area 12 – Wet Sulfuric Acid Production
- Area 16 – Regenerative Thermal Oxidizer (Ancillary Scope)
- Area 18 – Carbon Dioxide Compression
- Area 26 – Process Cooling Water Loop (Ancillary Scope)

Each of the project areas are discussed below in Section 2.2.

2.1 Process Design Basis

The process design for CO_2 capture is based on Air Liquide/Lurgi's licensed Rectisol® process. The syngas from the gasification process is fed to the Rectisol® system which extracts the sulfur containing compounds and CO_2. The sulfur containing stream is piped to the Haldor Topsoe licensed Wet Sulfuric Acid (WSA) process and the CO_2 is piped to compressors. Clean syngas from the Rectisol® system is sent to the methanol process and hydrogen rich gas to the hydrogen process.

The syngas to the Rectisol® system is adequate to produce approximately 231 MMSCFD of CO_2, approximately 13,400 TPD at full capacity, which will be compressed and supplied to the Denbury pipeline.

2.2 Process Description

2.2.1 Area 06 – Acid Gas Removal (Rectisol®)

The acid gas removal technology for this project is the Rectisol® process licensed by Air Liquide/Lurgi. The Rectisol® process is a physical absorption Acid Gas Removal (AGR) process that uses methanol at -78°F which is regenerated by stepwise flashing and final thermal regeneration. It selectively removes components that are detrimental to downstream process units such as H_2S, COS, CO_2 and trace impurities like HCN, NH_3, formic acid and metal carbonyls. It can achieve varying degrees of CO_2 removal depending on the downstream specification.

Prior to entering the AGR, the syngas is processed in shift conversion to produce two distinct gas streams. One stream is processed to contain a CO:H_2 ratio suitable for producing methanol and the other stream is shifted to a high H_2 concentration for purification into product H_2. Each stream is routed to an absorber column, which feeds a CO_2 and H_2S stripper. A single propylene refrigeration system provides the cooling required for the methanol.

The gas absorbers in Rectisol® are designed as a two-stage absorption process. The syngas from the cooling train enters the first stage of the gas absorber in Rectisol® where the sulfur compounds are absorbed using methanol pre-loaded with CO_2. In the second stage of the absorber, the CO_2 is absorbed. The clean sulfur-free syngas exits the absorber in the methanol train and is sent to the methanol synthesis reactor. The hydrogen rich gas from the absorber in the hydrogen train is sent to the PSA unit for purification.

The rich methanol solvent exits the bottom of each absorber and is sent to a lean/rich methanol exchanger where it is heated against hot regenerated methanol coming from the Hot Regenerator before it is flashed in to Hot Flash Column. The flashed gas from this column is cooled down in a series of heat exchangers before entering the Reabsorber. The methanol streams entering Hot Regenerator Column are fully regenerated by stripping with methanol vapor generated with LP steam. The methanol vapor in the sour gas is condensed with a cooling water system. The CO_2 is flash stripped from the methanol by pressure letdowns at three different levels. These three different pressure letdowns are identified as LP1, LP2 and LP3. LP1 is at the highest flash pressure, then LP2 and finally LP3. These three CO_2 streams are routed to the CO_2 compressor at different stages of compression to save compressor horsepower rather than providing one CO_2 stream at the lowest suction pressure to the CO_2 compressor.

The H_2S is removed from the methanol via steam stripping. The H_2S-rich acid gas is sent to the WSA process for conversion to sulfuric acid. The lean methanol exits the bottom of the H_2S stripper and is returned to the absorber columns as fresh solvent feed.

The AGR configuration incorporated in this design is simplified from that proposed in the June 2011 process description. At that time the Lurgi design included two 50% capacity AGR trains. This configuration was based on assuring that the absorber design was within the maximum absorber capacity Lurgi could demonstrate as proven. The current configuration utilizes three GE 900+ gasifiers to produce about 90% of the syngas from the previous design, sufficient for about 65% of the previous methanol volume, along with hydrogen. However, since the second syngas shift cycle necessary for the production of hydrogen generates a higher concentration of CO_2, total CO_2 production is not significantly changed. Based on this, Lurgi was re-engaged to prepare a design for the revised capacity along with syngas processing for two products. Lurgi determined that because of the lower total syngas throughput there would be significant cost savings by going to a design with two absorber columns, a single regeneration system, and a single propylene refrigeration system. This is the basis of the current design.

2.2.2 Area 10 – Propylene Refrigeration

One Propylene Refrigerant Compressor will be installed for the common regeneration train. The Propylene Refrigerant Compressor is a constant speed centrifugal compressor driven by a 30,000 HP synchronous fixed speed electric motor. Due to the high electrical demand for startup, a Load Commutated Inverter (LCI) will be used to minimize inrush load. The refrigeration system uses polymer grade propylene as the refrigeration medium. This refrigerant is composed of 99.5 wt% of propylene (min) and 0.5 wt% of propane (maximum). The Propylene Refrigerant Compressor discharges propylene vapor at 241 psig and 178°F and is desuperheated in the Desuperheater against cooling water, to 10°F above its saturation temperature and is then condensed in the Propylene Refrigerant Condenser. The condensed propylene flows into the Propylene Refrigerant Accumulator. The liquid propylene from the Propylene Refrigerant Accumulator is flashed in several stages and through a series of knock out drums. The liquid then flows to the users (process chillers/propylene vaporizers) of propylene refrigeration of the Rectisol® unit utilizing the refrigerant for cooling at temperatures of 39°F and -47°F.

2.2.3 Area 12 – Wet Sulfuric Acid

The WSA plant processes waste gases containing hydrogen sulfide and carbonyl sulfide generated in an upstream gasification unit. The waste gases have been separated from clean process gas in the acid gas removal unit. Additionally, for environmental compliance the WSA processes minor secondary ammonia rich and H_2S rich off gas streams produced within the gasification area.

The process layout for the WSA plant comprises seven main steps:

- Combustion of acid gas and off-gases
- Reduction of NO_x
- Oxidation of SO_2 and subsequent cooling
- Sulfuric acid condensation and cooling
- H_2O_2 scrubbing of process gas for final clean-up of SO_2
- Mist removal
- Heat exchange by means of boiler water/steam

The acid gas and off-gases are received at battery limits upstream the combustor. The acid gas and some of the off-gases are incinerated in the 1st combustor, and the remaining off-gases are incinerated in the 2nd combustor along with a small amount of acid gas to enhance combustion. To maximize efficiency, combustion air is preheated in the condenser. The SO_2 containing process gas from the combustion is cooled in the downstream waste heat boilers where steam is generated.

The off-gases contain ammonia (NH_3), which form nitrogen oxides (NO_x) in combustion. Although the acid gas is nitrogen free a small amount of thermal NO_x is formed from nitrogen (N_2) in the combustion air. Due to the relatively high NO_x concentration from the 2nd combustor, the process gas is treated in the no. 2 SCR reactor before being mixed with the process gas from the 1st combustor, which is then treated in the no. 1 SCR reactor.

Before the process gas enters the SO_2 converter superheated HP steam is injected to ensure sufficient water is available for sulfuric acid condensation. The process gas enters the SO_2 converter where the majority of SO_2 in the gas is converted to SO_3 in three adiabatic catalytic beds. Each bed is loaded with Topsoe VK catalyst. The process gas is cooled by heat exchange ultimately forming high pressure superheated steam. During the final cooling of the process gas in the process gas cooler some of the SO_3 reacts with the water vapor present in the process gas to form gaseous sulfuric acid. Additionally, saturated medium pressure steam is generated in the cooling process. From the gas cooler the process gas enters the WSA condenser in which: 1) the process gas is cooled, 2) the remaining SO_3 hydration reaction to sulfuric acid occurs, and 3) the condensation of sulfuric acid takes place.

The WSA condenser is a falling-film shell and tube type condenser with vertical glass tubes. The process gas, which now contains sulfuric acid in gas form, flows upwards inside the glass tubes, and the condensed sulfuric acid (condensation occurs due to cooling of the process gas) flows downwards along the inside walls of the glass tubes. The condensed acid is collected in the acid vessel and pumped to shift tanks prior to shipment to longer term storage

In order to minimize SO_2 emissions, a H_2O_2 scrubber reacts remaining SO_2 to dilute sulfuric acid. Additionally a Wet Electrostatic Precipitator (WESP) is installed downstream of the H_2O_2 scrubber to reduce acid mist emissions. Dilute acid from the H_2O_2 scrubber system and WESP is added upstream the acid vessel.

The WSA produces sulfuric acid with a nominal concentration of 97.5%. Provisions to add process water to the acid in order to lower acid concentration as desired are incorporated in the design.

The WSA system is designed to process up to 525 tpd sulfur (1050 tpd SO_2 equivalent) into 1600 tpd sulfuric acid. The permitted SO_2 emissions from the WSA is only 93.4 tpy, over 99.97% sulfur recovery.

2.2.4 Area 16 – Regenerative Thermal Oxidizer (RTO)

In the event that either of the two CO_2 Compressors is not in operation, the CO_2 streams will be sent to either of two CO_2 Regenerative Thermal Oxidizer (RTO) trains to oxidize the VOC (H_2S, CO_2, methanol, etc.) and CO content in the CO_2 off-gas prior to venting to atmosphere through a common exhaust stack. Two RTO trains will be installed in parallel, each designed to handle 50% of the CO_2 off-gas from the Rectisol® unit. Also, pipeline unavailability, or off-spec CO_2, can dictate the use of the RTOs.

The RTOs will burn the combustible contents in the CO_2 off-gas at high temperature and produce a clean flue gas. Combustible VOC contents, CO and methanol, will be combusted with a Destruction Removal Efficiency (DRE) of 99.9% and H_2S and COS with a minimum DRE of 98%.

Each RTO train consists of three ceramic canister beds and one combustion chamber above the canisters. The combustion chamber is equipped with two burners. The ceramic canisters operate under a swing bed principle. The contaminated CO_2 off-gas stream travels through the first canister bed, and then enters the combustion chamber. After the temperature has elevated about 1,600°F, the clean CO_2 off-gas stream passes through the second canister bed to the RTO stack. As the clean CO_2 off-gas stream passes through the first canister bed, the heat from the stream is transferred to the second canister bed. While the first and second beds handle the CO_2 off-gas stream, the third bed is on purge mode to get the trapped waste gas back into the combustion chamber. After the first bed has been depleted through the absorption of the incoming stream, the flow through the system is reversed. The second bed will receive the exhaust stream and the third bed will discharge the clean CO_2 off-gas stream and absorb the heat. The first bed will be in purge mode. One cycle of each bed consists of Receiving Process Gas, Purging and Discharging and Heat Absorbing from the CO_2 off-gas.

By using the reversal of exhaust flow through the canister beds; a minimal amount of heat energy needs to be added to the incoming CO_2 off-gas stream to maintain the systems minimum operating temperature for energy saving.

2.2.5 Area 18 – CO_2 Compression

Two 50% CO_2 Gas Compressors will be installed in parallel. The compressors will compress the LP1 (48.2 psig), LP2 (30.1 psig), and LP3 (5.2 psig), net of pressure losses, from Rectisol® unit to a pressure of 2,250 psig. Based on a study of the commercially-available CO_2 compressors as further described in Section 2.4, the selected compressor is an integrally gear centrifugal compressor (IGCC) driven by a synchronous fixed speed electric motor. Due to the high electrical demand for startup, a Load Commutated Invertor (LCI) will be used to start each of the 35,000 HP motors. Both the propylene refrigerant and CO_2 compressor motors will be started with a common LCI.

The choice of multistage compressor was governed by the profile requirements. The integrally geared compressor is characterized by low operating costs, a relatively low investment outlay and excellent partial load performance. The compressor consists of a gear unit with a central bull gear that drives eight radial-flow impellers. It is equipped with interstage coolers.

A suction drum for each CO_2 gas feed stream (LP1, LP2 and LP3) will be used to remove any residual liquids in the gas before it enters the compressor. Based on the composition of the CO_2 gas streams provided by Air Liquide/Lurgi, the CO_2 gas is under-saturated. Therefore, liquid formation is not expected. However, to handle upset conditions, a suction drum is provided for each CO_2 gas feed stream (LP1, LP2, and LP3) to prevent liquid carry over into the compressor.

In a multistage compressor the gas warms significantly upon compression. Therefore, the compressed gas is cooled between the stages against cooling water. A final after-cooler will be installed at the discharge of the eight-stage of the CO_2 Gas Compressor to meet pipeline specification temperature of 100°F.

2.2.6 Area 26 – Process Cooling Water

The project incorporates two cooling water loops. The larger system supplies water to the steam turbine condensers and the Air Separation Unit. The smaller loop provides cooling water to the process cooling system including the CO_2 compressor coolers, AGR and its propylene compressor coolers, the WSA acid cooling and other secondary process cooling. Each loop consists of a cooling tower, circulating water pumps and cooling water piping. The loops are not interconnected in order to assure that the larger power condensing system cannot be contaminated by a process cooler chemical leak.

The process cooling water system is designed to operate at nominal supply pressure of 70 psig and a nominal return pressure of 55 psig at any process unit header battery limit. The system is designed to supply the cooling water at a normal temperature of 85 ^{0}F, and the normal return temperature of 105 ^{0}F.

The process cooling tower uses a 10 cell cross flow design containing splash fill. The returned cooling water is evenly distributed through the cells of the tower. The flow into each cell can be controlled manually with valves and pressure gauges. Each cell of the cooling tower is equipped with a fan atop the cell. As the induced draft fans rotate, air is pulled in through the sides of the tower. As the water flows down the tower, it comes into contact with air moving up through the tower. High-efficiency drift eliminators are installed in order to decrease water loss and minimize particulate emissions from solids suspended or dissolved in the drift water. As the water flows down through the tower, it flows into the cooling water basin located below the tower cells. Water in the basin, subsequently flows into the pump sumps. The water in the basin is level controlled and makeup water is added to replace the losses. The CW circulating pumps are motor-driven vertical turbine pump design and are located in the pump sump.

To compensate for evaporation, drift, blowdown and miscellaneous water losses, makeup water is added to the cooling water basin. A portion of the circulating water is sent through side stream filters to remove any suspended particles such as dust, organic particles and fine dirt, leaving the circulating water cleaner. The filters decrease the chances of fouling the downstream heat exchangers.

Chemical treatment packages will be supplied to the cooling tower system.

- Sulfuric acid will be used to control the pH of the circulating cooling water.
- A corrosion inhibitor is added for corrosion control.
- A scale inhibitor is added for scale control.
- A chlorinator package is design to add chlorine to prevent biological growth.

2.2.7 Custody Transfer Station

A Custody Transfer Station (CTS) will be installed on the CO_2 product stream prior to the tie-in with the Denbury pipeline. The Custody Transfer Station is composed of two (each 100% redundant) AGA Report #3 orifice meter runs with associated instrumentation for producing custody transfer requirements of the metered CO_2 from LCCE to Denbury Resources. The selected meter type and vendor is based on recommendations from Denbury Resources to meet their custody transfer requirements.

2.2.8 Piping Tie-ins

The interconnecting piping between Areas 06, 10, 12, 16, 18, and 26 utilities, feed and products is shown in Table 2.2.6.1.

Table 2.2.6.1 – Piping Tie-ins

Service	Source	Destination
Acid Gas to WSA	CCS Piperack	WSA
De-inventoried Methanol	CCS Piperack	Boundary Limit
BFW	Boundary Limit	CCS Piperack
CO_2		
Compressed to Metering	CO_2 Compressors	CO_2 Meter
CO_2 to Compressors LP1	CCS Piperack	CO_2 Compressors
LP2	CCS Piperack	CO_2 Compressors
LP3	CCS Piperack	CO_2 Compressors
CO_2 to RTO		
Combined into Header	CCS piperack	RTO
Condensate	CCS piperack	Boundary Limit
Cooling Water In to Rectisol	Cooling tower	CCS piperack
Cooling Water Out of Rectisol	CCS piperack	Cooling tower
Cooling Water in to CO_2 Compressors	Boundary Limit	CO_2 Compressors
Cooling Water out of CO_2 Compressors	CO_2 Compressors	Boundary Limit
Cooling Water in to WSA	Cooling Tower	WSA
Cooling Water out of WSA	WSA	Cooling Tower
Demin Water	Boundary Limit	CCS Piperack

Service	Source	Destination
Flare Header	CCS Piperack	Boundary Limit
H2 Rich Gas	CCS Piperack	Boundary Limit
Impure Water	CCS Piperack	Boundary Limit
Makeup Methanol	Boundary Limit	CCS Piperack
Methanol - Deinventoried	CCS Piperack	Boundary Limit
Methanol Bleed	CCS Piperack	Boundary Limit
Natural Gas	Boundary Limit	CCS Piperack
N2 - MP	Boundary Limit	CCS Piperack
N2 - LP	Boundary Limit	CCS Piperack
Raw Syngas I	Boundary Limit	CCS Piperack
Raw Syngas II	Boundary Limit	CCS Piperack
Sour Water	CCS Piperack	Boundary Limit
Syngas to Methanol	CCS Piperack	Boundary Limit
Sulfuric Acid	WSA	Boundary Limit
Steam - HP	WSA	Boundary Limit
Steam - MP	Boundary Limit	CCS Piperack
Steam - LP	Boundary Limit	CCS Piperack

2.3 PFDs and P&IDs – AGR, Propylene Refrigeration, WSA, CO_2 Compression and RTO

Air Liquide/Lurgi developed PFDs and P&IDs for Area 06, Haldor Topsoe developed PFDs and P&IDs for Area 12, and SKE&C USA developed PFDs and P&IDs for Areas 10, 16. 18, and 26.

2.4 Compressor Selection Report

The Compressor Selection Study presented in the Decision Point Application submitted June 30, 2011 remains valid and is restated here. The conclusion retains selection of two 50% compressors, but for the current design they are supplied by a combined feed that is split to each compressor.

Introduction

The purpose of this study was to identify the type of compression equipment best suited for the CO_2 sequestering service required at the LCCE facility located in Lake Charles, Louisiana. The centrifugal compressor types considered were:

(a) The traditional "Between Bearings" type;

(b) The Integrally Geared Compressor (IGC) type.

Basis for Selection

The following criteria to be used in making this evaluation:

(1) Ability to meet process requirements;

(2) Proven experience with the type of unit being proposed;

(3) Reliability and availability;

(4) Initial capital cost;

(5) Life cycle costs base on operating the unit for 30 years at 8,672 hrs per year.

Based on the above criteria vendors were approached to supply a separate CO_2 compressor for each Rectisol® train.

The use of a single CO_2 compressor for this project would mean a single compressor mass flow capacity of 12,200 tons/day – twice the mass flow per compressor as currently proposed. The 12,200 tons/day is well beyond the current proven experience of dense phase CO_2 compressors – whether in an integrally geared or between bearing configuration. The largest CO_2 compressors in operation today are in the range of 2,000 ton/day to approximately 3,000 ton/day. A single train compressor for the LCCE project will be a prototype, and because of the size, would not be able to be shop tested on CO_2. In addition, the motor driver for the compressor would be in the range of 65,000 to 75,000 HP – depending on the compressor efficiency and compressor configuration chosen. In this size, an integrally geared design would be a development project for the integrally geared compressor suppliers (assuming they wanted to or had the resources available to embark on this unique application) and the between bearing design would be substantially less efficient because of less intercooling.

There will also be design issues around the electric motor (it would be another prototype as there are no 75,000 HP 1200 RPM or 1800 RPM motors in service) and the ability of the electrical network to supply power to a single 75,000 HP motor might also be an issue. Furthermore, the impact on the network when a full load trip occurred may be problematic as well. There may be issues with the CO_2 pipeline as well if the entire flow was disrupted at once – transient pressure pulsations, etc.

Thus, two compressors each sized for 50% of the Rectisol® recovered CO_2 volume is selected.

The Process

The compression process calls for two 50% compressor trains each of which take suction from three streams from the Rectisol® System (licensed from Air Liquide/Lurgi) identified as LP3, LP2 and LP1 and compressing the combination to a final pipeline discharge pressure of 2,265 psia. With initial suction provided by the LP3 stream, LP2 and LP1 would be processed as side-streams.

Inquiry Documents

The inquiry documents sent to Vendors were limited to identifying the primary applicable API specifications, the driver type, and the process duty requirements.

Compressor Vendors Considered

The inquiry documents were sent to known compressor manufacturers capable of providing a compressor to meet the process and technical specifications required for this service. For purposes of this report, they are identified as A18 through G18 with the letter identifying a prospective vendor and 18 reflecting the process area (CO_2 Compression).

Response from Vendors

Vendor A18 -

A proposed a traditional Between Bearings selection configured as follows:

LP body incorporating two side streams coupled in tandem to a HP intercooled body, and driven via a step-up gear by a synchronous motor utilizing a Load Commutated Inverter (LCI) type Variable Frequency Drive (VFD). Power required for max and min flow conditions being 34,075 HP and 32,146 HP, respectively.

Concerns regarding this preliminary selection, in particular re-cooled gas temperatures and the selection of an eight wheel casing in a high pressure environment where rapid changes in compressibility are envisaged, were sent to vendor A18. Although A18 responded that they would streamline their selection, there has been no response to date.

Vendor B18 -

At a clarification meeting, Vendor B18 expressed enthusiasm for pursuing this project and after outlining a preliminary selection based on the traditional “Between Bearings” design.

Details pertaining to vendor B18 proposal are addressed later on this report.

Vendor C18 -

Vendor C18 proposal is based on the combination of an Integral Gear unit followed by a separate motor driven pump for the last stage of the compression process. They said that this configuration represented their most efficient solution.

Vendor C18 did not recommend their traditional “Between Bearings” configuration, stating that this solution:

- Was less efficient;

- Was more costly;
- Took up more plot space;
- Cannot compete against the Integral Gear units on a lifecycle cost basis.

Details pertaining to Vendor C18's ultimate proposal are addressed later in this report.

Vendor D18 -

Vendor D18's proposal is based on their proven eight-stage Integral Gear unit – three of which have seen almost a decade of successful operation at another facility with an operating discharge pressure of 2,700 psig, which is greater than the 2,265 psia proposed for this application.

Vendor C18 included the desired starting means and capacity control methodology to be used for each of the two 50% compressor trains. The information fully describes the soft start methodology with an LCI VFD followed by Direct-on-Line operation when full speed was attained. Ultimate capacity control being achieved via the unit's Inlet Guide Vane (IGV) system.

Details pertaining to D18's proposal, after preliminary conditioning, are addressed later in this report.

Vendor E18 -

Vendor E18 provided a proposal Based on between bearing design. Details pertaining to their proposal are addressed later in this report.

Vendor F18 -

Vendor F18 provided a technical and commercial proposal offering their eight-stage Integral Gear unit. The unit is quoted with one LCI VFD for soft-start followed by Direct-on-Line operation when full speed attained. The capacity control being achieved via the unit's IGV system.

Details pertaining to F18's proposal, after preliminary conditioning, are addressed later in this report.

Vendor G18 -

Vendor G18 merely questioned the status of the Sequestering project and has not submitted a proposal.

<u>Review of Proposals</u>

Vendor C18 -

The proposal consists of a six-stage motor driven Integral Gear unit to conduct the first six stages of compression followed by a separate motor driven pump to conduct the final stage of compression up to the pipeline discharge pressure of 2,265 psia.

The six-stage Integral Gear unit is configured for motor drive using a VFD for soft start purposes. Capacity control is achieved via the unit's IGVs.

Final stage of compression is achieved by a CO_2 pump which is also driven by a separate VFD driven motor. Capacity control being achieved via the VFD system.

The Integral Gear unit plus pump variant offered is the truest sense a prototype and cannot be recommended. Also note that proposal does not include a mandatory full speed full pressure shop test. Their base include a 4 hour no load test under vacuum.

Power required at max flow = 21,480 KW (this number will change once the vendor fine-tunes the proposal.

Total US$26,688,159.00

Vendor D18 -

The proposal, for each 50% train consists of an eight-stage Integral Gear unit, complete with intercoolers and associated piping, service systems, and controls.

The two 50% trains are soft started using a single LCI and then switched over to Direct-On-Line steady state operation. Capacity control is achieved at constant speed using the three sets of IGVs.

Based on intercooler approach temperature of 9°F and interstage pressure drops which vary from 0.73 to 0.87 psi, the maximum flow case requirement is 22,451 kW.

Note: the Mix temps at discharge of first and second stages need to be reevaluated. The power increment resulting from this correction would be of the order of 84 kW.

Commercial aspects for the identified scope of supply are as follows;

Total US$25,298,956.00 +/- 10%

Vendor B18 -

Vendor B18 has proposed the traditional “Between Bearings” approach - an approach with which they have significant CO_2 high pressure application experience.

Each 50% train consists of a double ended synchronous motor rated at 36,863 HP driving, via a gear box, the tandem combination of a LP casing and an MP casing on the forward end and a casing via a step-up gear box at the aft end. Aft end compressor speed is 4,350 rpm. Forward end compressor speed is 10,600 rpm.

The proposed configuration uses three intercoolers to be supplied by others.

Vendor B18 has proposed variable speed for capacity control of each unit. This could at a later stage be modified to suction throttling, in which event a single VFD would be supplied for soft starting of both units prior to Direct-On-Line starting for steady state operation.

The efficiency of suction throttling as applied to three streams (LP3, LP2, and LP1) versus speed change should be considered prior to deciding on the capacity control methodology.

Another factor which would enter the equation would be reliability and availability of a VFD which will be on-line all the time.

Mix temperatures and re-cooled gas temperatures need to be fine-tuned. The overall impact on power as a result of this refinement is not expected to be significant.

Scope of supply includes:

(a) The compression unit located on three separate baseplates – motor on one, aft end gear, LP and MP casings on one, and forward end gear and HP casing on one.

(b) All service systems – lube oil buffer and dry seal gas, condition monitoring equipment Yokogawa Anti-surge system, control panels etc.

Budgetary Price for the two 50% trains is US$26,322,060 (+/-20%)

Vendor F18 -

Vendor F18's proposal, for each 50% train consists of an eight-stage Integral Gear unit, Model STC-GV (80-8) acc, complete with intercoolers and associated piping, service systems, and controls.

The two 50% trains are soft started using a single LCI and then switched over to Direct-On-Line steady state operation. Capacity control is achieved at constant speed using the three sets of IGVs.

Commercial aspects for the identified scope of supply are as follows;

Total US$27,091,047 +/- 10%

Vendor E18 -

Vendor E18 proposed the traditional "Between Bearings" approach.

Each 50% train consists of a double ended Synchronous Motor rated at 34,613 HP driving, via gear boxes, the tandem combination of a LP casing and a HP casing on the forward. Vendor E18 has not quoted Anti-surge system.

Vendor E18's proposal needs significant conditioning in order to bring it to a comparable level with the other quotes that have been received.

The proposed configuration uses three intercoolers to be supplied by others.

Total US$27,720,000 Budget

<u>Comparison</u>

The Table below illustrates the comparison of the two types of available compressor configurations - Integral Gear units (IGC) versus the traditional "Between Bearings" type.

Table 2.4.1 – CO_2 Compressor Vendor Comparison

Preliminary Summary

	IGC Compressors			Between Bearing Compressors				
Vendors	D18	F18	C18	B18	E18	A18	G18	C18
First Cost 2 Machines Excluding Freight and Spares	$25,298,956	$27,091,475	$26,688,159	$24,285,060	$27,720,000	Note 1	Note 2	Note 3
Tolerances	+/- 10%	Budgetry	Budgetary	+/- 20%	+/- 20%			
Experience at high discharge pressure(~2265 Psia)	3 units 8 to 10 Years - One Sold Last year	First unit Sold to KBR - under Engineering	No Experience - IGC+Pump would be a Prototype	At Least 15 units 1978 ~2005	Yes	Unknown	Unknown	Has experience Note 3
BHP at Max flow & CW Temp	22,451 KW	21,887 KW	21,626 KW	27,489 KW	25,811 KW			
Yearly Operating cost [MDT as Base]	Base	-$333,507	-$479,345	$2,927,199	$1,952,241			

Note 1: Basic body selection. Has not responded to KBR questions. No technical or commercial proposal provided.
Note 2: Did not provide technical or commercial proposal
Note 3: Declined to bid Between bearing machine because life cycle cost.
Note 4: The above first cost values represent initial equipment costs only. They do not include installation costs
Note 5: D and B have quoted Cr-Mo material for the wetted parts. This is based on the gas being totally dry. If off-design cases could result in the presence of water, both Vendors should be asked to provide stainless steel materials. D's proposal has offered stainless steel materials as an option at euro 4,800,000.00.
Note 6: If the presence of water is a factor, MDT should also be asked to include intercooler separation facilities – this is not included in their current scope.
Note 7: The provision of intercoolers, associated piping and knock-out facilities for the "Between Bearings" solution provide by B will be by others.

The comparison shows that the IGC machines have about 5 MW lower power consumption (and hence lower operating cost) with a comparable initial capital cost. D18 has the only installed machines with a comparable service.

Conclusions and Recommendations

The selection criteria outlined above was used to evaluate the five acceptable vendors:

Criteria	***D18***	***F18***	***C18***	***E18***	***B18***
Ability to meet process requirements	Yes	Yes	Yes	Yes	Yes
Proven experience	Yes	None	None	None	None
Reliability & Availability	Yes	Unknown	Unknown as proposed	Yes	Yes
Initial Capital Cost	Comparable	Comparable	Comparable	Comparable	Comparable
Life cycle cost	Low	Lower	Lowest	Higher	Highest

- The Integral Gear unit offered in conjunction with a pump by Vendor C18 is a unique and unproven entity at the pressures applicable to this project. The academic exercise to prove the integrity of the proposed configuration may well show this to be a viable solution. We do not, however, consider the academic proof to be a good substitute for actual operating experience. The recommendation must therefore be to disqualify C18's proposal in its current form;
- Vendor D18 is the only supplier with good operating experience in the application of an Integral Gear unit with CO_2 at the pressure levels applicable to this project. Based on operation efficiency, satisfactory reliability and availability the D18 must be viewed as the only viable supplier of an Integral Gear type solution;
- The "Between Bearings" solution proposed by Vendor B18 is technically acceptable. Initial equipment costs as shown currently are comparable with the Integral Gear unit proposed by D18. However that installation costs for the "Between Bearings" solution will be considerably higher than those associated with the packaged unit offered by D18;
- The proposal submitted by D18 should be further pursued during the formal inquiry stage at the next phase to fine-tune process related topics such as viable interstage pressure drops, intercooler approach temperatures, etc. and to finalize commercial aspects;
- The proposal submitted by Vendor F18 should be further pursued during formal inquiry stage. Due diligence must be exercised since F has no experience with high pressure CO_2 applications.

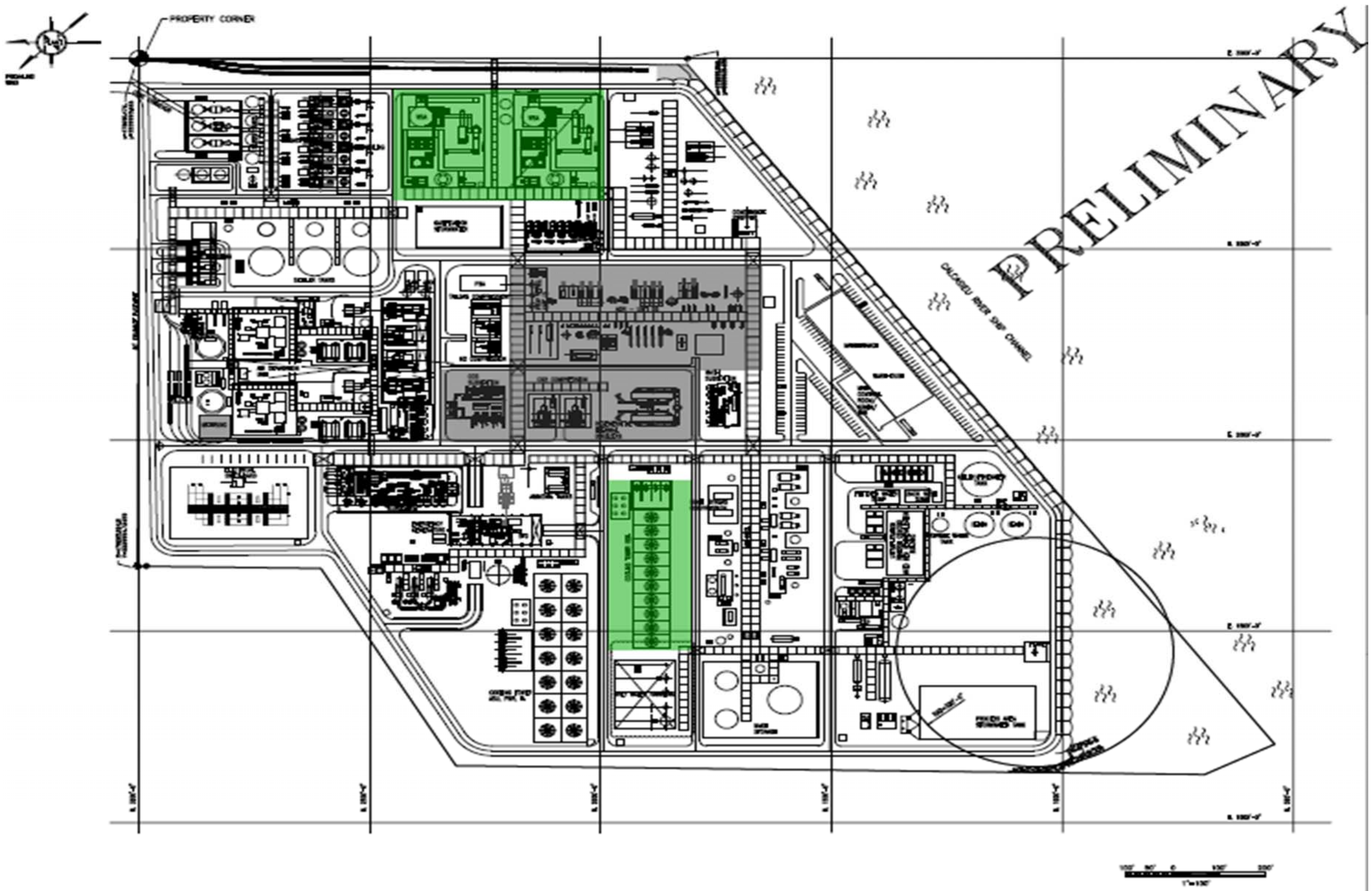
Current recommendation is to prepare complete assessment of technical and commercial compliance to the RFQ for the IGC machines with enquiries to Vendors D18, F18 and C18.

SKEC USA agreed with and continued design using Granherne's recommendation and completed RFQs for IGC machines, the results of which are detailed in section 4.1.1 below.

3.0 PLOT PLAN

Overall plot plan is shown in the figure on the following page. The shaded areas indicate the scope covered by the CCS project consisting of Area 06, 10, 16, and 18 as well as the Custody Transfer Station (CTS). The two complementary systems, Areas 12 and 26, are highlighted in green to denote these additions since the June 30, 2011 report.

The piperacks at the boundary limits of the CCS project scope interconnect with the utilities, feed and products. The Denbury pipeline will connect to the CO_2 pipeline at the CTS located in the north-west area of the site, just to the East of the electrical substation.


PROPERTY CORNER
PRELIMINARY

4.0 EQUIPMENT

The equipment list for the project by area is shown in Table 4.0.1 below.

Table 4.0.1 – Equipment List – CCS Project

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
AREA 06 ACID GAS REMOVAL SYSTEM			
AREA 06 METHANOL TRAIN HEAT EXCHANGERS			
06-E-0101	Raw Gas / Synthesis Gas Exchanger I	1	EACH
06-E-0102	Raw Gas Chiller I	1	EACH
06-E-0103	Boiler Feed Water Cooler	1	EACH
06-E-0104	Raw Gas / Synthesis Gas Exchanger II	1	EACH
06-E-0105	Raw Gas / LP3 CO_2 Heat Exchanger	1	EACH
06-E-0106	Raw Gas Final Chiller	1	EACH
06-E-0107	CO_2-Methanol / H_2S-Methanol Heat Exchanger	1	EACH
06-E-0108	H_2S Absorber Feed Chiller I	1	EACH
06-E-0111	CO_2-Methanol Chiller I	1	EACH
AREA 06 HYDROGEN TRAIN HEAT EXCHANGERS			
06-E-0126	Raw Gas / Crude H_2 Heat Exchanger I	1	EACH
06-E-0127	Raw Gas Chiller II	1	EACH
06-E-0128	Raw Gas / Crude H_2 Heat Exchanger II	1	EACH
06-E-0129	Raw Gas / LP2 CO_2 Heat Exchanger	1	EACH
06-E-0131A/B	CO_2-Methanol Chiller II	2	EACH
06-E-0132	H_2S Absorber Feed Chiller II	1	EACH
06-E-0133	CO_2-Methanol / Crude H_2 Gas Heat Exchanger	1	EACH
06-E-0134	CO_2-Methanol / LP3 CO_2 Heat Exchanger	1	EACH
AREA 06 COMMON HEAT EXCHANGERS			
06-E-0001	Exhaust Steam Condenser	1	EACH
06-E-0109	CO_2-Methanol Subcooler	1	EACH
06-E-0110A/B	CO_2 Flash Methanol Chiller	2	EACH
06-E-0112	Reabsorber Methanol / Lean Methanol Heat Exchanger	1	EACH
06-E-0113	H_2S Laden Methanol Subcooler	1	EACH
06-E-0114A-H	Laden / Lean Methanol Heat Exchanger	8	EACH
06-E-0115	Hot Flash Gas Condenser	1	EACH
06-E-0116	LP1 CO_2 / Hot Flash Gas Heat Exchanger	1	EACH
06-E-0117	Prewash Methanol Heater	1	EACH

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
06-E-0118	Hot Regenerator Condenser	1	EACH
06-E-0119A/B	Hot Regenerator Reboiler	2	EACH
06-E-0120	Methanol Water Column Reboiler	1	EACH
06-E-0121A/B	Impure Water Cooler	2	EACH
06-E-0122	Acid Gas Reheater	1	EACH
06-E-0123A/B	Acid Gas / LP3 CO_2 Heat Exchanger	2	EACH
06-E-0124	LP3 CO_2 / Recycle Gas Heat Exchanger	1	EACH
06-E-0125	Acid Gas Chiller	1	EACH
06-E-0130-1	Recycle Gas Compressor Intercooler	1	EACH
06-E-0130-2	Recycle Gas Compressor Aftercooler	1	EACH
AREA 06 METHANOL TRAIN TOWERS INCLUDING INTERNALS			
06-T-0101	Ammonia Scrubber I	1	EACH
06-T-0101-INT	Ammonia Scrubber I Internals	1	LOT
06-T-0102	Absorber I	1	EACH
06-T-0102-INT	Absorber I Internals	1	LOT
AREA 06 HYDROGEN TRAIN TOWERS INCLUDING INTERNALS			
06-T-0113	Absorber II	1	EACH
06-T-0102-INT	Absorber II Internals	1	LOT
06-T-0114	Ammonia Scrubber II	1	EACH
06-T-0102-INT	Ammonia Scrubber II Internals	1	LOT
AREA 06 COMMON TOWERS INCLUDING INTERNALS			
06-T-0103	H_2S Flash Column	1	EACH
06-T-0103-INT	H_2S Flash Column Internals	1	LOT
06-T-0103-PKG	H_2S Flash Column Packing	175	CU FT
06-T-0104	CO_2 Flash Column	1	EACH
06-T-0104-PKG	CO_2 Flash Column Packing	634	CU FT
06-T-0107	Reabsorber	1	EACH
06-T-0107-INT	Reabsorber Internals	1	LOT
06-T-0107-PKG	Reabsorber Packing	321	CU FT
06-T-0108	Hot Flash Column	1	EACH
06-T-0108-PKG	Hot Flash Column Packing	1,039	CU FT
06-T-0109	Hot Regenerator	1	EACH
06-T-0109-INT	Hot Regenerator Internals	1	LOT
06-T-0110	Methanol Water Column	1	EACH
06-T-0110-INT	Methanol Water Column Internals	1	LOT
06-T-0112	Prewash Flash Column	1	EACH
06-T-0112-PKG	Prewash Flash Column Packing	29	CU FT

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
AREA 06 COMMON VESSELS			
06-V-0001	Atmospheric Condensate Flash Drum	1	EACH
06-V-0002	MP Steam Condensate Drum	1	EACH
06-V-0003	Cold Flare KO Drum	1	EACH
06-V-0004	LP Flare KO Drum	1	EACH
06-V-0005	HP Flare KO Drum	1	EACH
06-V-0101	Make Up Methanol Storage Vessel	1	EACH
06-V-0102	Underground Slop Drum	1	EACH
06-V-0103	Hot Regenerator Reflux Vessel	1	EACH
06-V-0104	Acid Gas Separator	1	EACH
06-V-0130	Recycle Gas Compressor KO Drum	1	EACH
AREA 06 COMMON COMPRESSORS			
06-C-0130	Recycle Gas Compressor	1	EACH
AREA 06 COMMON PUMPS AND DRIVERS			
06-P-0001A/B	Condensate Pump	2	EACH
06-P-0004A/B	LP Flare KO Drum Pump	2	EACH
06-P-0005A/B	Acid Gas Flare KO Drum Pump	2	EACH
06-P-0101A-C	Main Wash Pump	3	EACH
06-P-0102A/B	CO_2 Laden Methanol Pump	2	EACH
06-P-0103A/B	Reabsorber Circuit Pump I	2	EACH
06-P-0104A/B	Reabsorber Circuit Pump II	2	EACH
06-P-0105A-C	Hot Flash Feed Pump	3	EACH
06-P-0106A-C	CO_2 Absorber Feed Pump	3	EACH
06-P-0107A/B	Methanol Water Column Feed Pump	2	EACH
06-P-0108A/B	Hot Regenerator Reflux Pump	2	EACH
06-P-0109A/B	Methanol Water Column Bottom Pump	2	EACH
06-P-0110A/B	Methanol Water Column Reflux Pump	2	EACH
06-P-0111A/B	Make Up Methanol Pump	2	EACH
06-P-0112	Underground Slop Pump	1	EACH
AREA 10 PROPYLENE REFRIGERATION			
AREA 10 HEAT EXCHANGERS			
10-E-0151	Propylene Refrigerant Desuperheater	1	EACH
10-E-0152	Propylene Refrigerant Condenser	1	EACH
AREA 10 COMPRESSORS			
10-C-0151	Propylene Refrigerant Compressor	1	EACH

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
	Includes the following:		
	- Lube Oil Console		
	- Rundown Tank		
	- Seal Gas Control Unit		
	- High speed anti-surge control system		
AREA 10 VESSELS			
10-V-0151	Propylene Refrigerant 1st Stage Suction Drum	1	EACH
10-V-0152	Propylene Refrigerant 2nd Stage Suction Drum	1	EACH
10-V-0153	Propylene Refrigerant 3rd Stage Suction Drum	1	EACH
10-V-0154	Propylene Refrigerant Accumulator	1	EACH
AREA 10 PUMPS AND DRIVERS			
10-P-0151	Propylene Refrigerant Pump Out Pump	1	EACH
AREA 16 REGENERATIVE THERMAL OXIDIZERS			
AREA 16 PACKAGED EQUIPMENT			
16-PK-1001	Regenerative Thermal Oxidizer Package	1	EACH
	Includes the following:		
	- 2 each 10.4 meter RTO Vessels		
	- Purge/Dilution Air Blower		
	- Ductwork		
	- Burners, Combustion Air Blower and valve train		
	- Hybrid random packing and structured heat exchange media		
	- Maintenance platform		
16-PK-2001	Regenerative Thermal Oxidizer Package	1	EACH
	Includes the following:		
	- 2 each 10.4 meter RTO Vessels		
	- Purge/Dilution Air Blower		
	- Ductwork		
	- Burners, Combustion Air Blower and valve train		
	- Hybrid random packing and structured heat exchange media		
	- Maintenance platform		
16-S-0001	Regenerative Thermal Oxidizer Stack	1	EACH

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
AREA 12 WET SULFURIC ACID UNIT			
AREA 12 COMBUSTORS/BURNERS TRAIN 1			
12-F-1001	1st Combustor	1	EACH
12-F-1002	2nd Combustor	1	EACH
AREA 12 COMBUSTORS/BURNERS TRAIN 2			
12-F-2001	1st Combustor	1	EACH
12-F-2002	2nd Combustor	1	EACH
AREA 12 HEAT EXCHANGERS TRAIN 1			
12-E-1001	1st Waste Heat Boiler	1	EACH
12-E-1002	2nd Waste Heat Boiler	1	EACH
12-E-1003	1st Interbed Cooler	1	EACH
12-E-1004	2nd Interbed Cooler	1	EACH
12-E-1005	Process Gas Cooler	1	EACH
12-E-1006	WSA Condenser	1	EACH
12-E-1007	Acid Cooler	1	EACH
12-E-1008	Air Preheater	1	EACH
12-E-1009	Ammonia Evaporator	1	EACH
12-E-1010	BFW Preheater	1	EACH
AREA 12 HEAT EXCHANGERS TRAIN 2			
12-E-2001	1st Waste Heat Boiler	1	EACH
12-E-2002	2nd Waste Heat Boiler	1	EACH
12-E-2003	1st Interbed Cooler	1	EACH
12-E-2004	2nd Interbed Cooler	1	EACH
12-E-2005	Process Gas Cooler	1	EACH
12-E-2006	WSA Condenser	1	EACH
12-E-2007	Acid Cooler	1	EACH
12-E-2008	Air Preheater	1	EACH
12-E-2009	Ammonia Evaporator	1	EACH
12-E-2010	BFW Preheater	1	EACH
AREA 12 REACTORS TRAIN 1			
12-R-1001	1st SCR Reactor	1	EACH
12-R-1002	2nd SCR Reactor	1	EACH
12-R-1003	SO_2 Converter	1	EACH
AREA 12 REACTORS TRAIN 2			
12-R-2001	1st SCR Reactor	1	EACH
12-R-2002	2nd SCR Reactor	1	EACH
12-R-2003	SO_2 Converter	1	EACH

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
AREA 12 BLOWERS AND DRIVERS TRAIN 1			
12-C-1001	Cooling Air Blower	1	EACH
12-C-1002	Hot Air Blower	1	EACH
12-C-1003	Clean Gas Blower	1	EACH
AREA 12 BLOWERS AND DRIVERS TRAIN 2			
12-C-2001	Cooling Air Blower	1	EACH
12-C-2002	Hot Air Blower	1	EACH
12-C-2003	Clean Gas Blower	1	EACH
AREA 12 PUMPS AND DRIVERS TRAIN 1			
12-P-1001A/B	Acid Pump	2	EACH
12-P-1002A/B	Acid Product Pump	2	EACH
12-P-1003A/B	Quench Pump	2	EACH
12-P-1004A/B	Scrubber Pump	2	EACH
12-P-1006A/B	H_2O_2 Dosing Pump	2	EACH
AREA 12 PUMPS AND DRIVERS TRAIN 2			
12-P-2001A/B	Acid Pump	2	EACH
12-P-2002A/B	Acid Product Pump	2	EACH
12-P-2003A/B	Quench Pump	2	EACH
12-P-2004A/B	Scrubber Pump	2	EACH
12-P-2006A/B	H2O2 Dosing Pump	2	EACH
AREA 12 VESSELS TRAIN 1			
12-V-1001	Process Condensate Stripper Overheads K.O. Drum	1	EACH
12-V-1002	Vacuum Pump Vent K.O. Drum	1	EACH
12-V-1003	Grey Water Ammonia Stripper Overhead K.O. Drum	1	EACH
12-V-1004	Acid Vessel	1	EACH
12-V-1005	HP Steam Drum	1	EACH
12-V-1006	MP Steam Drum	1	EACH
AREA 12 VESSELS TRAIN 2			
12-V-2001	Process Condensate Stripper Overheads K.O. Drum	1	EACH
12-V-2002	Vacuum Pump Vent K.O. Drum	1	EACH
12-V-2003	Grey Water Ammonia Stripper Overhead K.O. Drum	1	EACH
12-V-2004	Acid Vessel	1	EACH
12-V-2005	HP Steam Drum	1	EACH

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
12-V-2006	MP Steam Drum	1	EACH
AREA 12 COLUMNS TRAIN 1			
12-T-1001	Quench Column	1	EACH
12-T-1002	H_2O_2 Scrubber Column	1	EACH
AREA 12 COLUMNS TRAIN 1			
12-T-2001	Quench Column	1	EACH
12-T-2002	H_2O_2 Scrubber Column	1	EACH
AREA 12 MISCELLANEOUS TRAIN 1			
12-PR-1001	Wet Electrostatic Precipitator	1	EACH
12-S-1001	Stack	1	EACH
12-U-1001A/B/C-D	Mist Control Unit	4	EACH
12-U-1002	Ammonia/Air Mixer	1	EACH
AREA 12 MISCELLANEOUS TRAIN 1			
12-PR-2001	Wet Electrostatic Precipitator	1	EACH
12-S-2001	Stack	1	EACH
12-U-2001A/B/C-D	Mist Control Unit	4	EACH
12-U-2002	Ammonia/Air Mixer	1	EACH
AREA 18 CO_2 COMPRESSION AND TRANSFER			
AREA 18 VESSELS			
18-V-1001	CO_2 Compressor 1st Stage Suction Drum	1	EACH
18-V-1002	CO_2 Compressor 2nd Stage Suction Drum	1	EACH
18-V-1003	CO_2 Compressor 3rd Stage Suction Drum	1	EACH
18-V-2001	CO_2 Compressor 1st Stage Suction Drum	1	EACH
18-V-2002	CO_2 Compressor 2nd Stage Suction Drum	1	EACH
18-V-2003	CO_2 Compressor 3rd Stage Suction Drum	1	EACH
AREA 18 PACKAGED EQUIPMENT			
18-PK-1001	CO_2 Compressor Package	1	EACH
	Includes the following:		
	- Frame Coolers		
	- Cooler ST 1		
	- Cooler ST 2		
	- Cooler ST 3		
	- Cooler ST 4		
	- Cooler ST 5		
	- Cooler ST 6		
	- Aftercooler		

TAG NUMBER	DESCRIPTION	QTY	UNIT OF MEASURE
	- Rundown Tank		
	- Lube Oil Console		
	- High speed anti-surge control system		
18-PK-2001	CO_2 Compressor Package	1	EACH
	Includes the following:		
	- Frame Coolers		
	- Cooler ST 1		
	- Cooler ST 2		
	- Cooler ST 3		
	- Cooler ST 4		
	- Cooler ST 5		
	- Cooler ST 6		
	- Aftercooler		
	- Rundown Tank		
	- Lube Oil Console		
	- High speed anti-surge control system		
18-PK-0001	CO_2 Custody Transfer Station	1	EACH
AREA 26 PROCESS COOLING WATER			
AREA 26 PUMPS			
26-P-0001 A-F	ISBL COOLING WATER PUMPS	6	EACH
26-P-0003 A/B/C	COOLING WATER SULFURIC ACID PUMPS	3	EACH
AREA 26 TANKS			
26-SP-0001	ISBL CT BASIN & SUMP	1	EACH
AREA 26 VESSELS			
26-V-0001	ISBL COOLING WATER SULFURIC ACID DRUM	1	EACH
AREA 26 PACKAGED EQUIPMENT			
26-E-0001	ISBL COOLING TOWER	1	EACH
26-PK-0001	ISBL CW CORROSION INHIBITOR PACKAGE	1	EACH
26-PK-0003	ISBL CW SCALE INHIBITOR PACKAGE	1	EACH
26-PK-0005	ISBL CW CHLORINATOR PACKAGE	1	EACH

4.1 Bid Evaluation

Request for Proposals were sent out for CO_2 Compressor, Propylene Refrigerant Compressor and Regenerative Thermal/Catalytic Oxidizer. Bid evaluations are summarized below.

SKE&C USA also initiated enquiries for the balance of equipment within the CCS scope. The results of this process after technical and commercial evaluation of the submitted quotations are the basis for the cost estimate for this scope.

4.1.1 CO_2 Compressor

Formal proposals for two (2) integral gear-type centrifugal compressors in CO_2 service were solicited for the project. An initial high level scope review was performed in order to condition the bids for use in the estimate development, with emphasis in the following major areas:

- Scope of supply inclusive of major items;
- Demonstration of experience with similar compression services (installation references and component references);
- Capability of performing required performance testing at factory;
- Operating costs for power consumption, efficiency.

Proposals were received from four vendors (A18 and B18).

<u>Scope of Equipment Evaluated</u>

The scope of supply quoted for this package includes the following major items:

- Carbon Dioxide (CO_2) Compressors – 2 x 100% Trains;
- Gear Unit (If required);
- Lubrication Unit;
- Miscellaneous: skid mounted instrumentation/controls, special tools, spare parts, noise enclosure (if required).

Two integrally geared type centrifugal compressor trains with synchronous electric motor drivers. The CO_2 compressors take low pressure carbon dioxide streams (LP1, LP2 and LP3) from the Air Liquide/Lurgi Rectisol® unit and deliver high pressure carbon dioxide to an export pipeline for sale.

Each compressor train is to be provided with a separate lube oil console, multiple sets of inlet guide vanes for capacity control, shell and tube interstage coolers, interstage piping, a remote control panel containing a PLC controller, CCC anti-surge controller with Trainview and a Bently Nevada machinery monitoring system. Each compressor will have a synchronous motor, complete with all necessary controls for motor operation and regulation. A soft-start adjustable frequency drive is required for starting duty only (*one drive is to be used for starting both* CO_2 *compressor motors, as well as for starting the Propylene Refrigerant Compressor which may be supplied by a different compressor manufacturer than the* CO_2 *machines*). This is the Load Commutated Inverter (LCI).

In addition to factory mechanical run testing, a full load, full speed, full pressure ASME PTC 10 Type 1 performance test was requested to be included in the scope for one machine. These compressors are considerably larger in flow and power than any installed CO_2 compressor to date, and performing this Type 1 testing with contract components is critical to validate the thermodynamic and rotordynamic design of the compressor prior to shipment.

Evaluation Criteria

The following criteria were used to develop this evaluation:

- Compliance with the specified scope of supply and data sheets;
- Design features and performance of equipment;
- Proven experience in comparable applications;
- Operating power cost considerations;
- Completeness of quotation and supplier response to requests for supplementary information.

Vendor Evaluation

Summary:

A summary table presenting the offerings from Vendors A18 and B18, is shown below. It tabulates the major performance data, scope of supply, and power requirements for each of the bidders.

Based on the initial technical review of the proposals, A18 will be utilized for developing the project estimate.

Detailed Technical Bid Review meetings will be required with the suppliers before the complete technical evaluation and recommendation for purchase will be completed.

SK E&C USA

Attachment 3 Technical Bid Evaluation

REQUISITION No:	13046D-18-ME-MR-MG110-01	PROJECT No:	13046D
GROUP:	Mechanical	REV:	1
EQUIPMENT No:	18-PK-1001 / 2001	ENGINEER:	Megan Hanson
EQUIPMENT TITLE:	CO2 Compressor	CLIENT:	Lake Charles Clean Energy, LLC
PROJECT:	Lake Charles Clean Energy Project	LOCATION:	Lake Charles, Louisiana

DATE: 7-Nov-13

Key Legend Y = Acceptable (complies with Specification) * = Acceptable alternative X = Not acceptable ? = Needs Supplier clarification

DESCRIPTION	UNITS	SPECIFIED REQUIREMENTS	Key	A18	Key	B18	Key		Key	
CO2 Compressor [18-PK-1001 / 2001]										
Compressor - Type / Spec		Centrifugal / API-617	Y	According to API 617 /w comments and exceptions	Y	Centrifugal API 617				
Capacity Control		Variable Inlet	Y	Provided	Y	Variable Inlet Guide Vane Control				
Suction Pressure (LP 1 CO2 / LP 2 CO2 / LP 3 CO2)	psia	62.9 / 44.8 / 19.9	Y	49.3 (LP1) / 19.9 (LP2 & LP3)	Y	62.9 / 44.8 / 19.9				
Suction Temperature (LP 1 CO2 / LP 2 CO2 / LP 3 CO2)	°F	24 / 35 / 42	Y	103 (LP1) / 42 (LP2 & LP3)	Y	42 / 34.3 / 82.8 (mix temperatures)				
Discharge Pressure (LP 1 CO2 / LP 2 CO2 / LP 3 CO2)	psia	2267 / By Vendor / By Vendor	Y	2267	Y	2267 / 641.1 / 45.8				
Weight Flow (LP 1 CO2 / LP 2 CO2 / LP 3 CO2)	lb/h	121465 / 36073 / 397617	Y	433690 (LP2 & LP3) // 555155 (LP1&LP2&LP3)	Y	379613 / 415685 / 537149				
Molecular Weight (LP 1 CO2 / LP 2 CO2 / LP 3 CO2)		43.28 / 43.93 / 44	Y	44.01 / 44.01 / 44.01	Y	43.28 / 43.93 / 44				
Rated Power	hp	By Vendor	Y	29730 (for high cooling water case)	Y	28631 (inc. all mechanical losses)				
Rated Speed	RPM	By Vendor	Y	1800	Y	1200				
Number of stages / impellers		By Vendor	Y	8	Y	8				
Casing - Type		By Vendor	Y	Integral Gear Casing	Y	Radial Split				
Casing - Material of Construction		By Vendor	Y	A 516 Gr. 65	Y	GP240GH				
Impellers - Material of Construction		By Vendor	Y	A182 Gr. F 6NM	Y	X3CrNiMo13-4				
Shaft - Material of Construction		By Vendor	Y	A322 Gr. 4320 / A291 Class 7	Y	31CrMoV9				
Gearbox - Type / Spec		- / API-613 5th ed.	*	No intermediate gearbox necessary	Y	API 617 7 ed chapter 3 / AGMA				
Gearbox - Manufacturer / Model		By Vendor	*	No gearbox	Y	MAN Diesel & Turbo				
Gearbox - Ratio		By Vendor	*	No gearbox	Y	max.				
Gearbox - Material of Construction		By Vendor	*	No gearbox	Y	St 52 (S355J2G3).. Carbon Steel				
Driver - Type / Spec		Electric Motor	Y	Electric Motor	Y	Synchronous Motor				
Driver - Manufacturer / Model		By Vendor	Y	Siemens or equal	Y	ABB , Siemens, GE, WEG				
Driver - Rated Power		By Vendor	Y	32700 hp	Y	110% of rated compressor power - 31,494 hp				
Driver - Material of Construction		By Vendor	Y	to follow	Y	to follow				
Driver - Other		By Vendor	Y	-	Y	starter required (buyers scope) - coordination required				
Control System - Type / Spec		By Vendor	Y	SIEMENS SCAUT S7 incl. single stage control (So far not included in price, but will be)	Y	refer to PID (block diagram)				
Control System - Manufacturer / Model		By Vendor	Y		Y	Siemens S7 - 400H redundant - load sharing				
Control System - Accessories		By Vendor	Y	-	Y	as per PID				
Control System - Panel		By Vendor	Y	-	Y	Included				
Monitoring System - Type / Spec		Vibration & Temp. / API-670	Y	Vibration & Temp. / API-670	Y	Vibration & Temp / API 670				
Monitoring System - Manufacturer / Model		Bently Nevada	Y	Bently Nevada	Y	Bently Nevada 3500				
Monitoring System - Accessories		By Vendor	Y	incl. in Price	Y	as per PID				
Monitoring System - Other		By Vendor	Y	incl. in Price	Y	as per PID				
Dry Gas Seal System - Type / Spec		Tandem Seals / API-614 5th ed.	*	Carbon Ring seals will be provided	*	Carbon Ring Seals				
Dry Gas Seal System - Manufacturer / Model		By Vendor	Y	Siemens	Y	ManTurbo				
Primary Buffer Gas Type		Process Gas	Y	Process Gas	*	not applicable				
Secondary Buffer Gas Type		LP Nitrogen	Y	LP Nitrogen	Y	LP Nitrogen				
Dry Gas Seal System - Accessories		By Vendor	Y	incl. in Price	*	not applicable				
Dry Gas Seal System - Material of Construction		By Vendor	Y	incl. in Price	*	not applicable				
Couplings - Type / Spec		Dry Flex Disc/ API-671 4th ed.	Y	incl. in Price	Y	Dry Flex Disc/ API-671 4th ed.				
Couplings - Manufacturer / Model		By Vendor	Y	See Siemens Subsupplier List	Y	Euroflex , Kopflex, Bibturboflex - refer to vendor list				
Lube Oil System - Type / Spec		- / API-614 5th ed.	Y	according to API 614	Y	according to API 614				

SK E&C USA

Attachment 3 Technical Bid Evaluation

REQUISITION No:	13046D-18-ME-MR-MG110-01	PROJECT No:	13046D
GROUP:	Mechanical	REV:	1
EQUIPMENT No:	18-PK-1001 / 2001	ENGINEER:	Megan Hanson
EQUIPMENT TITLE:	CO2 Compressor	CLIENT:	Lake Charles Clean Energy, LLC
PROJECT:	Lake Charles Clean Energy Project	LOCATION:	Lake Charles, Louisiana

DATE: 7-Nov-13

Key Legend **Y = Acceptable (complies with Specification)** *** = Acceptable alternative** **X = Not acceptable** **? = Needs Supplier clarification**

DESCRIPTION	UNITS	SPECIFIED REQUIREMENTS	Key	A18	Key	B18	Key		Key	
Lube Oil System - Manufacturer / Model		By Vendor	Y	See Siemens Subsupplier List	Y	coes, AEL, Oeltechnik - refer to vendor list				
Lube Oil System - Accessories		By Vendor	Y	incl. in Price	Y	as per PID				
Lube Oil System - Material of Construction		By Vendor	Y	according to API 614	Y	according to API 614 - stainless steel				
Testing - Performance Complete Unit		Required - Witnessed	Y	will be offered as option price, details to be discussed	Y	at site or compressor only in shop				
Testing - Mechanical Run		Required - Witnessed	Y	incl. in Price	Y	MDT standard gear shop test				
Testing - High Speed Balancing		Required - Witnessed	Y	incl. in Price	*	low speed balancing as integrally geared type				
Testing - Rotor Unbalance response		Required - Witnessed	Y	incl. in Price	*	not possible for integrally geared type				
Testing - Impeller Overspeed		Required - Witnessed	Y	incl. in Price	Y	incl. in Price				
Testing - Hydrostatic		Required - Observed	Y	incl. in Price	Y	incl. in Price				
Testing - Vary Lube & Seal Oil Pressures &		Required - Witnessed	Y	incl. in Price	Y	incl. in Price				
Testing - Gas Leak at Discharge Pressure		Required - Witnessed	*	not included, because no DGS will be provided (but carbon ring seals)	Y	at site				
Testing - Helium Leak		Required - Witnessed	*	not included	*	not applicable				
Testing - Spare Parts		Required - Witnessed	Y	incl. in Price	Y	if ordered with main equipment				
Testing - Gas Seal		Required - Observed	*	no dry gas seals will be provided (but carbon ring seals)	*	no dry gas seals will be provided (but carbon ring seals)				
Testing - Sound Level		Required - Witnessed	*	only calculations; testing not possible due to interference	*	for information only				
Testing - Panel Functional		Required - Witnessed	Y	incl. in Price	Y	incl. in Price				
Testing - Impeller Resonance		Required - Witnessed	Y	incl. in Price	Y	if applicable for open impellers				
Testing - Aux Equipment		Required - Witnessed	Y	incl. in Price	Y	incl. in Price				
Testing - Full Load / Speed / Pressure		Required - Witnessed	*	will be offered as option price (details to be discussed)	Y	at site or compressor at lower pressure lower load and full speed in shop				
Paint Primer / Finish		Required	Y	as per manufacturer standard	Y	incl. in Price				
Special Tools		Required	Y	incl. in Price	Y	incl. in Price				
Shipping Preparation		Required	Y	incl. in Price	Y	incl. in Price				
Weight		Required	Y	580234 lb	Y	approximately 85t compressor + 50t motor + 50t coolers & piping +25t LOS				
Spare Parts - Commissioning		Required	Y	1 set included	Y	quoted separately				
Spare Parts - Capital		Required	Y	as option price	Y	quoted separately				
Spare Parts - 2 Year		Required	Y	as option price	Y	quoted separately				
TECHNICALLY ACCEPTABLE?				YES - Technically Acceptable		YES - Technically Acceptable				
ENGINEER COMMENTS				Weight to be confirmed by vendor.						

4.1.2 Propylene Refrigerant Compressor

Introduction

The inquiry documents were sent to known compressor manufacturers capable of providing a compressor to meet the process and technical specifications required for this service. For purposes of this report, they are identified as A10 and B6.

Scope of Equipment Evaluated

This technical evaluation covers a Propylene compressor, suction drums motor, couplings, dry gas seals, gearbox, LOS (lube oil system), anti-surge control and instrumentation.

Evaluation Criteria

The criterion used was the ability to achieve process conditions. The Technical bid evaluation is shown in the Tables below.

Technical Evaluation					
REQUISITION No:	13046D-10-ME-MR-MG100-02	PROJECT No:	13046D		
GROUP:	Mechanical	REV:	0	DATE:	1-Nov-13
EQUIPMENT No:	10-C-0151				
EQUIPMENT TITLE:	Propylene Refrigerant Compressor	CLIENT:	Lake Charles Clean Energy, LLC		
PROJECT:	Lake Charles Clean Energy Project	LOCATION:	Lake Charles, Louisiana		

DESCRIPTION	UNITS	SPECIFIED REQUIREMENTS	Key	A10	Key	B10
Control System - Accessories						
Control System - Panel					Y	Unit Control Panel UCP (PCS7 basis, SCAUT)
Monitoring System - Type / Spec		Vibration & Temp. / API-670	Y	Confirmed	Y	Vibration and Temp Detectors
Monitoring System - Manufacturer / Model			Y	BN/ 3300	Y	BN / 3330
Monitoring System - Accessories			Y	PROBE PROXIMATER / BN3300	-	
Monitoring System - Other			Y	Monitor by others	?	Needs Clarification
Dry Gas Seal System - Type / Spec			Y	TANDEM WITH LABYRINTH / API614	Y	2 tandem dry gas seals with internal labyrinths, bi directional / API 614
Dry Gas Seal System - Manufacturer / Model			Y	JOHN CRANE / EAGLE BURGMANN / FLOW SERVE / 28AT or Equivalent	Y	Siemens Choice
Primary Buffer Gas Type			Y	DISCHARGE GAS	Y	Nitrogen
Secondary Buffer Gas Type			Y	NITROGEN	?	Needs Clarification
Dry Gas Seal System - Accessories			Y	SEAL GAS UNIT	-	
Dry Gas Seal System - Material of Construction			Y	304L or 316L SS (PIPING)	Y	Stainless Steel (Piping)
Couplings - Type / Spec		- / API-671 4th ed.	Y	DIAGHRAM or DISC PACK/API671 4th	Y	Dry Type Coupling, multiple disk or diaphragm, non sparking coupling guard / API 617
Couplings - Manufacturer / Model			Y	EAGLE / JOHN CRANE or Equivalent	?	Needs Clarification
Lube Oil System - Type / Spec		- / API-614 5th ed.	Y	Separate unit/API614 5th	Y	Free Standing Unit / API 614
Lube Oil System - Manufacturer / Model			Y	COBEY or Equivalent	?	Needs Clarification
Lube Oil System - Accessories			Y	Reservoir, Oil pump, Oil filter, oil cooler, etc.	Y	Reservoir, Lube Oil Pumps, Rundown Tank, Filter, Oil mist demister, Valves, Air HEX
Lube Oil System - Material of Construction			Y	304L SS (PIPING)	Y	316 SS (Piping)
Testing - Performance Complete Unit		Required - Witnessed		To be discussed	?	
Testing - Mechanical Run		Required - Witnessed	Y	Confirmed	Y	Provided
Testing - Performance		Required - Witnessed	Y	Confirmed	Y	Provided
Testing - Impeller Overspeed		Required - Observed	Y	Confirmed	Y	Provided
Testing - Hydrostatic		Required - Observed	Y	Confirmed	Y	Provided
Testing - Vary Lube & Seal Oil Pressures & Temperatures		Required - Observed	Y	Confirmed	Y	Provided
Testing - Gas Leak at Discharge Pressure		Required - Witnessed	Y	Confirmed	Y	Provided
Testing - Helium Leak		Required - Witnessed	*	N/A	?	Needs Clarification
Testing - Spare Parts		Required - Witnessed	Y	Confirmed	?	Needs Clarification
Testing - Gas Seal		Required - Observed	Y	Confirmed	Y	Provided
Testing - Sound Level		Required - Witnessed	*	FOR REFERENCE ONLY	?	Needs Clarification
Testing - Aux Equipment		Required - Witnessed	Y	Confirmed	?	Needs Clarification
Testing - Full Load / Speed / Pressure		Required - Witnessed	?	Not Included	?	Needs Clarification
Inspector's Checklist Compliance		Required	Y	Confirmed	?	Needs Clarification

Technical Evaluation	REQUISITION No:	13046D-10-ME-MR-MG100-02	PROJECT No:	13046D		
	GROUP:	Mechanical	REV:	0	DATE:	1-Nov-13
	EQUIPMENT No:	10-C-0151				
	EQUIPMENT TITLE:	Propylene Refrigerant Compressor	CLIENT:	Lake Charles Clean Energy, LLC		
	PROJECT:	Lake Charles Clean Energy Project	LOCATION:	Lake Charles, Louisiana		

DESCRIPTION	UNITS	SPECIFIED REQUIREMENTS	Key	A10	Key	B10
Paint Primer / Finish		Required	Y	Confirmed	?	Needs Clarification
Special Tools		Required	Y	Confirmed	Y	Provided
Shipping Preparation		Required	Y	Confirmed	?	Needs Clarification
Weight		Required	Y	147.2 ton	?	Needs Clarification
Spare Parts - Commissioning		Required	Y	Confirmed	Y	Provided
Spare Parts - Capital		Required	Y	Confirmed	Y	Separately Priced
Spare Parts - 2 Year		Required	Y	Confirmed	Y	Separately Priced
TECHNICALLY ACCEPTABLE?				YES		YES
ENGINEER'S COMMENTS				Pending approval of vendor clarifications		Pending approval of vendor clarifications

For the purposes of the estimate proposal A10 was used. During the next phase of the project, a formal fixed price proposal will be requested.

Qualifications

As indicated above in 4.1.1, one LCI drive will start all the large motors.

4.1.3 Regenerative Thermal Oxidizer

Introduction

Based on previous studies on the suitability of a Regenerative Thermal Oxidizer (RTO) for the treatment of the predominantly CO_2 stream normally intended to be sent to the CO_2 Compressors and then to the Denbury pipeline was investigated, RTO technology was selected for the project.

Scope of Equipment Evaluated

This technical evaluation covers two identical 50% capacity trains of a packaged Regenerative Thermal Oxidizer with all necessary controls and spares.

Evaluation Criteria

The principle criterion used was the ability to meet the requested destruction efficiencies and the emission requirements.

Emission requirements are as follows:

Table 4.1.3.1 – Emissions

Component	DRE	Stack Limits (lb/hr)
VOC	-----	0.84
Methanol	≥ 99.9%	0.61
COS	> 98%	0.12
H_2S	> 98%	0.02
NOx	-----	1.13
CO	≥ 99.9%	36.17
PM10	-----	0.14
SO_2	-----	8.14

Conclusions and Recommendations

In order to increase certainty of meeting emissions standards, it was requested that the destruction efficiencies increase from what was previously presented in June 30, 2011. Based on the previous Granherne studies comparing the efficacy of an RTO unit or a Regenerative Catalytic Oxidizer (RCO) unit and the benefits/costs of each, an RTO design was selected. Due to previous vendor correspondence and the inability of some vendors to meet the emission requirements and /or the requested response time, only one vendor issued a formal proposal. For the purpose of this evaluation the vendor is identified as A16. The vendor was deemed technically acceptable and the costs were in line with historical quotes for a similar sized unit performing the same function.

The Technical bid evaluation is shown in the Tables below.

Technical Bid Evaluation								
REQUISITION No:	13046D-16-ME-MR-ME310-01	PROJECT No:	13046D					
GROUP:	Mechanical	REV:	0	DATE:	10/9/2013			
EQUIPMENT No:	See Below							
EQUIPMENT TITLE:	Regenerative Thermal Oxidizer							
PROJECT:	Lake Charles Clean Energy Project							

Key Legend Y = Acceptable (complies with Specification) * = Acceptable alternative X = Not acceptable ? = Needs Supplier clarification

DESCRIPTION	Units	SPECIFIED REQUIREMENTS	A16 Key	A16	Key		Key	
General								
Quantity		2 x 50%	Y	2 x 50%				
Total Design Process Flow	MMSCFD	118.4	Y	118.4				
Design Flow Capacity	SCFM	By Vendor	Y	90,000				
Type of Draft: Forced or Natural		Forced	Y	Forced				
Required Dilution / Oxidation Air Flow	SCFM	By Vendor	Y	6,000 to 7,500				
Operating Temperature	ºF	By Vendor	Y	1500 to 1600				
Heat Release	MM Btu/hr	By Vendor	Y	13.5 (Estimated)				
Stream Consumption		Per Data Sheet	Y	Confirmed				
Stream Summary		Per Data Sheet	Y	Confirmed				
Overall Dimensions	L x W x H (ft)	By Vendor	Y	145 x 100 x 40				
Total Weight	lbs	By Vendor	Y	850,000				
Off Gas CO2 Limit	microns	8	Y	8				
Emissions:								
Air Emission Limit / Destruction Removal Efficiency			*	99.9% NMHC or 20 ppmv (Hydrocarbon Destruction Efficiency)				
NO_X	lb/hr / %	1.13 / -	?	Not Specified				
CO	lb/hr / %	36.17 / ≥ 99.9	?	Not Specified				
COS	lb/hr / %	0.12 / ≥ 98	?	Not Specified				
H_2S	lb/hr / %	0.02 / ≥ 98	?	Not Specified				
PM/PM10	lb/hr / %	0.14 / -	?	Not Specified				
SO_2	lb/hr / %	8.14 / -	?	Not Specified				
MEOH	lb/hr / %	0.61 / ≥ 99.9	?	Not Specified				
VOC	lb/hr / %	0.84 / -	?	Not Specified				
Combustion Chamber								
Design Code		ASME VIII Div 1	Y	ASME VIII Div 1				
Design Temperature	ºF	By Vendor	Y	2,200				
Design Pressure	psig	By Vendor	Y	1				
Thickness	in	By Vendor	Y	1/4				
Material		By Vendor	Y	A516 Carbon Steel				
Firebox Temperature	ºF	By Vendor	Y	1500 to 1600 (operating)				
Residence Time	sec	By Vendor	Y	1+ (minimum)				
Insulation / Refractory Type		By Vendor	Y	Ceramic Fiber Block Insulation				
Insulation: Shell Casing Design Temperature	ºF	By Vendor	Y	70 over ambient				
Design Hot Face Temperature	ºF	By Vendor	Y	2,200 (rated)				
Preheat Exchangers								
Quantity		By Vendor	Y	3 (per RTO)				
Type		By Vendor	Y	Media Filled				
Design Temperature		By Vendor	?	Not Specified				
Design Pressure		By Vendor	?	Not Specified				
Material		By Vendor	Y	A516 Carbon Steel				
Insulation / Refractory Type		By Vendor	Y	Ceramic Fiber Block Insulation				
Insulation: Design Hot Face Temperature		By Vendor	Y	2,200 (rated)				
Access Doors		Required	Y	Provided				
Combustion Air Fan								
Quantity		By Vendor	Y	2				
Type		By Vendor	Y	New York Blower or Equivalent				
Capacity	SCFM	By Vendor	Y	5,000				
Driver		By Vendor	Y	Electric Motor (TEFC 480V/3PH/60HZ)				

Technical Bid Evaluation

REQUISITION No:	13046D-16-ME-MR-ME310-01	PROJECT No:	13046D
GROUP:	Mechanical	REV: 0	DATE: 10/9/2013
EQUIPMENT No:	See Below		
EQUIPMENT TITLE:	Regenerative Thermal Oxidizer		
PROJECT:	Lake Charles Clean Energy Project		

Key Legend Y = Acceptable (complies with Specification) * = Acceptable alternative X = Not acceptable ? = Needs Supplier clarification

DESCRIPTION	Units	SPECIFIED REQUIREMENTS	A16 Key	A16	Key		Key	
Driver HP	HP	By Vendor	Y	60				
Noise Level		85 dB @ 1 meter	Y	85 dB @ 1 meter				
Code		By Vendor	Y	API 673 Compliant				
Dilution/Purge Air Fan								
Quantity		By Vendor	Y	2				
Type		By Vendor	Y	New York Blower or Equivalent				
Capacity	SCFM	By Vendor	Y	45,000				
Driver		By Vendor	Y	Electric Motor (TEFC 480V/3PH/60HZ)				
Driver HP	HP	By Vendor	Y	200				
Noise Level		85 dB @ 1 meter	Y	85 dB @ 1 meter				
Code		By Vendor	Y	API 673 Compliant				
Damper and Actuator System		By Vendor	Y	Provided				
Quantity		By Vendor	Y	Inlet Damper (1 per Canister - 6 Total) Outlet Damper (1 per Canister - 6 Total)				
Material		By Vendor	Y	A516 Carbon Steel				
			Y					
Rupture Disk (Over Pressure Relief Panels)		By Vendor	Y	Provided				
Quantity			Y	2 for every 13 ft of ducting				
Set Point for Relief			Y	1.5 psig @ 72 ºF w/ + or - 0.25 psig tolerance				
Burners								
Manufacturer		By Vendor	Y	Maxon "Kinedizer" or equivalent				
Type / Number Required		By Vendor	Y	2				
Design Code		By Vendor	?	Not Specified				
Design Temperature	ºF	By Vendor	?	Not Specified				
Design Pressure	psig	By Vendor	?	Not Specified				
Turndown Ratio		By Vendor	Y	40 : 1				
Design Heat Release	MM Btu/hr	By Vendor	Y	9 (each)				
Stack								
Quantity		One Common	Y	Provided				
Type		By Vendor	Y	Steel Support Structure				
Casing Material		By Vendor	Y	A516 Carbon Steel				
Height	ft	By Vendor	Y	40				
Corrosion Allowance	in	By Vendor	?	Not Specified				
Diameter	in	By Vendor	Y	108 ID				
Minimum Thickness	in	By Vendor	?	Not Specified				
Insulation: Material		By Vendor	?	Not Specified				
EPA Sampling Port		Required	Y	Two 3" Diameter Ports at 90º				
				Yes, per OSHA (Protection Cage around first 8 feet of				
Stack Exit Temperature	ºF	250	?	Not Specified				
Burner Management System (BMS)								
Burner Controls		Required	Y	Provided				
Miscellaneous								
Interconnecting Piping, Ducts, Cables, Electrical Wiring		Required	?	Not Specified				
Instrumentation & Controls		Required	Y	Provided				

Technical Bid Evaluation

REQUISITION No:	13046D-16-ME-MR-ME310-01	PROJECT No:	13046D
GROUP:	Mechanical	REV: 0	DATE: 10/9/2013
EQUIPMENT No:	See Below		
EQUIPMENT TITLE:	Regenerative Thermal Oxidizer		
PROJECT:	Lake Charles Clean Energy Project		

Key Legend Y = Acceptable (complies with Specification) * = Acceptable alternative X = Not acceptable ? = Needs Supplier clarification

DESCRIPTION	Units	SPECIFIED REQUIREMENTS	A16 Key	A16	Key		Key	
Surface Preparation & Painting		Required	Y	Provided, As per Spec.				
Spare Parts								
Commissioning Spares		Required	?	Not Specified				
Two Years Spares		List & Price	?	Not Specified				
Technically Acceptable				YES				

5.0 ELECTRICAL

5.1 Load Summary

The total estimated connected load is 93.5 MW and normal operating load is 85.6 MW. When branch losses in the plant electrical power distribution network are accounted for, the total power consumption will be slightly more than this value.

Assumptions

The following assumptions were made during the estimate of connected and normal plant load. Note that all the loads are based on preliminary estimates and will be confirmed during detailed design phase of the project after finalizing the arrangement and purchasing the equipment.

- The CO_2 and Propylene Refrigerant compressors represent approximately 77% of the total electrical load for the six areas (Area 06, 10, 12, 16, 18, and 26). The CO_2 Compressors have the highest load and are based on the information supplied by the selected vendor. The Propylene Refrigerant Compressor load is based on the quotes provided by the vendors;
- Most of the other electrical loads are compressor and pump electrical motor drivers. The motor ratings are based on preliminary calculations performed by Air Liquide/Lurgi and Haldor Topsoe as a part of their PDP packages and/or quoted by vendors based on the performance data provided in the Material Requisition packages.
- Miscellaneous operating loads of 875 kW has been allowed for these areas, collectively to account for plant street and process area lighting, UPS and battery charger units and instrument panels;
- The efficiency for the electric motors is assumed to be in the range of 86% - 96%, based on the motor voltage and size;
- A lagging power factor of 0.76 – 0.95 is assumed for the loads based on motor size and service.

Process Units

The overall process flow diagram indicates the areas in Table 5.1.1. The connected and normal operation loads are estimated for these areas.

Table 5.1.1 – Areas

Area No.	Description	Acronym
6	Acid Gas Removal	AGR
10	Propylene Refrigeration	C3R
12	Wet Sulfuric Acid	WSA
16	Regernative Thermal Oxidizer	RTO
18	CO_2 Compression	CO_2
26	Process Cooling Water	ISBL CW

All the electrical loads in Areas 06, 10, 16, and 18are fed from the Electrical Switchgear building near the Air Separation Unit (Area 19) shown in the Overall Plot Plan. Area 12 (WSA) is fed from the Electrical Switchgear building located near the WSA in the Overall Plot Plan.

Load Diversity Factor

The facility electrical loads operate continuously, intermittently, or are spares as identified by the Process Load Lists. Accordingly a diversity factor is applied to the power consumed by the loads while computing the normal and connected plant load. This factor is 1, 0.5 and 0 for continuous, intermittent and spare motors, respectively.

Load Demand Factor

A demand factor is used to calculate the brake load for motors from the motor rating. The normal operation brake load for the loads is per the Process Load Lists. Motor ratings were calculated based on the brake load requirement. Load demand factor reported is the ratio of the brake load and the load rating.

Motor Loads

Electrical motors are mainly used as drivers for compressors, pumps and blowers in the process units. The motors in each unit are listed per the Process Load Lists. The motor rating is calculated using the following relation –

Motor Rating = Standard motor rating higher than (Process Load x API Multiplier)

If the load in the Process Load List (Process Load) was specified in kW it was divided by a factor of 0.7457 to get the load in HP. The API multiplier (per API Standard 610) value depends on the Process Load as described below.

Process Load (HP)	Multiplier
HP < 30	1.25
30 ≤ HP ≤ 75	1.15
kW > 75	1.10

Standard motor ratings were selected based on Section 20.3 of NEMA MG-1 (2011).

Motor rated voltages are selected based on the motor rating as follows.

Motor Rating (HP)	Rated Voltage
HP ≤ 250	460 V
250 < HP < 7000	4000 V
HP ≥ 7000	13200 V

Building Loads

The only building in CCS scope of work is the Electrical Switchgear buildings near the Air Separation Unit and WSA areas as shown in the Overall Plot Plan. These building will house all 13.8 kV switchgear and motor control centers (MCCs), 4.16 kV switchgear and MCCs and 480 V switchgear and MCCs. In addition, the building near the Air separation unit will also have the LCI starter drive for the CO_2 and Propylene Refrigerant compressor motors.

It was assumed that the air conditioning load operates intermittently (50% diversity factors) to account for other equipment in the building.

Miscellaneous Electrical Load

A miscellaneous lumped load of 875 kW connected load is assumed for the CCS scope areas, to account for the following electrical loads.

- Plant street and process area lighting;
- UPS and battery charger units;
- Instrument panels;

- Welding and other receptacles.

Estimated Normal Operation Load

The total estimated normal operation plant load is 83.8 MW as shown in Table 5.1.2. When branch losses in the plant electrical power distribution network are accounted for the total power consumption will be slightly more than this value.

Table 5.1.2 – Normal Operation Load per Switchgear/MCC

Normal Plant Load

Bus	Voltage	P (kW)	Q (kvar)	S (kVA)	PF (%)
18-S-0001-11	13.8 kV	23,102	7,594	24,318	95%
18-S-0001-13		23,102	7,594	24,318	95%
18-S-0001-14		19,271	6,334	20,286	95%
18-S-0001-20A	4.16 kV	4,120	1,908	4,543	89% - 92%
18-S-0001-20B		2,907	1,391	3,225	91% - 92%
03-S-0001-20A		2,851	1,432	3,192	91% - 92%
03-S-0001-20B		2,851	1,432	3,192	91% - 92%
09-S-0001-20A		3,069	1,212	3,300	91% - 92%
18-S-0001-30A	480 V	589	359	788	76% - 92%
18-S-0001-30B		589	359	788	76% - 92%
03-S-0001-31A		614	410	739	76% - 92%
03-S-0001-31B		614	410	739	76% - 92%
09-S-0001-30A		1900	1025	2159	76% - 92%
TOTAL		85,579	31,459	91,588	

<u>Estimated Connected Load</u>

The total estimated connected plant load is 93.5 MW (Table 5.1.3).

Table 5.1.3 – Connected Load per Switchgear/MCC

		Normal Plant Load			
Bus	**Voltage**	**P (kW)**	**Q (kvar)**	**S (kVA)**	**PF (%)**
18-S-0001-11	13.8 kV	23,102	7,594	24,318	95%
18-S-0001-13		23,102	7,594	24,318	95%
18-S-0001-14		19,271	6,334	20,286	95%
18-S-0001-20A	4.16 kV	5,573	2,604	6,156	89% - 92%
18-S-0001-20B		4,360	2,087	4,838	91% - 92%
03-S-0001-20A		3,151	1,602	3,537	91% - 92%
03-S-0001-20B		3,151	1,602	3,537	91% - 92%
09-S-0001-20A		6,138	2,424	6,600	91% - 92%
18-S-0001-30A	480 V	1121	681	1322	76% - 92%
18-S-0001-30B		1121	681	1322	76% - 92%
03-S-0001-31A		764	500	914	76% - 92%
03-S-0001-31B		764	500	914	76% - 92%
09-S-0001-30A		1900	1025	2159	76% - 92%
TOTAL		93,518	35,227	100,222	

Tables 5.1.4-6 show the electrical load list by voltage for the Project.

Table 5.1.4 – Electrical Loads

480 V Bus

EQUIPMENT TAG NO.	EQUIPMENT DESCRIPTION	RATED VOLTAGE	MOTOR NAMEPLATE HP	MOTOR HP REQUIRED AT DRIVE	Load KW	Load KVA	FULL LOAD PF	FULL LOAD EFF	CONNECTED LOAD				SERVICE DUTY	DIVERSITY FACTOR	OPERATING LOAD			
									KW	KVA	KVAR	AMPS			KW	KVA	KVAR	AMPS
06-PM-0103A	CO_2 Reabsorber Circuit Pump Motor I	480	200.0	171.9	128.20	149.07	0.86	0.96	133.82	155.61	79.40	187.16	C	1.00	133.82	155.61	79.40	187.16
06-PM-0103B	CO_2 Reabsorber Circuit Pump Motor I	480	200.0	171.9	128.20	149.07	0.86	0.96	133.82	155.61	79.40	187.16	S	0.00	0.00	0.00	0.00	0.00
06-PM-0104A	CO_2 Reabsorber Circuit Pump Motor II	480	150.0	124.1	92.58	112.90	0.82	0.95	97.04	118.34	67.74	142.35	C	1.00	97.04	118.34	67.74	142.35
06-PM-0104B	CO_2 Reabsorber Circuit Pump Motor II	480	150.0	124.1	92.58	112.90	0.82	0.95	97.04	118.34	67.74	142.35	S	0.00	0.00	0.00	0.00	0.00
06-PM-0107A	Methanol Water Column Feed Pump Motor	480	3.0	1.6	1.20	1.56	0.77	0.86	1.40	1.82	1.16	2.19	C	1.00	1.40	1.82	1.16	2.19
06-PM-0107B	Methanol Water Column Feed Pump Motor	480	3.0	1.6	1.20	1.56	0.77	0.86	1.40	1.82	1.16	2.19	S	0.00	0.00	0.00	0.00	0.00
06-PM-0108A	Hot Regenerator Reflux Pump Motor	480	25.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	C	1.00	12.20	14.44	7.72	17.37
06-PM-0108B	Hot Regenerator Reflux Pump Motor	480	25.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	S	0.00	0.00	0.00	0.00	0.00
06-PM-0109A	Methanol Water Column Pump Motor	480	1.5	1.0	0.75	0.99	0.76	0.86	0.87	1.16	0.76	1.39	C	1.00	0.87	1.16	0.76	1.39
06-PM-0109B	Methanol Water Column Pump Motor	480	1.5	1.0	0.75	0.99	0.76	0.86	0.87	1.16	0.76	1.39	S	0.00	0.00	0.00	0.00	0.00
06-PM-0110A	Methanol Water Column Reflux Pump Motor	480	30.0	19.5	14.55	17.22	0.85	0.92	15.86	18.77	10.04	22.58	C	1.00	15.86	18.77	10.04	22.58
06-PM-0110B	Methanol Water Column Reflux Pump Motor	480	30.0	19.5	14.55	17.22	0.85	0.92	15.86	18.77	10.04	22.58	S	0.00	0.00	0.00	0.00	0.00
06-PM-0111A	Make up Methanol Pump Motor	480	3.0	2.2	1.60	2.08	0.77	0.86	1.88	2.44	1.55	2.93	C	1.00	1.88	2.44	1.55	2.93
06-PM-0111B	Make up Methanol Pump Motor	480	3.0	2.2	1.60	2.08	0.77	0.86	1.88	2.44	1.55	2.93	S	0.00	0.00	0.00	0.00	0.00
06-PM-0102A	CO_2 Laden Methanol Pump Motor	480	150.0	115.0	85.79	104.62	0.82	0.95	89.93	109.67	62.77	131.91	C	1.00	89.93	109.67	62.77	131.91
06-PM-0102B	CO_2 Laden Methanol Pump Motor	480	150.0	115.0	85.79	104.62	0.82	0.95	89.93	109.67	62.77	131.91	S	0.00	0.00	0.00	0.00	0.00
06-PM-0112	Slop Pump Motor	480	10.0	6.6	4.90	6.17	0.80	0.89	5.54	6.97	4.23	8.38	I	0.50	2.77	3.48	2.11	4.19
06-PM-0001A	Condensate Pump Motor	480	15.0	13.0	9.70	11.41	0.85	0.91	10.66	12.54	6.60	15.08	C	1.00	10.66	12.54	6.60	15.08
06-PM-0001B	Condensate Pump Motor	480	15.0	13.0	9.70	11.41	0.85	0.91	10.66	12.54	6.60	15.08	S	0.00	0.00	0.00	0.00	0.00
06-PM-0004A	AGR LP Flare Knock Out Drum Pump Motor	480	7.5	5.9	4.40	5.54	0.80	0.89	4.97	6.26	3.79	7.52	C	1.00	4.97	6.26	3.79	7.52
06-PM-0004A	AGR LP Flare Knock Out Drum Pump Motor	480	7.5	5.9	4.40	5.54	0.80	0.89	4.97	6.26	3.79	7.52	S	0.00	0.00	0.00	0.00	0.00
06-PM-0006A	AGR HP Flare Knock Out Drum Pump Motor	480	7.5	5.9	4.40	5.54	0.80	0.89	4.97	6.26	3.79	7.52	C	1.00	4.97	6.26	3.79	7.52
06-PM-0006B	AGR HP Flare Knock Out Drum Pump Motor	480	7.5	5.9	4.40	5.54	0.80	0.89	4.97	6.26	3.79	7.52	S	0.00	0.00	0.00	0.00	0.00
10-PM-0151	Propylene Refrigerant Pump Out Pump	480	30.0	25.0	18.65	22.20	0.84	0.93	20.05	23.87	12.95	28.72	C	1.00	20.05	23.87	12.95	28.72
12-PM-1001A	Acid pump	480	30.0	25.0	18.65	22.20	0.84	0.93	20.05	23.87	12.95	28.72	C	1.00	20.05	23.87	12.95	28.72
12-PM-1001B	Acid pump	480	30.0	25.0	18.65	22.20	0.84	0.93	20.05	23.87	12.95	28.72	S	0.00	0.00	0.00	0.00	0.00
12-PM-2001A	Acid pump	480	30.0	25.0	18.65	22.20	0.84	0.93	20.05	23.87	12.95	28.72	C	1.00	20.05	23.87	12.95	28.72
12-PM-2001B	Acid pump	480	30.0	25.0	18.65	22.20	0.84	0.93	20.05	23.87	12.95	28.72	S	0.00	0.00	0.00	0.00	0.00
12-PM-1002A	Acid product pump	480	20.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	C	1.00	12.20	14.44	7.72	17.37
12-PM-1002B	Acid product pump	480	20.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	S	0.00	0.00	0.00	0.00	0.00
12-PM-2002A	Acid product pump	480	20.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	C	1.00	12.20	14.44	7.72	17.37

EQUIPMENT TAG NO.	EQUIPMENT DESCRIPTION	RATED VOLTAGE	MOTOR NAMEPLATE HP	MOTOR HP REQUIRED AT DRIVE	Load KW	Load KVA	FULL LOAD PF	FULL LOAD EFF	CONNECTED LOAD				SERVICE DUTY	DIVERSITY FACTOR	OPERATING LOAD			
									KW	KVA	KVAR	AMPS			KW	KVA	KVAR	AMPS
12-PM-2002B	Acid product pump	480	20.0	15.0	11.19	13.24	0.85	0.92	12.20	14.44	7.72	17.37	S	0.00	0.00	0.00	0.00	0.00
12-PM-1003A	Quench water pump	480	200.0	150.0	111.90	130.12	0.86	0.96	116.81	135.82	69.31	163.37	C	1.00	116.81	135.82	69.31	163.37
12-PM-1003B	Quench water pump	480	200.0	150.0	111.90	130.12	0.86	0.96	116.81	135.82	69.31	163.37	S	0.00	0.00	0.00	0.00	0.00
12-PM-2003A	Quench water pump	480	200.0	150.0	111.90	130.12	0.86	0.96	116.81	135.82	69.31	163.37	C	1.00	116.81	135.82	69.31	163.37
12-PM-2003B	Quench water pump	480	200.0	150.0	111.90	130.12	0.86	0.96	116.81	135.82	69.31	163.37	S	0.00	0.00	0.00	0.00	0.00
12-PR-0001-G01	Local Panel for WESP	480			400.00	470.59	0.85	1.00	400.00	470.59	247.90	566.03	C	1.00	400.00	470.59	247.90	566.03
12-E-0008	Air preheater	480			100.00	125.00	0.80	0.99	101.01	126.26	75.76	151.87	C	1.00	101.01	126.26	75.76	151.87
12-BHL-0001	Frost protection	480			4.00	5.00	0.80	0.99	4.04	5.05	3.03	6.07	C	1.00	4.04	5.05	3.03	6.07
12-BHL-0002	Frost protection	480			4.00	5.00	0.80	0.99	4.04	5.05	3.03	6.07	C	1.00	4.04	5.05	3.03	6.07
12-BHL-0003	Frost protection	480			4.00	5.00	0.80	0.99	4.04	5.05	3.03	6.07	C	1.00	4.04	5.05	3.03	6.07
12-BHL-0004	Frost protection	480			4.00	5.00	0.80	0.99	4.04	5.05	3.03	6.07	C	1.00	4.04	5.05	3.03	6.07
12-BHL-0005	Frost protection	480			4.00	5.00	0.80	0.99	4.04	5.05	3.03	6.07	C	1.00	4.04	5.05	3.03	6.07
12-E-1133	Air heater	480			30.00	37.50	0.80	0.99	30.30	37.88	22.73	45.56	C	1.00	30.30	37.88	22.73	45.56
12-E-2133	Air heater	480			30.00	37.50	0.80	0.99	30.30	37.88	22.73	45.56	C	1.00	30.30	37.88	22.73	45.56
12-U0001-A	Mist Control Unit	480			7.00	8.24	0.85	1.00	7.00	8.24	4.34	9.91	C	1.00	7.00	8.24	4.34	9.91
12-U0001-B	Mist Control Unit	480			7.00	8.24	0.85	1.00	7.00	8.24	4.34	9.91	C	1.00	7.00	8.24	4.34	9.91
12-U0001-C	Mist Control Unit	480			7.00	8.24	0.85	1.00	7.00	8.24	4.34	9.91	C	1.00	7.00	8.24	4.34	9.91
12-U0001-D	Mist Control Unit	480			7.00	8.24	0.85	1.00	7.00	8.24	4.34	9.91	C	1.00	7.00	8.24	4.34	9.91
12-AM-0001	Ammonia evaporator	480	10.0	10.0	7.46	8.78	0.85	0.91	8.20	9.64	5.08	11.60	C	1.00	8.20	9.64	5.08	11.60
12-PM-0001-01	120V AC Distribution Panel	480			7.0	10.00	0.85	1.00	7.00	8.24	4.34	9.91	C	1.00	7.00	8.24	4.34	9.91
12-OLP-01	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
12-OLP-02	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
12-OLP-03	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
12-OLP-04	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
12-OLP-05	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
12-OLP-06	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
16-BM-1001	Combustion Air Fan Motor	480	75	60	44.76	53.93	0.83	0.95	47.37	57.07	31.83	68.64	0	0.00	FALSE	0.00	0.00	0.00
16-BM-1002	Dilution/Purge Air Fan Motor	480	225	200	149.20	169.55	0.88	0.96	155.09	176.24	83.71	211.99	0	0.00	FALSE	0.00	0.00	0.00
16-BM-2001	Combustion Air Fan Motor	480	75	60	44.76	53.93	0.83	0.95	47.37	57.07	31.83	68.64	S	0.00	0.00	0.00	0.00	0.00
16-BM-2002	Dilution/Purge Air Fan Motor	480	225	200	149.20	169.55	0.88	0.96	155.09	176.24	83.71	211.99	S	0.00	0.00	0.00	0.00	0.00
18-PM-0101A-1	Lube Oil Pump Motor for 18-PK-0101A	480	75.0	70.0	52.22	54.97	0.95	0.95	55.26	58.17	18.16	69.96	C	1.00	55.26	58.17	18.16	69.96
18-PM-0101A-2	Lube Oil Pump Motor for 18-PK-0101A	480	75.0	70.0	52.22	54.97	0.95	0.95	55.26	58.17	18.16	69.96	S	1.00	0.00	0.00	0.00	0.00
18-VF-0101A	Lube Oil Vent Fan Motor for 18-PK-0101A	480	3.0	2.5	1.87	1.96	0.95	0.86	2.18	2.30	0.72	2.76	C	1.00	2.18	2.30	0.72	2.76
18-PM-0101B-1	Lube Oil Pump Motor for 18-PK-0101B	480	75.0	70.0	52.22	54.97	0.95	0.95	55.26	58.17	18.16	69.96	C	1.00	55.26	58.17	18.16	69.96
18-PM-0101B-2	Lube Oil Pump Motor for 18-PK-0101B	480	75.0	70.0	52.22	54.97	0.95	0.95	55.26	58.17	18.16	69.96	S	1.00	0.00	0.00	0.00	0.00
18-VF-0101B	Lube Oil Vent Fan Motor for 18-PK-0101B	480	3.0	2.5	1.87	1.96	0.95	0.86	2.18	2.30	0.72	2.76	C	1.00	2.18	2.30	0.72	2.76
18-OH-0101A-1	Oil Reservor Heater 1 for 18-PK-0101A-1	480			25.00	26.32	0.95	0.99	25.25	26.58	8.30	31.97	C	1.00	25.25	26.58	8.30	31.97
18-OH-0101A-2	Oil Reservor Heater 1 for 18-PK-0101A-2	480			25.00	26.32	0.95	0.99	25.25	26.58	8.30	31.97	C	1.00	25.25	26.58	8.30	31.97
18-OH-0101B-1	Oil Reservor Heater 1 for 18-PK-0101B-1	480			25.00	26.32	0.95	0.99	25.25	26.58	8.30	31.97	C	1.00	25.25	26.58	8.30	31.97
18-OH-0101B-2	Oil Reservor Heater 1 for 18-PK-0101B-2	480			25.00	26.32	0.95	0.99	25.25	26.58	8.30	31.97	C	1.00	25.25	26.58	8.30	31.97

EQUIPMENT TAG NO.	EQUIPMENT DESCRIPTION	RATED VOLTAGE	MOTOR NAMEPLATE HP	MOTOR HP REQUIRED AT DRIVE	Load KW	Load KVA	FULL LOAD PF	FULL LOAD EFF	CONNECTED LOAD				SERVICE DUTY	DIVERSITY FACTOR	OPERATING LOAD			
									KW	KVA	KVAR	AMPS			KW	KVA	KVAR	AMPS
18-HVAC-01	Substation HVAC	480			100.00	125.0	0.80	0.99	101.01	126.26	75.76	151.87	C	1.00	101.01	126.26	75.76	151.87
18-ILP-01	Indoor Lighting Panel	480			80.00	100.0	0.80	0.99	80.81	101.01	60.61	121.50	C	1.00	80.81	101.01	60.61	121.50
18-OLP-01	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
18-OLP-02	Outdoor Lighting Panel	480			50.00	62.5	0.80	0.99	50.51	63.13	37.88	75.94	C	1.00	50.51	63.13	37.88	75.94
18-ORP-01	Outdoor Receptacle Panel	480			100.00	125.0	0.80	0.99	101.01	126.26	75.76	151.87	I	0.50	50.51	63.13	37.88	75.94
18-WR-01	Welding Receptacle	480			80.00	100.0	0.80	0.99	80.81	101.01	60.61	121.50	I	0.25	20.20	25.25	15.15	30.37
18-WR-02	Welding Receptacle	480			80.00	100.0	0.80	0.99	80.81	101.01	60.61	121.50	I	0.25	20.20	25.25	15.15	30.37
18-U-0001-01	UPS - A	480			60.00	75.0	0.80	0.99	60.61	75.76	45.45	91.12	C	1.00	60.61	75.76	45.45	91.12
18-U-0001-02	UPS - B	480			80.00	100.0	0.80	0.99	80.81	101.01	60.61	121.50	C	1.00	80.81	101.01	60.61	121.50
18-Q-0001-01	DC Battery Charger	480			50.00	50.0	1.00	0.99	50.51	50.51	0.00	60.75	C	1.00	50.51	50.51	0.00	60.75
26-BM-0001A	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001B	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001C	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001D	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001E	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001F	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001G	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001H	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001I	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-BM-0001J	ISBL CT Fan	480	250.0	245.0	182.77	207.69	0.88	0.96	189.99	215.90	102.55	259.68	C	1.00	189.99	215.90	102.55	259.68
26-PK-0001-PM-001 A	Corrosion Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PK-0001-PM-001 B	Corrosion Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PK-0001-PM-001 C	Corrosion Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	S	0.00	0.00	0.00	0.00	0.00
26-PK-0003-PM-001 A	Scale Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PK-0003-PM-001 B	Scale Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PK-0003-PM-001 C	Scale Inhibitor Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	S	0.00	0.00	0.00	0.00	0.00
26-PK-0005-PM-001 A	Hypochlorite Pump Motor	480	1.5	1.0	0.75	0.99	0.76	0.86	0.87	1.16	0.76	1.39	C	1.00	0.87	1.16	0.76	1.39
26-PK-0005-PM-001 B	Hypochlorite Pump Motor	480	1.5	1.0	0.75	0.99	0.76	0.86	0.87	1.16	0.76	1.39	C	1.00	0.87	1.16	0.76	1.39
26-PK-0005-PM-001 C	Hypochlorite Pump Motor	480	1.5	1.0	0.75	0.99	0.76	0.86	0.87	1.16	0.76	1.39	S	0.00	0.00	0.00	0.00	0.00
26-PK-0005-PM-004 A	Brine Pump Motor	480	15.0	10.0	7.46	8.78	0.85	0.91	8.20	9.64	5.08	11.60	C	1.00	8.20	9.64	5.08	11.60
26-PK-0005-PM-004 B	Brine Pump Motor	480	15.0	10.0	7.46	8.78	0.85	0.91	8.20	9.64	5.08	11.60	C	1.00	8.20	9.64	5.08	11.60
26-PM-0003A	CW Acid Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PM-0003B	CW Acid Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	C	1.00	0.50	0.77	0.58	0.92
26-PM-0003C	CW Acid Pump Motor	480	1.5	0.5	0.37	0.57	0.65	0.75	0.50	0.77	0.58	0.92	S	0.00	0.00	0.00	0.00	0.00
	Total				5500.43				5689.23	6657.46	3402.76	8007.54			4325.21	5057.32	2576.66	6082.91

Table 5.1.5 – Electrical Loads

4.16 kV Bus

EQUIPMENT TAG NO.	EQUIPMENT DESCRIPTION	RATED VOLTAGE	MOTOR NAMEPLATE HP	MOTOR HP REQUIRED AT DRIVE	Load KW	Load KVA	FULL LOAD PF	FULL LOAD EFF	CONNECTED LOAD				SERVICE DUTY	DIVERSITY FACTOR	OPERATING LOAD			
									KW	KVA	KVAR	AMPS			KW	KVA	KVAR	AMPS
06-PM-0101A	Main Wash Pump Motor	4160	1500.0	1377.0	1027.24	1116.57	0.92	0.95	1083.59	1177.81	461.61	163.46	C	1.00	1083.59	1177.81	461.61	163.46
06-PM-0101B	Main Wash Pump Motor	4160	1500.0	1377.0	1027.24	1116.57	0.92	0.95	1083.59	1177.81	461.61	163.46	C	1.00	1083.59	1177.81	461.61	163.46
06-PM-0101C	Main Wash Pump Motor	4160	1500.0	1377.0	1027.24	1116.57	0.92	0.95	1083.59	1177.81	461.61	163.46	S	0.00	0.00	0.00	0.00	0.00
06-PM-0106A	CO_2 Absorber Feed Pump Motor	4160	2000.0	1785.8	1332.21	1505.32	0.89	0.95	1405.28	1587.89	739.31	220.38	C	1.00	1405.28	1587.89	739.31	220.38
06-PM-0106B	CO_2 Absorber Feed Pump Motor	4160	2000.0	1785.8	1332.21	1505.32	0.89	0.95	1405.28	1587.89	739.31	220.38	C	1.00	1405.28	1587.89	739.31	220.38
06-PM-0106C	CO_2 Absorber Feed Pump Motor	4160	2000.0	1785.8	1332.21	1505.32	0.89	0.95	1405.28	1587.89	739.31	220.38	S	0.00	0.00	0.00	0.00	0.00
06-PM-0105A	Hot Flash Feed Pump Motor	4160	600.0	534.9	399.00	438.46	0.91	0.95	418.24	459.60	190.55	63.79	C	1.00	418.24	459.60	190.55	63.79
06-PM-0105B	Hot Flash Feed Pump Motor	4160	600.0	534.9	399.00	438.46	0.91	0.95	418.24	459.60	190.55	63.79	C	1.00	418.24	459.60	190.55	63.79
06-PM-0105C	Hot Flash Feed Pump Motor	4160	600.0	534.9	399.00	438.46	0.91	0.95	418.24	459.60	190.55	63.79	S	0.00	0.00	0.00	0.00	0.00
06-C-0130	Recycle Gas Compressor Motor	4160	1750.0	1541.0	1149.59	1249.55	0.92	0.95	1212.64	1318.09	516.58	182.93	C	1.00	1212.64	1318.09	516.58	182.93
12-CM-1001	Cooling air blower	4160	1000.0	950.0	708.70	778.79	0.91	0.95	742.87	816.34	338.46	113.30	C	1.00	742.87	816.34	338.46	113.30
12-CM-2001	Cooling air blower	4160	1000.0	950.0	708.70	778.79	0.91	0.95	742.87	816.34	338.46	113.30	C	1.00	742.87	816.34	338.46	113.30
12-CM-1002	Hot air blower	4160	2000.0	1800.0	1342.80	1517.29	0.89	0.95	1416.46	1600.51	745.19	222.13	C	1.00	1416.46	1600.51	745.19	222.13
12-CM-2002	Hot air blower	4160	2000.0	1800.0	1342.80	1517.29	0.89	0.95	1416.46	1600.51	745.19	222.13	C	1.00	1416.46	1600.51	745.19	222.13
12-CM-1003	Clean gas blower	4160	550.0	500.0	373.00	409.89	0.91	0.95	390.99	429.65	178.14	59.63	C	1.00	390.99	429.65	178.14	59.63
12-CM-2003	Clean gas blower	4160	550.0	500.0	373.00	409.89	0.91	0.95	390.99	429.65	178.14	59.63	C	1.00	390.99	429.65	178.14	59.63
12-PM-1004A	Scrubber water pump	4160	400.0	386.0	287.96	330.98	0.87	0.96	300.42	345.31	170.26	47.92	C	1.00	300.42	345.31	170.26	47.92
12-PM-1004B	Scrubber water pump	4160	400.0	386.0	287.96	330.98	0.87	0.96	300.42	345.31	170.26	47.92	S	0.00	0.00	0.00	0.00	0.00
12-PM-2004A	Scrubber water pump	4160	400.0	386.0	287.96	330.98	0.87	0.96	300.42	345.31	170.26	47.92	C	1.00	300.42	345.31	170.26	47.92
12-PM-2004B	Scrubber water pump	4160	400.0	386.0	287.96	330.98	0.87	0.96	300.42	345.31	170.26	47.92	S	0.00	0.00	0.00	0.00	0.00
26-PM-0001A	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	C	1.00	1023.00	1100.00	404.31	152.66
26-PM-0001B	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	C	1.00	1023.00	1100.00	404.31	152.66
26-PM-0001C	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	C	1.00	1023.00	1100.00	404.31	152.66
26-PM-0001D	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	S	0.00	0.00	0.00	0.00	0.00
26-PM-0001E	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	S	0.00	0.00	0.00	0.00	0.00
26-PM-0001F	ISBL CW Pump Motor	4160	1500.0	1300.0	969.80	1042.80	0.93	0.95	1023.00	1100.00	404.31	152.66	S	0.00	0.00	0.00	0.00	0.00
	Total				21244.58				22374.29	24668.23	10321.47	3423.58			15797.34	17452.31	7376.55	2422.13

Table 5.1.6 – Electrical Loads

13.8 kV Bus

EQUIPMENT TAG NO.	EQUIPMENT DESCRIPTION	RATED VOLTAGE	MOTOR NAMEPLATE HP	MOTOR HP REQUIRED AT DRIVE	Load KW	Load KVA	FULL LOAD PF	FULL LOAD EFF	CONNECTED LOAD				SERVICE DUTY	DIVERSITY FACTOR	OPERATING LOAD			
									KW	KVA	KVAR	AMPS			KW	KVA	KVAR	AMPS
10-C-0151	Propylene Refrigerant Compressor	13800	30000.0	24800.0	18500.80	19474.5	0.95	0.96	19271.67	20285.96	6334.29	848.70	C	1.00	19271.67	20285.96	6334.29	848.70
18-PK-0101A	CO_2 Compressor Package	13800	35000.0	29730.0	22178.58	23345.8	0.95	0.96	23102.69	24318.62	7593.49	1017.42	C	1.00	23102.69	24318.62	7593.49	1017.42
18-PK-0101B	CO_2 Compressor Package	13800	35000.0	29730.0	22178.58	23345.8	0.95	0.96	23102.69	24318.62	7593.49	1017.42	C	1.00	23102.69	24318.62	7593.49	1017.42
	Total				62857.96				65477.05	68923.20	21521.27	2883.54			65477.05	68923.20	21521.27	2883.54

6.0 FIRE PROTECTION

6.1 General

Fire protection systems are provided to mitigate the consequences of fire and limit the scope for escalation of incidents. It is also effective in limiting the impact of hydrocarbon releases and fires. For a plant principally handling hydrocarbons, fire and gas detection, ESD, blow-down, fire protection (active) and fireproofing (passive), together form an integrated approach to controlling the risks of hydrocarbon releases and fires. The key objectives are to limit both the frequency and severity of fire incidents and diminish the scope for escalation of incidents.

The objectives of the fire protection systems are to:

- Provide exposure protection of hydrocarbon equipment;
- Control and extinguish fire;
- Protect utility systems, instrument systems and components important to safe shutdown.

6.2 Design Philosophy

The primary goal of the fire protection design is to provide adequate fire protection to suppress and extinguish incipient stage fires.

The risk of escalation of an event is considered when there is a possibility of the following:

- Escalation of an incident to adjacent equipment or involving additional hydrocarbon inventory within a fire area;
- Escalation of an incident into adjacent process areas, storage or utility systems if this would involve the release of any additional combustible process medium;
- Damage involving risk to life in normally occupied buildings, fire stations, control rooms including escape from such buildings;
- Loss of control room including other safely related equipment and systems, which support the control room function e.g., essential / emergency power supplies and Safety critical instrumentation systems.

6.3 Fire Protection Materials and Equipment

Fire protection materials and equipment used shall be new and unused, UL listed, and/or FM approved, and shall be acceptable to the AHJ. In addition to NFPA and API standards, materials and equipment shall be installed in accordance with the following standards, as applicable:

- American Society for Testing and Materials (ASTM);
- American Society of Mechanical Engineers (ASME);
- American National Standards Institute (ANSI).

6.4 Plant Fire Protection Design

The design of the LCCE facility has a direct bearing on the method by which fires may be controlled and extinguished. The general principles outlined in this design philosophy are intended as good practice. These principles identify areas that shall be considered during the design to help reduce the possibility of fire and to minimize the potential for escalation.

6.4.1 Layout

Drainage in hazardous areas shall be designed to drain away from any piperacks containing flammable or combustible liquids. All equipment handling flammable or combustible liquids shall be resting on concrete surfaces that shall be designed to slope away from the equipment. Processes handling flammable or combustible materials shall be in outdoor or open construction to manage the consequences of fire and explosion hazards.

Maximum fire water runoff, rain runoff, and process wastes shall be considered in sizing the drainage system and wastewater disposal.

6.4.2 Buildings

The design of buildings fire detection and suppression systems shall comply with applicable provisions of the National Fire Code and/or any applicable parts of the NFPA guidelines. Coverage areas for fire protection may be required in specific cases, such as the following:

Administration / Office

To include indoor hose reel stations, sprinkler system, portable A/B/C fire extinguishers.

Field Instrument Room

To include portable CO_2 fire extinguishers throughout the area and total flooding fire suppression system for the sub-floors.

Laboratory

To include in-door hose reel stations, sprinkler system, portable A/B/C fire extinguishers, and as well as portable CO_2 fire extinguishers and include fire detection and alarm system.

Substations

To include portable CO_2 fire extinguishers and include fire detection and alarm system.

Maintenance Building / Warehouse

To include in-door hose reel stations, sprinkler system, portable A/B/C fire extinguishers, and portable CO_2 fire extinguishers.

6.4.3 Roads

Access shall be provided to all facility areas by roads which are wide enough to permit adequate two way passage for vehicles. Two or more approaches by access roads to each process unit shall be provided. Adequate turning radius for a fire truck or other mobile equipment to clear pipe supports and equipment shall be provided.

6.4.4 Transformers

Oil-filled transformers shall be separated from adjacent structures and other adjacent transformers by fire walls, spatial separation, and other approved means as described in the NFPA 850 standards.

6.4.5 Hydrocarbon Piping

Piping shall be routed to avoid potential fire exposure. Shutoff valves and adequate access to the shutoff valves shall be provided so that operation of valves can be performed during an emergency situation.

Piping on sleepers shall not be exposed to drainage ditches or trenches, where flammable or combustible liquids may collect. Flanged or threaded joints shall be avoided on pipe lines crossing drainage ditches or trenches. If a trench that could contain hydrocarbons must run under the piperacks, consider covering the trench completely.

Areas under piperacks shall be sloped so that spillage will drain away from piperacks.

6.5 Plant Fire Protection Systems

6.5.1 Water Spray Systems

Automatic water spray systems shall be designed, installed and tested in accordance with NFPA 13 and NFPA 15.

As a minimum, the following equipment shall be protected with water spray:

- All pumps handling products close to or above their auto-ignition temperature;
- Pumps handling C_4 and lighter products;
- All compressors handling C_4 and lighter products which are not installed in an enclosure and not protected by fixed, manually operated water monitor;
- All vessels, columns and exchangers holding liquid volume C_4 and lighter products for greater than 176.5 ft^3 (5 m^3). Generally vertical vessel and columns shall be fully sprayed up to a height of 40 ft (12 m) above potential source of fire including the skirt, unless it is fireproofed.

Water spray protection for equipment and supports is an acceptable alternative to fireproofing.

Water spray systems shall be actuated automatically by hydraulic pilot detection system, manually at the deluge valve or remotely from the control room. Water Spray systems shall also be actuated from strategic locations within the area by manual trip valves.

Each deluge valve shall include pressure switches for indicating low water pressure and shall be monitored by the FGS located in the process unit control room.

The water spray system pipe and fittings will be in accordance with Project piping specifications.

6.5.2 CO_2 Extinguishing Systems

Fixed CO_2 systems shall not be used in occupied buildings.

All CO_2 extinguishing systems shall be designed and installed in accordance with NFPA 12.

6.5.3 Sprinkler Systems

Sprinkler systems shall be provided for buildings only when indicated by LCCE.

Wet pipe sprinkler systems shall be designed and installed in accordance with of NFPA 13.

The sprinkler pipe and fittings will be in accordance with Project piping specifications.

6.5.4 Foam Systems

Atmospheric storage tanks storing flammable or combustible liquids above their flashpoint shall be protected with foam according to NFPA 11.

6.5.5 Clean Agent Systems

The need for clean agent extinguishing systems (e.g. FM-200) shall be evaluated on a case by case basis by the Owner's Process Safety representative.

Clean agent systems shall be designed and installed in accordance with NFPA 2001.

6.5.6 Wet Chemical Extinguishing System

Wet chemical extinguishing system shall be used for kitchen galley hoods. Wet chemical extinguishing systems shall be designed and installed in accordance with NFPA 17A.

6.5.7 Portable and Mobile Fire Fighting Systems

Portable fire extinguishers shall be placed and installed in accordance with NFPA 10. Hand held portable and wheeled dry chemical extinguishers shall be installed strategically throughout the process unit areas and buildings for initial firefighting, with CO_2 portable extinguishers installed in rooms containing electrical equipment.

6.6 Safety Showers and Eye Wash Stations

The location and design of the Safety Showers and Eyewash Stations shall be in accordance with ANSI Z358.1.

6.7 Fireproofing

Fireproofing will be used primarily for protecting steel structures and equipment supports, although other selected equipment such as electrical components and motor operated valves that may be exposed to a liquid pool fire may also be protected.

A fire-scenario envelope is a three dimensional space into which fire-potential equipment can release flammable or combustible fluids capable of burning long enough and with enough intensity to cause substantial property damage.

Water spray protection for equipment and supports is an acceptable alternative to fireproofing.

The determination of fire hazardous areas shall be in accordance with API 2218. The extents of the fire hazardous areas shall be shown on a plot based, Fire Hazardous Area Plan.

6.8 Electrical Area Classification

Electrical Area Classification shall in accordance with API RP500, API RP505, NFPA 70 (NEC) Article 500 and NFPA 497. Electrical installations shall be carried out in accordance with the principles defined in the National Electric Code (NEC) – NFPA 70.

6.9 Fire and Gas Detection and Alarm Signaling System

The fire and gas detection system shall be designed in accordance with the Fire and Gas Detection System Basis of Design and company requirements.

6.10 Equipment Standardization

All fire protection system equipment, fire alarm and detection equipment, fire alarm control panels and other control system equipment shall be standardized for this project.

6.11 Maintenance and Testing

The fire protection systems, firefighting equipment, fire extinguishers, fire and gas detection system and fire pumps needs to be tested on a regular scheduled basis and maintained in accordance with their respective NFPA Standards and Company Guidelines.

7.0 CAPITAL COST ESTIMATE

7.1 Estimate Basis

Project Definition

A project level Estimate Plan was developed and implemented. The scope of the project is described earlier in the Report. This consists of treating the syngas with cold methanol to extract sulfur containing compounds and carbon dioxide. The CO_2 is separated from the methanol and compressed till it reaches a supercritical state and transported to the Hastings Field near Houston, TX for enhanced oil recovery. The extracted sulfur compounds are treated in the WSA unit and converted to sulfuric acid.

The estimate is based on engineering deliverables prepared by SKE&C USA, Air Liquide/Lurgi, and Haldor Topsoe and consists of the following:

- Firm and budget quotes for 80% of the value of the capital equipment account, in-house data for the 20% balance of equipment;
- Material take-offs for civil, concrete, electrical, instrument, piping and structural steel for the Rectisol® and WSA trains developed by SKE&C USA based on process designs provided by Air Liquide/Lurgi and Haldor Topsoe;
- Material take-offs for civil, concrete, electrical, instrumentation, piping, piperacks and structural steel CO_2 Compression, RTO, Propylene Refrigeration, Process Cooling Water and interconnections developed by SKE&C USA;
- All Construction labor costs are based on the man-hour unit rates, wage rates and productivity factors received from competitive proposals by qualified contractors for discipline specific construction work packages. This includes all necessary indirect costs, such as but not limited to, supervision, temporary facilities, construction equipment, indirect labor, scaffolding, pipe and steel fabrication, small tools and consumables, etc. for a turnkey installation.

Area Definition

The estimate is organized into the following areas. These areas are defined based on systems and project engineering input.

- Area 06 – Acid Gas Removal (Rectisol®)
- Area 10 – Propylene Refrigeration
- Area 12 – Wet Sulfuric Acid
- Area 16 – Regenerative Thermal Oxidizer
- Area 18 – CO_2 Compression
- Area 26 – Process Cooling Water
- Utilities – Interconnecting Piperack and defined Piping
- Utilities – LCI and Substation

Equipment

Pricing for this account is based on a combination of firm quotes and budget quotes to achieve a targeted 80% of the total equipment costs as quoted. Pricing for all equipment was solicited, but in-house data was utilized if vendor responses were not adequate to support the estimate.

Tagged electrical equipment and significant instruments were similarly priced through solicitation of quotations from approved vendors.

7.2 Costing Basis

Material take-offs (MTO) were generated for each of the bulk commodities (steel, pipe, cable, etc.). The basis of the direct field labor cost is labor rates received from the selected contractors applied against the MTO quantities developed by Engineering, supplemented by Estimating. See the Table below for wage rate breakout by each craft.

CRAFT/DISCIPLINE	COMPOSITE WAGE RATE CCS UNITS
Civil	$32.84
Concrete	$32.80
Steel	$37.32
Buildings	N/A
Mechanical Equipment	$36.98
Piping	$40.64
Electrical	$36.71
Instrumentation	$32.85
Paint & Insulation	Quoted as Subcontract
Fireproofing	Quoted as Subcontract
Scaffolding	$30.56

The Construction Basis of Estimate is further clarified by the following:

1. The standard field work week is based on an average of a 57 1/2 hour work week (3) 60 hour weeks then (1) 50 hour week for the duration of the construction phase of the project. The resulting average all-in labor rate for the construction portion is $80.48 per Direct Craft Hour.
2. Labor Escalation has been estimated considering the projected work in the area.
3. Indirect Labor is based on the following:
    a. Craft Attraction and Retention;
    b. Construction Support Craft;
        i. Firewatch
        ii. Holewatch
        iii. Tool room
        iv. General and final cleanup
        v. Town runner
        vi. Craft training
        vii. Welder testing
    c. Field Staff;
    d. Construction Equipment;
    e. Temporary Facilities;
    f. Small Tools and Consumables;
    g. Incentives;
    h. Contractors OH&P.
4. Staffing and supervision (above GF) is inclusive but not limited to the following:
    a. Site Manager;
    b. Area Superintendents;
    c. QAQC inspectors;
    d. Safety Inspectors;
    e. Surveyors;
    f. Material Coordinators;
    g. Field engineers
5. Piping is based on the following:
    a. The fabrication of the piping was priced by SKE&C USA based on recent quotes for overall dollar per tons of shop fab pipe.
    b. All of the labor to erect and test the piping is based on the man-hour unit rates provided by the mechanical construction contractor based on the quantities developed by SKE&C USA Engineering.
6. Electrical pricing includes the following:

a. Labor for electrical bulks, cable tray and instrumentation hook up;
b. Materials as defined by bulk quantities;
c. Tray materials;
d. Instrument materials (electrical hook up only);
e. Equipment rentals scaffolding and required lifts;
f. Shop fireproofing was priced and reported in the structural steel account;
g. Quantities for field fireproofing blockouts are based on 10% of the fireproofing quantities being field applied.

7.3 SKE&C USA Basis of Estimate

1. The construction estimate is based on current 2013 pricing levels escalated for the life of the project.
2. This estimate contains the following three types of piles:
    a. 18" sq. Prestressed Concrete Piles @ 60/LF each;
    b. Drilled shaft piles of varying sizes for piperacks @ 60-100/LF each
3. The concrete design basis for this project is a 4,000 psi application. However, 3,000 psi and 5,000 psi concrete will be utilized for the following items:
    a. 3,000 psi for area paving;
    b. 5,000 psi for table-top foundations.
4. Structural Steel erection is based on a combination of modularization and conventional “Stick Built”.
    a. All Structural Steel quantities are based on the project MTOs modified as a result of the Value Engineering efforts;
    b. Engineering provided quantities of ladders and platforms (L&P), price for L&Ps is based on recent in-house quotes for structural steel;
    c. The supply and fabrication of the structural steel for the for the Area 90 piperack steel was based on ROM quote from Conxtech;
    d. The supply and fabrication of the structural steel for the remaining portion of the steel was priced by SKE&C USA based on recent quotes at an average dollar per ton of $3,238
5. The Substation Enclosure Building is a prefabricated "skid" type structure. The supply and installation costs for this building are included in the E/I portion of this estimate.
6. Piping is Based on the Following;
    a. All piping quantities are based on the project MTOs modified as a result of the Value Engineering efforts;
    b. The material pricing for the piping is based on recent quotes received by SKE&C USA;

c. All valves 2” and above were taken off from the P&IDs;

d. For piping sized 6” and greater, all pipe lengths were routed from plot plans, equipment layouts and P&IDs along with all associated fittings;

e. For piping sized 2” to 4” all pipe lengths were routed from plot plans, equipment layouts and P&IDs, but fittings were factored based on pipe line length by size;

f. For piping sized 1 ½” and below a small bore allowance was assumed to be 30% of the total unit piping.

7.4 Capital Cost

The Capital cost is shown in Table 7.2.1 by area:

Table 7.2.1 – Estimate Summary by Area

Area Description	Tagged Equipment Cost	Tagged Materials Cost	Construction Hours	(1) Construction Labor Cost	Construction Material Cost	Construction Subcontractor Labor/Mtl Cost	Freight, Taxes and Duties Cost	Spares Cost	Vendor Rep Commission Cost	Sub total	Escalation, Contingency Cost	Totals Cost
Area 06 - AGR	$ 48,374,460	$ 3,072,893	282,933	26,965,722	$ 13,776,432	$ 8,381,158	$ 3,873,850	$ 546,117	$ 627,467	$105,618,100	$ 14,230,939	$ 119,849,039
Area 10 - Propylene Refrigeration	$ 11,045,113	$ 560,026	41,814	4,120,355	$ 1,850,018	$ 590,371	$ 799,145	$ 124,692	$ 143,267	$ 19,232,987	$ 2,591,445	$ 21,824,432
Area 16 - RTO	$ 3,865,720	$ 98,853	17,484	1,812,510	$ 644,325	$ 292,740	$ 273,737	$ 43,642	$ 50,142	$ 7,081,669	$ 954,181	$ 8,035,850
Area 16 - CTS, LCI, utilities	$ 1,867,328	$ 316,761	17,600	2,155,300	$ 1,763,522	$ 2,306,500	$ 234,461	$ 21,081	$ 24,221	$ 8,689,176	$ 1,170,776	$ 9,859,951
Area 18 - CO2 Compression	$ 27,667,751	$ 6,832,650	72,275	6,906,591	$ 3,798,486	$ 352,123	$ 2,274,694	$ 312,352	$ 358,880	$ 48,503,525	$ 6,535,345	$ 55,038,871
Area 12 - WSA	$ 71,086,918	$ 2,550,972	278,920	22,351,018	$ 13,188,289	$ 2,751,454	$ 5,156,885	$ 802,527	$ 922,071	$118,810,135	$ 16,008,429	$ 134,818,564
Area 26 - Process Cooling	$ 9,275,781	$ 340,051	175,162	14,422,035	$ 4,015,750	$ 2,805,107	$ 809,623	$ 104,718	$ 120,317	$ 31,893,382	$ 4,297,301	$ 36,190,683
Interconnecting Piping			117,350	11,324,806	$ 12,272,452	$ 1,173,870	$ 728,900			$ 25,500,027	$ 3,435,863	$ 28,935,891
Project and Construction Mgmt												$ 14,666,684
Home Office, Engineering, EPC fee												$ 90,272,016
TOTALS	**$ 173,183,071**	**$ 13,772,207**	**1,003,537**	**$ 90,058,336**	**$ 51,309,274**	**$ 18,653,324**	**$ 14,151,296**	**$ 1,955,129**	**$ 2,246,365**	**$365,329,002**	**$ 49,224,280**	**$ 519,491,982**

Notes:
1. Includes Construction Indirects

The bulk material quantities associated with the project are summarized below:

Table 7.2.2 – Project Bulk Quantities

Description	Quantity	Unit
Electrical	242,667	LF
Piping	112,844	LF
Concrete and Paving	18,762	CY
Steel	3,118	TN
Piles	2,954	LF
Instrumentation and Controls	2,176	EA
Mechanical Equipment	215	EA

Typical metrics associated with the cost estimate is shown in Table 7.2.3

Table 7.2.3 – Quantity Metrics

Bulk Quantity	Per Piece of Equipment	Units
Electrical	198.45	LF
Piping	524.86	LF
Concrete and Paving	87.26	CY
Steel	14.5	TN
Piles	9.08	LF
Instrumentation and Controls	10.12	LF

These metrics are consistent with values from other Petrochemical projects that SKE&C has executed.

7.5 Qualifications

The following exclusions are noted for this estimate:

- Costs or provisions for encountering contaminated materials.
- Costs or provisions for encountering underground obstructions.
- Costs or provisions for any catalyst required as a condition of the Licensor agreements. This is assumed to be part of the Owner's costs.
- Financing costs, including interest and premiums.
- Costs or provision associated with operation, maintenance and training.
- Schedule acceleration beyond a 57 1/2 hour work week.
- Costs for compliance with federal funding requirements.

The following clarifications are noted for this estimate:

- This is an Indicative Non-binding Estimate.
- All quantities are based on the Plot Plan post-Value Engineering, drawing number 13046D-90-PI-PP-0001 dated 30-Jan-2014.
- Pile and foundation design is based on the Geotechnical Report issued by Terracon dated 27-Sep-2013 and subsequent clarifications.
- All construction manhours and labor is based on the unit rate manhours provided by the construction contractors
- Indirect labor, project management and construction management estimates driven by the duration of the project have been based on 36 months to Mechanical Completion and an additional 7 months to Substantial Completion. These values require adjustment once the construction schedule has been verified.
- Estimate is based on purchased ready mix concrete. No consideration has been made for onsite batch plant.

7.6 Contingency Analyses

An Order of Magnitude Cost Risk Assessment was undertaken to address estimate uncertainty as part of the review requirements requested by the US Department of Energy. SKEC determined that the project contingency and escalation risk necessary to support an EPC Agreement totals 11.6% if cost excluding profit.

Cost ranges were solicited from the Project's participating Estimating and Engineering teams during facilitated sessions with the SKE&C USA Project Risk Management Department.

Select estimate line items were assigned optimistic, most likely and pessimistic ranges that addressed estimate uncertainty risk such as:

- Work hours
- Productivity
- Wage Rate
- Material & Equip Pricing Rate Variation
- Quantity Variation

The variation caused by these types of risk was introduced to the estimate using Monte Carlo simulation techniques to show both probabilistic drivers and possible outcomes based on confidence intervals.

Qualifications

The Order of Magnitude Cost Risk Assessment followed accepted industry best practices in risk management and adhered to the established SKE&C USA internal processes for project risk assessment with the following qualifications.

- Excludes time driven costs.
- Excludes discrete event driven risks.
- Excludes subcontractor claims.
- Excludes major scope additions or changes.
- Excludes Force Majeure disaster scenarios.
- Excludes Major labor strikes, civil unrest and environmental protests.
- Excludes re-scheduling caused by project financing (cash flow) constraints.

8.0 FLUOR FEED VALIDATION

8.1 Introduction

The SKE&C USA FEED produced design, cost and schedule documentation to be used as the basis for an Engineering Procurement and Construction (EPC) Agreement. However, LCCE did not reach an EPC Agreement with SKE&C.

Subsequently, LCCE approached three large, established engineering companies to solicit interest in an EPC execution of the project. KBR and CBI declined the invitation, but Fluor Corp. (Fluor) expressed interest. A Technical Services Agreement was signed with Fluor to review the FEED package for use within Fluor's standards. At the same time Fluor would evaluate implementing unique state-of-the-art, 3rd generation modularization techniques that could reduce site construction risks impacting cost and schedule. The review process was completed in September 2014.

8.2 Scope of Study

The FEED review prepared by Fluor included:

1. Technology review and an assessment of technology risk;
2. Review performance guarantees provided by licensors and the overall project performance guarantees;
3. Identify potential cost estimate changes;
4. Review EPC schedule;
5. Develop indicative EPC cost estimate incorporating Fluor's modular construction techniques

8.3 Technical Review Results

8.3.1 FEED Analysis

Area 06 – Acid Gas Removal

There were no technology risks identified. The PDP packaged prepared by Air Liquide/Lurgi was comprehensive.

Area 10 – Propylene Refrigeration

The capacity of the propylene refrigeration unit was reviewed and adjusted slightly to Fluor specifications.

Area 12 – Wet Sulfuric Acid

There were no technology risks identified. The PDP packaged prepared by Haldor Topsoe was comprehensive.

Area 16 – Regenerative Thermal Oxidizer

This unit is a vendor provided package and no technology risks were identified.

Area 18 – CO_2 Compressor

The CO_2 compressors would be re-specified with small flow adjustment to Fluor specifications. This is primarily a vendor provided package so most of the engineering documents will be finalized based on the chosen vendor's provided design.

Area 26 – Process Cooling Water

This is primarily a vendor provided package so most of the engineering documents will be finalized based on the chosen vendor's provided design. Final design specifications may result in small flow adjustments, but this is not a cause for concern.

8.3.2 Technology Review

The technology review consisted of identifying previously built units with similar feedstock and capacities and identifying any new considerations in the current design of the licensed AGR and WSA units that might pose any concerns. Additionally, a review of in service history for the primarily vendor package units (propylene refrigeration, RTO, CO_2 compressors, and the Process Cooling Water) was conducted to assure the design is within the vendors' experience.

There were no unresolved technology concerns identified.

8.4 Cost Review Measures

Fluor identified several areas for cost review:

Global sourcing strategies;

1. 3rd gen modularization;
2. Plot plan optimization.

8.4.1 Global Sourcing

Fluor's Global Sourcing group reviewed the FEED package Indicative Cost estimate from a scope and commercial perspective. The project equipment list and material bulks were considered to identify potential alternate bidders or the impact of Fluor's purchasing leverage in the market.

8.4.2 3rd Gen Modularization

Incorporation of 3rd generation modularization is one of the key strategies used by Fluor to control construction risk and cost. Based on a logistics review including clear access to the site via the Calcasieu River Ship Channel, Fluor verified the viability of 3rd Generation Modularization.

Key drivers for selecting 3rd Gen Modularization as a construction strategy include:

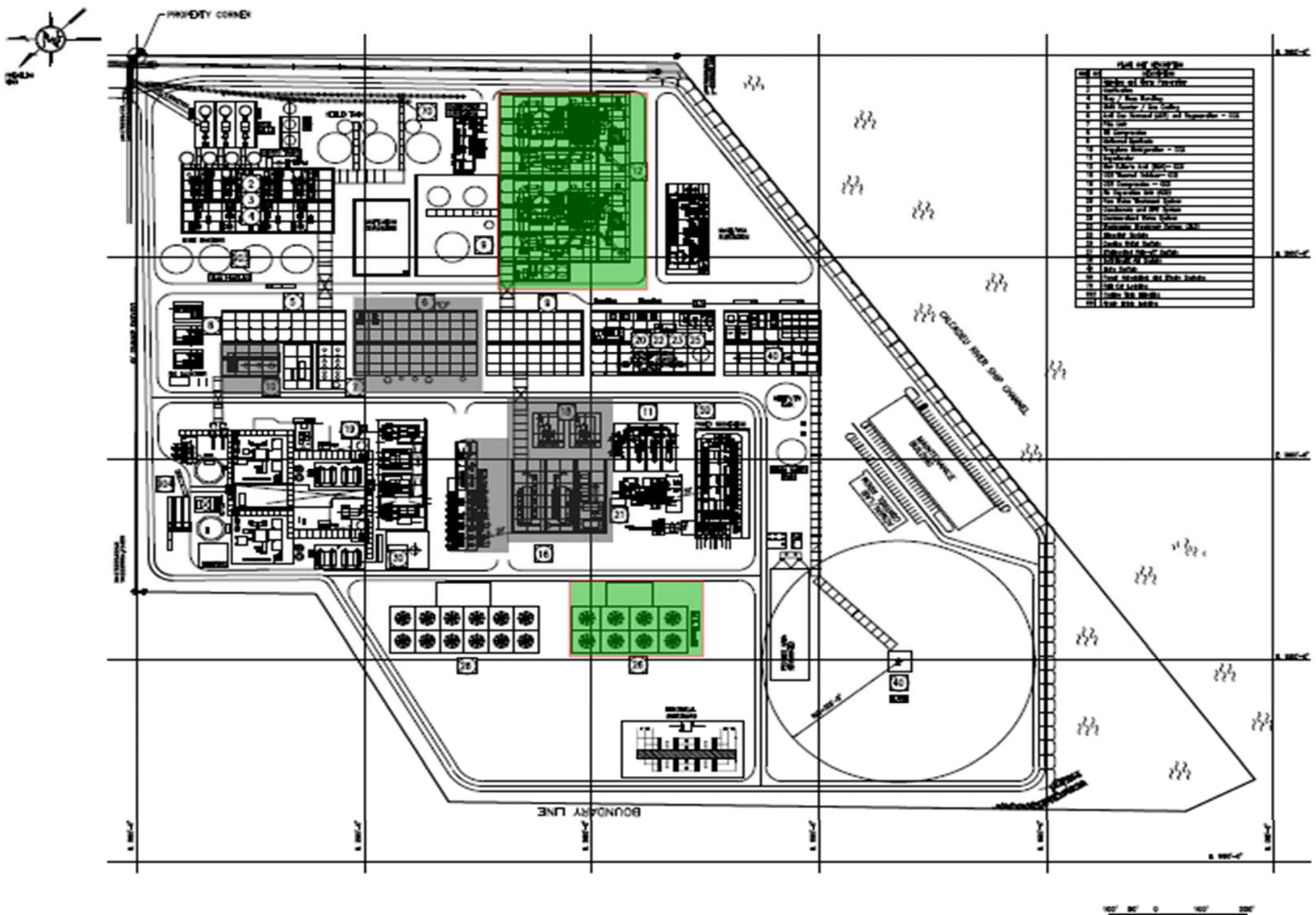
1. Availability of construction staff
2. Cost of Construction staff
3. Productivity in the field compared to in a shop setting
4. Schedule

Traditionally modularization consists of grouping together equipment such as heat exchanger banks or sections of pipe racks and "packaging" in a shop environment to be shipped to the project site. Modules are installed in a single lift as opposed field erection which requires multiple lifts for equipment and field assembly of pipe rack components. The size of the modules is typically constrained by shipping restrictions and site access (i.e. only truck or rail accessible or inadequate loading facilities for marine receiving). The LCCE project design incorporated provisions for roll on roll off (RORO) receiving at the project site for the larger prefabricated columns (such as the absorber and regeneration columns in the AGR unit). This accessibility made 3rd Gen modularization as a construction strategy achievable.

3rd Gen modularization can be characterized as several levels beyond traditional modularization. The intent is to modularize entire process units where practicable and ship to the site for a faster installation. All fireproofing, insulation, piping and pipe testing, electrical, Instrumentation, equipment installation and structural steel (to include stairs, hand rails, grating) and system testing to the greatest extent possible will be completed on each module. Additionally much of the commissioning can be done in the shop prior to shipment thereby reducing activity durations on the back end of the schedule. Plot plan optimization is concurrently performed with the 3rd Gen modularization strategy to reduce the plot space required and for ease of module installation. Fluor prepared an initial rearrangement of the Plot Plan based on 3rd Gen Modularization as shown below.

Site related cost impacts are expected due to:

1. Less congestion on site
2. A reduction in construction equipment on site
3. Reduced indirect field costs (i.e. less parking, bussing, support craft)
4. Reduced lay down yard requirements
5. Decreased in bulk quantities due to reduction in plot space required (with the exception of additional structural steel required for shipping of the modules).


PROPERTY CORNER
BOUNDARY LINE

8.5 Conclusion

Fluor completed the Phase I FEED validation study in mid-September 2014. No engineering deliverables were required as part of the FEED validation, however, several studies and analyses were developed.

The design analyses indicated that the FEED package was sufficient and as expected. The technology review indicated that proven processes were incorporated and the technologies acceptable for preparation of performance guarantees. Fluor also indicated that the anticipated guarantees were reasonable. However, Fluor considers the construction risk based on a stick-build approach to be unacceptable. Significantly, Fluor believes that the construction risk is substantially mitigated through utilization of the 3rd Generation Module plan whereby the site labor and schedule uncertainty is minimized. This avoids site congestion on the relatively small construction site, permits work to be performed in a controlled environment, and minimizes double handling of components from remote laydown areas.

Fluor did not provide an estimate of unit costs for the project. However, Fluor's estimate of the overall EPC project cost utilizing the revised construction plan was comparable to SKE&C's value after reflecting Fluor's assessment of project scope and risk characteristic.

ABBREVIATIONS

Abbreviation	*Description*
ACCE	Aspentech Capital Cost Estimator
AGA	American Gas Association
AHJ	Authority Having Jurisdiction
amsl	Above Mean Sea Level
ANSI	American National Standards Institute
ASCE	American Society of Civil Engineers
ASU	Air Separation Unit
BFD	Block Flow Diagram
BFW	Boiler Feed Water
BTU	British Thermal Units
CAD	Computer Aided Design
CAPEX	Capital Expenditure
CCS	Carbon Dioxide Capture and Storage
CH_4	Methane
CM	Construction Management
CO	Carbon Monoxide
COS	Carbonyl Sulfide
Co-Mo	Cobalt Molybdenum
CO_2	Carbon Dioxide

Abbreviation	*Description*
CS	Carbon Steel
CS_2	Carbon Disulfide
CTS	Custody Transfer Station
cu ft, CU FT	Cubic feet
CY	Cubic Yard
dB	Decibel
DCS	Distributed Control System
DOE	Department of Energy
DRE	Destruction Removal Efficiency
E&C	Engineering & Construction
EA	Environmental Assessment
EPC	Engineering, Procurement and Construction
EPCM	Engineering, Procurement and Construction Management
FEED	Front End Engineering Design
FM	Factory Mutual
ft	Feet
gal	Gallon
gpm	Gallons per minute
H_2	Hydrogen

Abbreviation	*Description*
H_2O	Water
H_2S	Hydrogen Sulfide
H_2SO_4	Sulfuric Acid
HC	Hydrocarbons
Hg	Mercury
HHV	High Heating Value
HMB	Heat & Material Balance
HP	Horsepower
HP	High Pressure
hr	Hour
HSE	Health Safety & Environment
Hz	Hertz (Frequency Unit of Measure, cycles per second)
I/O	Input/Output
ID	Inside Diameter
ISBL	Inside Battery Limits
kgs	Kilograms
KO	Knockout
kpph	Thousand Pounds per Hour
kV	Kilovolt

Abbreviation	***Description***
kW	Kilowatt
kWH	Kilowatt Hour
lb/hr	Pounds per Hour
LCI	Load Commutated Inverter
LCCE	Lake Charles Clean Energy, LLC
LEC	Leucadia Energy, LLC
LF	Linear Feet
LHV	Lower Heating Value
LP	Low Pressure
LTGC	Low Temperature Gas Cooling
m/sec	Meters per Second
m^3	Cubic Meter
MCC	Motor Control Center
mg/liter	Milligrams per Liter
mg/Nm^3	Milligrams per Normal Cubic Meter
mg-equiv/liter	Milligram Equivalent of an Ionic Species per Liter of Solution
mm	Millimeters
MMBTU	Million BTU’s
MMSCFD	Million Standard Cubic Feet per Day

Abbreviation	***Description***
MP	Medium Pressure
MTO	Material Take-off
MVA	Mega Volt Amperes
MVA	Monitoring, Verification and Analysis
MW	Megawatts
N_2	Nitrogen
NETL	National Energy Technology Laboratory
NFPA	National Fire Protection Association
Nm^3	Normal Cubic Meter
NO	Nitrogen Monoxide
NO_2	Nitrogen Dioxide
NO_x	Nitrogen Oxides, NO or NO_2
O&M	Operations and Maintenance
O_2	Oxygen
OAH	Overall Height
°C	Degrees Celsius
°F	Degrees Fahrenheit
OPEX	Operating Expenses
OSBL	Outside Battery Limits

Abbreviation	***Description***
P&ID	Process and Instrument Diagram
PDP	Process Design Package
PEA	Preliminary Environmental Assessment
PFD	Process Flow Diagram
POLC	Port of Lake Charles
pph	Pounds per Hour
ppm	Parts per Million
ppmv	Parts per Million by Volume
ppmvd	Parts per Million by Volume, Dry
ppmw	Parts per Million by Weight
PSA	Pressure Swing Adsorption
psf	Pounds per Square Foot
psia	Pounds per Square Inch, Absolute
psig	Pounds per Square Inch, Gauge
RAM	Reliability and Maintenance Analysis
RCO	Regenerative Catalytic Oxidizer
RFQ	Request for Quotation
RTO	Regenerative Thermal Oxidizer
S	Sulfur

Abbreviation	***Description***
S_X	Sulfur Compounds
SCFM	Standard Cubic Feet per Minute
SKE&C USA	SKE&C USA, Inc.
SO_2	Sulfur Dioxide
SO_3	Sulfur Trioxide
SO_X	Sulfur Oxides, SO_2 or SO_3
SRU	Sulfur Recovery Unit
SS	Stainless Steel
STG	Steam Turbine Generator
STPD	Short Tons per Day
SWS	Sour Water Stripper
SCFD	Standard Cubic Feet per Day
Syngas	Synthesis Gas generated by Gasification
TDS	Total Dissolved Solids
TIC	Total Installed Cost
TN	Ton
tpd	Tons per Day
TSP	Total Suspended Particulates
UFD	Utility Flow Diagram

Abbreviation	*Description*
UL	Underwriters Laboratory
US	United States
USD	United States Dollar
WSA	Wet Sulfuric Acid Process
WWT	Wastewater Treatment

END OF CAPTURE AND COMPRESSION

Lake Charles CCS Project

FINAL TECHNICAL REPORT

Phase 2

Reporting Period

November 16, 2009 – June 30, 2015

Transport

16” CO2 Pipeline Lateral

Prepared by

Denbury Onshore, LLC

Report Issue Date: June 30, 2015

DOE Award Number: DE-FE0002314

Submitting Organizations

Recipient
Leucadia Energy, LLC.
529 East South Temple
Salt Lake City, UT 84102

Sub-Recipient
Denbury Onshore, LLC
5320 Legacy Dr.
Plano, TX 75024

DISCLAIMER

ABSTRACT

The overall objective of the pipeline project is to construct a pipeline to transport captured CO2 from the Lake Charles Clean Energy project to the existing Denbury Green Line and then to the Hastings Field in Southeast Texas to demonstrate effective geologic sequestration of captured CO2 through commercial EOR operations. The DOE target for the project is to capture and implement a research MVA program to demonstrate the sequestration through EOR of approximately one million tons of CO2 per year as an integral component of commercial operations.

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Denbury Onshore, LLC
Transport - 16” CO_2 Pipeline Lateral

Executive Summary

Denbury concluded all CO2 pipeline-related Subphase 2A activities, including those tasks that supported obtaining a Record of Decision for the Environmental Impact Statement (EIS). The pipeline route and construction techniques were modified slightly around wetland areas to minimize impacts. Denbury submitted the application for the U.S. Army Corps of Engineers Nationwide 404 permit and was awaiting final approval and issuance of the permit and wetland mitigation requirements at the end of Subphase 2A.

While waiting for Subphase 2B approval, Denbury proceeded with engineering and ROW easement acquisition tasks, placing capital at risk. These tasks were undertaken to ensure easements were obtained for tracts critical to securing the overall pipeline route and to reduce the risk of route changes that could affect the project EIS.

Since the initial Phase 2A estimate was submitted, pipeline project costs potentially increased above the original 2010 submitted budget estimate. However, with respect to DOE, Denbury was prepared to absorb these additional costs.

Project Data – Subphase 2A Update

1. Updated Route Information

The pipeline route was modified in multiple areas to obtain an easement from industrial facilities and to attempt to reduce wetland impacts.

The pipeline route included a tie-in point on the north side of the LCCE facility where the CO2 custody transfer meter site was confirmed. This location was also the site for the pipeline pig launching facility and motorized isolation valve. The LCC property borders two industrial facilities owned by the City of Sulfur and the Louisiana Pigment Company (LA Pigment). The pipeline route was to cross these properties by completing a 2,500 foot horizontal directional drill (HDD) under the LA Pigment and the City of Sulfur industrial facilities and Bayou D'Inde Road.

The HDD under LA Pigment was approved by both LA Pigment and the City of Sulphur and easements were obtained from both landowners. The cost of this portion of the route was broken out as a separate estimate in the event that construction must be accelerated to avoid construction activities, including installation of pilings and equipment foundations, within the Leucadia plant.

The pipeline route was modified to parallel other pipelines between Bayou D'Inde Road and Bayou D'Inde, the water body. This modification reduced wetland impacts and improved discussions with the landowner.

The route was further modified to include an additional HDD under a large forested wetland area to the south of the Houston River. This drill reduced high value permanent and temporary wetland impacts.

These route changes are not reflected in the calculated impacts submitted for the EIS; however, these reroutes were evaluated by the U.S. Army Corps of Engineers under a permit amendment submitted in late November 2013.

2. Project Estimate Summary and Discussion *(See Attachment A for update)

Denbury Onshore, LLC (Denbury) originally proposed a pipeline route that originated at the Lake Charles Cogeneration (LCC) facility and flowed west/northwest 11.58 miles to the Green Pipeline owned by Denbury Gulf Coast Pipelines LLC. The estimated cost was $26.1MM. Since receiving approval to proceed with Subphase 2A, the pipeline route was modified to avoid potentially difficult industrial landowners and congested areas that would be encountered on the original route. The updated pipeline route exits the Leucadia facility to the north and traverses northerly to the Green Pipeline Lake Charles Pump Station located in Buhler, LA. The route would be approximately 11.78 miles and parallels several existing utility corridors and railroads. The updated project cost is approximately $30.6MM with cost increases due to:

- Additional 0.2 miles in overall route length
- Additional horizontal directional drills increased total drill length
- Additional mainline block valve stations required for river/waterbody crossings
- Landowner damage cost estimate increased
- Increased A/C power mitigation requirements due to parallel high voltage power lines
- ANSI class change from 900 to 1500 for some valves and fittings
- An approximate 15% increase in construction costs since 2010 due to number of crew move-arounds, increased drill footage, and high potential for use of numerous wooden mats for access in wet conditions.

Changes from the previous application:

	2010		2013		
Description	**Cost Estimate**	**Contingency**	**Updated Cost Estimate**	**Contingency**	**Variance**
Right of Way	$2,740,362	17%	$3,373,112	4%	$632,750
Construction	$13,401,428	17%	$16,750,994	12%	$3,349,566
Environmental	$810,639	17%	$484,995	8%	($325,644)
Materials	$6,066,460	17%	$6,979,291	0%	$912,831
Engineering	$2,676,549	17%	$2,157,594	4%	($518,955)
Inspection	$464,704	17%	$883,233	8%	$418,529
Line Fill	$10,935	0%	$0	0%	($10,935)
TOTAL:	**$26,171,077**		**$30,629,219**	**$2,302,004**	**$4,458,142**

Although the pipeline project cost potentially increased, Denbury remained committed to the project and with respect to DOE, was prepared to absorb any additional costs encountered above the original 2010 submitted budget estimate if the project were to move forward.

a. Right of Way Cost Discussion

The total Right of Way (ROW) cost in the original estimate was $2,740,362. The updated ROW estimate for the northern pipeline route totals $3,373,112, including a contingency of 4%. The difference of $632,750 in estimated costs included increased ROW acquisition cost, landowner damages, land agent support hours, and a reduction in contingency from 17% to 4% based on actual acquisition costs to date.

The original route estimate assumed a dollar per rod (1 rod = 16.5 feet) estimate for acquisition cost for the pipeline easement which changed with the updated route. The current estimate assumes a figure approximately 20% higher than the initial dollar per rod acquisition cost for an additional cost of $444,000 when coupled with the longer route length. The original estimate also did not include adequate funds to cover the predicted damage costs or provide enough labor support hours for the project. The updated estimate assumes that damage payments to landowners would increase per rod costs an additional 20% for a total additional cost of $235,500. Additional ROW/land agent project support for acquisition and title search adds approximately $66,000.

The additional water crossings would require installation of aboveground isolation valves, per 49 CFR 195 for Liquid Pipelines. Each valve site requires a 25 ft by 25 ft fenced site and additional payment to the affected landowner. The original estimate included one such site while the updated northern route will require six (6) valve sites. The additional cost to the project would be $35,550.

b. Construction Cost Discussion

As summarized above, Construction costs increased by $3,349,566 since the initial Subphase 2A estimate was submitted. This amount includes approximately 12% contingency on most construction costs due to remaining uncertainty related to high potential for use of many wooden mats if rainy conditions occur and persist during construction. There was also a variation in contractor quotes received and how much risk each contractor included in the estimates. The actual bidding process would include five to seven contractors and a negotiated contract to bracket and minimize cost risks.

The original westerly route was 11.58 miles long based on a table top selection of the route. The updated, surveyed northern route length increased slightly to 11.78 miles and included the additional distance resulting from elevation changes within HDDs. The new route included a total of 20,110 feet using HDD or horizontal bore installation method. This was an increase of 18,535 feet over the footage of HDDs and bores on the original westerly pipeline route, which was determined without benefit of ground surveys and an extensive construction method evaluation. The choice to conduct an HDD was based on many factors, including number of wooden mats required to maintain access and minimized damage, potential wetland impacts and mitigation requirements for open cut/trench method, and obstructions along the route. Wooden mats are 4 ft x 18 ft x 8" in size, installed two or three mats deep across the entire width and length of a wet area, and typically cost approximately$550 each. This cost can total in the hundreds of thousands and must be weighed against the additional $250/ft for use of an HDD or bored construction method.

c. Material Cost Discussion

As summarized above, Material and Equipment costs increased by $912,831 since the initial Subphase 2A estimate was submitted in 2010. This amount assumes no additional contingency.

The original pipeline design included 16" X-80 pipe with a wall thickness of 0.312 inches. The updated design and estimate includes 16" X-70 pipe with a wall thickness of 0.375 inches. The decision to increase the wall thickness and reduce the pipe strength from X-80 to X-70 was made to avoid the requirement to use the considerably more expensive automatic welding process required for X-80 pipe. The use of X-70 pipe allows the contractor to use manual stick welding, as well as to allow pipe mills to more easily meet the toughness requirements for mitigation of a running ductile fracture. The additional wall thickness, additional HDD and horizontal bore footage (requiring thicker pipe by design).

The water crossings listed above would also necessitate installation of six (6) mainline block valve stations, as required by the Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMSA) for liquid pipelines. The actual valve sites were still being determined and would be dictated by the presence of wetlands, available access via existing roads, and PHMSA approval concerning the setback distance from the waterways. The original westerly route required only one block valve site, as there were no water crossings of sufficient width requiring isolation valves.

The original project design also assumed an ANSI 900 class system from the outlet of the plant to the tie-in point of the Green Pipeline. After performing subsequent hydraulic analyses based on Green Pipeline tie-in pressures, the increased pipeline length, and the required discharge pressure of the Leucadia CO2 delivery compressors, it was determined that the fittings and valves upstream of the check meter at the Green Pipeline must all be ANSI 1500 class. This change in pressure rating class has resulted in a slight increase to the material cost of the project. This cost has been captured in the valve discussion above.

d. Engineering Cost Discussion

Engineering design, survey and engineering subcontracts decreased by $518,955 partly due to a reduction of engineering and subcontract contingency from 17% down to 4%. A reduction in engineering costs can also be attributed to a smaller scope of A/C mitigation design, as this will be completed within Denbury utilizing in-house corrosion specialists. This provides a $152,378 savings.

Survey for the project is included in the engineering scope as a subcontracted activity. An additional savings of $129,882 was achieved after an updated quote was received by Acculine Survey with fewer manhours expected than the original estimate assumed.

e. Inspection Cost Discussion

As pipelines are buried and exist in the public domain, it is especially important to ensure all construction is completed with the utmost attention to detail. Inspectors provide the eyes and direction to the contractor to protect the pipe, environment and workers, as well as ensure a quality work product. Inspectors will monitor trenching, pipe handling, coating, tie-in of HDDs/bores/valves, backfill, clean-up activities, safety, and environmental compliance.

As discussed above, the original route included fewer directional drills and mainline valve stations. During typical pipeline construction, there are separate contractor crews working simultaneously to construct the main pipeline and complete the directional drills. With only one directional drill on the previous westerly route, it was possible to utilize a floating inspection crew to monitor the one HDD. However, the northern route includes seven HDDs and would require much more attention than could be provided by one inspection group. Therefore, a comparably staffed inspection crew has been added to monitor all HDDs and horizontal bores while the mainline construction is being completed.

f. Environmental Impact and Cost Discussion

The estimated cost of wetland mitigation increased by $202,350 from the previous project estimate due to additional wetland impacts identified by the United States Army Corps of Engineers (USACE) in their draft Jurisdictional Determination. These additions to wetland impacts are due to a special aquatic feature called Pimple Mound Complexes. Pimple Mound Complexes are difficult to delineate and required very specific micro-delineations. Denbury accepted the historical data provided by the USACE on the special aquatic feature to eliminate additional field surveys at a micro-level.

A comparison of potential wetland impacts and mitigation credit costs between the original EIV route and subsequent route changes are shown in the table below.

Wetland Mitigation Cost Analysis for the Lake Charles Pipeline Project alternatives within the New Orleans Army Corps of Engineers District				
Route	**Cost Analysis**			
	Acres of Impact	**Cost Per Credit**	**Total**	**3:1**[c]
EIV Route[a]	PFO/PSS: 36.16 acres	$22 500	$813,600	$2,440,800
	PEM: 1.08 acres (No Mitigation)			
Modified Route (08/19/13)[b]	PFO/PSS: 5.93 acres	$22, 500	$133,425	$400,275
	PEM: 5.54 acres (No Mitigation)			

a - The wetland acreage impacts were determined using a generic 110-foot corridor centered on centerline and wetland areas identified during desktop review.
b - The wetland acreage impacts were determined using the route and workspaces received on 08/19/13 and wetland areas delineated in the field. Wetland impacts were not included for the proposed drill segments.
c - The USACE indicated the ratio from the new Modified Charleston Method for this Project should be within a range of 1.5-3.0.

3. Project Risk Analysis

In order to ensure a relevant cost risk analysis, as part of Subphase 2A, members of the Denbury and ENGlobal team jointly identified the potential risks associated with Denbury's CO2 pipeline project. Risk assessment was based in part upon historical data and in part upon both parties' cumulative experience with pipeline design and construction. The identified risks are discussed in more detail below but not quantified with a potential monetary impact to the project.

a. Route Risks

LCCE Plant Construction

The pipeline originates at the LCCE plant (Milepost 0). Plant construction activities will likely involve construction of equipment foundations and utilities near the time of the pipeline installation. The pipeline risk at this location involves possible conflicts with the plant construction activities and current timing differences in the design stages of the pipeline and the plant, which could introduce installation design errors, schedule delays and cost increases.

Bayou D'Inde HDD

The pipeline crosses Bayou D'Inde (Milepost 1.7 to 1.9) by an approximate 1,400 foot HDD. The HDD presents risk inherent in the construction method including soil instability and fracking out. Denbury would develop HDD frac-out plans prior to construction in an effort to prepare the contractor for these events and limit their impacts.

Pete Manena Road /Interstate Highway 10, Maplewood Drive HDD

The pipeline crosses Pete Manena Road, Interstate Highway 10, and Maplewood Drive (MP 3.2 to 3.4) by an approximate 1,100 foot HDD. The HDD presents risk inherent in the construction method including soil instability and fracking out. Denbury would develop HDD frac-out plans prior to construction in an effort to prepare the contractor for these events and limit their impacts. Additional risks associated with this crossing would be potential permit delays from the road and highway authorities, as well as the possibility of the limited remaining space for a utility easement being purchased by another project.

Railroad Crossings (Union Pacific, Kansas City Southern)

The pipeline route crosses railroads in five different locations. The Union Pacific crossing (at approximate MP 5.5) and the four Kansas City Southern crossings (at approximately MP 5.5, MP 6.1, MP 7.3, and MP 8.6) constitute the five railroad crossings. There is typically a long timeframe associated with obtaining railroad company permission and any necessary permits (several months), which can on occasion present project delays.

Sasol North America, Inc.

The proposed CO2 pipeline lateral route would bisect the proposed Sasol gas-to-liquids plant, and a mainline valve would be required on Sasol property to isolate the Sabine River Authority Canal per Federal regulations. Sasol is in the FEED stage of plant design, which typically does not have detailed plant layout dimensions and coordinates determined. Until an easement is obtained from Sasol, a pipeline reroute and relocation of the valve site would be possible risks to the project.

Kansas City Southern – Fee Property

Kansas City Southern proposed an expansion of the rail switching yard the pipeline would parallel starting at pipeline Milepost 5. The extent of the rail expansion and impacts on the pipeline route were being negotiated but are not fully known at this time. The risk to the project was the possible need to reroute the pipeline to the west or to directionally drill this property to provide additional clearance between the pipeline and the tracks. Each option would add cost to the project and introduce possible wetland impacts not previously applicable.

b. Engineering and Design Risks

Additional Surveying and Plat Development

Route modifications required by landowners or permitting authorities after the finalization of the route will require additional surveying and Plat Development. This additional surveying and Plat Development could add cost and schedule delays to the project.

Design Changes

Design changes, especially after issue of Issue for Construction drawings, can have a significant cost impact. This can occur due to route changes mandated by a landowner permitting entity. Until all easements and permits are obtained, there remains a risk of design changes.

c. Material and Equipment Risks

Cost Escalation

The TIC estimates currently accounts for material cost escalation based on 2010 values. However, specific materials can experience further significant cost escalation in short periods. Line pipe presents the most significant risk due to its cost being a significant part of the overall estimate in conjunction with the fluctuating price of steel. Denbury expected purchasing the line pipe in late 2014 and taking possession at the start of construction in 2014.

Material & Equipment Availability

Certain materials (e.g. pipe) and equipment (valves, meters) have long lead times. A general increase in demand resulting from an economic upturn could significantly increase these lead times by several weeks and potentially delay construction if not ordered in a timely manner.

d. Construction Risks

Weather Delays

Louisiana experiences significant rainfall in the spring and summer months. If construction takes place in these months, there is a high likelihood of rain-induced construction delays. This risk is somewhat mitigated by the number of HDDs used in crossing waterbodies and wetlands vs. the open-cut trenching method.

Contractor Availability and Rate Increase

Although contractor availability was not anticipated to be an issue, there is a risk that increased construction activity in the region could impact availability and rates charged by contractors.

e. Regulatory Risks

Threatened and Endangered Species

Initial ecological surveys identified Wading Bird nesting areas and Long Leaf Pine habitat along the pipeline route. The presence of Wading Bird nesting areas could hasten or delay construction if the birds begin nesting in or near designed crossings.

Wetlands

The project environmental consultant provided estimated costs associated with wetland mitigation credit purchase, but this cost could increase if mitigation bank credits are purchased by another entity, the USACE calculates a different ratio for mitigation or the species being mitigated is/are not presently being cultivated in the bank within the appropriate watershed.

Sabine River Authority Canal

The pipeline route crosses a canal owned by the Sabine River Diversion Canal System (MP 5.9 to 6.0) by an approximate 620 foot HDD. The HDD presents risk inherent in the construction method including soil instability and fracking out. Denbury would develop HDD frac-out plans prior to construction in an effort to prepare the contractor for these events and limit their impacts.

f. Expropriation

In the event that any remaining easements cannot be obtained through good faith negotiations with the landowner, Denbury could initiate expropriation proceedings as a last resort. Obtaining the right to expropriate to obtain an easement in Louisiana can be a lengthy process. In order to exercise the rights of expropriation, Denbury must have a current certificate of public convenience and necessity from the Louisiana Department of Natural Resources, Office of Conservation. Once a petition for expropriation is filed, the expropriation process was estimated to take approximately nine to eleven months before possession is obtained. Best project management practices support waiting to start construction until all easements and permits have been secured. The risk to the CO2 pipeline lateral would be a delay in the start of construction and subsequently a delay in completion of the construction

Subphase 2B

1. Work Completed at Risk

a. ROW Acquisition

Property plats and maps were drafted for all owned-in-fee tracts and provided to the Denbury Right of Way (ROW) team for use in negotiating easement agreements with landowners. Title and ownership information for every tract or easement crossed by the proposed pipeline have been researched in the local courthouses and compiled for project team reference.

As of September 23, 2013, Denbury obtained 43 out of 86 easement agreements required on properties owned in fee. The majority of these tracts are located in the southern, more industrial portion of the route where easement negotiations can take several months. In addition to the City of Sulphur and LA Pigment easements, which were essential to securing the overall pipeline route, Denbury also obtained a critical easement under Interstate 10 in an existing congested utility corridor.

Numerous tracts previously owned and occupied by private landowners were purchased by Sasol North America, Inc. for its future gas-to-liquids plant installation. This reduced the number of single landowners with which Denbury must negotiate easements agreements. Denbury was in negotiations with Sasol concerning route location and width and easement agreement approval.

Many tracts on the route are also owned by multiple family members and require negotiation, payment and signature with each individual landowner before an easement is obtained. Denbury obtained signatures from 222 of the 349 landowners.

In late 2013, Denbury reviewed the remaining unsecured easements and determined whether expropriation rights would have to be exercised as a last resort. In order to exercise the rights of expropriation, Denbury applied for and in April 2014, received a certificate of public convenience and necessity from the Louisiana Department of Natural Resources, Office of Conservation. In addition, in April 2014, Denbury also obtained an order from Louisiana Department of Natural Resources, Office of Conservation authorizing the construction of the proposed pipeline lateral. The order and the certificate of public necessity expire in April of 2016.

Crossing permits for roads and railroads were prioritized and applied for based on length of time expected to process a permit, as well as any time limits imposed on the permit time frame (i.e., road crossing permits expire within six months of issuance). Railroad permits typically require six months to obtain and have technical design requirements that must be negotiated and approved. Denbury designed all of the railroad crossings and submitted designs for preliminary review.

b. Engineering Design

The entire pipeline route was designed and documented on drawings called alignment sheets (refer to Attachment B for example). These drawings include landowner tract information, permanent easement width, temporary work space dimensions, crossing type and ownership, wetland type and dimensions, pipeline construction type and length, proposed pipeline depth, pipe and coating specifications, etc. The route and alignment sheets will only be modified in the event that landowner negotiations or U.S. Army Corps of Engineers permit requirements dictate a change in the route or temporary work space.

Process and Instrumentation (P&ID) drawings (refer to Attachment C) were drafted and approved and were used for detailed mechanical, civil, and instrumentation design, as well as material identification and procurement. Mechanical design drawings were prepared for all horizontal directional drills and mainline valve stations. These drawings will be deemed final after team review and/or approval by the appropriate permitting agency.

A pipe fracture toughness analysis was also performed by Tensor Engineering. This analysis is used to confirm the pipe wall thickness, strength and toughness requirements to mitigate a running ductile fracture (crack), which can occur in CO2 pipelines due to the energy released as the super critical CO2 changes to a gas during a pipeline release. By selecting pipe that prevents propagation of a crack, the overall pipeline risk profile is reduced.

Denbury contracted American Innovations to complete a CO2 dispersion and high consequence area analysis. This information was submitted for inclusion in the EIS and to meet the requirements of 49 CFR 195.452 Pipeline Integrity Management in High Consequence Areas (HCA). Pipeline design, including valve spacing and closure time, pipe depth of cover, and construction methods was evaluated using the results of the dispersion and HCA analysis, as well as the fracture toughness study discussed above.

2. Proposed Work if Project Were to Continue

Activities completed in Subphase 2A included predominantly only those tasks required to determine and survey the pipeline route, make initial contact with affected landowners, develop a high level project estimate, and support the effort to obtain necessary environmental permits and approvals, including the Environmental Impact Statement. If the project were to proceed further, the following actions would be taken to obtain a final design, acquire all regulatory permits, acquire all necessary easements, and to construct the pipeline.

a. Engineering Design and Procurement

Detailed mechanical, civil, electrical and instrumentation designs would be completed for the dual 12-inch check meter to be located at the tie-in point on the Denbury Green Pipeline, and for the motorized mainline valves along the pipeline route. Efforts would also begin on designing the crossing of the Leucadia plant perimeter drainage piping and the site layout for the smart tool launching barrel and pipeline isolation valve located inside the plant.

Denbury would continue work to design and finalize the pipeline construction details, such as road, highway, water canal and utility crossings and provide these drawings to the ROW/Land team for inclusion in the permit applications. An updated list of proposed pipeline crossings is shown in the table below.

LEUCADIA TO GREEN PIPELINE CO2 PIPELINE LATERAL CROSSING LIST			
#	DESCRIPTION	Length (feet)	Type
1	LA Pigment and City of Sulphur Plant Crossings	2500	HDD
2	Bayou D'Inde River Crossing	2400	HDD
3	Wetland Crossing	620	HDD
4	Interstate 10 Crossing	2300	HDD
5	Walcott Road Crossing	140	Bore
6	HWY 90/UPRR Crossing	600	HDD
7	Gulf States/Wetland Crossing	520	Bore
8	Sabine River Authority Canal Crossing	620	HDD
9	Hardy Cemetery Crossing	680	HDD
10	Wetland Crossing	2900	HDD
11	Wetland Crossing	620	HDD
12	Houston River Crossing	4150	HDD
13	Railroad Crossing	180	Bore
14	High Hope Road Crossing	160	Bore
15	Bankens Road Crossing	120	Bore
16	Ruth/Evelyn Street Crossing	1600	HDD
	Total Footage	**20,110**	

Engineering would prepare material lists and requisitions for use in obtaining quotes and delivery times, as well as for Denbury to seek bids and order materials and equipment. The project estimate would be reviewed and updated with material and equipment costs, expected contractor installation prices based on the current route configuration, and actual ROW and wetland mitigation costs. A cost increase over the stated amount in Subphase 2A is not anticipated.

b. ROW Acquisition

The Denbury ROW/Land project team would diligently continue efforts to negotiate in good faith to secure easements from all landowners and utility companies encountered along the pipeline route. If an impasse is reached in such good faith negotiations and a reroute is not feasible, Denbury would proceed with expropriation proceedings as a last resort. In order to exercise the rights of expropriation, Denbury must have a current certificate of public convenience and necessity from the Louisiana Department of Natural Resources, Office of Conservation. Prior to commencing any expropriation proceedings, Denbury would complete the property appraisal and provide the landowner with information from such appraisal in accordance with La. R.S. 19:2.2. In addition, at least 30 days prior to filing a petition for expropriation, Denbury would send a final offer letter to the landowner in accordance with the requirements of La. R.S. 19:2.2. Such final offer letter must include a copy of all appraisals previously obtained by Denbury and a plat of survey showing the proposed location and boundary of the easement along with any temporary work space.

Denbury would also prepare and submit applications for permits to cross roads, highways, railroads, and water canals. Where the route crosses a foreign utility, it is customary to obtain a Letter of No Objection from the utility owner to ensure the proposed design does not impact the foreign utility.

Upon construction and ROW restoration completion, the Denbury ROW/Land agents would address any damage settlement requirements with landowners.

c. Environmental

The CO2 pipeline environmental team would continue to monitor the ROW easement acquisition and evaluate any changes to the route that could affect the USACE Nationwide 404 permit. Should a reroute increase wetland impacts, the environmental team would prepare an amended application and seek approval from the USACE for the updated pipeline route.

Before construction begins, a survey of potential wading bird nesting areas would be conducted, as required by the Fish and Wildlife Service and USACE permit. Third party environmental inspectors would also monitor preconstruction route staking to ensure temporary work spaces are configured appropriately near wetland areas. These same inspectors would monitor erosion and storm water runoff mitigation measures during construction and after ROW clean-up and restoration activities have concluded. Environmental inspections would conclude once vegetation was established and the USACE permit closure requirements were met.

d. Construction

Construction of the pipeline lateral and associated facilities was estimated to take approximately four months assuming a start in early spring and no named storm events or other events beyond the control of Denbury delay the pipeline construction activities. Third party surveyors, nondestructive testing, and pipeline inspectors would monitor and document all aspects of pipeline installation.

All material data and testing paperwork, as-built survey points, and inspection and testing reports would be submitted to Engineering for use in compiling the project job books, which are required by 49 CFR for Hazardous Liquid Pipelines.

ATTACHMENT A

UPDATED
PROJECT SUMMARY & DISCUSSION

Executive Summary – Update June 2015

Since completion of this report, the Denbury CO_2 pipeline project proceeded with acquisition of pipeline easements and obtained fully executed easement agreements for 61 out of 86 fee tracts and 97% of all 383 landowners. The pipeline route continued to be impacted by land owner-requested route or construction method changes. Many route changes were associated with design and construction of a large chemical processing plant owned by Sasol North America S.L., its support facilities, and associated utilities (i.e., power and gas pipelines). The route changes resulted in additional costs associated with engineering design and civil, cultural and environmental surveying, as well as delays in issuance of the U.S. Army Corps of Engineers Nationwide Permit 12 due to permit amendments.

Project Estimate Summary and Discussion

The updated project cost is approximately $31.8MM, including $2.38MM in contingency. Potential cost increases or savings are due to:

- Multiple land owner required route changes, including:
  - Proposed Sasol ethane cracking facility and associated utilities.
  - Tract north of Interstate 10 requiring relocation of existing pipeline corridor from center of property to property line.
  - Proposed Axiall pipeline project in the same corridor as proposed CO_2 pipeline lateral across Axiall fee property.
  - Increased pipeline depth of cover through industrial areas.
- Denbury received estimates from two potential contractors indicating potential higher installation cost per foot for trenched and directional drilled construction. The project estimate reflects this potential. However, a competitive bidding process typically results in a range of costs based on company size of contractors selected to bid, existing workloads, size and staffing of crews, owned or leased equipment, and owned/leased/used wooden mats. The bidding process could result in a lower installed cost than what has been estimated.
- An increased number of wooden access mats is assumed in estimate for access in wet conditions; previous construction seasons were witnessed to be quite wet, and large sections of the proposed route were inaccessible during these conditions. Final costs will be dictated by actual weather during construction and potentially mitigated by shared risk between the selected construction contractor and Denbury. The estimate contingency reflects this uncertainty and risk.
- Additional directional drilling footage was added to existing crossing due to proposed future expansion of UPRC railroad facilities.
- Increased wetland mitigation costs – the U.S. Army Corps of Engineers dictates impacted species, calculation of credits to be purchased, and the mitigation bank from which to purchase credits. The original estimates assumed fewer required credits and a mitigation bank with slightly less costly credits. As of this time, the methodology for calculating mitigation credits is being reviewed on a Federal level and further delaying issuance of the permit and a final mitigation credit cost.
- Engineering and surveying increases due to the multiple route changes.
- Right of way cost reduction – Easement acquisition is over 70% complete. Contingency remains due to uncertainty of final costs for industrial tracts.

- Material cost reduction – A detailed review of the project design indicated some materials could be eliminated and still maintain the same operability and safety of the pipeline system.

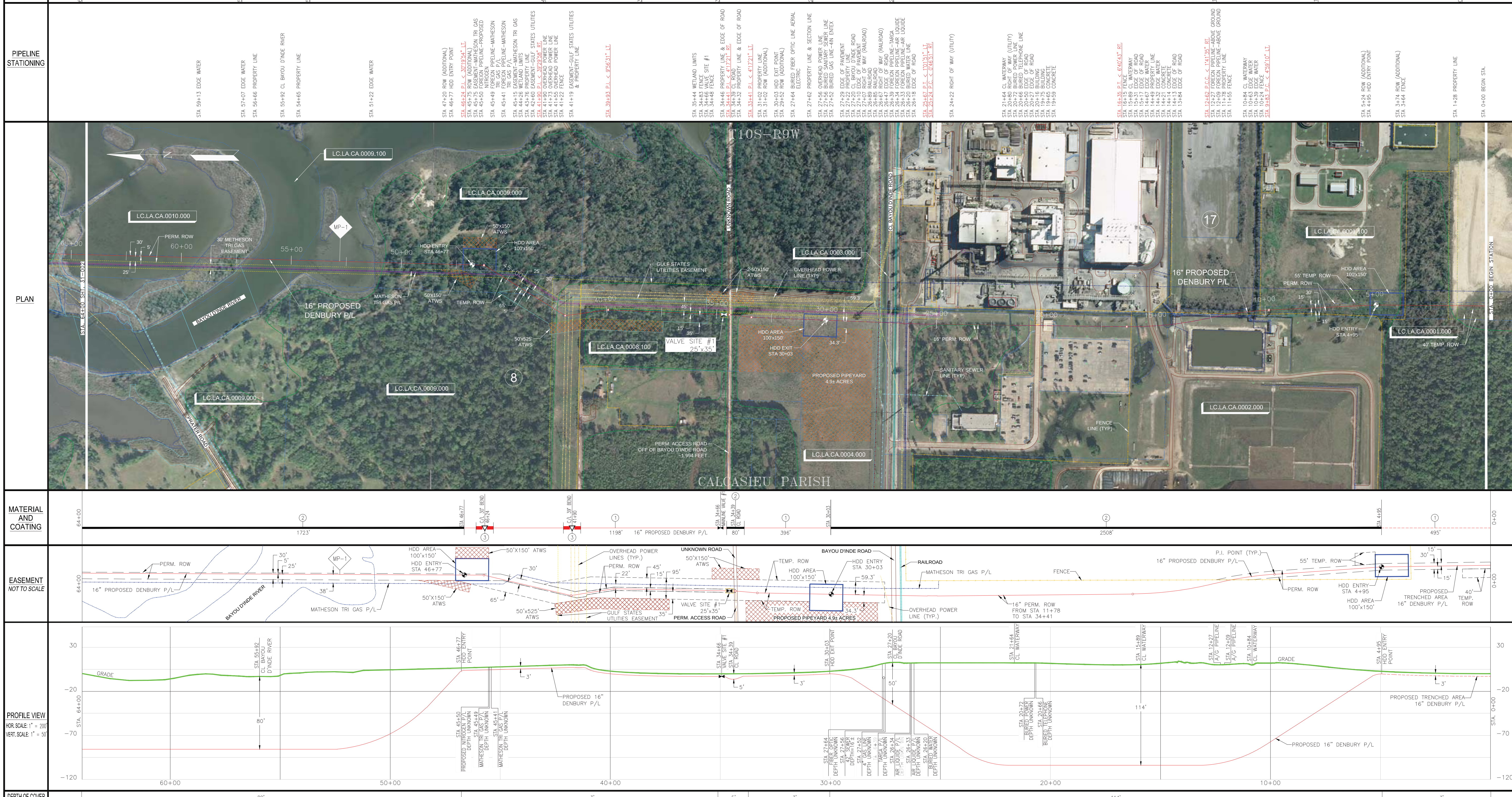
Cost Estimate Summary 2010-2014

	2010		2013		2014		
Description	**Cost Estimate**	**Contingency**	**Cost Estimate**	**Contingency**	**Cost Estimate**	**Contingency**	**Variance to 2013**
Right of Way	$2,740,362	17%	$3,373,112	4%	$3,248,182	4%	($124,930)
Construction	$13,401,428	17%	$16,750,994	12%	$18,724,328	12%	$1,973,334
Environmental	$810,639	17%	$484,995	8%	$675,406	8%	$190,411
Materials	$6,066,460	17%	$6,979,291	0%	$5,984,361	0%	($994,930)
Engineering	$2,676,549	17%	$2,157,594	4%	$2,291,262	8%	$133,668
Inspection	$464,704	17%	$883,233	8%	$913,896	8%	$30,663
Line Fill	$10,935	0%	$0	0%	$0	0%	$0
TOTAL:	**$26,171,077**		**$30,629,219**	**$2,302,004**	**$31,837,435**	**$2,382,189**	**$1,208,216**

ATTACHMENT B

EXAMPLE
ROUTE ALIGNMENT SHEET

OWNERSHIP										
	LC.LA.CA.0010.000	LC.LA.CA.0009.100	LC.LA.CA.0009.000	LC.LA.CA.0008.100	LC.LA.CA.XXXX.XXX	LC.LA.CA.0004.000	LC.LA.CA.0003.000	LC.LA.CA.0002.000	LC.LA.CA.0001.100	LC.LA.CA.0001.000
	AXIALL, INC.	BAYOU D'INDE RIVER	MICHAEL DEAN MOSS, ET AL (36 OWNERS)	SULPHUR PROPERTIES, INC. ET AL	UNKNOWN ROAD	LOUISIANA PIGMENT CO., L.P.	BAYOU D'INDE ROAD	LOUISIANA PIGMENT CO., L.P.	CITY OF SULPHUR, LOUISIANA	LAKE CHARLES HARBOR & TERMINAL DISTRICT
	44.48 RODS	12.18 RODS	81.58 RODS	40.79 RODS	0.85 RODS	40.61 RODS	2.42 RODS	93.58 RODS	63.64 RODS	7.76 RODS
Station	64+00 – 56+66	56+66 – 54+65	54+65 – 41+19	41+19 – 34+46	34+46 – 34+32	34+32 – 27+62	27+62 – 27+22	27+22 – 11+78	11+78 – 1+28	1+28 – 0+00



ENVIROMENTAL		
WETLANDS/ WATER BODIES	64+00 – 51+22	WETLAND
	44+26 – 35+44	WETLAND
WILDLIFE MEASURES AND EROSION CONTROL		

LEGEND

PROPOSED PIPELINE		HDD POINT	
EXISTING PIPELINE		BORE SAMPLE LOCATION	
CL ROAD		SECTION NUMBER	#
BANKLINE		CRACK ARRESTOR	
CL DITCH		CONCRETE WEIGHTS	
SECTION LINE		HDD/BORE AREA	
PROPERTY LINE		EXTRA TEMPORARY WORKSPACE (ETWS)	
NATURAL GRADE		CONCRETE COATING	
PERMANENT EASEMENT			
ACCESS ROAD			
HEAVY WALL PIPE			
WETLAND LIMITS			
LAND HOOK			

NOTES

1. GRID PROJECTION BASED UPON NAD 83 LOUISIANA STATE PLANES, SOUTHERN ZONE (GRID UNITS IN FEET).
2. AERIAL PHOTOGRAPH FROM LIDAR 2011

LEGEND (CONT.)

TEST LEADS

MATERIAL SUMMARY

MK. NO.	QTY.	DESCRIPTION
1	2089 LF	16" OD x .375" WT, API 5L X70, PSL2 ERW, W/ 14–16 MILS FBE COATING
2	4311 LF	16" OD x .562" WT, API 5L X70, PSL2 ERW, W/ 14–16 MILS FBE COATING AND 40 MILS A.R.O.
3	2 EA	INDUCTION BEND (SEE MATERIAL BAND FOR ANGLE)

REFERENCE DRAWINGS

DESCRIPTION
#1 VALVE SITE DRAWING
34–002 (BAYOU D'INDE RIVER CROSSING)
34–001 (EXHIBIT "B" PLANT CROSSING)

REVISIONS

NO.	DATE	DESCRIPTION
F	09/13/13	ISSUED FOR DESIGN
E	07/09/13	ISSUED FOR REVIEW
D	02/22/13	ROUTE REVIEW
C	01/21/13	ISSUED FOR REVIEW
B	10/07/11	ISSUED FOR REVIEW
A	08/15/11	PRELIMINARY REVIEW

SCALE	1" = 200'		
DRAWN	DMZ	DATE	06/16/11
CHK'D	MW	DATE	06/16/11
APPROVED		DATE	
PCS JOB NO.	JOB_NO		
AFE/P.O.NO.	AFE		
CLIENT FILE NO.			
PCS FILE NO.	31-001		

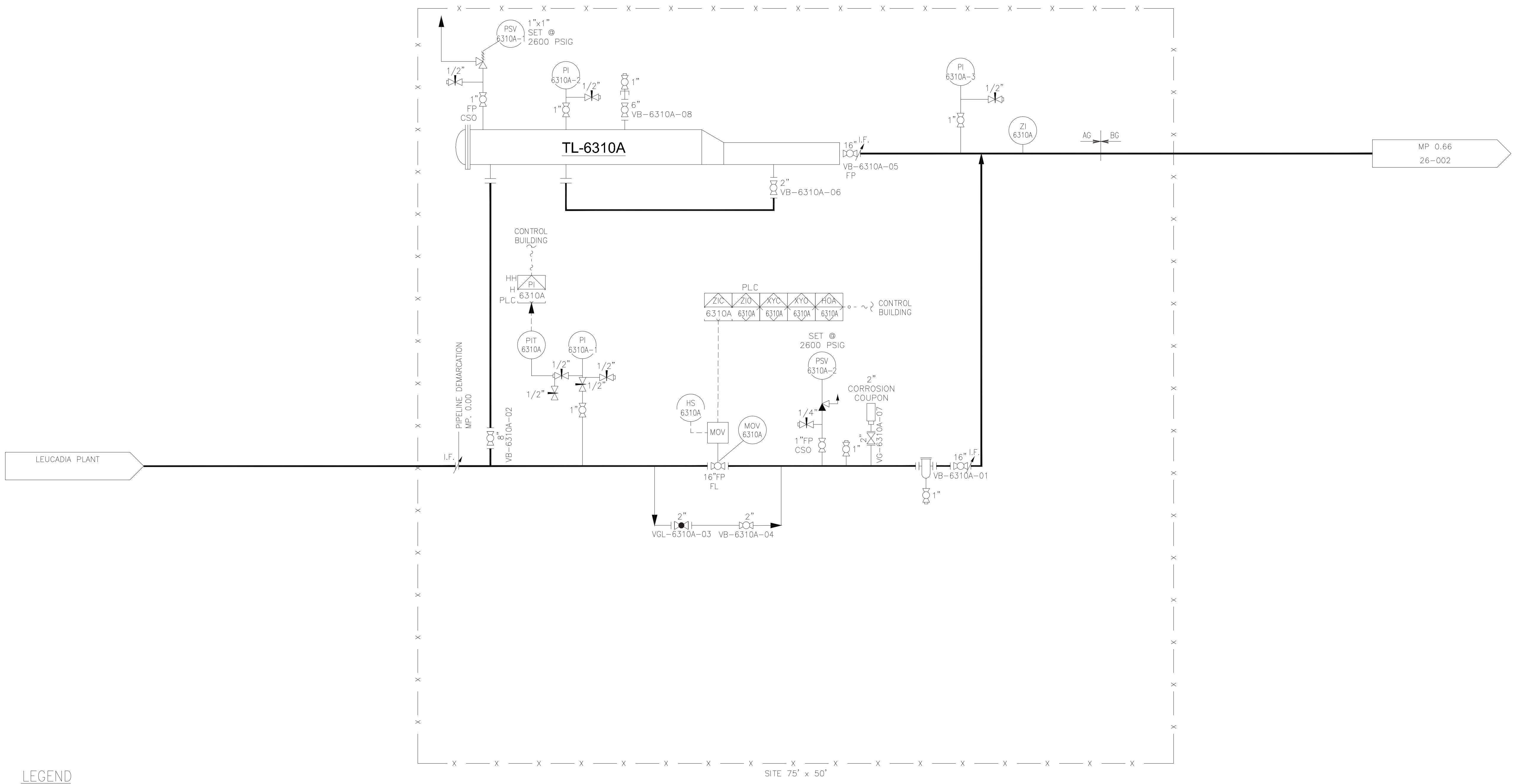
TITLE: LEUCADIA TO GREEN PIPELINE
STA. 0+00 TO STA. 64+00
T10S & R9W
CALCASIEU PARISH, LOUISIANA

NO. 31–001 REV. F

ATTACHMENT C

PROCESS & INSTRUMENTATION DIAGRAMS

TL-6310A
PIG LAUNCHER
SIZE: 20" O.D. x 12'-2" LG. MAIN BARREL
DESIGN: 2600 PSIG @ 100° F



LEGEND

I.F. – INSULATING FLANGE SET

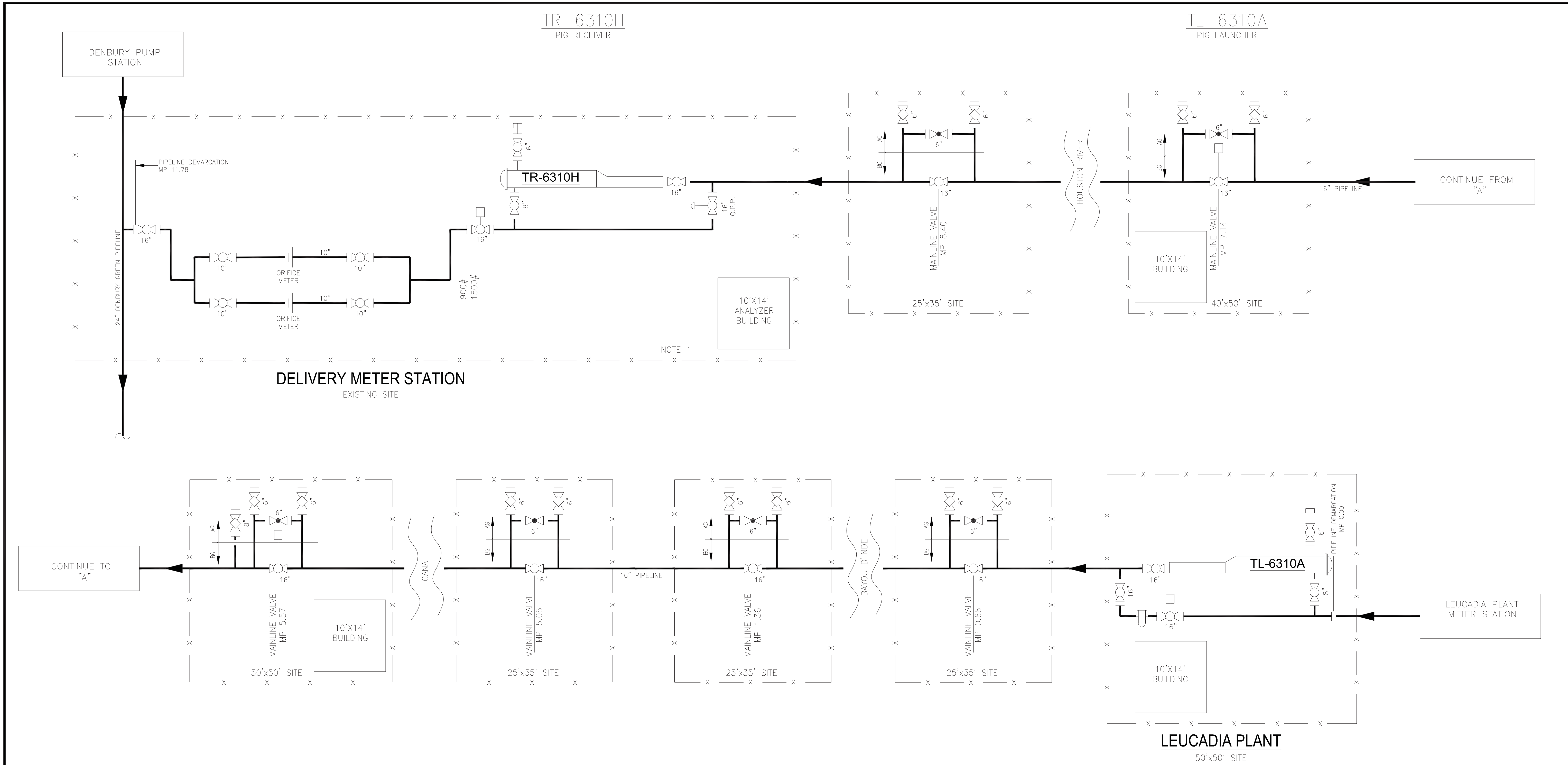
		NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
		C	RE–ISSUED FOR DESIGN	FA	MW	MV			
		B	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
		A	ISSUED FOR REVIEW	07/23/13	SLB	MW	MV		

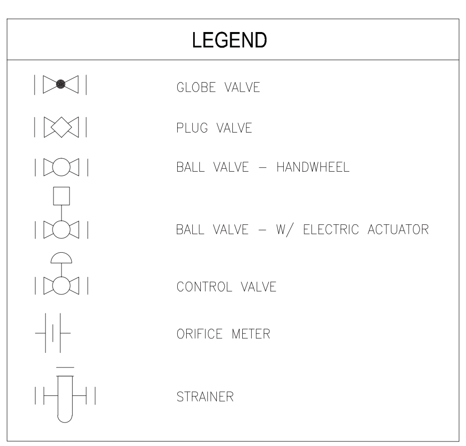
REFERENCE

PIPING AND INSTRUMENTATION DIAGRAM
LEUCADIA PROJECT
LEUCADIA PLANT

A.F.E.	
DRAWN: SLB	DATE: 07/23/13
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: N.T.S.	CAD. FILE: 10223726001
DRAWING NO. 26–001	REV. C

Sep 19, 2013 – 4:48pm J:\BRMAW\10-102237 Denbury-Leucadia to Green Pipeline\08.0 CAD Drawings\08.02 P & IDs\10223726001.dwg





NOTES:

1. METER STATION TO BE INSTALLED WITHIN EXISTING FENCED SITE.

PIPE SPECIFICATION

	DIA.	W.T.	GRADE	SEAM	D.F.	MAOP	COATING
PIPELINE	16"	0.375"	X70	ERW	72%	2360	14–16 MILS FBE
BORES	16"	0.562"	X70	ERW	60%	2360	14–16 MILS FBE W/ 40 MILS ARO
METER RUN	10"	0.375"	X70	ERW	60%	2220	PAINTED

REFERENCE	NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
	J	RE–ISSUED FOR DESIGN	09/16/13	FA	MW	MV		
	H	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
	G	REISSUED FOR APPROVAL	07/23/13	SLB	MW	MV		
	F	ISSUED FOR APPROVAL	06/24/13	DSL	MW	MV		
	E	ISSUED FOR REVIEW	06/13/13	DSL	AJ	MV		

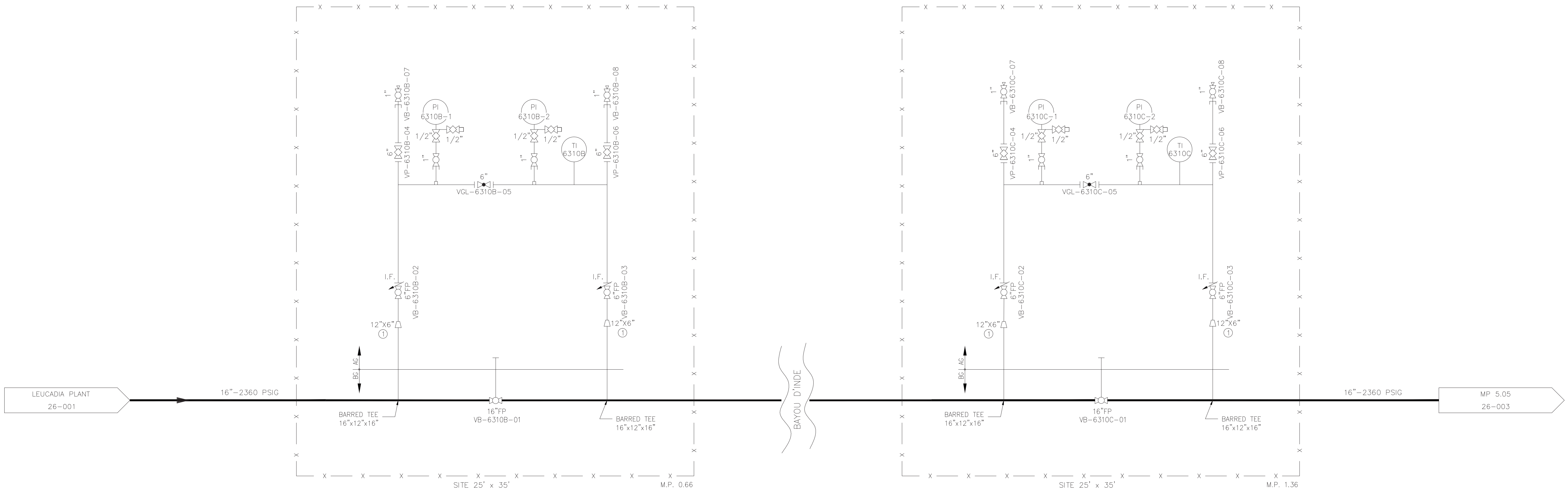
PROCESS FLOW DIAGRAM

LEUCADIA PROJECT
PROPOSED CO_2 PIPELINE

CALCASIEU PARISH LOUISIANA

A.F.E.	
DRAWN: DMZ	DATE: 02/24/10
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: NONE	CAD. FILE: 10223725001
DRAWING NO. 25–001	REV. J

Sep 19, 2013 – 4:49pm J:\BRMAW\10-102237 Denbury-Leucadia to Green Pipeline\08.0 CAD Drawings\08.01 PFDs\10223725001.dwg



NOTES:
(1) LOCATE DIRECTLY BENEATH VALVE.

LEGEND

I.F. – INSULATING FLANGE SET

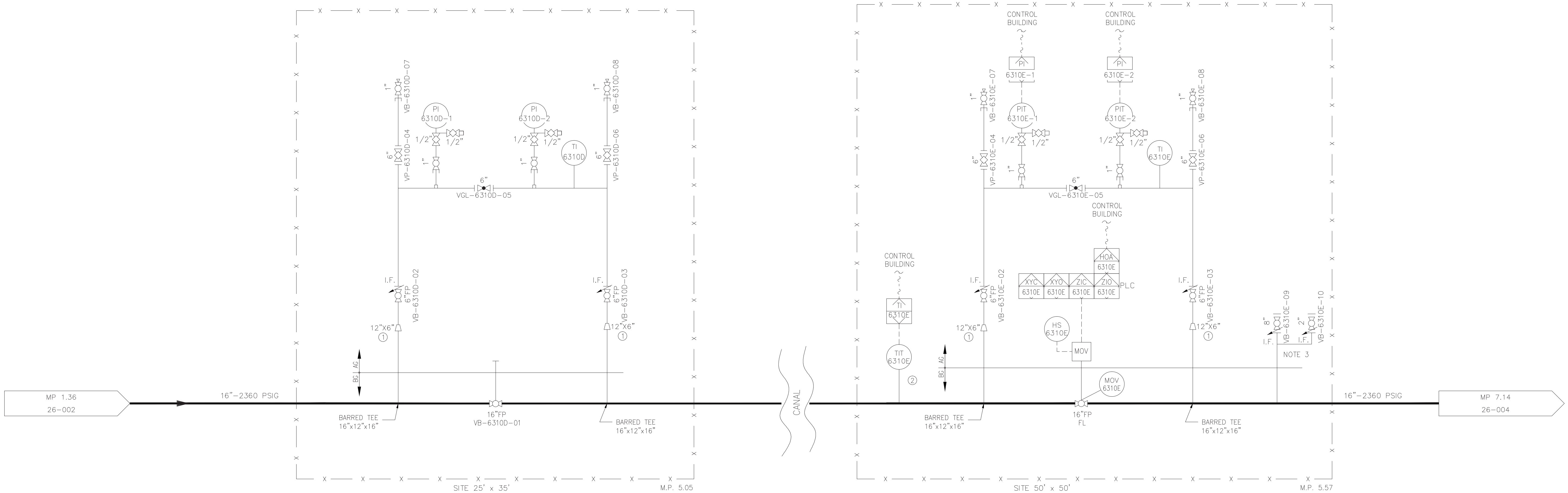
NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
E	RE-ISSUED FOR DESIGN	09/16/13	FA	MW	MV		
D	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
C	REISSUED FOR APPROVAL	07/23/13	SLB	MW	MV		
B	ISSUED FOR APPROVAL	07/01/13	DSL	MW	MV		
A	ISSUED FOR REVIEW	06/13/13	DSL	AJ	MV		

REFERENCE

PIPING AND INSTRUMENTATION DIAGRAM
LEUCADIA PROJECT
16" MAINLINE VALVES 6310B & 6310C

A.F.E.	
DRAWN: DSL	DATE: 06/12/13
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: N.T.S.	CAD. FILE: 10223726002
DRAWING NO. 26-002	REV. E

Sep 20, 2013 – 6:53am J:\BRMAW\10-102237 Denbury-Leucadia to Green Pipeline\08.0 CAD Drawings\08.02 P & IDs\10223726002.dwg



NOTES:

1. LOCATE DIRECTLY BENEATH VALVE.
2. RTD ATTACHED TO EXTERNAL PIPEWALL
3. FUTURE SASOL TIE-IN.

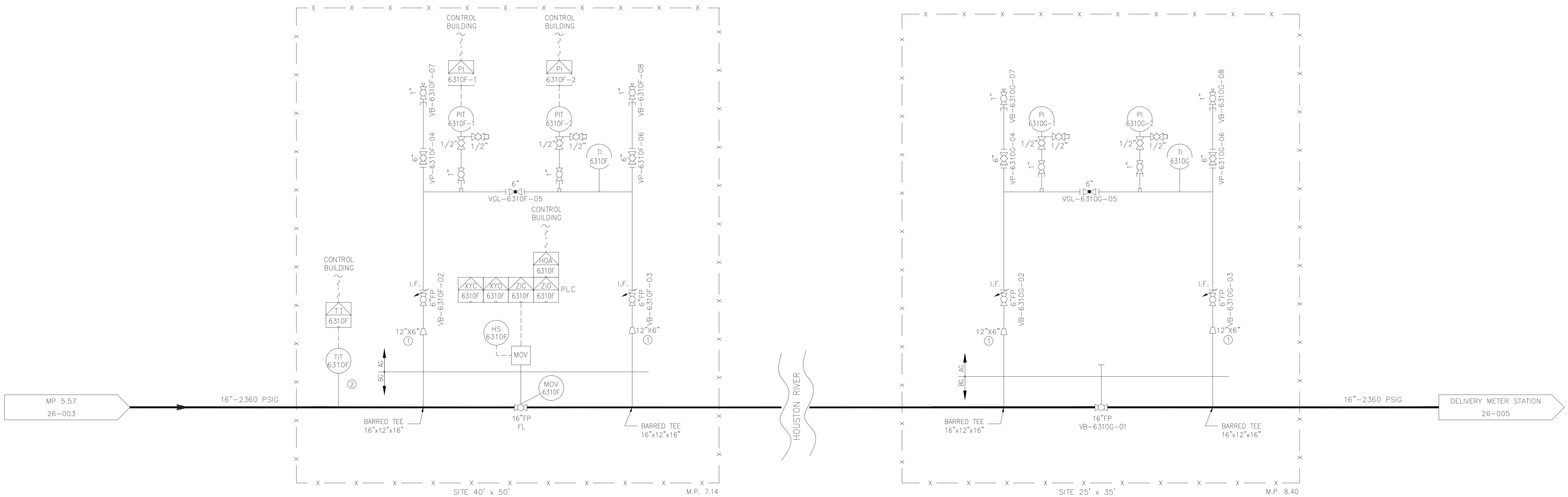
LEGEND

I.F. – INSULATING FLANGE SET

REFERENCE	NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
	D	RE-ISSUED FOR DESIGN	09/16/13	FA	MW	MV		
	C	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
	B	REISSUED FOR APPROVAL	07/23/13	SLB	MW	MV		
	A	ISSUED FOR APPROVAL	07/01/13	DSL	MW	MV		

PIPING AND INSTRUMENTATION DIAGRAM
LEUCADIA PROJECT
16" MAINLINE VALVES 6310D & 6310E

A.F.E.	
DRAWN: DSL	DATE: 06/12/13
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: N.T.S.	CAD. FILE: 10223726003
DRAWING NO. 26-003	REV. D



NOTES:

① LOCATE DIRECTLY BENEATH VALVE.

② RTD ATTACHED TO EXTERNAL PIPEWALL

LEGEND

I.F. – INSULATING FLANGE SET

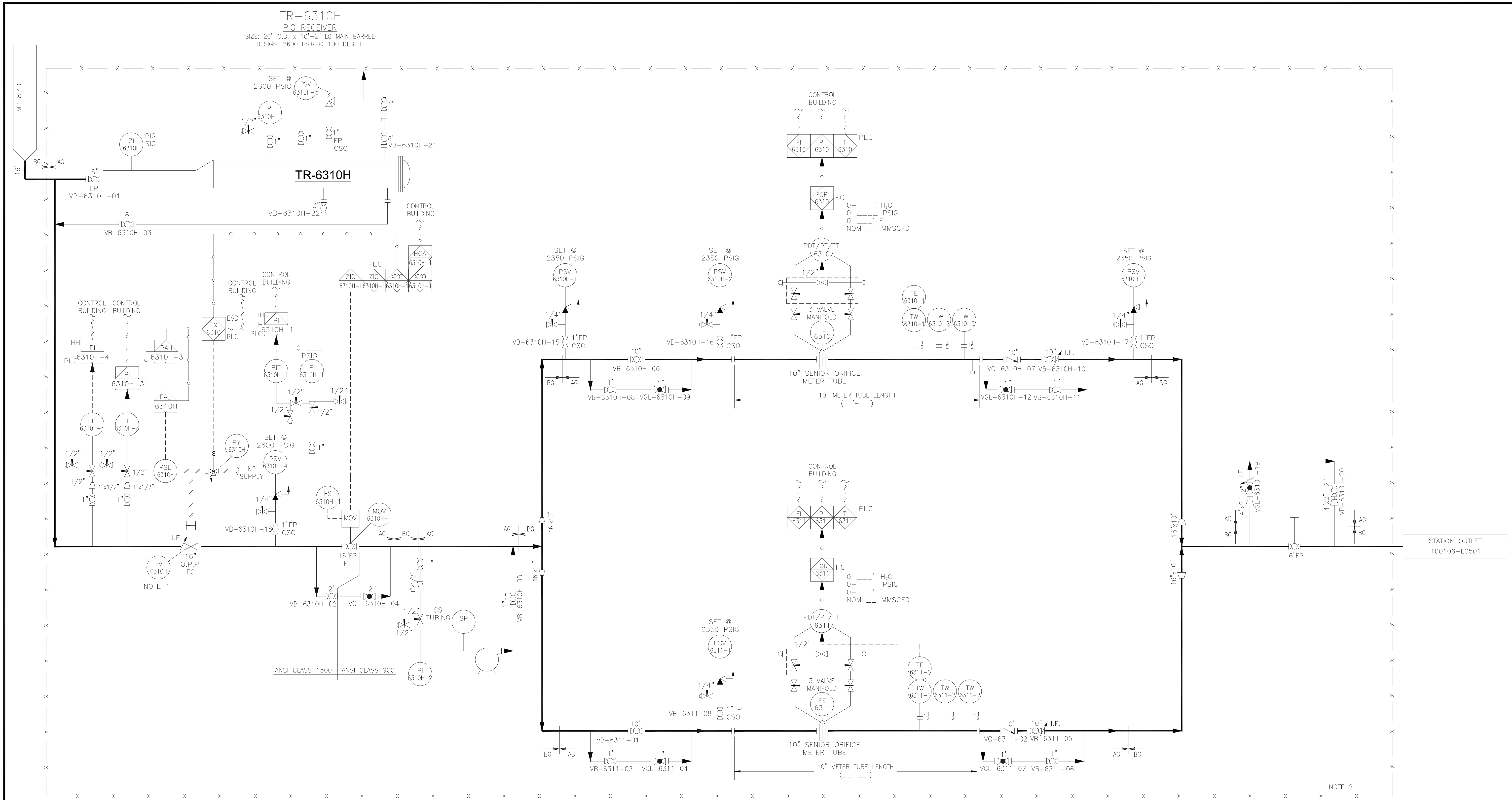
NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
D	RE-ISSUED FOR DESIGN	09/16/13	FA	MW	MV		
C	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
B	REISSUED FOR APPROVAL	07/23/13	SLB	MW	MV		
A	ISSUED FOR APPROVAL	07/01/13	DSL	MW	MV		

REFERENCE

PIPING AND INSTRUMENTATION DIAGRAM
LEUCADIA PROJECT
16" MAINLINE VALVES 6310F & 6310G

A.F.E.	
DRAWN: DSL	DATE: 06/12/13
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: N.T.S.	CAD. FILE: 10223726004
DRAWING NO. 26-004	REV. D

Sep 20, 2013 – 6:55am J:\BRMAW\10-102237 Denbury-Leucadia to Green Pipeline\08.0 CAD Drawings\08.02 P & IDs\10223726004.dwg



LEGEND

I.F. – INSULATING FLANGE SET

NOTES:

1. IF NITROGEN PRESSURE IS TOO LOW OR INLET PRESSURE IS TOO HIGH OR SOLENOID LOSES POWER, VALVE PV-6310 WILL FAIL CLOSED. VALVE MUST BE RESET MANUALLY.
2. METER STATION TO BE INSTALLED WITHIN EXISTING FENCED SITE.

REFERENCE		NO.	REVISION–DESCRIPTION	DATE	DRAWN	CHK'D	ENG. APP'D	OPER. APP'D	SAFETY APP'D
		E	RE-ISSUED FOR DESIGN	09/16/13	FA	MW	MV		
		D	ISSUED FOR DESIGN	07/25/13	DSL	MW	MV		
		C	REISSUED FOR APPROVAL	07/23/13	DMZ	MW	MV		
		B	ISSUED FOR APPROVAL	07/01/13	DSL	MW	MV		
		A	ISSUED FOR REVIEW	06/13/13	DSL	AJ	MV		

PIPING AND INSTRUMENTATION DIAGRAM
LEUCADIA PROJECT
DELIVERY METER STATION

A.F.E.	
DRAWN: DSL	DATE: 06/12/13
CHECK:	DATE:
ENG. APP.:	DATE:
OPER. APP.:	DATE:
SAFETY APP.:	DATE:
SCALE: N.T.S.	CAD. FILE: 10223726005
DRAWING NO. 26-005	REV. E

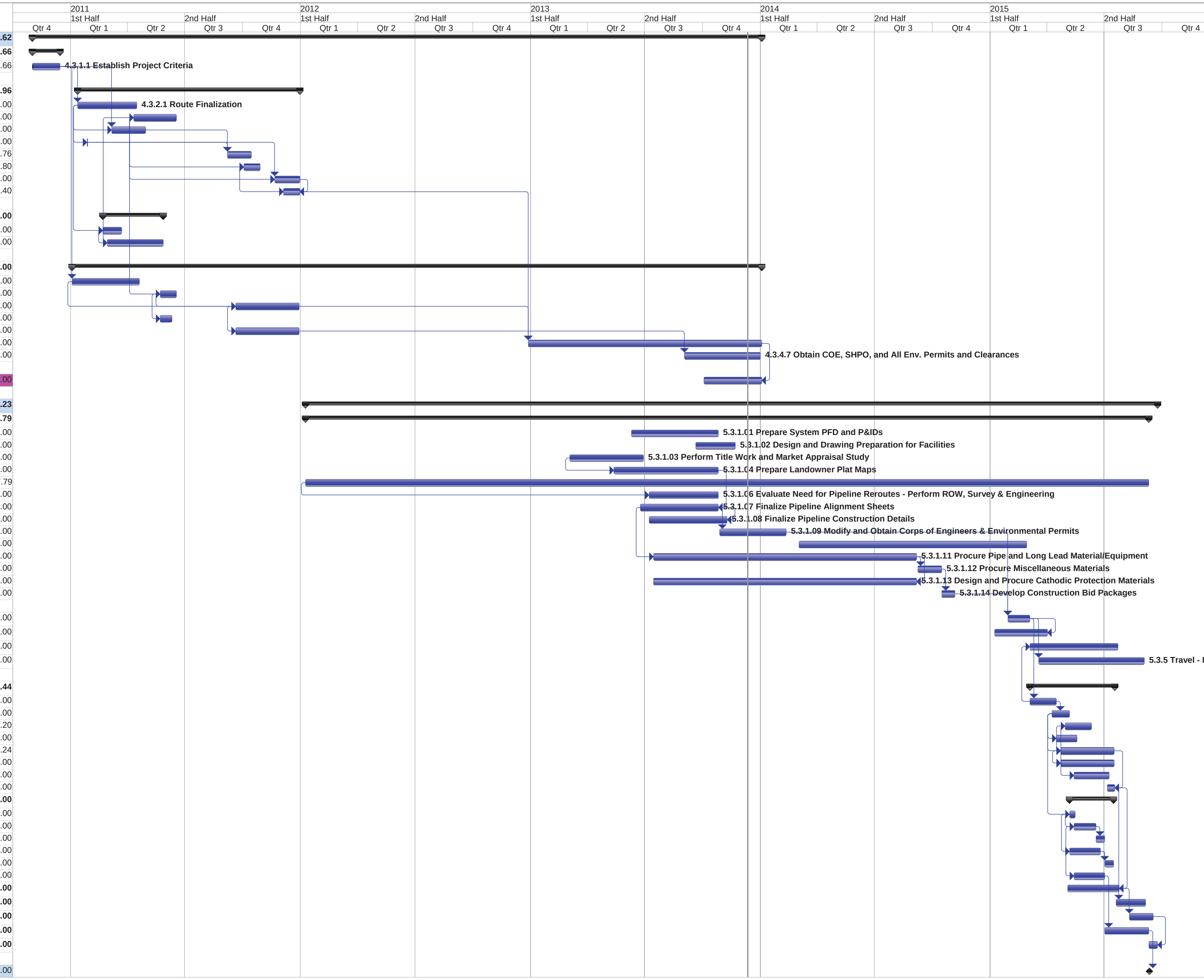
Sep 20, 2013 – 7:20am J:\BRMAW\10-102237 Denbury-Leucadia to Green Pipeline\08.0 CAD Drawings\08.02 P & IDs\10223726005.dwg

ATTACHMENT D

PROJECT SCHEDULE

DENBURY ONSHORE, LLC
LAKE CHARLES CO_2 PIPELINE FROM THE LEUCADIA PLANT TO THE GREEN PIPELINE
Udated 10-02-13

ID	ID	Task Name	Duration	Start	Finish	Predecessors	Total Cost
1	1	**4.3 SUBPHASE 2a: Pipeline Design and Environmental Permitting**	**829 days**	**Mon 11/1/10**	**Thu 1/2/14**		**$1,021,870.62**
2	2	**4.3.1 Project Kickoff**	**32 days**	**Mon 11/1/10**	**Tue 12/14/10**		**$1,747.66**
3	3	4.3.1.1 Establish Project Criteria	32 days	Mon 11/1/10	Tue 12/14/10		$1,747.66
4	4						
5	5	**4.3.2 Preliminary Engineering and Design**	**253 days**	**Wed 1/12/11**	**Fri 12/30/11**		**$567,615.96**
6	6	4.3.2.1 Route Finalization	68 days	Wed 1/12/11	Fri 4/15/11	3	$50,575.00
7	7	4.3.2.2 Preliminary Civil and Easement Survey	50 days	Mon 4/11/11	Fri 6/17/11	17SS+15 days	$226,390.00
8	8	4.3.2.3 Hydraulic Calculations	40 days	Mon 3/7/11	Fri 4/29/11	3,6SS+30 days	$18,792.00
9	9	4.3.2.4 Determine Crossing Permit Requirements	1 day	Thu 1/27/11	Thu 1/27/11	6SS+3 days	$1,250.00
10	10	4.3.2.5 Develop Material and Equipment Specifcations	28 days	Wed 9/7/11	Fri 10/14/11	8,9	$46,981.76
11	11	4.3.2.6 Prepare Alignment Drawings	20 days	Mon 10/3/11	Fri 10/28/11	7SS+6 wks	$46,980.80
12	12	4.3.2.7 Prepare Permit Exhibits	30 days	Mon 11/21/11	Fri 12/30/11	9,7SS+30 days	$56,376.00
13	13	4.3.2.8 Prepare Pipeline Construction Details	20 days	Mon 12/5/11	Fri 12/30/11	1SS+5 days,12FF	$120,270.40
14	14						
15	15	**4.3.3 Right of Way/Land**	**70 days**	**Mon 2/21/11**	**Fri 5/27/11**		**$221,660.00**
16	16	4.3.3.1 Update Landowner Line List (Tax cards)	22 days	Mon 2/21/11	Tue 3/22/11	6SS+28 days	$48,500.00
17	17	4.3.3.2 Obtain Access Permission for Preliminary Survey	65 days	Mon 2/28/11	Fri 5/27/11	16SS+5 days	$173,160.00
18	18						
19	19	**4.3.4 Environmental**	**784 days**	**Mon 1/3/11**	**Thu 1/2/14**		**$230,847.00**
20	20	4.3.4.1 Update Permit & NEPA Requirements	77 days	Mon 1/3/11	Tue 4/19/11	3	$49,650.00
21	21	4.3.4.2 Perform Environmental Field Surveys for Permitting and NEPA Requirements	20 days	Mon 5/23/11	Fri 6/17/11	7SS+25 days	$43,912.00
22	22	4.3.4.3 Prepare and Submit Permit Applications	73 days	Tue 9/20/11	Thu 12/29/11	ays,21SS-30 days	$38,210.00
23	23	4.3.4.4 Perform Cultural and Ecological Surveys, if required	15 days	Mon 5/23/11	Fri 6/10/11	21SS	$32,500.00
24	24	4.3.4.5 Submit Cutural and Ecological Reports to COE, DOE, SHPO	73 days	Tue 9/20/11	Thu 12/29/11	22SS	$5,000.00
25	25	4.3.4.6 Obtain NEPA FONSI or Record of Decision	265 days	Fri 12/28/12	Thu 1/2/14	22,13	$61,575.00
26	26	4.3.4.7 Obtain COE, SHPO, and All Env. Permits and Clearances	87 days	Mon 9/2/13	Tue 12/31/13	24	$0.00
27	27						
28	28	***DECISION POINT 1 - End of Subphase 2a (DOE 90-day Review)***	66 days	Thu 10/3/13	Thu 1/2/14	25FF	$0.00
29	29						
30	30	**5.3 SUBPHASE 2b: Pipeline Construction**	**968 days**	**Mon 1/9/12**	**Wed 9/23/15**		**$25,143,074.23**
31	31	**5.3.1 Design and Procurement**	**958 days**	**Mon 1/9/12**	**Wed 9/9/15**		**$4,028,346.79**
32	32	5.3.1.01 Prepare System PFD and P&IDs	5 mons	Mon 6/10/13	Fri 10/25/13		$15,000.00
33	33	5.3.1.02 Design and Drawing Preparation for Facilities	45 days	Fri 9/20/13	Thu 11/21/13		$142,000.00
34	34	5.3.1.03 Perform Title Work and Market Appraisal Study	85 days	Mon 3/4/13	Fri 6/28/13		$234,229.00
35	35	5.3.1.04 Prepare Landowner Plat Maps	120 days	Mon 5/13/13	Fri 10/25/13	34SS-5 days	$60,000.00
36	36	5.3.1.05 Right-of-Way and Site Acquistion, Damage Settlement, Wetland Mitigation	958 days	Mon 1/9/12	Wed 9/9/15		$3,129,117.79
37	37	5.3.1.06 Evaluate Need for Pipeline Reroutes - Perform ROW, Survey & Engineering	80 days	Mon 7/8/13	Fri 10/25/13	36SS	$50,000.00
38	38	5.3.1.07 Finalize Pipeline Alignment Sheets	90 days	Mon 6/24/13	Fri 10/25/13	35FF	$50,000.00
39	39	5.3.1.08 Finalize Pipeline Construction Details	90 days	Mon 7/8/13	Fri 11/8/13	38FF+2 wks	$72,000.00
40	40	5.3.1.09 Modify and Obtain Corps of Engineers & Environmental Permits	76 days	Mon 10/28/13	Mon 2/10/14	38	$20,000.00
41	41	5.3.1.10 Conduct Landowner Condemnation(s)	260 days	Mon 3/3/14	Fri 2/27/15		$106,000.00
42	42	5.3.1.11 Procure Pipe and Long Lead Material/Equipment	300 days	Mon 7/15/13	Fri 9/5/14	38SS+3 wks	$30,000.00
43	43	5.3.1.12 Procure Miscellaneous Materials	28 days	Mon 9/8/14	Wed 10/15/14	42	$30,000.00
44	44	5.3.1.13 Design and Procure Cathodic Protection Materials	300 days	Mon 7/15/13	Fri 9/5/14	42FF	$60,000.00
45	45	5.3.1.14 Develop Construction Bid Packages	15 days	Thu 10/16/14	Wed 11/5/14	43	$30,000.00
46	46						
47	47	**5.3.2 Bid & Award Construction**	**25 days**	**Thu 1/29/15**	**Wed 3/4/15**	40,45FS+12 wks	$19,468.00
48	48	**5.3.3 Receive Material and Equipment**	**60 days**	**Thu 1/8/15**	**Wed 4/1/15**	47FF+4 wks	$5,814,954.00
49	49	**5.3.4 Inspection**	**100 days**	**Thu 3/5/15**	**Wed 7/22/15**	53SS	$785,000.00
50	50	**5.3.5 Travel - Monitor Construction and Post Construction**	**120 days**	**Thu 3/19/15**	**Wed 9/2/15**	47FS+2 wks	$60,000.00
51	51						
52	52	**5.3.6 Pipeline Construction**	**97 days**	**Thu 3/5/15**	**Fri 7/17/15**		**$13,148,722.44**
53	53	5.3.6.1 Final Route Survey and Staking	30 days	Thu 3/5/15	Wed 4/15/15	47	$58,500.00
54	54	5.3.6.2 ROW Clearing	20 days	Thu 4/9/15	Wed 5/6/15	53FS-5 days	$440,000.00
55	55	5.3.6.3 Trenching and Horizontal Directional Drills (HDDs) - 3 rigs	30 days	Thu 4/30/15	Wed 6/10/15	57SS+5 days	$4,539,108.20
56	56	5.3.6.4 Pipe Stringing	23 days	Thu 4/16/15	Mon 5/18/15	54SS+5 days	$692,062.00
57	57	5.3.6.5 Welding and Tie-ins	61 days	Thu 4/23/15	Thu 7/16/15	54SS+10 days	$5,532,973.24
58	58	5.3.6.6 X-ray and Inspection	61 days	Thu 4/23/15	Thu 7/16/15	57SS	$138,000.00
59	59	5.3.6.7 Backfill and ROW Clean-up	40 days	Thu 5/14/15	Wed 7/8/15	55SS+10 days	$1,438,259.00
60	60	5.3.6.8 Perform Mainline Hydrostatic Test(s)	10 days	Mon 7/6/15	Fri 7/17/15	57FF+1 day	$309,820.00
61	61	**5.3.7 Facility Construction**	**50 days**	**Thu 5/7/15**	**Wed 7/15/15**		**$824,506.00**
62	62	5.3.7.1 Site Clearing	7 days	Thu 5/7/15	Fri 5/15/15	54SS+20 days	$33,725.00
63	63	5.3.7.2 Civil and Foundation Work	25 days	Thu 5/14/15	Wed 6/17/15	62SS+5 days	$168,625.00
64	64	5.3.7.3 Site Fence Installation	10 days	Thu 6/18/15	Wed 7/1/15	63	$33,725.00
65	65	5.3.7.4 Fabrication, Welding, and Installation	35 days	Thu 5/7/15	Wed 6/24/15	62SS	$337,255.00
66	66	5.3.7.5 Instrumentation and Electrical Installation	10 days	Thu 7/2/15	Wed 7/15/15	65FS+5 days	$101,176.00
67	67	5.3.7.6 X-ray, Inspection, and Painting	35 days	Thu 5/14/15	Wed 7/1/15	63SS	$150,000.00
68	68	**5.3.8 Complete Pipeline As-Built Survey**	**60 days**	**Mon 5/4/15**	**Fri 7/24/15**	60FF+5 days	**$322,077.00**
69	69	**5.3.9 Pipeline and Equipment Commissioning**	**35 days**	**Mon 7/20/15**	**Fri 9/4/15**	60	**$50,000.00**
70	70	**5.3.10 Complete Pipeline and Facility As-Built Drawings/Alignments**	**28 days**	**Mon 8/10/15**	**Wed 9/16/15**	68FS+2 wks	**$40,000.00**
71	71	**5.3.11 Road Repairs**	**50 days**	**Thu 7/2/15**	**Wed 9/9/15**	67	**$25,000.00**
72	72	**5.3.12 Complete Job Books and Final Pipeline Technical Report**	**10 days**	**Thu 9/10/15**	**Wed 9/23/15**	70FF+1 wk	**$25,000.00**
73	73						
74	74	***2c: END OF PIPELINE CONSTRUCTION - OPERATIONS BEGIN***	1 day	Thu 9/10/15	Thu 9/10/15	71	$0.00



Project: Denbury Lake Charles CO2 Pi Date: Thu 12/12/13	Task	Milestone	Project Summary	External Milestone	Inactive Milestone	Manual Task	Manual Summary Rollup	Start-only	Progress
	Split	Summary	External Tasks	Inactive Task	Inactive Summary	Duration-only	Manual Summary	Finish-only	Deadline

ATTACHMENT E

BASIS OF EXTIMATE

Denbury Lake Charles CO2 Pipeline - Leucadia Plant to Green Pipeline TIC Estimate (November 2013)

Basis of Estimate (BOE)

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1.0 PROJECT PURPOSE

Denbury plans to construct a carbon dioxide (CO_2) pipeline, approximately 11.42 miles long, from the future Leucadia Energy Plant in Lake Charles, LA to a tie-in point on Denbury's existing Green Pipeline in Calcasieu Parish, LA.

2.0 GENERAL DESIGN CRITERIA

2.1 GENERAL DESIGN REQUIREMENTS

1. The Denbury Lake Charles CO_2 pipeline is to be designed, installed, operated and maintained in accordance with:

   - U.S. Department of Transportation (DOT) 49 CFR, Part 195, Transportation of Hazardous Liquids by Pipeline.

   - ASME B31.4, Pipeline Transportation Systems for Liquid Hydrocarbons and Other Liquids

2. ENGlobal has performed hydraulic calculations to determine the optimum pipeline size, which is 16 inches nominal diameter.

3. The pipeline will have the following design flow parameters:

Maximum Operating Pressure (MOP)	2,360 psig
Maximum Flowrate	240 MMSCFD
Minimum Flowrate	194 MMSCFD
Maximum Anticipated Pressure at Leucadia Plant Outlet	2,271 psig
Minimum Pressure at Green Pipeline Tie-in	1,200 psig
Velocity Range (based on flowrates)	2.4 to 3.0 mph

4. The pipeline cost estimate will not include custody transfer metering of CO_2, but will include a check metering station at the Green Line tie-in for line integrity monitoring. A custody metering station will be provided by Leucadia at the plant, funded under the plant budget.

5. The pipeline will begin at a flanged connection within the Leucadia plant site, downstream of the Leucadia plant custody metering station.

6. The pipeline will be controlled and monitored by a Denbury remote Supervisory Control and Data Acquisition (SCADA) system, which is not within the scope of the project. The details of the pipeline's control have not been determined, however, following are the minimum capabilities of the system:

   - Motor Operated Valves (MOVs) will have their position monitored and be capable of remote operation.
   - Pressures on the pipeline will be monitored at the beginning and end of the line, as well as at two intermediate valve locations.

   - The meter station at the Green Line tie-in will be capable of remote operation and monitoring.

- Meter switching, regulation, overpressure protection and other functions will be controlled through a combination of local automation and remote operations.

2.2 PIPELINE DESIGN REQUIREMENTS

General

1. Line pipe will be API 5L ERW welded steel pipe, grade X70.

2. The pipeline will be constructed of double random length pipe joints averaging 40 ft. in length. Factory double jointing will not be used.

3. Manual stick welding will be employed. Automatic welding will not be used.

4. At the check measurement station only, fittings and flanges will be ANSI Class 900 to match the MOP of the adjacent Green Pipeline. For the rest of the pipeline, fittings and flanges will be ANSI Class 1500 due to the discharge pressures at the Leucadia Plant. Flanges will be raised face (RF) type.

5. No corrosion allowance (internal or external) will be included in the design.

6. The pipeline will be designed to be "piggable", capable of accommodating smart pig and geometry in-line inspection tools.

7. Compression, treating and dehydration of the CO2 stream will be performed by the plant and is not included in the pipeline project.

8. Overpressure protection is included in the cost estimate, for the check meter station, since it will be constructed using ANSI 900 flanges and fittings. Overpressure protection will also be provided at the Leucadia plant, but is not included in the estimate.

9. Pipeline bends for PI's (Point of Intersection), over bends and sag bends will be made in the following manner, similar to those on the Green Pipeline:
   - Angles 0 to 19 degrees – Field bends
   - Angles over 19 degrees – Induction bends, 5D radius
   - Reverse bends to above ground piping, 30 degrees – Induction bends, 5D radius

10. Reinforced concrete support pads will be installed under any risers and mainline valve stations in the pipeline.

11. The pipeline will have a preferred depth of cover of 48 inches and minimum depth of cover of 36 inches.

12. To limit the pipeline's susceptibility to running ductile fracture, special Charpy V-notch impact energy values have been calculated. CO2 stream composition for normal and upset plant operations has been evaluated to determine required pipe specifications. Results of calculations confirm that pipe mills can provide necessary toughness for the heavy wall pipe to be used in crossings and horizontal directional drills. The pipeline will require the use of crack arrestors to mitigate the risk of running ductile fracture in the regular wall pipe installed by open trench construction.

Design Factors

1. The following pipe pressure design factors will be utilized, similar to those used in the design of the Green Pipeline:

Pipeline	0.72
Road, Rail, Water Crossings	0.60
Bored and Cased Crossings	0.60
Induction Bends	0.60
Ells and Welded Fittings	0.60
Facilities and Fabricated Assemblies	0.60

Crossings

1. The most cost effective crossing method was estimated for water bodies, wetlands, roads, railroads, or other crossing unless dictated otherwise in a permit or by an agency, or agreed upon with a landowner.

2. Cased crossings shall be avoided, but may be required by railroads.

3. For bored and HDD crossings, the pipe will be coated with the standard FBE coating, plus an additional abrasion resistant overcoat (ARO) coating for protection during pipe pullback.

Valves

1. Mainline valves will be installed below grade and be ANSI 1500, welded end (note that valves at the check metering station will be ANSI 900). Water crossing isolation valves will be located at mileposts 0.66, 1,36, 5.05, 5.57, 7.14, and 8.40, within 25' x 35' fenced sites. Two of the mainline valve sites will include the 16" ball valve with electric actuation for remote activation, pressure transmitters for leak detection, 6" blowdown ball and plug valves, and a 6" cross-over line with plug valve. The four other mainline valve sites will not be automated or include blowdown facilities. A 16' wide swing gate will allow maintenance access to each valve site.

2. Valves over 2" will be through conduit, trunnion-mounted ball valves with double block and bleed capability.

3. Selected valves at the Leucadia Plant site and the Green Line tie-in will have electric motor actuators that will accommodate remote and local actuation. Other valves will have hand wheels or lever actuators. Hand wheels with bevel gears were estimated for valve sizes 6" and greater.

Coatings

1. Buried pipe will be coated with plant applied, 14 to 16 mils of fusion bonded epoxy (FBE).

2. Field applied FBE (SP2888 or RD-6) will be used for girth weld coating on the pipeline.

3. For bored and HDD crossings, the pipe will be coated with the standard FBE coating, plus an additional abrasion resistant overcoat (ARO) for protection during pulling.

4. Above ground piping will be painted with an approved three-part epoxy and polyurethane overcoat coating system.

5. Where pipe enters or exits the ground, the below ground coating shall extend at least 12" above grade.

Cathodic Protection

1. The pipeline will be protected from corrosion with an impressed current cathodic protection system.

2. The final cathodic protection system design will be completed following installation of the line and will be based on field tests to determine the integrity of the external coating and effects of ground conditions on the pipeline.

3. Flange insulation kits will be installed at above ground locations: the originating launcher trap between the trap and the pipeline, valve site blowdowns, at the meter station between the receiving trap and the pipeline, and at the end of each meter run between the meters and the Green Line.

4. AC power mitigation will be included where the pipeline parallels high voltage power transmission lines, to protect the pipeline from the damaging effects of induced currents on pipe coating.

Tie-in Point to Green Pipeline

The point for the tie-in to the Green Pipeline is located immediately downstream of pumps in the existing Denbury pump station in Buhler, Louisiana.

2.3 FACILITIES DESIGN REQUIREMENTS

General Site Criteria

1. Each site will be fenced with a security chain-link fence including one manual 16' vehicle gate. The Leucadia site will be located inside the plant fence, so a separate fence will not be provided.

2. Each site will be graveled.

3. Estimated site sizes are 50'x 50' for the Leucadia launcher, 25'x 35' to 50'x50' for the valve sites, and existing site will be utilized for the delivery meter site and receiver.

4. Site lighting will be provided at the Leucadia and delivery meter sites. A single steel light pole will be installed at plant location with either a single or dual light fixture.

5. All above ground piping will be field fabricated.

6. All facility sites will be electrically unclassified areas, as CO_2 is not flammable.

Leucadia Plant Station

The tie-in to the Leucadia Energy Plant will include a motorized isolation valve and a smart tool launcher barrel and associated valves and piping. These will be within a graded and graveled site assumed to be approximately 50’ x 50’.

<u>Check Meter Station Site and Green Line Tie-In</u>

1. One measurement facility will be constructed, consisting of a dual orifice meter run located at the delivery tie-in to the Green Pipeline. In addition to the metering equipment, the site will include a scraper receiver, isolation valves (upstream electric motor operator, downstream manual operator), Green Line tie-in valve, and overpressure protection.

2. The measurement installation will consist of two meter runs with a Daniel Senior Orifice Fitting, Daniel meter tubes, flow conditioner, and pressure and temperature transmitters. A pipeline logic controller (PLC), flow computer, and communication equipment for data and control communication to Denbury’s control center, will be installed in the existing SCADA building.

3. The orifice meters and tubes will be purchased as a complete assembly from the vendor. The assembled meter run will be field fabricated and assembled and pressure tested prior to operation.

4. The dual meter runs will be sized to handle the design flow rate range and have adequate turndown for low flow conditions.

5. The measurement facility will be designed for automated and unmanned operation. Data communication equipment will allow the control center to obtain flow, pressure and temperature data, operate motor actuated valves, and monitor status of valves and other selected equipment.

6. A sampling pump will be installed upstream of the flow meters and send a small stream to the gas chromatograph, which will be installed to analyze the CO_2 quality and provide a mass balance for accurate measurement. A water analyzer will also be installed to ensure water content is maintained within pipeline specifications.

<u>Electrical Installations</u>

1. All conduits from the meter run to the electronic flow measurement (EFM) building will be run under ground. All power distribution conduits to or from the EFM building will be run under ground. All conduits to site lighting will be run under ground.

2. All underground conduit will be PVC coated rigid galvanized steel (RGS) conduit. All above ground conduit will be RGS conduit.

3. The transition between conduit types shall be at least one foot above finished grade.

4. There will be an underground, insulated copper conductor ground grid attached to galvanized steel ground rods installed on the metering site.

5. The EFM building frame will be tied to the ground grid at two points. Security fencing shall be tied to the ground grid at two points.

6. Suitable ground test wells will be provided as part of the ground system for testing.

Site Utilities

1. New electrical utility 480 V power will be contracted with the local utility provider for each of the automated mainline valve sites.

2. No domestic water, restroom, septic, or other provision for human comfort will be provided at the sites.

3. No telephone service is estimated unless required for SCADA communication.

3.0 RIGHT OF WAY CRITERIA

3.1 RIGHT OF WAY REQUIREMENTS

The property rights required for this project will predominantly be servitudes (easements) and non-environmental permits for roads, railroads, canals and stream crossings. This permanent right of way will typically be 30 feet in width except in some heavy industrial areas where the rights granted may be limited to the width of the pipe. Temporary work space (TWS) for construction abutting the permanent servitude will typically be forty-five (45) feet in width except at roads, railroads, canals, and streams where additional temporary work space will be necessary to accommodate conventional or HDD boring operations.

4.0 ENVIRONMENTAL CRITERIA

4.1 REGULATORY ISSUES AND SCHEDULE IMPACTS

Regulatory issues were considered related to Threatened and Endangered Species, and Wetlands.

4.2 THREATENED AND ENDANGERED (T&E) SPECIES

Environmental surveys were performed along the pipeline route during the Spring of 2011, and potential T&E species issues were identified pertaining to Wading Bird nesting areas, as well as a potential Long Leaf Pine habitat. Follow-up T&E surveys will be completed prior to start of construction, as required by the U.S. Army Corps of Engineers permit received for the project.

4.3 WETLANDS

Wetland Mitigation costs were provided by CH2M Hill in May 2011 and updated in 2013. The updated 2013 cost has been incorporated into the estimate.

5.0 COST ESTIMATE ASSUMPTIONS AND UNKNOWNS

5.1 LIST OF COST ASSUMPTIONS AND UNKNOWNS

Cost Assumptions

1. The cost estimate for the Lake Charles CO2 Pipeline is based on a plan to have the pipeline constructed by the 3rd quarter of 2015. The major yearly activities are:

   2011 - Preliminary Engineering, Environmental, Right-of-Way Permissions and Title Work

2012 - NEPA, FONSI, and COE Permitting, DOE Funding Approval, Initial Right-of-Way Negotiations

2013 - Continue Right-of-Way Acquisition and Permitting, Final Engineering, Purchase of Pipe and Long Lead Items

2014 - Continue Right-of-Way Acquisition and Permitting, Purchase of Pipe and Long Lead Items, Cathodic Protection System Design

2015 - Purchase Remaining Items, Construction and Start-up

2. Right of Way acquisition cost is estimated from the information provided by Denbury ROW based on actual project acquisition data.

3. The construction cost estimate was originally based on average unit costs received from three separate pipeline contractors, and updated in 2013 after an on-site right-of-way review by two of the contractors.

4. Environmental costs were estimated by CH2MHill for all environmental permitting and mitigation activities and are found in the environmental section of the cost estimate.

5. Remaining surveying costs were estimated by Encompass and include pre-construction staking and as-built construction survey.

6. The contingency rate was determined in 2010 from an initial risk analysis that was run using the subtotals in each category. Contingency was reduced in the 2013 revised cost estimate based on further project definition.

7. The Louisiana sales tax rate of 8.25% was assumed for all materials.

8. Steel pipe pricing is based on budget quotes from Stupp Corporation and CPW for mill runs of 16-inch line pipe, obtained in October 2013. Other pipe sizes are in small quantities and pricing is based on budget estimates from pipe distributors.

9. The pipeline route is approximately 11.42 miles long, or 60,300 feet. The total estimated quantity of 16” pipe is 61,600 feet, which includes an extra 2% for unanticipated route deviations, depth of directional drills, welder testing, etc. The line pipe is assumed to be purchased in 2014 and received in 2015.

10. The cost of line pipe is based on 16” diameter, 0.375” wall, X70 pipe. Heavy wall pipe 0.562” thick will be utilized for horizontal directional drills and bores.

11. Pipe and material freight cost is estimated at 4% of item cost, based on prior project experience.

12. Valve estimates are based on budget quotes from Cameron Valves for Cameron and Grove ball valves, and from distributors for small valves and plug, check and globe valves.

13. Crack arrestors are included in this estimate.

14. Road, highway and waterway crossings were estimated based on the crossings list in this estimate.

15. Construction is estimated based on a work week of six 10-hour days, with hours over 40 charged as overtime.

16. The use of pipeline weights may be necessary in wet ground conditions, therefore 100 weights have been included in the estimate.

17. Dual orifice meter runs are included at the site of tie-in to the Green Pipeline. A flow computer will calculate flows using an "equation of state" program specific for CO_2 stream composition. A gas chromatograph is also included in the estimate.

<u>Construction Concerns and Contingencies</u>

1. Construction will take place in the spring and summer 2015. The spring and summer tends to have considerable rain in this area - thus the need for contingent wooden mats, which help maintain contractor access.

2. Construction requirements within the plant at the beginning of the route. There may be minimal workspace as a result ongoing plant construction concurrent with start of the pipeline construction.

3. Part of the pipeline will be located and constructed parallel to an existing high-voltage transmission power line with multiple existing pipelines running parallel. There may be a requirement for timber mats throughout - should any foreign pipeline(s) be within the prescribed workspace - to protect the pipelines from equipment loads.

4. The remainder of the route, with the exception of a few minor instances, is located adjacent to existing pipelines and small KV power lines. This portion will be standard mainline construction with continual workspace located on the outside of the existing adjacent pipeline(s).

5. Until right of way acquisition is complete, pipeline reroutes cannot be ruled out.

<u>Cost Unknowns</u>

1. Crossing methods in this report are assumed based on related pipeline construction experience.

2. It is unknown whether any condemnation for right-of-way will be required.

3. It is believed that all facility sites are near drivable access roads, but the year round condition of the access is uncertain, and therefore the need for improvements during construction is uncertain.

4. It is uncertain whether electric power for the scraper launcher facility will be provided by the Leucadia plant.

Lake Charles CCS Project
FINAL TECHNICAL REPORT
Phase 2

Reporting Period
November 16, 2009 – June 30, 2015

SEQUESTRATION
CO_2 Monitoring, Verification and Accounting (MVA)
Prepared by
Denbury Onshore, LLC

Report Issue Date: June 30, 2015
DOE Award Number: DE-FE0002314

Submitting Organizations

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ABSTRACT

In late September 2014 development of the Lake Charles Clean Energy (LCCE) Plant was abandoned resulting in termination of Lake Charles Carbon Capture and Sequestration (CCS) Project which was a subset to the LCCE Plant. As a result, the project only funded Phase 2A (Design) and did not enter Phase 2B (Construction) or Phase 2C (Operations).

The Monitoring, Verification and Accounting (MVA) program is a shared program under two independent Cooperative Agreements DOE entered into, one with Leucadia Energy LLC (DE-FE-0002314) and the other with Air Products and Chemicals, Inc. (DE-FE-0002381). This report will reference the approved Phase 2A MVA tasks partially funded and completed under Leucadia Energy LLC's Cooperative Agreement with the DOE. Phases 2B and 2C were approved by the DOE to move forward under Air Products in September 2011 (2B) and June 2013 (2C).

The overall objective of the MVA portion of the project, was to demonstrate effective geologic sequestration of captured CO_2 through commercial Enhanced Oil Recovery (EOR) operations in order to evaluate costs, operational processes and technical performance. The DOE target for the project was to capture and implement a research MVA program to demonstrate the sequestration through EOR of approximately one million tons of CO_2 per year as an integral component of commercial operations.

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Denbury Onshore, LLC
CO_2 Monitoring, Verification and Accounting (MVA)

Executive Summary

As a subawardee to Leucadia Energy LLC (Leucadia), Denbury Onshore LLC (Denbury) and its affiliate's responsibility was to provide the transportation infrastructure and EOR site for the sequestration of the captured CO_2 and the research MVA project. Denbury's plan was to build the pipeline lateral from the LCC site to the existing CO_2 pipeline known as the Green Pipeline to transport CO_2 to the Hastings Field in South Texas. The MVA program was designed for specific fault blocks in the Hastings Field, part of an ongoing commercial CO_2 EOR operations. Denbury developed a sub-contract with the University of Texas – Bureau of Economic Geology (UT-BEG) to design and implement the research MVA program.

The overall objective of the MVA portion of the project was to demonstrate effective geologic sequestration of captured CO_2 through commercial EOR operations in order to evaluate costs, operational processes and technical performance. The DOE target for the project was to capture and implement a research MVA program to demonstrate the sequestration of approximately one million tons of CO_2 per year as an integral component of commercial operations.

The baseline testing, project testing and performance monitoring plans for the research MVA project was designed to supplement ongoing monitoring activities conducted in conjunction with Denbury's existing EOR operations (1) to test the extent to which current commercial practices can meet possible future MVA expectations; and (2) to test MVA approaches to see if they increase confidence and otherwise add value to an EOR + sequestration project. The research MVA plan would have provided for baseline testing and characterization, assessing environmental, health and safety impacts of sequestration, and documenting the achievements of the research MVA project to demonstrate the permanent, verifiable sequestration of CO_2. The documentation was to take the form of interim reports after each of the subphases in Phase 2.

During the Design Phase, Phase 2A, tasks were proposed to integrate the commercial site characterization data to prepare an initial reservoir model. Initial work in Phase 2A progressed the static geologic model using available data. The quick-look flow model was operational prior to the start of Phase 2B. This was followed by predictive fluid flow and pressure modeling, and improved description of stress conditions on faults, leading to an improved assessment of risk of migration. Denbury was already well along on commercial development of the West Hastings Unit Fault Block A for CO_2 EOR. Prior to anthropogenic CO_2 (A-CO_2) availability, injection using natural CO_2 from Jackson Dome was used to develop the flood in Fault Block A. This experience greatly decreased uncertainties in developing Fault Blocks B and C. During Phase 2A, the research MVA team had started tests to determine sensitivity and feasibility of proposed soil gas, groundwater, and well-bore integrity methods.

The Hastings Field MVA Phase 2B under Air Products and Chemicals, Inc. (Air Products) was approved by the DOE (DE-FE-0002381) to move forward in September 2011 with Phase 2C being approved in June 2013.

During Phase 2B, or Construction Phase, the preparation for injection of A-CO_2 into Fault Blocks B and C was completed as part of Denbury's commercial field development operations. Site preparation, well workovers and selected wells in the above zone monitoring interval were used as access points to monitor ahead of the active injection. Baseline data on soil gas, groundwater, and subsurface pressure, fluid composition and rock properties was collected and input into a predictive model, allowing a revised

risk assessment. Baseline geophysics and baseline well logging was completed prior to initiation of the flood. At the end of the subphase, UT-BEG, in consultation with Denbury, prepared a report containing a revised MVA conceptualization, baseline data and a revised build out plan.

During the Operations Phase, Phase 2C, the commercial monitoring program tracks the CO_2 injected, the CO_2 recycled, and the performance of the reservoir and wells in retaining CO_2. The research program collects 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, UT-BEG, in consultation with Denbury, will prepare a final report evaluating the results of the research MVA program and revised model runs showing model match, comparing the effectiveness of the commercial program to the research program in documenting effectiveness and permanence of storage.

1. Phase 2 MVA Budget

At the completion of Phase 2A MVA tasks in September, 2011, the SOPO tasks identified and the budget proposed at the start of Phase 2 remain unchanged.

Under the original schedule and budget for Phases 2B and 2C, it was agreed upon by Air Products, the DOE and Denbury that charges would be submitted to Air Products for the Leucadia Project's share of the MVA activities with an 80%/20% cost share re-imbursement applied to both companies. Upon receiving the invoices, Air Products in turn sends the invoices to DOE for the 80% reimbursement. As of 03/15, Air Products has invoiced the DOE approx. $3.9MM for Phase 2B and approx. $7.9MM for Phase 2C.

Phase 2	LCC Task SOPO Task	Task #	Task Title	100% Estimated Cost Total, $
Subphase 2A	4.4.1	MVA.1	Adminstrative tasks & Contracting	-
Subphase 2A	4.4.2	MVA.2	Resrvoir Modeling-Initial Characterization and Modeling	260,329
Subphase 2A	4.4.3	MVA.3	Characterization and Geomechanical Description of Fault(s)	25,695
Subphase 2A	4.4.4	MVA.4	Soil Gas-Feasibility Test of Surveillance of P&A wells	52,934
Subphase 2A	4.4.5	MVA.5	Groundwater Monitoring-Feasibility Test of Surveillance of P&A wells	23,555
Subphase 2A	4.4.8	MVA.8	Decision Point, Risk Assessment & Updated MVA plan and cost distribution	71,259
Subphase 2A	4.4.9	MVA.20.1	Gravity Baseline Project Criteria	50,000
Subphase 2A Total				**483,771**
Subphase 2B	4.4.6	MVA.6	AZMI-Establish Current Pressure Profile via Repeat Formation	3,000,000
Subphase 2B	4.4.7	MVA.7	Logging-Feasibility Test of Surveillance of idle wells and fault	300,000
Subphase 2B	5.4.1	MVA.9	Commercial Flood Monitoring-Well Review and Remediation	-
Subphase 2B	5.4.2	MVA.10	Logging-Baseline Surveillance of idle wells and fault	840,000
Subphase 2B	5.4.3	MVA.11	Soil Gas-Site & Borehole preparation for surveillance of P&A wells	43,187
Subphase 2B	5.4.4	MVA.12	Soil Gas-Baseline surveillance of P&A wells	28,150
Subphase 2B	5.4.5	MVA.13	Ground Water Monitoring-Well preparation	500,000
Subphase 2B	5.4.6	MVA.14	Ground Water Monitoring-Baseline surveillance	105,277
Subphase 2B	5.4.7	MVA.15	Reservoir Modeling-Updated	87,001
Subphase 2B	5.4.8	MVA.16	AZMI-Well Completions	450,000
Subphase 2B	5.4.9	MVA.17	AZMI-Instrument Monitoring Wells	48,000
Subphase 2B	5.4.10	MVA.18	AZMI-Baseline geochemical sampling and hydrologic testing	40,000
Subphase 2B	5.4.11	MVA.19	VSP-Baseline	564,080
Subphase 2B	5.4.12	MVA.20	Gravity-Baseline	462,863
Subphase 2B	5.4.13	MVA.21	Measure Out-Of-Pattern Migration (Completion of downdip wells)	700,000
Subphase 2B	5.4.14	MVA.22	Decision Point, Risk Assessment & Updated MVA plan and cost distribution	9,589
Subphase 2B Total				**7,178,148**
Subphase 2C	6.4.1	MVA.23	Commercial Flood Monitoring-Injection and Production	-
Subphase 2C	6.4.2	MVA.24	Commercial Flood Monitoring-Best Practice Mitigation	-
Subphase 2C	6.4.3	MVA.25	Commercial Flood Monitoring-Pressure Maintenance	-
Subphase 2C	6.4.4	MVA.26	Commercial Flood Monitoring-IWR Calculation	-
Subphase 2C	6.4.5	MVA.27	Logging-Time lapse surveillance of idle wells and fault	300,000
Subphase 2C	6.4.6	MVA.28	Soil Gas-Time lapse surveillance of P&A wells	70,049
Subphase 2C	6.4.7	MVA.29	Groundwater Monitoring-Time lapse surveillance	97,614
Subphase 2C	6.4.8	MVA.30	VSP-Time lapse surveys	2,256,320
Subphase 2C	6.4.9	MVA.31	Gravity Time lapse surveys	2,051,450
Subphase 2C	6.4.10	MVA.32	Real Time BHP-Well Preparation	1,000,000
Subphase 2C	6.4.11	MVA.33	Real Time BHP-Sandia	20,000
Subphase 2C	6.4.12	MVA.34	Logging-Time lapse Surveillance	972,000
Subphase 2C	6.4.13	MVA.35	Natural geochemical tracers-Collected at wellhead	69,491
Subphase 2C	6.4.14	MVA.36	AZMI-Time lapse geochemical sampling & Hydrologic testing	60,000
Subphase 2C	6.4.15	MVA.37	Measure Out-Of-Pattern Migration	-
Subphase 2C	6.4.16	MVA.38	Reservoir Modeling-Updated	12,895
Subphase 2C	6.4.17	MVA.39	Overview and Evaluation Report	8,616
Subphase 2C Total				**6,918,435**
Grand Total				**14,580,354**

2. Phase 2A Timing Modifications

The following is a summary of the activity performed in Phase 2A of the Hastings MVA related to the Leucadia project. Although the SOPO tasks identified and the budget proposed at the start of Phase 2 were expected to remain unchanged for Phases 2B and 2C, some changes occurred with respect to timing of three SOPO tasks relative to the original Phase 2 submission, namely:

- SOPO 4.4.6 AZMI Establish Current Pressure profile via RFT on New Drill Wells: this task was moved from Phase 2A to Phase 2B. This was done to accommodate field activity. The budget remains unchanged for the task.

- SOPO 4.4.7 Logging - Feasibility Test of Surveillance of Idle Wells: this task was moved from Phase 2A to Phase 2B. This was done to accommodate field activity. The budget remains unchanged for the task.

- SOPO 5.4.12 Gravity Baseline: a portion of this task was moved into Phase 2A from Phase 2B. UT-Dallas (UTD) was subcontracted to initiate this work and preliminary baseline modeling was necessary to ensure future time constraints in Phase 2 are achieved.

Phase 2A was intended to design the MVA program and collect necessary data to inform the future MVA activity anticipated in Phases 2B and 2C.

3. Phase 2A Task Summary

The following is a summary of the activity performed in each task in Phase 2A and a description of how it related to future SOPO tasks.

SOPO 4.4.1 Administrative Tasks and Subcontracting – This was primarily work among the Leucadia/Denbury team and Denbury/UT-BEG team to develop, negotiate and approve the respective sub-contracts that define the scope of work and expectation for each party within the framework of the DOE Cooperative Agreement. The contracting effort was completed. This task was also related to the administrative progress reporting and ongoing communication between parties. Lines of communication and regularly scheduled meetings were established.

SOPO 4.4.2 Reservoir Modeling – Initial Characterization and Modeling – This task was intended to initially build a quick-look model that would be further refined into a more detailed static geologic model and associated flow model to understand and predict the CO_2 flow within the study area. UT-BEG built the models. The quick-look flow model was created with readily available data from both Denbury and the public domain to start running different scenarios with a wide range of uncertainties in order to identify influential parameters. This model was used to initially "test" the integrity of the bounding faults and predict what could happen if these faults did not seal. As additional data was collected throughout the project, the geologic and flow models were updated as necessary to reflect current understanding of the subsurface. The modeling effort aids in the MVA design, but also continued into Phases 2B and 2C to help describe the plume migration with time.

SOPO 4.4.3 Characterization and Geomechanical Description of Faults – This activity, while related to the reservoir geologic model was more focused on the behavior of subsurface faults as they relate to the CO_2 "container" and how they may behave in a sequestration scenario. The initial work on this was from the geologic modeling and additional data that was utilized to characterize and model the faults specifically. Denbury provided UT-BEG with data that helped progress this effort. The detailed work started in June 2011 and results were used to help design the fault monitoring plan.

SOPO 4.4.4 Soil Gas Feasibility Test of Surveillance of P&A Wells – UT-BEG and Denbury received Interim Action Approval from DOE to initiate this field work ahead of the EIS ROD. UT-BEG held meetings with Denbury field personnel and made an additional field trip to start the soil gas testing reconnaissance. Initial work was focused on establishing a base line of soil gas, including a determination of the variability and soil gas composition in the study area. Discussions with Denbury field and technical teams occurred to help determine the best locations within the field to start the work. The results of this work would have been used to inform the longer term soil gas monitoring plan.

SOPO 4.4.5 Groundwater Monitoring Feasibility Test of Surveillance of P&A Wells - UT-BEG and Denbury received Interim Action Approval from DOE to initiate this field work ahead of the EIS ROD. UT-BEG held initial meetings with Denbury field personnel and made an additional field trip to start the groundwater monitoring reconnaissance. UT-BEG utilized public domain data to determine groundwater gradients and any regional sinks. UT-BEG and Denbury collaborated to determine where existing water source wells were in the field area and the condition and usability of each. A field trip was made to gather initial samples. The results of this work would have been used to inform the longer term groundwater monitoring plan.

SOPO 4.4.8 Risk Assessment and Update MVA Plan and Cost Distribution – This work was ongoing. Phase 2B and 2C plans remained unchanged at this point of Phase 2A. The data and analysis completed through the end of Phase 2A had not resulted in the need for any significant change to the plan. Because of the rich data set available to the team prior to Phase 2, it was not anticipated that Phase 2A results would have a significant impact on Phase 2B and 2C plans. In addition, the budget appeared to remain adequate to complete the work as outlined in the original proposal.

SOPO 4.4.9 Gravity Baseline Project Criteria – This work was performed by UTD and was intended to provide an image of the plume movement with time. UTD received the necessary data to progress work on a basic geologic framework to define the geometry of the study area. This proprietary geologic model was used to simulate the gravity anomaly related to the CO_2 plume and help determine future measurement points.

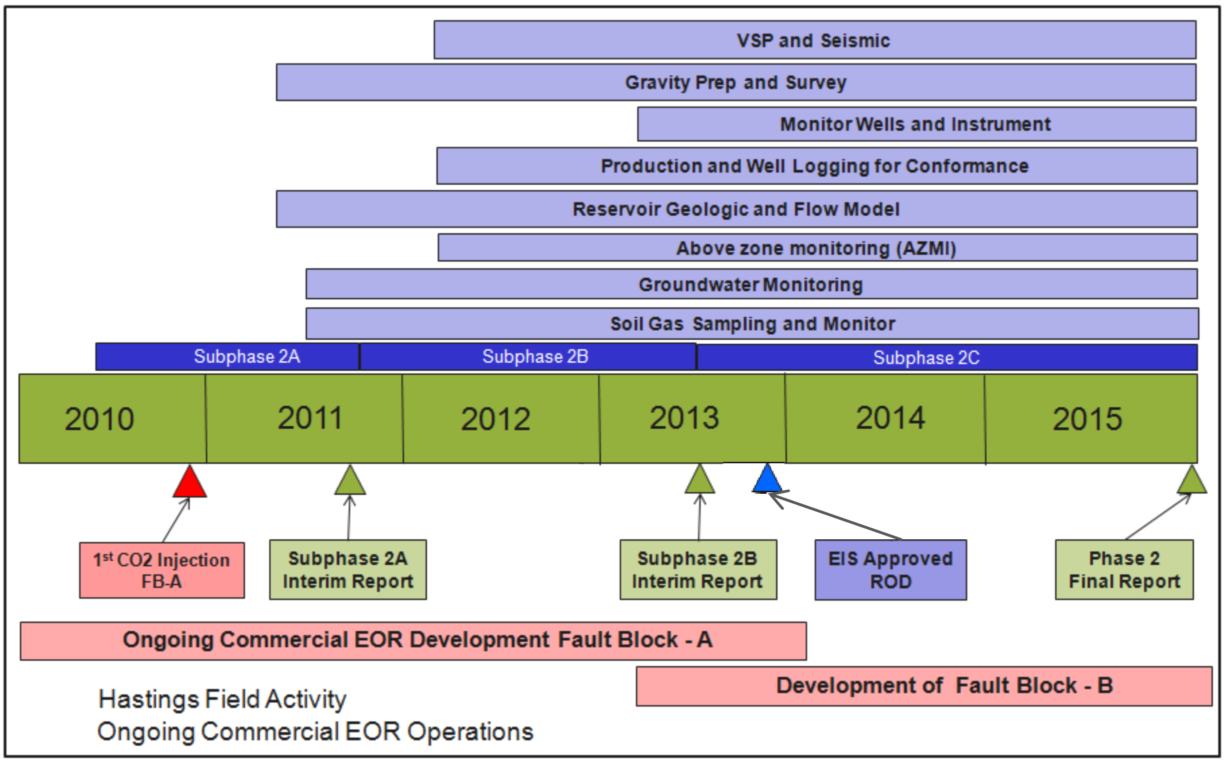
4. Phase 2A Final Report

The MVA plan was informed by a risk assessment based on the findings through September 2011 on the technical Phase 2A tasks:

- SOPO 4.4.2 Reservoir Modeling - Initial Characterization and Modeling
- SOPO 4.4.3 Characterization and Geomechanical Description of Faults
- SOPO 4.4.4 Soil Gas - Feasibility Test of Surveillance of P&A wells
- SOPO 4.4.5 Ground Water Monitoring - Feasibility Test of Surveillance of P&A wells
- SOPO 4.4.8 Risk Assessment and Updated MVA Plan and Cost Distribution

The MVA plan was composed of a list of monitoring technologies and strategies applied in identifying monitoring elements at carefully selected locations. The monitoring elements included a Formation above the injection zone, ground water, soil gas, and the injection zone.

Phase 2 Project Schedule and Milestones



Attachment A

Original Objectives and Work Completed

Phase 2 Sub Phase:	Statement of Project Objective (SOPO)	Task #	Description	Task (SOPO) Budget--US$	Original Objectives	Work Completed	Change From Original Objective
2A	4.4.1	MVA.1	Administrative Tasks and Subcontracting	$ -	This is primarily work among the Leucadia/ Denbury team and Denbury/UTBEG team to develop, negotiate and approve the respective sub-contracts that define the scope of work and expectation for each party within the framework of the DOE Cooperative Agreement.	Subcontract between Leucadia/Denbury signed 04-27-11; Subcontract between UT BEG/Denbury signed 06-14-11. **100% Complete**	No Change
2A	4.4.2	MVA.2	Reservoir Modeling-Initial Characterization and Modeling	$ 260,329	UT BEG will initially build a quick-look model that will be further refined into a more detailed static geologic model and associated flow model to understand and predict the CO_2 flow within the study area and pressure elevation.	Additional modern log and well data was transmitted to UT BEG from Denbury for use in model development. Phase 2A progressed the static geologic model using available data. The quick-look flow model was operational prior to the start of Phase 2B. **100% Complete**	No Change
2A	4.4.3	MVA.3	Characterization and Geomechanical Description of Faults	$ 25,695	UT BEG will undertake compilation of additional characterization data and further model the effect of a range of possible stress changes to faults, with focus on the mail sealing fault at the east edge of the field.	Ggeologic modeling and additional data was utilized to characterize and model the faults specifically. Denbury provided UTBEG with data that helped progress this effort. **100% Complete**	No Change
2A	4.4.4	MVA.4	Soil Gas - Feasibility Test of Surveillance of P&A Wells	$ 52,934	UT BEG will undertake an initial assessment of soil gas conditions near representative P&A wells to consider complexities that should be considered for soil gas assessment to reduce uncertainties about well integrity in P&A wells.	UT BEG and Denbury received Interim Action Approval from DOE to initiate field work ahead of the EIS ROD. UT BEG took samples in the field on May 31, 2011. The purpose of the trip was to collect preliminary soil gas measurements to obtain baseline data. **100% Complete**	No Change
2A	4.4.5	MVA.5	Ground Water Monitoring - Feasibility Test of Surveillance of P&A Wells	$ 23,555	UT BEG will sample existing available domestic and other water wells and review historic water well records of aquifer properties to obtain information about the range of ground water chemistries and how to best test for rock-CO2-water interaction in the aquifer should unintended CO2 migration occur.	UT BEG and Denbury received Interim Action Approval from DOE to initiate field work ahead of the EIS ROD. UT BEG discussed available wells to sample on the May 31, 2011 field trip and started the groundwater monitoring reconnaissance. UT BEG has utilized public domain data to determine groundwater gradients and any regional sinks to establish a baseline. **100% Complete**	No Change

Phase 2 Sub Phase:	Statement of Project Objective (SOPO)	Task #	Description	Task (SOPO) Budget--US$	Original Objectives	Work Completed	Change From Original Objective
2A	4.4.9.20.1 See task 5.4.12.20	MVA.20.1	Gravity Baseline Project Criteria	$ 50,000	This work is being performed by UT-Dallas (UTD) and is intended to provide an image of the plume movement with time.	UTD received the necessary data to progress work on a basic geologic framework to define the geometry of the study area. The goal for UTD was to have some representative 4D gravity simulations done by mid-June. **100% Complete**	$50,000 was moved from Subphase 2B to Subphase 2A
2A	4.4.8	MVA.8	Risk Assessment and Updated MVA Plan and Cost Distribution	$ 71,259	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.	This work was related to the Decision Point Application and subsequent subphase 2A Interim Report. The data and analysis completed has not resulted in the need for any significant change to the plan. Subphase 2A results were used as an established baseline for 2B and 2C plans. The subphase 2B and 2C plans remained unchanged. In addition, the budget remained unchanged as outlined in the original proposal. **100% Complete**	No Change