FINAL SCIENTIFIC/TECHNICAL REPORT

Department of Energy – National Energy Technology Laboratory

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

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1 General

This is the final report prepared to document project status as well as support project close-out. The scheduled milestone for the project to deliver the Final Project Report was Planned February 2024. Progression of FEED Study efforts ceased as of June 21, 2023, at Shell Chemical's direction following a fire incident at the host site unit OP3 that occurred on May 5, 2023. After evaluating the available site resources to handle cleanup, recovery and rebuild of OP3 and those needed to support the ongoing FEED Study, Shell made the decision to withdraw their participation (and funding) for the project. This decision was made to allow the facility to focus available resources on rebuilding after the incident and return to regular operations as soon as possible. Shell will consider a path forward on decarbonization efforts at the facility at a later date.

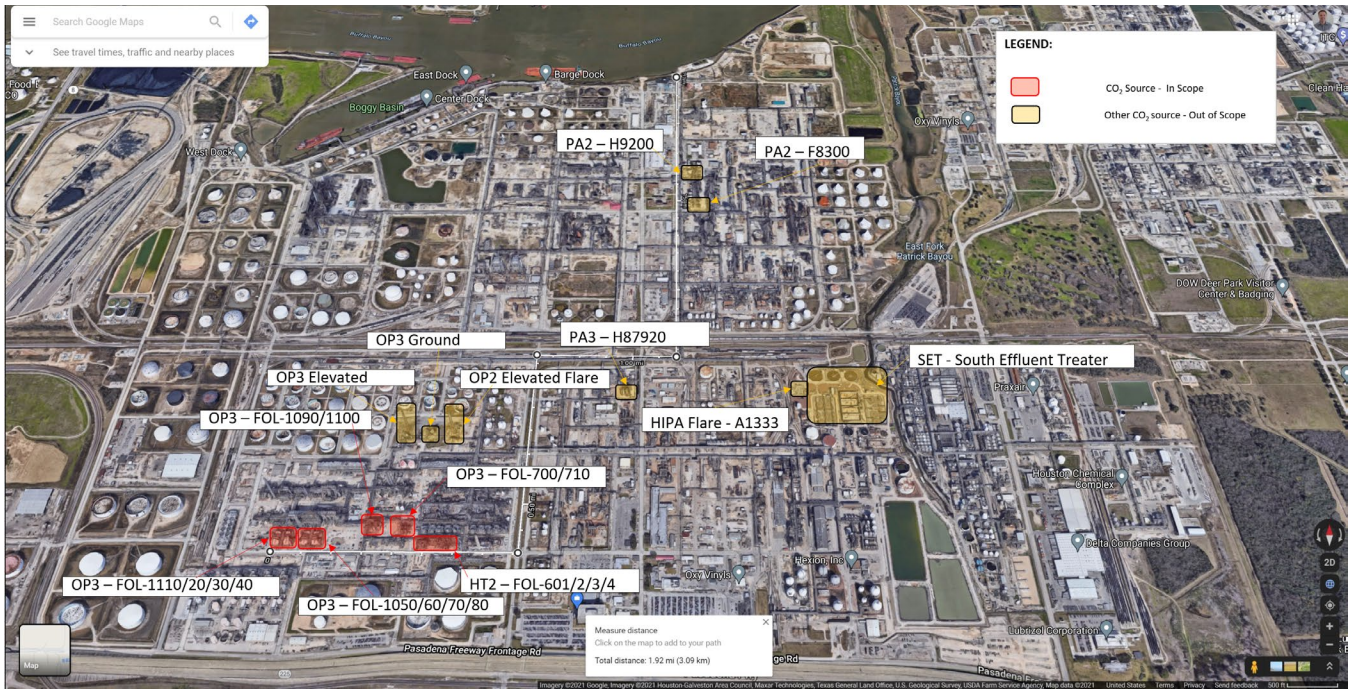
1.1 Project Summary

The host site Shell Deer Park is located on the Houston Ship Channel near some of the nation's largest refineries and petrochemical complexes. The Houston Ship Channel provides ample opportunities for a sizable pipeline segment that could ultimately collect CO2 and connect into the Denbury Green Pipeline. As the first multi-source post-combustion carbon capture FEED project at a petrochemical site, the project offered opportunities for future expansion and development of a Houston CCUS hub.

The project objective was to execute and complete Front-End Engineering and Design (FEED) to separate and capture over 820,000 tonnes per year (tpy) CO2 emissions from the commercially operated Shell Chemicals Complex located in Deer Park, Texas, USA reducing the overall facility CO2 emissions by 95% while providing energy transition jobs in a commercial area with a high concentration of refinery and chemical facilities producing CO2 emissions. Refer to the plot plan view of the refinery depicting the emission sources at the site that include the following:

- Total of Sixteen Furnaces (In Scope)
    - Eight OP3 Furnaces
    - Eight OP3/HT2 Furnaces
- Other Minor Sources (Out of Scope)

Figure 1: Shell Deer Park Chemical Complex – CO2 Emission Sources



1.2 Project Scope

The Project Scope included development of a Project Design Basis that provides site characteristics, ambient conditions, fuel feedstock and flue gas characteristics, and host site environmental requirements. The design basis identifies permits and environmental reviews necessary to initiate construction. All internal or corporate approvals required by the host site to initiate construction were identified. Wood was subcontracted to deliver the Project Design Basis with inputs from Shell and other engineering Subcontractors – Technip Energies (Technip) and Shell Global Solutions (SGS).

The Project scope also included overall PM support, including but not limited to the development and maintenance of integrated project schedule, common execution plans and procedures (example: Safety Execution Plan, Document numbering system), and integration support for final delivery of the FEED package. A Project Cost Estimate was to be developed for a Class 3 (-20% to +30%) TIC estimate, with inputs from other stakeholders. FEED Study Report was to be developed for the FEED package including

the Project Design Basis, FEED Engineering/Design package, and Cost Estimate, with inputs from other stakeholders.

WSP served as the primary recipient for the project - responsible for overall project management, contracting, financials, and submittals to DOE. WSP would have also delivered the Environmental, Health and Safety Risk Assessment if the project had not been terminated prior to completion.

The FEED OSBL (Outside Battery Limits) scope was the responsibility of Wood Group USA which included delivery of the Front-End Engineering and Design scope for the Balance-of-plant (Outside Battery Limits or OSBL). Balance-of-plant includes, but is not limited to, utilities such as compression, cooling water, water softener treatment, waste treatment, and the sources of energy, electricity, and/or steam, necessary to power the carbon capture system. FEED included process, civil, architectural, structural, mechanical, piping, electrical, and control systems engineering and design for the carbon capture system and OSBL to support development of the Cost Estimate.

The FEED ISBL (Inside Battery Limits) scope was the responsibility of Technip and SGS which included the ISBL Project Management Engineering and Design, scheduling, progress reporting, FEED Engineering and Design package and estimate, in collaboration with SGS, and inputs to stakeholders.

All permits, environmental reviews, and approved suppliers list were the responsibility of the Shell Chemicals LP – Deer Park. SGS is the CANSOLV Technology provider, and responsible for the inputs to ISBL engineering.

1.3 Study Participants

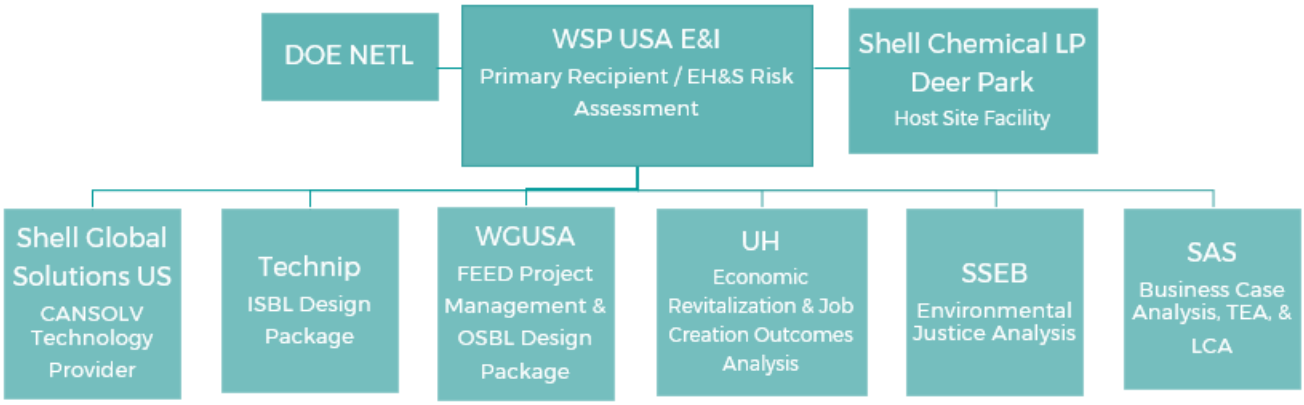
The various participants of the project are listed in the table below:

Table 1: Roles - Project Participants

Name / Entity	Role
DOE NETL	Project funding
WSP (former Wood E&IS)	Primary Recipient/Principal Investigator Overall Project Management including Subcontractors Contract holder with DOE NETL and Shell Chemical Financials Environmental Health & Safety Risk Assessment
Shell Chemical LP- Deer Park	Owner
Shell Global Solutions (SGS)	CANSOLV technology provider
Technip Energies	ISBL FEED Contractor
Wood Group USA	OSBL FEED Contractor
University of Houston's Center for Carbon Mgmt in Energy (UH)	Economic revitalization and job creation outcome analysis
Southern States Energy Board (SSEB)	Environmental Justice Analysis
SAS	Business case analysis

Figure 2: Organization Chart - Project Participants

The high-level Organization Chart showing the project participants is given below:



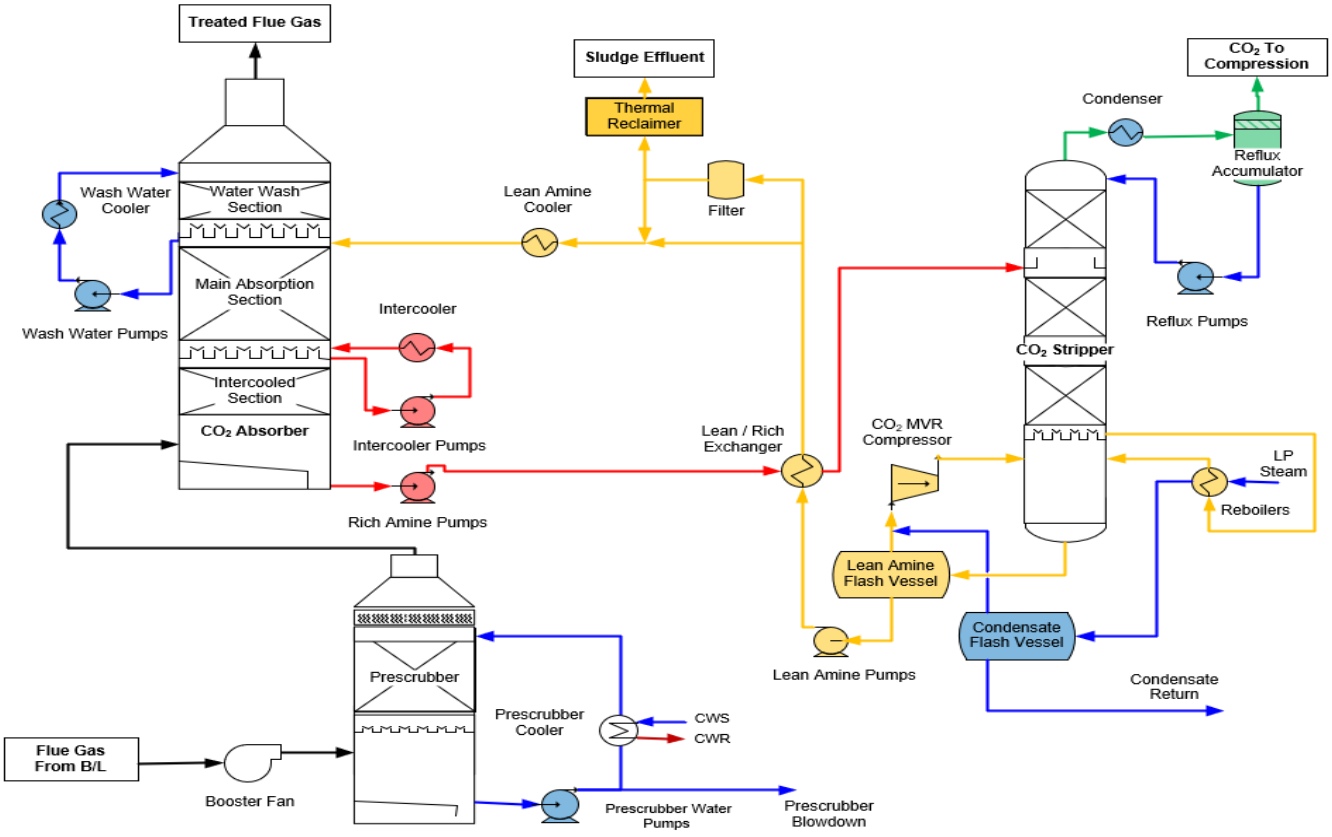
1.4 Technology Overview

The project utilized CANSOLV technology to capture CO2 emitted from Olefin Units and a Hydrotreater Unit to reduce the overall facility CO2 emissions by 95%. Refer to Figure 3 process flow diagram below.

The CANSOLV CO2 capture process generally consists of flue gas quenching/pre-scrubbing, CO2 absorption and solvent regeneration facilities. Hot flue gas at slightly above atmospheric pressure is routed via blowers to the Prescrubber, which cools the flue gases to the required temperature for the capture process via direct contact with recirculating water over a bed of structured packing. Since water is condensed from the flue gas in the Prescrubber packing, a continuous blowdown from the Prescrubber water circulation loop is provided downstream of the Prescrubber Water Cooler and is routed to wastewater treatment. Cooled flue gas is fed to the base of the CO2 Absorber, where CO2 is captured from the flue gas by counter-current contact with cooled lean solvent in a multi-level packed-bed. The treated flue gas leaving the top of the CO2 absorption section will pass through a water wash section before being released to the atmosphere. The rich solvent collected in the sump of the CO2 Absorber is pumped through lean/rich exchanger(s) for heat recovery prior to feeding the rich solvent to the CO2 Stripper. The CO2 bound in the rich solvent is liberated within the CO2 Stripper by the

addition of heat, provided by LP steam in the Reboilers, which regenerates the solvent required for the absorption process in the CO2 Absorber. A mechanical vapor recompression (MVR) system is also included to optimize the regeneration energy requirements. The hot lean solvent from the bottom of the CO2 Stripper is cooled against cool rich solvent before partially filtering the solvent and further cooling the solvent feeding the CO2 Absorber. The process also includes a Thermal Reclamation Unit (TRU) for the continuous reclamation of degraded amine generated within the process.

Figure 3: CANSOLV CO2 Capture Process



Highlights of the CANSOLV CO2 Capture Process include:

- Technology Readiness Level (TRL) 8
- Deployed and operated at commercial scale for approximately 10 years
- Proven at large scale (~1 Mtpa)
- High loading efficiency (up to 99% capture efficiency)
- Low energy consumption (< 2.5 GJ/tonne CO2)
- Low degradation rate (as low as 0.15 - 0.2 kg/tonne CO2)
- Low emissions (< 1 ppm amines, 1 ppm ammonia)

1.5 Project Status

Due to the early termination of the project, this is the Final Report. The engineering design package and FEED report were not fully developed. The milestones table below provides high level summary of the project status at the time of discontinuation of the project.

Table 2: Project Milestone Status - Deliverables

Task / Sub-task	Milestone Title and Description	Sub-task / Deliverable and Status
1.0	Project Management and Planning	1.1 Project Management Plan – Complete 03/15/22
2.0	Process Design Basis	2.2 Process Design Basis - Complete 10/21/22
3.0	Engineering Design Package	3.1 Process Flow Diagrams (PFDs) – Complete Issued for Use (IFU) 5/25/23 3.2 P&IDs – ISBL Complete Issued for Package (IFP) OSBL In Progress Issued for HAZOP (IFH) Plot Plan – ISBL Complete, OSBL Working HAZOP – ISBL Complete, OSBL Not Held 3D Model – In Progress
4.0	Project Cost Estimate	4.1 TIC Estimate - Not Started
5.0	FEED Study Report	5.0 FEED Study Report – In progress as part of final project report

6.0	Business Case Analysis, TEA, and LCA	6.0 Business Case Analysis / Techno-Economic Analysis / Life Cycle Analysis – Not started
7.0	Technology EH&S Risk Assessment	7.0 Technology EH&S Risk Assessment – Not Started
8.0	Environmental Justice Analysis	8.0 EJA – Not started
9.0	Economic Revitalization and Job Creation Outcomes Analysis	9.0 ERJCOA – Not Started

1.6 Project Summary of Learnings

The FEED study illustrates that it is possible to collect emissions from multiple sources at a site and remove up to 95% of the site CO2 emissions. Following are findings and general drivers for a carbon capture project of this nature:

- When planning a carbon capture project, it is important to focus on the larger emission sources at the site to provide maximum impact from the capital expenditure.
- Improved efficiencies with CO2 Absorbers should be targeted to reduce equipment sizes.
- Input from site Operations and Maintenance personnel is critical when routing and supporting the CO2 collection ductwork. The ductwork should have removable sections or be routed to not interfere with operation and maintenance of the Furnaces as much as practical. The large CO2 collection ductwork can be a significant impact to project cost and routing is a major consideration. The current study was based on utilizing circular ductwork less than or equal to 12 feet in diameter and rectangular ductwork greater than 12 feet diameter. The large rectangular ductwork would be fabricated as flat panels to facilitate shipping and transported to the site for assembly at site.
- The best control method for flue gas ductwork pressure was determined to be variable speed motor drivers for the fans.
- The design requires a large quantity of cooling water with large supply/return lines. New Cooling Towers should be located as close as practicable to the ISBL users. Cooling water lines were routed above grade, rather than underground due to the large number of existing known and potential unknown obstructions.
- Steam requirements are considerable, and a Steam Letdown Turbine Generator should be used to recover energy if steam is not available at the required pressure.

- CO2 Compressor and stack noise abatement should be considered based on local area requirements.
- For similar future projects, consideration should be given to using one CO2 Absorber Unit centrally located based on the existing facility emission source layout. Note: This study utilizes two Flue Gas CO2 Absorber Units due to source dispersed geographic locations.

2 Technical Deliverables

A description of final status of key technical deliverables developed as part of this project is given below, organized by each discipline. A comprehensive list of all deliverables prepared during the project has been included in Section 4.6 for information. All public version deliverables issued during the project are also attached to this report in Appendix A. Due to the early termination of the project, not all deliverables could achieve final completion as originally planned.

2.1 Process

2.1.1 Summary

The Process Design Basis has been developed for the project.

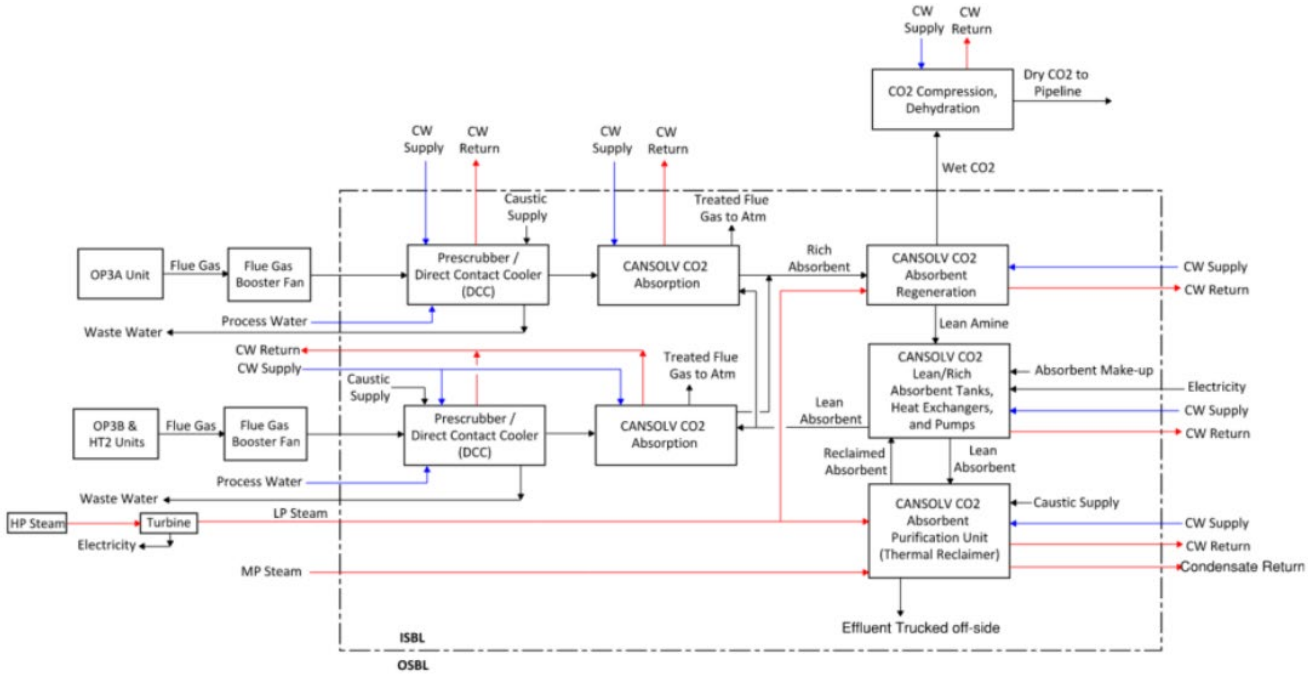
- Process Flow Diagrams and Process & Utility Flow Diagrams for ISBL / OSBL were issued.
- Piping and Instrument Diagrams for ISBL/OSBL P&IDs were developed, and Review Meetings held.
- An ISBL HAZOP review Meeting was held.
- Preliminary ISBL HAZOP recommendations were made available at the conclusion of the meeting.
- OSBL HAZOP Meeting was not held.
- Heat and Material Balances were Issued.
- Development of Utility Usage Summaries for ISBL and OSBL were issued for review.
- Development of Chemical Usage Summaries for ISBL and OSBL were not completed. Due to the early termination of the project, Process Engineering activities were not progressed further.

2.1.2 Process Design Basis

An overall Process Design Basis, consistent across ISBL and OSBL, was developed and issued for the project. It lays out the design basis including flue gas conditions, treated flue gas specs, CO2 flow rate and conditions for wet and dry CO2, Utility systems including Steam, Cooling Water, Water Quality, and Plant Caustic. It also provides the equipment sparing philosophy, battery limit conditions and design

considerations. Figure 4, which follows, provides a block flow diagram showing the representative battery limits to depict the project scope at a high level.

Figure 4: Block Flow Diagram – representative battery limits



The eight collection points for OP3A flue gases are combined and treated in one CO2 Absorber OP3A train. In addition, the eight collection points for OP3B & HT2 flue gases are combined and treated separately in a second CO2 Absorber OP3B train. This approach was selected in order to minimize the large ductwork required to collect the sixteen Furnace stack discharges that are essentially located in two separate areas.

Future projects should consider the capital cost / operating cost and practicality of combining all collection points into one train for a common CO2 Absorber Unit.

Then, the CO2 Rich Amine stream is treated and regenerated in a common Amine Regenerator Unit located in the main Inside Battery Limit (ISBL) area. A common Amine Regeneration Unit was selected

since this is more cost effective than separate units. Not only do you achieve equipment cost synergies of scale with one Amine Regeneration train, but operation and maintenance costs are reduced due to the reduction of the total number of equipment.

A new Cooling Tower and cooling water system supplies dedicated cooling water for the project. Large cooling water lines are routed on a new piperack to/from the Cooling Tower and ISBL area. Cooling water lines were routed above grade, rather than underground due to the large number of existing known and unknown obstructions present in an established plant. Other miscellaneous process water comes via a new tie-in to the existing site distribution network.

The primary steam supply for the site is currently from the adjacent Calpine facility. Calpine will continue to supply steam for this project through the existing site distribution system. This project will use 1,250 psi and 650 psi steam tied into the existing site headers. Low pressure steam is planned to come from a new Steam Turbine Generator which will use 1,250 psi inlet steam.

No new wastewater treatment facilities are required for the project since the existing system is deemed to be adequate.

Existing instrument air supply is considered adequate to supply the project.

2.1.3 Process Flow Diagrams (PFDs)

2.1.3.1 ISBL

Initial Process Flow Diagrams were developed earlier in the project. They were formally reviewed with the project team, including Shell. The PFDs were subsequently issued for Review, issued for Use and issued for Package. The public version of the PFDs (see Appendix A) illustrate the extent of work completed. Due to the early termination of the project, the PFDs were not developed further.

2.1.3.2 OSBL

Initial Process Flow Diagrams were developed earlier in the project. They were formally reviewed with the project team, including Shell. The PFDs (see Appendix A) were subsequently updated based on the review comments. and Issued for Package. The public version of the PFDs illustrate the extent of work completed. Due to the early termination of the project, the PFDs were not developed further.

2.1.4 Process & Instrumentation Diagrams (P&IDs)

2.1.4.1 ISBL

ISBL P&IDs were prepared and issued for Hazop. A Hazop (what-if hazard analysis) review with Shell was held and facilitated by Shell's third party contractor. The ISBL P&ID's were subsequently Issued for Package (IFP) and updated with the Hazop recommendations.

2.1.4.2 OSBL

OSBL P&IDs were prepared and issued for Hazop. The P&ID set included the new Process P&IDs including depiction of packaged vendor P&IDs based on the vendor quotes, revamp P&IDs, Utility P&IDs including those depicting Shell proposed tie-ins from existing utility headers. OSBL Hazop review was not held. Due to the early termination of the project, the P&IDs were not developed further.

2.1.5 Heat & Material Balance (H&MB)

2.1.5.1 ISBL

Heat & Material Balance document was developed and issued for Package. The public version of the Heat & Material Balance report illustrates the extent of work completed. See Appendix A, DPKCCS-2000-PRO-PFD-N-0002 Heat and Material Balance.

2.1.5.2 OSBL

OSBL Heat and Material Balance report was developed earlier in the project. It was Issued for Use for the project estimate. The public version of the Heat & Material Balance was not completed.

2.1.6 Catalyst and Chemical Summary

2.1.6.1 ISBL

The Catalyst and Chemical Summary (See Appendix A) was developed and issued for Use for the project estimate. It provides a list of flow rates and consumption of chemicals including catalysts. The public version of the Catalyst and Chemical Summary issued for information illustrates the extent of work completed.

2.1.6.2 OSBL

The Catalyst and Chemical Summary was planned to be developed based on input from package vendors. However, due to early termination of the project, this was not developed. A OSBL Utility Consumption list (See Appendix A) was being developed, along with input from ISBL for additional users. Due to the early termination of the project, this list was not developed further. The public version of the Utility Consumption List issued for information illustrates the extent of work completed.

2.2 Piping

2.2.1 Summary

Major Plot Plans were issued to serve as the basis for developing the 3D Model. Layout Drawings were not completed. 3-D Modeling of ISBL/OSBL for 8" and above, critical lines, and equipment were in development. Formal 3-D Model Review Meetings for ISBL and OSBL were not held. Due to the early termination of the project, piping and modeling were not fully developed. Development of piping material take-offs (MTOs) was not started.

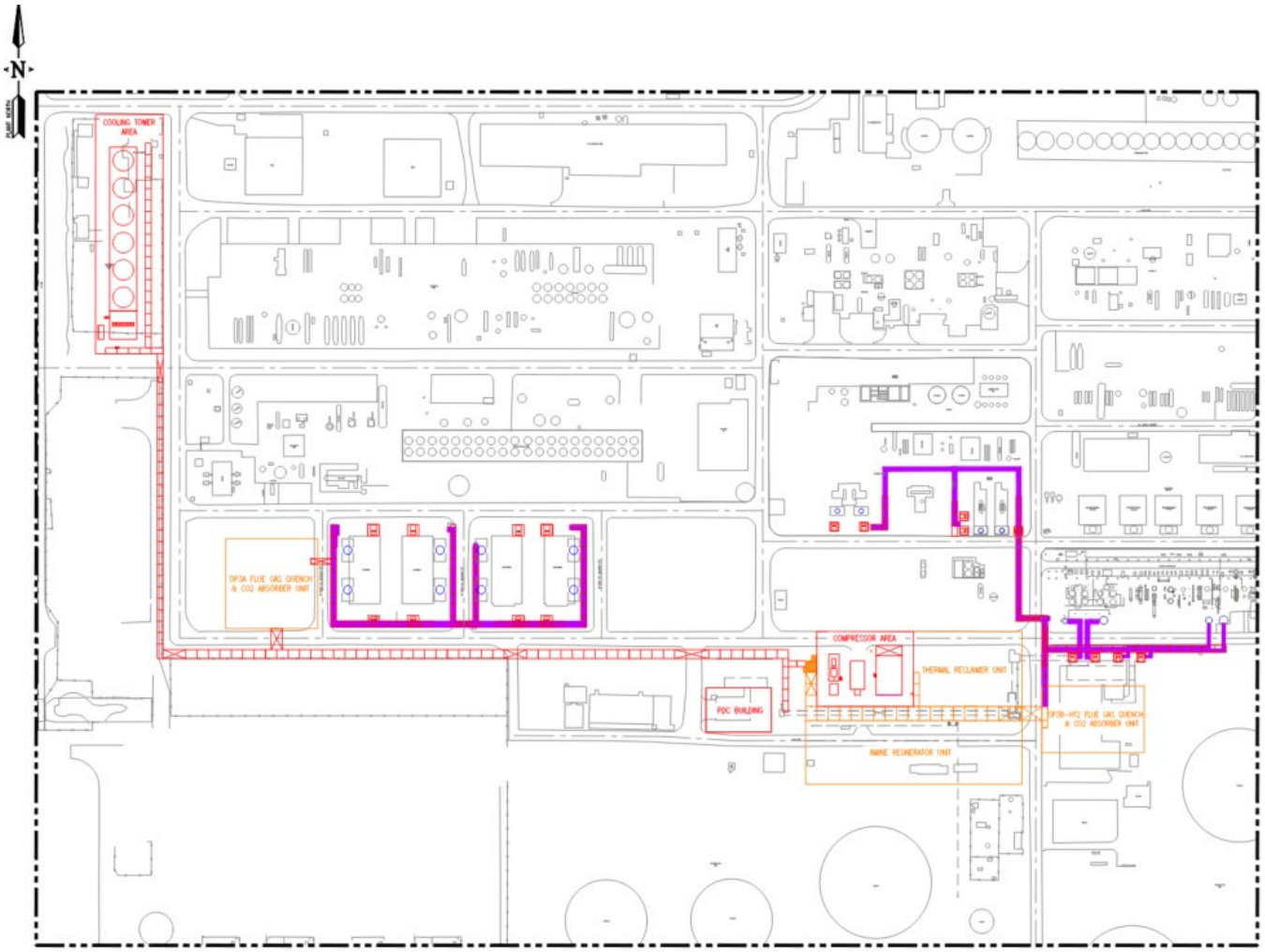
2.2.2 3D Model (Summary)

The development of 3D model for Piping, Civil/ Structural and Electrical scopes of work was in progress for ISBL as well as OSBL areas. Preliminary layout of all major mechanical and instrumentation/ electrical equipment was being advanced. Large bore piping greater than 8" diameter as well as identified critical piping were being modeled. Civil Structural foundations for equipment, pipe rack, RIE/PDC building were being modeled. Foundations for flue gas duct supports were being modeled.

2.2.3 Plot Plan

An overall plot plan depicting ISBL as well as OSBL layout of equipment, flue gas ducts, and pipe racks was in preparation for issue for Hazop. Due to the early termination of the project, the plot plan was not developed further. The public version of Plot Plan issued for information illustrates the extent of work completed.

Figure 5: Overall ISBL/OSBL Plot Plan



2.2.4 Line List

Line Lists for ISBL and OSBL were in progress. Due to the early termination of the project, these were not developed further.

2.3 Mechanical

2.3.1 Summary

Mechanical datasheets and/or mechanical requisition packages for major equipment were prepared for inquiry. High level technical bid evaluations (TBE) were performed based on vendor quotes received, and subsequent vendor correspondence. Detailed bid clarifications were not part of the project scope, and therefore not performed. Detailed bid clarifications will be necessary for confirming technical acceptability of the vendor offerings, and making recommendation for vendor selection, prior to purchase.

2.3.2 Mechanical Equipment List

2.3.2.1 ISBL

ISBL Mechanical Equipment List was prepared to support Inquiry bids. Due to the early termination of the project, the Mechanical Equipment List was not developed further, and the Priced Mechanical Equipment List was not started.

2.3.2.2 OSBL

Mechanical Equipment List was prepared and issued for review. Due to the early termination of the project, the Mechanical Equipment List was not developed further, and the Priced Mechanical Equipment List was not started.

2.4 Civil

2.4.1 Summary

Civil Structural model was in development.

- Development of Site Preparation Requirements/MTO early work had not started.
- Preliminary OSBL paving plan sketches had been started.
- Preliminary OSBL underground Piping and Drainage plans had been started.

- Preliminary foundation design for most major equipment, PDC building, and pipe racks was in development.
- Foundation design for flue gas ducts was in development.
- Civil sketches and structural steel sketches were in development.
- Steel for pipe racks was in design.
- Scope for steel at piping and electrical battery limit interface points was being coordinated between the ISBL and OSBL Subcontractors.
- Structural steel standard details had been identified for the project and issued.
- The Civil Structural model development was not completed, and therefore the MTO package preparation was not started.
- Due to early termination of the project, further progression of the Civil Structural design and engineering was discontinued.

2.5 Electrical

2.5.1 Summary

Primary electrical power for the project was provided from a new PDC Building and transformers located adjacent to the new ISBL area. A new Steam Turbine Generator was provided to capture the energy of the let down steam that will contribute to the additional project electrical supply.

Following is the current document status:

- Area Class Plans, Single Line Diagrams were in preparation.
- Sketch for PDC building layout in coordination with Instrumentation for RIE space was in development.
- Electrical input to the 3D model for cable tray routings and BL interface was in progress.
- Cable tray routing for the power feed to the PDC building identified by Shell was in development.
- Due to the early termination of the project, these activities and deliverables were not advanced further.

- Electrical plans including Power plan, Grounding plan, Lighting plan, and the Electrical MTO were not started.

2.5.2 ISBL

2.5.2.1 Electrical Load List

ISBL Electrical Load List was developed for ISBL loads and issued for Use. Due to the early termination of the project, it was not developed further.

2.5.2.2 Single Line Diagrams

ISBL Electrical One-Line Diagrams were issued for Use. Due to the early termination of the project, these were not developed further.

2.5.3 OSBL

2.5.3.1 Electrical Load List

Electrical load list including ISBL and OSBL loads was issued for Use. Due to the early termination of the project, these were not developed further.

2.6 Instrumentation

2.6.1 ISBL

- Instrumentation specs for DCS- SIS systems, Control System Architecture, Cause and Effect diagram were issued for Use.
- Instrumentation input to ISBL P&IDs was completed.
- Instrument List, I/O list, Fire Detection and Alarm system specification, and Relief Valve datasheets were in preparation.
- Due to the early termination of the project, these activities and deliverables were not developed further.

- Inquiry packages for pricing of major inline instruments as well Instrumentation MTO for estimate were not started.

2.6.2 OSBL

- Instrumentation Design Basis, I/O list, Control System Architecture, Cause and Effect diagram were in preparation.
- Significant Instrumentation input to Process & Utility P&IDs as well as Packaged vendor P&IDs were in development.
- Instrument List was in development.
- Inquiry packages for pricing of major inline instruments as well Instrumentation MTO for estimate were not started.
- Due to the early termination of the project, these activities and deliverables were not developed further.

2.7 Technical Safety

2.7.1 ISBL

A Hazop review with Shell, facilitated by Shell's third-party contractor was held. ISBL Hazop report was received from facilitator and recommendations were made.

2.7.2 OSBL

- Existing applicable area class plans were reviewed to provide input to Electrical Design.
- Consequence analysis report was not prepared. This analysis would have summarized the Carbon Dioxide dispersion consequence modeling results for the OSBL scope of the project based on the information available, and assumptions applicable at the time.
- Firefighting protection system study, layout, and MTO were not started.
- OSBL HAZOP review was not held. Due to the early termination of the project, this work was not developed further.

3 Project Support

3.1 Procurement

Supply Chain supported development of the approved suppliers list in coordination with Shell for OSBL and ISBL equipment. Supply Chain also formally issued requisition bid packages for major OSBL mechanical equipment for budget bid inquiry, as technical requisition packages were developed by Engineering. Supply Chain provided Expediting support for timely turnaround of budget bid packages and/or initial clarifications from bidders. High level Commercial Bid Evaluations were in preparation for bids received. Due to the early termination of the project, these were not developed further. Refer to the following table for initial unconditioned pricing and delivery estimates received for major equipment.

Table 3: Preliminary Priced List - Equipment

Equipment	Suppliers Solicited	Unconditioned Price ($)	Unconditioned Delivery (Weeks)
Vessels	Contract Fabricators	3,060,000	42
	Freeport Welding and Fabrication		
	Cembell Industries		
	Ward Vessel & Exchanger		
	GCAW		
	Jettweld		
	Boardman		
Tanks	CBI	5,124,000	40

Equipment	Suppliers Solicited	Unconditioned Price ($)	Unconditioned Delivery (Weeks)
	HMT		
	Specialty Tank Services		
	Matrix SVC Inc.		
	Advance Tank and Construction Co.		
	Kennedy Tank and Manufacturing		
	Modern Welding Co.		
	Smith Tank and Steel		
Plate and Frame Heat Exchangers	Kelvion	5,368,000	-
	APV/SPX		
	Alfa Laval		
Cooling Water Pumps	Flowserve	2,900,000	60
	Sulzer		
	Ruhrpumpen		
Pumps	Flowserve	7,449,000	-
	Sulzer		
	Ruhrpumpen		

Equipment	Suppliers Solicited	Unconditioned Price ($)	Unconditioned Delivery (Weeks)
Fans	Robinson Fans	10,100,000	36
	Howden		
	Clarage		
Cooling Towers	International Cooling Towers	7,250,000	56
	Industrial Cooling Towers		
	Cooling Tower Technologies		
	SPX		
	Precision Cooling Towers		
	Delta Cooling Towers		
Compressor Package	Siemens	6,255,000	60
	Atlas Copco		
	Sullair		
	Gardner Denver		
	Ingersoll Rand		
	Baker Hughes/Nuovo Pignone		
	Siemens	15,800,000	83

Equipment	Suppliers Solicited	Unconditioned Price ($)	Unconditioned Delivery (Weeks)
CO2 Compressor Package	MAN		
	Baker Hughes/Nuovo Pignone		
CO2 Drying Package - TEG System	Dickson Process Systems	7,200,000	72
	NOV Completions & Product Solutions		
	Enerflex		
	GasTech Engineering LLC		
Steam Turbine and Generator	Mitsubishi Heavy Industries	11,600,000	78
	Ebara Elliott		
	Siemens		
Flue Gas Duct Package	BD Energy	18,500,000	101
	Exotherm		
	Great Southern Technologies		
	Tulsa Heaters Inc.		

3.2 Estimating

3.2.1 Estimate Plan

The Estimate Plan describes the means, methods, and approach by which the FEED TIC (Total Installed Cost) Estimate was to be prepared for the project. The purpose of this Estimate Plan was to develop a capital cost estimate consistent with AACE (Association of the Advancement of Cost Engineering) Class 3 with an expected accuracy range of -10% to -20% on the low side and +10% to +30% on the high side. Due to the early termination of the project, the Estimate was not started. (See Appendix A)

3.3 Supporting Documents

3.3.1 Risk Register

The Risk Register was developed and maintained through the life of the project with inputs from key stakeholders. Risk Register is attached separately. (See Appendix A)

3.3.2 DOE Milestone Schedule

The DOE Milestone Schedule was used as basis for the project schedule. An excerpt of the same is included below for reference. Project Overall Schedule is attached separately. (See Appendix A)

Figure 6: DOE Milestones

Activity ID	Activity Name	Remaining Duration	Start	Finish
Department of Energy Required Milestones		151	11-May-22 A	27-Feb-24
General		151	11-May-22 A	27-Feb-24
Common Area - ISBL/OSBL		151	11-May-22 A	27-Feb-24
DOEMS1180	Project Kick-off Meeting Complete	0		11-May-22 A
DOEMS1190	Process Design Basis Rev.B Complete - IFR	0		21-Oct-22 A
DOEMS1200	Heat and Material Balances Complete	0		26-Jan-23 A
DOEMS1210	Process Flow Diagrams (PFDs) Rev.A Complete	0		26-May-23 A
DOEMS1230	Plot Plan Complete	0		31-Jul-23
DOEMS1240	3D Model Complete	0		07-Aug-23
DOEMS1250	Constructability Review Complete	0		14-Aug-23
DOEMS1220	P&IDs Rev.A Complete	0		21-Aug-23
DOEMS1260	HAZOP Review Complete	0		28-Aug-23
DOEMS1270	Development of chemical usage summaries ISBL/OSBL Complete	0		28-Aug-23
DOEMS1280	TIC Estimate Issue of Rev.A Complete	0		03-Nov-23
DOEMS1290	FEED Study Report Complete	0		29-Nov-23
DOEMS1300	Busines Case Analysis Complete	0		27-Feb-24
DOEMS1310	Final TEA Complete	0		27-Feb-24
DOEMS1320	Final LCA Complete	0		27-Feb-24
DOEMS1330	EH&S Risk Assesment Complete	0		27-Feb-24
DOEMS1340	Environmental Justice Analysis Complete	0		27-Feb-24
DOEMS1350	Economic Revitalization & Job Creation Outcomes Analysis Compl	0		27-Feb-24

3.3.3 Project Financial Summary

The table below provides the financial summary for the Project.

Table 4: Financial Summary

Categories	Total
Personnel	
Travel	
Contractual Total	
Subrecipient - SSEB	
Subrecipient - Univ. Houston	
Vendor - Shell / CANSOLV	
Vendor - Wood Group USA, Inc.	
Vendor - Technip	
Vendor - SAS Institute	
ODCs (DOE Audit)	
Total Direct Charge	
Indirect Charges Total	
Overhead Costs	
G&A Costs	
Total	**$ 9,044,955**

Source	Type	Amount
Shell Chemical Deer Park	Cash	
Wood Group USA, Inc.	Cash	
Cost Share Total	Cash	**$ 5,044,955**

Project Costs		$ 9,044,955
Cost Share % of Award		55.8%

3.3.4 Document List

3.3.4.1 Public Documents List

This list provides documents that were formally issued as non-protected project deliverables. The list is included in Appendix A. Documents attached separately.

Appendix A Public / Support Documents

This appendix contains the document list (documents attached separately) that were formally issued as non-protected project deliverables.

Reference	Title	Revision	Revision Date	Discipline	Reason for Issue
DPKCCS-0000-PRO-DES-N-0001	Project Design Basis	B	Oct 21, 2022	Process Eng	IFI - Issue for Information
DPKCCS-1000-PIP-DWDG-N-0001	Piping Drawing Overall Plot Plan	A	Aug 1, 2023	Piping	IFI - Issue for Information
DPKCCS-1000-PRO-PFD-N-0001	Process Flow Diagram Flue Gas Fans	0	May 24, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-1000-PRO-PFD-N-0002	Process Flow Diagram CO2 to Pipeline	0	May 24, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-1000-PRO-PFD-N-0003	Process Flow Diagram Cooling Tower	0	May 24, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-1000-PRO-PFD-N-0005	Process Flow Diagram Utilities	0	May 24, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-LIS-N-0004	Catalyst and Chemical Summary	0	Aug 2, 2023	Process Eng	IFI - Issue for Information
DPKCCS-2000-PRO-PFD-N-0002	Heat and Material Balance	0	Aug 2, 2023	Process Eng	IFI - Issue for Information

Reference	Title	Revision	Revision Date	Discipline	Reason for Issue
DPKCCS-2000-PRO-PFD-N-0001-001	Process Flow Diagram - CO2 Capture Unit Legends and Symbols	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-002	Process Flow Diagram - OP3A Flue Gas Quench and CO2 Absorber	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-003	Process Flow Diagram - OP3B-HT2 Flue Gas Quench and CO2 Absorber	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-004	Process Flow Diagram - Amine Cooling and Filtration	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-005	Process Flow Diagram - Amine Regenerator	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-006	Process Flow Diagram - Thermal Reclaimer	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-2000-PRO-PFD-N-0001-007	Process Flow Diagram - Amine Drain and Storage	0	Aug 14, 2023	Process Engineering	IFP - Issue for Package
DPKCCS-1000-PRO-LIS-N-0004	OSBL Utility Consumption List	A	Apr 19, 2023	Process Engineering	IFI - Issue for Information
DPKCCS-0000-PMT-EST-P-0001	Estimate Plan	0	May 30, 2023	PMT - General	IFI - Issue for Information

Reference	Title	Revision	Revision Date	Discipline	Reason for Issue
DPKCCS-1000-PMC-LIS-N-0002	Project Risk Register	0	Jun 1, 2023	PMT - General	IFU-Issued for Use

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

Project Design Basis

Date of Issue:	Oct 21 2022
Internal Document Number:	DPKCCS-0000-PRO-DES-N-0001
Internal Document Revision:	B
Customer Name:	Department of Energy NETL
Customer Document Number:	---
Customer Document Revision:	---

Federal Prime Contract No. DE-FE0032142

Non-protected Data

Project Name:	**FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX**	
Internal No.:	**DPKCCS-0000-PRO-DES-N-0001**	**Rev. No.: B**
Customer No.:	**---**	**Rev. No.: ---**

Important Notice

THIS PROJECT DESIGN BASIS (REPORT) WAS PREPARED EXCLUSIVELY FOR DEPARTMENT OF ENERGY NETL BY WOOD. THE QUALITY OF INFORMATION, CONCLUSIONS, AND ESTIMATES CONTAINED HEREIN IS CONSISTENT WITH THE TERMS OF REFERENCE, CONSTRAINTS AND CIRCUMSTANCES UNDER WHICH THE REPORT WAS PREPARED BY WOOD AND THE REPORT IS BASED ON I) INFORMATION AVAILABLE AT THE TIME OF PREPARATION, II) DATA SUPPLIED BY OUTSIDE SOURCES, AND III) THE ASSUMPTIONS, CONDITIONS, AND QUALIFICATIONS SET FORTH IN THIS REPORT. THIS REPORT IS INTENDED FOR USE BY DEPARTMENT OF ENERGY NETL ONLY SUBJECT TO TERMS AND CONDITIONS OF ITS CONTRACT WITH WOOD. ANY USE OF, OR RELIANCE ON, THIS REPORT BY ANY THIRD PARTY IS AT THAT PARTY'S SOLE RISK.

Rev	Date	Issued For	Wood		Department Manager/ Technical Authority	Project Manager	Customer
			Prepared	Checked			
A	28 Jul 2022	Review	KT	JH/MG	---	RJ	---
B	21 Oct 2022	Information	TS 21-Oct-22 12:48	MG 21-Oct-22	---	RR 21-Oct-22	---

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3 Fuel Feedstock and Flue Gas Characteristics 7

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Project Name:	**FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX**	
Internal No.:	**DPKCCS-0000-PRO-DES-N-0001**	**Rev. No.: B**
Customer No.:	**---**	**Rev. No.: ---**

1 Purpose

The purpose of this document is to provide standardized site conditions. It is intended for use by all engineering contractors during FEED.

2 Site Characteristics and Ambient Conditions

Table 2-1: Climate Data

	Design	
	Min (°F)	Max (°F)
Ambient Temperature (1)	19	104
Wet Bulb	19	85

Note:

1. Average Summer High is 97ºF and Average Winter Low is 31ºF.
2. Source Reference Shell Deer Park Site Order E-31

Table 2-2: Unit Elevation

Unit Elevation	
Elevation of the site above sea level	20 ft
Barometric Pressure	
Design Barometric Pressure, psia	14.7

Table 2-3: Wind

Wind	
Max Design Wind Speed	150 mph
Average Wind Speed	8.5 mph

Note:

1. Direction of Prevailing Wind: South East (summer) & North East (winter)

Table 2-4: Seismic Design Criteria

Seismic Design Criteria	
Site Soil	Class D
Earthquake	Category A
Design Code S_s = 0.068*g S_1 = 0.04*g	ASCE 7-16
Importance Factor	1.25

Note:

1. Source Reference Shell Deer Park Site Order E-31

Table 2-5: Rainfall

Rainfall Design Criteria	
Average annual rainfall	58.3 inches
Snow	None
Dust Storm, number/year	None
Maximum 10-year rainfall intensity	3.4 inches/hr

Note:

1. Average annual rainfall source Reference Shell Deer Park Site Order E-31
2. Design storm values in accordance with NOAA Atlas 14, Volume 11, Station # 41-4315.
3. Maximum 10 year rainfall intensity is per NOAA Atlas 14 Point Precipitation Frequency Estimates

3 Fuel Feedstock and Flue Gas Characteristics

3.1 Fuel Feedstock

None used.

3.2 Flue Gas Feed Characteristics

The carbon capture unit will be designed to remove 98% of the CO_2 from the Olefins unit (OP3A/B) and Hydrotreater unit (HT2) furnaces to reduce the overall facility CO_2 emissions by 95%. The combined CO_2 emissions rate provided by Shell Chemicals is approximately **934,000 tonnes per year** (annualized basis) and the annualized flue gas emissions characteristics provided by Shell Chemicals are shown in Table 3-1 through Table 3-3 below. Carbon Capture Unit design will be based on additional considerations for daily operation as discussed with Shell Chemicals and Shell Global Solutions. There are two separate duct systems to transport flue gas from the olefins unit OP3A and from olefins unit OP3B & hydrotreater unit HT2.

Table 3-1: Olefins Plant OP3A Flue Gas

Process Unit		**OP3A**								**TOTAL**
Equipment No.		F-P3-1050	F-P3-1060	F-P3-1070	F-P3-1080	F-P3-1110	F-P3-1120	F-P3-1130	F-P3-1140	
Flue Gas Flowrate	tpy	965,267	912,996	912,003	983,394	799,241	908,756	727,299	670,968	**6,779,924**
CO_2 Flowrate	tpy	103,348	96,004	97,854	104,063	83,954	95,962	72,010	67,775	**720,970**
CO_2	(wt%)	10.7	10.5	10.7	10.6	10.5	10.6	9.9	10.1	-

Table 3-2: Olefins Plant OP3B and Hydrotreater HT2 Flue Gas

Process Unit		**OP3B**				**HT2**				**TOTAL**
Equipment No.		F-OL-710	F-OL-700	F-P3-1100	F-P3-1090	F-OL-601	F-OL-602	F-OL-603	F-OL-604	
Flue Gas Flowrate	tpy	456,012	447,493	442,428	481,783	190,435	100,408	171,171	133,912	**2,423,642**
CO_2 Flowrate	tpy	39,379	41,627	46,818	49,262	12,030	5,660	7,150	11,150	**213,076**
CO_2	(wt%)	8.6	9.3	10.6	10.2	6.3	5.6	4.2	8.3	-

In addition, there are other emissions sources from other units that are included in the total CO_2 plant emissions. The rates of those sources are listed in Table 3-3 below.

Table 3-3: Remaining Emission Sources

Process Unit / Source	Emission Source	Description	CO_2 Emission Rate (tpy)
PA2A	H9200	Spent Air Incinerator	4,026
PA2B	F8300	Heavy Ends Furnace	5,810
PA3	H87920	Steam Boiler	0
OP3	OP3GRFLA	OP3 Ground Flare	2,229
HIPA	A1333	HIPA Flare	2,595
OP3	OP3ELFLA	OP3 Elevated Flare	0
OP2	OP2ELFLA	OP2 Elevated Flare	0
SET	SET GHG	South Effluent Treatment	6,170
-	GHG Vehicles	CO_2 from Vehicles	3,550
-	P87107	Fire Water Pump	10

3.3 Treated Flue Gas Specifications

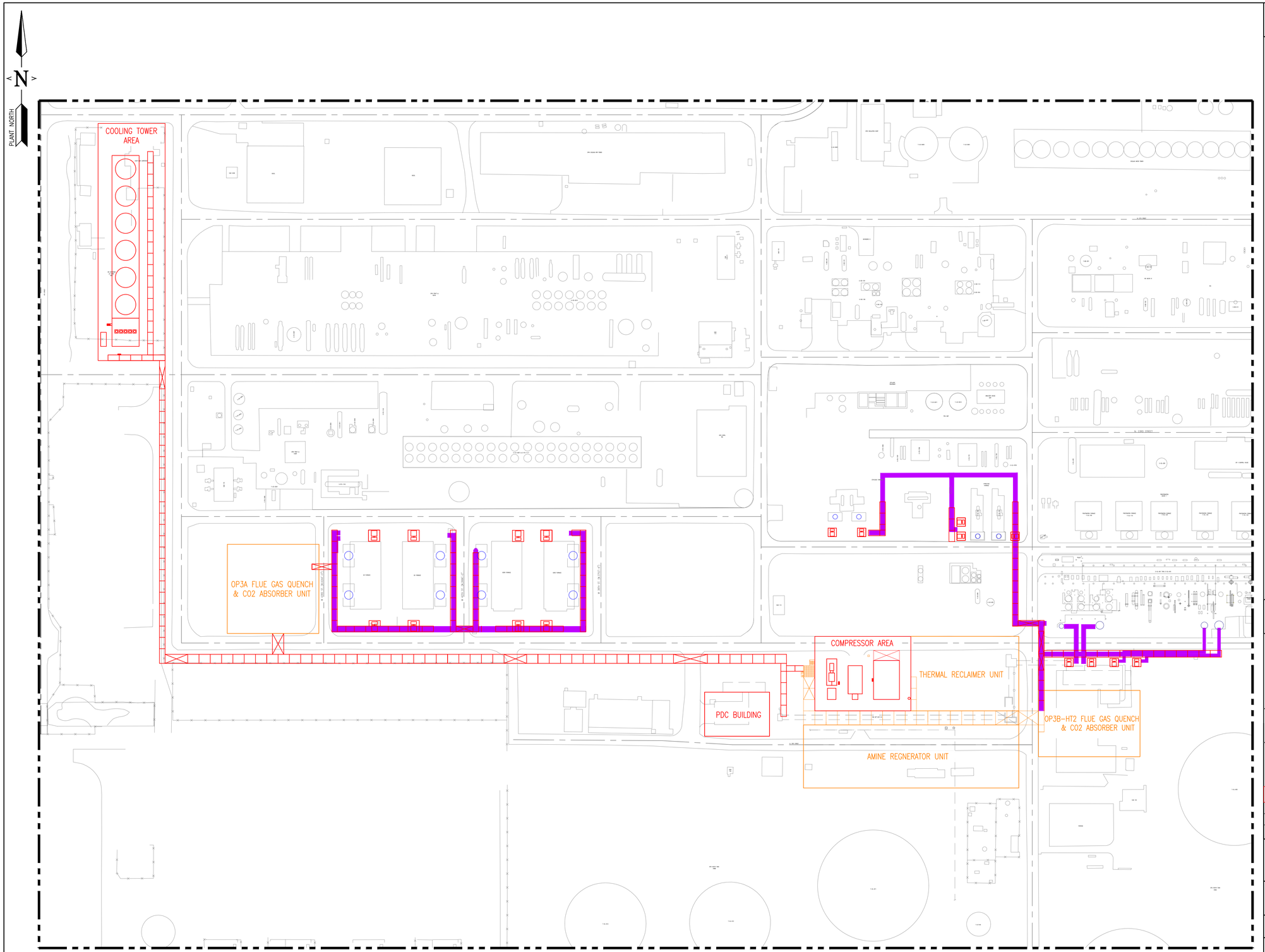
The treated flue gas stream from the carbon capture unit shall meet the following specifications. Data to be confirmed by Shell Chemicals.

Table 3-4: Treated Flue Gas Specifications

Components		Specification (Dry Basis)
CO2 Capture Efficiency	%	>=98
Amine	ppmv	< 2
Ammonia	ppmv	< 5
Nitrosamine	ppbv	< 5

4 Host Site Environment Requirements

This information will be provided by Shell Chemicals at a later date.



NOTES

LEGEND

- OSBL SCOPE
- OSBL SCOPE DUCT ROUTING
- ISBL SCOPE
- EXISTING MODIFIED
- EXISTING

NOTES

NON-PROTECTED DATA

REV	DATE	BY	DESCRIPTION	ENGR	CH'D	DTA	APPR
A	08/01/2023	DN	ISSUED FOR INFORMATION	ZA	DJ	"	RR

WOOD GROUP USA, INC.
TEXAS REGISTERED ENGINEERING FIRM F-2999

CLIENT: DEPARTMENT OF ENERGY NETL

WOOD PROJECT NO:	FEDERAL PRIME CONTRACT NO:
254206	DE-FE-0032142

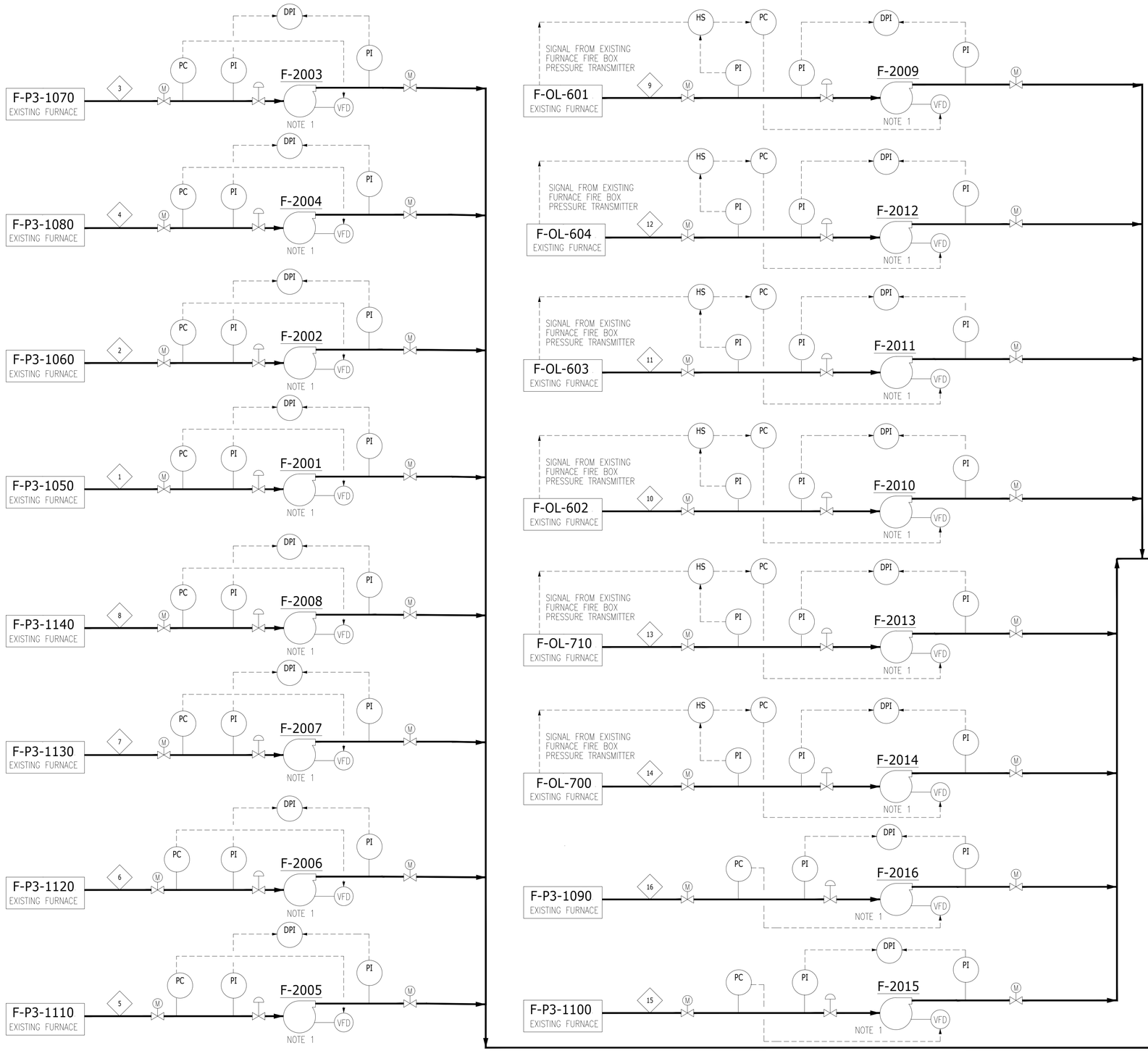
PROJECT LOCATION
SHELL CHEMICALS IN DEER PARK, TEXAS

PROJECT NAME
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

PIPING DRAWING
OVERALL PLOT PLAN

DWG NO:	DPKCCS-1000-PIP-DWDG-N-0001	REV:	A

F-2001 F-P3-1050 BOOSTER FAN
F-2002 F-P3-1060 BOOSTER FAN
F-2003 F-P3-1070 BOOSTER FAN
F-2004 F-P3-1080 BOOSTER FAN
F-2005 F-P3-1110 BOOSTER FAN
F-2006 F-P3-1120 BOOSTER FAN
F-2007 F-P3-1130 BOOSTER FAN
F-2008 F-P3-1140 BOOSTER FAN
F-2009 F-OL-601 BOOSTER FAN
F-2010 F-OL-602 BOOSTER FAN
F-2011 F-OL-603 BOOSTER FAN
F-2012 F-OL-604 BOOSTER FAN
F-2013 F-OL-710 BOOSTER FAN
F-2014 F-OL-700 BOOSTER FAN
F-2015 F-P3-1110 BOOSTER FAN
F-2016 F-P3-109 BOOSTER FAN



NOTES

1. CONTROLS AROUND FANS TO BE CONFIRMED WITH SHELL DP.

LEGEND

LC	LEVEL CONTROLLER
FC	FLOW CONTROLLER
TC	TEMPERATURE CONTROLLER
PC	PRESSURE CONTROLLER
HC	MANUAL (HAND) CONTROLLER
ASC	ANTI-SURGE CONTROLLER
NNF	NORMALLY NO FLOW
————	VENDOR PACKAGE SCOPE BOUNDARY
DPI	DIFFERENTIAL PRESSURE INDICATOR
PI	PRESSURE INDICATOR
CCS	CARBON CAPTURE AND STORAGE
VFD	VARIABLE FREQUENCY DRIVE
AI	ANALYZER
AC	ANALYZER CONTROLLER

REV	DATE	BY	DESCRIPTION	DB	MG	JH	RR
				BY	CH'D	APPR	PM
0	05/24/23	CY	ISSUED FOR PACKAGE	DB	MG	JH	RR
A	11/23/22	LB	ISSUED FOR REVIEW	TS	MG	JH	RR

wood. **WOOD GROUP USA, INC.**
TEXAS REGISTERED ENGINEERING FIRM F-2999

CLIENT: DEPARTMENT OF ENERGY NETL

WOOD PROJECT NO:	FEDERAL PRIME CONTRACT NO:
254206	DE-FE-0032142

PROJECT LOCATION
SHELL CHEMICALS IN DEER PARK, TEXAS

PROJECT NAME
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

PROCESS FLOW DIAGRAM
FLUE GAS FANS

DWG NO: DPKCCS-1000-PRO-PFD-N-0001 REV: 0

NOTES

1. COMPRESSOR ANTI-SURGE CONTROL BY COMPRESSOR PACKAGE VENDOR.
2. CO2 DRYING PACKAGE SHALL BE A TRIETHYLENE GLYCOL (TEG) UNIT. PACKAGE EQUIPMENT INCLUDES TEG CONTACTOR, TEG REGENERATION AND RELATED.
3. STEAM REQUIREMENT TO BE CONFIRMED.
4. COMPRESSOR PACKAGE EQUIPMENT INCLUDES COMPRESSION, KO DRUMS AND COOLERS.

LEGEND

LC	LEVEL CONTROLLER
FC	FLOW CONTROLLER
TC	TEMPERATURE CONTROLLER
PC	PRESSURE CONTROLLER
HC	MANUAL (HAND) CONTROLLER
ASC	ANTI-SURGE CONTROLLER
NNF	NORMALLY NO FLOW
————	VENDOR PACKAGE SCOPE BOUNDARY
DPI	DIFFERENTIAL PRESSURE INDICATOR
PI	PRESSURE INDICATOR
CCS	CARBON CAPTURE AND STORAGE
VFD	VARIABLE FREQUENCY DRIVE
AI	ANALYZER
AC	ANALYZER CONTROLLER

REV	DATE	BY	DESCRIPTION	BY	CH'D	APPR	PM
0	05/24/23	LB	ISSUED FOR PACKAGE	DB	MG	JH	RR
A	11/23/22	LB	ISSUED FOR REVIEW	TS	MG	JH	RR

WOOD GROUP USA, INC.
TEXAS REGISTERED ENGINEERING FIRM F-2999

CLIENT: DEPARTMENT OF ENERGY NETL

WOOD PROJECT NO:	FEDERAL PRIME CONTRACT NO:
254206	DE-FE-0032142

PROJECT LOCATION
SHELL CHEMICALS IN DEER PARK, TEXAS

PROJECT NAME
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

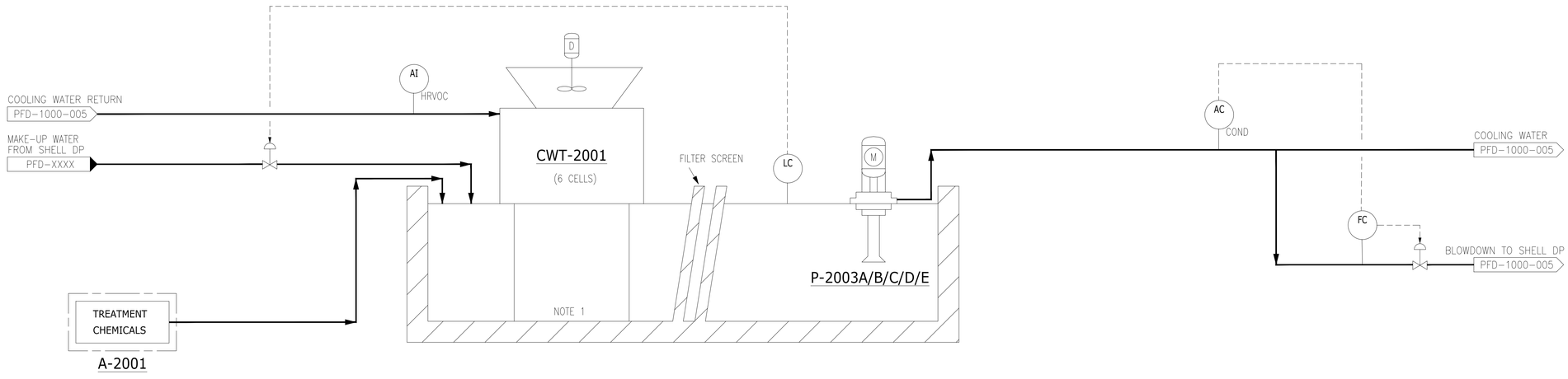
PROCESS FLOW DIAGRAM
CO2 TO PIPELINE

DWG NO: DPKCCS-1000-PRO-PFD-N-0002 REV: 0

A-2001
COOLING WATER CHEMICALS PACKAGE

CWT-2001
COOLING TOWER

P-2003A/B/C/D/E
COOLING WATER PUMPS



NOTES

1. FANS ARE INCLUDED IN COOLING TOWER PACKAGE.

LEGEND

LC	LEVEL CONTROLLER
FC	FLOW CONTROLLER
TC	TEMPERATURE CONTROLLER
PC	PRESSURE CONTROLLER
HC	MANUAL (HAND) CONTROLLER
ASC	ANTI-SURGE CONTROLLER
NNF	NORMALLY NO FLOW
— — — —	VENDOR PACKAGE SCOPE BOUNDARY
DPI	DIFFERENTIAL PRESSURE INDICATOR
PI	PRESSURE INDICATOR
CCS	CARBON CAPTURE AND STORAGE
VFD	VARIABLE FREQUENCY DRIVE
AI	ANALYZER
AC	ANALYZER CONTROLLER

REV	DATE	BY	DESCRIPTION	BY	CH'D	APPR	PM
0	05/24/23	CY	ISSUED FOR PACKAGE	DB	MG	JH	RR
A	11/23/22	LB	ISSUED FOR REVIEW	TS	MG	JH	RR

WOOD GROUP USA, INC.
TEXAS REGISTERED ENGINEERING FIRM F-2999

CLIENT: DEPARTMENT OF ENERGY NETL

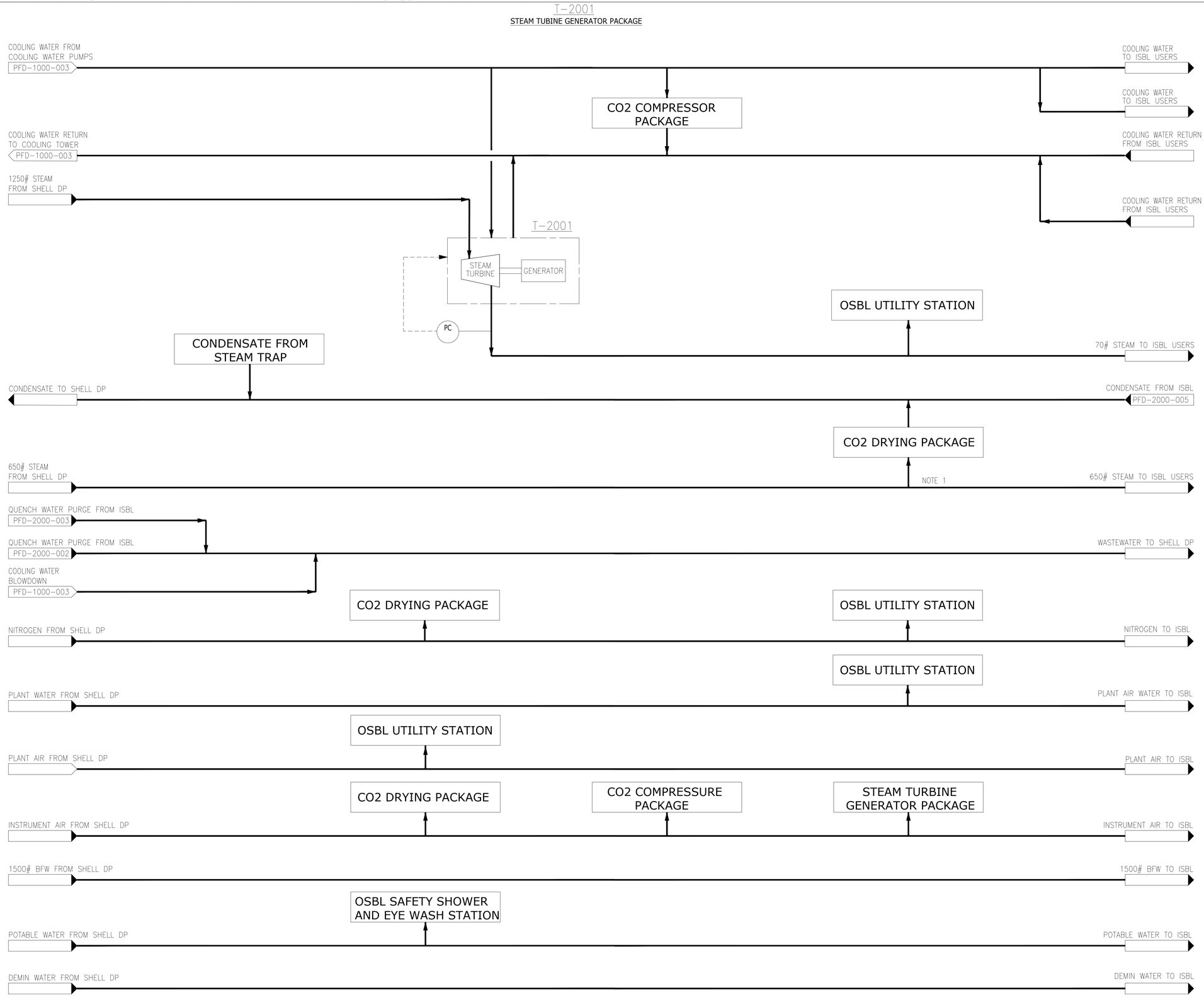
WOOD PROJECT NO:	FEDERAL PRIME CONTRACT NO:
254206	DE-FE-0032142

PROJECT LOCATION
SHELL CHEMICALS IN DEER PARK, TEXAS

PROJECT NAME
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

PROCESS FLOW DIAGRAM
COOLING TOWER

DWG NO: DPKCCS-1000-PRO-PFD-N-0003 REV: 0



NOTES

1. STEAM REQUIREMENT TO BE CONFIRMED.

LEGEND

LC	LEVEL CONTROLLER
FC	FLOW CONTROLLER
TC	TEMPERATURE CONTROLLER
PC	PRESSURE CONTROLLER
HC	MANUAL (HAND) CONTROLLER
ASC	ANTI-SURGE CONTROLLER
NNF	NORMALLY NO FLOW
————	VENDOR PACKAGE SCOPE BOUNDARY
DPI	DIFFERENTIAL PRESSURE INDICATOR
PI	PRESSURE INDICATOR
CCS	CARBON CAPTURE AND STORAGE
VFD	VARIABLE FREQUENCY DRIVE
AI	ANALYZER
AC	ANALYZER CONTROLLER

REV	DATE	BY	DESCRIPTION	BY	CH'D	APPR	PM
0	05/24/23	LB	ISSUED FOR PACKAGE	DB	MG	JH	RR
A	11/23/22	LB	ISSUED FOR REVIEW	TS	MG	JH	RR

wood. **WOOD GROUP USA, INC.**
TEXAS REGISTERED ENGINEERING FIRM F-2999

CLIENT: DEPARTMENT OF ENERGY NETL

WOOD PROJECT NO:	FEDERAL PRIME CONTRACT NO:
254206	DE-FE-0032142

PROJECT LOCATION
SHELL CHEMICALS IN DEER PARK, TEXAS

PROJECT NAME
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

PROCESS FLOW DIAGRAM
UTILITIES

DWG NO:	REV:
DPKCCS-1000-PRO-PFD-N-0005	0

Summary List for

Shell Global Solutions

CATALYST & CHEMICAL

Front-End Engineering Design for Carbon Capture from Shell's Deer Park Chemical Complex

CO2 Capture Unit

CATALYST & CHEMICAL SUMMARY

Non-protected Data

Revisions:

Made by: GM	Date: 8/2/2023	PROJECT: FEED for Carbon Capture from Shell's Deer Park Chemical Complex	Rev. Letter:	0			
			Date:	8/2/2023			
Checked by: GB	Date: 8/2/2023	PLANT: Shell Deer Park Chemicals	Signature:	GM			
			Sheet No.	1	Continued on sheet No.		2
Approved by: GB	Date: 8/2/2023	CONSIGNEE: WSP USA Environment and Infrastructure Inc			Document No: DPKCCS-2000-PRO-LIS-N-0004		

CONSIGNEE	WSP USA Environment and Infrastructure Inc
LOCATION	Deer Park, TX, US
UNIT	CO2 Capture
DOCUMENT No.	DPKCCS-2000-PRO-LIS-N-0004

REVISION	0				SHEET
DATE	8/2/2023				2
MADE BY	GM				OF
CHECKED BY	GB				3
APPROVED BY	GB				

Rev.

Catalyst & Chemical Summary, Expected values - Issued for Information

NOTES:

1) Normal consumption flow rates refer to continuous production/consumption based on the determining H&MB case.
2) Maximum consumption flow rates refer to peak production/consumption.
3) Intermittent consumption flow rates refer to production/consumption during a short period (non-continuous).
4) Antifoam injection is intermittent (not continuous) on an as-needed basis. The specified consumption rate is based on an assumed 10% active ingredient in the emulsion, a target of 5 ppmw undiluted antifoam in the solvent system and assumes 2 shots per day total. Actual consumption rate is to be determined based on site operating experience. The recommended type of antifoam agent is UCARSOL^{TM} GT-10.
5) Changeout of the carbon bed is expected to occur every 6 - 12 months or as required with bed performance. The specified consumption rate assumes 2 changeouts per year. Consumption quantities can be expected to be higher during startup. The recommended type of activated carbon is GAC-830 with a minimum Iodine number of 900 mg/g.
6) Sodium carbonate solution is used to clean the CO_2 Capture unit during pre-commissioning. The specified consumption is based on one inventory of 3 wt% aqueous soda-ash (Na_2CO_3) solution. Quoted consumption rate is based on pure sodium carbonate.
7) All consumption rates quoted are "As Delivered" concentration basis unless otherwise noted.
8) The design of the carbon capture unit includes provisions for caustic injection in the quench water systems in case SO2 in the flue gas is higher than expected. The Catalyst & Chemical summary does not include these injection volumes which are only intended to be used in the future if necessary.

Project:	Front-End Engineering Design for Carbon Capture from Shell's Deer Park Chemical Complex	Plant:	Shell Deer Park Chemicals	Project No:	
Location:	Deer Park, TX, US	Unit:	CO2 Capture Unit	Doc No:	DPKCCS-2000-PRO-LIS-N-0004

Chemicals: CANSOLV CO2 Process

Equipment No.	Service	Chemical	Units	Consumption (Note 7)			As delivered	As used	Shipping Container	Remarks
				Normal Note 1	Maximum Note 2	Intermittent Note 3				
T-1050	Amine Storage Tank	DC-103 Amine	lbs							Initial Fill
T-1050	Amine Storage Tank	DC-103 Amine	lb/hr							Makeup
V-1002 V-1012	OP3A/OP3B-HT2 CO2 Absorbers	Amine Antifoam	lb/day			446	TBD	10 wt%	TBD	Note 4
V-1020	Amine Regenerator									
V-1030	Amine Reclaimer	Caustic Soda	lb/hr	25			47 wt%	20 wt%	TBD	
V-1026	Lean Amine Carbon Filter	Activated Carbon	ft3			2,522	-	-	TBD	Note 5
-	CO2 Capture Unit	Sodium Carbonate	lbs			0	TBD	0.5 - 3 wt%	TBD	Note 6

Revision

Shell Global Solutions

Front-End Engineering Design for Carbon Capture from Shell's Deer Park Chemical Complex

CO2 Capture Unit

Heat and Material Balance

Non-protected Data

Revisions:

Made by: GM	Date: 8/2/2023	PROJECT: FEED for Carbon Capture from Shell's Deer Park Chemical Complex	Rev. Letter:	0			
			Date:	8/2/2023			
Checked by: GB	Date: 8/2/2023	PLANT: Shell DPK Chemicals	Signature:	GM			
			Sheet No.	1	Continued on sheet No.		2
Approved by: GB	Date: 8/2/2023	CONSIGNEE: WSP USA Environment and Infrastructure Inc			Document No: DPKCCS-2000-PRO-PFD-N-0002		

			HEAT AND MATERIAL BALANCE			Design book No:			Page:
			Stream number						
			1	4	6	13	16	30	31
			Stream description						
			OP3A	OP3A	OP3A	OP3B-HT2	OP3B-HT2	WET CO2	COND WATER
			FLUE GAS	TREATED GAS	QUENCH PURGE	FLUE GAS	TREATED GAS	TO CO2 COMPR	FROM CO2 COMPR
			FROM OSBL	TO STACK	TO OSBL	FROM OSBL	TO STACK		
	Constituent (mole fraction)		Mole fraction						
1	CO2		0.071910	0.001702	0.000021	0.046826	0.001013	0.939406	0.006320
2	N2		0.709723	0.842141	0.000006	0.730275	0.792015	0.000049	
3	O2		0.041009	0.048660	0.000001	0.098704	0.107048	0.000007	
4	Ar								
5	H2O		0.177300	0.107428	0.999972	0.124163	0.099889	0.060538	0.993680
6	CO								
10									
11									
12		TOTAL	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000
13									
14	**Total Stream:**								
15	Temperature	F	563	117	101	695	115	115	128
16	Pressure	psia	15.7	14.7	79.0	15.7	14.7	24.7	25.1
17	Molar Flow	lbmol/hr	78,233	65,931	8,172	24,866	22,927	7,086	374
18	Mass Flow	lb/hr	2,155,680	1,790,735	147,227	694,120	629,533	300,707	6,796
19	Molecular Weight		27.6	27.2	18.0	27.9	27.5	42.4	18.2
20	Mole Vapor Fraction	-	1.00	1.00	0.00	1.00	1.00	1.00	0.01
21									
22	**Vapor Phase:**								
23	Molar Flow	lbmol/hr	78,233	65,931		24,866	22,927	7,086	2
24	Mass Flow	lb/hr	2,155,680	1,790,735		694,120	629,533	300,707	99
25	Std. Gas Flow (NOTE 2)	MMSCFD	713	600		226	209	65	0
26	Molecular Weight		27.6	27.2		27.9	27.5	42.4	41.8
27	Mass Density	lb/cuft	0.039	0.065		0.035	0.066	0.171	0.167
28	Cp/Cv	-	1.348	1.391		1.348	1.392	1.290	1.288
29	Mass Heat Capacity	Btu/lb-R	0.280	0.262		0.276	0.259	0.215	0.219
30	Viscosity	cP	0.028	0.019		0.031	0.019	0.016	0.016
31	Thermal Conductivity	Btu-ft/hr-sqft-R	0.025	0.015		0.028	0.015	0.011	0.011
32	Z-Factor	-	1.000	0.999		1.000	0.999	0.993	0.993
33									
34	**Aqueous Phase:**								
35	Molar Flow	lbmol/hr			8,172				371
36	Mass Flow	lb/hr			147,227				6,696
37	Actual Volume Flow	GPM			296				14
38	Mass Density	lb/cuft			62.0				61.5
39	Viscosity	cP			0.688				0.508
40	Thermal Conductivity	Btu-ft/hr-sqft-R			0.360				0.370
41	Mass Heat Capacity	Btu/lb-R			0.998				1.000
42	Surface Tension	dyne/cm			70.19				67.2

REMARKS	Made by:	Date:	CASE:	Revision	0		
	GM	8/2/2023	Design Case	Date:	08/02/2023		
	Checked by:	Date:	PLANT:	Signature:	GM		
	GB	8/2/2023	Shell DPK Chemicals - CO2 Capture Unit	Sheet No. 2		Continued on	3
	Approved by:	Date:	CONSIGNEE:	Document No:			
	GB	8/2/2023	WSP USA Environment and Infrastructure Inc	DPKCCS-2000-PRO-PFD-N-0002			

			HEAT AND MATERIAL BALANCE		Design book No:			Page:
			Stream number					
			50					
			Stream description					
			OP3B-HT2					
			QUENCH WATER					
			TO OSBL					
	Constituent (mole fraction)		Mole fraction					
1	CO2		0.000013					
2	N2		0.000006					
3	O2		0.000002					
4	Ar							
5	H2O		0.999979					
6	CO							
10								
11								
12	**TOTAL**		1.000000					
13								
14	**Total Stream:**							
15	Temperature	F	101					
16	Pressure	psia	55.0					
17	Molar Flow	lbmol/hr	1,173					
18	Mass Flow	lb/hr	21,123					
19	Molecular Weight		18.0					
20	Mole Vapor Fraction	-	0.00					
21								
22	**Vapor Phase:**							
23	Molar Flow	lbmol/hr						
24	Mass Flow	lb/hr						
25	Std. Gas Flow (NOTE 2)	MMSCFD						
26	Molecular Weight							
27	Mass Density	lb/cuft						
28	Cp/Cv	-						
29	Mass Heat Capacity	Btu/lb-R						
30	Viscosity	cP						
31	Thermal Conductivity	Btu-ft/hr-sqft-R						
32	Z-Factor	-						
33								
34	**Aqueous Phase:**							
35	Molar Flow	lbmol/hr	1,173					
36	Mass Flow	lb/hr	21,123					
37	Actual Volume Flow	GPM	42					
38	Mass Density	lb/cuft	62.0					
39	Viscosity	cP	0.689					
40	Thermal Conductivity	Btu-ft/hr-sqft-R	0.360					
41	Mass Heat Capacity	Btu/lb-R	0.998					
42	Surface Tension	dyne/cm	70.2					

REMARKS	Made by:	Date:	CASE:	Revision	0	
	GM	8/2/2023	Design Case	Date:	08/02/2023	
	Checked by:	Date:	PLANT:	Signature:	GM	
	GB	8/2/2023	Shell DPK Chemicals - CO2 Capture Unit	Sheet No. 3	Continued on	4
	Approved by:	Date:	CONSIGNEE:	Document No:		
	GB	8/2/2023	WSP USA Environment and Infrastructure Inc	DPKCCS-2000-PRO-PFD-N-0002		

HEAT AND MATERIAL BALANCE	Design book No:	Page:

NOTE 1. Atmospheric pressure is 14.696 psia per the Process Design Basis.

NOTE 2. Standard conditions for gas flow are 14.696 psia and 60°F per the Process Design Basis.

REMARKS	Made by:	Date:	CASE:	Revision	0		
	GM	8/2/2023	Design Case	Date:	08/02/2023		
	Checked by:	Date:	PLANT:	Signature:	GM		
	GB	8/2/2023	Shell DPK Chemicals - CO2 Capture Unit	Sheet No. 4			
	Approved by:	Date:	CONSIGNEE:		Document No:		
	GB	8/2/2023	WSP USA Environment and Infrastructure Inc		DPKCCS-2000-PRO-PFD-N-0002		

SYMBOLOGY

LINE WEIGHTS

- PROCESS
- INSTRUMENT SIGNAL
- PACKAGE BREAK
- BATTERY LIMIT
- DUCT

LINE CONNECTORS

- YYY — OFF PAGE CONNECTOR (OSBL)
- YYY — OFF PAGE CONNECTOR
  WHERE YYY = DRAWING SEQUENCE NUMBER
- UTILITY CONNECTOR

- BLOCK VALVE NORMALLY OPEN
- BLOCK VALVE NORMALLY CLOSED
- GLOBE VALVE
- BUTTERFLY VALVE
- NON RETURN VALVE
- CONTROL VALVE
- ON/OFF VALVE
- LETDOWN VALVE WITH INTEGRATED DESUPERHEATER
- SELF REGULATING VALVE
- 3 WAY ON/OFF VALVE
- 3 WAY CONTROL VALVE
- XX — INSTRUMENT CONTROL
- RO — RESTRICTION ORIFICE
- DESUPERHEATER
- DAMPER (ACTUATED ON/OFF)
- DAMPER (MODULATING)
- HOSE COUPLING
- HOSE CONNECTION
- OPEN DRAIN
- T — STEAM TRAP
- INLINE STATIC MIXER

ABBREVIATIONS

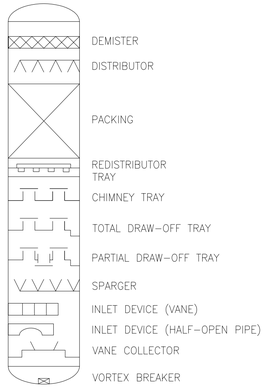
AG	ABOVE GROUND	HL	HIGH LEVEL	PC	PRESSURE CONTROLLER
AI	ANALYSER INDICATOR	HLO	HIGH LEVEL OVERRIDE	PDC	PRESSURE DIFFERENTIAL CONTROLLER
AC	ANALYSER CONTROLLER	HPC	HIGH PRESSURE CONDENSATE	PLC	PROGRAMMABLE LOGIC CONTROLLER
AMB	AMBIENT	HPS	HIGH PRESSURE STEAM	PW	PLANT WATER
APU	AMINE PURIFICATION UNIT	HS	HAND SWITCH	RO	RESTRICTION ORIFICE
ATM	ATMOSPHERE	IA	INSTRUMENT AIR	SC	SPEED CONTROLLER
BFW	BOILER FEED WATER	IBC	INTERMEDIATE BULK CONTAINER	SP	SET POINT
CC	CLEAN CONDENSATE	LI	LEVEL INDICATOR	SS	SATURATED STEAM
COND	CONDUCTIVITY	LC	LEVEL CONTROLLER	SIL	SAFETY INTEGRITY LEVEL
CCP	CARBON CAPTURE PLANT	LL	LOW LEVEL	TC	TEMPERATURE CONTROLLER
CSW	CLEAN STORM WATER	LPS	LOW PRESSURE STEAM	TI	TEMPERATURE INDICATOR
CW	COOLING WATER	LPC	LOW PRESSURE CONDENSATE	TRU	THERMAL RECLAIMER UNIT
CWR	COOLING WATER RETURN	MFR	MINIMUM FLOW RECYCLE	UG	UNDERGROUND
CWS	COOLING WATER SUPPLY	MPC	MEDIUM PRESSURE CONDENSATE	VFD	VARIABLE FREQUENCY DRIVE
CEMS	CONTINUOUS EMISSIONS MONITORING SYSTEM	MPS	MEDIUM PRESSURE STEAM	VIGV	VARIABLE INLET GUIDE VANES
DW	DEMINERALISED WATER	NO	NORMALLY OPEN	WWTP	WASTE WATER TREATMENT PLANT
FC	FLOW CONTROLLER	NC	NORMALLY CLOSED	Y	CONTROL FUNCTION
FFC	FLOW RATIO CONTROLLER	NNF	NORMALLY NO FLOW	ZC	POSITION CONTROLLER
FG	FUEL GAS	OCS	OPEN COOLING WATER SUPPLY		
FI	FLOW INDICATOR	OCR	OPEN COOLING WATER RETURN		
HC	HAND CONTROLLER	OSBL	OUTSIDE BATTERY LIMITS		
HP	HIGH PRESSURE	OWS	OILY WATER SEWER		
		PA	PLANT AIR		

STREAM SYMBOLS

- STREAM NUMBER

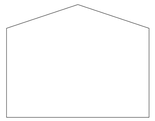
MISCELLANEOUS

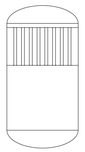
EQUIPMENT

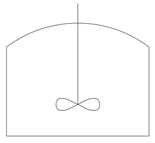


TOWER/VESSEL

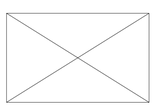

SWAGED TOWER

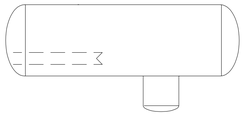

CONED ROOF STORAGE TANK

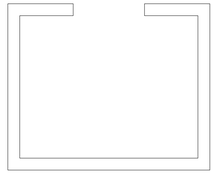

FILTER COALESCER

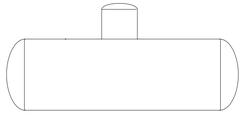

STORAGE TANK (WITH MIXER)


VESSEL


PACKED SECTION


HORIZONTAL VESSEL WITH BOOT AND STEAM COIL

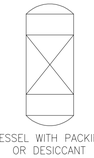

SUMP

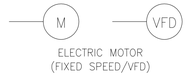

BOILER DEAERATOR


STATIC MIXER


PRESSURISATION VESSEL WITH DIAPHRAGM

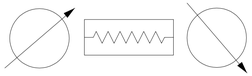

VAPORIZER


VESSEL WITH PACKING OR DESICCANT



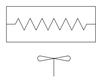
ELECTRIC MOTOR (FIXED SPEED/VFD)


SHELL & TUBE EXCHANGER


HEAT EXCHANGER (GENERIC)


ELECTRICAL REBOILER/HEATER


KETTLE REBOILER


AIR COOLER (FORCED DRAFT)

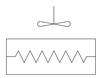
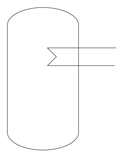
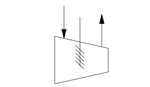

AIR COOLER (INDUCED DRAFT)

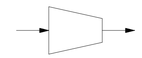

PLATE AND FRAME HEAT EXCHANGER (GASKETED/WELDED)


HEAT EXCHANGE TUBES IN DUCT


ROTARY REGENERATIVE HEAT EXCHANGER


SELF DRAINING HEAT EXCHANGER


COMPRESSOR/BLOWER/FAN (WITH INLET GUIDE VANE) (CENTRIFUGAL)


COMPRESSOR/BLOWER/FAN (AXIAL)


STEAM TURBINE

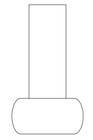

GAS TURBINE


LP STEAM TURBINE


CENTRIFUGAL PUMP

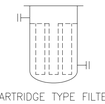

METERING PUMP

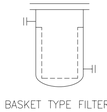

RECIPROCATING PUMP


VERTICAL PUMP


RECIPROCATING COMPRESSOR


FILTER/STRAINER


CARTRIDGE TYPE FILTER


BASKET TYPE FILTER


EJECTOR


GENERATOR

STACK

TRUCK

NOTES

REV	REVISION DESCRIPTION	DATE	CHECKED	APPROVED	PROJ APR
0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

NON-PROTECTED VERSION

Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX
DEER PARK, TX

TITLE
PROCESS FLOW DIAGRAM
CO2 CAPTURE UNIT LEGENDS AND SYMBOLS

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-001	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0008	0

V-1001
OP3A QUENCH COLUMN
NOTE 7

P-1001 A/B
OP3A QUENCH WATER PUMP

E-1001A/B
OP3A QUENCH WATER COOLER

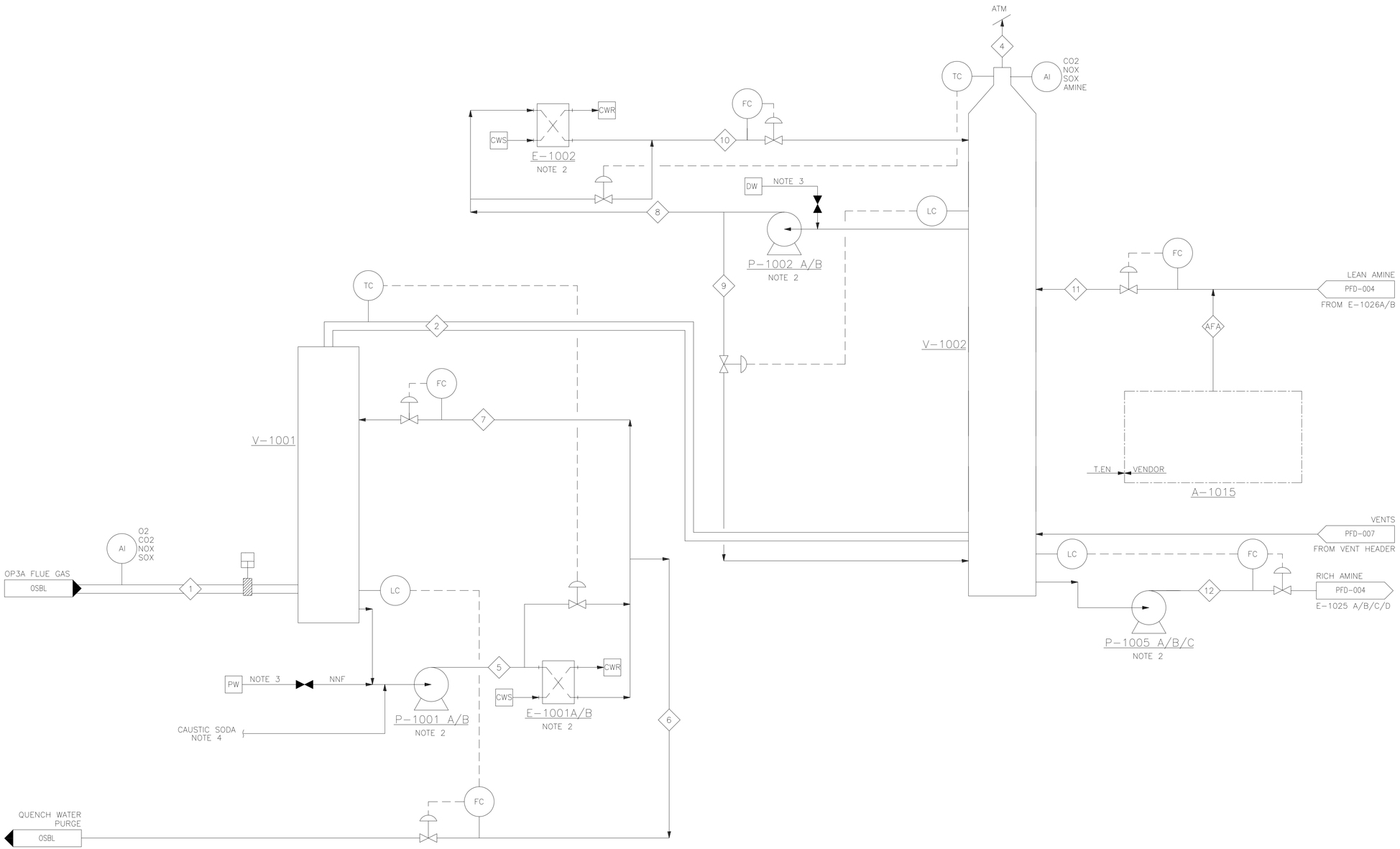
E-1002
OP3A WATER WASH COOLER

P-1002 A/B
OP3A WATER WASH PUMP

V-1002
OP3A CO2 ABSORBER
NOTE 7

P-1005 A/B/C
OP3A RICH AMINE PUMP

A-1015
OP3A ANTIFOAM CHEMICAL INJECTION PACKAGE



NOTES

1. THE OVERALL PLANT CONFIGURATION FOR THE CO2 CAPTURE FACILITIES CONSISTS OF TWO (2) SEPARATE QUENCH AND ABSORBER TRAINS FOR THE OP3A AND OP3B/HT2 FEEDS, AS WELL AS COMMON REGENERATION, THERMAL RECLAIMING, AND AMINE DRAIN / STORAGE SYSTEMS THAT SERVE BOTH THE OP3A AND OP3B/HT2 QUENCH AND ABSORBER TRAINS.
2. THE SPECIFIED NUMBER OF PUMPS AND EXCHANGERS REFLECTS THE MINIMUM SPARING PHILOSOPHY APPLIED FOR THE PROJECT. THE FINAL EQUIPMENT SPARING PHILOSOPHY IS SUBJECT TO CHANGE BASED ON THE APPLICATION OF INDUSTRY STANDARD EQUIPMENT SIZING LIMITATIONS.
3. WATER SUPPLY LINE CONSIDERED FOR START-UP ONLY. THE QUENCH WATER AND WASH WATER SYSTEMS ARE EXPECTED TO CONSTANTLY PURGE WATER.
4. PROVISION FOR FUTURE CAUSTIC INJECTION UPSTREAM OF QUENCH PUMPS IN CASE SO2 IN FLUE GAS FEED IS HIGHER THAN EXPECTED.
5. DELETED.
6. DELETED.
7. RECTANGULAR / SQUARE TOWER.
8. DELETED.

THIS DRAWING HAS BEEN DRAFTED BASED ON THE INPUTS RECEIVED FROM THE PROCESS LICENSOR, SHELL CATALYSTS AND TECHNOLOGIES (SCT).

REV.	REVISION DESCRIPTION	DATE	CHECKED	APPROVED	PROJ APR
0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

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Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX
DEER PARK, TX

TITLE

PROCESS FLOW DIAGRAM
CO2 CAPTURE UNIT LEGENDS AND SYMBOLS

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-002	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0009	0

V-1011
OP3B-HT2 QUENCH COLUMN

P-1011 A/B
OP3B-HT2 QUENCH WATER PUMP

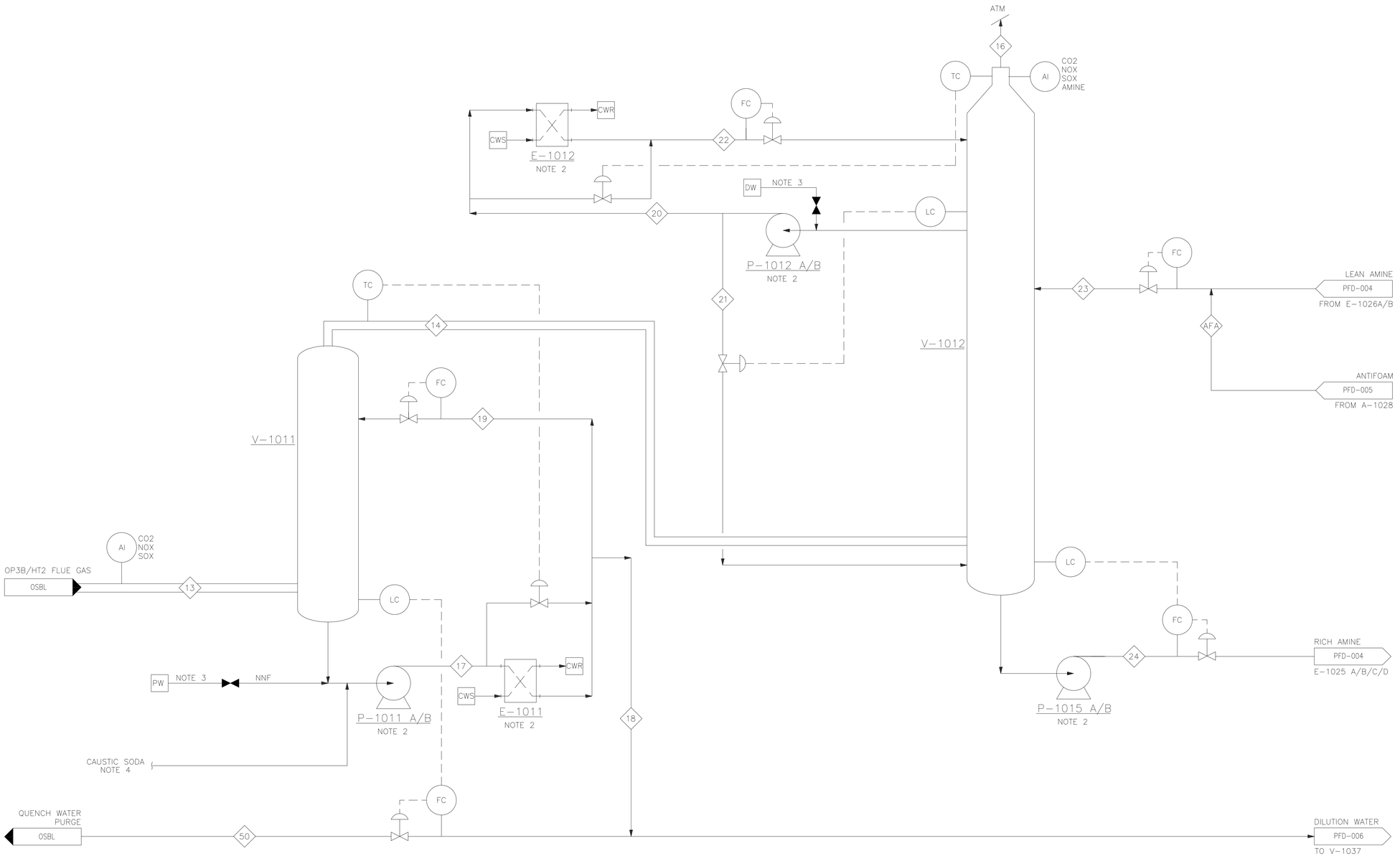
E-1011
OP3B-HT2 QUENCH WATER COOLER

E-1012
OP3B-HT2 WATER WASH COOLER

P-1012 A/B
OP3B-HT2 WATER WASH PUMP

V-1012
OP3B-HT2 CO2 ABSORBER

P-1015 A/B
OP3B-HT2 RICH AMINE PUMP



NOTES

1. THE OVERALL PLANT CONFIGURATION FOR THE CO2 CAPTURE FACILITIES CONSISTS OF TWO (2) SEPARATE QUENCH AND ABSORBER TRAINS FOR THE OP3A AND OP3B/HT2 FEEDS, AS WELL AS COMMON REGENERATION, THERMAL RECLAIMING, AND AMINE DRAIN / STORAGE SYSTEMS THAT SERVE BOTH THE OP3A AND OP3B/HT2 QUENCH AND ABSORBER TRAINS.
2. THE SPECIFIED NUMBER OF PUMPS AND EXCHANGERS REFLECTS THE MINIMUM SPARING PHILOSOPHY APPLIED FOR THE PROJECT. THE FINAL EQUIPMENT SPARING PHILOSOPHY IS SUBJECT TO CHANGE BASED ON THE APPLICATION OF INDUSTRY STANDARD EQUIPMENT SIZING LIMITATIONS.
3. WATER SUPPLY LINE CONSIDERED FOR START-UP ONLY. THE QUENCH WATER AND WASH WATER SYSTEMS ARE EXPECTED TO CONSTANTLY PURGE WATER.
4. PROVISION FOR FUTURE CAUSTIC INJECTION UPSTREAM OF QUENCH PUMPS IN CASE SO2 IN FLUE GAS FEED IS HIGHER THAN EXPECTED.
5. DELETED.

THIS DRAWING HAS BEEN DRAFTED BASED ON THE INPUTS RECEIVED FROM THE PROCESS LICENSOR, SHELL CATALYSTS AND TECHNOLOGIES (SCT).

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0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

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Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX
DEER PARK, TX

TITLE

PROCESS FLOW DIAGRAM
CO2 CAPTURE UNIT LEGENDS AND SYMBOLS

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-003	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0010	0

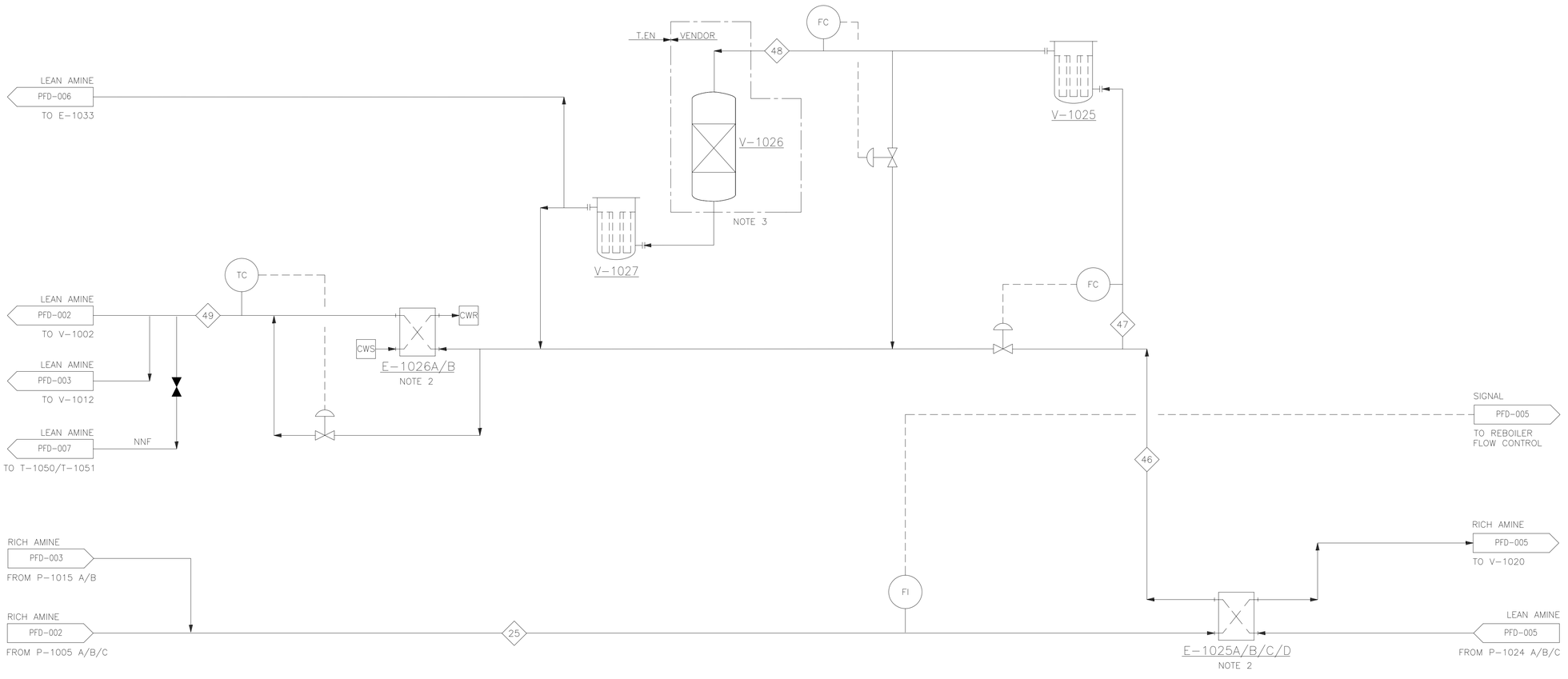
E-1026A/B
LEAN AMINE
COOLER

V-1027
LEAN AMINE
POST-FILTER

V-1026
LEAN AMINE
CARBON FILTER

V-1025
LEAN AMINE
FILTER

E-1025A/B/C/D
LEAN / RICH AMINE
EXCHANGER



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2. THE SPECIFIED NUMBER OF PUMPS AND EXCHANGERS REFLECTS THE MINIMUM SPARING PHILOSOPHY APPLIED FOR THE PROJECT. THE FINAL EQUIPMENT SPARING PHILOSOPHY IS SUBJECT TO CHANGE BASED ON THE APPLICATION OF INDUSTRY STANDARD EQUIPMENT SIZING LIMITATIONS.
3. FILTER VENDOR SCOPE.

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0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

NON-PROTECTED VERSION

Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

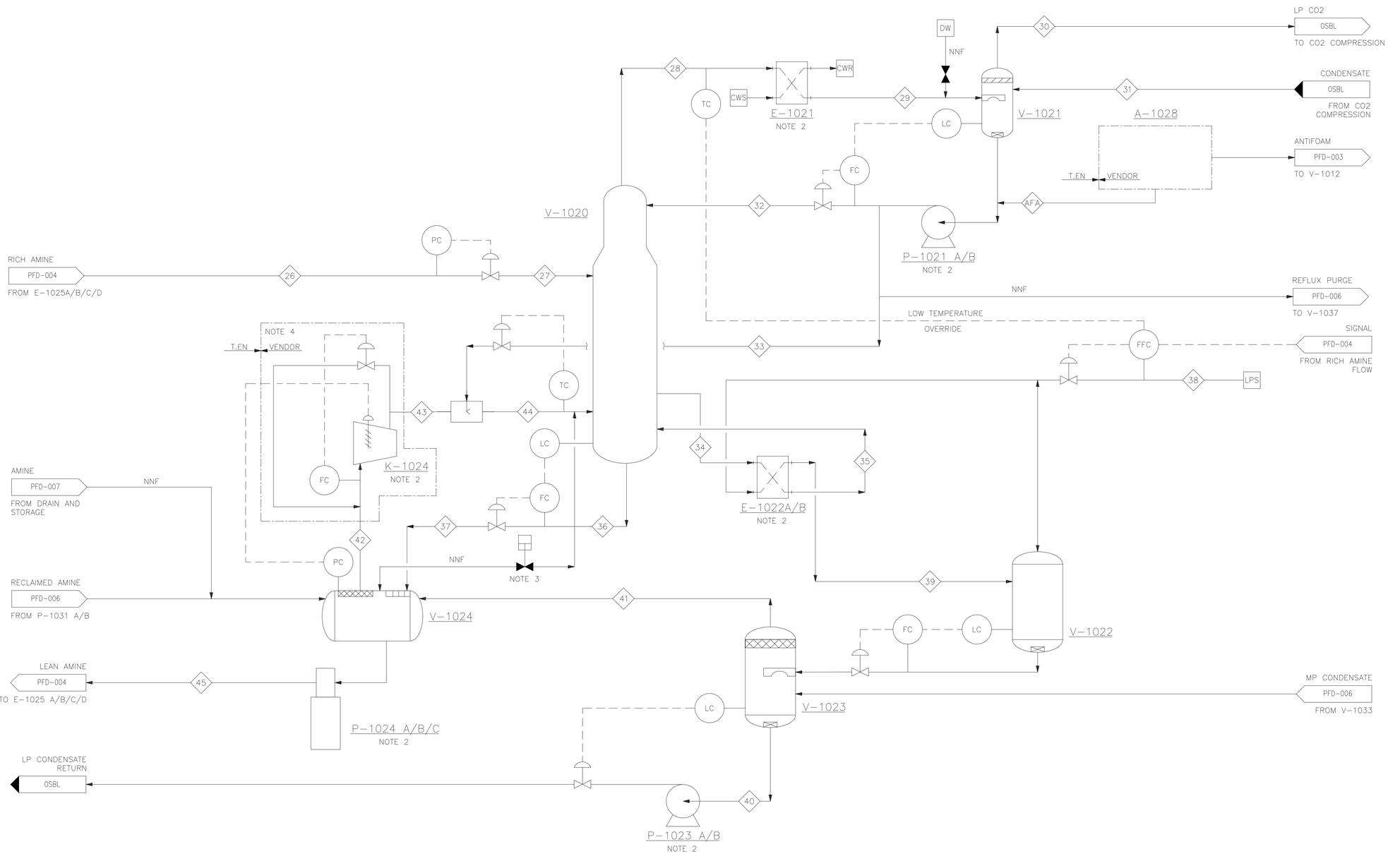
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX DEER PARK, TX

TITLE

PROCESS FLOW DIAGRAM
CO2 CAPTURE UNIT LEGENDS AND SYMBOLS

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-004	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0011	0

P-1024 A/B/C	V-1024	K-1024	V-1020	P-1023 A/B	V-1023	E-1022A/B	E-1021	P-1021 A/B	V-1021	V-1022	A-1028
LEAN AMINE PUMP	LEAN FLASH VESSEL	LEAN FLASH COMPRESSOR	AMINE REGENERATOR	CONDENSATE PUMP	CONDENSATE FLASH VESSEL	AMINE REBOILER	AMINE REGENERATOR REFLUX CONDENSER	REGENERATOR REFLUX PUMP	AMINE REGENERATOR REFLUX VESSEL	REGENERATOR REBOILER CONDENSATE VESSEL	REGENERATOR ANTIFOAM CHEMICAL INJECTION PACKAGE



NOTES

1. THE OVERALL PLANT CONFIGURATION FOR THE CO2 CAPTURE FACILITIES CONSISTS OF TWO (2) SEPARATE QUENCH AND ABSORBER TRAINS FOR THE OP3A AND OP3B/HT2 FEEDS, AS WELL AS COMMON REGENERATION, THERMAL RECLAIMING, AND AMINE DRAIN / STORAGE SYSTEMS THAT SERVE BOTH THE OP3A AND OP3B/HT2 QUENCH AND ABSORBER TRAINS.
2. THE SPECIFIED NUMBER OF PUMPS AND EXCHANGERS REFLECT THE MINIMUM SPARING PHILOSOPHY APPLIED FOR THE PROJECT. THE FINAL EQUIPMENT SPARING PHILOSOPHY IS SUBJECT TO CHANGE BASED ON THE APPLICATION OF INDUSTRY STANDARD EQUIPMENT SIZING LIMITATIONS.
3. VALVE SHALL BE OPENED TO EQUALIZE PRESSURE BEFORE START-UP OR AFTER TRIP OF LEAN FLASH COMPRESSOR.
4. COMPRESSOR VENDOR SCOPE.

THIS DRAWING HAS BEEN DRAFTED BASED ON THE INPUTS RECEIVED FROM THE PROCESS LICENSOR, SHELL CATALYSTS AND TECHNOLOGIES (SCT).

REV	REVISION DESCRIPTION	DATE	CHECKED	APPROVED	PROJ APR
0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

NON-PROTECTED VERSION

Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

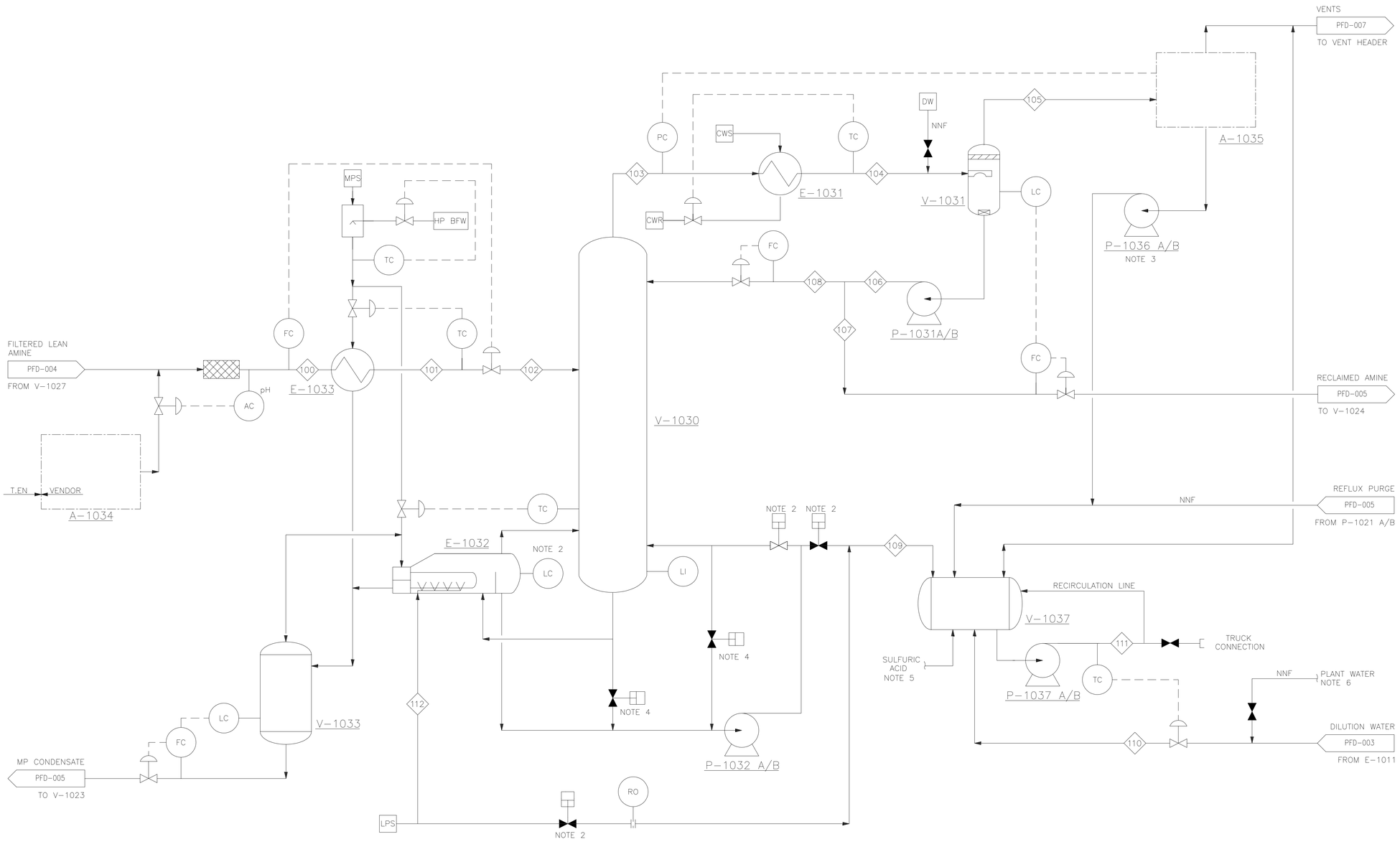
FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX DEER PARK, TX

TITLE

PROCESS FLOW DIAGRAM AMINE REGENERATOR

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-005	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0012	0

V-1030 AMINE RECLAIMER	V-1031 THERMAL RECLAIMER REFLUX VESSEL	A-1034 CAUSTIC PACKAGE	V-1037 DEGRADED AMINE STORAGE VESSEL	V-1033 TRU REBOILER CONDENSATE VESSEL	E-1033 THERMAL RECLAIMER PREHEATER	E-1031 THERMAL RECLAIMER CONDENSER	E-1032 THERMAL RECLAIMER REBOILER	P-1031A/B THERMAL RECLAIMER REFLUX PUMP	P-1037A/B DEGRADED AMINE PUMP	P-1036 A/B VACUUM PACKAGE CONDENSATE PUMP	P-1032 A/B THERMAL RECLAIMER BOTTOMS PUMP	A-1035 VACUUM PUMP PACKAGE



NOTES

1. THE OVERALL PLANT CONFIGURATION FOR THE CO2 CAPTURE FACILITIES CONSISTS OF TWO (2) SEPARATE QUENCH AND ABSORBER TRAINS FOR THE OP3A AND OP3B/HT2 FEEDS, AS WELL AS COMMON REGENERATION, THERMAL RECLAIMING, AND AMINE DRAIN / STORAGE SYSTEMS THAT SERVE BOTH THE OP3A AND OP3B/HT2 QUENCH AND ABSORBER TRAINS.
2. TRU BOTTOMS RECIRCULATION AND DISCHARGE VALVES OPERATED BY TRU SEQUENCE CONTROL LOGIC WITH STEAM PRE-HEATING/PURGING BEFORE AND AFTER MATERIAL DISCHARGE. TRU SEQUENCE CONTROL LOGIC INITIATED BY HIGH AND LOW LEVELS IN POST-WEIR COMPARTMENT ON THERMAL RECLAIMER REBOILER E-1032.
3. CONDENSATE PUMP P-1036 A/B MAY BE SPECIFIED AS PART OF VENDOR SCOPE FOR A-1035, AND AS SUCH P-1036 A/B MAY NOT BE REQUIRED.
4. VALVES SHALL BE OPENED TO DRAIN COLUMN SUMP, REBOILER, AND ASSOCIATED LINES TO PREVENT SOLIDIFICATION UPON LOSS OF STEAM TO REBOILER.
5. PROVISION FOR FUTURE SULFURIC ACID CONNECTION TO NEUTRALIZE WASTE.
6. PLANT WATER SHALL BE USED FOR DILUTION WATER WHEN OP3B-HT2 QUENCH SYSTEM IS OUT OF SERVICE.

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REV	REVISION DESCRIPTION	DATE	CHECKED	APPROVED	PROJ APR
0	ISSUED FOR PACKAGE	5/12/23	KC	EA	AL

NON-PROTECTED VERSION

Technip Energies USA, Inc. TBPE Firm Reg. No. F-3030

CLIENT
SHELL

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX
DEER PARK, TX

TITLE
PROCESS FLOW DIAGRAM
THERMAL RECLAIMER

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS-2000-PRO-PFD-N-0001-006	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C-000-PFD-0010-0013	0

P–1056 REGEN–TRU DRAIN VESSEL PUMP

V–1056 REGEN–TRU AMINE DRAIN VESSEL

V–1057 REGEN–TRU DRAINED AMINE FILTER

P–1053 OP3B–REGEN DRAIN VESSEL PUMP

V–1053 OP3B–REGEN AMINE DRAIN VESSEL

V–1054 OP3B–REGEN DRAINED AMINE FILTER

T–1050/T–1051 AMINE STORAGE TANKS

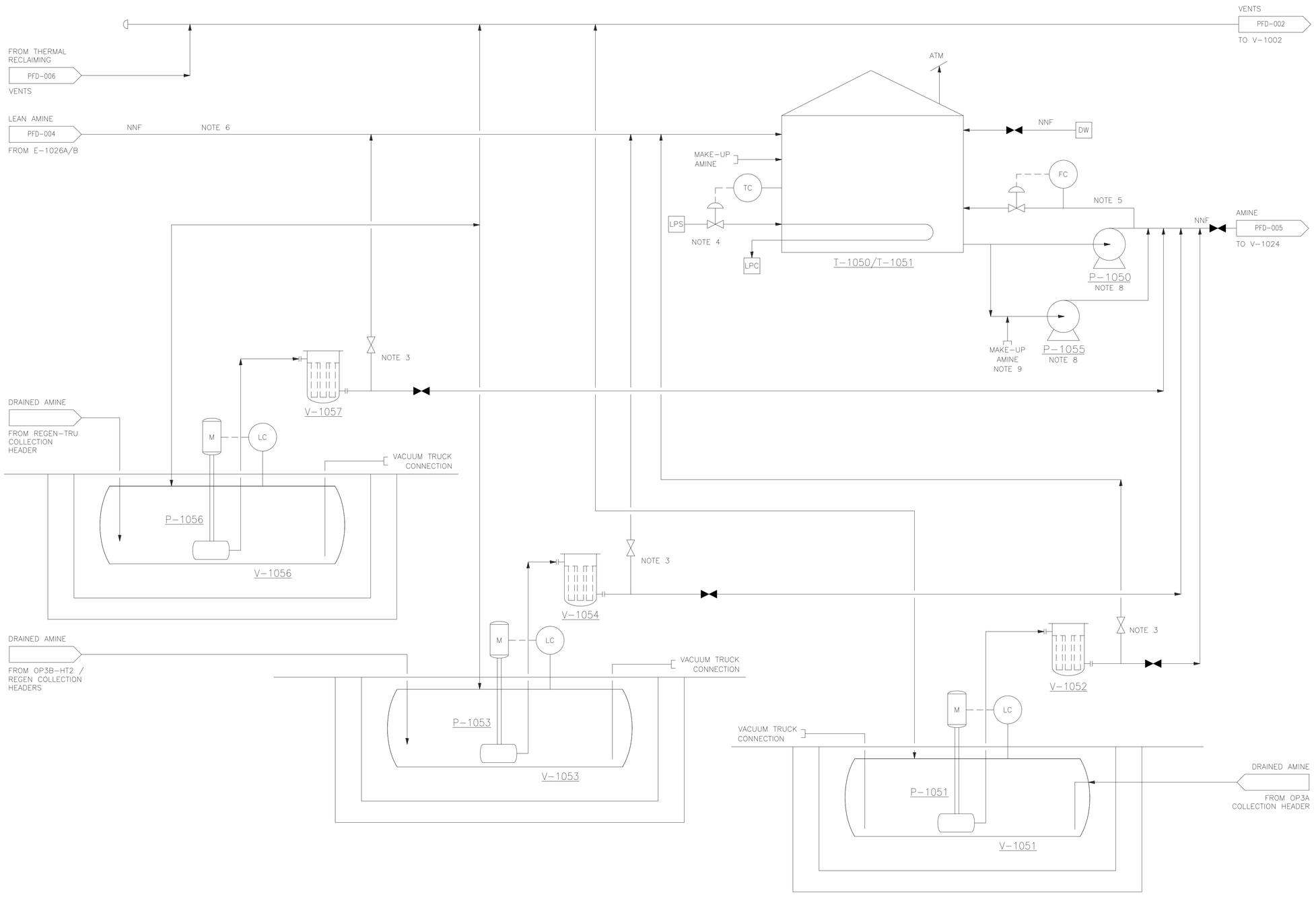
P–1051 OP3A DRAIN VESSEL PUMP

V–1051 OP3A AMINE DRAIN VESSEL

V–1052 OP3A DRAINED AMINE FILTER

P–1050 AMINE TANK TRANSFER PUMP

P–1055 AMINE MAKEUP PUMP



NOTES

1. THE OVERALL PLANT CONFIGURATION FOR THE CO2 CAPTURE FACILITIES CONSISTS OF TWO (2) SEPARATE QUENCH AND ABSORBER TRAINS FOR THE OP3A AND OP3B/HT2 FEEDS, AS WELL AS COMMON REGENERATION, THERMAL RECLAIMING, AND AMINE DRAIN / STORAGE SYSTEMS THAT SERVE BOTH THE OP3A AND OP3B/HT2 QUENCH AND ABSORBER TRAINS.
2. DELETED.
3. VALVES TO BE INTERLOCKED SO THAT ONLY PATH TO T–1050/T–1051 OR V–1024 IS OPEN.
4. HEATING COIL TO BE PROVIDED AT BOTTOM OF T–1050 / T–1051 TO PREVENT FREEZING EXCESSIVE VISCOSITY WHEN CONCENTRATED AMINE IS STORED IN T–1050 / T–1051.
5. RECYCLE TO PROMOTE MIXING OF FRESH AMINE WITH WATER IN TANK.
6. LINE IS USED FOR BULK DE–INVENTORYING OF THE AMINE SYSTEM DURING TURNAROUND.
7. DELETED.
8. THE AMINE MAKE–UP PUMP SHALL BE USED FOR NORMAL AMINE MAKE–UP OPERATIONS, WHILE THE AMINE TANK TRANSFER PUMP SHALL BE USED TO INVENTORY SYSTEM IN A REASONABLE DURATION DURING INITIAL FILL.
9. TRUCK CONNECTION CAN BE USED TO INVENTORY FRESH AMINE DIRECTLY FROM TRUCK TO THE SYSTEM.

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REV	REVISION DESCRIPTION	DATE	CHECKED	APPROVED	PROJ APR
0	ISSUED FOR PACKAGE	6/16/23	AFA	EA	AL

NON–PROTECTED VERSION

Technip Energies USA, Inc. TBPE Firm Reg. No. F–3030

CLIENT
SHELL

FRONT–END ENGINEERING DESIGN FOR CARBON CAPTURE
FROM SHELL'S DEER PARK CHEMICAL COMPLEX
DEER PARK, TX

TITLE

PROCESS FLOW DIAGRAM
AMINE DRAIN AND STORAGE

PROCESS BY	CLIENT NUMBER	DRAWN BY
AFA	DPKCCS–2000–PRO–PFD–N–0001–007	JV
PROJECT NUMBER	TECHNIP ENERGIES NUMBER	REVISION
214176C001	214176C–000–PFD–0010–0014	0

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

OSBL

UTILITY CONSUMPTION LIST

Date of Issue :	19-Apr-23
Wood Document Number:	DPKCCS-1000-PRO-LIS-N-0004
Wood Document Revision:	A
Customer Name:	Department of Energy NETL
Customer Document Number:	---
Customer Document Revision:	---

Federal Prime Contract No. DE-FE0032142

Non-protected Data

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Rev	Date	Issued For	Wood		Department Technical Authority	Project Manager	Customer
			Prepared	Checked			
A	19-Apr-23	Information	DB	MG	JH	RR	

wood.	**OSBL UTILITY CONSUMPTION LIST**	REV.	DATE	DESCRIPTION	APPV.	SHEET 1 OF 1	
		A	19-Apr-23	Issued For Information	MG	SPEC. NO.:	DPKCCS-1000-PRO-LIS-N-0004
						REV. NO.:	A
CLIENT:	Department of Energy NETL					PROJ. NO.:	254206
PROJECT:	FEED For Carbon Capture From Shell's Deer Park Chemical Complex					BY:	DB
LOCATION:	Shell Deer Park Complex, Texas					DATE:	19-Apr-23

SERVICE	UOM	DESIGN VALUE (NOTE 1, 2)	REMARKS / BASIS	REV
MAKE-UP WATER FOR OSBL USERS	GPM	(5,300)		
MAKE-UP WATER IMPORT FROM SHELL DEER PARK	GPM	**5,300**		
INSTRUMENT AIR CONSUMPTION TO OSBL USERS	SCFM	(160)	Normal usage for instruments / equipment packages has been estimated, since vendor data is not available yet. Intermittent / start-up usage could be higher, to be developed later.	
INSTRUMENT AIR CONSUMPTION TO ISBL USERS	SCFM	(180)	NOTE 3	
INSTRUMENT AIR IMPORT FROM SHELL DEER PARK	SCFM	**340**		
UTILITY / PLANT AIR CONSUMPTION TO OSBL USERS	SCFM	(150)		
UTILITY / PLANT AIR CONSUMPTION TO ISBL USERS	SCFM	(100)	NOTE 3	
UTILITY / PLANT AIR IMPORT FROM SHELL DEER PARK	SCFM	**250**		
DEMIN WATER CONSUMPTION TO ISBL USERS	GPM	(140)	NOTE 3	
DEMIN WATER IMPORT FROM SHELL DEER PARK	GPM	**140**		
POTABLE WATER CONSUMPTION TO OSBL USERS	GPM	(70)		
POTABLE WATER CONSUMPTION TO ISBL USERS	GPM	(90)	NOTE 3	
POTABLE WATER IMPORT FROM SHELL DEER PARK	GPM	**160**		
SERVICE / PLANT WATER CONSUMPTION TO OSBL USERS	GPM	(70)		
SERVICE / PLANT WATER CONSUMPTION TO ISBL USERS	GPM	(340)	NOTE 3	
SERVICE / PLANT WATER IMPORT FROM SHELL DEER PARK	GPM	**410**		
WASTE WATER / QUENCH WATER GENERATION FROM OSBL USERS	GPM	110		
WASTE WATER / QUENCH WATER GENERATION FROM ISBL USERS	GPM	380		
WASTE WATER / QUENCH WATER RETURN TO SHELL DEER PARK	GPM	**(490)**		
HP BFW IMPORT FROM SHELL DEER PARK	GPM	**10**		
NITROGEN IMPORT FROM SHELL DEER PARK	SCFM	**510**		

NOTES:

1. Selected utilities and estimated value are shown based on currently available data, pending additional design development. Other utilities like HP/MP/LP Steam, Condensate Return, Cooling Water, Power may be needed.
2. Utility import from Shell Deer Park and internal production are shown as positive xxx values. OSBL /ISBL internal consumption and return to Shell Deer Park are shown as negative (xxx) value.
3. Per "UTILITY CONSUMPTION LIST ISBL (DPKCCS-2000-PRO-LIS-P-0018)", Rev. A.
4. (DELETED)

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

Estimate Plan

Date of Issue:	30 May 2023
Internal Document Number:	DPKCCS-0000-PMT-EST-P-0001
Internal Document Revision:	<0>
Customer Name:	Department of Energy NETL
Customer Document Number:	--
Customer Document Revision:	--

Federal Prime Contract No. DE-FE0032142

Protected Data

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Rev	Date	Issued For	Wood		Department Manager/ Technical Authority	Project Manager	Customer
			Prepared	Checked			
A	11 April 2023	Review	A. Garcia	T. Mann	---	R. Ramsey	---
0	30 May 2023	Use	A. Garcia	T. Mann	---	R. Ramsey	---
				Tracy Mann	---		---

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Project Name:	**FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX**	
Internal No.:	**DPKCCS-0000-PMT-EST-P-0001**	**Rev. No.: <0>**
Customer No.:	**--**	**Rev. No.: --**

1.0 PROJECT DESCRIPTION

The project objective is to execute and complete front-end engineering and design (FEED) to separate and capture 915,000 tonnes per year (tpy) CO2 emissions from the commercially operated Shell Chemicals Complex located in Deer Park, Texas, USA reducing the overall facility CO2 emissions by 95% while providing energy transition jobs in a commercial area with a high concentration of refinery and chemical facilities producing CO2 emissions. The project will use CANSOLV technology to capture CO2 emitted from Olefin Units and a Hydrotreater Unit to reduce the overall facility CO2 emissions by 95%.

2.0 PURPOSE

The purpose of this document is to describe the means, methods, and approach by which the FEED TIC Estimate will be prepared for the Carbon Capture from Shell Deer Park's Chemical Complex Project and the roles and responsibilities for the project team. While it is intended that this document, once accepted by the project team, will serve as the official Estimate Plan, some additions and revisions may be required as the project progresses.

The purpose of this Estimate Plan is to develop -20% to +30% FEED TIC Estimate.

3.0 REQUIRED ESTIMATE ACCURACY

In this phase, Wood will be responsible and accountable to develop a Class 3 type TIC Estimate based on the AACEI Cost Estimate Classification System[1] with a target accuracy range of -10% to -20% on the low side and +10% to +30% on the high side.

[1] *AACE International Recommended Practice No. 18R-97*

4.0 ESTIMATE CONTENT & SCOPE

The estimate will be consistent with the overall Project Execution Philosophy. The estimate will include assessed costs for overall project management, home office engineering and support required for the FEED, and Detailed phase(s), and construction up to and including mechanical completion of the IBSL and OSBL facilities scopes of work. The estimate will include Wood assessed Escalation, Contingency, and Event Driven Risk.

5.0 ESTIMATE SCHEDULE MILESTONES

Reference: DOE FOA Carbon Capture FEED Project Schedule (March 28, 2023)

- ISBL (Technip) Final MTO's to Estimating — Aug 21, 2023
- OSBL (Wood) Final MTO's to Estimating — Sept 11, 2023
- Wood Management Review — Sept 29, 2023
- Issue Estimate (IFR) — Oct 06, 2023
- Issue Estimate (IFU) — Nov 3, 2023

6.0 WORK BREAKDOWN STRUCTURE

The estimate will be organized according to the project defined Work Breakdown Structure (WBS) as provided by Shell. The WBS will reflect the physical and/ or contractual boundaries of the work and provide the framework to organize and summarize the estimate. Estimated material, labor, and subcontract costs will be compiled in accordance with Wood Standard Code of Accounts for each of the units.

7.0 CURRENCY BASIS & EXCHANGE RATES

All costs will be reported Q3 2023 United States Dollars (USD).

Foreign Exchange Rates (FOREX) conversion rates will be applied as applicable (fixed on August 1, 2023) and noted in the Estimate Basis.

8.0 ESTIMATE METHODOLOGY & DELIVERABLE REQUIREMENTS

8.1 GENERAL

a) The cost estimate will be developed in strict accordance with DOE and Shell requirements, Wood Estimating procedures, and the requirements defined in the Estimate Plan. The Cost Estimate will be developed utilizing Aspen Capital Cost Estimator™ (ACCE). The estimate will be compiled and presented utilizing ACCE, incorporating the Work Breakdown Structure for the project with all quantities and costs compiled in ACCE standard COA for each of the units.

b) The Engineering Group(s) are responsible for developing a quantity-based representation[1] (material take-off) that accurately reflects the final FEED scope of work based on project specific specifications, applicable codes and standards, vendor data, and design parameters utilizing a combination of design software and manual techniques. The Engineering Group(s) are responsible for identifying, conceptualizing, and developing a material take-off's for scope items excluded from the design model. More specifically:

- Scope items excluded from the design model(s) are to be identified
- Engineering will develop a representation, such as a design sketch, for each scope item
- Engineering will develop a quantity-based representation that accurately reflects the design

The Estimating and Engineering Group(s) will work together throughout the project life cycle to develop the required scope and quantities. All work will be jointly reviewed and owned by both groups during and at the project end.

c) The Engineering Manager is responsible for the following:

- Monitoring the status of deliverable from the Engineering Group(s)
- Expediting the deliverables from the Engineering Group(s) in accordance with the Estimate Execution Plan, Estimate Schedule, and Estimate Checklist
- Ensuring the deliverables from the Engineering Group(s) to Estimating are complete, correct, and the WBS codes have been assigned to each MTO line item

- Final release and transfer of the engineering deliverables to Estimating

d) The material take-off (MTO) will be based on the design as represented on the drawings with no allowances included. Allowances[2] (identified as line items in the estimate detail) will be applied/ incorporated into the summary of material costs and labor hours for each prime account to cover a specific element of scope that is not yet fully defined. (Scope which is not fully defined shall be identified to DOE and Shell). The amount is usually based on broad experience rather than direct pricing or factoring against the cost of a defined item, such as equipment. There will be multiple allowances in the estimate, and each will be a separate line item. Estimating, in conjunction with the engineering discipline specialists that provided input into the estimate, will establish appropriate allowances for each prime account based on a combination of formal assessment and historical results.

e) All material take-off's shall be traceable to design drawings, sketches, or layouts

f) All quantities will be reported in the United States Customary System Units (USCS) of measurement.

g) Materials pricing (equipment and bulks), fabrication (pipe spools and modules), and subcontract unit rates will be based on a combination of budget quotations and in-house data. (As a minimum, 80% of the equipment and bulk materials pricing will be based on budget quotations). Final analysis and evaluation of quotations will be completed by the Estimating Group.

h) The Estimating Group will identify the various labor operations for each commodity group, quantify each labor operation, and assign unit work hours for each labor operation utilizing the ACCE generated hours (indexed to the Wood Standard Unit Work Hours). Work hours for non-standard labor operations (such as: set and place of modules, equipment modifications, tie-in's into existing piping systems, etc.) will be developed utilizing crew size-duration methods (tasks required to execute the work are identified, in sequential order, and crew sizing with defined durations assigned for each task). A site-specific calibration factor by prime account will be applied to the base Wood Standard Unit Work Hours to arrive at the site hours and module assembly yard hours based on a combination of current experience and recent comparable history. Project specific adjustments will be made for:

- Craft availability and skill level
- Supervision availability and skill level
- Labor posture
- Work week
- Project size
- Project type
- Health and safety requirements
- Site location/ climate variables

i) A composite all-in subcontract wage rate will be developed for each prime account based on historical crew mix(s) and the project defined work week (5 days on, 2 days off, 10 hours per day).

The all-in subcontract wages rates will include:

- Base Wage Rate
- Scheduled Overtime Premium

- Unscheduled (Spot) Overtime Premium
- Benefits & Burdens
- Government Assessments
- Basic Indirect Field Costs:
  - Temporary Construction Facilities
  - Construction Services
  - Field Staff & Supervision
  - Construction Equipment
  - Small Tools & Consumables
  - Contractor Mobilization/ De-mobilization.
- Contractor Overhead & Profit

Scaffolding hours and associated costs are considered a Direct Field Cost and as such included as a line item in the DFC estimate. Craft per-diem costs are considered an Indirect Field Cost and as such included as a line item in the IFC estimate.

j) A Basis of Estimate will be developed along with the Cost Estimate and will explain in detail the key components of the estimate including quantity development, labor hours, productivity adjustments, wage rates, subcontract unit rates, material and equipment pricing basis, indirect costs, taxes, escalation, contingency, and all other below the line costs. All allowances, assumptions, and clarifications that were made during the development of the Cost Estimate will be explained and summarized.

Presented below is an overview discussion for each engineering discipline concerning the roles, responsibilities, and deliverables required from each to prepare the estimate. Inputs to the estimate for ISBL and OSBL facilities will be provided by the respective contractor's Engineering group(s).

[1] *Reference Appendix 1 – Material Take-off Methods and Techniques*

[2] *Reference Appendix 2 – Allowances*

8.2 DIRECT FIELD COSTS

8.2.1 Demolition

The development of the material take-off for the Demolition scope of work will be completed by either the Engineering Group(s) or the Estimating Group, depending on the scope of work to be completed.

The Engineering Group(s) will be responsible for the development of a material take-off that reflects the defined scope for:

- Fencing (Fence quantity by type)
- Concrete (Concrete quantity by foundation type)
- Structural Steel (Steel quantity – by weight category)

- Buildings (Building List with sizing – length, width, height)
- Mechanical Equipment (Equipment List with basic design information)
- Pipelines and Piping (Location – AG/ UG, metallurgy, diameter, length)
- Electrical (Equipment List with basic design information, cable quantity)
- Instrumentation (Instrument List)

The Engineering Group(s) will provide supporting documentation (plot plans with demolition scope identified, marked-up/ highlighted P&ID's for piping systems, and marked-up/ highlighted electrical single-line diagrams)

Modularization

Current design is based on stick-built construction. No modularization is to be considered in this phase.

8.2.2 Civil Works

The development of the material take-off for the Civil Works scope of work will be completed by either the Civil Engineering Group or the Estimating Group, depending on the scope of work to be completed.

The Civil Engineering Group will be responsible for the development of a material take-off that reflects the final FEL-3 defined scope for:

- Hazardous material
- Site clearing and grubbing
- Rough grading
- Mass excavation and backfill
- Excavation and backfill for equipment, building, and structural foundations
- Plant roads
- Paving (asphalt/ gravel)
- Landscaping
- Underground services (non-process piping systems and electrical)
- Railroad systems
- Bridges
- Dikes or drainage ditches
- Fencing
- Piles
- Soils improvements

The Estimating Group will develop unit rate pricing based on a combination of budgetary pricing and in-house data.

The estimate will be coded to the defined WBS.

8.2.3 Concrete

The development of the material take-off for the Concrete scope of work will be completed by either the Civil Engineering Group or the Estimating Group, depending on the scope of work to be completed.

The Civil Engineering Group will be responsible for the development of a material take-off that reflects the final FEL-3 defined scope for:

- Area paving (concrete)
- Concrete structures
- Equipment foundations
- Building foundations
- Structural foundations
- Pre-cast assemblies
- Culverts, sumps, pits, basins
- Plant road curbs and parking lot bumpers
- Mud mats
- Grout

All concrete quantities will be kept separate by individual component and by foundation type[1]. The formwork, rebar, embeds, and finishes will be generated by the Estimating Group referencing standard models for each foundation type. An allowance for concrete overpour will be included for each foundation type.

The Estimating Group will develop bulk material pricing based on a combination of budgetary pricing and in-house data for formwork, rebar, embeds, and concrete.

The Estimate will be coded to the defined WBS.

[1] Reference Appendix 3 – Foundation Types

8.2.4 Structural Steel

The development of the material take-off for the Structural Steel scope of work will be completed by either the Structural Engineering Group or the Estimating Group, depending on the scope of work to be defined.

The Structural Engineering Group will be responsible for the development of a material take-off that reflects the defined scope for:

- Equipment structures
- Process unit and interconnecting pipe racks
- Sleepers and bridges
- Valve access platforms
- Equipment access platforms
- Truck loading platforms and conveyor systems

- Equipment ladders and platforms
- Support steel (mechanical equipment, piping, electrical)
- Guard rail for roads
- Cladding

The structural steel quantities will be divided into typical weight categories: light, medium, heavy, and extra heavy, by structure. Connection allowances will be included as a percentage addition to the neat quantity take-off. In addition, quantities will be divided into typical weight categories for grating, stairs, ladders, platforms, and handrails and in addition will reflect linear foot and square foot respectively. All quantities will also reflect coating requirements. Drawings for pipe racks, structures, and access platforms will be provided.

The Estimating Group will develop bulk material pricing based on a combination of budgetary pricing and in-house data for structural steel components.

The Estimate will be coded to the defined WBS.

8.2.5 Architectural

The Architectural Engineering Group will develop the project Building Matrix (for non-electrical buildings) with input from their architectural and HVAC experts. The Building Matrix will identify the building type, dimensions, number of floors, stick-built or modular, HVAC requirements, electrical requirements, utility requirements, fire protection requirements, and plumbing requirements. Dimension drawings/ sketches for each building will be provided.

The Estimating Group will develop pricing based on in-house data for buildings.

The Estimate will be coded to the defined WBS.

8.2.6 Mechanical Equipment

The Process/ Mechanical Engineering Group will be responsible for the development of a mechanical equipment list and associated data sheet(s) for all tagged mechanical equipment/packages, and heater ducts, as per the defined WBS. The equipment list will provide basic design information, as applicable for each equipment type, including: physical dimensions, weight, capacity, surface area (exchangers), horsepower, flow rate, materials of construction, design temperatures, design pressures, and any paint, tracing, insulation, refractory or fireproofing requirements.

The equipment pricing will be based on a combination of budgetary quotations and in-house data

The Engineering Group in conjunction with the Procurement and Estimating Groups will develop equipment pricing based on technically and commercially approved quotations in accordance with the following parameters:

- Three (3) vendors for tag items valued greater than $ 250,000
- Two (2) vendor quotations for tag items valued between $ 50,000 and $ 250,000
- One (1) vendor quotation or validated in-house pricing data shall be required for items valued less than $ 50,000.

A review meeting will be held between the three disciplines prior to handover in which all cost basis will be discussed and agreed.

The Supply Chain Group will complete the commercial evaluation and accept complete ownership, accountability and responsibility for the quality, completeness, and accuracy of the Commercial Bid Evaluation (CBE). The Engineering Group will complete the technical evaluation and accept complete ownership, accountability and responsibility for the quality, completeness, and accuracy of the Technical Bid Evaluation (TBE).

The equipment pricing will exclude the design development allowance. Estimating, in conjunction with the Mechanical Engineering Group and Supply Chain Group, will establish appropriate allowances based on a combination of formal assessment and historical results. Any additional pricing for ladders & platforms, fireproofing, tracing, insulation, freight, etc. should be listed separately. Suppliers who elect to assemble equipment on site (tanks, heaters, etc.) shall provide estimated site erection man-hours and on-site requirements (temporary facilities, water, etc.). Capital spares and first fill of chemicals, and lube oils will be included.

The Mechanical Engineering Group will work closely with the Estimating Group to communicate the required scope of assembly for the equipment (i.e., skids, modules, and/ or equipment requiring field assembly, heavy lifts, long reach, etc.).

The Estimate will be coded to the defined WBS.

Reference Appendix 4 – Minimum Equipment Data Required

8.2.7 Piping

The development of the material take-off for the Piping scope of work will be completed by either the Piping Engineering Group or the Estimating Group, depending on the scope of work to be completed.

The Piping Engineering Group will develop a material take-off that reflects the project scope based on project specifications, applicable codes and standards, vendor data, and design drawings utilizing a combination of design software and manual techniques.

The Piping Engineering Group will generate a complete material take-off (pipe, fittings, flanges, and valves) for all above ground and underground piping systems including line identifications for all critical lines and large bore (6" diameter and greater) pipe utilizing a combination of SmartPlant™ 3-D (modeling software) and a manual material take-off. Piping one-line diagrams, isometric sketches or material take-offs will be provided to Estimating for non-modeled 3" and above lines. Piping 2" and below will be factored based on historical norms. The Piping Engineering Group will be responsible for compiling the piping material take-off into the Piping Standard MTO Template provided by estimating and populating the applicable attributes for each line item developed.

Fitting (3D model) and valve (P&ID and 3D model) shall be reviewed. Fitting frequencies will be adjusted based on historical averages by the Estimating group. The Engineering Group will identify, conceptualize, and quantify supplementary utility systems.

The Piping Engineering Group will generate a complete material take-off (pipe, fittings, flanges, and valves) for all underground piping systems, specialty items, fire protection systems (excluding building fire protection system), deluge systems, steam/glycol heat tracing, etc.

The Estimating Group will derive costs for shoes, guides, hangers, vents and drains, gasket, nuts and bolts, non-destructive examination (NDE), stress relieving, chemical cleaning (the Piping Engineering Group will identify piping systems/ lines), hydro-testing, and flushing of the pipe up to mechanical completion. Prorates will be applied for labor operation that cannot be quantified, such as hydrotesting, based on historical data.

The Estimating Group will develop bulk material and shop fabrication pricing based on a combination of budgetary pricing and in-house data.

The Estimate will be coded to the defined WBS.

8.2.8 Electrical

The development of bulk material quantities for the Electrical scope of work will be completed by either the Electrical Engineering Group or the Estimating Group, depending on the scope of work to be completed.

The Electrical Engineering Group will develop a material take-off that represents the defined scope of work for:

- Incoming (high voltage) power feed
- Main substation and unit substations
- Major electrical equipment
- Home run/ fiber optic cable (based on input from Instrumentation/Telecom group)
- Pole lines
- Cathodic protection
- Transformers
- Power cable from equipment to MCC
- Control cable from instrument(s) to junction box(s) (based on input from Instrumentation group)
- Lighting
- Cable tray and associated fittings
- Grounding
- Cable for telephone, radio, and intercom systems (based on input from Instrumentation/Telecom group)
- Building electrical
- Electrical heat tracing

The Electrical Engineering Group will be responsible for compiling the material take-off into the Electrical Standard MTO Template provided by estimating and populating the applicable attributes for each line item developed.

Electrical heat tracing requirements for piping systems (tracing type and number of tracers) will be defined on the Piping MTO Requirements template. The Estimating Group will develop a material take-off for electrical heat tracing required for mechanical equipment tags. Electrical heat tracing required for specific instruments will be defined on the associated instrument installation detail(s).

The Engineering Group in conjunction with the Procurement and Estimating Groups will develop equipment pricing based on technically and commercially approved quotations from at least three (3) vendors for all electrical equipment items valued at greater than $ 50,000. One (1) quotation or validated in-house data shall be required for items valued less than $ 50,000. A review meeting will be held between the three disciplines prior to handover in which all cost basis will be discussed and agreed.

The Supply Chain Group will complete the commercial evaluation and accept complete ownership, accountability and responsibility for the quality, completeness, and accuracy of the Commercial Bid Evaluation (CBE). The Engineering Group will complete the technical evaluation and accept complete ownership, accountability and responsibility for the quality, completeness, and accuracy of the Technical Bid Evaluation (TBE).

The Estimating Group will develop pricing for all bulk materials pricing based on a combination of budgetary pricing and in-house data.

The Estimate will be coded to the defined WBS

8.2.9 Control Systems

The development of Instrumentation scope of work will be completed by either the Instrumentation Engineering Group or the Estimating Group, depending on the scope of work to be completed.

The Instrumentation Engineering Group will develop a material take-off that represents the defined scope of work for:

- Distributed Control System (DCS)
- Process Control System (PCS)
- Emergency Shutdown System (ESD)
- Programmable Logic Controller (PLC)
- Tagged instruments
- Fiber Optic and Home Run cable
- Analyzers
- Fire & Gas Detection Systems
- Satellite Buildings (RIEs), remote I/O panels
- Bulk materials

All tagged instruments in the Instrument index will be taken off by Engineering from the P&IDs with applicable installation details assigned. The Instrumentation Engineering Group will develop pricing for all control systems and instruments based on a combination budgetary pricing and in-house data. The Estimating Group will develop pricing for all bulk materials based on a combination of budgetary pricing and in-house data.

The Estimate will be coded to the defined WBS.

8.2.10 Telecommunication

The development of material quantities for the Telecommunication scope of work will be completed by the Telecommunication Engineering Group.

The Estimating Group will develop pricing based on in-house data.

The Estimate will be coded to the defined WBS.

8.2.11 Insulation

The development of the material take-off for the insulation scope of work will be completed by either the

Mechanical Engineering Group, Piping Engineering Group, or the Estimating Group, depending on the scope of work to be completed.

The Mechanical Engineering Group will define the insulation requirements (insulation type, thickness, and jacket type) on the mechanical equipment list. The Estimating Group will develop the material take-off utilizing models that account for insulation on the component.

The Piping Engineering Group will be responsible for identifying the insulation requirements (insulation type, thickness, and jacket type) in the Piping Standard MTO Template provided by estimating and populating the applicable attributes for each line item developed. The Estimating Group will develop material take-off utilizing ACCE.

It is assumed all insulation (to the maximum extent possible) will be applied off-site. Insulation on mechanical equipment and/ or module piping will be identified as off-site installed or on-site installed as applicable. An allowance will be made for field "block outs" as required.

An allowance will be included for on-site repair of insulation (damaged as a result of construction activities) on mechanical equipment and piping.

The Estimating Group will develop bulk material pricing and/ or unit rates based on a combination of budget quotations and in-house data for insulation.

The Estimate will be coded to the defined WBS.

8.2.12 Paint

The development of the material take-off for the paint scope of work will be completed by the Estimating Group utilizing ACCE.

The Structural Engineering Group will be responsible for identifying the paint requirements in the Structural Standard MTO Template provided by estimating and populating the applicable attributes for each line item.

The Mechanical Engineering Group will be responsible for identifying the paint and/ or coating requirements for mechanical equipment tags which require on-site application (typically field fabricated storage tanks). The intent is that the majority mechanical equipment tags will arrive at the site finish painted and will require field touch-up only.

The Estimating Group will develop a material take-off utilizing ACCE models (in accordance with the parameters defined in Shell DEPS) that account for paint on the pipe, fittings, valves, and related components. It is assumed that prefabricated pipe spools fabricated at an off-site location will arrive at site painted.

An allowance will be included for on-site repair of paint (damaged as a result of construction activities) on structural steel, mechanical equipment, and piping.

Paint material and labor costs for mechanical equipment tags which arrive at site painted will be included in the mechanical equipment cost.

The Estimating Group will develop bulk material pricing and/ or unit rates based on a combination of budget quotations and in-house data.

The Estimate will be coded to the defined WBS.

8.2.13 Fireproofing

The Structural Engineering Group will be responsible for identifying the fireproofing philosophy and requirements for all structures and similar work.

The Mechanical Engineering Group will be responsible for identifying the fireproofing requirements in the Equipment List.

The Structural Engineering Group will be responsible for identifying the fireproofing requirements on structural components and providing associated drawings.

The development of material take-off for the fireproofing scope of work will be completed by Engineering Group.

It is assumed all fireproofing (to the maximum extent possible) will be applied off-site.

An allowance will be included for on-site application for "block outs" and repair of fireproofing (damaged as a result of construction activities) on structural steel and mechanical equipment.

The Estimating Group will develop bulk material pricing and/ or unit rates based on a combination of budget quotations and in-house data.

The estimate will be coded to the defined WBS.

8.2.14 Scaffolding

The Estimating Group will develop the scaffolding requirements based on scope definition in conjunction with historical data from projects similar in nature and geographic location. Estimated scaffolding hours will be calculated as a multiplier applied the direct field labor hours associated with the applicable prime accounts. Scaffolding material costs (purchase and/ or rental) will be based on in-house data.

8.2.15 Freight

Freight costs for general cargo will be calculated as a multiplier (percentage) applied to the bulk material and equipment costs for standard inland transportation.

Freight costs for ocean transportation, over-weight cargo (OWC)[1] and over-dimension cargo (ODC)[2] will be developed based on budget quotations.

Freight costs will include export packing, port terminal charges, port handling charges, and brokerage/ agent fees.

[1] *Over-weight cargo (OWC) – Exceeding maximum GVWR which may be operated on Texas State highways (80,000 pounds)*

[2] *Over-dimension cargo (ODC) – Exceeding maximum dimensions which may be operated on Texas State highways (Width – 8' 6" /Height – 14' /Length – 59')*

8.3 CONSTRUCTION INDIRECT FIELD COSTS

Construction contractor indirect cost shall be included with All-in labor rates (Refer to section 8.1.I).

All –in labor rates shall be compared against semi detailed bottoms-up indirect estimate.

Wood Estimating will develop the per diem and the how it will be applied the estimated direct and indirect craft hours.

8.4 GENERAL SITE MANAGEMENT & SITE WIDE SERVICES COSTS

The General Site Management and Site Wide Services costs will be developed by the Wood Estimating Group, with support from the Wood Construction Group.

8.5 HOME OFFICE COSTS

Home Office Costs are the costs of the EPC contractor's home office-based engineering and support personnel engaged in the execution and/ or management of a project. HOC costs typically include home office labor (salaries, benefits, and burdens), contractual mark-up, expenses, and third-party costs.

A home office staffing plan will be developed for this project. The engineering and support discipline groups will provide the estimated home office work hours to complete the detail engineering phase. These hours will be based on the project deliverables list, execution plan, and the EPC schedule. The hours assigned to the High Value Execution Centre (HVEC) will be delineated from the total hours with productivity adjustments defined and additional hours required for coordination/ interface identified. Allocation of hours to HVEC shall be based on deliverable assigned to HVEC office. Project Controls Group will compile the home office hours and develop the commercial rates including contractual mark-up's as per the terms in effect.

Home office expenses such as:

- Assignment policy costs – will be developed based on the commercial agreements in-place and assumed allocation of personnel eligible for policy
- Business travel costs – will be based on a combination of historical data and the estimated number of trips, durations, and destinations required.

Third party expenses such as:

- Speciality consultants – the Project Management and Engineering Group will identify any requirements and scope
- Supplier quality surveillance (SQS) and shop expediting – the Procurement Group will identify requirements and durations required.

8.6 OTHER COSTS

8.6.1 Vendor Representatives

The Estimating Group in conjunction with the Wood Engineering Group(s) will identify the vendor representatives required for mechanical equipment, electrical equipment, control systems, and instrumentation (including source Country and duration) for the construction, pre-commissioning, commissioning, and start-up phase(s).

8.6.2 Capital, Warehouse, Construction, Commissioning, & Operating Spares

Spares are defined as follows:

- Capital spares are partial assemblies which are typically quoted, evaluated, and purchased along with the original equipment. Partial assemblies (such as rotors, reduction gear sets, pump seals, etc.), are usually identical to installed units. Capital spares may require a trial fit-up, however generally they are stored in a warehouse in accordance with applicable equipment preservation procedures.
- Warehouse spares are complete assemblies which are typically quoted, evaluated, and purchased along with the original equipment. Assemblies (such as spare pumps) are usually identical to installed units. Warehouse spares may require a trial fit-up, however generally they are stored in a warehouse in accordance with applicable equipment preservation procedures.

  Warehouse spares are excluded.
- Construction spares are parts and assemblies which are typically quoted, evaluated, and purchased along with the original equipment. Construction spares are used or consumed during the installation, cleaning, flushing, and testing of equipment and systems. Parts and assemblies (such as gaskets, filters, screens, etc.), are usually identical to installed units.
- Commissioning spares are parts and assemblies which are typically quoted, evaluated, and purchased along with the original equipment. Commissioning spares are used or consumed from mechanical completion to start-up. Parts and assemblies (bearings, seals, etc.), are usually identical to installed units. Costs for commissioning spares will be factored as a percentage of the rotating equipment cost.
- Operating spares are parts and assemblies which are typically quoted, evaluated, and purchased along with the original equipment. Operating spares are those required for the 2nd and 3rd year of plant operation. Parts and assemblies (bearings, seals, etc.), are usually identical to installed units.

  Operating spares are excluded.

8.6.3 Pre-commissioning, Commissioning, & Start-up

Typically, owners provide standards and/ or guidelines which define mechanical completion and delineate completion activities (and define responsibilities) into three (3) phases: Pre-commissioning, Commissioning, and Start-up. Wood will not assess and/ or include costs associated with pre-commissioning, commissioning, and start-up.

8.6.4 First Fills

The Mechanical and Electrical Engineering Group(s) will identify (on the applicable equipment lists) the requirements and associated quantities for first fill of lubricants, transformer oils, chemicals, reagents, adsorbents, catalyst, etc.

The Estimating Group will develop bulk material pricing based on in budget quotes for first fills.

8.6.5 Duties & Taxes

Wood will not assess and/ or include costs associated with import duties and taxes including, but not limited to, Texas State Sales and Use Tax, as well as taxes associated with local taxing jurisdictions (City Sales and Use Tax, County Sales and Use Tax, Special Purpose Districts Sales and Use Tax, and Transit Sales and Use Tax).

8.7 ESCALATION

The Estimating group will develop the escalation model based on escalation indices for the various material commodities and the project schedule. Individual escalation rates will be determined for tagged equipment (mechanical, electrical, and control systems), bulk materials, construction labor, subcontracts, construction indirects, and home office engineering services based on the most current market intelligence available for the various cost categories. Escalation is a separate standalone calculation.

8.8 CONTINGENCY & EVENT DRIVEN RISK ANALYSIS

Estimating contingency is the allocation of cost to cover the risk of potential but uncertain cost variances from within the defined scope of the project. Contingency typically covers risk of cost variances in bulk commodities, omissions and errors, productivity, technical problems, and like items. Scope changes are specifically excluded from contingency. The estimate contingency will be based on a combination of a formal risk assessment, historical results, and management judgments. The contingency will be assessed utilizing a Monte Carlo risk analysis program (Palisade @Risk™). This process will be facilitated by the Wood Estimating group.

The Event Driven Risks (EDRs) relate to the unique circumstances for the project risk evaluation, which are not included in the project contingency evaluation for typical project related risks (called normal risks) common to most projects. The EDRs can briefly be described as: Events which, if occur, will be easily recognizable and acknowledged as having occurred or events which usually have significant cost impacts on a project.

The EDRs are developed based on an itemized list of events, which are unique to the project, and must meet the criteria defined above i.e., should be easily recognizable if the event took place and should have a significant cost impact. These events are itemized and quantified on a magnitude basis and assigned a probability of occurrence. These risks should be discussed between the Client (Shell) and Wood to establish a Risk Mitigation Plan, with the residual risk carried as EDR contingency. The Plan should be evaluated on a regular basis to ensure that timely actions are being taken for mitigation. The Risk Evaluation should be done on a periodical basis to re-evaluate the risks.

The Event Driven Risks and associated mitigation plans will be developed by the Wood Estimating Group in conjunction with the project team. The risk assessment tool used will be a Monte Carlo risk analysis program that has been set into a standard project template developed by Wood. This process will be facilitated by the Wood Estimating Group and project manager.

The finial Risk analysis report shall be provided to management, together with details of the analysis with separate cost line items for each risk item.

8.9 OWNERS COST

Shell will provide Owner's cost for Wood to include in the estimate.

8.10 DOCUMENT CONTROL

All documents, engineering deliverables, and procurement deliverables to be used by estimating will be transmitted to the lead estimator via document control. The transmittal can be either electronic or paper but must include the drawing name, drawing number, revision number, and date as a minimum.

The project engineering manager or delegate will review and approve (sign-off) all transmittals to estimating. The lead estimator will keep a master set of all documents that have been issued to the estimating group. The documents covered by this requirement include all material take-off's, design drawings such as plot plan(s), PFD's, P&ID's, line lists, electrical one-lines, material quotes, schedules, etc.

8.11 BENCHMARKING & VALIDATION

All aspects of the estimate will be benchmarked and validated against Wood project data (equipment costs, bulk materials costs, subcontract unit rates, all-in subcontract wage rates, labor productivity factors, etc.) as applicable and in-house historical data from similar type process units.

The estimate analysis will address the following major areas:

- Validation of labor productivity factors.
- Validation of all-in subcontract wage rates.
- Validation of rates of placement (e.g., installation man-hours per CY of concrete, per TN of steel, per LF of pipe, per LF of cable, etc.) by prime account.
- Validation of mechanical equipment costs (e.g., vessels: cost per kg, pumps: cost per hp).
- Cost relationships between prime accounts for direct field cost and indirect field cost

8.12 ESTIMATE REVIEWS

An integral part of estimate preparation is a structured review process to validate the accuracy and completeness of the estimate. The prime objective of the estimate review is to evaluate the adequacy of the estimate for its intended use. There are several levels of review that occur in the estimate cycle. The estimate schedule must include adequate time for these reviews, particularly the later, higher level reviews which involve senior management.

Wood has established its own governance policies with regard to the review and approval of estimates. The reviews described below are the key elements of that approval process. The lead estimator will schedule all reviews and confirm that the appropriate individuals with approval authority have been invited to attend the reviews.

The following are the primary estimating reviews prior to estimate completion and approval. The process for each of these is described in subsequent sections. These reviews will be held with the respective contractor based on ISBL and OSBL facilities, as necessary:

- Scope Review
- Discipline Level Review
- Project Team Review
- Estimating Team Review
- Wood Management Review
- Client Review

8.12.1 Scope Review

This review includes the project lead estimator, discipline estimator, engineering discipline lead and the engineering discipline specialists which supplied information to be used in the estimate.

The scope review meeting is a preliminary/ interim review held after the MTO's developed by the various Wood Engineering Group(s) have been submitted to estimating. The purpose of the review is to ensure that the estimator has interpreted the information supplied by the various Wood Engineering Group(s) in the proper manner and to identify any scope gaps, double dips in quantities, and discrepancies.

Any discrepancies and/ or adjustments and shall be resolved and corrected prior to the discipline level review.

8.12.2 Discipline Level Review

This review includes the project lead estimator, discipline estimator, discipline lead and the discipline specialists which supplied information to be used in the estimate.

The purpose of the review is to ensure that the estimator has interpreted the information supplied by the various Wood Engineering Group(s), procurement group, contracts group, and construction group in the proper manner, and the resulting estimate reflects that agreement. The lead estimator will complete the estimate checklist and check the quantities and costs defined for a given scope against historical benchmarks and ratios. Variations to historical norms will be highlighted and rationalized.

During this review, the Basis of Estimate (BOE) document developed by the discipline specialists is reviewed to ensure completeness, accuracy, and project requirements are represented. The BOE, as a minimum, must include a write-up from each engineering and support discipline (procurement, contracts, and construction) on their understanding of the project, use of reference documents, the methodology applied to develop the estimate deliverables, and a listing of assumptions, clarifications, inclusions, and exclusions. The engineers will also be consulted for the evaluation of various design/ MTO allowances and the assessment of the project contingency requirements by discipline.

Preliminary/ interim reviews may be held prior to the discipline level reviews primarily to review information that has been issued to estimating and identify any scope gaps.

Any discrepancies and/or adjustments and shall be resolved and corrected prior to the project team review.

8.12.3 Project Team Review

This review includes the proposal/ project team including the project manager, engineering manager, project controls manager, estimating manager, lead estimator, discipline estimator(s) engineering discipline lead(s), procurement lead, contracts lead, and construction lead. Office functional representatives may attend on an as required basis.

The purpose of this review is to ensure that the estimate accurately reflects the project scope and objectives. During this review, the lead estimator will present the BOE document, review the estimate checklist, project fact sheet, and discuss the methodology and processes utilized to develop the cost estimate. It is the responsibility of the lead estimator to ensure that the BOE is compiled and collated with the information that has been provided by all engineering and support disciplines.

If previous estimates have been prepared, variance explanations will be reviewed as well as benchmarks used for comparative purposes. The escalation, contingency, and risk model will also be finalized. Any discrepancies and/ or adjustments shall be resolved and corrected prior to the estimating team review.

8.12.4 Estimating Team Review

After the discipline level review, the estimate will be reviewed by the chief estimator and/or assigned delegate with the lead estimator and discipline estimators. The direct field costs (DFC), indirect field costs (IFC), home office costs (HO), escalation, contingency, and risk assessment will be reviewed for scope coverage, proper application of estimating principles, logic of assumptions, proper application of costs, lab. The lead estimator will present all benchmarking and analysis results as well as recommended adjustments. The BOE will be reviewed and finalized.

Any discrepancies and/ or adjustments and shall be resolved and corrected prior to the Wood Management Review.

8.12.5 Wood Management Review

This review includes a combination of business unit leadership (depending on the organizational responsibilities defined within the division), regional management, project operations, functional leadership, and project team members. Attendees in this review vary depending on the requirements defined in the Estimate Review Protocol Matrix.

During this review, the Estimate Management Review Package will be presented by the project team. The project lead estimator will direct the review with support from the proposal/ project team as required. Depending on Approval Matrix limitations, this review could possibly result in approval to release the estimate to the client. Estimates may not be submitted to the client without approvals as defined in the Estimate Review Protocol Matrix.

8.12.6 Client Review

The lead estimator will direct the formal submission of the approved estimate with support from the proposal/project team as required. The client presentation of the scope, basis of estimate, estimate, etc. will typically be contained in the Wood Management Review Package.

Wood encourages participation and input by the Shell Project Team in development of the estimate and participation in the estimate review process. This participative approach will be helpful to Wood in incorporating Shell input in a timely manner and to Shell in understanding the detailed methodology and basis of estimate development. Typically, the client representative(s) participate in the scope review, discipline level reviews, and project team review.

Key components of the estimate such as craft wage rates, labor productivity factors, materials pricing, subcontract rates, escalation models, and contingency models will be reviewed prior to final submission of the estimate in order to ensure early alignment on the values to be carried.

9.0 QUALIFICATIONS & EXCLUSIONS

9.1 QUALIFICATIONS

- The estimate assumes that an adequate supply of skilled craft labor is available in the geographic areas for construction.
- A clear and uninterrupted access to all of the job sites shall be available

- Existing lay down and production areas for; equipment dressing, equipment staging, pipe fabrication, rebar fabrication, formwork, painting, and temporary construction facilities shall be available for the project's use throughout the construction phase of the Project.

9.2 EXCLUSIONS

- Program Management Consultant/ Contractor Costs
- Owners staff and expenses required throughout project lifecycle
- Cost of land and right of way
- Owner's financing charges
- Operator training costs
- Sustaining capital cost
- All taxes per (reference section: 8.6.5)
- Municipal, State, and Federal permitting
- Operating costs
- Geotechnical investigation
- Laser Survey
- Contaminated soil investigation
- Lead and/ or asbestos abatement
- Inspection of existing equipment and associated systems
- Safe and blind of existing equipment and associated systems
- Machine shop equipment and tools
- Maintenance equipment and tools
- Staff and craft attraction and/ or retention incentives
- Staff and craft show-up pay
- Owner Suppled Site Wide Services
- Pre-commissioning, Commissioning, and start-up

10.0 APPENDICES

10.1 Appendix 1 – Material Take-off Methods & Techniques

a) Overview

This methodology is prepared to quantify the material for all discipline Scope of Works, minimum engineering deliverables and guideline for the material Take-off (MTO).

The quantity calculation will be based on project specifications and documentation/drawings available at the time of issuing the material take-off (MTO) to the Wood estimating group.

Actual material take-off will be neat quantities developed manually, 3D model and by ACCE (Estimation group shall utilize ACCE for certain specific scopes). Any allowances, wastages, and rounding off for lot sizes should be totally excluded from material take-off.

b) Civil Works

Minimum engineering documents/drawings required are as follows:

- Plot Plans
- Geotechnical Reports
- Foundation and Piling plan
- Piling Plan
- Under Ground Plans
- Building layout and elevation Plans
- Structural Layout drawings
- Grading and paving layout plans
- Key plan
- Drainage system layout
- Electrical/instrument layouts plans & details
- Foundation plans
- Piping layouts
- Site finishing plans
- Pipe racks plans
- Cable racks plans
- Platforms plans
- Shelters plans
- Steel frames plans
- Architectural building drawings and foundation plans
- Structural building drawings (including foundations)
- Sanitary sewer network layouts

Activity	Material Take-off Method
Earth works	Minimum design requirements: • Plot Plans

Activity	Material Take-off Method
General earthwork - rough grading, site preparation. Excavation and backfill	• Geotechnical/Topographical Survey • Grading plans • Earthwork Cross Sections Drawings
Trench excavation for U/G networks and foundations pits/basin	Minimum design requirements: • Detail Foundation Sketches • Detail Piping Layouts • Electrical/instrument layouts (plot plans) • Concrete works: formwork drawings Take-offs will be taken manually of excavation volumes through evaluation of surface areas and depth of excavation on the basis of the above drawings.
Roads	Take-offs on the basis of the surfaces shown on Plot plans, roads general layout, road details, civil specifications, and geotechnical report.
Paving	Take-offs on the basis of road surfaces shown on Plot plans, Paving details, Paving plans civil specifications and geotechnical report.
Site Finishing	Manual calculation of surface areas on the basis of plot plan, site finishing plan and details.
Concrete and structures foundations	Take-offs will be based on standard formwork & reinforcement details, foundation plans and other detail foundation drawings. Foundations whose dimension is imposed by equipment dimensions and not by loads will be sized accordingly.
Concrete Pits and Basin (Pits, Manholes, Basins, and Above grade canal)	Minimum engineering requirements • Formwork & reinforcement details • Foundation plans • Piping/Electrical/Instrument layouts Manual calculation of the volumes, surfaces areas or quantity of each component on the basis of the above-mentioned documents.
Concrete Firewalls Transformer firewalls	Minimum engineering requirements • Formwork & reinforcement details • Substation plans Manual calculation for volumes, surfaces areas or quantity.
Concrete Duct banks (Concrete duct banks)	Minimum design requirements: • Electrical/instrumentation layouts • Electrical/instrumentation duct banks details

Activity	Material Take-off Method
	Manual calculation of the volumes of each component on the basis of the above-mentioned documents.
Sewer and Drainage	Minimum design requirements: • Drainage system details • Sanitary sewer network layouts • Rainwater drainage layouts Quantification will be manual based on above documents.
Underground works for Electrical and Instrument	Minimum design requirements: • Electrical/instrumentation cable laying details • Electrical/instrumentation cable layouts Manual calculation of each component on the basis of the above-mentioned documents.
Fencing and Gates	Minimum design requirements: • Civil works general layout • Plot plan • Fencing details Manual calculation of the length of each fence and quantity and type of gate.

c) Structural Steel

Activity	Material Take-off Method
• Pipe racks • Cable racks • Platforms and walkways • Shelters • Steel frames and supports • Stairs • Ladders	Minimum design requirements: • Pipe racks plans & details • Cable racks plans & details • Platforms plans & details • Structural layout drawings • Shelters plans & details • Steel frames & supports details • Walkways/stairs plans & details 3D model /Manual calculation of the weight of structure (bracing and connection plates included), surface area of cladding, weight of ladders, handrails and quantity of self-closing gates based on characteristic of the structure and required bearing capacity.

For steel structures the unit rate of the components shall be inclusive of all materials, welds, work, consumables, surface treatments; for ladders and cladding, all connecting fitting and accessory (i.e., clamps, bolts, screws, flushing, downspouts, etc.), laboratory tests, inspections, certificates, shop drawings, installation instructions, packing, profits, etc. to supply components complete ex-factory.

Total steelwork weight will be shown in below categories:

- Extra-Light steel structures
- Light steel structures
- Medium steel structures
- Heavy steel structures
- Extra-Heavy steel structures
- Handrail
- Cladding
- Ladders
- Stair stringers
- Checkered plate
- Self-closing gates for ladders
- Grating non-shaped panels
- Grating treads

d) Buildings

Activity	Material Take-off Method
Buildings	Minimum design requirements: • Building list with dimensions • Architectural layout drawings and specifications • HVAC system drawings • Electrical system drawings • Fire and smoke detection system drawings • Telecommunication system drawings • Plumbing system drawings

e) Mechanical

Minimum Engineering documents/drawings required are as follows:

- P&ID's
- Equipment List
- Material Requisition
- Technical Specification
- Equipment Data Sheet

All equipment shall be quantified manually using the latest and approved equipment list.

f) Piping

Minimum Engineering documents/ drawings required are as follows:

- Process & Instrument Drawings (P&ID's)
- Plot Plans
- Piping Line List(s)
- Piping Material Classes
- SP3D Model
- Piping Layout Drawings
- Piping Assembly
- Piping Specification(s)
- Paint Specification
- Insulation Specification

Item	Material Take-off Method
A/G Pipe [feet - pound]	• Pipe diameter 3" and greater: The Piping Engineering Group will generate piping lengths (in feet), fitting, and valve quantities, with line number and material specification assigned, utilizing SP3D (modeling software), isometrics, or material take-offs. • Pipe diameter less than 3" shall be factored. • Take-offs will be line by line to each P&ID. Each line will be broken down as per Area Breakdown requirements indicating whether the piping is shop fabricated or field run.
U/G Pipe [feet - pound]	• The Piping Engineering Group will generate piping lengths (in feet), fitting, and valve quantities, with line number and material specification assigned, utilizing manual techniques supported by design drawings/ sketches.
Fittings [number – pound]	• Pipe diameter 3" and greater: The Piping Engineering Group will generate fitting quantities, with line number and material specification assigned, utilizing SP3D (modeling software), isometrics, or material take-offs. • Pipe diameter less than 3" shall be factored.
Flanges [number – pound]	• Pipe diameter 3" and greater: The Piping Engineering Group will generate flange quantities, with line number and material specification assigned, utilizing SP3D (modeling software), isometrics, or material take-offs. • Pipe diameter less than 3" shall be factored.
Valves [number – pound]	• Pipe diameter 3" and greater: The Piping Engineering Group will generate valve quantities, with line number and material specification assigned, utilizing SP3D (modeling software), isometrics, or material take-offs. • Pipe diameter less than 3" shall be factored

Item	Material Take-off Method
Gasket & Bolts [number - pound]	• Bolts and Gaskets quantity will be generated by Aspen Capital Cost Estimator (ACCE) based on the flange count, valve count, and equipment nozzle count.
Supports [number - pound]	• Supports quantity will be generated by Aspen Capital Cost Estimator (ACCE) based on project defined parameters.
Spring Supports [number - pound]	• Material Take Off will be done manually referencing the SP3D model as a reference and stress analysis calculations of critical lines.
Painting, Coating, and Insulation [square foot]	• The piping paint and insulation quantity will be generated by Aspen Capital Cost Estimator (ACCE) based on the requirements defined on the line list. The requirements (paint code, insulation type, insulation thickness, and jacketing) will be input into ACCE for each line and ACCE will calculate the paint and insulation quantity.
Piping internal lining [pieces for fittings and flanges, feet for pipes]	• Drawings are used to extract from the complete piping Material Take Off a report listing the total length of pipe to be lined together with the total number of fittings and flanges, each of these split per size.

g) Electrical

Minimum Engineering documents/drawings required are as follows:

- Design criteria
- Electrical Load List
- Single Line Diagrams
- Plan/Layouts (cable routing and power system layout/ grounding system/ lighting system)
- Cable schedules

Item	Method of Material Take-offs
Transformers, Cable Busses, and Bus Duct (if any) [number & kg]	The number of the power transformers and the length of the cable busses will be quantified on the basis of the following documents/drawings: • Single Line Diagrams. • Electric Load List/ Load Summary. • Plot Plan/ Electrical Layout • Specification Sheet Equipment

Item	Method of Material Take-offs
GIS System	• GIS components will be quantified from single line diagrams and equipment layout.
LV/MV Switchgear (Panels and Feeders number and type) [number - pound]	• The number and the components (number of circuit breakers, bus bare ratings, auxiliary circuits etc.) of the switchgear will be quantified from single line diagrams and electric load list/ load summary
AC / DC UPS	The quantity of the DC UPS will be based on below listed documents/drawings: • Single Line Diagrams • Electric Load List/ Load Summary • Specification sheet Equipment layout.
Feeder and Power Cables [feet]	Taken off on the basis of the following documents/drawings: • Cable Route Plan/Layouts & elevation • Cable schedule Power cables quantities will be based on cable schedule. The quantities will be verified with cable route plan and layout.
Control Cable [feet]	Taken off on the basis of the following documents/drawings: • Cable Route Plan/Layouts & elevation • Cable schedule Control cables quantities will be based on cable schedule. The quantities will be verified with cable route plan and layout.
Trenches [cubic feet] Tray [feet – pound] Conduit [feet – pound] Duct [number]	Taken off on the basis of the following documents/drawings: • Cable Route Plan/Layouts & elevation • Cable schedule Trench volume, duct banks dimensions, cable trays and conduit pipes will be taken off from cable route plan and layouts.
Grounding [feet & number]	Taken off on the basis of the following documents/drawings: • Electrical Design Criteria & Calculation grounding system for electrical S/S • Grounding Plan/Layouts • Grounding system installation details Grounding bulk materials and cables will be quantified on the basis on grounding plan/layout. Related bulk materials such as switchgears, transformer, etc. will be based on Grounding installation details.

Item	Method of Material Take-offs
Lighting [feet & number]	Taken off on the basis of the following documents/drawings: • Electrical Design Criteria & calculation • Lighting requirements • Lighting Plans / Layout Drawing Lighting materials (fixtures, poles, etc.) will be quantified based on illumination requirements. Related bulk materials will be quantified on the basis of illumination requirements.
Remote Control Stations and Safety Switches [number]	Remote control stations and switches will be quantified based on below documents/drawings: • Electrical Design Criteria • Electrical typical installation drawings • Electrical load list/SLDs
Power Sockets [number]	Power sockets shall be counted on the basis of the following documents/drawings: • Electrical Design Criteria • Electrical load list • Power system Layout/estimated Related materials necessary for the installations will be evaluated on the basis of the installation details
Local Power Distribution Panels [number – pounds]	Local panel will be counted on the basis of the following documents/drawings: • Electrical Design Criteria • Electrical typical installation drawings • Electrical load list • Cable route/ illumination requirements /Layouts & Power System Layout Related materials necessary for the installations will be evaluated on the basis of the installation details
Cable Glands [number]	Cable gland will be counted and sized on the basis on Cable schedule.
HV and MV Cable Joints and Terminations [number]	Terminations will be counted on the basis of cable schedule.
Conduit Fittings [number]	Taken off on the basis of the following documents/drawings: • Electrical Design Criteria • Electrical typical installation drawings • Cable route/ illumination requirements /Layouts & Power System Layout

Item	Method of Material Take-offs
Cathodic Protection (package supply)	MTO is part of the Cathodic Protection sub-contacting package (site survey, engineering, materials, commissioning) that a NACE certified selected Vendor will supply. The Material take-off will be based on Purchase Order quantities.
Electrical Heat Tracing	Design based on process conditions/ requirements. Line List will identify tracer type (MI / SR / Steam / Glycol)

h) Instrumentation

Minimum Engineering documents/drawings required are as follows:

- Cable Tray and Conduit schedules
- Cable tray cross-sectional fill details
- Cable tray layouts
- DCS ESD & VMS I/O List
- Instrument Block interconnecting diagrams
- Instruments data sheets
- Instrument Installation Schedule/Instrument Index
- P&ID's
- Buildings fire Detection System Layout
- Installation details
- Instrument cable list
- Instrument cable routing layout
- Instrument location layout
- Main cable routing layout/ section
- Plot plan with pneumatic instruments and pneumatic secondary sketches
- Hook-up details for primary connection
- Hook-up details for electrical connection
- Hook-up details for instrument support
- Control cabinet & extensions – block diagram
- Internal Building - telephones, loudspeakers, junction boxes location layout
- Plant - Telephones, loudspeakers, junction boxes location layout
- Overall Site Plant – Main cables layout from CCR to distribution points

- Internal Building – Typical telephones and loudspeakers mechanical installation.
- Plant - Typical telephones and loudspeakers mechanical installation
- Central control supervision station – block diagram
- Overall site plant – cameras location and fibre optic cable layout
- Plant - typical cameras mechanical installation

Item	Method of Material Take Off
Control Valves On-off Valves (pneumatic and electric)	Valve MTO will be based on: • Instrument valves • P&ID's. Valves quantifications will be based on Instrument Installation Schedule – Valves and will be verified according to the P&ID's.
Flow Instruments	Flow Instruments MTO will be based on: • Instrument installation schedule – flow instruments • P&ID's From instrument installation schedule the instruments material will be quantified, and it will be verified according to the P&ID's.
Pressure Instruments	Pressure Instruments MTO will be based on: • Instrument installation schedule – pressure instruments • P&ID's From instrument installation schedule the instruments material will be quantified, and it will be verified according to the P&ID's.
Level Instruments	Level Instruments MTO will be based on: • Instrument installation schedule – level instruments • P&ID's From instrument installation schedule the instruments material will be quantified, and it will be verified according to the P&ID's.
Temperature Instruments	Temperature Instruments MTO will be based on: • Instrument installation schedule – temperature instruments • P&ID's From instrument installation schedule the instruments material will be quantified, and it will be verified according to the P&ID's.
Miscellaneous Instruments	Miscellaneous Instruments MTO will be based on: • Instrument installation schedule – miscellaneous instruments • P&ID's From instrument installation schedule the instruments material will be quantified, and it will be verified according to the P&ID's.

Item	Method of Material Take Off
Fire and Gas Detectors and Fire Alarm Panels	Fire and gas detector sensors and alarm panels MTO will be based on the buildings fire and gas detection system layout.
Interface Panels	Interface panels will be quantified based on the number of electric substations where they are foreseen and of the number of I/O to be connected on each electric substation.
Single Pair/ Tern Cables	Single pair/ tern cables (from instrument to JB) MTO shall be based on the electric and electronic instrument and valve list.
Homerun (Multicore) Cables Fiber optic Home run Cables	Home-run multi-core cables MTO will be based on: • Instrument cable list • Instrument cable routing layout From Instrument Cable List the multi-core cables quantity will be taken off and it will be verified by instrument cable routing layout.
Junction Boxes	Junction boxes MTO will be based on the instrument location layout.
Cable Trays	Cable trays MTO will be based on: • Main cable routing layout • Main cable routing sections.
Instrument Air Supply Bulk Materials	Instrument air bulk material MTO will be based on: • Plot plan with pneumatic instruments • Instrument installation details – hook-up for pneumatic connection.
Process Connection Bulk Materials	Process connection bulk material MTO will be based on the instrument installation details – hook-up for primary connection.
Electric Connection Bulk Materials	Electric connection bulk material MTO will be based on the instrument installation details - hook-up for electrical connection
Minor Steel Structures	Minor steel structures bulk material MTO shall be based on the instrument installation details - sketches for instrument supports.

i) Automation

Item	Method of Material Take Off
MOC	The MOC scope and quantification shall be based quotes from Emerson and in-house.

j) Telecommunications

Item	Method of Material Take Off
PA/GA Equipment	PA/GA equipment MTO will be based on: • Control cabinet and extensions – block diagram • Internal building – telephones, loudspeakers, and junction boxes location layout • Plant - telephones, loudspeakers, and junction boxes location layout.
PA/GA multi/single pair signal cables and power cables	PA/GA multi/single pair signal cables and power cables will be based on: • Overall site plant – main cables layout from CCR to distribution points • Internal building -telephones, loudspeakers, and junction boxes location layout • Plant - telephones, loudspeakers, and junction boxes location layout.
PA/GA bulk installation material	PA/GA bulk installation material will be based on: • Internal Building – typical telephones and loudspeakers mechanical installation • Plant - typical telephones and loudspeakers mechanical installation.
CCTV Equipment	CCTV equipment MTO will be based on: • Central control supervision station – block diagram • Overall site plant – cameras location and fiber optic cable Layout. Application Software will be based on: • Specification for CCTV system.
CCTV Fiber Optic Cables	CCTV fiber optic cables shall be based on: • Overall site plant – cameras location and fiber optic cable layout.
CCTV Bulk Installation Material	CCTV bulk installation material shall be based on the typical camera mechanical installation
Fiber Optic System	MTO based on: • Fiber optic block diagram • Fiber optic pedestal / patch panel layout

10.2 Appendix 2 – Allowances

By definition, an allowance is an allocated amount to cover a specific element of a project that is not yet fully defined. The amount is usually based on broad experience rather than direct pricing or factoring against the cost of a defined item, such as equipment. There may be multiple allowances in an estimate,

and each is a separate line item. Each allowance will be based on an assessment of the particular project inputs, estimate methodology, and the requirements. Typical allowances include:

a) Design Development Allowance (DDA) - Design development allowances provide for items and/ or cost elements that have not been individually identified during the preliminary engineering phase(s) of a project for scope not yet defined in sufficient detail. The allowance for design development is money that is expected to be expended without any scope changes. As the design progresses, the allowance for design development decreases, typically being offset by specific cost elements that have been identified. Normally the design development allowance is zero by the time preliminary engineering is complete.

   Typically, a design development allowance is applied to the estimated or quoted engineered (tagged) equipment cost that is necessitated by expected engineering revisions for stability, stiffness, additional nozzles, nozzle rotation, placement of lifting lugs, etc. These are changes that are too insignificant to be listed individually. They are reported as costs in an estimate, not quantities.

   Design development allowances may also be applied as an adjustment to quantities (rather than cost) that provide for scope not yet defined in sufficient detail that are expected to materialize as a result of final design.

b) Material Take-off Allowance (MTO) – The MTO allowance is an adjustment to quantities (rather than cost) that provides for the difference between neat takeoff quantities of bulk commodities and final in-place quantities. The MTO allowance is intended to apply only to scope elements that exist in the estimate that may later change in quantity from the original engineering basis due to more definitive design calculations, actual equipment weights and dimensions, detailed piping/ cable routings, piping stress analysis results, interference checks, and the like. MTO allowances are not considered contingency and should be applied to the material and labor costs as appropriate. They are reported as quantities in the estimate, not just a dollar amount.

c) Contract Growth Allowance (CG)

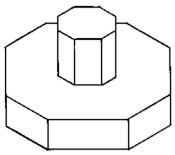
   This allowance is to cover additional compensation by contractors for a myriad of reasons within the terms of the contract and historically is experienced on all contracts. Contract growth allowances are applied to the subcontract cost.

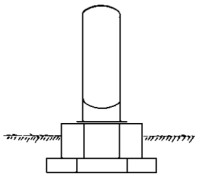
d) Construction Allowance (CA)

   Construction allowance include additional materials, in excess of design requirements, which are required during the construction phase to cover cutting loss or wastage, misuse of materials, normal loss, and damage in the field. Construction allowances are applied to the material cost. They are reported as quantities in the estimate, not just a dollar amount.

10.3 Appendix 3 – Foundation Types

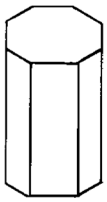
1 OCT+PROJ Octagon Slabs & Piers with Projections

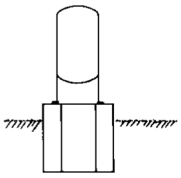




Foundation Typical Application

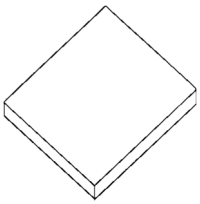
2 OCTAGONL Octagon Slabs & Piers without Projections





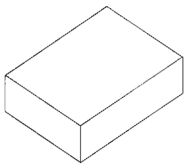
Foundation Typical Application

3 PAVING Area Paving



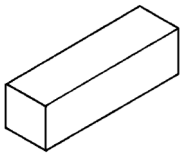
Foundation Typical Application

4 MASSPOUR Mass Pours - Large Mats, Pile Caps, & Other Shapes (> 25 CY / 19 M3)

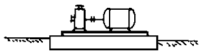


Foundation Typical Application

5 SM BLOCK Small Blocks - Pumps, Compressors (< 3 CY / 2.3 M3)

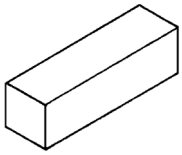


Foundation

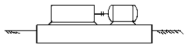


Typical Application

6 LG BLOCK Large Blocks - Large Compressors & Turbines (3 - 25 CY / 2.3 - 19 M3)

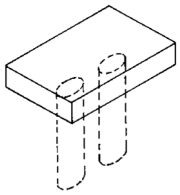


Foundation

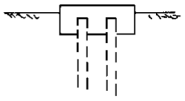


Typical Application

7 PILECAP Pile Caps (< 5 CY / 3.8 M3)

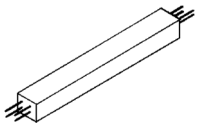


Foundation



Typical Application

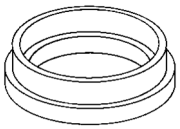
8 CONDUIT Conduit Envelope

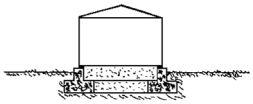


Foundation

Typical Application

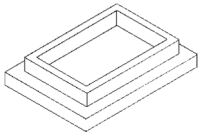
9 RING Circular Ring Foundation - For Large Tanks.

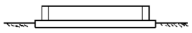




Foundation Typical Application

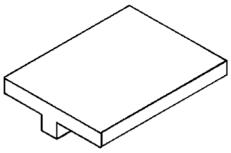
10 BASIN Basins.





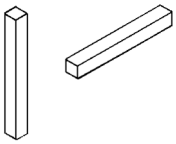
Foundation Typical Application

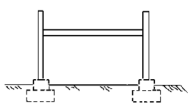
11 EL SLAB Elevated Slab.



Foundation Typical Application

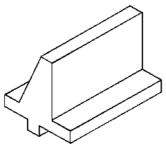
12 COLM/BM Columns & Beams.

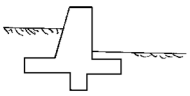




Foundation Typical Application

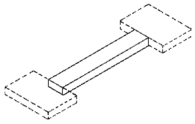
13 WALL Walls and Wall Footings.





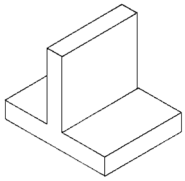
Foundation Typical Application

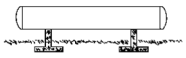
14 GRND BM Grade Beam



Foundation Typical Application

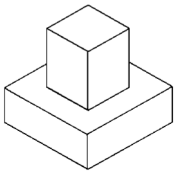
15 PIER

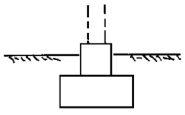




Foundation Typical Application

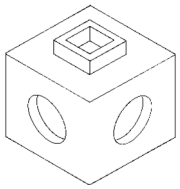
16 FOOTING Column Footings & Sleepers.



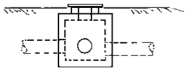


Foundation Typical Application

17 BOX Valve Boxes, Manholes, etc.

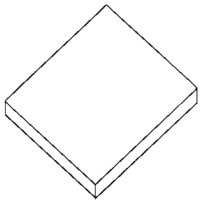


Foundation



Typical Application

18 SLAB GRD Slab on Grade



Foundation

Typical Application

10.4 Appendix 4 – Minimum Equipment Data Required

The following attributes will be populated on the Mechanical Equipment List

Bold: Minimum Data Required to Load Aspen Capital Cost Estimator

a) Heat Exchangers (Shell & Tube)

- **Type (U-Tube, Floating Head, Fixed Head, Plate & Frame, etc.)**
- **TEMA Type**
- **Bare Tube Surface Area**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation (Shell, Tube Sheet, Channel, and Tubes)**
- **Wall Thickness (Shell, Tube Sheet, Channel, and Tubes)**
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

b) Heat Exchangers (Air Coolers)

- **Bare Tube Surface Area**
- **Design Conditions (Pressure and Temperature)**

- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation (Tubes)**
- Wall Thickness (Tubes)
- Number of Bays, Tube Length, and Bay Width
- Number of Fans per Bay
- Fan Power

c) Columns

- **Type (Double Diameter or Single Diameter)**
- **Dimensions (Diameter and T-T per Section)**
- **Type of Internals (Tray or Packing)**
- **Number of Trays or Packing Height**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation (Shell, Cladding, Trays)**
- **ASME Design Basis (ASME Division 1 or ASME Division 2)**
- **Wall Thickness**
- Skirt Height
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

d) Vessels

- **Type (Horizontal, Vertical, Boot)**
- **Dimensions (Diameter and T-T)**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation (Shell, Cladding, Trays)**
- **ASME Design Basis (ASME Division 1 or ASME Division 2)**
- **Wall Thickness**
- Skirt Height
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

e) Tanks

- **Capacity**
- **Dimensions (Diameter and T-T)**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation (Shell)**
- **Wall Thickness**
- Roof Type
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

f) Compressors

- **Type (Centrifugal, Reciprocating, Fan, etc.)**
- **Actual Inlet Capacity (Am3/ hr)**
- **Design Inlet Pressure**
- **Design Outlet Pressure**
- **Material – ASME Designation**
- **Driver Type (Electric Motor, Turbine)**
- **Driver Power (HP)**
- Number of Stages
- Lube Oil System (Yes/ No)
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

g) Filters

- **Type (Cartridge, Plate & Frame, etc.)**
- **Flow Rate**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation**
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)

- Fireproofing (Material and Thickness)

h) Furnaces

- **Type (Vertical, Cylindrical, Box Type, etc.)**
- **Duty (MW)**
- **Standard Gas or Liquid Flow**
- **Process Type (Gas or Liquid)**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation**
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

i) Pumps

- **Type (Centrifugal, API 610, Reciprocating, Multi Stage, Metering, Gear, etc.)**
- **Capacity (M3/ HR)**
- **Head**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation**
- **Driver Type (Electric Motor, Turbine)**
- **Driver Power (HP)**
- Primary, Secondary, and Cooling Water Plan
- Lube Oil System (Yes/ No)
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

j) Flare

- **Type (Derrick Supported, Guyed, Self -Supported, Horizontal Ground, etc.)**
- **Gas Flow Rate (M3/ HR)**
- **Dimensions (Diameter and T-T)**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**

- **Material – ASME Designation**
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

k) Packaged Equipment

- **Type**
- **Capacity**
- **Design Conditions (Pressure and Temperature)**
- **Operating Conditions (Pressure and Temperature)**
- **Material – ASME Designation**
- **Weight**
- **Dimensions (Length, Width, Height)**
- **Details (Scope of Supply)**
- Tracing (ST/ GT/ EHT-MI/ EHT-SR and Quantity)
- Insulation (Material, Thickness, and Jacket)
- Fireproofing (Material and Thickness)

FRONT-END ENGINEERING DESIGN FOR CARBON CAPTURE FROM SHELL'S DEER PARK CHEMICAL COMPLEX

Project Risk Register

Date of Issue : 1-Jun-23

Internal Document Number: DPKCCS-1000-PMC-LIS-N-0002

Internal Document Revision: 0

Customer Name: Department of Energy NETL

Federal Prime Contract No. DE-FE0032142

Non-protected Data

Important Notice

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Rev	Date	Issued For	Wood		Department Manager/ Technical Authority	Project Manager	Principal Investigator
			Prepared	Checked			
0	1-Jun-23	Issued For Use	D. Jethwa	C. Falkenberg	---	R. Ramsey	B. Clark
					---	01-June-2023	---
					---		---

Project Risk Register:Front-End Engineering Design for Carbon Capture from Shell's Deer Park Chemical Complex

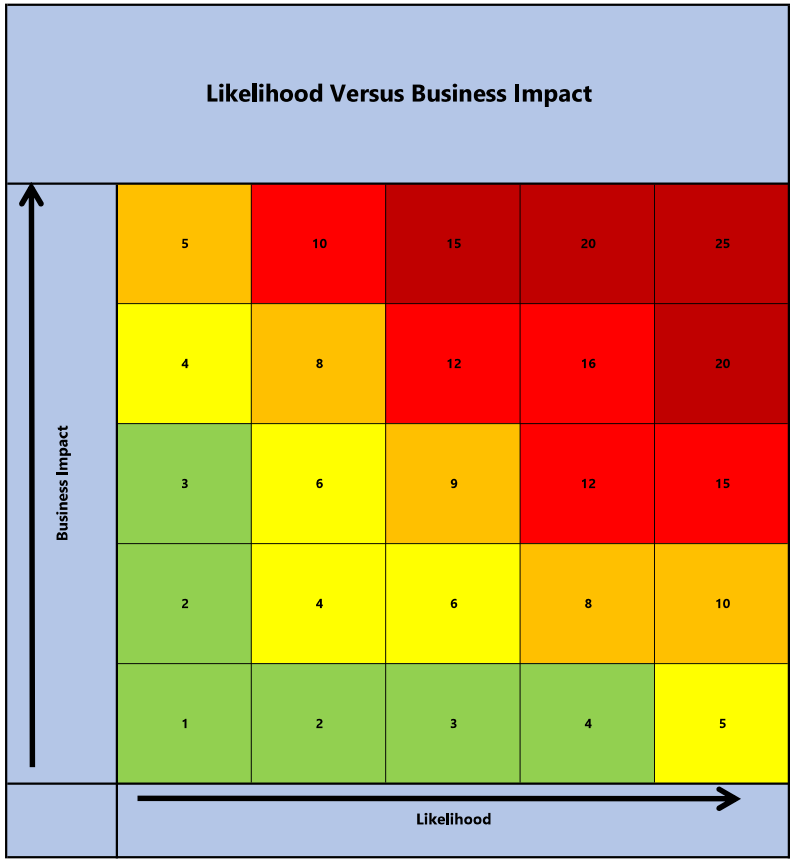
Rev: 0 June 1, 2023

Risk Identification								Pre-Risk Analysis					Post-Risk Analysis				Assurance		
Risk ID	Threat or Opportunity	Date Recorded	Risk Title	Risk Description	Risk Owner	Risk Driver	Category	Risk Likelihood	Impact Rating	Matrix Rating	Risk Manageability	Risk Status	Risk Likelihood	Impact Rating	Matrix Rating	Actions Total	Risk Closed Date	Risk Accepted By	Comments
1	T	12/9/2022	Delays in project start	Cause: Contract completion delays. Restarting the job after suspension. Event: Extended negotiation over contract terms. Also, Inefficiencies caused by restarting the job procedures and new project staff. Consequence: Financial and schedule impact to the project.	WSP / Shell	Financial	Active	5	1	5	Low	Closed	4	1	4	2	12/28/2022		Mitigation: Retaining original staffing for restart where available. 11/30/22 Was able to retain some key staffing such as Wood, Technip, Shell SGS Process Engineers. 12/28/2022 Restart is complete so this risk can be closed.
2	T	6/15/2021	Information from Site and Subcontractors, including site access	Cause: Delay in receipt of PDP information from Licensor, FEED information from ISBL contractor or design data from Shell Deer Park, including site access Event: Project deliverables will be delayed Consequence: Schedule impact; Increased cost as longer duration of project	WSP	Financial	Active	4	3	12	High	Open	3	2	6	6			Cost/Schedule Risks - Mitigation: After project kick-off, an interactive schedule planning session was held with all applicable parties and a schedule will be developed to support the project goals. The teams will participate in periodic schedule review meetings to facilitate adherence to the schedule and implementation of corrective actions as required. Close monitoring of the flow of work and intermediate deliverables; ensure input information from Licensors and contractors areon track. Integrated schedule which ISBL subcontractor updates. Clear requirements and dates on the Needs List. Expediting companies for schedule development and update. 11/30/2022 Milestones have been included in schedule for information. Schedule and Action List are review in Weekly Client Meetings to expedite needed information. 1/30/2023 Received majority of initial information needed for early work. 5/12/2023 Needs list is maintained and discussed during ongoing Weekly Meeting highlighting information needed. 5/30/2023 This risk also includes information that is not available. 5/30/2023 Restricted access to site will be partially mitigated by utilizing Shell personnel at site to provide information and field observations as they are available.
3	T	6/16/2021	Unforeseen Events Could Result in Changes in Scope	Cause: Unforeseen Events Event: Outside Community or other impact to project Consequence: Required scope changes. Rework due to changes.	WSP	Financial	Active	3	3	9	High	Open	2	2	4	2			Technical/Scope Risk - Conduct Project Risk Review Meetings to identify and mitigate risks. 5/17/2023: Ongoing Weekly Meetings with all project participants.
4	T	6/16/2021	Unforeseen Scope Growth Due to Unknowns	Cause: Scope of work is not firm Event: Since PDP/ pre-FEED documents have not been provided, there could be scope changes/design development Consequence: If not funded externally to the project, these changes could lead to higher cost and rework	PM	Financial	Active	3	3	9	High	Open	3	2	6	3			Technical/Scope Risk - Site visits early in the project will allow the team to identify and proactively address any unknowns. Negotiate with Shell /change order to cover any increase in scope. 2/20/2023 PFDs have been issued and reviewed with no significant changes. This decreases the likelihood of major changes at this early part of FEED. 4/3/2023 PIDs have been issued and reviewed with minimal changes.
5	T	12/9/2022	Delays in Completion Due to Staff Workload or availability	Cause: Staff workload or availability Event: Delays in project completion. Consequence: Schedule impact; Increased cost as longer duration of project.	PM	Financial	Active	5	3	15	Medium	Open	4	3	12	3			Management, Planning and Oversight Risks - Participants are experienced in appropriately staffing projects. 5/12/2023 This risk has been upgraded due to the fire at the Shell site on 5/5/23. Some support staff for the project at Shell will be unavailable since they will be diverted to address the emergency conditions at the site. Mitigation is to identify and focus on critical areas where site support is required. Shell Project Engineer and Engineering Manager will fill-in for Operations and Maintenance personnel that are diverted to plant recovery effort. Team will proceed with documented assumptions as the project progresses.

Risk Identification								Pre-Risk Analysis					Post-Risk Analysis				Assurance		
Risk ID	Threat or Opportunity	Date Recorded	Risk Title	Risk Description	Risk Owner	Risk Driver	Category	Risk Likelihood	Impact Rating	Matrix Rating	Risk Manageability	Risk Status	Risk Likelihood	Impact Rating	Matrix Rating	Actions Total	Risk Closed Date	Risk Accepted By	Comments
6	T	12/9/2022	Key Person Replacement	Cause: Staff turnover, re-assignment. Event: Key person replacement. Consequence: Loss of project knowledge, Schedule impact, Re-work	WSP / Wood Group / Shell SGS / Technip	Reputation	Active	3	2	6	Medium	Open	3	1	3	1			Management, Planning and Oversight Risks - Recipient will have plans in place and PI's will vet personnel to mitigate the impact of any personnel which are replaced during the course of the project.
7	T	12/9/2022	Delayed or late reports	Cause: Lack of clarification of reporting requirements. Event: Delayed or late reports. Consequence: Schedule impact, Incorrect reading of project status, delay in identification and resolution of project concerns, Non compliance with DOE	WSP / Wood Group	Reputation	Active	2	2	4	Medium	Open	2	1	2	2			Management, Planning and Oversight Risks - Reporting requirements and milestones are manageable and not constrained by any single participant or event. 5/17/2023: Ongoing Weekly Meetings with all project participants.
8	T	12/9/2022	Environmental Impact	Cause: Waste production due to project. Event: Release with environmental impacts to air, land and water resources and potential impacts of waste production Consequence: Potential future environmental impacts.	WSP / Wood Group / Shell SGS / Technip	Environment	Enduring	2	2	4	Medium	Open	2	1	2	2			ES&H Risks - A Pre-Operational Risk Workshop will be conducted and risk mitigation strategies will be identified and employed. HAZOP will be performed to identify and mitigate potential hazards. 5/17/2023: FEL3 phase does not include any significant field work.
9	T	12/9/2022	Technology EH&S Risks	Cause: EH&S risks from use of proposed technologies. Event: Impact to EH&S. Consequence: Environment, Health and Safety issues, concerns; Financial/ legal costs, Loss of Reputation	WSP	Environment	Enduring	3	3	9	Medium	Open	2	2	4	2			ES&H Risks - The Recipient will prepare an EH&S Risk Assessment of the proposed technologies in accordance with SOPO Appendix D. HAZOP will be performed to identify and mitigate potential hazards. 5/17/2023: Carbon capture provides a positive environmental impact.
10	T	6/15/2021	Changes in Process Design Conditions	Cause: Changes in process design conditions Event: Due to changes in Process conditions, there may be additional scope Consequence: Delay in schedule and increased cost	Shell / Wood Group	Financial	Active	2	4	8	High	Open	1	2	2	3			12/28/2022 Scope was verified in OSBL & ISBL PFD review meetings. Heat & Material balances have been preliminarily performed. 1/30/2023 Heat & Material Balances have been completed and issued 5/12/2023 P&IDs have been issued and reviewed which decreases the likelihood of this risk.
11	T	6/15/2021	Invoice Payment	Cause: Delay in payment or submittal of invoices. Event: Delays in invoice payments. Consequence: Cash flow impact.	WSP	Financial	Active	4	3	12	High	Open	2	2	4	2			Invoices are pre-coded for clarity, and reviewed before submittal.
12	T	6/15/2021	Coordination	Cause: Coordination breakdown between stakeholders Event: Due to extensive coordination requirements, there is potential for communication breakdown Consequence: Delay in schedule, cost increase, poor quality engineering, unhappy client	WSP / Wood Group / Shell SGS / Technip	Reputation	Enduring	3	3	9	High	Open	2	2	4	4			Integrated schedule has been completed. Weekly meetings are held to review Actions, Needs, Decisions and schedule. 12/28/2022 update - Held joint ISBL and OSBL PFD review meetings during the month. 4/3/2023 - Held joint PID reviews during March/April. 5/12/2023 - A series of weekly Interface Meetings are being held with Wood & Technip to facilitate coordination and address any gaps or duplication in scope.
13	T	6/16/2021	Scope Gap	Cause: Gaps with scope interface between Licensors, subcontractors and Shell. Event: Omissions from TIC Estimate due to scope gaps Consequence: Cost to engineer these gaps, schedule & cost impact. Unidentified future costs.	WSP / Wood Group / Shell SGS / Technip	Financial	Enduring	3	3	9	High	Open	2	3	6	2			5/12/2023 TIC Estimate Basis Plan has been developed and reviewed with team. TIC Estimate will note limit of the scope included and known items that may be needed external to the project. 5/12/2023 - A series of weekly Interface Meetings are being held with Wood & Technip to facilitate coordination and address any gaps or duplication in scope.

Risk Identification								Pre-Risk Analysis					Post-Risk Analysis				Assurance		
Risk ID	Threat or Opportunity	Date Recorded	Risk Title	Risk Description	Risk Owner	Risk Driver	Category	Risk Likelihood	Impact Rating	Matrix Rating	Risk Manageability	Risk Status	Risk Likelihood	Impact Rating	Matrix Rating	Actions Total	Risk Closed Date	Risk Accepted By	Comments
14	T	6/16/2021	Management of Change	Cause: Failure to manage change within Project / Contract Event: Inability to control project / contract & potential for Scope Creep Consequence: potential for schedule, HSSE& cost issues.	WSP / Wood Group / Shell SGS / Technip	Financial	Enduring	4	3	12	High	Open	2	2	4	2			Strict adherence to the project change management program by all parties. 5/17/2023: Ongoing weekly meetings with all project participants to identify any potential changes. Documenting scope additions for including in next phase, and also decisions for FEL3. 5/30/2023: Maintain an Opportunities log to capture scope deferred to the next phase and also the opportunities for further investigation.
15	T	1/7/2023	Meet Project Objectives	Cause: Design does not meet project objectives. Event: Design Objective of capturing 95% of Site CO2 emissions and other DOE project objectives are not met. Consequence: Loss of Reputation, Rework, Schedule Impact	WSP / Wood / Shell SGS / Technip	Financial	Enduring	3	3	9	Low	Open	1	3	3	3			1/27/2023 Technip and Shell SGS design is based on several other previous designs. Continue to compare current project to previous projects executed by the licensor. Also, gain knowledge from previous project equipment approaches and vendors. 5/12/2023 Shell SGS has completed the majority of Licensor requirements.
16	T	3/3/2023	Noise Abatement for CO2 Compressor	Cause: CO2 Compressor noise exceeds latest area noise requirements. Event: Noise abatement for new CO2 Compressor required. Consequence: New enclosed building for CO2 Compressor required.	Shell/ Wood	Environment	Active	3	3	9	Medium	Open	2	3	6	3			3/3/2023 Action item #101 has been assigned to Shell to determine if building is required for noise abatement. 5/12/2023 Local sound enclosure for the CO2 Compressor will be included in the TIC Estimate for this phase. Next project phase will revisit and perform acoustic analysis.
17	T	5/17/2023	Delays in Project completion	Cause: Scope changes, lack of staff resources, unforeseen events, commercial challenges. Event: Delay in project completion. Consequence: Schedule and Financial impact	WSP	Financial	Active	4	3	12	Medium	Open	3	3	9	4			8/2022: Work suspension put into place due to commercial challenges with SGS. 10/2022: Subcontracts in place with all participants. 11/2022: Developed overall integrated project schedule. 5/17/2023: Ongoing weekly meetings with all project participants. 6/2023: Submittal of extension request for project schedule to DOE.
18	T	5/17/2023	Impacts to DOE relationship	Cause: Poor communication with DOE, missing contractual milestones, or quality of deliverables does not meet requirements. Event: DOE dissatisfaction on project delivery. Consequence: Reputational damage	WSP / Wood / Shell / Technip	Reputation	Active	2	3	6	High	Open	1	3	3	2			Monthly meetings with DOE, deliverables submitted per schedule.
19	T	5/30/2023	Availability of outside utilities and infrastructure	Cause: Large utility requirements and large equipment logistics. Event: Outside utilities and infrastructure are not sufficient to support project. Consequence: Late changes/ undocumented scope. Schedule and cost impact	WSP / Wood / Shell / Technip	Financial	Active	3	4	12	Medium	Open	2	2	4	4			5/30/2023: This phase will perform adequate design to understand equipment and utility requirements. Heavy haul study will be performed. Local utility suppliers will be engaged to understand power availability for project. Will identify potential gaps this phase and address as appropriate. Any additional requirements not fully defined this phase will be documented in the TIC Estimate Basis and Opportunity Log for further refinement in the next phase.

Business Impact							Value
Injury / Health	Environmental	Damage	Security	Financial*	Reputational	Legal	
Severe	Severe	Severe	Severe	Severe	Severe	Severe	5
Major	Major	Major	Major	Major	Major	Major	4
Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	3
Minor	Minor	Minor	Minor	Minor	Minor	Minor	2
Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	1



Value	1	2	3	4	5
Likelihood					
Likelihood	Rare	Unlikely	Possible	Likely	Almost Certain