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COMMERCIAL-SCALE FRONT-END ENGINEERING DESIGN (FEED) STUDY FOR MTR'S MEMBRANE CO_2 CAPTURE PROCESS

by

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Membrane Technology & Research, Inc.
DRY FORK STATION UNIT 1

Full Scale Carbon Capture FEED Study S&L Summary Report

Report SL-016769

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ISSUE SUMMARY AND APPROVAL PAGE

This is to certify that this document has been prepared, reviewed and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0405, which is based on ANSI/ISO/ASSQC Q9001 Quality Management Systems.

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1. INTRODUCTION

1.1. PROJECT OVERVIEW

Sargent & Lundy (S&L) was retained by Membrane Technology and Research, Inc. (MTR) to support the work outlined in the National Energy Technology Laboratory (NETL) sponsored project, DE-FE00031846 (FPO-2058). MTR and S&L, in cooperation with Basin Electric Power Cooperative (BEPC), Electric Power Research Institute (EPRI), and Trimeric Corporation (Trimeric), completed a full scale Front End Engineering and Design (FEED) study to evaluate the retrofit of MTR's membrane-based post-combustion carbon dioxide (CO_2) capture technology to the BEPC Dry Fork Station (DFS) Unit 1. The capture plant is designed to treat the entire flue gas flow from DFS; it is estimated that this system will capture 6,560 tonnes per day (TPD) of carbon dioxide, approximately 70% of DFS's current CO_2 emissions. This capture rate reflects a 90% capacity factor of Dry Fork Station. The captured CO_2 is compressed to 2,213 psia (152.58 bara) before flowing to the capture plant boundary tie-point. It was assumed for this study that the CO_2 would be pumped to the Carbon Storage Assurance Facility Enterprise (CarbonSAFE) storage complex for geological sequestration; alternatively, the CO_2 could be sent to a pipeline off-site for Enhanced Oil Recovery (EOR).

S&L was tasked with preliminary engineering and design of all balance of plant (BOP) components and providing input and oversight on other project deliverables. The S&L BOP design included utility tie-ins, interconnecting ductwork/piping, wet surface air coolers, cooling tower, reagent/chemical supply and storage, wastewater collection and treatment, wastewater fixation, process vent stack, structural, civil, switchyard, substation, electrical, and instrumentation and controls. S&L prepared the overall project design criteria, execution phase technical specifications, plot plan and general arrangement drawings, overall process flow diagram, process and instrumentation diagrams (P&IDs), system descriptions, single line diagrams, network architecture diagrams, controls description, typical loop diagrams and I/O tables, and instrument and I/O lists. S&L also performed a preliminary Process Hazard Analysis (PHA) review of the CO_2 capture facility, developed the detailed engineering and design project schedule and completed other critical engineering deliverables or tasks to support the design effort. In addition, S&L supported the development of budgetary request templates, soliciting equipment budgetary requests, and the development of detailed cost estimates.

Trimeric, in coordination with MTR, was tasked with the preliminary design of the direct contact cooler (DCC), the CO_2 purification unit (CPU), and all other capture process heat exchangers, compression/rotating equipment, knockout drums (KO), etc. EPRI was tasked with evaluating the process cooling (water) options for the CO_2 capture system in coordination with Trimeric. S&L developed the preliminary design for the flue gas booster fan and the integrated layout between all pieces of equipment. The overall goal of the project was to develop an Association for the Advancement of Cost Engineering (AACE) Level 2 Capital Cost Estimate with an accuracy of ± 15% to demonstrate the economic feasibility of constructing and operating the MTR CO_2 capture plant. This summary report outlines the scope, engineering approach, and results of the MTR Full Scale Carbon Capture FEED Study, as supplemented by the information presented in the various appendices.

1.2. FULL SCALE OVERVIEW

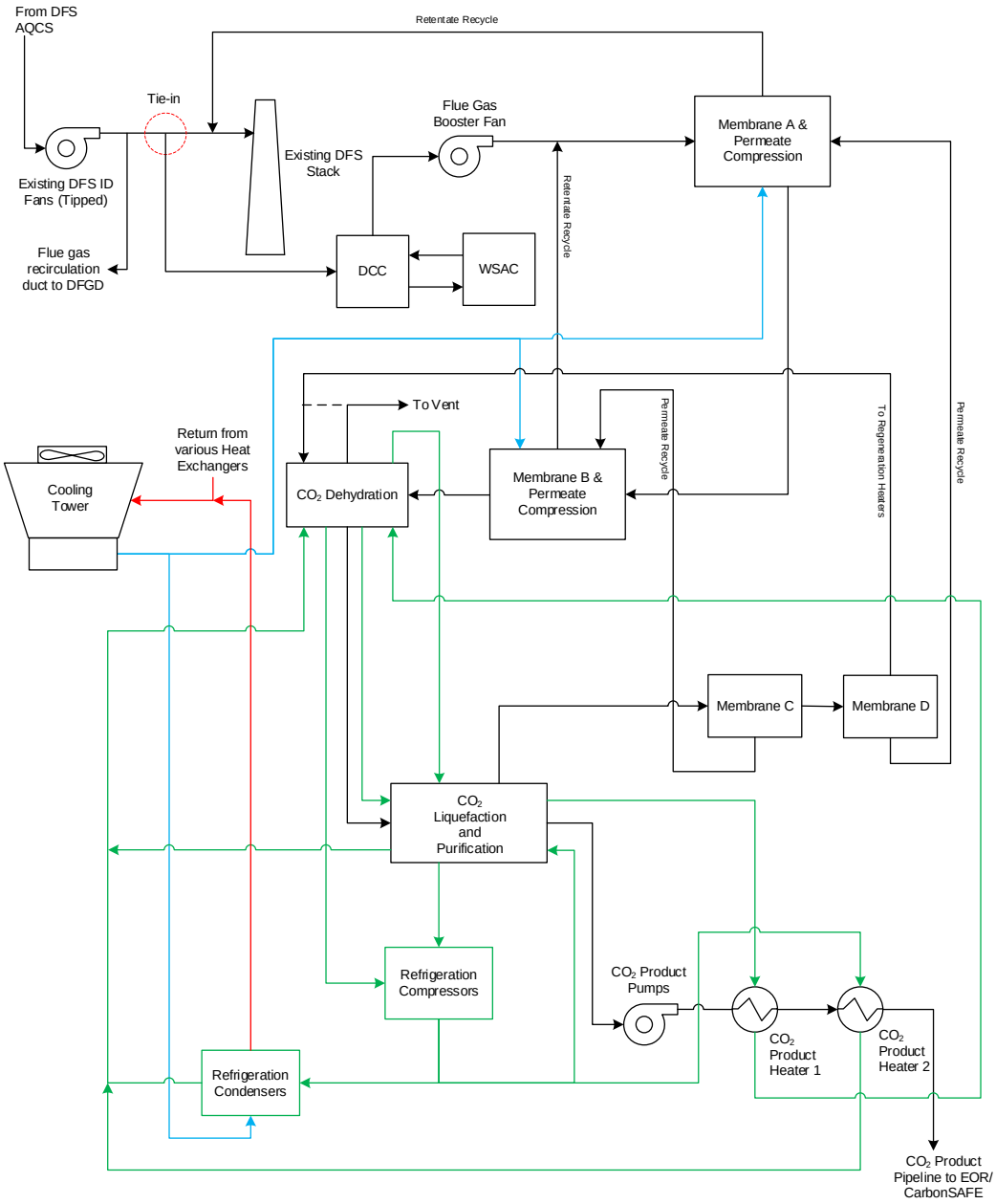
The proposed full scale CO_2 capture plant will consist of the following major pieces of equipment/systems and scope:

1. Existing Induced Draft (ID) Fan(s) Modifications
2. Direct Contact Cooler (DCC) System, includes an integrated SO_2 Polishing Section
3. Hybrid Wet Surface Air Cooler (WSAC) Systems
4. Flue Gas Booster Fans
5. Membrane A (MEMA) and Permeate Compression
6. Membrane B (MEMB) and Permeate Compression

7. CO_2 Purification Unit (CPU) including Refrigeration System
8. CO_2 Booster and Product Pumps
9. Membrane C & D (MEMC & MEMD)
10. Circulating and Closed Cooling Water System
11. Wastewater Treatment System
12. Well Water System
13. Service Water System
14. Compressed Air System
15. Process Condensate Collection and Injection
16. Wastewater Fixation System
17. Existing 230kV Switchyard Modification & New 230kV Substation
18. Auxiliary Power System
19. Emergency Power and Purge System
20. Control System

Figure 1-1 on the following page, depicts the overall block flow diagram for the full scale application at DFS. A more detailed process flow diagram (PFD) is included in Appendix A.

Figure 1-1 — MTR Full Scale Overall Block Flow Diagram



2. PROCESS & BALANCE OF PLANT (BOP) DESIGN

S&L was tasked with performing preliminary engineering and design for the BOP scope to support implementation of the MTR membrane based CO_2 capture plant at DFS. BOP design and engineering was supplemented by information provided by BEPC regarding the operating conditions of the DFS unit, acceptable tie-in conditions, existing electrical layouts, surrounding landscape and facilities, and available utilities.

The approach for the preliminary design and engineering for the CO_2 capture plant is summarized in the following sections.

2.1. DESIGN INPUTS

DFS Unit 1 is a low-sulfur Powder River Basin (PRB) coal-fired, base-loaded 445 MW (Gross) generating unit that has a 90% annual capacity factor. The unit utilizes an air-cooled condenser (ACC) to minimize the amount of plant water consumption. The unit also utilizes B&W AireJet® low NOx burners, overfire air and selective catalytic reduction (SCR) for nitrogen oxides (NOx) emission control; activated carbon injection for mercury (Hg) control; and a Nooter-Eriksen dry flue gas desulfurization (DFGD) system that consists of a circulating dry scrubber (CDS) followed by two (2) fabric filter baghouses, to control sulfur dioxide (SO_2) and stack particulate matter emissions from the unit. Flue gas from each baghouse is currently transferred by a dedicated ID fan to opposing breechings on a single stack.

In 2018, DFS was retrofitted as the host-facility for the Wyoming Integrated Test Center (ITC) to facilitate post-combustion carbon capture research and testing demonstrations. The ITC consists of six (6) Small Test Center (STC) test bays and one (1) Large Test Center (LTC) test bay that tie-in to the existing flue gas ductwork 1B (north flue gas train). There are five (5) STC test bays located north of the DFS Unit 1, the one (1) LTC test bay is located east of DFS Unit 1, and the sixth STC test bay is located north of the LTC test bay. The CO_2 capture facility will be located in the current LTC/6th STC area; as such, the ductwork, LTC fan and security fencing will be demolished as part of the CO_2 capture facility installation. The 5 STC bays will remain intact.

The inlet flow gas composition for the MTR full scale unit was established based on S&L combustion calculations and BEPC provided information. Table 2-1 shows the flue gas conditions used for the design of the full scale CO_2 capture plant at full load, summer operating conditions once the existing ID fans are tipped to transfer flue gas to the CO_2 capture plant; refer to the S&L Design Criteria included in Appendix A for other site parameters assumed and Appendix A for further details on other operating conditions assessed by S&L to establish a range of expected inlet conditions throughout the year and at various unit operating points.

Table 2-1 — Design Inlet Flue Gas Conditions

Parameter	Data
MTR Full Scale	445 MWe (gross)
Temperature	222°F (106°C)
Pressure	13.216 psia (0.911 bara)
Nitrogen (N_2)	65.48 % vol
Oxygen (O_2)	3.71 % vol
Water (H_2O)	18.79 % vol
Carbon Dioxide (CO_2)	12.01 % vol
Sulfur Dioxide (SO_2)	27.0 ppmv wet

Parameter	Data
Sulfur Trioxide (SO_3)	1.0 ppmv wet
Hydrogen Chloride (HCl)	0 ppmv wet
Hydrogen Fluoride (HF)	0 ppmv wet
Total Flow	5,096,990 lb/hr (2,311,954 kg/hr)
Fly Ash	53 lb/hr (24 kg/hr)
Nitrogen Oxide (NO)	31.0 ppmv wet
Nitrogen Dioxide (NO_2)	2.0 ppmv wet
Ammonia (NH_3) Slip	5 ppmv dry

2.2. BALANCE OF PLANT SCOPE

S&L performed the front-end engineering and design for the major BOP scope to support the development of the detailed cost estimate and technical specifications for the CO_2 capture plant. The balance of plant scope includes equipment layout, flue gas ductwork, process vent stacks, interconnecting piping, electrical equipment, structural supports, foundations, buildings, utilities, wastewater treatment, etc. Details of the major BOP scope are described in the sections below.

2.2.1. Site Plot Plan

The CO_2 capture plant will be located to the east of DFS Unit 1. Note: all cardinal directions referred to in this report reference the “plant” direction; plant north is approximately 45 degrees east of state plane north. Refer to Figure 2-1 for the existing DFS Site Plan; refer to Figure 2-2 and Appendix A for the CO_2 capture plant general arrangement drawings.

The majority of the process equipment will be enclosed in a building that will be located where the LTC test bay is currently located. The CO_2 Purification Unit (CPU) Building will be located north of the CO_2 Capture Plant Process Building near the existing cold storage warehouses 1 & 2 and the existing storm water pond #2. The new CO_2 capture substation will be located due east of the CPU Building. The closed cooling water system, wastewater treatment system and well water system will be located to the south of the CO_2 Capture Plant Process Building. The wastewater forwarding tank and fixation lime silo will be located near the existing DFS waste ash storage silo. Excess water (surplus) from the CO_2 capture plant will be pumped to a reservoir located to the southwest of DFS Unit 1. Flow from the CO_2 capture reservoir will be routed to the CO_2 capture plant and Dry Fork Station.

The original design of DFS included Unit 1 and provisions and reserve space for a future Unit 2. The location of the CO_2 capture plant and its associated equipment and supports were selected to maintain the Unit 2 reserve space.

The location of the CO_2 capture plant was also originally selected to maintain as much of the 300-foot buffer zone from the Waters of the United States (WOTUS), which was located at the far east end of the DFS property. Upon further investigation, it was discovered that the buffer-zone was proposed in a draft Environmental Impact Statement (EIS) during the original plant design and construction. However, the EIS was never submitted to the Environmental Protection Agency (EPA). S&L reviewed the permitting documentation, and there are no buffer-zone requirements in terms of USACE, Wyoming state or local Campbell county permits; so, no wetland permits would be required for the CO_2 capture project and legally, there are no buffer-zones except within the water (stream) itself. Based on the layout, the closest point to the wetland boundary where civil/grading work would be completed is 100 ft; and the CO_2 facility equipment is over 200 ft away from the stream. It was agreed by this project team that no construction would be considered in or east of 100 ft from the WOTUS boundary.

Figure 2-1 — Existing DFS Site Plan

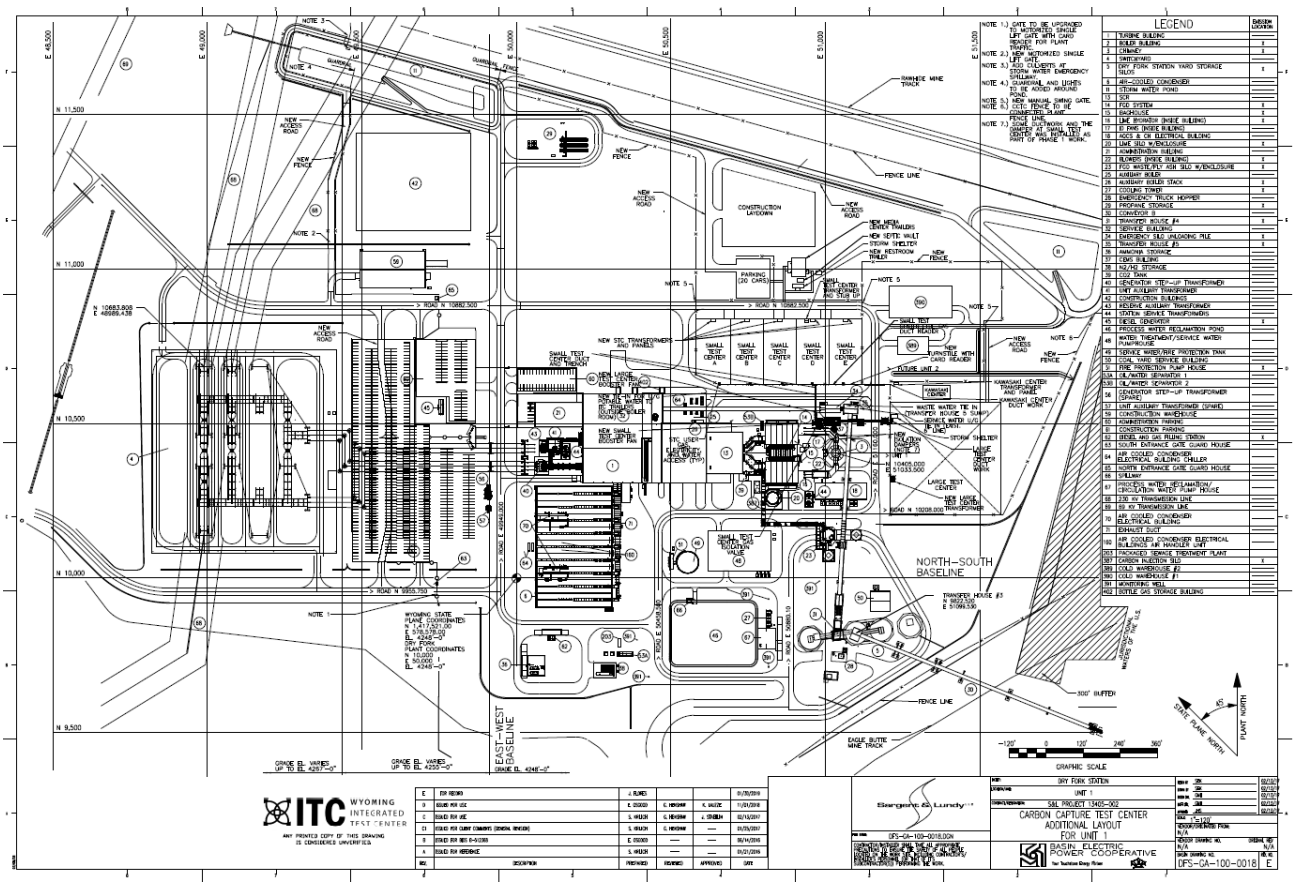
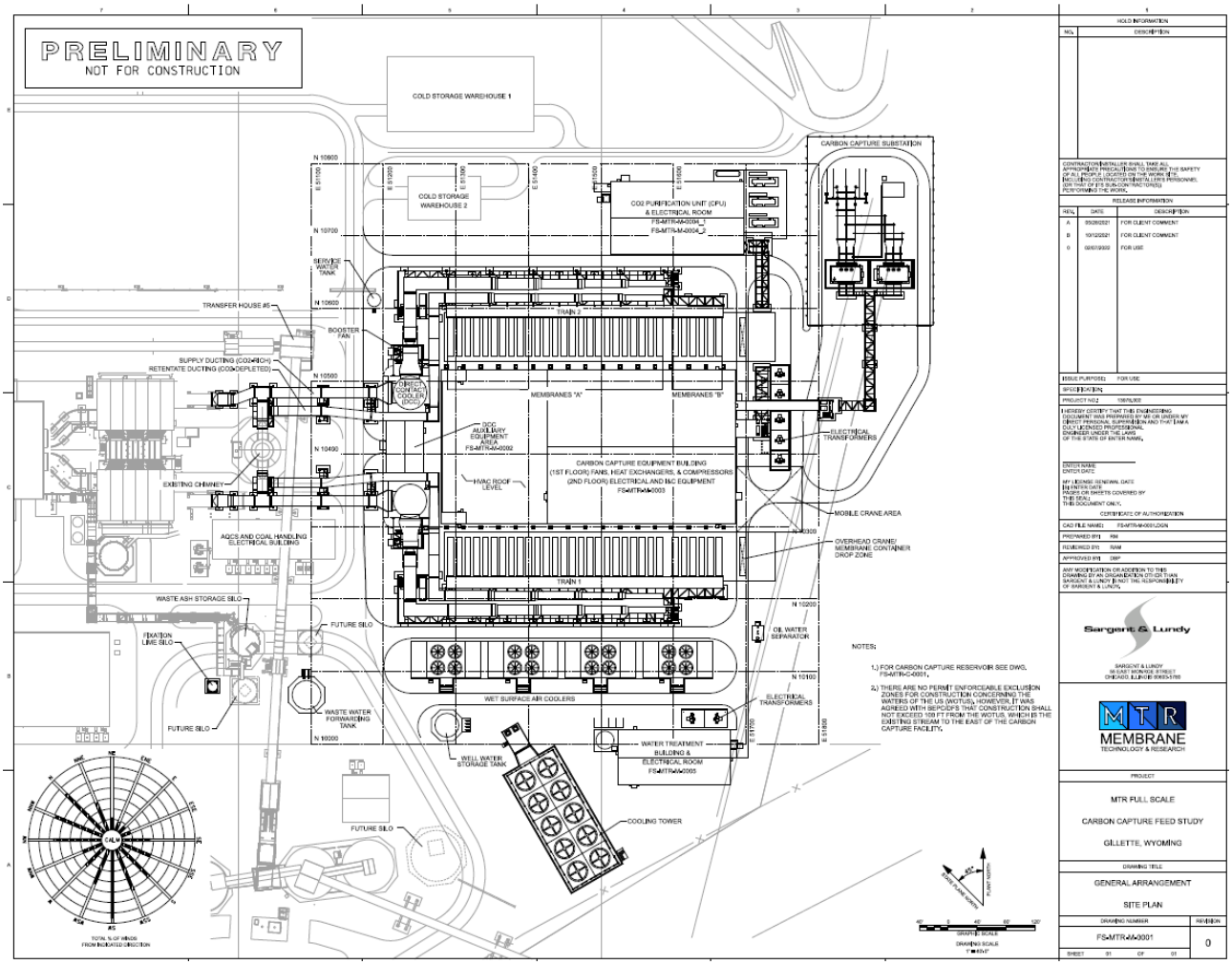


Figure 2-2 — MTR CO_2 Capture FEED Study Site Plan



2.2.2. Equipment General Arrangement

The MTR full scale CO_2 capture plant was arranged to meet MTR's preferences, comply with international, federal, state and local codes, meet the process requirements (minimize pressure drop in the process piping), provide access to equipment for maintenance, include appropriate separation/barriers for safe operation, and minimize construction costs. Refer to Appendix A for the General Arrangement Drawings.

Flue gas is routed from DFS Unit 1 east to the CO_2 capture plant and is sent through the DCCs. At the outlet of each DCC a flue gas booster fan increases the flue gas pressure before sending the gas through Membrane A outside the north and south walls of the CO_2 Capture Plant Process Building. Retentate (CO_2-depleted) flue gas from the Membrane A is sent back to the existing stack. Permeate equipment, used to compress the CO_2 rich permeate gas and create the required vacuum for Membrane A and B, is located in the center of the CO_2 Capture Plant Process Building.

Following Membrane B compression, the gas is sent to the CPU Building. The CPU Building houses the CO_2 dehydration, CO_2 liquefaction & purification system, and the CO_2 booster and product pumps. The refrigerant system compressors, condensers and receiver are located outdoors along the eastern wall of the CPU Building.

Water is circulated by the DCC circulating water pumps in the DCC Auxiliary Equipment Building through the WSACs located south of the CO_2 Capture Plant Process Building. The Water Treatment Building, located to the southeast of the site, includes the wastewater processing equipment and the chemical feed systems for the WSACs and cooling tower. The cooling tower, which feeds closed cooling water to the process heat exchangers, is located to the southwest of the Water Treatment Building.

2.2.3. Flue Gas Ductwork Tie-in

The CO_2 capture plant flue gas ductwork will tie-in to the existing 15-foot diameter round clean DFGD gas ductwork (1A & 1B) downstream of the existing louver dampers at the outlet of each ID fan to bypass the existing stack and transfer CO_2-rich flue gas to the CO_2 capture plant when it is operating. The existing 15-foot round ductwork and associated structural supports will be demolished downstream of the existing louver dampers to the existing 15-foot by 12-foot chimney ducts that connect to the stack breechings. The existing chimney ducts will remain in-place and unmodified; the CO_2-depleted flue gas return ductwork from the CO_2 capture plant will tie back into these chimney ducts.

A series of double louver isolation dampers will be provided in the new ductwork arrangement in order to maintain the capability of venting flue gas directly to the existing stack and allow DFS to continue to operate in the event the CO_2 capture plant is offline. While the CO_2 capture plant is in operation, these isolation dampers will be configured to allow for two isolated flue gas paths: a CO_2-rich flue gas path supplying flue gas to the CO_2 capture plant and a CO_2-depleted flue gas path returning flue gas from the CO_2 capture plant to the stack.

Some additional modifications will be made in the tie-in area. The existing clean DFGD gas ducts (1A & 1B), between the existing ID fan evase and the existing louver damper, will require duct support modifications; these modifications are required due to the change in duct support configuration from demolishing portions of the existing round clean DFGD gas ducts. The ITC LTC ductwork, support steel and foundations will be demolished to facilitate the installation of the new CO_2 capture plant ductwork. A new ITC STC supply and recirculation tie-in nozzle will be installed in the new CO_2 capture plant ductwork to replace the existing tie-in nozzles which also need to be demolished in order to install the new CO_2 capture plant ductwork.

2.2.4. Flue Gas Ductwork

The new flue gas ductwork will consist of CO2-rich supply duct segments and CO2-depleted retentate duct segments. Duct segments will vary in cross-sectional area throughout the ductwork arrangement to accommodate geometric constraints and to provide fairly smooth transitions for flow reasons. CO2-rich supply ductwork will average a cross-sectional geometry of 11’-0” x 18’-0” (W x H) and CO2-depleted ductwork will average a cross-sectional geometry of 9’-0” x 12’-6” (W x H). From the tie-in locations, new flue gas ductwork will maintain the two separate trains of flue gas from the existing Unit 1 ID fans to the DCC vessels, booster fans and then Membrane A blocks. The flue gas ductwork will form a header feeding each of the Membrane A containers. The ductwork will reduce in cross-section along the header to maintain adequate flue gas velocity and flow. Preliminary computational fluid dynamics (CFD) modeling was performed by MTR to confirm adequate, evenly distributed flow to each of Membrane A skids. CFD modeling will be performed during the detailed design phase to ensure balanced flow is maintained throughout the final ductwork arrangement to minimize overall ductwork pressure drop. See Appendix D and Appendix A for the ductwork design drawings. Note: the FRP sections of the ductwork are shown in the piping isometric drawings.

Double louver isolation dampers and seal air systems will be provided throughout the flue gas ductwork arrangement. A series of isolation dampers is located between the tie-in and the existing stack to create a bypass configuration. The remaining ductwork arrangement will be provided with double louver isolation dampers and seal air systems downstream of the booster fans to allow for membrane container “stacks” (set of 3 containers tall) to be isolated for trouble-shooting and/or changeout. Seal air systems and access platforms will be provided, as necessary, at each damper location. No modulating dampers are expected throughout the ductwork arrangement.

The flue gas ductwork between the Unit 1 tie-in and Membrane A header will be carbon steel. The connection between the Membrane A header and the inlet of Membrane A will utilize fiber reinforced plastic (FRP) round

ducting designed and supplied by an FRP vendor. The outlet of Membrane A will utilize FRP round ductwork to route flue gas from Membrane A to the Membrane A compression equipment. Isolation valves and access platforms will be provided as necessary.

The new carbon steel ductwork will be bottom supported by new structural steel framing. Ductwork supports will be furnished with flat of spherical slide bearing plates to reduce friction forces during thermal expansion and contraction cycles. New flue gas ductwork will be routed across existing plant roads, as necessary. Wide flange and channel stiffeners will be designed using ASTM A992 and ASTM A36 materials respectively. Duct plate, base plates, sole plates, turning vanes and miscellaneous plates will be designed using ASTM A572 Grade 50 materials. Pipes and test ports will be designed using ASTM A500 Grade C materials.

All new CO_2 capture plant carbon steel ductwork will be internally coated using Carboline Plasite 4310, a vinyl ester resin with special curing and inert flake pigment. This coating system will protect the otherwise raw steel from moisture and acid condensate fallout that may occur in the ductwork system. This coating system recommendation is based on the flue gas composition and operating data for the ID fan outlet and stack temperatures received from DFS. The design temperature of the coating system is considered 300°F for dry operating conditions and 350-400°F for excursion conditions; this design temperature is higher than considered for ductwork design and adds additional robustness to the protective coating system. In addition to the coating system, the ductwork will be sloped and drains installed at the bottom of the expansion joints to remove condensate that has been collected at the low points.

2.2.5. CO_2-Depleted Vent Streams

As noted in Section 2.2.3, upstream of the Unit 1 stack, the new flue gas ductwork will be provided with double louver isolation dampers and seal air systems. This arrangement of the isolation dampers will allow DFS Unit 1 to operate with flue gas flow going to the CO_2 capture system or to operate bypassing the CO_2 capture system. When flue gas is routed to the CO_2 capture facility, retentate flue gas from Membrane A is routed back to the existing Unit 1 stack; this maintains a single point of emission.

CO_2-depleted flue gas from DFS will be vented from two (2) locations after the CO2 capture facility is installed: Membrane A retentate will be vented to atmosphere via the existing stack; and regeneration exhaust from the CPU dehydration beds (or MEMD retentate when the regeneration is not taking place) will be vented to atmosphere via new process vents (or stacks). The process gas venting from the CPU will consist of vertical piping purposed as stacks. Refer to Section 3.7.1 for additional details on process vents and the associated emissions.

2.2.6. Circulating and Closed Cooling Water System

The CO_2 capture plant water cooling is provided by two separate cooling systems. The circulating water system consists of four Hybrid WSAC units. The hybrid units contain a separate dry (air-cooled) section followed by a wet surface air cooler that cool the circulating water feeding the upper section of the DCCs. The closed cooling water system consists of a cooling tower that provides cooling water to the process system heat exchangers.

The circulating water system WSACs work via two circulating loops. Each DCC (Train 1 and Train 2) has two (2) x 100% DCC circulating water pumps that pump water from the upper section of each DCC through two (2) WSACs (Train 1 feeds WSAC 3 and 4 and Train 2 feeds WSAC 1 and 2) before returning cooled process water back to the upper section of each DCC to cool the incoming flue gas. Each WSAC basin includes a set of three (3) x 50% WSAC pumps that circulate water from each WSAC basin through a set of sprays located above each WSAC cell and discharges the water back into the WSAC basin.

Trimeric determined the DCC heat loads based on the CO_2 capture process heat and mass balance and DFS system and site data. S&L determined the quantity of water available for supply to the CO_2 process (see Section 3.4). Then, Trimeric solicited vendor quotes from Alfa-Laval who sized a “hybrid” WSAC system. The hybrid system allows for wet and/or dry cooling to meet the (DCC) process cooling requirements; this minimized well water consumption by relying on the DCC condensate collected from the flue gas for use as makeup to the cooling water. S&L analyzed the quotes received for use in the overall water balance,

wastewater treatment design solution, plant layout and balance of plant piping design.

The closed cooling water system for the process equipment will use an evaporative, ten-cell, counterflow mechanical draft cooling tower (CT). For the cooling tower sizing, S&L consolidated the cooling water system heat loads, flowrates, and DFS system and site data to determine the total cooling tower heat rejection duty. This information was used to solicit a vendor budgetary quote from SPX for the cooling tower sizing.

The remainder of the process equipment closed cooling water system, designed by S&L, includes the closed cooling water pumps, closed cooling water piping to and from the plant water cooled heat exchangers, and all associated valving and instrumentation.

The cooling tower loop uses two (2) x 100% closed cooling water pumps that take suction from the cooling tower basin. The closed cooling water pumps send cooled water into the main supply header which cycles the cooling water through the process heat exchangers. Each of the process heat exchangers are equipped with inlet isolation and outlet throttling valves, a thermal pressure relief valve, and outlet temperature instrumentation. Downstream of the heat exchangers, the return lines connect into a common header that leads back to the cooling tower. The return water is sent through a set of sprays located above each cooling tower cell before being discharged back to the cooling tower basin. During winter months, the return water can be redirected away from the cells directly to the basin.

2.2.7. Wastewater Treatment and Storage

The wastewater treatment and storage system takes blowdown and filtrate from CO_2 capture plant process systems, treats the process water through a water treatment system (including microfiltration and reverse osmosis (RO)) to produce treated water. The treated water is used for DCC mist eliminator wash water and CT basin makeup. During winter conditions, excess treated water will be sent to the well water tank for storage.

The wastewater system major equipment shall include one (1) equalization tank, two (2) x 100% equalization forwarding pumps, water treatment system (vendor quote by Evoqua), one (1) RO permeate holding tank, and two (2) x 100% RO permeate tank forwarding pumps.

Wastewater from the RO process will be pumped via two (2) x 100% RO wastewater sump pumps to the wastewater forwarding tank, along with SO_2 blowdown from the DCCs, to be used in the lime fixation system process. Waste solids produced as part of the water treatment process shall be removed via a filter press system (also provided as part of the water treatment equipment quoted by Evoqua). The filtrate water collected as part of the dewatering process shall be pumped back to the equalization tank via two (2) x 100% filtrate recycle sump pumps.

Additional details on the water treatment system equipment are described in Section 2.4.3.

2.2.8. Well Water System

Well water will be supplied from the existing well water supply line feeding the existing service water and fire protection tank located south west of the CO_2 capture plant. The well water system provides makeup water to the CO_2 capture plant including the water treatment system, WSAC's, and cooling tower. The system includes one (1) carbon capture well water storage tank, two (2) x 100% well water forwarding pumps, and two (2) x 100% reservoir return pumps, as well as associated piping, valves, and instrumentation and controls.

During winter conditions, when excess water is produced by the CO_2 capture plant, water shall be transferred from the CO_2 capture plant well water storage tank to the CO_2 capture plant reservoir. During summer conditions, water shall be returned to the CO_2 capture plant well water storage tank from the reservoir via the two (2) x 100% reservoir forwarding pumps to supplement the well water (make-up) supply to the CO_2 capture plant.

2.2.9. Service Water System

The CO_2 capture plant service water supply will be provided from the existing DFS plant service water system. The service water supply shall be tied into the existing ITC tie in off the existing 6 inch line in Transfer House 5. The CO_2 capture plant service water system will include a service water storage tank and two (2) x 100%

service water pumps which will provide service water to the washdown stations located throughout the various buildings of the CO_2 capture plant.

2.2.10. Compressed Air System

The CO_2 capture plant will be provided with an independent compressed air system consisting of air compressors, air dryers, and service and instrument air receivers. Instrumentation and valving requiring compressed air will be supplied off the instrument air receiver while a second receiver is provided for service air.

2.2.11. Process Condensate Collection and Injection

Condensate is collected from various process drains in the membrane permeate compression process via process condensate collection sumps located in the CO_2 Capture Plant Process Building and CPU Building. These sumps will be designed with a curb to prevent washdown or other contaminants from entering into the process condensate collection sumps. Sump pumps will pump the condensate from these sumps to a process condensate collection tank located inside the CO_2 Capture Plant Process Building south of the Membrane B compressor. Condensate from the condensate collection tank is pumped to Train 1 and Train 2 permeate fans for injection cooling at the fan inlets. Additional process condensate is sent to the cooling tower basin for makeup water.

At certain points in the CO_2 capture process, the process condensate to be collected is from a section of the process that is under vacuum. For these sections, a Spirax system with Pivotrol air powered vacuum pump was selected to remove the condensate from the system without allowing back flow of ambient air into the process gas.

2.2.12. Reagent and Chemical Supply and Storage

A caustic (sodium hydroxide, NaOH) reagent dosing system is required by each DCC to control pH and will add 25% NaOH solution to the recirculating liquid via a dosing pump to maintain a set pH level of 7-8. One (1) common caustic reagent tank will be provided, connected in service to a dosing pump to each DCC. The caustic reagent dosing systems and storage tank are located in the DCC Auxiliary Equipment Building.

The WSACs include a chemical feed system consisting of three (3) chemical feed skids for corrosion inhibitor, bleach, and caustic to treat the supply water. These chemicals will be injected directly into the WSAC basin. Totes and metering pumps will be located in the Water Treatment Building and placed inside curbed areas sized to contain the entire contents of a spill.

The cooling tower includes a chemical feed system consisting of three (3) chemical feed skids for scale inhibitor (anti-scalant), bleach, and bromide to treat the supply water. These chemicals will be injected directly into the cooling tower basin. Totes and metering pumps will be located in the Water Treatment Building and placed inside curbed areas sized to contain the entire contents of a spill.

2.2.13. CO_2 Capture Plant Buildings

The majority of the process equipment will be enclosed in buildings. The use of these buildings will be special purpose power plant equipment enclosures which are not regularly occupied. The height and area of the buildings are characterized by open space that is dictated by the equipment, interrelated processes and accommodation for equipment removal and maintenance. All buildings will be engineered and stick-built to allow for adequate first floor height. Equipment and electrical rooms on the second floor are supported by elevated concrete slabs.

Interior fire rated partitions will be provided for egress components and area separation as required by International Building Code (IBC) and as recommended by National Fire Protection Association (NFPA) 850. Personnel doors and stairways will be provided for personnel access and safety. Overhead doors, elevators, where required, and the use of removable wall panels, will be provided for equipment access and maintenance. Wall penetrations will be located, as necessary, for all process piping, electrical bus and ducts, and building louvers. Roof and wall penetrations will be provided and located, as necessary, for HVAC equipment. Building

security will be included to ensure North American Electric Reliability Corporation-Critical Infrastructure Protection (NERC-CIP) requirements are satisfied.

2.2.14. Structural Supports & Building Steel

Structural support steel and foundations will be provided for all flue gas ductwork, equipment, above ground process piping, above ground BOP piping, electrical cable tray, cable bus, and non-segregated phase bus. A utility rack will be provided for electrical cable tray, cable bus, and non-segregated phase bus leading from the CO_2 capture plant substation to the CO_2 Capture Plant Process Building. The utility rack will extend north to the CPU Building and will support electrical cable tray, cable bus, and BOP piping to and from the CO_2 Capture Plant Process Building. Stair towers are placed along the utility rack to access utility rack gallery levels that are elevated to maintain roadway clearance. Utility racks are grated to provide access, where required.

Along the flue gas ductwork arrangement, where access doors are provided, gallery access will be provided with ladder or stair access. A stair tower and access gallery steel are provided for the DCCs and are incorporated into the layout of duct support tower. Access gallery will also be provided around the Membrane A & B removal crane steel and will provide access to each membrane container inlet and outlet. A raised platform is also provided for the refrigerant condensers outside of the northeast corner of the CPU Building.

Support steel will be provided for the bottom supported ten-cell cooling tower. Height of the cooling tower support steel is sized based on a minimum height, provided by the cooling tower vendor, to provide adequate air intake to the cooling tower cells. A stair tower will also be provided to access the rooftop of the cooling tower cells. Support steel for the fixation lime silo will be provided by the silo vendor.

Building steel will be provided for the CO_2 Capture Plant Process Building, Water Treatment Building, CPU Building, and DCC Auxiliary Equipment Building. The steel is laid out to provide necessary support for all secondary floors housing mechanical and electrical equipment, and to provide support for all miscellaneous equipment and cable tray.

2.2.15. Containment and Foundations

Foundations and equipment pads will be provided for the CO_2 Capture Plant Process Building, Water Treatment Building, CPU Building, and DCC Auxiliary Equipment Building. Foundations will be provided for all ductwork support steel, membrane and gallery support steel, utility rack support steel, cooling tower, and all other exterior and interior equipment, and pumps. Where soil conditions are met, ground supported foundations will be provided, and will include non-frost susceptible fill material placed from the bottom of the foundation down to frost depth to prevent frost heave. All other foundations will be placed on H-piles or drilled piers, refer to Appendix A for more details. The bottom of pile cap elevation will extend to frost depth to prevent frost heave from inducing tension loads between the connection of the H-piles/drilled piers and the pile cap.

All foundations will be designed for the applicable equipment loads and to meet the requirements of the applicable building codes. Containment curbs will be provided where necessary, and containment will be sized according to vendor provided information and governing codes and requirements. Building sumps and trenching will be provided in the CO_2 Capture Plant Process Building, Water Treatment Building, and CPU Building to accommodate drainage, spills, and various other processes. The building process sumps, RO wastewater sump, and filtrate recycle sump will include containment curbs to prevent any washdown water from mixing into the sump.

2.2.16. Electrical Equipment

The major electrical equipment will be housed in dedicated electrical equipment rooms located on the second floor of the CO_2 Capture Plant Process Building, CPU Building, and Water Treatment Building. Appendix A contains datasheets style specifications for the major electrical equipment.

2.2.17. Supervisory Control System

Supervisory control and monitoring of the CO_2 capture plant will be accomplished via an expansion to the existing DFS distributed control system (DCS). The new DCS expansion will be fully integrated into the DFS DCS. BOP equipment, packaged equipment, and system skids will interface to the DCS expansion via hardwired and datalink signals. Operators will control the CO_2 capture plant primarily via the human machine interfaces (HMIs) located in the existing DFS Unit 1 Main Control Room (MCR) and occasionally via remote engineering/operator workstations located in the CO_2 capture plant DCS rooms or local field mounted HMI's; for major packaged equipment or system skids. The CO_2 capture plant control system will include all necessary supervisory control and monitoring to operate the plant and provide adequate protection for personnel and equipment.

2.2.18. Emergency Diesel Generator and Purge Fan

Upon a total loss of power to the CO_2 capture plant, a purge of the membranes should be completed to prevent damage due to residual flue/CO_2 gas and condensation. An emergency purge fan for each capture equipment train was sized based on MTR's purge flow and pressure requirements: 1.8 psi pressure rise, 10,900 scfm, that will need to operate for approximately 1 hour to complete the purge. S&L solicited Howden for a budgetary quote for the fans. Subsequently, a diesel generator was sized to support the purge fan and purge duration in this scenario. This purge is not intended to be an automatic process. The generator was specified with an output voltage of 13.8 kV such that it can tie into one of the facility's 13.8 kV switchgear buses and subsequently feed various downstream 4.16 kV or 480 V loads through proper circuit breaker coordination. This power distribution architecture matches the design of the existing Dry Fork Station emergency diesel generator. It should be noted that the final purge concept will be developed during the detailed engineering and design phase; a general concept was utilized for this study to account for cost of the equipment and associated BOP.

2.3. GENERAL ENGINEERING

An outline of the general engineering scope and supporting deliverables produced by S&L for the MTR Full Scale FEED Study includes the following:

2.3.1. Overall Process Flow Diagram (PFD)

S&L prepared an overall PFD for the entire system (including BOP and CO_2 capture components) using Visio. This deliverable was used to visualize all project components and tie-in locations related to the full scale CO_2 capture plant. The final PFD is attached to this report in Appendix A.

2.3.2. Project Design Criteria

S&L prepared the project design criteria to outline all design considerations, major system design basis, and governing engineering codes. The final project design criteria is attached to this report in Appendix A.

2.3.3. Budgetary Quote Solicitation Support

S&L, Trimeric, and MTR worked together to prepare templates for the team to utilize when requesting budgetary quotes for the various process components. S&L took the lead on issuing the budgetary requests, analyzing quotes and recommending selected vendors for the following equipment: flue gas booster fan, DCC, miscellaneous pumps, miscellaneous tanks, compressed air system, cooling tower, process heat exchanger, pre-engineered building, electrical equipment (PDC, cable bus, transformer), supervisory control system, and emergency diesel generator and purge fan. S&L also reviewed budgetary quotes received and prepared clarification questions in parallel with Trimeric and MTR's similar efforts for the process equipment downstream of MEMA. S&L supported the development of the budgetary quote summary tables used to compare quotes received from various vendors, which ultimately were used to determine which vendor's design would be used as the basis for the FEED study.

2.3.4. Site Plan, General Arrangement, Ducting and Piping Isometric Drawings

General arrangement (GA) and site/plot plan drawings were prepared using Bentley MicroStation software. The site plan drawing was prepared to show the location of the DFS CO_2 capture plant site overlaid on the existing DFS site. Major equipment, wastewater treatment and fixation, well water storage, service water, miscellaneous utilities, and electrical tie-ins are also depicted on the general arrangement drawings. Ducting drawings and isometric process piping drawings were prepared to display the size and arrangement of all ducting and piping runs from the tie-in location through to all process equipment. The final full scale CO_2 capture plant plot plan, general arrangements, process piping drawings, and ducting drawings are included in Appendix A and Appendix A.

2.3.5. Equipment List

S&L prepared an overall equipment list for the CO_2 capture plant, documenting key parameters of individual equipment and components, as well as pricing received from various vendors. The final version of the equipment list is included in Appendix A.

2.3.6. Process Hazard Analysis

A preliminary process hazard analysis (PHA) was conducted to identify potential operating hazards and risks in the system and processes; additional discussion on the PHA is included in Section 3.10.

2.3.7. Technical Specifications

Several technical specifications were prepared for the FEED study; the specifications are intended to be "ready for bid" once the detailed design and engineering work is awarded. The technical specifications prepared are listed below and included in Appendix A thru Appendix A:

- Topographic Mapping
- Geotechnical Investigation and Soil Load Analysis
- Controls Integration
- General Work Contract (GWC) Contractor

A separate Geotechnical Investigation specification was prepared by S&L and executed by BEPC during the FEED study. BEPC awarded Inberg-Miller to perform ten (10) soil borings around the proposed area for the CO_2 capture plant reservoir to obtain subsurface information to design the reservoir. Inberg-Miller also performed three (3) soil borings near the CO_2 Capture Plant Process Building and Membrane A north train.

2.4. PROCESS & ENVIRONMENTAL ENGINEERING

The process and environmental engineering scope and associated deliverables for the MTR Full Scale FEED Study included the following:

2.4.1. Overall Water Balance

Prior to preparing and integrating the CO_2 capture process into an overall DFS water balance, S&L updated the existing DFS water balance for an accurate starting point: any systems that were added/removed from service were updated accordingly and actual water usage/flow were updated based on plant operating data. This initial update was prerequisite to completing the other water related evaluations during the FEED study, discussed in more detail in Section 3.

S&L then prepared overall water balances for three (3) cases based on ambient temperatures of 0°F, 62°F and 88°F to illustrate the effect of changes in ambient conditions throughout the year, and assess interfaces with the existing plant and the CO_2 capture plant. These temperatures were chosen as they represent the largest surplus of water generated by the CO_2 capture process, the surplus transition point (where the net water used and condensed by the CO_2 process is zero over a 24 hour period), and the hot summer design

case (uses the most makeup water), respectively. These water balances were essential to complete the design of the wastewater treatment system, sizing pipelines and pumps, and estimating commodity consumption rates. The final balances are included in Appendix A.

2.4.2. Water Supply Evaluation

S&L completed a water supply evaluation to ensure adequate water resources are available for continuous operation of the CO_2 capture plant and to appropriately size the well water surge tank to account for water consumption fluctuations over a 24-hour day. The DFS well water supply system was evaluated and input from BEPC was obtained to understand current plant water consumption and establish available well water capacity for the CO_2 capture plant. The water supply evaluation is discussed in more detail in Section 3.4 and included in Appendix A.

2.4.3. Water Management and Wastewater Treatment Evaluation

Wastewater in the form of blowdown is generated by both the SO_2 polishing section and upper section of the DCC, the WSAC, and conventional wet cooling tower. The excess condensate collected in the process drains and the upper section of the DCC is sent to the cooling tower basin. The WSAC and cooling tower blowdown are treated in a high efficiency reverse osmosis (RO) process in which some mineral constituents are first chemically precipitated and removed by microfiltration (MF), allowing the RO to operate at a high recovery factor. The RO permeate is recycled to the CO_2 capture process, while RO reject is combined with the SO_2 polisher blowdown and fixated by mixing with DFGD byproduct and pebble lime (CaO) as part of the material loadout process from the existing DFS waste ash silo. The resulting fixated waste is physically stable making it easy to handle and suitable for landfill disposal.

The water management and wastewater treatment evaluation is discussed in more detail in Section 3.6 and included in Appendix A.

2.4.4. Project Permitting Matrix

S&L reviewed the current design and applicable regulations to determine required permits for the construction of the full scale CO_2 capture plant at DFS. The following assumptions were made when determining permit applicability:

- The full scale CO_2 capture plant will be considered a modification to an existing major source of air pollutants.
- BEPC has sufficient existing water rights to supply the full scale CO_2 capture plant with cooling and process water.
- Solid waste from the full scale CO_2 capture plant will be disposed of at the existing DFS landfill.

The permitting matrix for the project is included in Appendix A.

2.5. MECHANICAL ENGINEERING

The mechanical engineering scope for the MTR Full Scale FEED Study included the balance of plant scope identified above, interconnections to the DFS utilities, and in some instances CO_2 process design deliverables (e.g., P&IDs). The following deliverables were developed as part of the preliminary mechanical engineering and design:

2.5.1. Process & Instrumentation Diagrams (P&IDs)

P&IDs were developed for all the systems discussed in this report, including the membranes, permeate compression equipment, and other supporting equipment that make up the full scale CO_2 capture plant. Utility requirements were provided by the various equipment suppliers' budgetary quotes for the CO_2 capture plant and integrated into the P&IDs. Preliminary pipe and equipment sizing were developed using S&L standard engineering and design practices and sound engineering judgement. Bentley MicroStation Connect software

was utilized for P&ID generation. The final P&IDs are attached to this report in Appendix A.

2.5.2. Piping Design Tables

S&L prepared Piping Design Tables (PDTs) based on fluid constituents, pressures, and temperatures for the CO_2 capture process and BOP piping. For the CO_2 process piping, piping materials and PDT selection took into account the process gas composition changes that take place throughout the process. The specific process gas composition for each section of the process can be found in the heat and mass balances developed by Trimeric and Salof (for the CPU system scope). The final piping design tables are attached to this report in Appendix A.

2.5.3. Pipeline List

A pipeline list was developed for the process and balance of plant piping. It includes maximum and design pressure and temperature conditions, pipe materials, pipe sizes, etc. The final pipeline list is attached to this report in Appendix A.

2.5.4. Piping Isometrics

Piping isometrics were developed based on the project P&IDs for the large bore process piping (and FRP ducting) as well as circulating and closed cooling water main piping runs. Isogen software was utilized for piping isometric generation. The final piping isometrics are attached to this report in Appendix A.

2.5.5. System Descriptions

System descriptions were prepared for the well water, service water, circulating and closed cooling water, and compressed air systems. The final system descriptions are attached to this report in Appendix A.

2.5.6. Mechanical Equipment Specifications/Datasheets

Budgetary requests for mechanical process equipment were developed and issued by S&L and Trimeric to several vendors for the process mechanical equipment. Balance of plant mechanical equipment specifications/datasheets were prepared for the following pieces of mechanical equipment:

- Miscellaneous Pumps
- Miscellaneous Tanks
- Air Compressor, Dryers, and Receivers
- Emergency Diesel Generator
- HVAC

S&L used the equipment specifications/datasheets to solicit budgetary quotations from vendors to use as input for the cost estimate. Budgetary requests and specifications/datasheets are included in Appendix A.

2.6. ELECTRICAL ENGINEERING

The electrical engineering scope focused on development of the CO_2 capture plant auxiliary power system and its constituent equipment. The following deliverables were developed as part of the preliminary electrical engineering and design:

2.6.1. Electrical Load List

The load list summarizes the power requirements of all major equipment. The nameplate horsepower column reflects the rated motor horsepower for each piece of equipment, while the operating horsepower reflects the anticipated operating point for the summer design basis conditions. The annualized operation factor column acts as a multiplier in the full load operating power and current calculation, which is used to capture the loading on a seasonal basis. The load list also includes information on the starter type for each piece of equipment. The list includes variable frequency drives (VFDs), full voltage non-reversing starters (FVNR), full voltage

reversing starters (FVR), full voltage contactors (FVC), medium voltage circuit breakers (MV CB), low voltage switchgear circuit breakers (LV SWGR CB), and molded-case circuit breakers (MCCB). The electrical loading information included in the load list was used to size the transformers and distribution equipment shown on the electrical single line, as well as inform the power cable sizes included in the cost estimate. The final electrical load list is attached to this report in Appendix A.

2.6.2. Electrical Single Line

The single line diagram provides an overview of the auxiliary power system architecture. This drawing details all electrical distribution equipment. The final electrical single line is attached to this report in Appendix A.

The top portion of the single line identifies how power will be imported to the auxiliary power system. As part of this study, S&L engaged BEPC to preliminarily design a new interconnection required between the CO_2 capture plant power system and the existing DFS switchyard. The existing switchyard currently includes space reserved for the addition of a bay of new circuit breakers as well as a new takeoff structure. BEPC provided cost information for all the required work within the switchyard. The redlined switchyard modification drawings are attached to this report in Appendix A.

BEPC also preliminarily designed and provided cost information for the installation of a new transmission line to serve the CO_2 capture plant. This transmission line will run from a new takeoff structure in the DFS switchyard over to a dead-end structure located within a new, dedicated CO_2 capture plant substation. S&L took responsibility for developing the layout and pricing for the new substation. A layout of the CO_2 capture plant substation can be found in Appendix A.

The substation will include two (2), fully redundant main power transformers that service the entire CO_2 capture plant auxiliary power system. These transformers will step down the incoming 230 kV to 13.8 kV. The main electrical equipment room includes four (4) standalone 13.8 kV buses. All the 13.8 kV buses have two (2) main incoming feeds, one (1) from each main power transformer. Two (2) of the 13.8 kV buses are dedicated to serving the 13.8-4.16 kV and 13.8 kV-480 V transformers, while the other two (2) 13.8 kV buses are dedicated to serving 13.8 kV motor loads. All of the 4.16 kV and 480 V switchgear are shown as main-tie-main configuration. Feeds to 480 V motor control centers and individual 480 V loads are not identified on the drawing.

All medium voltage motor loads and VFDs are shown individually on the single line diagram. VFDs shown directly connected to a motor load indicate that the VFD will be used continuously while the motor is in operation. VFDs shown connecting to a motor through an output circuit breaker will be used for starting purposes only. Each of these motors are also shown with a bypass circuit breaker connection to the main switchgear bus, which will be the motors' power source during continuous operation. A detailed motor starting analysis was not performed as part of this FEED study. As such, S&L included full rated starting VFDs to ensure that all VFD starting group connected motors could be started sequentially and to eliminate any potential voltage sag issues that could be caused by starting the 13.8kV motors across the line. The CO_2 Capture Plant Process Building 13.8kV Bus B and Bus C depict multiple motors connected to a single VFD for starting purposes. This configuration also reduced the total number of starting VFDs.

2.6.3. Electrical Equipment Datasheets

Equipment datasheets were prepared for the following pieces of electrical equipment:

- Medium Voltage Switchgear
- 480 V Secondary Unit Substation Type Switchgear
- 480 V Motor Control Centers (MCCs)
- 125 Vdc Battery System and Battery Chargers
- Uninterruptible Power Supply (UPS) System
- Medium Voltage VFDs

- Low Voltage VFDs
- Medium Voltage Cable Bus
- Medium Voltage Non-Segregated Phase Bus Duct
- Liquid Filled Transformers

S&L used these datasheets to solicit budgetary quotations from vendors to use as input for the cost estimate. These datasheets are attached to this report in Appendix A.

2.6.4. Control and Electrical Room Layouts

General arrangement drawings were prepared specifically for the electrical equipment rooms. These drawings detail the equipment housed within each room as well as their physical arrangement. There are three (3) electrical equipment rooms total; located on the second floor of the CO_2 Capture Plant Process Building, the CPU Building, and the Water Treatment Building. Each room includes elevator access to facilitate equipment removal. The electrical equipment rooms are environmentally controlled via redundant HVAC equipment; VFD rooms have ventilation only. Additionally, each room has a dedicated DCS equipment room included within the footprint. The DCS rooms have separate, redundant HVAC systems, and will house the DCS hardware cabinets, network cabinets, and remote engineering/operator workstations. The CO_2 Capture Plant Process Building Electrical Room and the Water Treatment Building Electrical Room will both have battery rooms to house 125 Vdc valve-regulated, lead acid rack mounted batteries. The CPU Building Electrical Room will have a 125 Vdc sub-panel fed from the main electrical equipment room 125 Vdc panel. The control and electrical room layout drawings are included in Appendix A of this report.

2.6.5. Cable Tray, Cable Bus, and Non-Segregated Phase Bus Layouts

As part of the 3D model development, cable tray, cable bus, and non-seg bus duct layouts were modeled to account for the major electrical raceway required to connect the capture plant utilization equipment. The single line diagram identifies which connections are cable bus and non-seg bus connections. These two installations are utilized for higher current connections were the expense of installing cable in cable tray or conduit is not cost effective. Cable bus is utilized between the secondary side of the 13.8-4.16kV transformers and the 4.16kV switchgear. The non-seg bus is utilized on the secondary of the substation transformers and the 13.8kV switchgear. S&L also used the 3D model to capture the necessary foundations and steel support structures required for these installations. To facilitate the installation of the vertical cable bus segments outside of the CO_2 Capture Plant Process Building, the design includes a platformed staircase that encompasses the cable bus runs. These layout drawings are attached to this report in Appendix A.

2.6.6. Lighting and Grounding Drawings

S&L prepared preliminary lighting drawings to develop a design for both the interior and exterior lighting systems. Layout drawings as well as fixture schedules are attached to this report in Appendix A. Additionally, grounding and lightning protection sketches were developed for the site and are included in Appendix A.

2.7. INSTRUMENTATION AND CONTROLS ENGINEERING

The instrumentation and controls (I&C) scope included all BOP instrumentation design and the design of the DCS expansion and network architecture required for the full scale CO_2 capture plant. The following deliverables were developed as part of the preliminary I&C engineering and design:

2.7.1. Network Architecture Diagram

A network architecture diagram was prepared to provide details on the existing DCS tie-in point, new DCS expansion hardware, network cable connections, and the interfaces to the CO_2 capture plant control system. The interfaces include operator interfaces, I/O hardware, electrical equipment, and PLCs or local controllers for equipment packages and system skids. Major equipment and their connections are depicted in a geographical representation to convey the connections between each major area and the quantity of hardware

located in each area. This information was used as input to the final controls integration cost and cable take-offs included in the cost estimate. The final network architecture diagram is in Appendix A.

2.7.2. Control Equipment List

A control equipment list was developed in conjunction with the network architecture diagram to provide additional details on the DCS expansion hardware, network equipment, and vendor furnished PLC's or control equipment. The final controls equipment list is attached to this report in Appendix A.

2.7.3. Controls Description

An overall controls description was developed, detailing the control system layout, high level control narrative, design assumptions, system requirements, and controls implementation plan. The detailed design and engineering control system execution plan was also discussed. The final controls description is attached to this report in Appendix A.

2.7.4. Typical Loop Diagrams

Because detailed control system design and cable design drawings were not available during this FEED study, typical loop diagrams were developed to provide details on instrument, valve, and equipment connections to the DCS in a loop or circuit format. This provides insight into how each signal is wired to the DCS and the hardware or network components in between. This information was used as input to the final controls integration cost and cable take-offs included in the cost estimate. The final typical loop diagrams are attached to this report in Appendix A.

2.7.5. Typical I/O Tables and Preliminary I/O List

Typical I/O tables were developed as a predecessor to the preliminary I/O List and serve to define the typical I/O signals and their attributes on a load type or instrument type basis. This allows a unified design to be applied for all instruments, devices, or equipment of the same type. Typical I/O tables were modeled after the existing DFS I/O signals database and logic macros.

A preliminary listing of the I/O signal interfaces to the CO_2 capture plant control system was developed and presented in tabular form in the preliminary I/O list. This list includes all DCS signals used for control and monitoring of the BOP instrumentation and equipment, as well as, interfaces to PLC's or local controllers for equipment packages or system skids. Basic signal design parameters are defined for each signal, sorted by drawing and major equipment association.

The final typical I/O tables and preliminary I/O list are attached to this report in Appendix A.

2.7.6. Instrument List

An overall instrument list for the full scale CO_2 capture plant was developed from the process P&IDs and information obtained from the suppliers' budgetary quote requests. The instrument list defines the basic attributes for each instrument and the scope for instrument procurement and installation. This information was used to develop the instrumentation procurement and installation costs included in the cost estimate. The final instrument list is attached to this report in Appendix A.

2.7.7. Controls Integration Technical Specification

A controls integration technical specification was developed to define the requirements for the new DCS expansion hardware and integration services. The scope of supply also included all network hardware required for the CO_2 capture plant, an expansion to the existing DFS vibration monitoring system, and expansion to the existing DFS DCS simulator to include a high fidelity simulation of the CO_2 capture plant for training and performance tuning purposes. This specification was submitted to the DCS vendor of choice at DFS for the purpose of obtaining a budgetary quote for use in our capital cost estimate. The final controls integration technical specification is attached to this report in Appendix A.

2.8. STRUCTURAL AND CIVIL ENGINEERING

The structural engineering scope included support structures, foundations and building enclosures for all CO_2 capture plant equipment. Structural engineering scope also included the design of carbon steel ductwork. Civil engineering scope included sitework for the entire site plan and evaluations and studies on existing civil systems at DFS Unit 1. The following deliverables were developed as part of the preliminary architectural, civil, and structural engineering and design.

2.8.1. Architectural Drawings

An architectural general notes and code summary drawing was developed and building plans and elevations drawings were developed for all building enclosures. The architectural drawings provide building access information, including personnel doors and overhead doors, and provide information on building envelope materials; refer to Appendix A.

2.8.2. Structural Support Steel Drawings

Structural steel drawings were prepared for the CO_2 Capture Plant Process Building, CPU Building, Water Treatment Building, and DCC Auxiliary Equipment Building. A building steel isometric drawing was prepared to provide general information on the building framing layout and location in relation to the other buildings. Building framing plan and roof framing plan drawings were also developed for each building.

Structural steel drawings were prepared for the utility rack. An arrangement plan and isometric drawing was prepared to provide the overall arrangement layout of the utility rack. The utility rack arrangement supports electrical equipment from the CO2 Capture substation to the east side of the main CO2 Capture process equipment building, and the utility rack extends to the north to the CPU building providing support to electrical tray/bus and mechanical piping.

Structural gallery steel, duct support steel, and miscellaneous steel support drawings were prepared for the FEED study. Isometric drawings, plan and elevation drawings were prepared for duct support steel, membrane removal crane support steel, CPU refrigerant compressors and condensers support steel, and cooling tower support steel.

Preliminary structural steel design considers all loads including dead, live, snow, impact, wind, thermal, dynamic, settlement, movement, seismic, friction, and other appropriate load conditions. These loads were determined in accordance with the applicable codes, which are documented in the S&L Design Criteria included in Appendix A of this report. Structural support steel drawings are included in Appendix A.

2.8.3. Foundation Drawings

A foundation arrangement plan drawing and typical foundation plans, sections, and details drawing were prepared for the FEED study. A conceptual foundation summary table is provided on the typical foundation plans, sections, and details drawing. The foundation summary table was prepared to show the dimensions size, thickness, and type of foundation anticipated for each piece of equipment and buildings. Each foundation was sized and estimated based on information from budgetary quotes, the general arrangement drawings, and in-house estimating data. Foundation drawings are included in Appendix A.

2.8.4. Flue Gas Ductwork Drawings

A typical ductwork arrangement, sections, and details drawing was prepared to show typical stiffener, cross-section, and support truss configuration. The typical ductwork arrangement, section and detail also provides typical grounding detail, and expansion joint detail for the ductwork. The expansion joint detail was selected based on BEPC/DFS input to match existing internally mounted ductwork expansion joints currently being used at DFS Unit 1. Ductwork isometric, plan, and elevation drawings were prepared to show the flue gas path, ductwork size, and shape. Expansion joints, isolation dampers, turning vanes, access doors, and support truss locations are also depicted. Flue gas ductwork drawings are included in Appendix A.

2.8.5. Spill Containment Plan Drawing

A spill containment plan drawing was prepared for the FEED Study. This drawing identifies containment area, associated equipment, the potential spill, and the containment type, including where areas are located on the site plan layout.

2.8.6. Civil Sitework

A conceptual civil design was prepared for the site. The existing site consists of seeded topsoil with a uniform slope. The site will be prepared by installing temporary erosion control measures and removal of existing surfacing. Final surfacing will consist of aggregate roads and aggregate ground cover. In addition, bollards will be installed to protect equipment at various locations. The site will be graded to accommodate installation of foundations and equipment and provide positive drainage.

An underground storm sewer system will be installed at the site to control the flow of water during storm events. The site grading will provide positive drainage towards catch basins on site. On the east side of the site, a drainage ditch will be constructed to capture additional runoff from the site. The ditch will flow north and outlet into the existing stormwater pond. The existing pond was sized to accommodate the development of the full catchment area of the site. As a result, the existing pond size is sufficient and does not need to be enlarged. The existing pond will store water from a storm event and release it at a controlled rate through an existing outlet structure.

The project also includes installation of a carbon capture reservoir basin to store surplus condensate collected from the CO_2 process during colder months. The basin will be located west of the existing station. The basin will have a minimum capacity of 160 ac-ft. Basin side slopes will be sloped at a 3H:1V slope and have a composite liner. The liner will consist of an HDPE geomembrane and 24” thick clay. In lieu of the clay layer, a geosynthetic clay liner (GCL) may be used instead. The composite liner will be covered with a 9” protective aggregate cover to protect the liner from being damaged. An inlet structure will be incorporated into the pond and liner design to accommodate piping to the basin. To avoid having the basin classified as a dam, the maximum allowable berm height is limited to 6 feet. To ensure this is not exceeded, the berm height will be set at 5.5 feet. As a result, the basin construction will result in a significant amount of excess excavated material to be disposed of. An on-site disposal area will be developed so the material will not need to be hauled off-site. In addition, there is existing bedrock in the area of the basin. Preliminary borings were taken to determine the depth of rock and it was not found to be within the limits of the basin. Therefore, rock excavation is not anticipated for basin construction.

There will be various sources of oily water from different buildings and equipment enclosures. These will be collected in sumps and piped to an oil water separator (OWS). The OWS influent will be a gravity sewer consisting of metallic piping to protect the system from potential high temperatures. The OWS will have an integral lift station and pump the effluent to the existing wastewater pond. The effluent piping will be HDPE pipe.

The existing site fence located along the east edge of the site will be relocated further east to accommodate site grading activities. A fence will also be installed around the new carbon capture substation. This fence will have vehicle gates at road crossings and man gates for pedestrian access to the substation.

The civil drawings are attached to this report in Appendix A.

2.8.7. Civil and Geotechnical Technical Specifications

A topographic mapping technical specification of the existing DFS site was prepared for execution during the detailed design phase. Survey information obtained from this work will be used to verify existing grade elevation conditions and will be used as input to initial and final sitework design. This specification defines the requirements of the land surveyor and defines the limits of the survey.

Similarly, a geotechnical investigation technical specification was prepared for the FEED study for execution during the detailed design phase. Subsurface conditions obtained from this work will be used as input to the foundation design. This specification defines the requirements to perform the soil borings, requirements for

laboratory testing of soil samples, and defines the number and location of soil samples to be taken.

A second geotechnical investigation technical specification was prepared during the FEED study by S&L and executed during the FEED study by BEPC. Specification requirements were similar to the first geotechnical investigation technical specification prepared for the FEED study; however, the location of the soil borings was targeted around the proposed CO_2 capture reservoir. The purpose of executing this work during the FEED study was to confirm subsurface conditions near the reservoir. Because the proposed CO_2 capture reservoir is located near an existing hill, and original DFS geotechnical reports and construction indicated rock in the region, these soil borings provide information to design the reservoir such that rock can be avoided as much as possible. This also provides a higher level of confidence that the design of the reservoir will not be impacted during detailed design by location of rock. The CO_2 capture reservoir will be a mass earthwork construction activity. Rock excavation is costly compared to alternate earthwork removal; subsurface results from this work will minimize the potential for rock excavation. Final civil and geotechnical specifications can be found in Appendix A and Appendix A. The final geotechnical soil reports are also included in Appendix A.

3. ENGINEERING EVALUATIONS

S&L conducted several evaluations and studies throughout the MTR Full Scale Carbon Capture FEED Study to identify design considerations or requirements for modifications or additions to existing systems and equipment, evaluate the optimal design in areas with numerous considerations, and evaluate the safety of the design. The conclusions of these studies were used as a basis of the preliminary design. This section of the report outlines the purpose, scope, and conclusions of those evaluations and studies.

3.1. EXISTING STACK REUSE ASSESSMENT

One of the major costs of CO_2 capture plants is a new, dedicated stack for the system. To determine if the DFS existing stack could be used as the primary exhaust of the new CO_2 capture plant, dispersion modeling was performed by S&L to evaluate the extent of dispersion impact. This evaluation would determine if ground-level concentration of any criteria pollutants may cause exceedance of the applicable National Air Ambient Quality Standards (NAAQS). Based on preliminary evaluation, SO_2 and NO_2 concentration were not expected to exceed NAAQS standards and moisture concentration was estimated to be lower than current conditions resulting in no visual impacts; therefore, the (re-)use of the existing DFS stack was incorporated into the CO_2 capture plant design. The results of various cases modeled are included in Appendix A.

3.2. EXISTING ID FAN MODIFICATION STUDY

S&L prepared a study evaluating the existing ID fan operating pressure versus the newly calculated system pressure required for operation of the CO_2 capture plant. The manufacturer of the existing ID fans, TLT-Babcock/Howden, predicted that a 15% static pressure increase could be expected if the existing fan blades are tipped. Pressure losses were calculated across the ductwork and DCC leading to the flue gas booster fan. The performance increases expected by tipping the fan existing ID fan blades were sufficient to overcome the pressure losses and move flue gas to the inlet of the flue gas booster fan, while maintaining a positive pressure up to the flue gas booster fan inlet. The results of this study are included in Appendix A.

3.3. BUILDING SECURITY INFRASTRUCTURE STUDY

An evaluation of the existing BEPC security requirements was conducted to ensure the new CO_2 capture plant design would adhere to all applicable BEPC physical security requirements. As a result of this study, security hardware including cameras, barriers and door access control were incorporated into the design to meet BEPC requirements and any applicable NERC-CIP requirements. Details on the general security hardware required for each type of access area and entry type are provided in the study, which is included in Appendix A. Security hardware requirements for each CO_2 capture plant building area are noted on the control and electrical room layout drawings included in Appendix A.

3.4. WATER SUPPLY STUDY

S&L completed a water supply evaluation to ensure adequate water resources are available for continuous operation of the CO_2 capture plant. S&L supported this effort by first updating the existing DFS water balance to reflect actual usage based on historical operating data. Based on the annual reports submitted to the Wyoming State Engineer's Office, the total well water usage by DFS on a yearly basis was concluded to be 190 million gallons or 360 gpm. Basin personnel reviewed the updated water balance and indicated an additional 55 gpm of well water is sent directly to the existing recycle pond to provide enough recycle water for the dry flue gas desulfurization (DFGD) process. Therefore, the resulting current well water usage during DFS full load operation, after some conservatism is applied to ensure water is always available, is approximately 420 gpm. Based on certificated well output of 1,025 gpm from Wells No. 1 and 3, this results in 610 gpm well water available for the CO_2 capture plant. It should be noted, S&L did investigate the option of creating a new well to support DFS and the CO_2 capture plant, which would prove to be a very difficult process

considering the location and water rights; the team agreed this option would not be pursued.

Trimeric and S&L further examined the hourly fluctuations in water consumption of the CO_2 capture plant over a 24-hour day and concluded that water requirements will vary significantly throughout the day. A water surplus is generated at night and early morning, and a water deficit exists for the remainder of the day. Trimeric recommended a surge tank be installed to help manage the water fluctuations over the course of the day, and S&L selected a surge tank capacity of 150,000 gallons based on water level during summer conditions. The Trimeric simulation results as revised by S&L and the evaluation of water supply are included in Appendix A.

3.5. CO_2 CAPTURE PROCESS COOLING EVALUATION

S&L was not responsible for preparing the CO_2 Capture Process (Water) Cooling Evaluation; however, a considerable amount of upfront support was provided to EPRI and Trimeric for this effort. In addition to the water supply evaluation, S&L worked with Trimeric to estimate wastewater generated by the DCC and SO_2 polisher, which EPRI needed to perform their evaluation. Following the initial discussions on cooling options being considered, S&L prepared a simple block diagram water balance for the CO_2 capture system for a hybrid cooling scheme; based on the water supply available, the scheme would be able to support 2/3 “wet” cooling and 1/3 “dry (air)” cooling. Trimeric created a more detailed salt and water balance with this information, which S&L reviewed and provided input based on previous experience with cooling towers and Alfa Laval (WSAC vendor); subsequently, Trimeric made adjustments to drift rates, cycles of concentration, etc. With an updated process salt and water balance, the team turned to investigating wastewater compositions and options for wastewater treatment and/or recycle within the CO_2 capture process. The limiting factor in most cases appeared to be the total dissolved solids (TDS) of the waste stream. The wastewater could not be sent to the existing DFS ponds due to the TDS limit for both permitting and DFGD spray water limitations, therefore an RO system was recommended by MTR to treat the incoming well water to lower the TDS being introduced. S&L prepared one last water balance to support this effort, which compared an RO system being utilized to treat the incoming well water (make-up) against treating only the blowdown streams. Treating only the wastewater streams from the cooling tower and WSAC systems would accomplish the same performance by treating 70% less water, which would result in a smaller RO unit (lower capital cost), and the smaller unit would also have lower recurring operating cost. As such, the team decided to proceed with the wastewater RO treatment.

3.6. WATER MANAGEMENT AND WASTEWATER TREATMENT STUDY

3.6.1. Wastewater Treatment & Disposal

S&L evaluated various treatment options for the blowdown from the SO_2 polishing section of the DCC, hybrid WSAC cooling system, and conventional wet cooling tower. Each option was required to recycle most of the blowdown as high quality permeate or distillate to allow DFS to continue to operate as a zero-liquid discharge (ZLD) facility. Based on the responses from wastewater treatment system suppliers, S&L concluded that the most cost effective option is high efficiency reverse osmosis (RO) using upstream chemical precipitation and microfiltration to first remove certain mineral constituents such as silica. The RO reject from this process will then be combined with SO_2 polisher blowdown for disposal. Although the lowest cost option for treatment of RO reject and SO_2 polisher blowdown was found to be use of an enhanced evaporation pond, there were concerns regarding space constraints at site, solid removal (dredging) from the pond, and the potential increase in drift emissions from the forced evaporation process. Therefore, the team decided that a lime fixation system would be used for the elimination of these two wastewater streams. The lime fixation process is described in more detail in Section 3.7.3.

The technical and commercial evaluations of the various wastewater treatment options are included in Appendix A.

3.6.2. Water Surplus Management

As both the recoverable flue gas condensate and cooling tower/WSAC evaporation rates change throughout the year depending on ambient temperatures, S&L estimated the amount of water surplus that would occur throughout the year and developed a water management plan by first performing a net surplus (or deficit) analysis. The analysis was based on the plot for net water consumption vs. daily maximum dry bulb temperature provided by Trimeric. The low temperature portion of this plot (below 62°F) was eventually modified by S&L based on information from the selected cooling tower vendor, SPX, because the original cooling tower evaporation rate for this ambient temperature range, based on an earlier estimate obtained by Trimeric from a different cooling tower vendor, was lower than expected based on S&L experience and engineering judgement. This update was beneficial to the project because the amount of surplus that needed to be managed was significantly decreased. From the final analysis, it was concluded that the carbon capture process incurs a modest deficit (26 million gallons per year (gpy) or 50 gpm) on an annual average basis but also generates a sizeable water surplus during the seven coldest months each year. DFS is only willing to accept a small portion of this surplus (45 gpm, which excludes water used for FGD byproduct conditioning) that would displace an equivalent amount of well water currently being sent directly to their wastewater recycle pond.

Maintaining ZLD operation will require construction of a 160 acre-ft reservoir that will collect excess water produced from the process during the colder months and return water to the carbon capture process during the warmer months when a deficit exists. Surplus from the reservoir will also be provided to the DFS pond (up to 55 gpm) when it is available.

The assessment of various options to handle the surplus and reservoir sizing are included in Appendix A and Appendix N.

3.7. PROJECT EMISSIONS & WASTE DISPOSAL ESTIMATES

In order to support the development of the permitting matrix, potential project-related emissions and increase in waste generation associated with the implementation of the full scale CO_2 capture plant at DFS was estimated. Additional details on calculation inputs and assumptions for the calculated project-related emission changes and waste disposal estimates are included in Appendix A.

3.7.1. Process Vent Emissions

The MTR CO_2 capture plant is designed to preferentially remove SO_2 and CO_2 from the DFS flue gas while allowing other flue gas constituents to pass through. CO_2-depleted flue gas from DFS will be vented from two (2) locations: the existing stack and a new process vent (or stack). The emissions from the CO_2 capture process are therefore only treated flue gas from DFS, as described below:

- Main process vent for Membrane A (EGU001) – Flue gas from DFS will pass through the DCC, which cools the flue gas and removes SO_2 prior to entering the Membrane A train (MEM A). Membrane A contains a selective membrane which will allow a CO_2-rich stream to permeate. CO_2-depleted flue gas not passing through the membrane, also known as retentate, will be sent back to the existing DFS stack to vent to atmosphere (via the current emission point). In addition to significant CO_2 emission reductions, main stack emissions of NO_X and SO_2 will also be reduced as a result of the CO_2 capture plant operation. Emissions of other pollutants, including CO, PM and VOC, will remain unchanged.
- Dehydration beds' regeneration exhaust (DHY/STK-01) – During the dehydration of the CO_2-rich stream, the dehydration beds act as a mole sieve to remove water from the gas. The water accumulates within the bed over time and needs to be regenerated by "backwashing" it by evaporating it into a heated dry gas stream. In order to regenerate the bed, the Membrane D retentate stream will be routed through an electric heater and used to regenerate the dehydration beds – i.e. the heated slipstream flows backwards through the beds, serving to evaporate the water within the bed material. This slipstream and the moisture removed is vented to the separate regeneration exhaust vent (or stack). A small amount of CO_2 and NO_X will also be released from the dehydration vent.

3.7.2. Cooling System Emissions

Emissions calculations have been prepared to estimate potential air emissions associated with the new cooling tower and WSACs. Both the cooling tower and WSACs will be equipped with drift eliminators to control PM emissions. Emissions from the cooling tower were estimated based on the following assumptions: (1) circulating water flow rate of 57,250 gpm, (2) recirculating water total dissolved solids (TDS) level of 4,090 ppm, 0.001% drift, and 8,760 hours per year operation. WSAC emissions were estimated based on the following assumptions: (1) circulating water flow rate of 25,000 gpm, (2) recirculating water TDS level of 109 ppm, 0.001% drift, and 8,760 hours per year operation. Emissions estimates for the cooling tower and the WSACs are included in Appendix A.

3.7.3. Waste Generation

The design of the MTR membrane based CO_2 capture plant will not inherently produce any waste solids. However, blowdown wastewater will be produced from the DCC, WSAC and cooling tower in order to maintain process/water chemistry and will require treatment.

The DCC will be segmented into a lower SO_2 polishing section and an upper cooling section. SO_2 removed in the SO_2 polishing section will react to form salts that will be removed in the blowdown. The segmented DCC design allows for recovery of higher quality condensate in the upper cooling section by first removing SO_2 laden salts in the lower section. Other process condensate collected throughout the CO_2 capture plant will be collected and utilized as makeup to the cooling tower. In order to maximize the amount of wastewater recycled within the process and thereby, minimize well water consumption, a high efficiency RO system will treat the WSAC and cooling tower blowdown. The RO system permeate will be recycled and the reject will be combined with SO2 polisher blowdown and sent to a lime fixation process.

The fixation process generates a solid waste material by mixing wastewater with the dry FGD byproduct (a mixture of fly ash, calcium sulfate and calcium sulfite) and pebble lime (CaO). The resulting fixated waste is physically stable making it easy to handle and suitable for landfill disposal. The waste fixation process will subsequently increase the current amount of waste material from the station that must be landfilled.

The initial pretreatment step in the RO wastewater treatment system will also produce a dewatered sludge from the removal of constituents (mostly silica) and the chemicals added to achieve this removal. The sludge is dewatered in a filter press and collected in a dumpster for periodic removal. The sludge behaves as a solid, which will pass a paint filter test and is suitable for landfill disposal. The sludge produced from this wastewater pretreatment step will also incrementally increase the current amount of solid waste material from the station that must be landfilled.

The estimated increase in solid waste generation that will be sent to the existing permitted Basin landfill is included in Appendix A.

3.8. PERMEATE COMPRESSION EQUIPMENT SELECTION

Early in the FEED Study, MTR requested S&L to quantify the installed cost difference between three equipment configurations to raise the Membrane A permeate train pressure to the required Membrane B inlet pressure. S&L prepared three (3) cost estimates to compare the differential cost between the following configurations:

- 60 Fans
- 20 Fans (2 sets per Membrane block) and 4 Compressors (2 per train)
- 4 Compressors (2 per train)

Even though the last option for only four (4) compressors was the lowest cost, it carried a significant amount of risk: the compressor company has not actually built this size (1.6 m impeller diameter) of this type of hybrid (Axial – radial (centrifugal) series combination) compressor, or sold this type of compressor for a CO_2 service before (although they have built 1.4 m impeller diameter compressors of this configuration for other gas

services), so it would be a first of its kind; and for operation support, one compressor failure would result in the whole CO_2 capture facility (or at least half) being unavailable. For the other design configurations, a failure of one piece of equipment should allow for continued operations, albeit in a less efficient mode. Comparing the 60 fan to 20 fan and 4 compressor option, the 20 fan and 4 compressor option was only 2% (approximately $3M) higher than the 4 compressor (only) option, while the 60 fan option was 36% higher (approximately $49M). Therefore, the team selected the fan and compressor combination for the permeate compression design.

Two configurations were also evaluated for the Membrane B compression. Similar to Membrane A permeate, two (2) trains of two (2) fans in series were supplied to first boost the pressure upstream the Membrane B compressor. Two (2) x 50% verse one (1) x 100% train options were evaluated for the Membrane B compressor. Currently there is not a plan to operate a single train at a time, but if required in the future, a single compressor configuration offers 50% turndown operating capabilities with inlet guide vanes and recycle. The compressors have a high machine reliability and availability and are design for minimal scheduled maintenance. A single unit also required less equipment to be maintained, allows for a smaller overall footprint, and is a lower cost.

3.9. COMPRESSOR SYSTEM OVERPRESSURE RELIEF STUDY

A compressor system overpressure relief study was performed to identify possible sources of over-pressurization within the CO2 capture plant main compressor system. The study indicates what measures will be taken to protect against an over-pressurization condition, and the details/sizing of each protection method will be completed in the detailed engineering phase. The results of this study are included in Appendix A.

3.10. PRELIMINARY PROCESS HAZARD ANALYSIS

A preliminary process hazard analysis (PHA) was conducted to identify potential operating hazards and risks within the CO_2 capture plant system and processes. The PHA review consisted of a systematic review of the available project P&IDs and PFDs and supporting vendor packages, which were critically evaluated in the presence of S&L, MTR, Trimeric, and third-party proctors from S&L to identify possible areas of concern.

Risks identified by the project team were assigned a rating (1-5) based on the severity of the hazards, and the likelihood of the hazard occurring.

Each hazard identified during the PHA study was discussed to determine whether or not it warranted consideration as a feasible or destructive hazard. The applicable risks were assigned a score (1-5) for severity and likelihood; each hazard was assigned a Risk Ranking (A = intolerable/unacceptable, B = intolerable/undesirable, C = tolerable, D = tolerable/broadly acceptable and U = unclassified) according to the standard risk matrix.

Hazards identified in the PHA that were assigned a risk ranking of 4 or higher warranted the immediate review of the engineering team to implement adequate controls for risk reduction for achieving safe operation. As the project design is still preliminary, items that required additional follow-up were broken up into recommendations to be implemented during the FEED study design and those to be completed during detailed engineering and design. These recommendations were included as a section in the final PHA report which is attached to this report in Appendix A.

3.11. CONSTRUCTABILITY REVIEW

The constructability review was conducted to review the construction processes and preliminary construction sequence required for the MTR full scale CO_2 capture plant, any potential design changes that could be considered to save on installation costs, and identify any requirements, such as bussing contractors to site, that should be captured in the overall project cost estimate and execution schedule. The constructability review was conducted by S&L, including the S&L Construction Management group, and with participation from MTR, BEPC/DFS, and Trimeric. No major issues were identified with the installation of the current design. The final constructability review report is included in Appendix A.

A composite construction sketch was created by overlaying the CO_2 capture plant site plot plan over a Google Earth site aerial view. The composite sketch included proposed construction laydown areas, contractor parking, potential delivery unloading area, as well as access points to the plant to solicit BEPC/DFS input.

The CO_2 capture plant site plan and 3D model supplemented the discussion for the construction tasks and sequence, including mass earth work and drainage, construction equipment/locations, construction trailer park and facilities, construction traffic, lighting, and waste. BEPC/DFS provided input on day-to-day plant operation, which was considered in designating construction activity areas and traffic flow to minimize impact to plant operation. S&L also identified potential crane locations for construction and maintenance purposes.

Construction assumptions that were made for the purposes of the FEED study were also reviewed with participants for concurrence. Assumptions included, but not limited to, outages for tie-in activities, craft non-outage working time, etc.

3.12.CONTRACTING / PROCUREMENT STRATEGY

S&L prepared an evaluation to identify the most cost-effective approach for the detailed engineering and design, procurement, and construction of the CO_2 capture facility considering the required implementation schedule and risk associated with a large and lengthy project. The analysis reviewed two general contract models: Engineering, Procurement, and Construction (EPC) and Engineering, Procurement and Construction Management (EPCM); for the design, supply and erection of the CO_2 capture facility and compared them on these key issues: schedule, cost, and project oversight and quality. Based on these criteria, either contracting method would be acceptable to complete the CO2 capture facility retrofit project at BEPC DFS based on current regulatory requirements.

To complete the study, S&L consulted MTR and BEPC to discuss the aforementioned concepts and request input regarding any other requirements that may influence the selection of one contract method over the other; schedule, funding and resources were discussed. The team agreed either option would work, but the EPCM multiple contract approach was preferred, as it allows for more project and quality control, a lower overall project cost, and shorter overall project schedule. Therefore, the EPCM method was utilized for the development of the FEED study schedule and cost estimate deliverables. The Contracting Strategy has been included in Appendix YY.

3.13.AIR IN-LEAKAGE ASSESSMENT

MTR indicated that the overall cost effectiveness of the CO_2 capture system is greatly impacted by the concentration of CO_2 in the inlet flue gas and thereby effected by the amount of air in-leakage that occurs throughout the ductwork. Basin Electric elected to complete air in-leakage testing through the use of a 3rd party testing contractor, Mostardi Platt, to determine the amount of air in-leakage that occurs from the economizer outlet to the air preheater (APH) outlet. From this testing, it was determined that the air in-leakage that occurs across the APH is not a considerable amount. Any reduction in air in-leakage that could be achieved with a major APH modification and the incremental improvement to the CO_2 capture system overall cost effectiveness would not offset the capital cost of the major APH modification. However, there are air in-leakage contributors both upstream and downstream of the APH. As such, it is recommended that these other air in-leakage contributors be further analyzed to quantify the amount of air in-leakage attributed to each source and to determine if the air usage could be modified in a way to reduce its air in-leakage contribution during the detailed design phase. Pending the results, cost benefit analyses would be completed to determine if the modifications to reduce air in-leakage would be cost effective to consider pursuing further as part of the design. The results of the Mostardi Platt testing and discussion of the air in-leakage contributors are summarized in the air in-leakage testing conclusions included in Appendix A.

4. DETAILED ENGINEERING AND DESIGN SCHEDULE

A preliminary Level 2 schedule for the detailed engineering, design, and construction work has been prepared by S&L and is included in Appendix A.

S&L consolidated inputs from MTR, S&L engineers, and S&L Construction Management into a single project schedule for the detailed engineering, design, and construction work. MTR provided the engineering and fabrication timelines for the membranes and associated equipment. S&L developed the detailed engineering, design, procurement, and construction portion of the schedule.

Detailed engineering, design and procurement is anticipated to last approximately twenty (20) months. Detailed engineering will begin with the preparation of the technical specifications and issuing for procurement; this is anticipated to last approximately seventeen (17) months. During the fifth month of detailed engineering and design, the initial specification bids will start to be evaluated, and contract awards will commence in month six to seven. Vendor drawing review will start after the first contract is awarded and span approximately eighteen (18) months. The vendor drawings are required to verify the BOP design, after which, “construction” drawings can start being issued.

Major equipment delivery dates are based on the fabrication and delivery times indicated by vendors solicited during the FEED study, while smaller commodity item delivery is based on S&L’s previous experience. As indicated, MTR provided input on the membrane fabrication and delivery durations. Membrane fabrication is planned to start after MTR final engineering and will take approximately thirteen (13) months.

The construction plan indicates the construction sequencing and equipment handling, to ensure the key construction activities can be carried out in an efficient order. An assumed work schedule of 5 x 10 hour days was used for the development of the construction durations; this is standard industry practice in current times to attract quality labor. It was discussed that a 6 x 10 hour workday construction schedule could be considered based on Dry Fork Station’s remote location; however, for the purposes of this study, to obtain a more generic installation timeline, the 5 x 10 hour schedule was used. A comparison schedule was developed and the 6 x 10 hour workdays would result in a timeline savings of approximately 85 days.

Laydown areas of sufficient size and close proximity to the construction site were discussed during the Constructability Review with DFS. Sequencing of equipment delivery is not considered as critical because adequate laydown space is available. Consideration was also given to the timing of the start of civil/foundation work, as it is optimal, and most cost effective, to complete these tasks in non-winter months. Larger foundations are scheduled for non-winter months. However, to avoid construction “breaks”, some smaller foundation installations occur during the winter timeframe, and in those cases, a 15% duration extension was added to the original estimated duration to allow for extra installation provisions (warming blankets/tents) for concrete curing in the cold conditions.

A DFS outage is required to complete the existing ductwork and supports demolition at the ID fan outlet to the existing stack, installation of the new ductwork up to the CO_2 capture facility bypass (including dampers and structural supports) and complete the ID fan tipping. DFS provided their current outage schedule; major outages are scheduled approximately every three years. The retrofit schedule targeted completing the outage tasks mentioned above during the Spring outage of 2028, which is 6 weeks in duration.

It was assumed that the current 45Q schedule requirement of construction start by January 1, 2026, will be modified based on current proposed legislation to a construction start date of January 1, 2032.

For the FEED study schedule, a date of July 1, 2025 was selected as the engineering start date to meet the above mentioned outages and government mandate construction start dates. Pending actual project authorization, the schedule may need to be adjusted to modify for partial release of construction work.

5. COST ESTIMATE DEVELOPMENT

A Class 2 cost estimate for the fully integrated CO_2 capture retrofit at DFS Unit 1 was prepared according to AACE Standards, with an expected accuracy of -15% to +15%. Costs are broken down by material, equipment, labor, and subcontracted costs. Inputs for the estimate were prepared by BEPC, MTR and S&L then combined into a single cost estimate report prepared by S&L. Many pieces of critical equipment are costed based on budgetary quotes received by vendors, while other prices are based on recent project experience and engineering judgement.

The operating and maintenance (O&M) cost estimate was developed using commodity pricing confirmed by BEPC/DFS, chemical/reagent/propane suppliers, process flows depicted on the Trimeric and Salof material balances, S&L water balances, and engineering judgement.

5.1. CAPITAL COST ESTIMATE INPUTS

5.1.1. Budgetary Quotes Utilized

Budgetary quotes were solicited from several vendors for each of the following components and/or equipment systems identified below, with exception of the Controls Integration quote which was sole-sourced to the DFS vendor of choice. Quotes were evaluated based on cost and performance. The vendor that offered the most effective option was selected, as identified in Table 5-1 below and used as input for the cost estimate and engineering design.

Table 5-1 — Budgetary Quote Inputs

Equipment/System	Scope Included	BOP by Others
Existing ID Fan Modifications	Fan housing, impeller, main drive motor, and vibration monitoring instrumentation	
DCCs	Two (2) vessels; each with SO_2 polishing recycle pumps & interconnecting piping, caustic pumps	DCC circulating pumps, caustic storage tank, containment & piping
Booster Fans	Two (2) booster fans; each with fan housing, lubrication system, main drive motor, and vibration monitoring instrumentation	VFDs
Membrane A Permeate Compression – Fans	Twenty (20) turbofans; each with fan housing, lubrication system, main drive motor, and vibration monitoring instrumentation	VFDs
Membrane A Permeate Compression – Compressor	Four (4) three stage centrifugal compressor, intercoolers; each with integrated KO, lube oil cooler, control system (vendor PLC)	Starting Duty VFDs

Equipment/System	Scope Included	BOP by Others
Membrane A Permeate Compression - Aftercooler	Water cooled desuperheater and integral KO	
Membrane B Permeate Compression - Fans	Two (2) turbofans; each with fan housing, lubrication system, main drive motor, and vibration monitoring instrumentation	VFDs
Membrane B Permeate Compression – Compressor	Six stage centrifugal compressor, intercoolers with integrated KO, aftercooler with integrated KO, lube oil cooler, control system (vendor PLC)	Starting Duty VFD
Membrane C & D Permeate Vent Heaters	Process vent air heaters, remote SCR control panel for each heater	
DHY	Refrigerated after cooler, water separator, dual tower driers, regeneration gas heater, desiccant dust filter.	
CPU	Stripper column, CO_2 reboiler, aux CO_2 reboiler, CO_2 condenser, CO_2 reflux pumps (two (2) x 100% per train), CO_2 product heaters, control system (vendor PLC)	
Refrigeration System	Refrigerant compressors, oil coalescers, refrigerant water cooled condensers, Refrigerant high pressure receiver, control system (vendor PLC), initial propylene fill	Starting Duty VFD for compressors
CO_2 Booster Pumps	Four (4) pumps and motors	
CO_2 Product Pumps	Three (3) pumps and motors	VFDs
Hybrid DCC Circulating Water WSACs	Four (4) series coolers, each with fans, fan motors, a dry (air-cooled) section followed by a WSAC with WSAC circulating pumps	VFDs

Equipment/System	Scope Included	BOP by Others
Cooling Tower	Pre-assembled counterflow cooling tower with fans	VFDs
RO Water Treatment	Three (3) x 50% MF/RO trains for redundancy, single set of reaction tanks, a single sludge dewatering system	VFDs
Lime Fixation	Lime storage silo, screw conveyor, pug mill modifications	
Miscellaneous Pumps	DCC circulating water pumps, service water pumps, EQ tank forwarding pumps, condensate injection pumps, condensate collection tank pumps, wastewater forwarding pumps, well water forwarding pumps, well water reservoir pumps, process drains sump pumps, RO wastewater sump pumps, filtrate recycle sump pumps, closed cooling water pumps, reservoir pumps	
Miscellaneous Tanks	EQ storage tank, wastewater forwarding tank, well water storage tank, service water tank, RO permeate holding tank, process drains condensate collection tank	
Compressed Air System	Air compressors, dryers and air receivers, control system (vendor PLC)	
Condensate Drains (Vacuum Pump)	All-inclusive skid with pressure powered pump, strainer, trap, drain, valving	
FRP Piping	Piping from Membrane A outlet to Membrane A Fan 1 inlet	
Liquid Immersed Transformers	Transformers	

Equipment/System	Scope Included	BOP by Others
Medium and Low Voltage Switchgear	Switchgear	
Medium Voltage VFDs	MV VFD assemblies, including input isolation transformers	
Non-Segregated Phase Bus Duct	NSPBD system and misc. hardware	Foundation / Steel Supports
Cable Bus	Cable bus system and misc. hardware	Foundation / Steel Supports
UPS, Batteries, Chargers	UPS system, manual bypass transformer, redundant battery chargers, 125 Vdc battery system	
480 V MCCs	MCCs	
Controls Integration	DCS expansion hardware, network hardware, system integration services, vibration monitoring system, simulator expansion	
Emergency Purge Fan	Fan	
Emergency Diesel Generator	Diesel generator with control panel	

All budgetary costs obtained for the equipment and other various systems are considered as material and/or subcontracted costs, reflecting as-delivered pricing for the components. S&L incorporated these costs into the cost estimate, applying installation labor and indirect costs as necessary.

5.1.2. BOP Cost Development

Equipment pricing developed by S&L for other BOP items are based on previous project experience combined with engineering judgement.

Dampers and expansion joints are based on the dimensions and length of the ductwork/piping. Damper cost estimates include the costs of ancillary equipment like motors and seal air systems. Pumps outside of equipment supplier's costing scope outlined in Table 5-1 above included the chemical supply pumps. These pumps were assumed to be centrifugal type pumps with stainless steel internals. The cost of the building sump that collects condensate and wastewater from finger trenches was developed based on the required size and material of construction.

Civil quantities were developed for sitework including, but not limited to, temporary sediment and erosion control, earthwork (including onsite disposal of excess material), reservoir liner system, roadways, area surfacing, storm sewer system, oily sewer system, oil water separator, and chain link fences and gates.

Structural quantities were developed for foundations according to the estimated dimensions and weights shown on the foundation drawings. Specifically, cubic yards of concrete for foundations, square foot of formwork for concrete foundations and structures, pounds of carbon steel for embedment, and tons of concrete reinforcing were provided. Quantities for miscellaneous foundation items including, but not limited to,

mudmats, premolded joint filler, and grout are also included.

Architectural costs were based on the building dimensions indicated on the architectural plan and elevation drawings. Quantities developed include siding, roofing, downspouts and gutters, doors, interior partitions, and elevators.

Tons of steel is provided for building steel, utility rack steel, duct support steel, membrane removal crane steel, cooling tower steel and access gallery, platforms, and miscellaneous piping and cable tray supports. In addition, square footage of grating and linear feet of handrail were also developed. Tons of steel is provided for the carbon steel ductwork. Square footage of insulation and lagging and linear feet of expansion joints, along with ductwork accessories including slide bearing plates, spherical bearings, and access doors are also included.

Demolition quantities were developed for known ductwork, structures, and foundations that currently interfere with installation of the CO_2 capture plant. Cost allowances are considered for steel and foundations that are anticipated, but that do not have sufficient information to develop further during the FEED study. These allowances are based on previous construction and design projects with similar design layouts or arrangements. Allowances include, but are not limited to, pipe and electrical support auxiliary steel and associated foundations, access galleries interior to CO_2 capture buildings for maintenance and access, modifications to the existing N/E round clean gas ductwork and supports, and modifications to the ITC small test center tie-in.

All piping costs are based on material, diameter, thickness, and length as indicated on the S&L P&IDs, piping isometrics, and routing sketches. Insulation is included as needed and is based on process conditions. Mineral fiber insulation with a vapor barrier and jacketing shall be used on process piping and equipment where temperatures exceed 140°F to provide personnel protection and process heat conservation. Elastomer insulation shall be used on process piping and equipment where process operating temperatures fall below 50°F to prevent surface condensation. Heat tracing shall be used in conjunction with mineral fiber insulation on piping and equipment that could be subject to freezing or process interruption upon exposure to freezing conditions.

S&L received vendor pricing for the liquid filled transformers, medium voltage VFDs, medium voltage switchgear, low voltage switchgear, USS transformers, UPS, batteries, chargers, regulating transformers, medium voltage non-seg bus duct, medium voltage cable bus, and low voltage motor control centers. Grounding, lighting, lightening protection, conduit, cable, and cable tray costs are based on the single line diagrams, electrical building layouts, cable tray drawings, lighting layouts, load list, I/O list, and the overall plant GA. The costs for lighting and distribution transformers and panels, disconnect switches, welding receptacles, junction boxes and other miscellaneous electrical equipment and components are based on S&L pricing information with adjustments to account for recent pricing adjustments; due to supply chain issues. Costs related to the existing switchyard modifications and new 230kV overhead transmission line were developed by BEPC and are included in the cost estimate.

Controls Integration costs are based on the preliminary control system hardware design and system integration services required for the fully integrated CO_2 capture plant DCS expansion. This cost includes all DCS hardware, network hardware, vibration monitoring system, and all engineering or support services required to design, fabricate, deliver, and assist in commissioning the complete DCS expansion. Modification of the existing DFS simulator to include a high fidelity simulation of the CO_2 capture plant was also included in the cost. Preliminary control system hardware design was developed based on the I/O quantities defined in the preliminary I/O list and the interfaces required per the network architecture diagram.

Instrumentation costs are based on BOP instrumentation quantities depicted on the process P&IDs and extracted from the various vendor quote information received. Manufacturer configuration tools and historic procurement costs were used to develop the estimated costs for each instrument type. Costs for installation materials, tubing, instrument stands and enclosures, and GWC installation labor are also included. Procurement and installation costs were included for each instrument type, listed as separate line items by instrument type. Together, these costs represent the total installed instrumentation cost not covered by a

supplier package or major equipment cost represented in other sections of the cost estimate.

Allowances are included for performance testing by a 3rd party testing contractor, an additional complete HAZOP analysis, hazardous gas mapping services, existing CEMS modifications, construction management oversight of the GWC, and S&L startup and commissioning services.

Labor-hour estimates are included for most line items in the cost estimate, with the exception of some all-in costs provided for subcontracted efforts and allowances. The magnitude of labor-hours is indicative of the level of effort for the installation for each item, as determined by S&L. The labor rates shown in individual line items are reflective of an average 2022 wage rate. Labor rates are based on 5x10 hour work weeks, single shift and includes per diem. S&L also included costs for crane and hoist trolleys to assist in the construction process.

5.1.3. Cost Escalation

Escalation is included at 2.5% per year for material, equipment, construction equipment, and subcontracts; escalation is included at 3% per year for labor and project indirects. Escalation is calculated based on the preliminary project schedule.

Prices in the estimate represent 2022 current prices. These prices reflect the effects of the COVID-19 pandemic on the supply chain. It is anticipated that the rapid increase incurred in the past two years will slow down, and prices are expected to start regulating themselves in the near future. However, considering the current volatile market conditions and the inability to accurately predict the market at the time this project will materialize, escalation has been included for conservativeness; but it may not be fully incurred.

5.1.4. Cost Contingency

Based on project definition, contingency is included at 15% for all cost categories except for the process equipment and BOP for which budgetary quotes were received; 5% contingency is applied to the latter. The contingency relates to pricing and quantity variation in the specific scope estimated; the contingency does not cover new scope outside what has been defined for the project.

5.2. CAPITAL COST ESTIMATE

The detailed capital cost estimate and basis of estimate documents are included in Appendix A. The estimate itemizes the equipment cost, labor hours, and a total cost of installation for each piece of equipment and/or commodity. The basis of estimate explains the assumptions and methodology used to develop the estimate. The following paragraphs highlight the key components of the estimate and overall project cost.

The total direct cost (sum of material, subcontract, equipment, and direct labor costs) is approximately $760,437,574 as shown in 2022 dollars.

Table 5-2 — Total Direct Cost

Parameter	Amount
Labor	$123,211,463
Material	$154,200,570
Subcontract	$65,384,210
Construction Equipment	$29,867,024
Process Equipment	$387,774,307
Total Direct Cost	**$760,437,574**

The indirect costs are applied to the total direct cost for the overall project estimate. Examples of indirect costs included are below; please see the Basis of Estimate in Appendix A for the full list of indirect costs:

- Labor indirects are applied to the direct labor cost, and include labor supervision, overtime, per diem, and liability insurance
- Site indirects are applied to the total direct cost and include construction management, engineering, material and quality control, site services, safety equipment, temporary facilities and utilities, mobilization and demobilization, and legal expenses
- Other construction indirects include small tools and consumables, scaffolding, liability insurance, construction equipment mobilization and demobilization, sales tax, and contractor's expenses
- Engineering and contractor costs – Construction Management (CM), Engineering and Design, Contractor Profit, etc.
- Start-Up Costs
- Spare Parts
- Third-Party Support/Testing.
- Owner's Cost
- AFUDC (Interest During Construction)
- Escalation: individual estimate line items are in 2022 cost; refer to Section 5.1.3 for escalation rates applied
- Contingency: as indicated in Section 5.1.4
- Freight for equipment is included in the direct equipment costs
- Taxes

After all indirect costs are applied; the Total Project Cost is approximately $1,558,360,927. The detailed Capital Cost Estimate is in Appendix A.

Table 5-3 — Total Project Capital Cost

Parameter	Amount
Total Direct Cost	$760,437,574
Construction Indirect	$223,363,000
Project Indirects	$79,925,000
Owner's Cost	$53,186,000
Interest During Construction	$96,064,000
Contingency	$125,778,353
Escalation Note 1	$219,607,000
Total Project Cost	**$1,558,360,927**

Note 1: Escalation was based on the project schedule per the year that costs would be incurred.

5.3. OPERATING & MAINTENACE COST ESTIMATE

The fixed and variable operating and maintenance (O&M) cost estimate were developed for the CO_2 capture plant using commodity pricing available from BEPC/DFS staff, chemical/reagent suppliers, process flows, and various utility needs of all new systems. The detailed O&M cost estimate is included in Appendix A.

The consumption rates for the caustic reagent required for the SO_2 polisher, lime for the fixation system and incremental increase in solid waste, chemicals for the cooling tower and WSAC, number of membrane skid containers changeouts, and the overall power and water consumption to operate the MTR CO_2 capture plant is summarized in Table 5-4 on the next page.

Table 5-4 — Annual O&M Rates (at 100% Capacity)

Parameter	Units	Amount
SO_2 Polisher – 25% Caustic Reagent	ton/yr	3,767
Fixation System – Lime	lb/yr	7,533,600
Fixation System – Incremental Solid Waste Increase	ton/yr	64,709
CPU – Annual Propylene Makeup Rate Note 1	lb/yr	5,000
RO Water Treatment – Treated Water Inlet Flow	1,000 gal/yr	110,290
RO Water Treatment – Solid Waste Disposal	ton/yr	172
Membrane System – Skid Containers Changeout Note 2	No./yr	38
Cooling Tower – Antiscalant Chemical	lb/yr	84,971
Cooling Tower – Oxidizing Biocide Chemical Note 3	lb/yr	31,800
Cooling Tower – Bromine Chemical Note 3	lb/yr	3,050
WSAC – Bleach Chemical Note 3	gal/yr	91,250
WSAC – Sodium Bromide Note 3	lb/yr	14,600
WSAC – Corrosion Inhibitor	lb/yr	15,131
WSAC – DBNPA (Microbiocide) Note 4	lb/yr	2,848
WSAC – Isothiazolinone (Microbiocide) Note 4	lb/yr	4,295
Well Water Supply – On-Site	1,000 gal/yr	87,621
Well Water Supply – Off-Site Note 5	1,000 gal/yr	87,621
Power Required Note 6	MW/yr	1,012,882

Note 1 – Based on Trimeric input, refrigerant makeup is expected to occur annually, regardless of unit capacity factor, therefore refrigerant makeup rate costs are included in fixed operating costs.

Note 2 – Based on MTR input, individual membrane skids will have an average 5-year service life. Reserved space for future membrane skids are included in the general arrangement to facilitate a membrane management program that will maintain the long-term performance of the CO_2 capture system. Although details of the membrane management program will be developed during detailed design, an annual number of membrane changeouts were estimated based the membrane replacement frequency on an hourly basis (8,760 hours/yr ÷ 43,800 hours service life) x total number of membrane skids (including MEM A, MEM B, MEM C and MEM D) to estimate first year O&M costs.

Note 3 – Although the cooling tower and WSAC require similar chemicals, the chemical treatment programs may be managed by two different chemical suppliers because ChemTreat is the only supplier with experience with WSAC type cooling systems.

Note 4 – Chemical supplier recommends monthly dosage rate which would continue regardless of unit capacity factor, therefore biocide consumption rate costs are included in fixed operating costs.

Note 5 – DFS has three (3) wells that supply water to the site, one (1) is located on-site and uses auxiliary power from the station and the other two (2) are off-site that draw power from the grid to operate.

Note 6 – Includes CO_2 capture plant, incremental increase in existing ID fan power consumption (tipping), and on-site well water pump operation.

5.3.1. Variable O&M Costs

The first year variable O&M costs are summarized on in Table 5-5.

Table 5-5 — First Year Variable O&M Costs ($2022)

Cost	Amount ($/year)
SO_2 Polisher – 25% Caustic Reagent	2,260,000
Fixation System – Lime	1,174,000
Fixation System – Incremental Increase in Solid Waste Disposal	298,000
RO Water Treatment – Chemicals	107,000
RO Water Treatment – Solid Waste Disposal	900
Membrane System – Maintenance Replacement	15,000,000
Cooling Tower – Antiscalant Chemical	183,000
Cooling Tower – Oxidizing Biocide Chemical	31,000
Cooling Tower – Bromine Chemical	7,000
WSAC – Bleach Chemical	82,000
WSAC – Sodium Bromide Chemical	59,000
WSAC – Corrosion Inhibitor Chemical	54,000
Water Consumption	0
Off-Site Well Water Supply Power	67,000
On-Site Power Consumption – CO_2 Capture Island	21,847,000
On-Site Power Consumption – Existing ID Fans & Well Water Supply	436,000
Total Variable O&M at 100% Capacity Factor	**41,606,000**
Total Variable O&M at 90% Capacity Factor	**37,445,000**

5.3.2. Fixed O&M Costs

The fixed O&M costs include operating personnel and maintenance costs (including material and labor). The anticipated staffing required to operate and maintain the new CO_2 capture system are summarized in Table 5-6.

Table 5-6 — Operating Personnel Requirements

Position	Position Type	No. Shift	No. Personnel/ Shift Note 1	Total No. Staff	Hours Worked per Year Note 2
Shift Supervisor	Full Time	1	1	1	no increase
Admin Support	Full Time	1	1	1	no increase
Support Engineer	Full Time	1	1	1	2,080
Operations Manager	Full Time	1	1	1	no increase
CEMS Technician	Full Time	1	0.25	0.25	no increase
Lab Technician (Analyst/Chemist)	Full Time	1	1	1	2,080
Mechanical Maintenance	Full Time	1	1	1	2,080
Electrical/Instrumentation Technician	Full Time	1	1	1	2,080
Control Room Operator	Shift Work	4	1	4	no increase
Cooling Tower and WSAC Infield Operator	Shift Work	5	0.50	2.5	no increase
DCC and Flue Gas Booster Fan Infield Operator	Shift Work	5	0.25	1.25	no increase
MEMA/MEMB Compressor Building Infield Operator	Shift Work	5	1	5	10,400
CPU Building Infield Operator	Shift Work	2	1	2	no increase
RO Water Treatment Infield Operator	Shift Work	2	0.87	1.73	no increase
Wastewater Lime Fixation Infield Operator	Shift Work	2	0.25	0.50	no increase

Note 1 – For number of personnel required < 1, it is assumed that operators in those specific positions could be shared amongst various areas.

Note 2 – Number of hours worked per year reflects the additional hours that would be paid to additional staff. For items listed as “no increase,” it is assumed that existing station staff would be able to accommodate the additional responsibilities without having to hire additional staff.

As shown in Table 5-6, an estimated nine (9) operators and maintenance personnel will be required for the project. Operating labor costs are estimated using an operator wage rate of $72.12/hr and based on a 40-hour week schedule. Fixed maintenance material and labor costs are applied at 2.5% of the total purchased equipment and material costs and 60% of subcontract costs (excluding the membrane costs), with 60% attributed to the maintenance material and the remaining 40% attributed to maintenance labor. DFS shifts include four (4) regular shifts (day, evening, graveyard, and weekend) plus one (1) relief shift, which includes personnel on-site to complete the majority of the preventative maintenance (PM) activities; it is assumed that the number of additional personnel required for the project accounts for maintenance labor expected and therefore is not included as an additional cost. The fixed labor assumptions and first-year O&M costs are summarized in Table 5-7.

Table 5-7 — First Year Fixed O&M Costs ($2022)

Parameter	Units	Input
Additional No. of Operators	No.	9
Operators Schedule (assumed)	hrs/week	40
Operator Hourly Wage Rate	$/hr	72.12
Operating Labor Cost	$/yr	1,350,000
CPU Propylene Refrigerant Makeup Cost	$/yr	10,000
WSAC DBNPA (Microbiocide) Cost	$/yr	17,000
WSAC Isothiazolinone (Microbiocide) Cost	$/yr	16,000
Maintenance Material Cost	$/yr	6,784,000
Maintenance Labor Cost	$/yr	0
Total Fixed O&M Cost	**$/yr**	**$8,177,000**

5.3.3. Total O&M Costs

As the total O&M costs will not be incurred until the plant is constructed, the total O&M costs were escalated from the base year (2022) to 2029 when construction is estimated to be completed and the system operational. An annual escalation rate of 3% was used. Table 5-8 summarizes the total O&M costs.

Table 5-8 — Total O&M Costs

O&M Costs	Amount ($/year)
Variable – at 90% Capacity Factor	37,445,000
Fixed	8,177,000
Total O&M Cost ($2022)	**45,622,000**
Escalation Rate	3%
Escalated Total O&M Cost ($2029)	**56,109,000**

The final MTR CO_2 capture plant O&M cost estimate is included in this report in Appendix A.

6. NEXT STEPS

MTR and S&L held a face to face meeting toward the end of the FEED study project to strategize what could be done following the completion of the study to help secure financing for the execution of the CO_2 capture plant retrofit project; the team discussed this on a general level and for a DFS-specific installation. The team also started looking forward to the development of performance guarantees for the CO_2 capture plant: what parameters could and/or should be guaranteed, and which project entities would have ownership for meeting the guarantee(s), etc. Other future considerations such as potential developers and construction firms that would be able to support a project of this size were also discussed. This section captures the "next steps" that should be considered by MTR.

6.1. REDUCE RISK

To further progress the project development, it is anticipated that MTR will need to reduce risks associated with the CO_2 capture plant application. As such, the following activities are recommended to pursue in order to secure financing for the project:

There are several components in the CO_2 capture plant that will be considered first-of-a-kind (FOAK) for the vendors solicited during the FEED study as identified below. It is recommended to consider issuing Limited Notice to Proceed (LNTP) contracts for these particular items to allow the vendors to start engineering and design of the equipment. This would allow for project detailed engineering to begin based on the (engineered) vendors' input, which could then be used to update the cost estimate with a tighter accuracy range to achieve an AACE Class 1 estimate level.

- DCC – B&W
- MEMA Permeate Fans – Piller
- MEMB Permeate Fans – Piller
- MEMB Compressor – Siemens/Dresser Rand
- CPU – Salof

Furthermore, issuing LNTP contracts may also generate more interest from other vendors.

It is also recommended to find an alternative CPU supplier or separate suppliers for the dehydration, CO_2 distillation column and refrigeration systems. Only one vendor provided a bid during the FEED Study phase; having a single point of failure for the CO_2 capture plant or project poses a very high risk for investors. Additionally, the CPU vendor delivered the budgetary quote several months past the due date, resulting in schedule delays, which would encourage consideration for an alternate supplier.

The last recommendation to reduce risk for the commercial scale CO_2 capture plant is to "prove" the technology in a scaled, integrated CO_2 capture system; i.e. successfully operate the MTR Large Test Pilot.

6.2. ENGINEERING INVESTIGATIONS

To increase the chances of funding, it is recommended that the following engineering improvements to optimize the CO_2 capture plant and/or provide potential cost savings be investigated:

- Implementation of any membrane design modifications to improve efficiency.
- Investigate ways to decrease operating costs, including, but not limited to, the following:
  - Turndown capabilities vs. limits; e.g. review application of medium voltage variable frequency drives included on the major process equipment against other potential means for turndown.
  - Detailed auxiliary power assessment for different ambient conditions throughout the year.

- All aspects of water usage:
  - In depth investigation to optimize cooling to the CO_2 capture plant including technical and economic review.
  - Water treatment review: with actual wastewater composition from the Large Pilot operations, determine if an alternate, more cost effective solution is available and/or if DFS would consider using condensate from the CO_2 capture plant in the DFS power plant.
  - Options for decreasing the CO_2 facility water makeup requirements.
- Increased lime usage in BEPC DFGD to minimize DCC caustic consumption & fixation lime consumption.
- Detailed assessment of membrane replacement sequence, frequency and cost.

- Reduce air in-leakage
  - Characterization of major air in-leakage contributors to determine the amount of air in-leakage attributed to each source and if the air usage could be modified in a way to reduce its air in-leakage contribution.
  - Cost benefit analyses for implementation costs vs. CO_2 capture plant capital & operating cost savings.
- Investigate increasing CO_2 capture rate up to 90-95% removal to increase 45Q credits.
- Investigate CO_2 recirculation to boiler and/or upstream of Membrane A (note that this may be considered separately or may subsequently be part of the air in-leakage reduction and/or increased capture rate assessments); include assessment of DFS boiler & CO_2 capture plant performance impacts and itemization and pricing of DFS existing equipment modifications required.
- Incorporation of any significant findings from the Large Test Pilot demonstration.
- Perform detailed motor starting analysis on group connected VFD motors to determine if these motors can be started without the application of VFDs. This will require a detailed description of start-up sequencing with time intervals identified.
- Consider removing the DCS CO_2 capture plant DCS simulator upgrade option included in the scope of the FEED study design. Cost is itemized in the capital cost estimate. This option can be removed without affecting the performance and safety of the system; however, the simulator would provide invaluable training and performance tuning capabilities, and insight into proposed engineering changes for a first of a kind system and should be considered last when optimizing cost.
- Optimize reservoir size to minimize construction cost. This will include reservoir footprint and depth modifications and consideration for liner and excavation costs. Excavation to also consider potential rock excavation at deeper excavations.

6.3. DRAFT CONSTRUCTION PERMIT

Of the several federal and state permits required for the installation of the CO_2 capture plant, it is recommended that the draft Wyoming Department of Environmental Quality (WYDEQ) Air Quality Division (AQD) new source review (NSR) application for a construction permit be started. Preparation of the application can take several months. In the event a state construction permit is required (in lieu of an authorization letter), the state application review time is expected to be over 120 days and has the risk of further delays in the event a public commenting period is prolonged.

Because permitting timeframes are a potential schedule risk, a way to mitigate potential schedule impacts would be to apply for this permit early. In the event BEPC would like to pursue early submission of the NSR application, BEPC personnel are expected to lead and/or be closely involved in this effort based on their

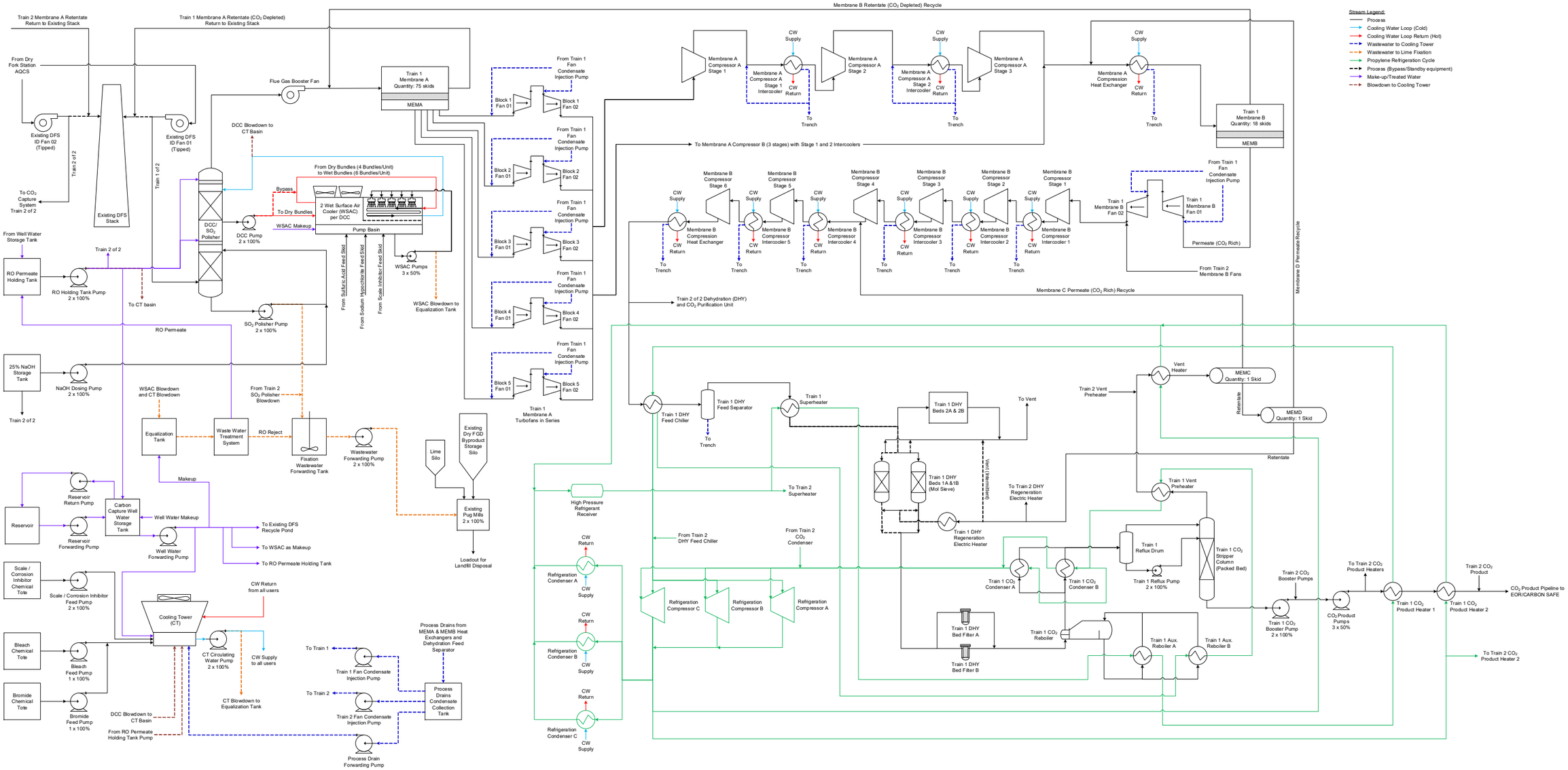
experience and relationship with WYDEQ. A pre-application meeting with the WYDEQ is also recommended to discuss anticipated project-related changes which can also be coordinated.

APPENDIX A.

APPENDIX A. FULL SCALE OVERALL PROCESS FLOW DIAGRAM (PFD)

Dry Fork Station Unit 1
Full-Scale Carbon Capture
Process Flow Diagram

Project: 13978-002
For Use – Rev. 0
Date: December 10, 2021



APPENDIX B. S&L DESIGN CRITERIA



Membrane Technology & Research

DRY FORK STATION UNIT 1

FULL SCALE CARBON CAPTURE FEED STUDY PROJECT DESIGN CRITERIA

Issue: For Use
Rev. 0

February 7, 2022
Project 13978-002

Prepared by



55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

ISSUE SUMMARY			
Revision	**Issue Purpose**	**Issue Date**	**Sections Affected**
0	For Use	02/07/2022	All

PREPARED, REVIEWED, AND APPROVED				
Revision	**Discipline**	**Prepared**	**Reviewed**	**Approved**
0	Mechanical	Digitally signed by Kelly Gandy Kelly Gandy	Digitally signed by Marion Teslik Marion Teslik	
	Environmental	Digitally signed by Vrushant Patel Vrushant Patel	Holly Hills	
	Structural	Christie Ainge	For: Elizabeth LaMere	
	Electrical	Digitally signed by Alexander Vincent Alexander Vincent	Stephan Nealon	
	Instrumentation and Controls	Digitally signed by Harley Hudetz Harley R. Hudetz	Digitally signed by James R. Robeson James R. Robeson	
				Dana B. Pierik S&L Project Manager

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1. PROJECT OVERVIEW

As part of the awarded work under the Department of Energy's (DOE) Funding Opportunity Announcement (FOA), DE-F00031846 (FPO-2058), Membrane Technology and Research, Inc. (MTR), in cooperation with Basin Electric Power Cooperative (Basin), Electric Power Research Institute (EPRI), Trimeric Corporation (TRI) and Sargent & Lundy (S&L), will further develop MTR's membrane-based post-combustion carbon dioxide (CO_2) capture technology by completing a full scale Front End Engineering Design (FEED) study. The study will evaluate retrofitting MTR's membrane CO_2 capture technology to Basin's Dry Fork Station (DFS) and deliver captured carbon dioxide to the CarbonSAFE Project. It is estimated that this system will capture 6,560 tonnes per day (TPD) of carbon dioxide, approximately 70% of DFS's current CO_2 emissions. This capture rate reflects a 90% capacity factor of Dry Fork Station.

S&L has prepared this document to compile the design criteria for the project upon which the FEED study will be based. This document summarizes the full scale design considerations and the major system design basis, as supplemented by the data presented in the various attachments.

1.1 FULL SCALE UNIT OVERVIEW

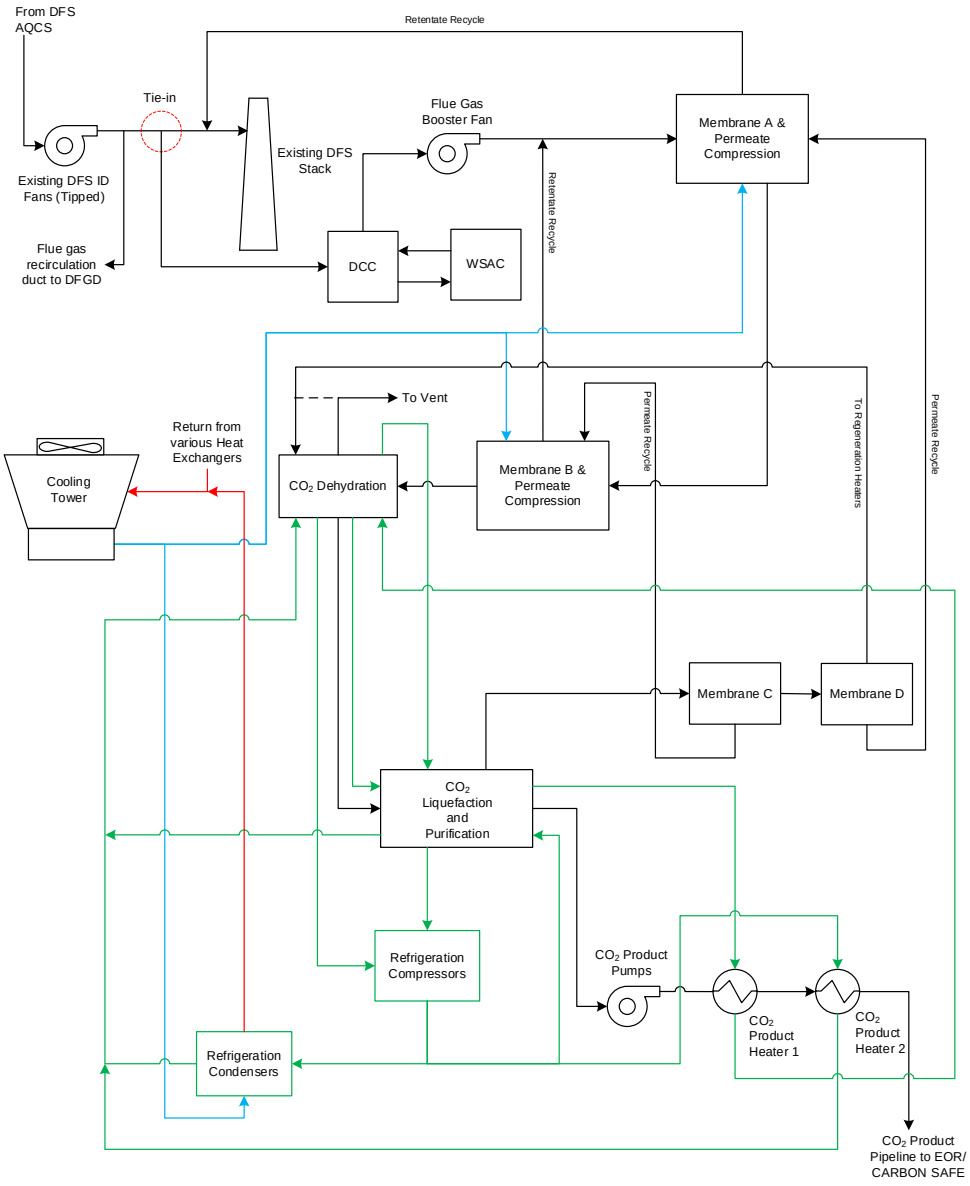
The proposed full scale CO_2 Capture system will consist of the following major pieces of equipment/systems:

1. Existing ID Fan(s) Modifications
2. Direct Contact Cooler (DCC) Systems, includes SO_2 Polishing Capabilities
3. Wet Surface Air Cooler (WSAC) Systems
4. Flue Gas Booster Fans
5. Membrane A and Permeate Compression
6. Membrane B and Permeate Compression
7. CO_2 Dehydration System (DHY)
8. CO_2 Dehydration Regeneration Vent
9. CO_2 Liquefaction & Purification (CPU)
10. CO_2 Booster and Product Pumps
11. Membrane C & D

12. Propylene Refrigeration System
13. Close Cooling Water System
14. Wastewater Treatment System
15. Well Water System
16. Service Water System
17. Compressed Air System
18. Wastewater Fixation System
19. Existing DCS modifications and new DCS expansion
20. Existing 230kV switchyard modification & new 230kV substation
21. Auxiliary Power System
22. Emergency Power and Purge System

Below in Figure 1-1 is the overall block flow diagram for the full scale unit, a more detailed process flow diagram (PFD) is included in Appendix A.

Figure 1-1: MTR Full Scale Overall Block Flow Diagram



2. SITE LOCATION, WEATHER CONDITIONS

2.1 LOCATION

Dry Fork Station is located at 12460 N. Highway 59, Gillette, WY. The plant can be accessed via the main plant entrance off highway WY-59. Construction traffic, for large loads, can use the plant's North entrance. Plant North is 45° East of State Plane North as seen in Appendix C; all references to direction are with respect to Plant North.

2.2 WEATHER CONDITIONS

Table 2-1 lists the major site conditions, which are based on American Society of Heating, Refrigeration and Air Conditioning (ASHRAE) data.

Table 2-1
Major Site Conditions

Parameter	Data
Nearest ASHRAE (2017 Fundamentals) weather	Gillette, Wyoming
World Meteorological Organization Number	726650
Latitude/longitude	44.339°N/105.542°W
Elevation	4,354 feet (1,327 meter)
Standard pressure	12.53 psia (0.86 bar)
Heating dry bulb temperature, 99.6% occurrence	-9.3°F (-22.9°C)
Extreme wind speed, 1% occurrence	28.9 mph (12.9 m/s)
50-year occurrence temperatures:	
High	108.2°F (42.3°C)
Low	-35.6°F (-37.6°C)
Cooling dry bulb temperature, 2.0% occurrence	88.4°F (31.3°C)
Cooling wet bulb temperature, 2.0% occurrence	63.2°F (17.3°C)

3. INLET FLUE GAS DESIGN CONDITIONS

3.1 SITE BACKGROUND

The DFS Unit 1 is a low-sulfur Powder River Basin (PRB) coal-fired, base-loaded 445 MW (Gross) generating unit with an air-cooled condenser to minimize the amount of plant water consumption.[1] The plant utilizes B&W AireJet® low NO_X burners, overfire air and a selective catalytic reduction (SCR) system for nitrogen oxides (NO_X); activated carbon injection for mercury (Hg) control; and a dry flue gas desulfurization (FGD) system consisting of a circulating dry scrubber (CDS) and fabric filter baghouse to control sulfur dioxide (SO_2) and stack particulate matter (PM) emissions. The annual capacity factor for DFS Unit 1 is 90%.

The inlet flow gas composition for the MTR full scale unit was established based on S&L combustion calculations. Table 3-1, on the next page, shows the flue gas conditions to be used for the design of the MTR full scale unit at full load, summer operating conditions once the existing ID fans are tipped to transfer flue gas to the CO_2 capture island.

[1] Due to the use of dry cooling for the condensing system, unit capacity will vary with outdoor temperature. Historical full load operation during summer months is 445 MW (Gross) per Basin personnel correspondence and during winter months, from January through May, has shown operation at 431 MW (Gross).

Table 3-1
Design Inlet Flue Gas Conditions (Full Load, Summer Conditions)

Parameter	Data
MTR Full Scale MWe	445 MWe (gross)
Temperature	222°F (106°C)
Pressure	13.216 psia (0.911 bara)
Nitrogen (N_2)	65.48 % vol
Oxygen (O_2)	3.71 % vol
Water (H_2O)	18.79 % vol
Carbon Dioxide (CO_2)	12.01 % vol
Sulfur Dioxide (SO_2)	27.0 ppmv wet
Sulfur Trioxide (SO_3)	1.0 ppmv wet
Hydrogen Chloride (HCl)	0 ppmv wet
Hydrogen Fluoride (HF)	0 ppmv wet
Total Flow	5,096,990 lb/hr (2,311,954 kg/hr)
Fly Ash	53 lb/hr (24 kg/hr)
Nitrogen Oxide (NO)	31.0 ppmv wet
Nitrogen Dioxide (NO_2)	2.0 ppmv wet
Ammonia (NH_3) Slip	5 ppmv dry

1. Refer to Dry Fork Station Unit 1 Flue Gas Characteristics at CO2 Capture System Tie-In, Calc No. 2020-03849, Rev. 2 dated 3-19-21 for details on each parameter's source, and other assumptions/calculations completed to quantify the MTR Full Scale inlet flue gas conditions.

4. APPLICABLE STANDARDS & CODES

Unless a specific edition is noted below, all materials, equipment, products, accessories and essential services supplied shall be designed, fabricated, constructed, or provided in accordance with the latest recommended engineering standards and all applicable local, state, and federal codes, laws, and standards. The codes, laws, and standards include, but are not limited to:

1. American Conference of Government Industrial Hygienists Standards (ACGIH)
2. Air Movement and Control Association Publications and Standards (AMCA)
3. American National Standards Institute Publications and Standards (ANSI)
4. American Industrial Hygiene Association Standards and Publications (AIHA)
5. Air-Conditioning and Refrigeration Institute Standards and Publications (ARI)
6. American Society of Heating, Refrigerating, and Air Conditioning Engineers Publications and Standards (ASHRAE)
7. American Water Works Association Publications and Standards (AWWA)
8. Hydraulics Institute (HI) Publications and Standards
9. Instrument Society of America (ISA) Publications and
10. American Petroleum Institute (API) Selected Publications and Standards
11. American Society of Mechanical Engineers (ASME)
12. American Society for Testing and Materials (ASTM)
13. Cooling Tower Institute (CTI)
14. General Climate Summary 1925 to 2004, Gillette 9 ESE, WY, High Plains Regional Climate Center
15. Heat Exchanger Institute (HEI) Standards and Publications
16. International Code Council - International Building Code - 2018
17. International Code Council - International Mechanical Code - 2018
18. International Code Council - International Fire Code - 2018
19. International Energy Conservation Code – 2018
20. National Electric Code (NEC)
21. National Electrical Manufacturers Association (NEMA) Codes and Standards
22. National Fire Protection Association (NFPA) Codes and Standards
23. Occupational Safety and Health Administration (OSHA) Regulations and Publications
24. Sheet Metal and Air Conditioning Contractors' National Association (SMACNA)
25. Tubular Exchanger Manufacturers Association Standards (TEMA)

26. Underwriters Laboratories, Inc. Laboratories Standards and Publications

27. American Concrete Institute - Building Code Requirements for Structural Concrete (ACI 318) - 2014

28. American Institute of Steel Construction – Specification for Structural Steel Buildings (AISC 360) - 2016

29. American Society of Civil Engineers - Minimum Design Loads for Buildings and Other Structures (ASCE 7) - 2016

30. Research Council on Structural Connections - Specifications for Structural Joints Using High-Strength Bolts- 2014

31. Compressed Gas Association – Carbon Dioxide (CGA G-6) – 2009

5. PLANT LAYOUT

5.1 GENERAL

The full scale carbon capture system will be tied into the flue gas path upstream of the DFS stack and located on the East side of the plant as seen in Appendix C. There are two duct lines that run from the dry FGD system to the stack. These lines will be redirected to the proposed carbon capture system before returning the CO_2-depleated flue gas back to the stack. Naming convention at the site lists the plant south duct as Train A and the north duct as Train B. Flue gas processing equipment, ducting, and piping in the CO_2 plant that continues from Train A will be referred to as Train 1; this will be on the southside of the CO_2 plant. Continuations from Train B to the CO_2 plant will be referred to as Train 2 and be located on the northside of the CO_2 plant.

5.2 ACCESS/ENCLOSURE REQUIREMENTS

Outdoor equipment shall be designed to remain operable under the most extreme site environmental conditions of heat, cold, and wind. Enclosures used to meet these conditions shall have doors, access panels, or removable sections, depending on enclosure size, to facilitate maintenance and overhaul work.

Indoor and outdoor equipment shall feature personnel protection, as appropriate for the location, including noise attenuation panels, guards on rotating components, guards on components with surface temperatures exceeding 140°F (60°C), and other provisions such that equipment complies with all OSHA requirements for personnel work environments.

5.3 MAINTENANCE

Buildings and equipment layout shall be arranged in a manner to provide access to equipment, as well as adequate space around the equipment for maintenance. Roll up doors will be used on buildings to provide access for forklifts.

Membrane containers will be serviced using a crane and trolley system designed around each membrane train. Roadways around the carbon capture equipment building will provide access for trucks to be loaded by the crane system.

6. PROCESS DESIGN

Detailed descriptions of specific system sizing assumptions and design considerations are discussed in the following sections. The design inlet conditions for each major piece of equipment/system is provided by the heat and mass balance sheet created by Trimeric as seen in Appendix D.

6.1 EXISTING ID FANS

The existing DFS Unit 1 has two (2) ID fans downstream of the DFGD, one (1) serving each DFGD train (A & B). There is a flue gas recirculation duct at the outlet of each ID fan to supply clean flue gas to its dedicated DFGD train to maintain the suspended fluidized beds within the DFGD vessels during low load operation. The ID fan outlet ducts convey flue gas to the stack via two (2) separate stack breechings. The new MTR membrane CO_2 capture system will be tied into the ductwork downstream of the existing DFGD flue gas recirculation duct take-off points and upstream of the existing stack breaching. Existing ductwork leading to the stack will be demolished up to the first isolation dampers downstream of the ID fans. New ductwork will tie in at this point and either direct flue gas to the CO_2 capture system or bypass the CO_2 capture system and go directly to the stack.

The manufacturer of the existing ID fan, TLT-Babcock/Howden, predicted that a 15% static pressure increase could be expected if the existing fan blades are tipped. Pressure losses were calculated across the ductwork and DCC leading to the Flue Gas Booster fan. The performance increases expected by tipping the fan existing ID fan blades are sufficient overcome the pressure losses and move flue gas to the inlet of the Flue Gas Booster fan, while maintaining a positive pressure up to the Flue Gas Booster fan inlet.

Appendix B & Appendix D shows the temperatures, pressures, and flow rates for the existing fan upgrades and downstream ductwork upgrades.

6.2 DIRECT CONTACT COOLER (DCC)

The DCC will serve to reduce flue gas temperature from 222°F (106°C) to 90°F (32°C), and will also reduce acid gases and moisture carryover to the membranes. The DCC will be designed to achieve an outlet SO_2 content of less than 5 ppmv to ensure the quality of the CO_2 product (as defined in Appendix

F); the MTR membrane technology removes SO_2 from flue gas more efficiently than CO_2 (i.e. 60% CO_2 capture is equivalent to 80-90% SO_2 capture), hence a lower initial SO_2 value is required.

There will be 2 x 50% DCC vessels (one for each train), each located upstream of a new flue gas booster fan, as the first piece of equipment in the carbon capture island. The DCC will utilize a counter-current design with liquid flowing opposite (downward) to the upward flow of flue gas. In order to optimize the water consumption and re-use it within the CO_2 capture island, an integrated DCC vessel design will be utilized that splits the vessel into a lower SO_2 polishing section and an upper cooling section, where further cooling will increase moisture removal from the flue gas. The upper and lower DCC sections will each consist of a packed bed, with re-circulating liquid introduced via a liquid spray distribution system, located above the random packing. High efficiency mist eliminators with spray wash headers will be located in between the two sections and at the outlet of the upper cooling section to remove any entrained liquid from the gas before entering the booster fan to Membrane A.

The SO_2 polisher section will utilize a 25% caustic (NaOH) solution as it does not require freeze protection (heat tracing and insulation can be avoided with the more dilute solution). A regulated amount of caustic reagent will be mixed using metering pumps in the re-circulating liquid to maintain a set-point pH level of 7-8. A portion of the SO_2 polisher recirculating liquid will be removed in the form of blowdown to maintain chemistry within the vessel and be sent directly to the wastewater forwarding tank.

In the upper cooling section of the DCC, cooling water will be circulated by a wet surface air cooler (WSAC). Cool water from the WSAC will supply the DCC, and the moisture content of the flue gas that is condensed out will be collected with the warm cooling water return and sent back to the WSAC.

6.3 FLUE GAS BOOSTER FANS

The booster fans, for the MTR full scale carbon capture system, shall be sized to supply plant flue gas from the Direct Contact Cooler (DCC), through Membrane A, and return to the existing plant stack as CO_2 depleted flue gas. Appendix E shows the pressure drop calculated across the ducting leading to the Membrane A containers and back to the plant stack. Fan sizing is based on this pressure drop.

6.4 MEMBRANE A, MEMBRANE B, PERMEATE COMPRESSION, AND DUCTING

MTR's membrane capture process separates CO_2 from flue gas. Separated CO_2 is concentrated in a permeate stream leaving the membrane. The membrane separation for the full scale system consists of a two-stage membrane system, referred to as Membrane A and Membrane B, which are made up of Polaris™ CO_2 selective membranes.

6.4.1 Membrane A and Associated Ductwork

Membrane A consists of one-hundred and fifty (150) skid containers split evenly between two trains. Each container is 53 feet in length and 9.5 feet high. The containers will be stacked three high.

Ducting options for feeding flue gas from the booster fans to Membrane A were modeled by MTR. Since the membranes act as a passive flow regulator, MTR's modeling confirmed that the flue gas did not need to be directed to the center of the membrane container cluster. This eliminated additional ducting length and saved on overall footprint of the membrane ducting. Flue gas is fed to the containers from a header that reduces in size as it moves from west to east. The reduction in header size maintains a relatively constant velocity and saves on ducting material. The CO_2 depleted flue gas (Membrane A retentate) will be vented via new ductwork to the atmosphere through the existing plant stack.

6.4.2 Membrane A Permeate Compression

CO_2 rich gas, permeate, leaves Membrane A due to a vacuum created by the permeate compression system. This system initially divides the permeate stream into ten (10) blocks, five (5) per train. Each block consists of two (2) fans in series for a total of twenty (20) fans. The fans feed the permeate into a shared header that lead to two (2) compressors in parallel, per train, for a total of four (4) compressors for both trains. A single heat exchanger cools the compressed permeate for each train before feeding Membrane B.

6.4.3 Membrane B and Associated Ductwork

Membrane B contains thirty-six (36) skids split evenly across two trains. Each skid is 53 feet (ft) in length and 9.5 feet high. The containers will be stacked three high.

The feed header leading to Membrane B was designed similar to Membrane A. Supply gas from Membrane A permeate feeds the Membrane B supply header. Ducting is routed to the containers from the side rather than the middle since the ducting does not need to facilitate even gas distribution to the membranes given the passive flow regulation of the technology. Membrane B retentate is recirculated to the inlet of the Membrane A supply ducting.

6.4.4 Membrane B Permeate Compression

CO_2 rich gas, permeate, leaves Membrane B due to a vacuum created by the permeate compression system. Each train feeds Membrane B permeate to two (2) fans in series. The two (2) trains then combine after the fans into a shared six-stage compressor.

6.4.5 Stack

CO_2 depleted flue gas (retentate) from Membrane A will be vented to atmosphere via the existing stack. Note that the existing stack and CEMS equipment will be evaluated later to determine if any modifications are required. The existing stack penetrations will be used, avoiding needing new penetration(s). During normal operation isolation dampers will be used to block flow to the stack from the ID fan and direct it to the carbon capture plant. In the event that the carbon capture plant is not in operation, isolation dampers leading to the carbon capture plant will be actuated to block flow. Dampers leading to the stack will be opened to allowing flue gas to pass unprocessed bypassing the carbon capture plant.

6.5 CO_2 DEHYDRATION SYSTEM

An adsorption-based dehydration system is typically selected for applications where CO_2 will later be liquefied via refrigeration. The dehydration system will consist of two identical parallel trains of two (2) sets of packed beds, for a total of four beds per train (8 total for both trains). At any given time, one bed per set will be in dehydration (drying) mode and the other bed will be in regeneration mode.

Before entering each trains' dehydration beds, the process gas is chilled to 50°F (10°C) using intermediate pressure refrigerant and sent through a knockout drum in order to reduce the water content of the gas; which will help to reduce the size, capital costs, and operating costs of the dehydration system. The process gas then passes through a superheater for further integration with the refrigeration cycle, warming the gas to 60°F (16°C), prior to being fed to the beds in dehydration

mode. The gas enters the top of the bed and flows downward through the vessels to exit the dehydration system with the water content reduced to less than 1 ppmv. Although designed to achieve the ultra low water content, a maximum water content experienced could be as high as 10 ppmv.

During the regeneration process, the offline beds are regenerated (heated) at pressure and then cooled over the course of a drying cycle that lasts approximately 12 hours. Membrane D retentate (CO_2-depleated) gas is used as the regeneration gas. The regeneration gas is then heated in an electric heater and flows up through the dehydration beds. The regeneration gas slowly heats the bed to evaporate the water adsorbed to the media. The moisture-laden regeneration gas then exits the top of the bed and is routed to a new dehydration vent stack.

6.6 CO_2 LIQUIFICATION AND PURIFICATION

The 2 x 50% CO_2 Purification Unit (CPU) trains use refrigeration and distillation to meet CO_2 end-use specifications. The CPU design will be based on the concept that the product CO_2 should meet recommended limits for use in Enhanced Oil Recovery (EOR) provided by the U.S. DOE National Energy Technology Laboratory (NETL) outlined in Appendix F.

6.7 CO2 BOOSTER AND PRODUCT PUMPS

CO_2 booster pumps on each CPU train, in a 2 x 100% configuration for a total of four (4) pumps, draw liquid CO_2 from the bottom of the train distillation column. All four (4) pumps combine into a shared header that feeds the CO_2 Product Pumps that are arranged in a 3 x 50% configuration. The product pumps increase the pressure of the CO_2 product stream from the booster pumps in order to meet specifications for CO_2 pipeline pressure. The booster pump is used to increase the pressure by approximately 30 psi (2.1 bar) to get the CO_2 above its bubble point before feeding it to the main CO_2 product pumps. This avoids cavitation in the main pumps. Before joining the CO_2 pipeline, the product passes through two heaters in series, which help offload the refrigeration system.

6.8 MEMBRANE C & D

Membrane C and D skids each consist of traditional MTR spiral cylinder membranes and are used to treat the overhead stream from the CPU distillation column, with the CO_2-rich Membrane C permeate recycled back to the an intermediate point in the Membrane B permeate multi-stage centrifugal compressor. The Membrane C retentate is sent to Membrane D for further recovery. Membrane D permeate is recycled back to the inlet of the Membrane A compression heat exchanger and the retentate

is used for the dehydration bed regeneration process. During times of the regeneration cycle in which no heated gas flows are needed, the Membrane D retentate will be sent directly to the dehydration vent stack.

6.9 REFRIGERATION SYSTEM

The propylene refrigeration package provides the cooling duty required to cool and condense the CO_2 at -31°F (-35°C) in the CPU. Subcooling of refrigerant is also utilized to decrease the refrigeration system compressor power requirement. The refrigeration package serves the parallel CPU trains, with 3 refrigeration compressors, 3 condensers, and 1 high pressure refrigerant receiver shared as common for both CPU trains.

Each CPU train has the following major pieces of refrigeration equipment:

1. Dehydration Feed Chiller
2. Dehydration Superheater
3. CO_2 Condenser
4. CO_2 Aux Reboiler
5. CO_2 Product Heaters
6. Column Overhead Vent Preheater
7. Column Overhead Vent Heater

6.10 CIRCULATING AND COOLING SYSTEMS

Circulating and cooling systems consist of heat exchangers, conventional evaporative cooling tower systems, and wet surface air coolers. A hybrid approach will be required due to water supply and disposal limitations at the site.

Two (2) wet surface air coolers (WSAC) will be used to cool each direct contact cooler (DCC) for a total of four (4) WSACs. Wet surface air coolers cool process fluid in a closed tube system. During normal operation during the summer months the tubes route through the WSAC dry cooling section then through the wet cooling section before returning to the process. The wet cooling section resembles a conventional cooling tower as water from the WSAC basin is sprayed over the tubes. A central fan draws air over the tubes with the spray water and is forced back up through the dry cooling section. This redirect removes most of the spray water in the wet cooling section making the normal operation of the WSAC conserve water. During the winter months process water will be redirected

away from the dry cooling section and only pass through the wet cooling section. Running the process only through the wet cooling will assist with water evaporation in the winter months when there is a water surplus. Wet surface air coolers typically have higher capital cost than other cooling systems, but they can be more tolerant of water supply quality and provide a lower difference between the wet bulb temperature and the final temperature of the cooled stream than conventional cooling towers.

The conventional cooling tower will be an evaporative, counter flow, multi-cell, mechanical draft design. Closed cooling water, provided by the cooling tower, will be supplied to the process coolers and refrigeration condensers. The cooling tower will consist of 10-cells and be arranged in a 2 x 5 configuration. Closed cooling water from the cooling tower will be supplied at an average temperature of 72.2°F (22.3°C), hot water returning from the coolers will return at an average temperature of 97.2°F (36.2°C). The cooling tower will use a wet bulb design temperature of 63.8°F (17.6°C). This includes a 2°F increase to the site wet bulb temperature to account for airflow recirculation. Due to wastewater treatment / disposal systems at the site, evaporation of water produced in the capture process in wet (evaporative) cooling systems will need to be considered.

7. GENERAL SYSTEM DESIGN BASIS

7.1 PLANNED OPERATION PHILOSOPHY

The full scale carbon capture plant will be in operation for the life of the Dry Fork Station Unit 1 power plant. Control system automation will be implemented to the greatest extent possible to allow one auxiliary Operator to monitor and operate the CO_2 plant from the DFS Unit 1 Main Control Room (MCR) during normal working shifts. Protections will be put in place within the system design to allow the plant to safely shutdown in the event of major equipment failure, unsafe process transients or conditions, or a loss of flue gas feed from the station. Remote engineering/operator workstations will be furnished in the major process building DCS rooms of the new CO2 plant to assist in start-up, commissioning, and maintenance activities; these workstations will not be permanently occupied. Detailed operating procedures, maintenance procedures, and staffing plans will be developed in Phase 3 of this project.

7.1.1 Direct Contact Cooler

As noted in section 6.2, the DCC will cool and reduce the SO_2 content of the flue gas supply prior to reaching the flue gas booster fan. Circulation water is cooled prior to returning to each DCC using a set of WSACs. The flowrate in each circulation loop is set by the associated DCC pump curve and will generally be operated at the design point of the pump to maximize cooling in each DCC. If necessary, the operator can reduce this flowrate or liquid level in each DCC by discharging to the associated WSAC basin(s) or cooling tower basin.

A caustic solution (NaOH + H2O) is added to each SO_2 polishing loop to remove SO_2 in the DCC. Caustic addition is adjusted to maintain pH within a set range.

7.1.2 Flue Gas Booster Fan

Each Flue Gas Booster Fan is equipped with a variable frequency drive (VFD). The VFD will automatically adjust the speed of the fan motor to create the necessary pressure rise to overcome the ducting to and from Membrane A and the membrane itself. This approach will allow the fan to respond to potential upsets or changes in the amount of flue gas that is being supplied to the plant.

7.1.3 Membrane A Permeate Fans

The Membrane A permeate fans are equipped with VFD's. The VFD's will automatically adjust the speed of the motors to maintain suction pressure of the fans. The suction pressure at the inlet to the first fan also sets the vacuum pressure of the permeate stream at the exit of Membrane A, which is a critical operating parameter that directly affects Membrane A performance. Controls related to the cooling water exchangers and knockout vessels are described later in this section.

7.1.4 Membrane A Permeate Compressors

The Membrane A permeate compressors are equipped with inlet guide vanes at each stage for capacity control. The inlet guide vanes will be adjusted by the compressor PLC to load or unload the compressors in response to changes in the suction pressure and/or flow. The compressors will also include a recycle loop to maintain sufficient suction flow to prevent surge in the machine. The compressor PLC will control the surge recycle valve position. A VFD will be used to reduce inrush current when starting the compressor motor.

7.1.5 Membrane B Permeate Fans

The Membrane B permeate fans are equipped with VFD's. The VFD's will automatically adjust the speed of the motors to maintain suction pressure on the fans. Similar to the Membrane A fans, the suction pressure to the first fan also sets the vacuum pressure of the permeate stream at the exit of Membrane B, which is a critical operating parameter that directly affects Membrane B performance.

7.1.6 Membrane B Compressor

The Membrane B compressor will be equipped with inlet guide vanes at each stage for capacity control. The inlet guide vanes will be adjusted by the compressor PLC to unload or load the compressor based on changes in the suction pressure and/or flow. The compressor will also include a recycle loop to maintain sufficient suction flow to prevent surge in the machine. The compressor PLC will control the surge recycle valve position. A VFD will be used to reduce inrush current when starting the compressor motor.

7.1.7 Dehydration Unit

The dehydration or "dehy" unit will be automated to switch adsorption beds between gas drying mode and regeneration mode. No operator intervention is required. The timing will be fixed in the

programming based on the design of the mole sieve beds. At the fixed time, the automated switching valves will move to the correct position to line up the saturated bed for regeneration and the regenerated bed for gas drying. The regeneration heater will also be turned on and off at the appropriate times by the control system in order to maintain a temperature set point for the Membrane D retentate used for bed regeneration.

7.1.8 CO_2 Purification Unit (CPU) and Refrigeration

The refrigerant compressors are equipped with a slide valve for capacity control. The slide valve automatically adjusts to load and unload the compressor as needed to maintain a given suction pressure on the compressor. A VFD will be used to reduce inrush current when starting the compressor motor. Controlling the suction pressure at the compressor in turn sets the pressure at which the refrigerant boils in the upstream CO_2 condensers. Setting the pressure at which the refrigerant boils fixes the temperature in the CO_2 condenser based on the thermodynamic properties of the refrigerant. Therefore, selection of the suction pressure set point on the refrigerant compressor sets the temperature of the refrigerant in the CO_2 condenser, which indirectly sets the CO_2 temperature exiting the CO_2 condenser. Liquid refrigerant is fed to the CO_2 condenser on level control.

Pressure in the CPU distillation tower is controlled by a pressure control valve on the vapor outlet at the top of the tower. Level in the bottom of the tower is controlled by a level controller, which adjusts the speed of the CO_2 product pump via VFD. The boil-up in the tower is based on the heat input to the reboiler and the auxiliary reboiler. The reboiler receives heat input from the CO_2 exit stream from the dehy unit before this CO_2 gas stream flows to the CO_2 condenser. The auxiliary reboiler receives heat input from liquid refrigerant from the refrigerant surge tank. The temperature in the tower is controlled by adjusting the amount of refrigerant that flows through the auxiliary reboilers. This is accomplished using a bypass line between the aux reboiler and reboiler.

7.1.9 Closed Cooling Water Heat Exchangers

Each water cooled heat exchanger is equipped with a manual flow adjustment valve on the water discharge from the exchanger. The operator will use these valves to hydraulically balance flow to the various water cooled exchangers. Each valve will be equipped with a manual lock so that the valve position can be set in place when the required flow is determined. The supply temperature of

the closed cooling water will also be automatically controlled at the cooling tower using a bypass to the basin if less cooling tower heat rejection is needed. This is often referred to as a tempering loop.

7.1.10 Knockout Vessels

Each knockout vessel is equipped with a mechanical drain system that automatically drains liquid from the vessel. Knockout vessels under vacuum are equipped with a vacuum condensate return system and vessels above atmospheric pressure are equipped with a liquid drain trap. Each knockout vessel is also equipped with a high level switch which will shut down downstream equipment if the mechanical drain system fails and the liquid level gets too high in the knockout vessel.

7.1.11 Plant Monitoring and Control

Supervisory control and monitoring of the systems and equipment shall be performed using the an expansion the existing Emerson Ovation DCS at DFS. Operator interface of the systems and equipment shall be performed using (a) Human Machine Interface(s) (HMIs) located in the existing DFS Unit 1 MCR and CO_2 plant DCS rooms. Packaged equipment/system skids with PLCs or local controllers will be controlled from the local HMIs with supervisory monitoring and control from the DCS.

7.2 EQUIPMENT SPARING AND REDUNDANCY PHILOSOPHY

Equipment sparing is intended to be minimized in order to minimize capital costs. Regarding mechanical equipment, pumps will be the exception to this philosophy given their relative low cost and all have a backup with either 2 x 100% or 3 x 50% arrangements. The compressed air system will also be designed for a 2 x 100% arrangement (two compressors, two dryers) since compressed air is a critical system for supporting of process instrumentation.

The auxiliary power system will implement redundancy in a variety of ways to minimize the risk of any single point equipment failure disrupting operation. The carbon capture auxiliary power system will be sourced by two (2) three-winding 230-13.8-13.8 kV transformers. Both transformers will be sized such that they can independently support the power demand of the carbon capture facility. The main electrical equipment room will contain the four (4) 13.8 kV buses that source the entirety of the auxiliary power system. Each of the 13.8kV buses will be stand alone, with no tiebreakers

between each other. Each bus will have two (2) incoming breakers, one normally connected to one of the substation transformers, and the other connected to the other substation transformer as a reserve feed. The switchgear at the 4.16 kV and 480 V levels will be main-tie-main configuration. This configuration allows for two normally separate buses to be tied together if one of the transformers feeding one of the mains is taken out of service. With this distribution architecture, the loss of any one transformer will not disrupt operation. The switchgear lineups themselves will each be outfitted with a minimum of one (1) spare breaker for future use. The MVA rating of the transformers and bus current ratings of the switchgear will be selected such that there is a minimum of 20% spare capacity to allow for the addition of future loads.

Spares for instrumentation will not be provided. The DCS expansion hardware will include the following spare capacities; additional inventory spares for major components will be considered during Phase 3:

a. 25% functional control and communication capability.
b. 25% database points available for use in each processor.
c. 25% data highway capability for additional points or tags.
d. 25% database memory in each processor.
e. 50% capability for additional graphic screens.
f. 20% component space in control and I/O cabinets.
g. 20% active I/O (by type) in each control cabinet wired out from the I/O cards.
h. 10% spare I/O module slots in each I/O cabinet.
i. 10% spare termination units and terminal blocks distributed on a per module basis.

Control system redundancy will include the following redundant equipment or hardware:

a. DCS control processors.
b. Power supplies.
c. Network switches.
d. Network cabling (to the greatest extent possible).

8. MECHANICAL SYSTEMS

This subsection discusses the mechanical aspects of the carbon capture full scale installation.

8.1 PIPING

8.1.1 Piping shall be designed to meet code ASME B31.1 (Non-boiler external piping).

8.1.2 Process piping will be fiberglass reinforced plastic (FRP) except where service conditions, fluid characteristics or other considerations dictate use of metallic or alternative non-metallic pipe materials. A common exception to the use of FRP will be where process conditions exceed 180°F. 304 stainless steel (or other corrosion resistant piping) will be required for wet CO2 service, particularly as the pressure and temperature of the CO2-rich stream increases prior to dehydration.

8.1.3 Utility piping, in general, will be carbon steel manufactured in accordance with ASTM A106, Grade B. Piping wall thickness shall be selected in accordance with applicable codes and standards. Where schedule piping is not available in sufficient size or wall thickness for the application, special wall seamless or plate pipe may be used as approved by the Owner.

8.1.4 Other pipe materials shall be used for special services such as corrosive liquids, refrigerant, and instrument air piping one inch and larger in diameter.

8.1.5 Tubing shall be used for sample lines, dead end instrument sensing lines, or instrument distribution lines downstream of air supply root valve and pneumatic signal lines.

8.1.6 Process piping will be color coded using ANSI standard symbols and colors. Paint, insulation jackets, or decals may be used.

8.1.7 Metallic piping joints shall be welded, except where threads or flanges are required for maintenance or connection details (e.g., butterfly valve, equipment flange, etc.) or as noted below.

a. Carbon steel and alloy piping 2½ inches and larger shall be butt-welded.

b. Socket welded connections may be used for piping 2 inches and under in diameter.

c. Avoid the use of threaded connections on stainless steel piping due to issues with galling of the threads.

8.1.8 Piping 2 inches and smaller in diameter shall not be less than schedule 80 thickness.

8.1.9 Process piping less than ¾ inch diameter typically is not used.

The following maximum velocities shall be used for sizing water piping systems if other criteria, such as pressure drop, equipment standards, or matching connection size does not govern:

a. General service water piping velocities shall be limited to 10 fps.

b. Piping upstream of a pump shall be at least as large as the pump suction connection. Velocity should be limited to 5 fps if there is a suction lift.

c. Piping carrying water with high-suspended solids content should not have velocities lower than 4 fps, exceed 8 fps or Reynolds number less than 4,000.

d. A corrosion/erosion allowance of 0.0625 inch shall be added to the calculated pipe wall thickness for carbon steel piping systems.

8.1.10 The following maximum velocities shall be used for sizing flue gas piping / ductwork if other criteria, such as pressure drop, equipment standards, or matching connection size does not govern:

a. Process piping / duct work velocities shall be limited to 4,500 fpm.

b. Process gas piping / duct work velocities at vacuum conditions shall be sized based on pressure. The allowable velocity based on pressure can be determined using the Pressure vs Velocity table found in Process Vacuum System Design and Operation, McGraw-Hill Book Co., Inc., 1986.

8.1.11 The following maximum velocities shall be used for sizing propylene refrigerant piping if other criteria, such as pressure drop, equipment standards, or matching connection size does not govern:

a. Propylene (liquid) piping velocities shall be limited to 10 fps.

b. Propylene (gaseous) piping velocities shall be limited to 6000 fpm.

8.2 INSULATION

8.2.1 Provide heat conservation insulation on piping and equipment with surface temperatures exceeding 140°F during normal operation.

8.2.2 Provide personnel protection insulation in accessible areas for piping and equipment with surface temperatures exceeding 140°F during transient conditions or when heat conservation is not important. Insulation shall be calcium silicate or mineral wool type.

8.2.3 Provide anti-sweat insulation on piping and equipment with operating temperatures below 50°F. Insulation shall be mineral fiber, fiberglass or elastomeric type (closed cell or foam glass).

8.2.4 Provide electric heat trace and heat retention insulation on equipment and piping that could be subject to freezing or process interruption upon exposure to freezing conditions.

8.2.5 Provide calcium silicate, mineral wool, mineral fiber, and fiberglass insulation with a vapor barrier and lagging.

8.2.6 Design insulation system to ensure insulation or lagging surface does not exceed 140°F.

8.3 VALVES

8.3.1 Gate valves are normally used for isolation service in either the full open or full closed positions.

8.3.2 Globe valves may be used in either isolation or throttling service.

8.3.3 Ball valves are preferred and should be use on process piping 3 inches and under to the fullest extent practical for manual isolation. Ball valves up to 4 inches in size should be used for low pressure gas applications (air, nitrogen, etc.). Other valve types may be used as required based on arrangement issues, operational impact, etc.

8.3.4 Check valves are used to automatically prevent flow reversal. Since the sealing force in a check valve is obtained solely as a result of system pressure differential, obtaining a tight seal at low differential pressures may be difficult.

8.3.5 Check valves located on pump discharges shall be placed between the pump and the system block valve so the check valve may be serviced.

8.3.6 Butterfly valves may be used for isolation or throttling in lower pressure and temperature systems such as service and cooling water systems.

8.3.7 Valves used in liquid CO_2 service must have drilled or vented internals to prevent trapped liquid from actuating the valve.

8.4 VALVE OPERATORS

8.4.1 Handwheels or lever actuators may be used for smaller valves that do not require excessive force to open.

8.4.2 Gear operators shall be furnished for manually actuated valves to obtain mechanical advantage when opening forces with handwheels or levers are excessive and for manually actuated valves 8-in. size and larger. Handwheel rim pull for manually operated valves shall generally not exceed 50 lb at the maximum operating torque requirement. This limit can be exceeded where the valve supplier recommends a higher force limit for valves in which the seating / unseating torque exceeds the running torque. In such cases, the handwheel rim pull shall not exceed 100 lbs.

8.4.3 Portable air motors may be used to operate valves for infrequently repositioned valves where gear operators are not practical.

8.4.4 Electric motors may be used for automatic operation of valves. Electric motors should not be used in applications where failure in last position is not acceptable (for example TWIP drain lines).

8.4.5 Pneumatic actuators may be applied where fast closing times or modulating service is required (e.g., control valves). Pneumatic valves may be specified to fail in place, fail opened, or fail closed, as required by the system.

8.4.6 Remote indication of valve position may be required. Limit switches or geared position switches may be used for valves that are normally fully opened, fully closed or opened to a predetermined intermediate position. Valves requiring full range position indication shall be provided with position transmitters.

8.5 PUMPS

8.5.1 Material selection: The following guidelines shall be used for materials selections. Alternate materials may be used based on detailed evaluations:

a. Water systems shall utilize cast iron or carbon steel casings with bronze trim and impellers.

b. CO2 product pumps shall use duplex stainless steel impellers/diffuser with 4140 steel casing and a UHS Inconel shaft.

c. Caustic systems shall use 316 stainless steel materials

8.5.2 Net Positive Suction Head (NPSH) available to pumps should be at least 25% greater than the manufacturer's NPSH requirements, based on 3% head loss. Suction specific speed rating of the impeller should not exceed 9,500.

8.5.3 A minimum flow of 25% of the pump's best efficiency flow should be used to protect pumps from operation with insufficient flow, unless the manufacturer requires a higher flow.

8.5.4 Pump Selection

a. Horizontal, centrifugal, direct motor drive pumps shall be used most for general pump services.

b. Positive displacement pumps shall be used for chemical injection. If metering is required precise flow control is will be provided. Either piston type or rotary type pumps may be used.

8.6 HEAT EXCHANGER SIZING AND SELECTION

8.6.1 Process heat exchangers may utilize shell and tube or plate and frame construction.

8.6.2 Process shell and tube heat exchangers shall conform to Tubular Exchanger Manufacturer Association requirements. Miscellaneous shell and tube heat exchangers shall be purchased with 10% excess tubes or surface area compared to design requirements and shall be designed with fouling factor of 15%.

8.7 FLUE GAS BOOSTER FAN

8.7.1 Design static pressure shall be 115% of the static pressure required to send the flue gas through the full Scale CO2 capture plant at boiler MCR design pressure.

8.7.2 Fan speed shall not exceed 900 rpm.

8.7.3 Design temperature for lubrication shall be 35°F to 110°F.

8.7.4 Fans shall be variable speed airfoil bladed centrifugal fans with VFDs.

8.8 CLOSED COOLING WATER SYSTEM

The closed cooling water system provides a means of heat rejection, by means of a water-cooled heat exchanger, which shall be designed to eliminate heat from pumps, fan(s), and various other process heat exchangers. This system shall include water cooled heat exchangers, cooling towers, pumps, screens, valves, piping, instruments, and controls as follows:

8.8.1 A cooling tower consists of a multi-celled induced draft, counterflow cooling tower.

8.8.2 The closed cooling water system receives makeup water from the carbon capture well water system, wastewater treatment system, process condensate, and DCC blowdown.

8.8.3 Chemical treatment shall be provided, if required, to protect the cooling tower and heat exchangers that use closed cooling water.

8.8.4 Any blowdown from the circulating water system shall be discharged to the Equalization Tank before continuing to the wastewater treatment system.

8.8.5 Closed cooling water cooled by the cooling tower is sprayed over composite fill and falls by gravity into the cold water collection basin located at the bottom of the cooling tower. This water, in turn, flows by gravity to the pump suction, which includes trash screen on the basin outlet nozzles to protect the pumps and heat exchange equipment from major debris.

8.8.6 One of 2 x 100% closed cooling water pumps provides water to plant heat exchangers and refrigerant condensers to remove heat.

8.8.7 The cooling tower shall include a bypass system shall be provided to direct a portion of the flow directly to the basin during freezing conditions and low heat load scenarios.

8.8.8 The circulating water system shall provide controlled high quality cooling water at sufficient pressure and temperature required for the following plant equipment:

a. Equipment Oil Coolers
b. Permeate Compression Interstage Coolers
c. Permeate After Coolers
d. Refrigerant Condensers

8.9 WASTEWATER TREATMENT SYSTEM

The wastewater treatment system monitors and treats cooling tower and WSAC blowdown. The system shall include piping, valves, pumps and controls as follows:

8.9.1 Process wastewater treatment design flow will be based on the maximum flowrate generated from the full scale plant, plus an additional 10% margin.

8.9.2 Process Wastewater Treatment Piping Design

a. The design temperature shall be based on the maximum operating temperature of the system plus 10% margin rounded off to the next higher 5°F.

b. The design flow will be based on the maximum expected flow in each piping segment plus an additional 10% margin rounded up to the next 5 gpm.

c. The velocity in the process wastewater treatment piping shall not exceed 10 fps.

d. All piping shall have drains at low points and vents at high points.

e. Piping material shall be carbon steel for above ground piping.

8.10 WELL WATER SYSTEM

The well water system provides makeup water to the CO_2 capture facility including the water treatment system, WSACs, and cooling tower. The system shall include pumps, piping, valves, instruments and controls as follows:

8.10.1 The system shall consist of one (1) carbon capture well water storage tank, two (2) x 100 % well water forwarding pumps, and two (2) x 100% reservoir return pumps.

8.10.2 During winter conditions, when excess water is produced by the CO_2 plant, water shall be transferred from the carbon capture well water storage tank to the CO_2 plant reservoir.

8.10.3 During summer conditions water may be returned to the carbon capture well water storage tank from the reservoir via the two (2) x 100% reservoir forwarding pumps to supplement the well water supply to the CO_2 capture facility.

8.10.4 Well water design flow will be based on the maximum flowrate generated from the full scale plant, plus an additional 10% margin.

8.10.5 Well Water System Piping Design

a. The design temperature shall be based on the maximum operating temperature of the system plus 10% margin rounded off to the next higher 5°F.

b. The design flow will be based on the maximum expected flow in each piping segment plus an additional 10% margin rounded up to the next 5 gpm.

c. The velocity in the well water piping shall not exceed 10 fps.

d. All piping shall have drains at low points and vents at high points.

e. Piping material shall be carbon steel for above and below ground piping.

8.11 SERVICE WATER SYSTEM

The Service Water system will provide washdown water to the various buildings at the CO_2 capture facility. The service water will consist of one (1) carbon capture service water tank and two (2) x 100% carbon capture service water pumps as well as associate piping, valves, and instruments and controls as follows:

8.11.1 Service Water design flow will be based on the maximum flowrate generated from the full scale plant, plus an additional 10% margin.

8.11.2 Service Water Piping Design

a. The design temperature shall be based on the maximum operating temperature of the system plus 10% margin rounded off to the next higher 5°F.

b. The design flow will be based on the maximum expected flow in each piping segment plus an additional 10% margin rounded up to the next 5 gpm.

c. The velocity in the service water piping shall not exceed 10 fps.

d. All piping shall have drains at low points and vents at high points.

e. Piping material shall be carbon steel for above ground and below ground piping.

8.11.3 Service water taps shall be located at no more than 100 feet apart throughout the facility or as specified by the owner and shall be located on each operating floor/platform elevation.

8.12 COMPRESSED AIR SYSTEM

The compressed air system provides service and instrument-grade compressed air to the carbon capture plant. This system includes compressors, filters, after-coolers, receivers, dryers, piping, valves, instruments, and controls as follows:

8.12.1 A compressor station with 2 x 100% compressors.

a. Air will be provided at a minimum pressure of 125 psig.

b. Compressors shall only be of the rotary or centrifugal type.

c. The compressor station shall be sized to meet 125% of the plant's design requirements. This includes a 10% leakage allowance and a 15% expansion allowance.

d. The compressors will serve both the service air and instrument air systems.

8.12.2 Service air shall be oil-free and maintain an atmospheric dew point of -40°F using regenerative desiccant air dryers.

8.12.3 Instrument air dryers shall have the capacity to dry 125% of the line design flow rate to an atmospheric dew point of -40°F for instrument air inside and outside the carbon capture plant. The dryers will use regenerative desiccant air dryers. The air shall be adjusted to an atmospheric dew point shall be adjusted to an atmospheric dew point of -55°F when the outside air temperature drops below -30°F.

8.12.4 Service air taps shall be located at no more than 100 feet apart throughout the facility or as specified by the owner and shall be located on each operating floor/platform elevation. Air taps shall be on the top of the header.

8.12.5 All instrument air piping components, including valves and fittings, shall be corrosion-resistant to water, either stainless steel or copper based on cost. The service air piping system shall use best engineering practice to limit corrosion if carbon steel material is used. Underground service air and instrument air piping shall be stainless steel.

8.13 WASTEWATER FIXATION SYSTEM

The wastewater fixation system shall provide a means of disposing of the CO_2 capture wastewater streams from the SO_2 blowdown and reverse osmosis (RO) reject from the wastewater treatment system. This system includes a wastewater storage tank, lime storage silo, pumps, piping, valves, instruments, and controls as follows:

8.13.1 Wastewater streams will be sent to a wastewater forwarding tank before being injected into the existing dry FGD byproduct storage silo pugmills. The wastewater forwarding tank shall be designed for 7 days of storage based on the summer design case.

8.13.2 The lime storage silo will feed lime to the existing dry FGD byproduct storage silo pugmill where wastewater forwarded by the wastewater forwarding pumps will be added. The existing pugmill shall be modified to accept the new lime and wastewater streams. The lime storage silo shall be designed for 14 days of storage based on annual average operating conditions.

9. ELECTRICAL

9.1 SWITCHYARD EXPANSION & SUBSTATION ADDITION

A new auxiliary power system, independent of the existing DFS auxiliary power system, shall be designed to service the full-scale carbon capture plant. The existing DFS 230kV switchyard will be outfitted with new circuit breakers to protect a new transmission line serving the carbon capture auxiliary power system. The DFS switchyard currently includes space for the addition of a new circuit breaker bay, and a new takeoff structure, so no modifications to the overall 230kV switchyard footprint are required.

The new transmission line will run from the 230kV switchyard to a new, dedicated carbon capture plant substation. Refer to Appendix C for the location and general arrangement of the substation. This substation will include 2x100%, three-winding transformers that will step-down from 230kV to 13.8kV at each secondary winding.

9.2 AUXILIARY POWER SYSTEM FOR THE FULL-SCALE CARBON CAPTURE SYSTEM

The auxiliary power system and its constituent electrical components will be designed to match the original Dry Fork Station design criteria to the greatest extent possible. See Appendix H for an overview of the major electrical equipment requirements.

The auxiliary power system will utilize voltage levels of 13.8 kV, 6.9 kV, 4.16 kV, 480 Vac, and 120 Vac. Motor voltages will correspond to the following breakpoints:

- For Non-VFD applications, system voltage shall be:
  - 480 V for motors ≥ 1/2 hp through 250 hp
  - 4,160 V for motors > 250 hp and < 3,000 hp
  - 13.8 kV for motors ≥ 3,000 hp
  - Motors shall be rated 460 Vac, 4000 Vac and 13,200 Vac, 3PH, 60Hz respectively.
- For VFD applications, system voltage shall be:
  - 480 V for motors ≥ 1/2 hp through 250 hp
  - 4,160 V for motors > 250 hp and < 4,500 hp
  - 6.9 kV for motors ≥ 4500 hp thru 9,000 hp. Note: VFD to be sourced from 13.8 kV bus and provided with 13.8 KV-6.9 kV input transformer.

- 13.8 KV for motors > 9,000 hp

There will be three (3) electrical equipment rooms located throughout the carbon capture facility, one located on the second floor of the main process building, one located on the second floor of the CPU building, and one located on the second floor of the water treatment building. The main electrical equipment room will contain the four (4) 13.8 kV buses that source the entirety of the auxiliary power system. Each of the 13.8kV will be stand alone, with no tiebreakers between each other. Each bus will have two (2) incoming breakers, one normally connected to one of the substation transformers, and the other connected to the other substation transformer as a reserve feed. The switchgear at the 4.16 kV and 480 V levels will be main-tie-main configuration.

Both the main electrical room and the water treatment building electrical room will contain battery rooms housing 125 Vdc, valve-regulated lead acid (VRLA) type batteries to provide control power to the switchgear along with other DC users. There will be two (2) uninterruptible power supplies (UPS) in the main electrical room, and one (1) UPS in the water treatment building to service essential 120 Vac loads. All the electrical equipment rooms will be environmentally controlled via dedicated, redundant HVAC systems. The main electrical equipment room will house over thirty (30) medium voltages VFDs. In lieu of all these drives directly rejecting heat into the room, these drives will connect to dedicate ductwork that exhausts the heat outside of the electrical equipment room. All three (3) of the electrical equipment rooms will include separate, dedicated DCS I/O rooms within their footprint. These DCS rooms will have their own separate, redundant HVAC systems.

An emergency diesel generator will be provided with a terminal voltage of 13.8 kV. This generator will tie-into the main electrical room 13.8 kV switchgear and service essential downstream 4.16 kV and 480 V loads via proper circuit breaker coordination.

10. INSTRUMENTATION AND CONTROLS

10.1 INSTRUMENTATION REQUIREMENTS

10.1.1 Redundancy: Measurement redundancy is implemented on an as-needed basis with considerations for how critical the service is or if more than one measurement point is required to achieve the desired accuracy.

10.1.2 Ambient Conditions: All field mounted instruments and control devices shall be designed to withstand site ambient outdoor temperature, indoor plant temperature extremes, and site relative humidity throughout the temperature range without loss of accuracy.

10.1.3 Transmitters: Transmitters shall be used in favor of process switches whenever possible. Transmitters shall have solid state electronics, be 2-wire design, and have NEMA 4 housing, or NEMA 4X if located in a corrosive environment. Transmitters shall have local LCD indication and have zero and span adjustments. Wetted materials shall be selected based on the process fluid to preclude corrosion and scaling. All transmitters shall be HART capable with 4-20 mA signal range.

10.1.4 Process Switches: When transmitters are not practical to use, process switches shall provide safe and reliable electrical contacts for alarms, interlocks, and/or indicating purposes. Setpoints shall be field adjustable and have a minimum of one double pole-double throw contact.

10.1.5 Local Indicators: Ranges on local indicators shall be selected such that the operating point falls between 1/3 and 2/3 of the full scale range. Dial faces shall be a minimum of 4 ½" in diameter.

10.1.6 Instrument Tubing and Piping: Instrument sensing line, valves, tubing, fittings, etc. shall conform to the requirements of ANSI/ASME-B31.1, "Power Piping". All remote mounted instrument installations shall include a shutoff and drain valve for the instrument. Pressure transmitters shall include a 2-valve manifold. Differential pressure transmitters shall include a 5-valve manifold. Installation of instrument primary piping and tubing shall be in accordance with the following criteria:

a. Primary piping and tubing length shall be kept to a maximum of 50 feet in order to minimize response time.

b. Horizontal runs shall have a slope of not less than one (1) inch per foot and must be adequately supported to maintain a constant slope.

c. Compression type tubing joints shall be used to a temperature of up to 800 degF. Tubing using compression type joints shall be continuously supported using tubing tray.

10.1.7 Instrument Enclosures, Racks, and Pedestals: Remote mounted instruments located indoors shall be mounted on instrument racks or pedestals. Instruments located outdoors or in corrosive environments shall be mounted in NEMA 4X enclosures. If the process is prone to freezing, then the enclosure shall be heated.

10.1.8 Control Drives and Actuators: Control drive units shall be electric type and provided with a local position indicator and manual handwheel. Control drive units for modulating services shall be able to accept a 4-20 mA demand signal and return a position feedback signal via the superimposed HART data on the demand signal. Control drives used for open/close or on/off services shall accept separate digital signals for open and close commands and provide dry contacts for open and close end of travel positions.

10.2 CONTROL SYSTEM REQUIREMENTS

10.2.1 Overall control and monitoring of the systems and equipment shall be performed using an expansion to the existing Dry Fork Station distributed control system (DCS). The DCS is an Emerson Ovation DCS currently running Ovation Version 3.5.1 with plans to upgrade to the current version of Ovation in 2022.

10.2.2 Operator interface to the system and equipment shall be performed using existing HMIs located in the station's Unit 1 MCR. Separate auxiliary DCS rooms, equipped with HMI's and engineering workstations, will be provided throughout the new CO_2 capture plant DCS Room for use during commissioning and start-up, troubleshooting, and maintenance activities.

10.2.3 Packaged equipment or system skids furnished with their own PLCs or local controllers shall be wired to the DCS for supervisory control. The DCS shall communicate with these devices via Modbus TCP. Hardwire signals will be used for critical functions such as emergency stop push buttons or commands, compressor or fan inlet guide vane positions, or protective relay failure alarms.

10.2.4 Medium voltage motors, VFDs, and breakers will interface to the DCS via Modbus TCP. Low voltage breakers and switchgear fed motors will also interface to the DCS via Modbus TCP. Low

voltage motor control centers will interface to the DCS via Profibus.

10.2.5 Instruments, modulating control valves, and solenoid operated valves will interface to the DCS via hardwired analog and digital signals.

10.2.6 The hardwired signal level requirements for each type of DCS input/out signal are defined below.

a. Analog Inputs: 4-20mA (@ 24 VDC)
b. Analog Outputs: 4-20mA (@ 24 VDC)
c. Digital Inputs: 24 VDC (Ext), 48VDC (Int), 120VAC (Ext), 125VDC (Ext)
d. Digital Outputs / Relay Outputs: 24 VDC (Ext), 48VDC (Ext), 120VAC (Ext), 125VDC (Ext)
e. Thermocouple and RTD: 4-20mA (@ 24 VDC, via transmitter)

Note: Int and Ext refer to internal and external power, respectively, and indicate whether the circuit power (a.k.a. wetting voltage) is introduced within the DCS module/termination assembly or external to the DCS hardware. Additionally, signals such as 120 VAC externally powered DI's and DO's for automated valve circuits may use routed power from within the DCS cabinet to supply the circuit power externally.

10.2.7 Profibus and Modbus will be utilized for control and monitoring of most mechanical or electrical equipment; however, hardwired I/O signals will be used for critical, fast-response signals or wherever digital bus technology is not applicable or cost prohibitive.

10.2.8 Large motor bearing and winding RTD's will be hardwired directly to their protective devices or local PLCs with signals retransmitted to the DCS via a Modbus datalink. All emergency push button signals and fan or compressor inlet guide vane (IGV) position feedback and demand signals will be hardwired to the DCS.

10.2.9 The DCS and I/O interface hardware shall be located in the DCS rooms located within each electrical equipment room. In addition, remote I/O cabinets shall be located near the process equipment and connected to the DCS network via fiber optic cable. The remote I/O cabinets shall be furnished primarily to consolidate vibration monitoring signals to dedicated VMS modules in the DCS racks.

10.2.10 I/O signal marshalling hardware will be furnished with the associated DCS hardware and be mounted in the rear or side panels of the same cabinet or enclosure. External marshalling cabinets are not allowed unless approved otherwise.

10.2.11 Network cabinets equipped with fiber optic patch panels and network switches, as needed, will be furnished in the DCS rooms to connect the new DCS hardware to the existing DCS network and to consolidate datalink traffic before interfacing to the DCS. Network switches will also be furnished within each switchgear lineup to further consolidate the datalink traffic.

10.2.12 Redundant Profibus trunk segments will be furnished integral to each MCC lineup and connected to the DCS via special Profibus modules.

10.2.13 Analyzer cabinets with extractive sampling systems shall be provided for each composition, oxygen, or carbon dioxide process measurement. Multiple sample points of the same measurement type may be routed to each analyzer cabinet with the maximum number of samples per cabinet not to exceed eight samples. Each analyzer shall interface to the DCS via datalink with key measurements and fault signal hardwired to the DCS.

11. STRUCTURAL AND CIVIL

11.1 GENERAL

11.1.1 Calculations and drawings shall use United States Customary System (USCS) units. It is also acceptable to present values in both USCS and International System (SI) units.

11.1.2 Drawings and calculations shall be prepared under the supervision of, and be stamped by, a registered professional engineer (PE) in the structural discipline, licensed in the State of Wyoming.

11.1.3 Materials

1. Structural Steel	
W-Shapes and WT-Shapes	ASTM A992 (Fy=50 ksi)
Channels (C, MC)	ASTM A36
Angles	ASTM A529, Gr. 50
Structural Plates and Bars (connections, gusset plates, girders, baseplates, etc.)	ASTM A572, Gr. 50
Miscellaneous Plates and Bars (guard plate, ladder rails, ladder cages, etc.)	ASTM A36
Threaded Rods (not for anchor bolts/rods)	ASTM A36
HSS Shapes (Rectangular)	ASTM A500, Gr. C
HSS Shapes (Round)	ASTM A500, Gr. C
Pipe for structural use	Use equivalent round HSS (see above)
2. Ductwork	
Wide Flange and WT Stiffeners	ASTM A992
Channel Stiffeners	ASTM A36
Corner Angle & Angle Stiffeners	ASTM A572 Gr. 50
Duct Plate	ASTM A572 Gr. 50 Minimum plate thickness shall be 3/16”
Misc. Plates (Gussets, Turning Vanes, Sole/Base plates, etc.)	ASTM A572 Gr. 50
HSS Shapes (Rectangular)	ASTM A500, Gr. C
HSS Shapes (Round)	ASTM A500, Gr. C
Pipe for structural use	Use equivalent round HSS (see above)

3. Bolts, Nuts, and Washers	
High Strength Bolts	ASTM F3125, Grade A325, Type 1, 7/8" Diameter, Pre-Tensioned
High Strength Bolts, where required	ASTM F3125, Grade A490, Type 1, 1 ¼" Diameter, Pre-Tensioned
Miscellaneous Bolts (handrail)	ASTM F3125, Grade A325, 5/8" Diameter
Nuts	ASTM A563, Grade DH, Heavy Hex
Washers	ASTM F436
Washers, direct tension indicator	ASTM F959, Type 325
4. Pipe Handrail & Posts	ASTM A500, Grade C
5. Floor Grating and Stair Treads	
Steel Grating	W-19-4 (1 1/4 x 3/16) ASTM A36 Galvanized per ASTM A123 Plain (Non-serrated) for indoor; serrated for outdoor
Grating Fasteners	Grating shall be fastened using Grate-Fast Clips, hot-dipped galvanized, as manufactured by Struct-Fast or approved equal.
6. Ladders and Cages (Galvanized)	ASTM A36 Steel meeting requirements of OSHA 1910.27 – Fixed ladders.
7. Safety Gate	To be determined during detailed design
8. Checkered Plate	ASTM A786 fabricated from ASTM A36 material
9. Welding Electrodes	E70XX
10. Filler Material	In accordance with AWS D1.1
11. Drilled-In Anchors	
Adhesive	HILTI HIT-HY 200 or HIT-RE 500 v3 adhesive system with galvanized HIT-Z anchors, galvanized threaded rods, or stainless steel HIT-Z-R anchors or approved equal.
12. Reinforced Concrete	ASTM C94 Minimum Compressive Strength (f'c) 4,500 psi at 28 days
13. Reinforcing Steel	
Reinforcing Bars	ASTM A615 Gr 60 deformed (fy = 60,000 psi)

Welded Wire Fabric	ASTM A1064 Grade 70 (fy = 70,000 psi)
14. Anchor Bolt (Anchor Rod) Assemblies (Hot-Dipped Galvanized)	
Bolts	ASTM F1554 Grade 36, 55 (with supplement S1), or 105 as required.
Nuts	ASTM A563 Grade DH. Grade A shall not be specified.
Washers	ASTM F436 or ASTM A36 for plate washers

11.1.4 All exterior structural steel shall be painted using coating system CS-309 and color shall be Federal Standard 595B #15065 'Accent Blue'. All interior structural steel shall be painted using coating system CS-307 and color shall be Sherwin William 7060 'Attitude Gray'. Ductwork interior surfaces shall be coated using Carboline Plasite 4310, vinyl ester resin with special curing system and inert flake pigment.

a. Guardrails, handrails, and ladders shall be painted safety yellow.

11.2 CIVIL & SITE WORK

11.2.1 Foundations will be minimum 42 inches below final grade for frost protection.

11.2.2 Finished grade is considered to be Elevation 4248ft-0in.

11.2.3 Design normal groundwater table is approximately Elevation 4225ft-0in.

11.2.4 Rainfall (from NOAA Technical Paper 40)

	Return Period					
Duration	2-year	5-year	10-year	25-year	50-year	100-year
24-hours	1.6	2.2	2.6	3.2	3.6	4.0
60-mins	0.8	1.2	1.4	1.7	2	2.2
(1) Data In Inches						

11.3 GEOTECHNICAL

11.3.1 General Description of Soils: The geotechnical criteria is developed based on the findings of the geotechnical investigation performed by CE&MT and presented in drawings DFS-GG-000-0002 to DFS-GG-000-0015, dated February 2007 (geotech report). Soil borings B-24, B-25, and B-27 are nearest to the carbon capture test center foundations. During original power plant construction, cut and fill was performed in this area. In the area of the proposed test center ID fan (near B-25) and to the northwest, up to 10ft of lean clay fill was placed. In the area of the proposed test center transformer (near B-27), up to 12ft of cut was performed. As a result, shallow claystone bedrock (weak, augerable) is likely present in this area.

11.3.2 Groundwater: Groundwater was not encountered in the above-mentioned soil borings during the geotechnical investigation. However, seasonal fluctuations and locally heavy precipitation could change these conditions and should be considered for construction.

11.3.3 Excavation Criteria: All temporary excavations will conform to 29 CFR, Part 1926 (OSHA) Subpart B – Excavations and any existing local code requirements. After excavating to the founding level, the exposed subgrade shall be proof-rolled prior to construction of foundations. Any pockets of dumped rock, coal and debris, or soft areas encountered during excavation must be removed.

11.3.4 Backfill Criteria: On-site materials free of organic matter and debris, consisting of granular and low-plasticity cohesive soils, can be used as both general backfill and structural fill. All fill soils should contain less than 1% organic deleterious materials. Low-plasticity cohesive soils should have a Liquid Limit less than or equal to 45, and Plasticity Index less than or equal to 20. Inclusions of high-plasticity soils should be removed from the fill material prior to placement and compaction. The largest particle size in the general backfill materials should not exceed 3-inches. Fill materials placed within 3-feet of pavement slabs and unheated slabs, or within 2-feet of a foundation system should not contain particles larger than 2-inches in dimension. All proposed fill soils shall be tested and approved prior to construction.

11.3.5 Compaction Criteria: All fill materials shall be placed and compacted in lifts not exceeding 8-inches in loose thickness. The compaction moisture content shall be ±2 percent of the optimum moisture content. The fill material shall be compacted to densities in excess of the values shown below:

Minimum Percent Compaction (ASTM D1557)	**Area Affected**
95%	Under footings, foundations, slabs-on-grade, pavement structures, railroad tracks, and subgrade beneath fills
90%	All other areas

11.3.6 Shallow Foundations: The allowable bearing pressure will be based on future geotechnical calculation.

11.3.7 Concrete Slabs-on-Grade: The in situ soil shall be proof-rolled, and a minimum of 9-inch thick engineered structural fill shall be placed directly beneath the slab or mat. Slabs on grade shall have perimeter beams extended 42” below grade for frost protection. The use of non-frost susceptible materials beneath settlement sensitive slabs to the frost depth should be evaluated as necessary. The soil shall be compacted in accordance with the compaction criteria.

11.3.8 Other Geotechnical Design Parameters

Parameter	**On-Site Clays (In situ)**	**Silty Clay Fill (compacted)**	**Sandy Granular Fill**
Angle of Friction (degree)	22	25	32
K_a	0.45	0.41	0.31
K_p	2.20	2.46	3.25
K_o	0.63	0.58	0.47
CBR	6	10	20
Sliding Friction Coefficient, μ	0.3	0.35	0.4

To check lateral/sliding stability, use the sliding friction resistance from the bottom of the foundation alone and determine if this satisfies the design factor of safety. If not, then add additional resistance from the lateral earth pressure from the lower half of the embedded foundation using Ka and Kp given above.

11.3.9 Dynamic Parameters of Subsoil

Elevation (ft)	**Soil Type**	**Shear Wave Velocity, Vs (ft/s)**	**Total Density(pcf)**	**Poisson's Ratio**
Final Grade to El. 4238	Compacted fill and lean Clay (CL)	700	110	0.25
El. 4238 to El. 4214	Lean Clay (CL)	550	125	0.35
Below El. 4214	Claystone	1600	130	0.16

Dynamic soil parameters were recommended in "Geophysical Reconnaissance for CE&MT at Dry Fork Station Unit 1, Gillette, WY" prepared by Jim O'Donnell (received from CE&MT on 1/29/07), which were based on the results of surface seismic surveys conducted near Boring B-13 for the power block area. At boring B-25 where the test center ID fan is located, its subsurface profile is similar to that of B-13. Minor modifications were made to the dynamic soil parameters recommended by Jim O'Donnell to incorporate the B-25 profile and the revised dynamic soil parameters in the table above are applicable for the test center ID fan.

Site specific dynamic parameters may be determined if new soil borings are required.

11.3.10 Slope Stability: Permanent slopes will be designed to meet the following minimum factors of safety:

a. Up to End of Construction 1.3
b. Long Term Stability 1.5

Permanent slopes in fill should be constructed at a slope no steeper than 2.5 horizontal to 1 vertical. Permanent slopes constructed in site soils require location-specific analysis for long term stability.

11.4 DESIGN LOADS

11.4.1 Load Combinations: Load combinations shall be in accordance with ASCE 7. Structures shall be designed for all applicable dead, live, wind, seismic, equipment, service and thermal loads. Roof framing shall be designed to sustain wind load, roof load, lighting, roof vents, piping and cable tray loads. Where practicable, efforts should be made to optimize the design of steel members by designing to an interaction ratio as close as possible to, but not greater than 1.0.

11.4.2 Dead Loads: Dead load shall be considered as the weight of all material forming a permanent part of the structure and all fixed service equipment. It shall be defined as the total weight of the equipment, structures, insulation, piping, electrical conduit, cable tray, and ductwork. The following weights shall be considered for design:

Description	**Value**	**Unit**
1 1/4” Standard Steel Grating	12	lb/ft^2

Additionally, the following material densities shall be considered for design:

Description	**Value**	**Unit**
Steel	490	lb/ft^3
Plain Concrete	145	lb/ft^3
Reinforced Concrete	150	lb/ft^3

11.4.3 Live Loads: Each floor shall be designed to sustain the live load listed below in addition to the equipment loads, piping loads, and electrical loads it supports. Live load reduction shall not be permitted except as noted below.

Plant Area	Minimum Uniform LL in PSF to Design	
	Beams and Slabs	Columns and Footings(1)
Floors, Ground (UNO)	350 psf	Not Applicable
Floors, Steel Grating or Checkered Plate	100 psf	100 psf
Handrail, Process Areas	200 lbs applied in any direction	Not Applicable
Lay Down Areas	Equipment Weight	Equipment Weight
Roofs – Concrete	125 psf	100 psf
Roofs – Other	20 psf	20 psf

Note - (1) Carrying over 400 square feet of floor area per floor. For columns and footings carrying less than 400 square feet of floor area per floor, use beam and slab live loads.

11.4.4 Wind Loads: Wind loads shall be calculated in accordance with ASCE 7 and the following criteria:

a. Risk Category: III

b. Basic Wind Speed (3 sec. gust, strength level): 120 mph

c. Exposure Category C

Wind loads for open structure shall be calculated using ASCE 7-16 Chapter 29 with guidance from ASCE “Wind Loads for Petrochemical and Other Industrial Facilities.”

11.4.5 Equipment Loads:

a. Equipment weights shall be obtained from the Engineering discipline responsible for specifying the equipment, or obtained from certified manufacturer's drawings of the specified equipment.

b. Weights and applied reaction forces of other major equipment (pumps, fans, and similar equipment) shall be obtained, whenever possible, from certified manufacturer's drawings of the equipment purchased for this project. Where structural design must proceed before manufacturer's certified drawings are obtained, the approximate weights may be obtained from the manufacturer, known similar equipment, or catalog data. Such approximate weights shall be increased as directed by the responsible Civil/Structural Engineer (CSE). Equipment loads shall include the effects of any piping or other appurtenances attached thereto, including pressure loads.

c. Minor equipment loading may be estimated from similar Projects or catalog data and shall be increased 20 percent to cover changes and contingencies.

d. Equipment loads shall include hydrostatic test loads. The effect of equipment removal for maintenance shall also be considered in design of structural members as directed by the CSE. Where equipment loads, including impact, are less than the live load over the area occupied by the equipment, the live load shall be used.

e. Impact factors shall be applied for machinery in accordance with industry standard practice.

11.4.6 Piping Loads: Loads from pipes 6 inches in diameter or larger shall be accounted for as concentrated loads where they occur. Loads from smaller piping shall be estimated and applied as a uniform load, but shall not be less than 25 psf on floors and roofs in process areas. Pipe loads are in addition to the dead load. Piping loads shall be considered as dead loads in load combinations, but shall not be considered to resist uplift forces.

11.4.7 Cable Tray and Conduit Loads: Cable tray and conduit loads shall be established with the Electrical Engineering Team. Where structural design must proceed before this information is available, general cable tray and conduit loads shall be estimated and applied as a uniform load, but shall not be less than 25 psf on floors and roofs in process areas. Cable tray and conduit loads are in addition to the dead load. Cable tray and conduit loads shall be considered as dead loads in load combinations, but shall not be considered to resist uplift forces. In addition to the loads below, 10 lb/ft shall be added to the lowest tray for lighting fixtures, and a 200 lb point load shall be added to each hanger for the weight of a man.

Description	**Value**	**Unit**
6” Tray Width	35	lb/ft
9” Tray Width	48	lb/ft
12” Tray Width	59	lb/ft
18” Tray Width	86	lb/ft
24” Tray Width	107	lb/ft
30” Tray Width	134	lb/ft
36” Tray Width	160	lb/ft

11.4.8 Seismic Loads: Lateral forces due to earthquake shall be determined in accordance with the requirements of the ASCE 7 with the parameters given in the table below. This design is intended to provide for life safety in the event of an earthquake. No provision for continuing functionality of equipment is provided.

Seismic Factor	
Mapped short-period acceleration, S_S	0.205g
Mapped one-second acceleration, S1	0.057g
Risk Category	III
Site Classification (Soil Class)	D
Seismic Design Category	B

11.4.9 Snow and Ice Loads: Snow loads on building roofs will be determined in accordance with IBC and ASCE 7, based on a ground snow load of 20psf. The minimum roof snow load will be 35 psf with no reductions, as dictated by Campbell County.

11.4.10 Stability of Structures

a. For purposes of design, stability loading with regard to uplift, overturning and sliding shall be investigated in accordance with standard engineering practice as governed by applicable codes and standards.

b. Structures shall be designed to meet the minimum factors of safety listed in the table below.

Stability Type	Minimum Factor of Safety
Uplift (wind or seismic)	1.5
Uplift (hydrostatic flotation)	1.2
Overturning (wind, seismic, or other)	1.5
Sliding (wind, seismic, or other)	1.5

c. Note that the above factors of safety shall be considered met if the structure is designed to meet the ASCE 7 load combinations which utilize 0.6D to resist overturning and sliding.

d. Friction and passive pressure resistance shall be considered to act in combination. Passive pressure shall be determined in accordance with the Geotechnical Engineering Report.

11.5 FOUNDATION AND CONCRETE STRUCTURE DESIGN

11.5.1 General: Reinforced concrete structures (except secondary containment and environmental structures) shall be designed in accordance with ACI 318. Secondary containment of hazardous materials and environmental structures shall be designed in accordance with ACI 350. Design of new concrete foundations shall include factored loads and load combinations as specified in Section 11.4 of this criteria. Each of the following subsections provides specific criteria for analysis and design. Included are general design considerations, materials, and structural loads for each structure. Evaluation of existing foundations for load-carrying capability shall be as described in the individual subsections and in accordance with ACI 318.

11.5.2 Materials: Materials are specified in Section 11.1.3 of this Design Criteria.

11.5.3 Load Combinations: Load combinations for structural concrete shall be in accordance with ASCE 7 (see Section 11.4). In combinations to counteract an uplift condition, equations shall include only dead load permanently present in the structure.

11.5.4 Ground Floor Slabs: Equipment pads shall be 6 inches above finished slab elevation.

11.5.5 Expansion Joints: Expansion joints in slabs shall be 1/2 inch minimum thick premolded joint filler located where the slab abuts foundation walls, equipment foundations, columns, piers, masonry walls, or other similar obstructions.

11.5.6 Grounding: Grounding of reinforcing, as required, shall be in accordance with Electrical Design Criteria.

11.5.7 Concrete Anchors: Anchors installed in concrete shall be designed in accordance with ACI 318 requirements. In areas where anchors may be exposed to corrosive materials including, but not limited to coal, slag, FGD chemicals, or acids, Type 316 stainless steel anchors shall be specified. This includes anchors used to connect handrails to concrete walls or other concrete surfaces.

11.6 STRUCTURAL STEEL DESIGN

11.6.1 General: Design of steel structures shall conform to the AISC Specification.

11.6.2 Connections

a. Connections shall be developed in accordance with the AISC specification and AISC Manual.

b. Beam and connection angles shall have a thickness not less than one-half the thickness of the beam's web, or as required to satisfy minimum AISC Specification requirements. Minimum connection angle thickness shall be 3/8 inch.

c. Connection design shall be completed by Sargent & Lundy; therefore connection forces will not be posted on the structural steel design drawings and all connections will be shown on the steel design drawings.

d. Connections shall contain a minimum of 2 rows of bolts or the equivalent capacity of weld. The minimum diagonal bracing connection shall be two bolts in double shear or four bolts in single shear or the equivalent capacity weld. The minimum diagonal bracing connection for miscellaneous gallery steel shall be two bolts in single shear or the equivalent capacity weld.

e. Re-entrant corners of copes shall be shaped to a radius of approximately 1/2" inch.

f. Minimum fillet weld size shall be in accordance with the AISC but not less than 3/16 inch.

g. The use of high-strength bolts shall conform to the AISC Specification and RCSC Specification unless otherwise noted herein. High-strength bolts shall be pre-tensioned and shall utilize direct tension indicating washers. Where specifically indicated on the design drawings, bolts shall be slip-critical with a Class B faying surface. For miscellaneous gallery steel, bolted connections shall be bearing type connections. Threads should be included in the shear plane.

h. High-strength bolt shall not be welded.

i. Anchor bolts (rods) shall not be assumed to transfer any shear loads to the foundations from the column base plate unless approved by the CSE. Shear loads in combination with net downward loads may be transferred through friction between the base plate and top of concrete pier if adequate resistance is provided.

j. Shear lugs welded to the bottom of the column base plate shall be provided at column bases to transfer horizontal loads to the foundations.

k. A minimum of four (4) anchor bolts (rods) shall be provided for columns exceeding 300 pounds in weight. Reference OSHA Section 1926.751 and Section 1926.755(a).

11.6.3 Materials: Specify materials in accordance with Section 11.4 of this Design Criteria.

11.6.4 Load Combinations

a. Either the Allowable Strength Design (ASD) or Load and Resistance Factor Design (LRFD) method are acceptable. Structures shall be analyzed for load combinations as specified in the ASCE 7 and designed for the most severe condition. The analysis requirements of the AISC Specification shall be met.

b. The method used (ASD or LRFD) shall be clearly indicated on any deliverable. Any transfer of information about loads shall indicate whether the loads are service level (ASD) or strength level (LRFD).

11.6.5 Code Checks: Code checks for structural steel shall be in accordance with the AISC Specification.

11.6.6 Deflections: Members shall be proportioned so that service level deflections do not result in damage to supported equipment or finishes. Roof members shall be designed for ponding stability. Flexural members shall include beams, trusses, steel joists, and similar members. In no case shall deflections exceed the values listed in the table below, where L is the span, center to center of supports, or total length of member in the case of jib cranes.

Condition	Max. Allowable Deflection	
	Live Load	Total Load
Members Supporting Unoccupied Roofs	L/240	L/180
Monorails / Trolley Beams	n/a	L/450 (vertical) L/400 (lateral)
All Other Flexural Members	L/360	L/240

(1) Steel shall be designed so that vibrations due to equipment or foot traffic do not adversely affect the structural integrity, equipment performance, or occupant comfort. Standard industry methods for evaluation of vibrations shall be used and documented in calculations.

11.6.7 Minimum beam size: The nominal depth of beams (using C-, M-, MC-, S-, or W-Shapes) shall be no less than 8 inches unless this results in an interference.

11.6.8 Flue Gas Duct Design

a. For flue gas system design parameters, see Section 3.

b. Ductwork design shall consider a minimum duct roof live load of 25psf. This load need not be applied when the roof slopes are more than 30 degrees from horizontal.

c. A minimum of 1ft of ash load shall be considered. Ash density considered for design shall be 90 pcf.

d. Materials shall be specified in accordance with Section 11.1.3 of this Design Criteria.

11.6.9 Trolley Beams

a. Required trolley loads shall be defined by the mechanical group. Forces for design shall be in accordance with AISC Steel Construction Manual.

b. Impact loads shall include the following:

i. Vertical impact load shall be 25% of the maximum static wheel load.

ii. Horizontal impact load (lateral) shall be 20% of the sum of the lifted load plus the weight of the hoisted component.

iii. Horizontal impact load (longitudinal) shall be 10% of the sum of the lifted load plus the weight of the lifted component

c. Bolted stops shall be provided at monorail ends.

d. Trolley beam surfaces shall be painted yellow. The design capacity of each trolley beam shall be stenciled on both sides of the web at the approximate midspan of each beam, using the notation "CAPACITY _____ TONS" lettered in 3 inch (75 mm) high block letters with black paint.

11.7 ARCHITECTURAL DESIGN

11.7.1 General: Design of buildings and enclosures shall conform to the requirements of the adopted building code and energy code.

11.7.2 Exterior Envelope

a. Roof and wall systems shall provide continuous insulation in accordance with the energy code. Provide all accessories, trim, closures and flashing needed for a complete system.

b. Roof and wall systems shall be FM approved. All roof systems shall be FM listed Roof-Nav assemblies.

c. Metal roof and wall systems shall have a 20 year finish warranty.

d. Metal Roof and wall systems shall be composite foam insulated assemblies.

e. Low-slope membrane roofs shall be used where equipment or access is required. Low slope roofs shall be FM approved and designed for Very Severe Hail (VSH).

f. Roof systems shall drain to gutter and downspout or scupper and downspout assemblies.

g. Provide a canopy over all exterior doors.

11.7.3 Interior Areas

a. General floor areas shall have a hard troweled natural gray concrete floor with a non-slip hardener/sealer. Provide three coat epoxy traffic grade floor coating for containment areas and areas subject to chemical spills.

b. Provide fire rated assemblies where indicated on the Drawings, assemblies shall be UL approved designs. Provide UL firestop assemblies at the interfaces with the exterior envelope and at all penetrations.

c. CMU partitions shall comply with NCMA guidelines.

d. Gypsum board partitions shall be metal stud assemblies. Finish levels shall comply with Gypsum Association recommendations.

e. In general, interior partitions shall have a painted finish. Where needed for durability provide fiberglass reinforced plastic (FRP) or metal panel coverings.

f. Provide acoustical panels, assemblies or coverings where required.

g. Finishes are minimal due to the industrial nature of the areas within the project scope. Chemical resistant finishes will be provided where required for containment or maintenance.

11.7.4 Doors and Hardware

a. Interior and egress personnel doors shall be hollow metal swing-type with hollow metal frames. All exterior doors and frames shall be galvanized steel, and door panels shall be insulated and provided with seals to prevent infiltration per the requirements of the IECC. Prepare doors and frames as required to allow for the installation of electrified door hardware where noted on the drawings. Hollow metal doors shall be field painted.

b. General purpose exterior personnel doors shall be a suspended metal sliding door configuration. Sliding door systems shall be field painted.

c. Personnel doors shall have a lite kit installed with tempered glazing meeting the requirements of ANSI Z97.1. At exterior doors the glazing shall be an insulated assembly with two layers of glass and an air space. Lite kits at fire rated doors shall meet the fire rating of the assembly.

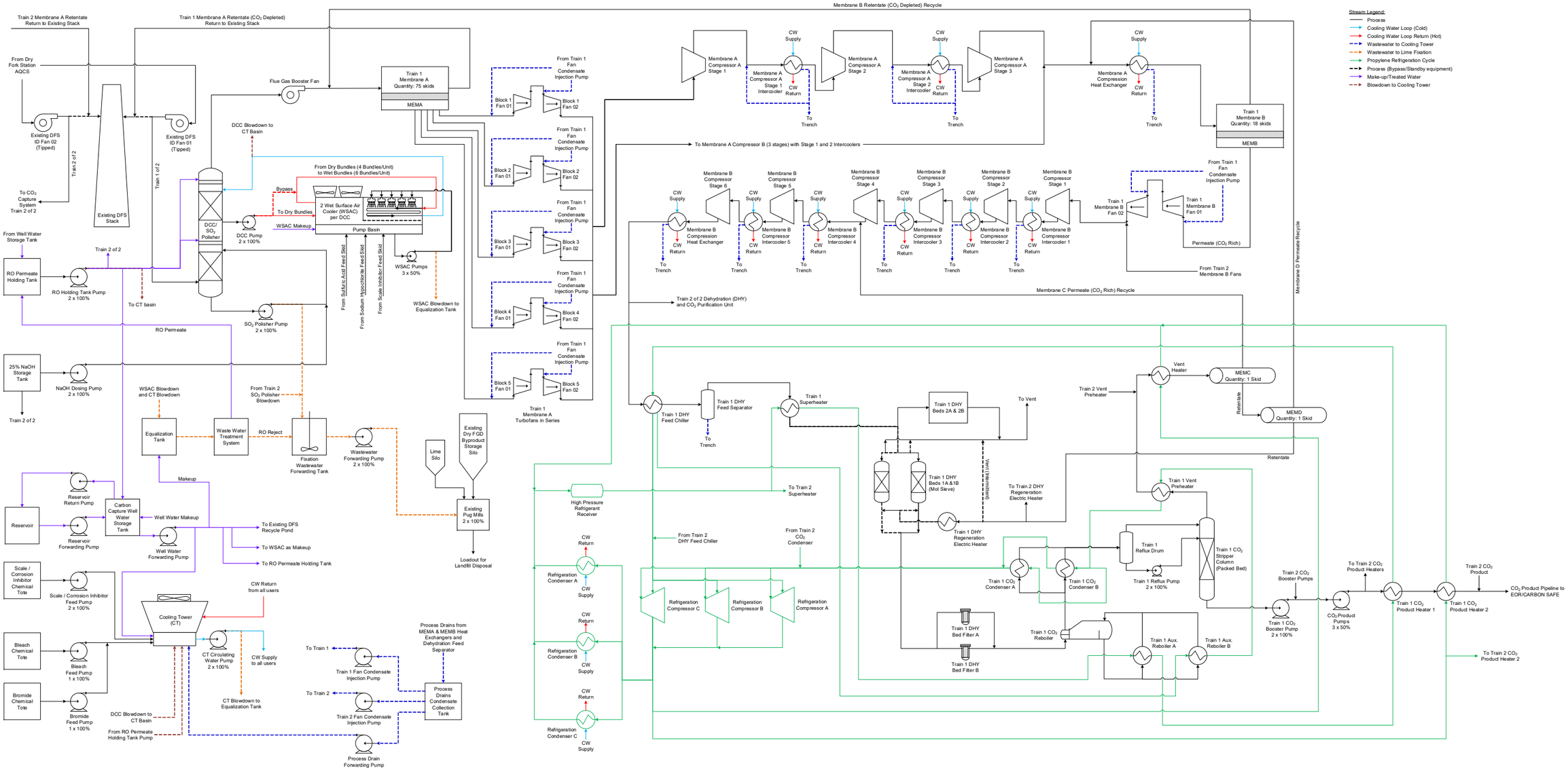
d. Door hardware shall be ANSI/BHMA Grade 1 hardware with a stainless steel finish. Coordinate electrified door hardware with the Owner's security package. Spring operated closers shall be provided at fire rated doors and at doors provided with card readers. Card readers shall be located at all exterior door locations and as indicated on the drawings. At locations with card readers provide power supply and electrified locksets or exit devices with internal REX. Provide removable construction cores for replacement with permanent keyway by others. Provide seals as required for exterior locations or fire rated assemblies.

11.7.5 Access doors shall be overhead rolling steel doors or sectional doors. Access doors shall be provided for vehicle traffic and large equipment maintenance access or installation or removal. All doors shall be motor-operated and supplied with interior operating stations and a back-up chain operator. Door curtain shall have galvanized steel face sheets with a powder coat finish. Door curtain shall be insulated and provided with seals to meet infiltration requirements.

APPENDIX A. FULL SCALE OVERALL PROCESS FLOW DIAGRAM (PFD)

Dry Fork Station Unit 1
Full-Scale Carbon Capture
Process Flow Diagram

Project: 13978-002
For Use – Rev. 0
Date: December 10, 2021



APPENDIX B. EXISTING ID FAN DATA SHEET

Documentation

Customer	Basin Electric Power Cooperative
Project Name	Dry Fork Station – Unit #1
N/E Project Number	074130
N/E Project Manager	Dan Sullivan

The following Nooter/Eriksen and/or subvendor documents are included with this cover sheet:

REV. NO.	NO. OF SHEETS	DOCUMENT DESCRIPTION	REV. DATE
B	13	Performance Curves S&L Pkg. 15	06/012/2007

NE NOOTER/ERIKSEN

Project: Dry Fork	Job No.-Code-Sheet	Release Date	OM
N/E Drawing No.	074130 – PC - 001	06/12/2007	

cc: G. Kerwin

REVIEWED FOR DESIGN INPUT/CONSTRUCTION
BASIN ELECTRIC POWER COOPERATIVE
DRY FORK STATION UNIT 1
SARGENT & LUNDY LLC

STATUS 5

☐ VOIDED ☒ SUPERSEDED

NEW DOCUMENT NO.: 074137-DU-701

ANY ACTION SHOWN ABOVE IS SUBJECT TO THE TERMS OF THE CONTRACT AND DOES NOT RELIEVE CONTRACTOR FROM THE OBLIGATIONS UNDER THE CONTRACT INCLUDING DESIGN AND DETAILING.

ANY ACTION SHOWN ABOVE IS SUBJECT TO THE TERMS OF THE CONTRACT AND DOES NOT RELIEVE CONTRACTOR FROM THE OBLIGATIONS UNDER THE CONTRACT INCLUDING DESIGN AND DETAILING.

FOR: AQCS DESIGN & SUPPLY
RE: L. BARBIN
SPECIFICATION NO.: B-512266

DATE: AUGUST 14, 2009
PROJECT NO.: 11786-002

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

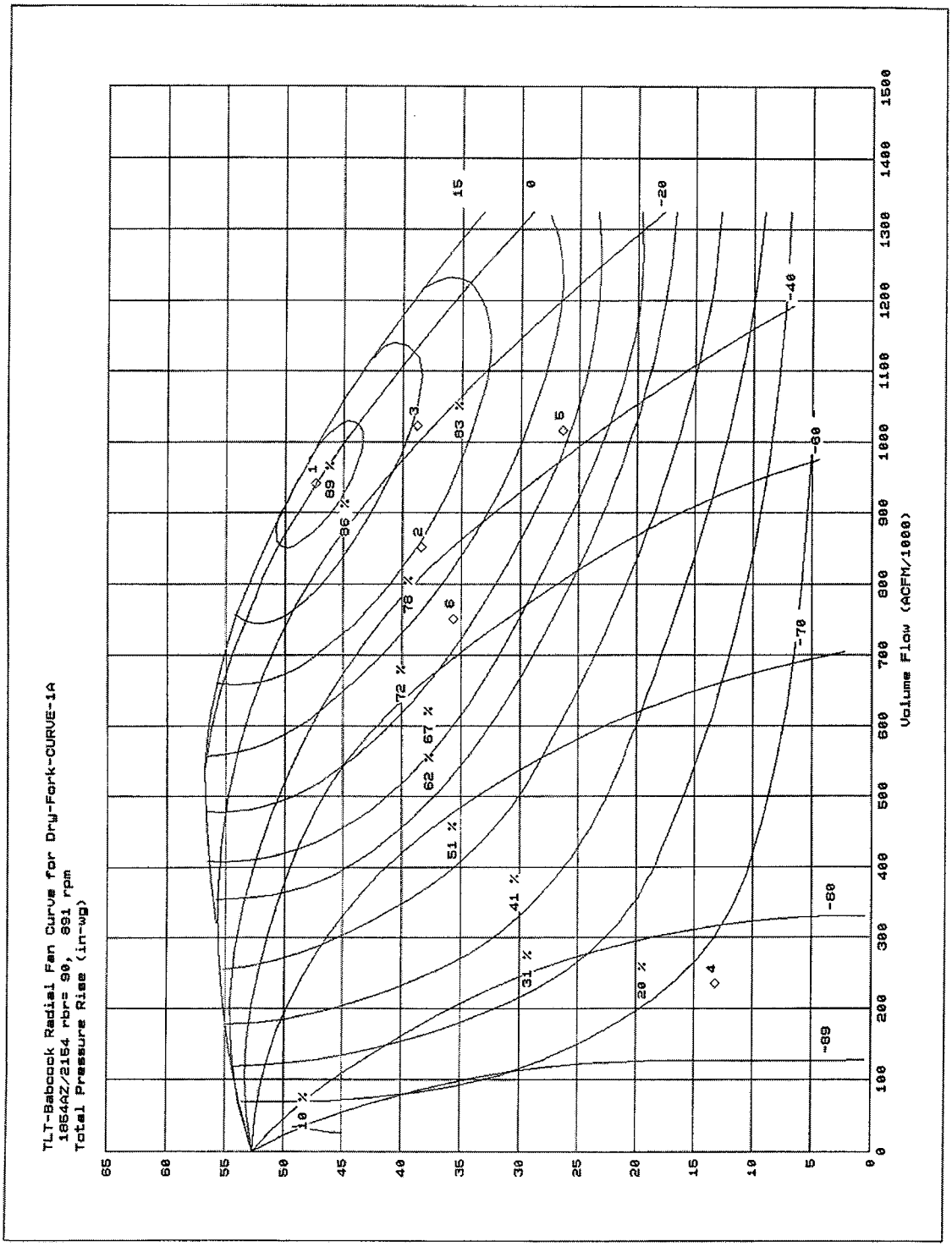
DESIGN CONDITIONS:

Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (NEW AND CLEAN):

Load	Test Block	Table 1.1 Flue Gas Design	MCR - Perf Coal 44F - 1 BH Compartment Out	NE Calc - 25% Perf Coal - 100F Ambient	1 - Fan in Service NE Calc - 60% Perf Coal - 100F Ambient	HIL - Best Blend 100F Ambient
Curve Number	1A	1A	1A	1A	1A	1A
Point on Curve	1	2	3	4	5	6
Volume flow (acfm)	940,817	852,263	1,022,715	234,565	1,016,672	751,433
Inlet temperature (°F)	166	166	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0480	0.0488	0.0514	0.0499	0.0485
Inlet pressure ("wg)	-44.55	-36.5	-36.5	-14.22	-24.59	-34.69
Static pressure rise ("wg)	44.85	37	37.05	14.27	24.84	35.04
LOSSES ("wg):						
Dynamic pressure rise	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.55	0.81	0.04	0.82	0.43
IVC	0.46	0.38	0.56	0.03	0.57	0.30
Inlet Damper	0.19	0.16	0.23	0.01	0.24	0.12
Outlet Damper	0.19	0.16	0.23	0.01	0.24	0.12
Evase	0.75	0.63	0.92	0.05	0.93	0.49
Shaft	0.70	0.59	0.86	0.05	0.87	0.46
Rectangle to Round Adptr	0.05	0.04	0.06	0.00	0.06	0.03
SYSTEM PERFORMANCE:						
Total press. rise ("wg)	47.85	39.51	40.72	14.47	28.55	37.01
Fan total efficiency	89.0%	82.5%	85.7%	----	73.0%	74.2%
Power at fan shaft (bHp)	7473	6089	7213	----	5950	5615
Fan speed (rpm)	891	891	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-1A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
10 %
31 %
41 %
51 %
62 %
67 %
72 %
78 %
83 %
86 %
89 %
15
0
-20
-40
-60
-70
-80
-89
1
2
3
4
5
6

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

DESIGN CONDITIONS:

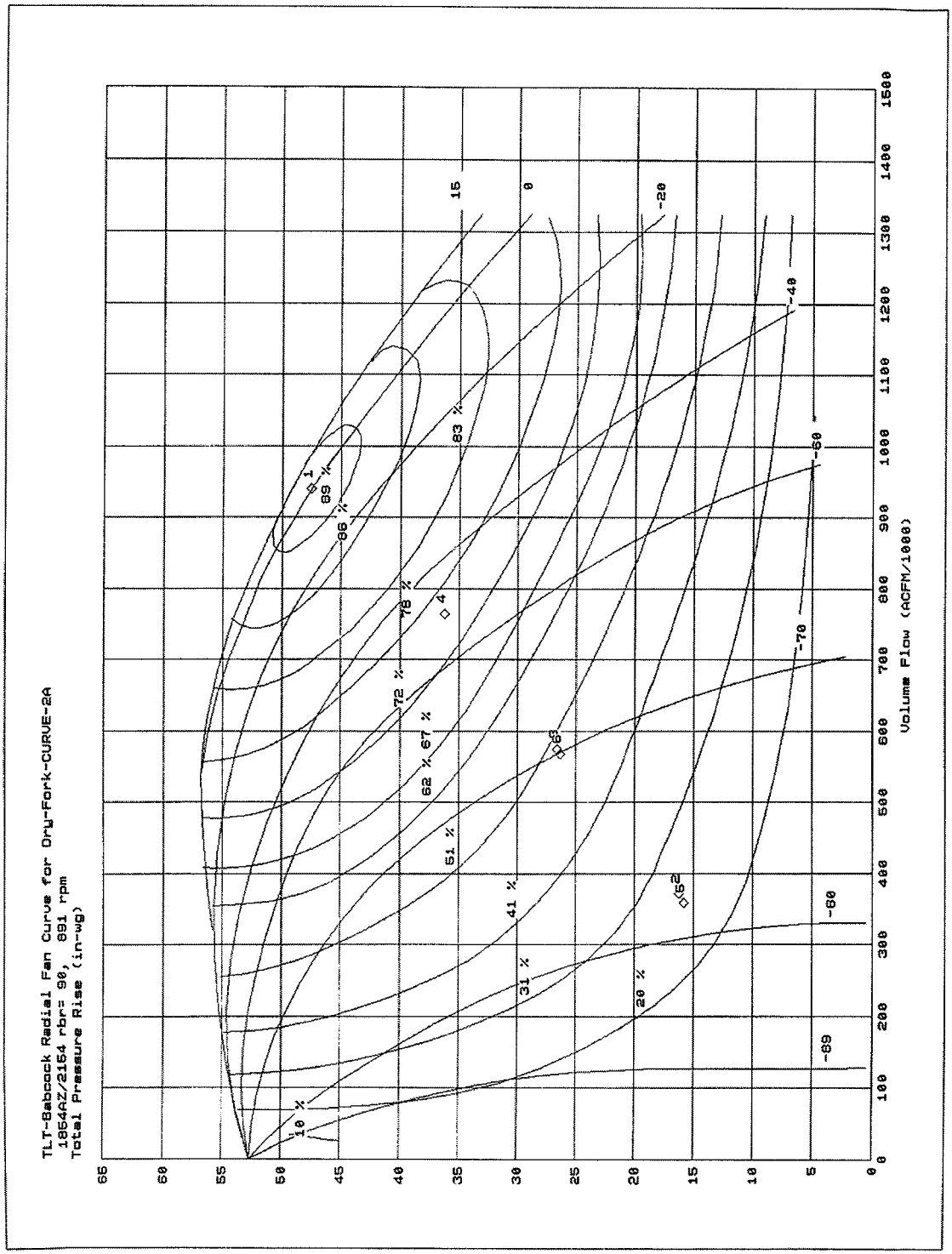
Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (NEW AND CLEAN):

Load

	Test Block	40% Worst Blend 100F Ambient	70% Worst Blend 100F Ambient	HIL Worst Blend 100F Ambient	40% Perf Coal 100F Ambient	70% Perf Coal 100F Ambient
Curve Number	2A	2A	2A	2A	2A	2A
Point on Curve	1	2	3	4	5	6
Volume flow (acfm)	940,817	371,965	574,355	764,860	358,325	568,266
Inlet temperature (°F)	166	166	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0510	0.0495	0.0483	0.0514	0.0496
Inlet pressure ("wg)	-44.55	-17.06	-26.75	-35.1	-16.79	-26.57
Static pressure rise ("wg)	44.85	17.16	26.96	35.46	16.89	26.78
LOSSES ("wg):						
Dynamic pressure rise	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.11	0.26	0.45	0.10	0.25
IVC	0.46	0.08	0.18	0.31	0.07	0.18
Inlet Damper	0.19	0.03	0.07	0.13	0.03	0.07
Outlet Damper	0.19	0.03	0.07	0.13	0.03	0.07
Evase	0.75	0.13	0.29	0.51	0.12	0.29
Shaft	0.70	0.12	0.27	0.47	0.11	0.27
Rectangle to Round Adptr	0.05	0.01	0.02	0.03	0.01	0.02
SYSTEM PERFORMANCE:						
Total press. rise ("wg)	47.85	17.67	28.14	37.49	17.36	27.93
Fan total efficiency	89.0%	26.9%	49.7%	75.5%	25.8%	49.0%
Power at fan shaft (bHp)	7473	3754	4929	5685	3706	4911
Fan speed (rpm)	891	891	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-2A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
15
0
-20
-40
-60
-70
-80
-89
10 %
31 %
41 %
51 %
62 %
67 %
72 %
78 %
83 %
86 %
89 %
1
4
65
52

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

DESIGN CONDITIONS:

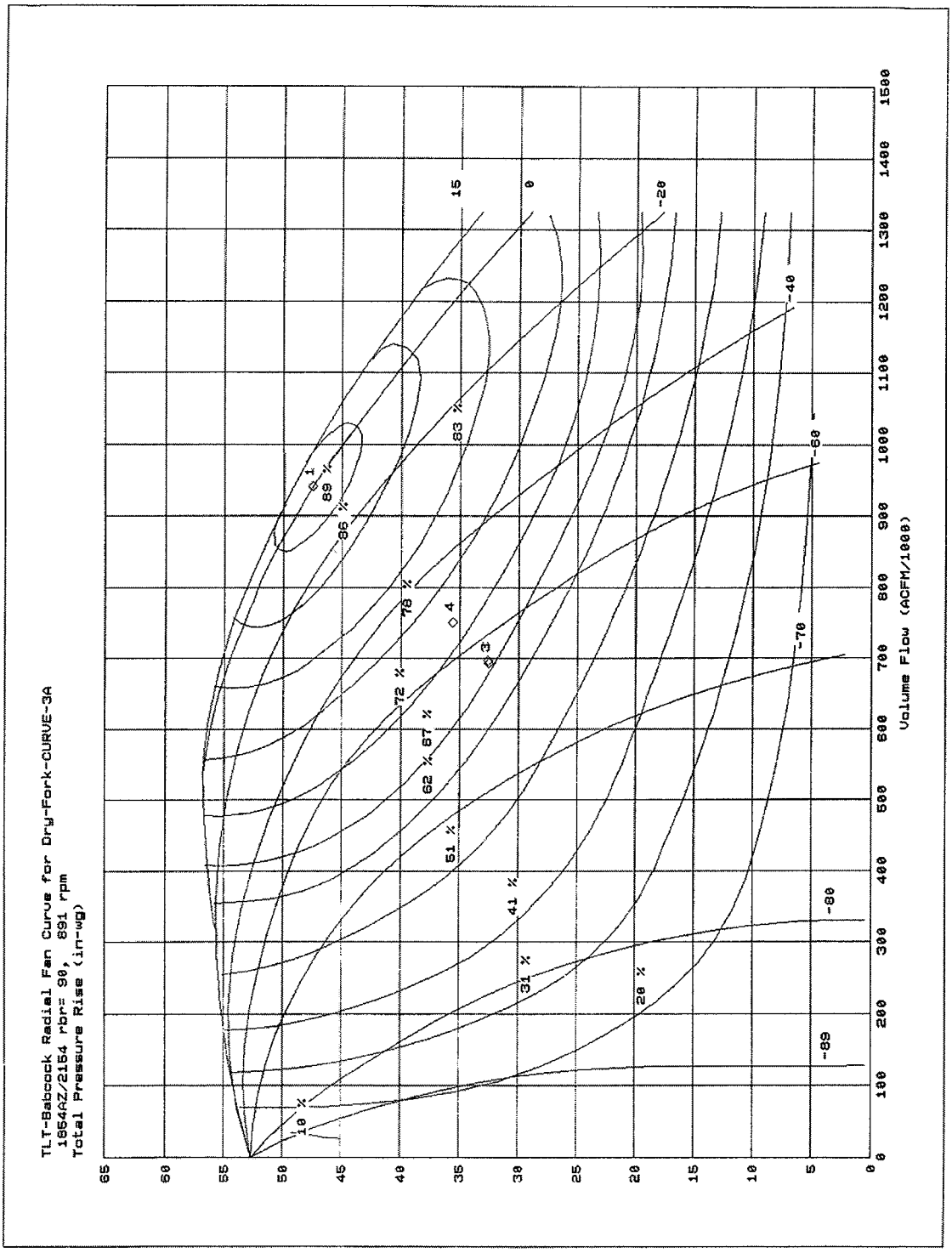
Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (NEW AND CLEAN):

Load

	Test Block	MCR Perf Coal 44F Ambient	MCR Perf Coal 100F Ambient	HIL Perf Coal 100F Ambient
Curve Number	3A	3A	3A	3A
Point on Curve	1	2	3	4
Volume flow (acfm)	940,817	696,722	693,732	751,721
Inlet temperature (°F)	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0488	0.0491	0.0484
Inlet pressure ("wg)	-44.55	-32.02	-32.14	-34.56
Static pressure rise ("wg)	44.85	32.32	32.44	34.91
LOSSES ("wg):				
Dynamic pressure rise	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.38	0.37	0.43
IVC	0.46	0.26	0.26	0.30
Inlet Damper	0.19	0.11	0.11	0.12
Outlet Damper	0.19	0.11	0.11	0.12
Evase	0.75	0.43	0.43	0.49
Shaft	0.70	0.40	0.40	0.46
Rectangle to Round Adptr	0.05	0.03	0.03	0.03
SYSTEM PERFORMANCE:				
Total press. rise ("wg)	47.85	34.02	34.14	36.88
Fan total efficiency	89.0%	67.6%	67.8%	74.1%
Power at fan shaft (bHp)	7473	5274	5253	5606
Fan speed (rpm)	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-3A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
5
10
15
20
25
30
35
40
45
50
55
60
65
15
0
-20
-40
-60
-70
-80
-89
10 %
31 %
41 %
51 %
62 %
72 %
78 %
83 %
86 %
89 %
87 %
1
3
4

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

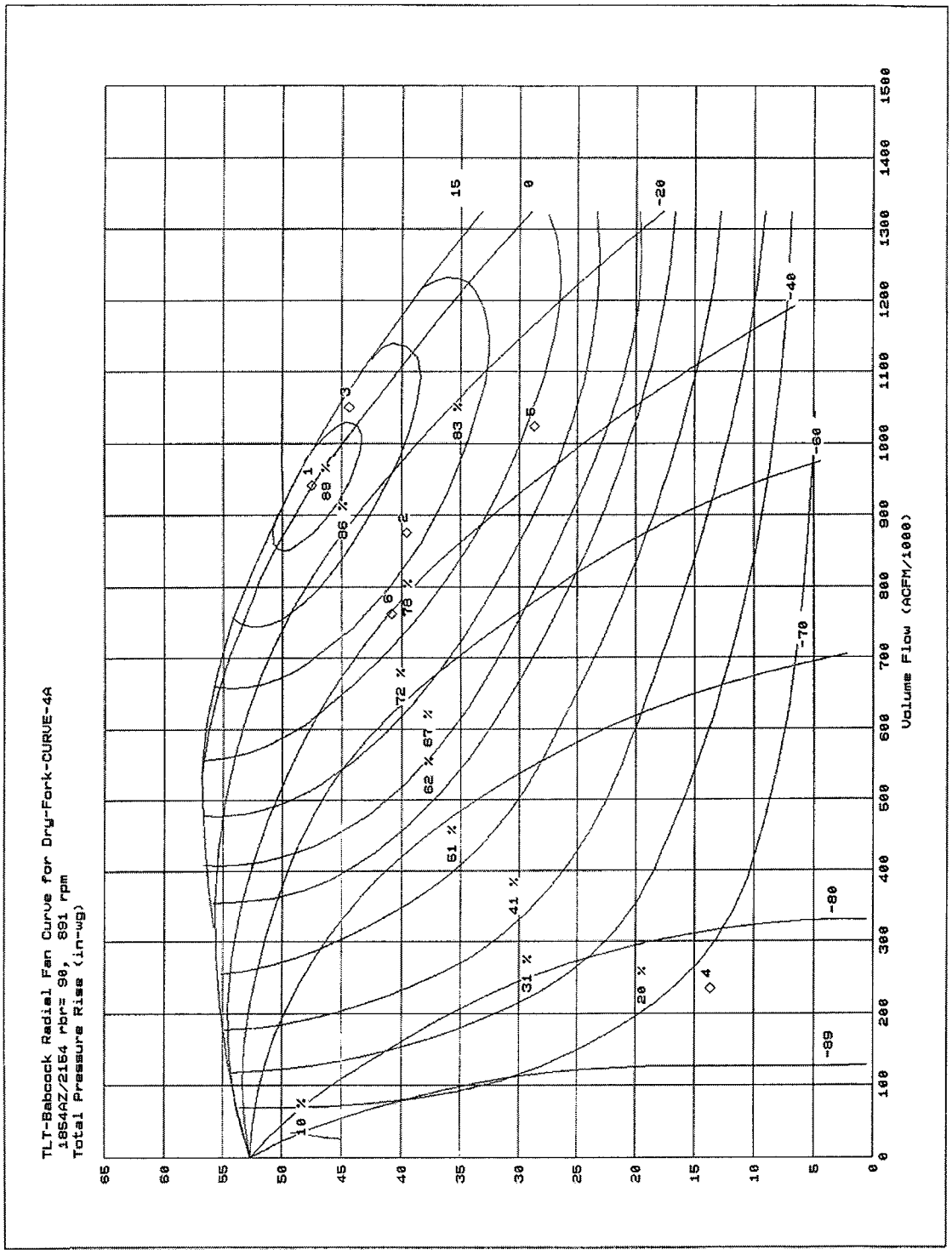
DESIGN CONDITIONS:

Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (DIRTY BOILER CONDITIONS):

Load	Test Block	Flue Gas Design	MCR - Perf Coal 44F - 1 BH Compartment Out	NE Calc - 25% Perf Coal - 100F Ambient	1 - Fan in Service NE Calc - 60% Perf Coal - 100F Ambient	HIL - Best Blend 100F Ambient
Curve Number	4A	4A	4A	4A	4A	4A
Point on Curve	1	2	3	4	5	6
Volume flow (acfm)	940,817	875,823	1,050,987	234,905	1,023,691	762,766
Inlet temperature (°F)	166	166	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0530	0.0481	0.0514	0.0495	0.0477
Inlet pressure ("wg)	-44.55	-41.58	-41.58	-14.7	-26.79	-39.32
Static pressure rise ("wg)	44.85	42.03	42.05	14.78	27.03	39.67
LOSSES ("wg):						
Dynamic pressure rise	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.64	0.84	0.04	0.82	0.44
IVC	0.46	0.45	0.59	0.03	0.57	0.31
Inlet Damper	0.19	0.19	0.24	0.01	0.24	0.13
Outlet Damper	0.19	0.19	0.24	0.01	0.24	0.13
Evase	0.75	0.73	0.96	0.05	0.93	0.50
Shaft	0.70	0.68	0.89	0.05	0.87	0.47
Rectangle to Round Adptr	0.05	0.05	0.06	0.00	0.06	0.03
SYSTEM PERFORMANCE:						
Total press. rise ("wg)	47.85	44.96	45.87	14.98	30.76	41.67
Fan total efficiency	89.0%	83.9%	88.3%	——	76.9%	80.6%
Power at fan shaft (bHp)	7473	6955	8061	——	6119	5880
Fan speed (rpm)	891	891	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-4A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
5
10
15
20
25
30
35
40
45
50
55
60
65
10 %
31 %
41 %
51 %
62 %
67 %
72 %
78 %
86 %
89 %
83 %
15
0
-20
-40
-60
-70
-80
-89
1
2
3
4
5
6

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

DESIGN CONDITIONS:

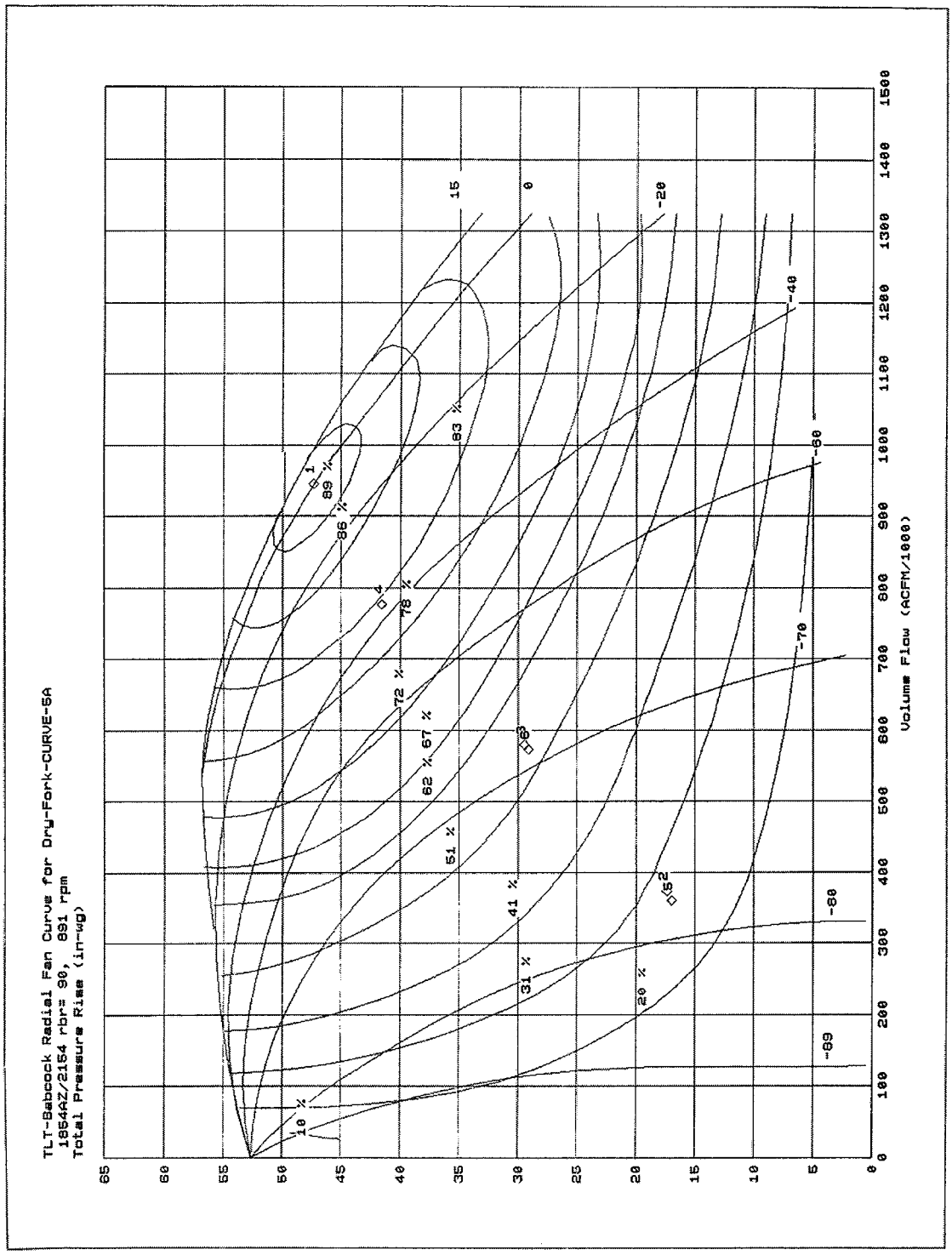
Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (DIRTY BOILER CONDITIONS):

Load

	Test Block	40% Worst Blend 100F Ambient	70% Worst Blend 100F Ambient	HIL Worst Blend 100F Ambient	40% Perf Coal 100F Ambient	70% Perf Coal 100F Ambient
Curve Number	5A	5A	5A	5A	5A	5A
Point on Curve	1	2	3	4	5	6
Volume flow (acfm)	940,817	373,271	579,318	776,666	359,516	573,102
Inlet temperature (°F)	166	166	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0508	0.0491	0.0475	0.0512	0.0492
Inlet pressure ("wg)	-44.55	-18.21	-29.49	-39.82	-17.88	-29.26
Static pressure rise ("wg)	44.85	18.31	29.7	40.18	17.98	29.47
LOSSES ("wg):						
Dynamic pressure rise	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.11	0.26	0.45	0.10	0.26
IVC	0.46	0.08	0.18	0.32	0.07	0.18
Inlet Damper	0.19	0.03	0.08	0.13	0.03	0.07
Outlet Damper	0.19	0.03	0.08	0.13	0.03	0.07
Evase	0.75	0.13	0.30	0.52	0.12	0.29
Shaft	0.70	0.12	0.28	0.48	0.11	0.27
Rectangle to Round Adptr	0.05	0.01	0.02	0.03	0.01	0.02
SYSTEM PERFORMANCE:						
Total press. rise ("wg)	47.85	18.82	30.89	42.24	18.46	30.63
Fan total efficiency	89.0%	28.4%	55.0%	82.2%	27.4%	53.9%
Power at fan shaft (bHp)	7473	3796	4919	5947	3718	4925
Fan speed (rpm)	891	891	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-5A
1854AZ/2154 nbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
15
0
-20
-40
-60
-70
-80
-89
10 %
20 %
31 %
41 %
51 %
62 %
72 %
78 %
86 %
89 %
83 %
67 %
52
63
4
1

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

DESIGN CONDITIONS:

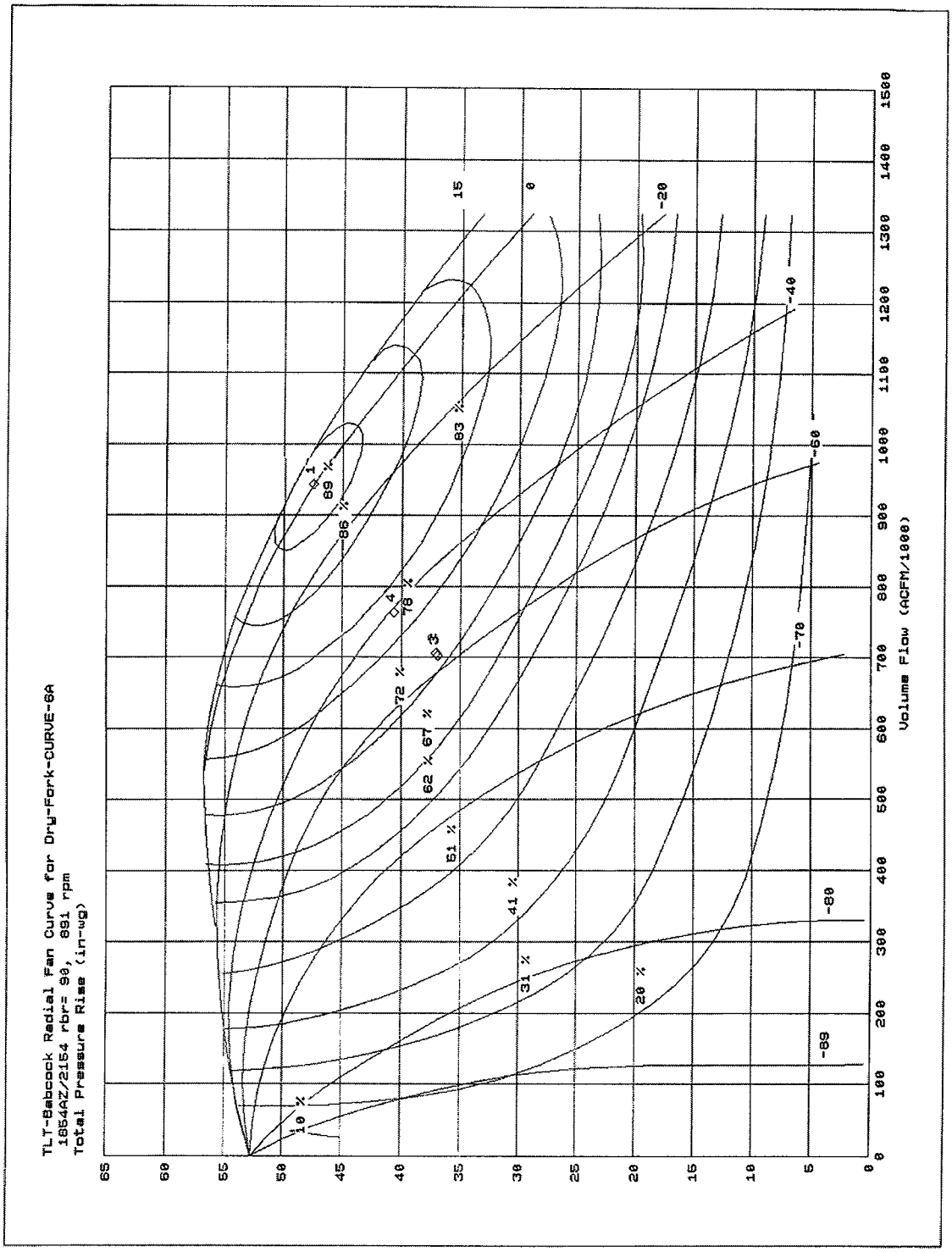
Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (DIRTY BOILER CONDITIONS):

Load

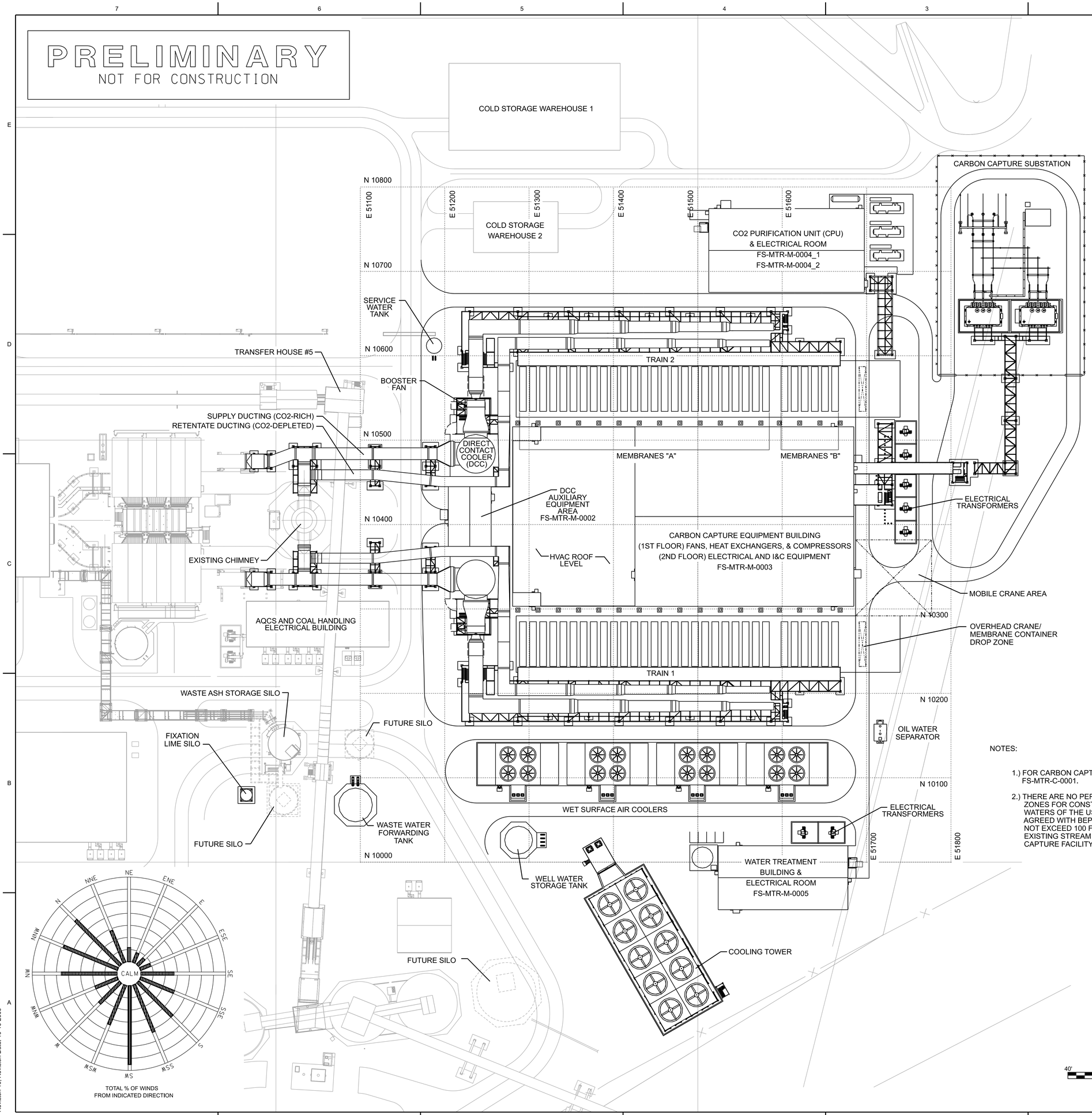
	Test Block	MCR Perf Coal 44F Ambient	MCR Perf Coal 100F Ambient	HIL Perf Coal 100F Ambient
Curve Number	6A	6A	6A	6A
Point on Curve	1	2	3	3
Volume flow (acfm)	940,817	705,921	702,963	762,978
Inlet temperature (°F)	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0481	0.0485	0.0477
Inlet pressure ("wg)	-44.55	-36.11	-36.26	-39.16
Static pressure rise ("wg)	44.85	36.41	36.56	39.51
LOSSES ("wg):				
Dynamic pressure rise	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.38	0.38	0.44
IVC	0.46	0.26	0.26	0.31
Inlet Damper	0.19	0.11	0.11	0.13
Outlet Damper	0.19	0.11	0.11	0.13
Evase	0.75	0.43	0.43	0.50
Shaft	0.70	0.40	0.40	0.47
Rectangle to Round Adptr	0.05	0.03	0.03	0.03
SYSTEM PERFORMANCE:				
Total press. rise ("wg)	47.85	38.13	38.28	41.51
Fan total efficiency	89.0%	73.5%	73.2%	80.5%
Power at fan shaft (bHp)	7473	5486	5507	5868
Fan speed (rpm)	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.


TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-6A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
Volume Flow (ACFM/1000)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
15
0
-20
-40
-60
-70
-80
-89
10 %
20 %
31 %
41 %
51 %
62 %
67 %
72 %
78 %
83 %
86 %
89 %
91

APPENDIX C. DRY FORK STATION 1 PLOT PLAN

PRELIMINARY
NOT FOR CONSTRUCTION



NOTES:

1.) FOR CARBON CAPTURE RESERVOIR SEE DWG. FS-MTR-C-0001.

2.) THERE ARE NO PERMIT ENFORCEABLE EXCLUSION ZONES FOR CONSTRUCTION CONCERNING THE WATERS OF THE US (WOTUS). HOWEVER, IT WAS AGREED WITH BEPC/DFS THAT CONSTRUCTION SHALL NOT EXCEED 100 FT FROM THE WOTUS, WHICH IS THE EXISTING STREAM TO THE EAST OF THE CARBON CAPTURE FACILITY.

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
A	05/28/2021	FOR CLIENT COMMENT
B	10/12/2021	FOR CLIENT COMMENT
0	02/07/2022	FOR USE

ISSUE PURPOSE: FOR USE

SPECIFICATION:

PROJECT NO.: 13978.002

I HEREBY CERTIFY THAT THIS ENGINEERING DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT PERSONAL SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF ENTER NAME.

ENTER NAME
ENTER DATE

MY LICENSE RENEWAL DATE IS: ENTER DATE
PAGES OR SHEETS COVERED BY THIS SEAL:
THIS DOCUMENT ONLY.

CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-M-0001.DGN

PREPARED BY: RM

REVIEWED BY: RAM

APPROVED BY: DBP

ANY MODIFICATION OR ADDITION TO THIS DRAWING BY AN ORGANIZATION OTHER THAN SARGENT & LUNDY IS NOT THE RESPONSIBILITY OF SARGENT & LUNDY.

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT

SITE PLAN

DRAWING NUMBER	REVISION
FS-MTR-M-0001	0
SHEET 01 OF 01	

PL:\12849\00M1743\D\DFM\TR\cadms\design\Full Scale\General Arrangements\Site Plan\FS-MTR-M-0001.dgn
Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

2/7/2022 5:04:28 PM ...\Site Plan\FS-MTR-M-0001.dgn

APPENDIX D. HEAT AND MASS BALANCE WITH ASSOCIATED PROCESS FLOW DIAGRAM

MTR DFS Full Scale FEED
Process Stream Table
Rev 2, 9/17/21

Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		100	102	104	105	106	108	109	110	113	114	116	117	119	120	121	123	124	126	127	128	130
Stream Description		**Flue Gas from Boundary**	**Flue Gas from DCC**	**Flue Gas from Booster Fan**	**MemA Feed**	**Recycle from MemB**	**MemA Retentate**	**MemA Permeate**	**MemA Fan 1 Discharge**	**MemA Fan 2 Discharge**	**MemA Compressor Stage 1 Discharge**	**MemA Comp Stage 1 Cooler Vapor Outlet**	**MemA Compressor Stage 2 Discharge**	**MemA Comp Stage 2 Cooler Vapor Outlet**	**MemA Compressor Stage 3 Discharge**	**MemA Comp Stage3 Cooler Inlet with MemD Recycle**	**MemB Feed**	**MemB Permeate**	**MemB Fan 1 Discharge**	**MemB Fan 2 Discharge**	**MemB Compressor 1 Discharge**	**MemB Comp 1 Cooler Vapor Outlet**
PFD Reference		PFD-01	PFD-01	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-03	PFD-03	PFD-03	PFD-03
Vapor Fraction (mole basis)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Temperature, °F		222.0	90.2	108.4	106.4	81.2	106.3	106.4	91.2	108.5	209.9	81.2	175.8	81.2	184.0	180.9	81.2	81.2	78.7	96.2	201.9	81.2
Pressure, psia		13.10	12.71	13.87	13.87	15.53	12.89	1.45	2.15	3.44	5.86	5.61	9.71	9.46	16.50	16.50	16.25	2.90	4.27	6.31	12.07	11.82
Total Molar Flow, lbmol/hr		180,708	155,178	155,178	167,621	12,443	131,064	36,557	37,929	38,963	38,963	32,321	32,321	31,048	31,048	31,763	31,059	18,616	19,240	19,618	19,618	18,495
Total Mass Flow, lb/hr		5,097,169	4,637,036	4,637,036	5,019,031	381,995	3,787,432	1,231,600	1,256,320	1,274,950	1,274,950	1,155,275	1,155,275	1,132,345	1,132,345	1,160,206	1,147,515	765,519	776,749	783,559	783,559	763,319
Actual Volumetric Flow, acfm		1,679,758	1,199,825	1,135,491	1,222,184	77,443	1,028,853	2,550,714	1,739,785	1,149,817	794,790	556,107	377,691	316,714	216,187	220,092	184,252	620,387	433,195	308,439	191,863	150,757
Molecular Weight		28.21	29.88	29.88	29.94	30.70	28.90	33.69	33.12	32.72	32.72	35.74	35.74	36.47	36.47	36.53	36.95	41.12	40.37	39.94	39.94	41.27
Enthalpy, Btu/hr		8.91E+08	6.01E+08	6.22E+08	6.69E+08	4.71E+07	5.18E+08	1.52E+08	1.53E+08	1.63E+08	1.96E+08	1.26E+08	1.51E+08	1.21E+08	1.47E+08	1.49E+08	1.20E+08	7.33E+07	7.55E+07	8.01E+07	9.86E+07	7.26E+07
Vapor																						
Molar Flow, lbmol/hr		180,708	155,178	155,178	167,621	12,443	131,064	36,557	37,929	38,963	38,963	32,321	32,321	31,048	31,048	31,763	31,059	18,616	19,240	19,618	19,618	18,495
Mass Flow, lb/hr		5,097,169	4,637,036	4,637,036	5,019,031	381,995	3,787,432	1,231,600	1,256,320	1,274,950	1,274,950	1,155,275	1,155,275	1,132,345	1,132,345	1,160,206	1,147,515	765,519	776,749	783,559	783,559	763,319
Standard Volumetric Flow, MMSCFD		1,645.80	1,413.30	1,413.30	1,526.60	113.32	1,193.70	332.94	345.44	354.86	354.86	294.37	294.37	282.78	282.78	289.28	282.87	169.55	175.23	178.67	178.67	168.44
Density, lb/ft^3 @ PT		0.051	0.064	0.068	0.068	0.082	0.061	0.008	0.012	0.019	0.027	0.035	0.051	0.060	0.087	0.088	0.104	0.021	0.030	0.042	0.068	0.084
Specific Heat, Btu/lb°F		0.268	0.245	0.245	0.245	0.237	0.245	0.242	0.245	0.250	0.258	0.227	0.235	0.223	0.231	0.231	0.221	0.211	0.215	0.219	0.230	0.211
Viscosity, cP		0.019	0.017	0.017	0.017	0.017	0.018	0.015	0.014	0.015	0.017	0.015	0.018	0.016	0.018	0.018	0.016	0.015	0.015	0.015	0.018	0.015
Thermal Conductivity, Btu/hr-ft-°F		0.017	0.014	0.014	0.014	0.014	0.015	0.012	0.012	0.012	0.015	0.012	0.014	0.012	0.014	0.014	0.012	0.010	0.010	0.011	0.014	0.010
Compressibility		0.999	0.999	0.999	0.999	0.999	1.000	1.000	0.999	0.999	0.999	0.999	0.999	0.998	0.998	0.998	0.997	0.999	0.999	0.998	0.998	0.996
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	0.1202	0.1399	0.1399														0.8464	0.8189	0.8032	0.8032	0.8519
Nitrogen	28.0	0.6548	0.7625	0.7625														0.0866	0.0837	0.0821	0.0821	0.0871
Oxygen	32.0	0.0372	0.0433	0.0433														0.0170	0.0164	0.0161	0.0161	0.0171
Water	18.0	0.1878	0.0543	0.0543														0.0500	0.0808	0.0985	0.0985	0.0438
Sulfur Dioxide	64.1	2.67E-05	5.00E-06	5.00E-06														3.51E-05	3.40E-05	3.33E-05	3.33E-05	3.53E-05
Sulfur Trioxide	80.1	7.60E-07	4.94E-07	4.94E-07														3.44E-06	3.33E-06	3.27E-06	3.27E-06	3.45E-06
Ammonia	17.0	3.64E-06	4.24E-06	4.24E-06														2.64E-05	2.55E-05	2.51E-05	2.51E-05	2.54E-05
Nitric Oxide	30.0	2.80E-05	3.26E-05	3.26E-05														7.72E-06	7.47E-06	7.33E-06	7.33E-06	7.77E-06
Nitrogen Dioxide	46.0	2.04E-06	2.37E-06	0.0000														0.0000	0.0000	0.0000	0.0000	0.0000
Propylene	42.1	0.0000	0.0000	0.0000														0.0000	0.0000	0.0000	0.0000	0.0000
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		955,692	955,660	955,660														693,422	693,422	693,422	693,422	693,406
Nitrogen		3,314,558	3,314,554	3,314,554														45,137	45,137	45,137	45,137	45,137
Oxygen		214,874	214,874	214,874														10,112	10,112	10,112	10,112	10,112
Water		611,545	151,712	151,712														16,774	28,004	34,814	34,814	14,591
Sulfur Dioxide		309	50	50														42	42	42	42	42
Sulfur Trioxide		11	6	6														5	5	5	5	5
Ammonia		11	11	11														8	8	8	8	8
Nitric Oxide		152	152	152														4	4	4	4	4
Nitrogen Dioxide		17	17	17														14	14	14	14	14
Propylene		0	0	0														0	0	0	0	0

MTR DFS Full Scale FEED
Process Stream Table
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Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		100	102	104	105	106	108	109	110	113	114	116	117	119	120	121	123	124	126	127	128	130
Stream Description		**Flue Gas from Boundary**	**Flue Gas from DCC**	**Flue Gas from Booster Fan**	**MemA Feed**	**Recycle from MemB**	**MemA Retentate**	**MemA Permeate**	**MemA Fan 1 Discharge**	**MemA Fan 2 Discharge**	**MemA Compressor Stage 1 Discharge**	**MemA Comp Stage 1 Cooler Vapor Outlet**	**MemA Compressor Stage 2 Discharge**	**MemA Comp Stage 2 Cooler Vapor Outlet**	**MemA Compressor Stage 3 Discharge**	**MemA Comp Stage3 Cooler Inlet with MemD Recycle**	**MemB Feed**	**MemB Permeate**	**MemB Fan 1 Discharge**	**MemB Fan 2 Discharge**	**MemB Compressor 1 Discharge**	**MemB Comp 1 Cooler Vapor Outlet**
Liquid																						
Molar Flow, lbmol/hr		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Mass Flow, lb/hr		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Standard Volumetric Flow, gpm		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Density, lb/ft^3 @ PT		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Specific Heat, Btu/lb^{o}F		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Viscosity, cP		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Surface Tension, dynes/cm		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Thermal Conductivity, Btu/hr-ft-F		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen	28.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oxygen	32.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Water	18.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Dioxide	64.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Trioxide	80.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ammonia	17.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitric Oxide	30.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen Dioxide	46.0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Propylene	42.1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Oxygen		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Water		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Dioxide		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Trioxide		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ammonia		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitric Oxide		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen Dioxide		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Propylene		--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

NOTES

1. DCC /SO2 Polisher water streams (202 and 212) should not be used for wastewater design. Refer to Trimeric Aspen Plus simulation of the DCC/SO2 Polisher dated 11/24/2020. Refer to B&W vendor quote for wash water requirements.
2. Solid species (e.g. fly ash) and ionic species are not accounted for in this model.
3. Balance of plant parameters (such water treatment or cooling water equipment) are not included in the PFD or H&MB.

MTR DFS Full Scale FEED
Process Stream Table
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Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		131	133	134	136	137	138	140	141	143	144	146	147	147A	148	149	150	151	156	157	158	159
Stream Description		**MemB Comp 2 Discharge**	**MemB Comp 2 Cooler Vapor Outlet**	**MemB Comp 3 Discharge**	**MemB Comp 3 Cooler Vapor Outlet**	**MemB Comp 4 Discharge**	**MemB Comp 4 Cooler Inlet**	**MemB Comp 4 Cooler Vapor Outlet**	**MemB Comp 5 Discharge**	**MemB Comp 5 Cooler Vapor Outlet**	**MemB Comp 6 Discharge**	**MemB Comp 6 Cooler Vapor Outlet**	**Dehy Feed Chiller Outlet**	**Dehy Feed Separator Vapor Outlet**	**Superheated Dehydration Inlet**	**Dry CO2 to Reboiler / CO2 Cross Exchanger**	**CO2 Condenser Inlet**	**CO2 Distillation Column Inlet**	**CO2 Distillation Column Bottoms**	**CO2 Product from CO2 Booster Pump**	**CO2 Product from CO2 Product Pump**	**CO2 Product from CO2 Product Heater 1**
PFD Reference		PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-04	PFD-04	PFD-04	PFD-04	PFD-05	PFD-05	PFD-05	PFD-05	PFD-05	PFD-05
Vapor Fraction (mole basis)		1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.999	1.00	1.00	1.00	1.00	0.18	0.00	0.00	0.00	0.00
Temperature, °F		184.4	81.2	184.3	81.2	184.4	165.0	81.2	215.3	81.2	216.7	81.2	50.0	50.0	60.0	60.0	19.4	-31.0	10.4	10.8	29.7	60.0
Pressure, psia		22.79	22.54	43.46	40.46	78.00	78.00	75.00	172.97	169.97	392.00	389.00	386.00	386.00	383.00	376.00	373.00	370.00	362.00	391.60	2219.08	2216.08
Total Molar Flow, lbmol/hr		18,495	18,103	18,103	17,917	17,917	20,848	20,764	20,764	20,684	20,684	20,649	20,649	20,626	20,626	20,614	20,614	20,614	15,256	15,256	15,256	15,256
Total Mass Flow, lb/hr		763,319	756,256	756,256	752,910	752,910	877,743	876,215	876,215	874,766	874,766	874,130	874,130	873,704	873,704	873,485	873,485	873,485	671,425	671,425	671,425	671,425
Actual Volumetric Flow, acfm		93,061	77,112	47,573	42,267	26,065	29,370	26,116	14,077	11,101	5,976	4,440	4,066	4,066	4,240	4,333	3,794	834	177	177	174	189
Molecular Weight		41.27	41.78	41.78	42.02	42.02	42.10	42.20	42.20	42.29	42.29	42.33	42.33	42.36	42.36	42.37	42.37	42.37	44.01	44.01	44.01	44.01
Enthalpy, Btu/hr		8.95E+07	7.07E+07	8.72E+07	6.96E+07	8.58E+07	9.61E+07	7.98E+07	1.04E+08	7.73E+07	1.01E+08	7.17E+07	6.45E+07	6.48E+07	6.71E+07	6.73E+07	5.83E+07	-4.39E+07	-3.70E+07	-3.69E+07	-3.21E+07	-2.07E+07
Vapor																						
Molar Flow, lbmol/hr		18,495	18,103	18,103	17,917	17,917	20,848	20,764	20,764	20,684	20,684	20,649	20,626	20,626	20,626	20,614	20,614	3,738	--	--	--	--
Mass Flow, lb/hr		763,319	756,256	756,256	752,910	752,910	877,743	876,215	876,215	874,766	874,766	874,130	873,704	873,704	873,704	873,485	873,485	137,766	--	--	--	--
Standard Volumetric Flow, MMSCFD		168.44	164.87	164.87	163.19	163.19	189.88	189.11	189.11	188.38	188.38	188.06	187.85	187.85	187.85	187.74	187.74	34.04	--	--	--	--
Density, lb/ft^3 @ PT		0.137	0.164	0.265	0.297	0.481	0.498	0.559	1.037	1.313	2.440	3.281	3.581	3.581	3.434	3.360	3.838	3.505	--	--	--	--
Specific Heat, Btu/lb°F		0.223	0.210	0.222	0.211	0.222	0.221	0.213	0.229	0.222	0.241	0.251	0.257	0.257	0.254	0.252	0.266	0.260	--	--	--	--
Viscosity, cP		0.018	0.015	0.018	0.015	0.018	0.017	0.016	0.019	0.016	0.019	0.016	0.016	0.016	0.016	0.016	0.015	0.015	--	--	--	--
Thermal Conductivity, Btu/hr-ft-°F		0.013	0.010	0.013	0.010	0.013	0.013	0.011	0.015	0.011	0.015	0.012	0.011	0.011	0.012	0.012	0.011	0.011	--	--	--	--
Compressibility		0.996	0.993	0.992	0.987	0.985	0.984	0.976	0.972	0.944	0.938	0.867	0.838	0.838	0.850	0.853	0.805	0.848	--	--	--	--
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	0.8519	0.8703	0.8703	0.8793	0.8793	0.8829	0.8865	0.8865	0.8899	0.8899	0.8914	0.8924	0.8924	0.8924	0.8929	0.8929	0.5349	--	--	--	--
Nitrogen	28.0	0.0871	0.0890	0.0890	0.0899	0.0899	0.0869	0.0872	0.0872	0.0876	0.0876	0.0877	0.0878	0.0878	0.0878	0.0879	0.0879	0.3924	--	--	--	--
Oxygen	32.0	0.0171	0.0175	0.0175	0.0176	0.0176	0.0189	0.0190	0.0190	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0191	0.0727	--	--	--	--
Water	18.0	0.0438	0.0231	0.0231	0.0130	0.0130	0.0112	0.0072	0.0072	0.0034	0.0034	0.0017	0.0006	0.0006	0.0006	0.0000	0.0000	0.0000	--	--	--	--
Sulfur Dioxide	64.1	3.53E-05	3.60E-05	3.60E-05	3.64E-05	3.64E-05	3.16E-05	3.17E-05	3.17E-05	3.18E-05	3.18E-05	3.19E-05	3.19E-05	3.19E-05	3.19E-05	3.19E-05	3.19E-05	1.19E-06	--	--	--	--
Sulfur Trioxide	80.1	3.45E-06	3.52E-06	3.52E-06	3.55E-06	3.55E-06	3.06E-06	3.06E-06	3.06E-06	3.07E-06	3.07E-06	3.07E-06	3.06E-06	3.06E-06	3.06E-06	3.06E-06	3.06E-06	9.68E-09	--	--	--	--
Ammonia	17.0	2.54E-05	2.52E-05	2.52E-05	2.48E-05	2.48E-05	2.20E-05	2.17E-05	2.17E-05	2.10E-05	2.10E-05	2.03E-05	1.93E-05	1.93E-05	1.93E-05	1.93E-05	1.93E-05	2.40E-06	--	--	--	--
Nitric Oxide	30.0	7.77E-06	7.94E-06	7.94E-06	8.02E-06	8.02E-06	8.18E-06	8.22E-06	8.22E-06	8.25E-06	8.25E-06	8.26E-06	8.27E-06	8.27E-06	8.27E-06	8.28E-06	8.28E-06	3.13E-05	--	--	--	--
Nitrogen Dioxide	46.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	--	--	--	--
Propylene	42.1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	--	--	--	--
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		693,406	693,396	693,396	693,386	693,386	810,095	810,088	810,088	810,071	810,071	810,055	810,040	810,040	810,040	810,040	810,040	87,981	--	--	--	--
Nitrogen		45,137	45,137	45,137	45,137	45,137	50,744	50,744	50,744	50,744	50,744	50,744	50,744	50,744	50,744	50,744	50,744	41,087	--	--	--	--
Oxygen		10,112	10,112	10,112	10,112	10,112	12,628	12,628	12,628	12,628	12,628	12,628	12,628	12,628	12,628	12,628	12,628	8,693	--	--	--	--
Water		14,591	7,538	7,538	4,201	4,201	4,201	2,681	2,681	1,249	1,249	628	219	219	219	0	0	0	--	--	--	--
Sulfur Dioxide		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	0	--	--	--	--
Sulfur Trioxide		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	0	--	--	--	--
Ammonia		8	8	8	8	8	8	8	8	7	7	7	7	7	7	7	7	0	--	--	--	--
Nitric Oxide		4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	4	--	--	--	--
Nitrogen Dioxide		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	0	--	--	--	--
Propylene		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	--	--

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Process Stream Table
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Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		131	133	134	136	137	138	140	141	143	144	146	147	147A	148	149	150	151	156	157	158	159
Stream Description		**MemB Comp 2 Discharge**	**MemB Comp 2 Cooler Vapor Outlet**	**MemB Comp 3 Discharge**	**MemB Comp 3 Cooler Vapor Outlet**	**MemB Comp 4 Discharge**	**MemB Comp 4 Cooler Inlet**	**MemB Comp 4 Cooler Vapor Outlet**	**MemB Comp 5 Discharge**	**MemB Comp 5 Cooler Vapor Outlet**	**MemB Comp 6 Discharge**	**MemB Comp 6 Cooler Vapor Outlet**	**Dehy Feed Chiller Outlet**	**Dehy Feed Separator Vapor Outlet**	**Superheated Dehydration Inlet**	**Dry CO2 to Reboiler / CO2 Cross Exchanger**	**CO2 Condenser Inlet**	**CO2 Distillation Column Inlet**	**CO2 Distillation Column Bottoms**	**CO2 Product from CO2 Booster Pump**	**CO2 Product from CO2 Product Pump**	**CO2 Product from CO2 Product Heater 1**
Liquid																						
Molar Flow, lbmol/hr		--	--	--	--	--	--	--	--	--	--	--	23	--	--	--	--	16,876	15,256	15,256	15,256	15,256
Mass Flow, lb/hr		--	--	--	--	--	--	--	--	--	--	--	426	--	--	--	--	735,719	671,425	671,425	671,425	671,425
Standard Volumetric Flow, gpm		--	--	--	--	--	--	--	--	--	--	--	2,359	--	--	--	--	2,358	1,643	1,643	1,643	1,643
Density, lb/ft^3 @ PT		--	--	--	--	--	--	--	--	--	--	--	3.58	--	--	--	--	17.46	63.10	63.12	64.41	59.21
Specific Heat, Btu/lb^{o}F		--	--	--	--	--	--	--	--	--	--	--	1.010	--	--	--	--	0.464	0.604	0.602	0.529	0.595
Viscosity, cP		--	--	--	--	--	--	--	--	--	--	--	1.3414	--	--	--	--	0.1816	0.1303	0.1304	0.1372	0.1088
Surface Tension, dynes/cm		--	--	--	--	--	--	--	--	--	--	--	73.05	--	--	--	--	11.32	6.78	6.75	4.73	1.87
Thermal Conductivity, Btu/hr-ft-F		--	--	--	--	--	--	--	--	--	--	--	0.330	--	--	--	--	0.081	0.072	0.072	0.075	0.067
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	--	--	--	--	--	--	--	--	--	--	--	0.0156	--	--	--	--	0.9722	0.9999	0.9999	0.9999	0.9999
Nitrogen	28.0	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0204	1.82E-07	1.82E-07	1.82E-07	1.82E-07
Oxygen	32.0	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0073	1.01E-05	1.01E-05	1.01E-05	1.01E-05
Water	18.0	--	--	--	--	--	--	--	--	--	--	--	0.9833	--	--	--	--	0.0000	1.56E-06	1.56E-06	1.56E-06	1.56E-06
Sulfur Dioxide	64.1	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0000	4.26E-05	4.26E-05	4.26E-05	4.26E-05
Sulfur Trioxide	80.1	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0000	4.14E-06	4.14E-06	4.14E-06	4.14E-06
Ammonia	17.0	--	--	--	--	--	--	--	--	--	--	--	0.0010	--	--	--	--	0.0000	2.51E-05	2.51E-05	2.51E-05	2.51E-05
Nitric Oxide	30.0	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0000	1.61E-09	1.61E-09	1.61E-09	1.61E-09
Nitrogen Dioxide	46.0	--	--	--	--	--	--	--	--	--	--	--	0.0001	--	--	--	--	0.0000	1.94E-05	1.94E-05	1.94E-05	1.94E-05
Propylene	42.1	--	--	--	--	--	--	--	--	--	--	--	0.0000	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		--	--	--	--	--	--	--	--	--	--	--	16	--	--	--	--	722,058	671,353	671,353	671,353	671,353
Nitrogen		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	9,657	0	0	0	0
Oxygen		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	3,935	5	5	5	5
Water		--	--	--	--	--	--	--	--	--	--	--	410	--	--	--	--	0	0	0	0	0
Sulfur Dioxide		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	42	42	42	42	42
Sulfur Trioxide		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	5	5	5	5	5
Ammonia		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	7	7	7	7	7
Nitric Oxide		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	2	0	0	0	0
Nitrogen Dioxide		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	14	14	14	14	14
Propylene		--	--	--	--	--	--	--	--	--	--	--	0	--	--	--	--	0	0	0	0	0

NOTES

1. DCC /SO2 Polisher water streams (202 and 212) should not be used for wastewater design. Refer to Trimeric Aspen Plus simulation of the DCC/SO2 Polisher dated 11/24/2020. Refer to B&W vendor quote for wash water requirements.
2. Solid species (e.g. fly ash) and ionic species are not accounted for in this model.
3. Balance of plant parameters (such water treatment or cooling water equipment) are not included in the PFD or H&MB.

MTR DFS Full Scale FEED
Process Stream Table
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Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		160	161	162	163	164	166	167	202	212	222	223	224	227	228	230	231	232	233	234	235
Stream Description		**CO2 Product from CO2 Product Heater 2**	**CO2 Distillation Column Overheads**	**MemC Inlet**	**MemD Inlet**	**MemD Retentate**	**MemD Permeate Recycle**	**MemC Permeate Recycle**	**Water Purge from SO2 Polisher**	**Water Purge from DCC**	**Water from MemA Comp 1 Cooler**	**Water from MemA Comp 2 Cooler**	**Water from MemA Comp 3 Cooler**	**MemA Fan 1 Water Injection**	**MemA Fan 2 Water Injection**	**Water from MemB Comp 1 Cooler**	**Water from MemB Comp 2 Cooler**	**Water from MemB Comp 3 Cooler**	**Water from MemB Comp 4 Cooler**	**Water from MemB Comp 5 Cooler**	**Water from MemB Comp 6 Cooler**
PFD Reference		PFD-05	PFD-05	PFD-05	PFD-05	PFD-05	PFD-05	PFD-05	PFD-01	PFD-01	PFD-02	PFD-02	PFD-02	PFD-02	PFD-02	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03	PFD-03
Vapor Fraction (mole basis)		0.00	1.00	1.00	1.00	1.00	1.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Temperature, °F		68.0	-26.5	81.0	81.0	80.9	46.6	44.3	144.1	83.8	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2	81.2
Pressure, psia		2213.08	360.00	357.00	356.28	355.55	17.25	79.77	50.00	39.29	5.61	9.46	16.25	43.51	43.51	11.82	22.54	40.46	75.00	169.97	389.00
Total Molar Flow, lbmol/hr		15,256	5,357	5,357	2,427	1,712	715	2,931	837	24,712	6,642	1,272	704	1,372	1,034	1,123	392	185	85	80	35
Total Mass Flow, lb/hr		671,425	202,060	202,060	77,231	49,371	27,861	124,829	15,268	445,186	119,675	22,930	12,691	24,720	18,630	20,240	7,064	3,346	1,528	1,449	637
Actual Volumetric Flow, acfm		194	968	1,344	640	461	3,732	3,201	4	119	32	6	3	7	5	5	2	1	0	0	0
Molecular Weight		44.01	37.72	37.72	31.82	28.83	38.99	42.59	18.24	18.02	18.02	18.02	18.02	18.02	18.02	18.02	18.03	18.04	18.07	18.14	18.28
Enthalpy, Btu/hr		-1.74E+07	1.39E+07	1.93E+07	8.89E+06	6.30E+06	2.56E+06	1.03E+07	-1.14E+07	-3.63E+08	-9.80E+07	-1.88E+07	-1.04E+07	-2.02E+07	-1.53E+07	-1.66E+07	-5.78E+06	-2.73E+06	-1.25E+06	-1.17E+06	-5.08E+05
Vapor																					
Molar Flow, lbmol/hr		--	5,357	5,357	2,427	1,712	715	2,931	--	--	--	--	--	--	--	--	--	--	--	--	--
Mass Flow, lb/hr		--	202,060	202,060	77,231	49,371	27,861	124,829	--	--	--	--	--	--	--	--	--	--	--	--	--
Standard Volumetric Flow, MMSCFD		--	48.79	48.79	22.10	15.60	6.51	26.69	--	--	--	--	--	--	--	--	--	--	--	--	--
Density, lb/ft^3 @ PT		--	3.480	2.505	2.011	1.787	0.124	0.650	--	--	--	--	--	--	--	--	--	--	--	--	--
Specific Heat, Btu/lb°F		--	0.259	0.242	0.247	0.254	0.210	0.209	--	--	--	--	--	--	--	--	--	--	--	--	--
Viscosity, cP		--	0.015	0.017	0.018	0.018	0.015	0.015	--	--	--	--	--	--	--	--	--	--	--	--	--
Thermal Conductivity, Btu/hr-ft-°F		--	0.011	0.013	0.015	0.015	0.010	0.009	--	--	--	--	--	--	--	--	--	--	--	--	--
Compressibility		--	0.842	0.928	0.972	0.988	0.995	0.967	--	--	--	--	--	--	--	--	--	--	--	--	--
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	--	0.5882	0.5882	mol frac	0.0146	mol frac	mol frac	--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen	28.0	--	0.3381	0.3381		0.8383			--	--	--	--	--	--	--	--	--	--	--	--	--
Oxygen	32.0	--	0.0736	0.0736		0.1471			--	--	--	--	--	--	--	--	--	--	--	--	--
Water	18.0	--	0.0000	0.0000		0.0000			--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Dioxide	64.1	--	0.0000	0.0000		0.0000			--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Trioxide	80.1	--	0.0000	0.0000		0.0000			--	--	--	--	--	--	--	--	--	--	--	--	--
Ammonia	17.0	--	2.72E-06	2.72E-06		5.10E-09			--	--	--	--	--	--	--	--	--	--	--	--	--
Nitric Oxide	30.0	--	3.18E-05	3.18E-05		7.07E-05			--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen Dioxide	46.0	--	0.0000	0.0000		0.0000			--	--	--	--	--	--	--	--	--	--	--	--	--
Propylene	42.1	--	0.0000	0.0000		0.0000			--	--	--	--	--	--	--	--	--	--	--	--	--
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		--	138,687	138,687		1,101			--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen		--	50,744	50,744		40,208			--	--	--	--	--	--	--	--	--	--	--	--	--
Oxygen		--	12,623	12,623		8,058			--	--	--	--	--	--	--	--	--	--	--	--	--
Water		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Dioxide		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--
Sulfur Trioxide		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--
Ammonia		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--
Nitric Oxide		--	5	5		4			--	--	--	--	--	--	--	--	--	--	--	--	--
Nitrogen Dioxide		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--
Propylene		--	0	0		0			--	--	--	--	--	--	--	--	--	--	--	--	--

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Process Stream Table
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Stream Number		160	161	162	163	164	166	167	202	212	222	223	224	227	228	230	231	232	233	234	235
Stream Description		**CO2 Product from CO2 Product Heater 2**	**CO2 Distillation Column Overheads**	**MemC Inlet**	**MemD Inlet**	**MemD Retentate**	**MemD Permeate Recycle**	**MemC Permeate Recycle**	**Water Purge from SO2 Polisher**	**Water Purge from DCC**	**Water from MemA Comp 1 Cooler**	**Water from MemA Comp 2 Cooler**	**Water from MemA Comp 3 Cooler**	**MemA Fan 1 Water Injection**	**MemA Fan 2 Water Injection**	**Water from MemB Comp 1 Cooler**	**Water from MemB Comp 2 Cooler**	**Water from MemB Comp 3 Cooler**	**Water from MemB Comp 4 Cooler**	**Water from MemB Comp 5 Cooler**	**Water from MemB Comp 6 Cooler**
Liquid																					
Molar Flow, lbmol/hr		15,256	--	--	--	--	--	--	837	24,712	6,642	1,272	704	1,372	1,034	1,123	392	185	85	80	35
Mass Flow, lb/hr		671,425	--	--	--	--	--	--	15,268	445,186	119,675	22,930	12,691	24,720	18,630	20,240	7,064	3,346	1,528	1,449	637
Standard Volumetric Flow, gpm		1,643	--	--	--	--	--	--	30	890	239	46	25	49	37	40	14	7	3	3	1
Density, lb/ft^3 @ PT		57.66	--	--	--	--	--	--	61.61	62.12	62.15	62.15	62.16	62.15	62.15	62.16	62.17	62.19	62.22	62.32	62.52
Specific Heat, Btu/lb^{o}F		0.614	--	--	--	--	--	--	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010	1.010
Viscosity, cP		0.1018	--	--	--	--	--	--	0.4618	0.8185	0.8449	0.8451	0.8453	0.8447	0.8447	0.8454	0.8459	0.8469	0.8487	0.8535	0.8637
Surface Tension, dynes/cm		1.22	--	--	--	--	--	--	65.59	71.39	71.60	71.60	71.59	71.61	71.61	71.59	71.56	71.53	71.46	71.26	70.85
Thermal Conductivity, Btu/hr-ft-F		0.065	--	--	--	--	--	--	0.373	0.354	0.353	0.353	0.353	0.353	0.353	0.353	0.353	0.352	0.352	0.350	0.347
Components	mol weight	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac	mol frac
Carbon Dioxide	44.0	0.9999	--	--	--	--	--	--	0.0000	0.0000	0.0001	0.0002	0.0003	0.0000	0.0000	0.0003	0.0006	0.0011	0.0021	0.0047	0.0103
Nitrogen	28.0	1.82E-07	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Oxygen	32.0	1.01E-05	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Water	18.0	1.56E-06	--	--	--	--	--	--	0.9951	1.0000	0.9999	0.9998	0.9997	1.0000	1.0000	0.9997	0.9993	0.9988	0.9978	0.9951	0.9893
Sulfur Dioxide	64.1	4.26E-05	--	--	--	--	--	--	0.0048	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sulfur Trioxide	80.1	4.14E-06	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Ammonia	17.0	2.51E-05	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0002	0.0004
Nitric Oxide	30.0	1.61E-09	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Nitrogen Dioxide	46.0	1.94E-05	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Propylene	42.1	0.0000	--	--	--	--	--	--	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Components		mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow	mass flow
Carbon Dioxide		671,353	--	--	--	--	--	--	0	0	28	9	9	0	0	16	11	9	8	16	16
Nitrogen		0	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0
Oxygen		5	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0
Water		0	--	--	--	--	--	--	15,006	445,184	119,646	22,920	12,682	24,720	18,630	20,223	7,053	3,337	1,520	1,432	621
Sulfur Dioxide		42	--	--	--	--	--	--	259	0	0	0	0	0	0	0	0	0	0	0	0
Sulfur Trioxide		5	--	--	--	--	--	--	3	2	0	0	0	0	0	0	0	0	0	0	0
Ammonia		7	--	--	--	--	--	--	0	0	1	0	0	0	0	0	0	0	0	0	0
Nitric Oxide		0	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0
Nitrogen Dioxide		14	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0
Propylene		0	--	--	--	--	--	--	0	0	0	0	0	0	0	0	0	0	0	0	0

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Process Stream Table
Rev 2, 9/17/21

Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		236	240	241	
Stream Description		**Water from Dehy Feed Separator**	**MemB Fan 1 Water Injection**	**MemB Fan 2 Water Injection**	
PFD Reference		PFD-04	PFD-03	PFD-03	
Vapor Fraction (mole basis)		0.00	0.00	0.00	
Temperature, °F		50.0	81.0	81.0	
Pressure, psia		386.00	43.51	43.51	
Total Molar Flow, lbmol/hr		23	623	378	
Total Mass Flow, lb/hr		426	11,230	6,810	
Actual Volumetric Flow, acfm		0	3	2	
Molecular Weight		18.42	18.02	18.02	
Enthalpy, Btu/hr		-3.49E+05	-9.20E+06	-5.58E+06	
Vapor					
Molar Flow, lbmol/hr		--	--	--	
Mass Flow, lb/hr		--	--	--	
Standard Volumetric Flow, MMSCFD		--	--	--	
Density, lb/ft^3 @ PT		--	--	--	
Specific Heat, Btu/lb°F		--	--	--	
Viscosity, cP		--	--	--	
Thermal Conductivity, Btu/hr-ft-°F		--	--	--	
Compressibility		--	--	--	
Components	mol weight	mol frac	mol frac	mol frac	
Carbon Dioxide	44.0	--	--	--	
Nitrogen	28.0	--	--	--	
Oxygen	32.0	--	--	--	
Water	18.0	--	--	--	
Sulfur Dioxide	64.1	--	--	--	
Sulfur Trioxide	80.1	--	--	--	
Ammonia	17.0	--	--	--	
Nitric Oxide	30.0	--	--	--	
Nitrogen Dioxide	46.0	--	--	--	
Propylene	42.1	--	--	--	
Components		mass flow	mass flow	mass flow	
Carbon Dioxide		--	--	--	
Nitrogen		--	--	--	
Oxygen		--	--	--	
Water		--	--	--	
Sulfur Dioxide		--	--	--	
Sulfur Trioxide		--	--	--	
Ammonia		--	--	--	
Nitric Oxide		--	--	--	
Nitrogen Dioxide		--	--	--	
Propylene		--	--	--	

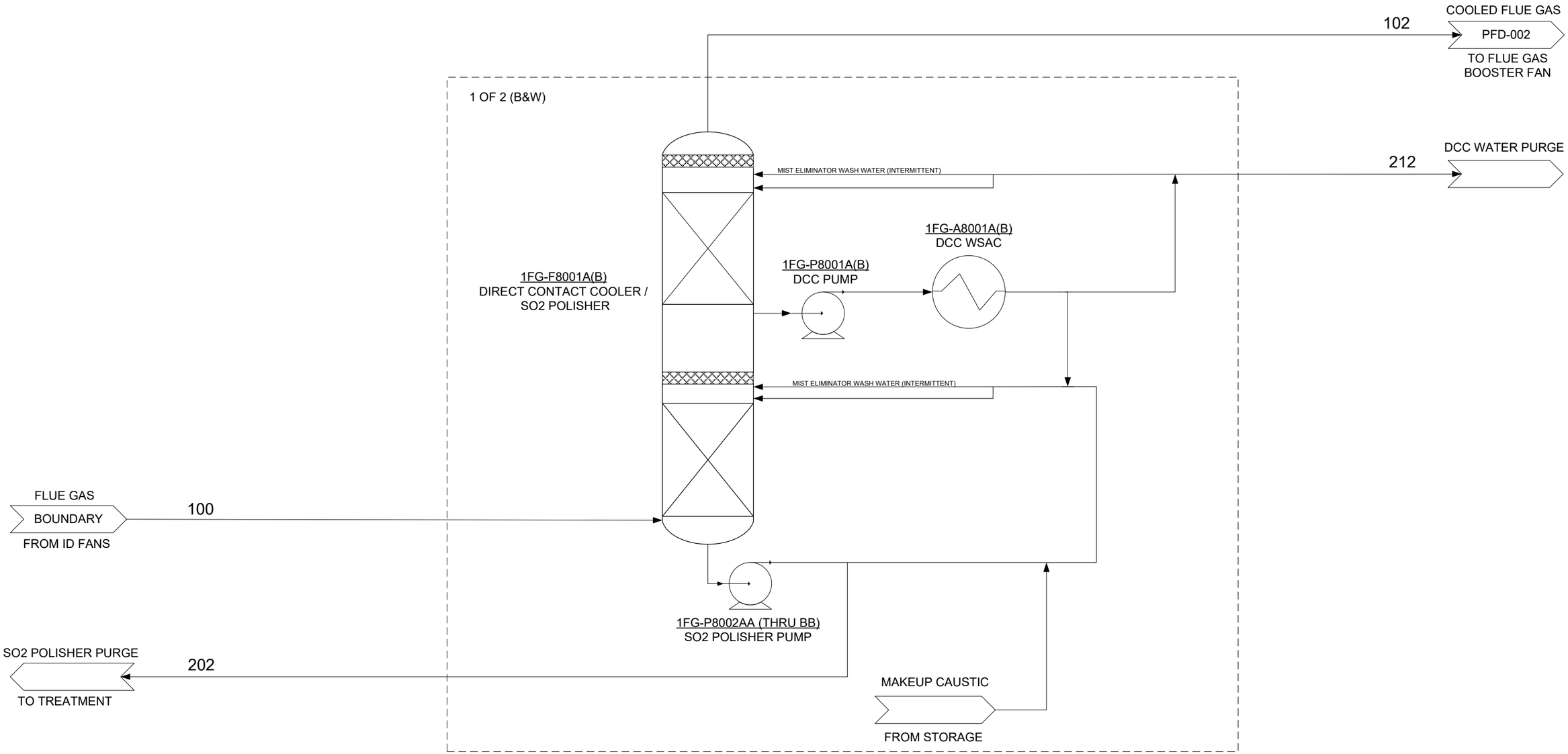
MTR DFS Full Scale FEED
Process Stream Table
Rev 2, 9/17/21

Flow rates are total plant flow rates. The total flow rate in the stream table should be divided by the number of trains indicated on the PFD to calculate the flow rate to each piece of equipment.

Stream Number		236	240	241	
Stream Description		**Water from Dehy Feed Separator**	**MemB Fan 1 Water Injection**	**MemB Fan 2 Water Injection**	
Liquid					
Molar Flow, lbmol/hr		23	623	378	
Mass Flow, lb/hr		426	11,230	6,810	
Standard Volumetric Flow, gpm		1	22	14	
Density, lb/ft^3 @ PT		63.00	62.15	62.15	
Specific Heat, Btu/lb^{o}F		1.010	1.010	1.010	
Viscosity, cP		1.3414	0.8468	0.8468	
Surface Tension, dynes/cm		73.05	71.63	71.63	
Thermal Conductivity, Btu/hr-ft-F		0.330	0.353	0.353	
Components	mol weight	mol frac	mol frac	mol frac	
Carbon Dioxide	44.0	0.0156	0.0000	0.0000	
Nitrogen	28.0	0.0000	0.0000	0.0000	
Oxygen	32.0	0.0000	0.0000	0.0000	
Water	18.0	0.9833	1.0000	1.0000	
Sulfur Dioxide	64.1	0.0000	0.0000	0.0000	
Sulfur Trioxide	80.1	0.0000	0.0000	0.0000	
Ammonia	17.0	0.0010	0.0000	0.0000	
Nitric Oxide	30.0	0.0000	0.0000	0.0000	
Nitrogen Dioxide	46.0	0.0001	0.0000	0.0000	
Propylene	42.1	0.0000	0.0000	0.0000	
Components		mass flow	mass flow	mass flow	
Carbon Dioxide		16	0	0	
Nitrogen		0	0	0	
Oxygen		0	0	0	
Water		410	11,230	6,810	
Sulfur Dioxide		0	0	0	
Sulfur Trioxide		0	0	0	
Ammonia		0	0	0	
Nitric Oxide		0	0	0	
Nitrogen Dioxide		0	0	0	
Propylene		0	0	0	

NOTES

1. DCC /SO2 Polisher water streams (202 and 212) should not be used for wastewater design. Refer to Trimeric Aspen Plus simulation of the DCC/SO2 Polisher dated 11/24/2020. Refer to B&W vendor quote for wash water requirements.
2. Solid species (e.g. fly ash) and ionic species are not accounted for in this model.
3. Balance of plant parameters (such water treatment or cooling water equipment) are not included in the PFD or H&MB.



Dry Fork Station Full-Scale FEED

REVISIONS

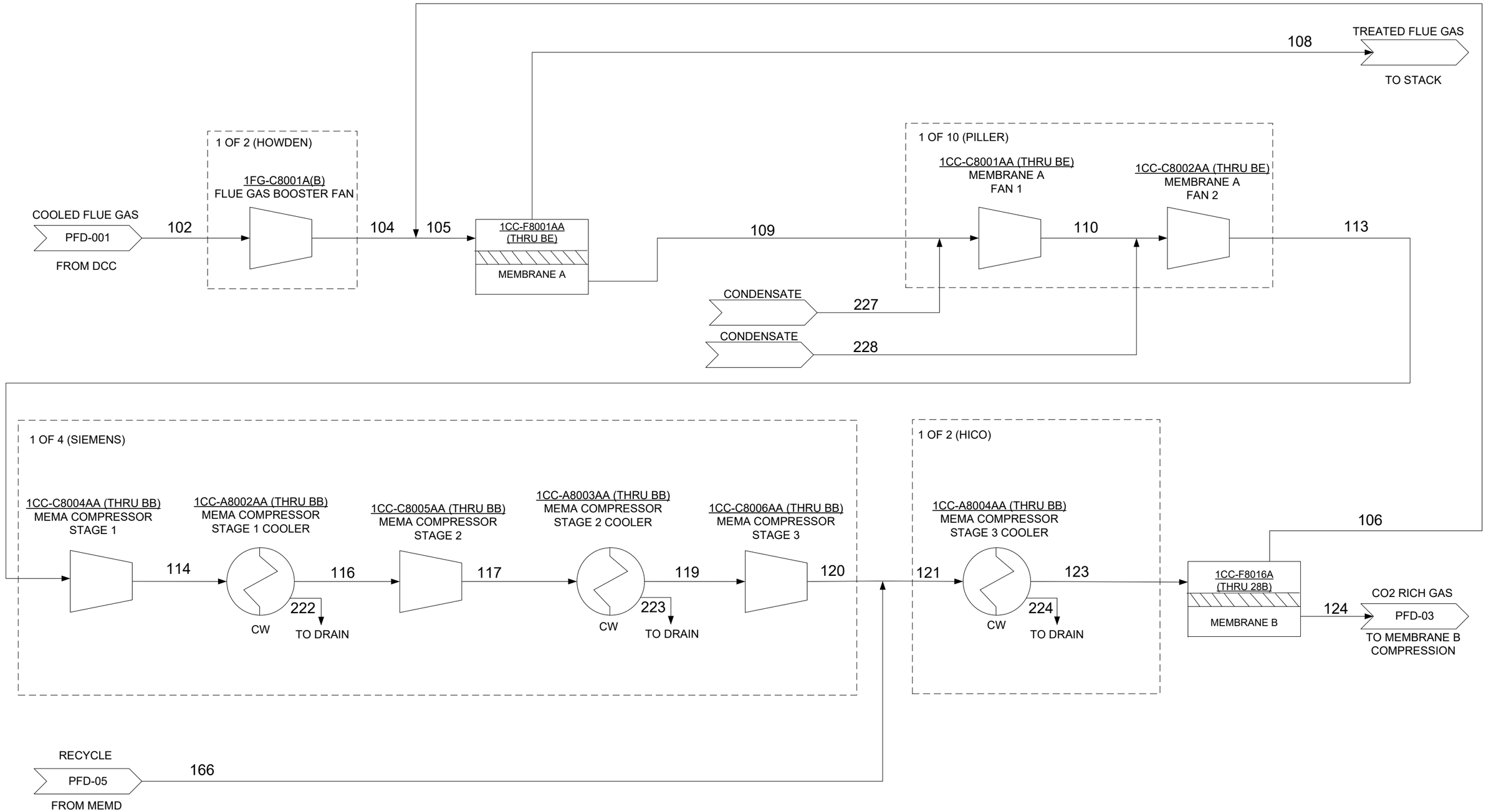
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1	3/24/2021	ISSUE WITH H&MB	AIR	MJM		
2	4/15/2021	REVISE PER EXTERNAL REVIEW	AIR	MJM		
3	9/17/2021	REVISE FOR EQUIPMENT SELECTION	AIR	MJM		

FILENAME	DATE		DRAWN BY
MTR DFS FEED PFD REV 3.VSD	August 3,2020		Anne I Ryan

TRIMERIC CORPORATION
P.O. Box 826
Buda, Texas 78610

MTR DFS FULL SCALE
PROCESS FLOW DIAGRAM
DCC/SO2 POLISHER

CLIENT/SITE	JOB NUMBER
MEMBRANE TECHNOLOGY AND RESEARCH	50144.03
DRAWING NUMBER	SCALE
PFD-01	NONE



Dry Fork Station Full-Scale FEED

REVISIONS

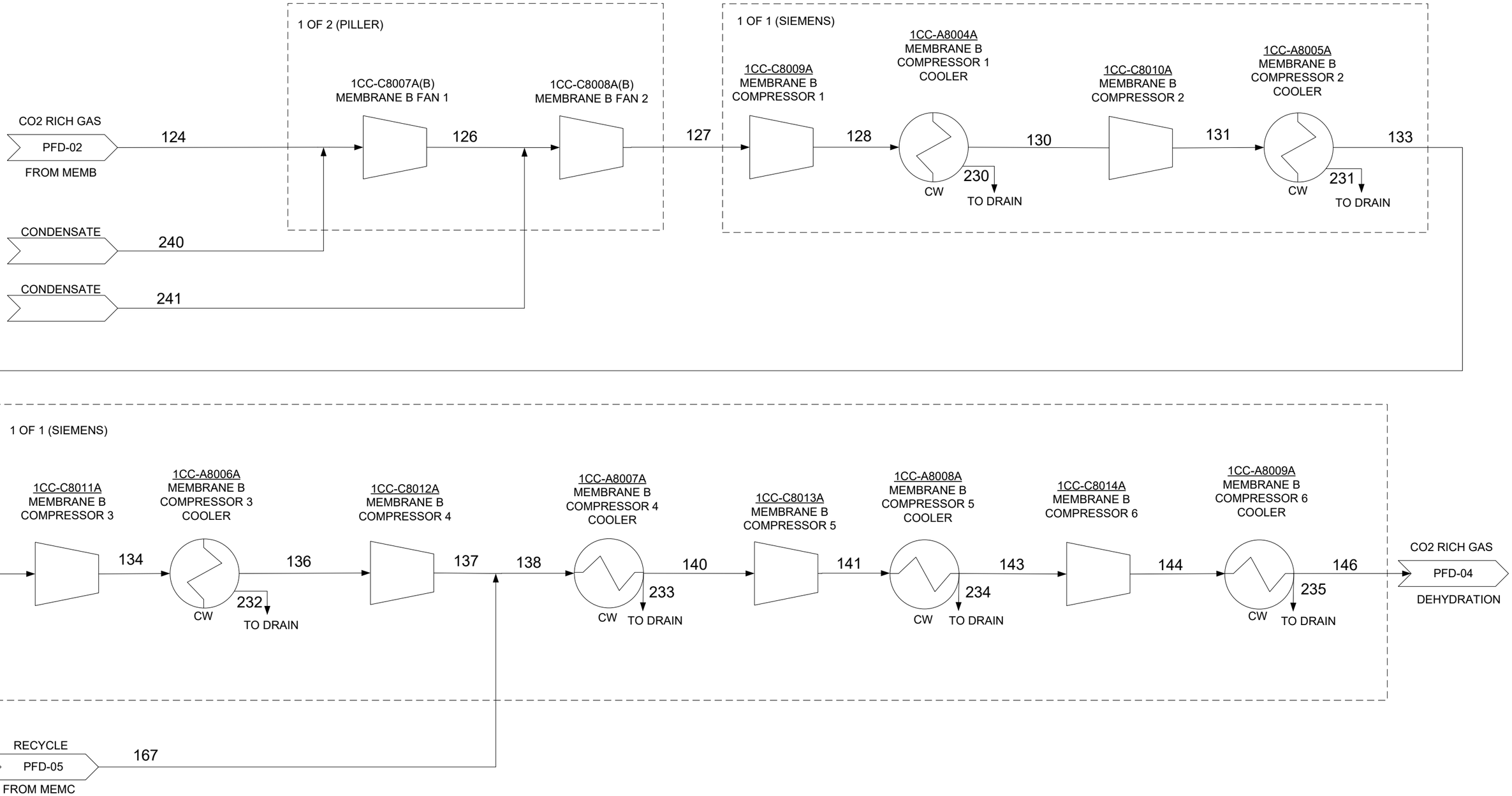
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1	3/24/2021	ISSUE FOR H&MB	AIR	MJM		
2	4/15/2021	REVISE PER EXTERNAL REVIEW	AIR	MJM		
3	9/17/2021	REVISE FOR EQUIPMENT SELECTION	AIR	MJM		

FILENAME	DATE		DRAWN BY
MTR DFS FEED PFD REV 3.VSD	August 2,2020		Anne I Ryan

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Buda, Texas 78610

MTR DFS FULL SCALE
PROCESS FLOW DIAGRAM
FLUE GAS CONDITIONING

CLIENT/SITE	JOB NUMBER
MEMBRANE TECHNOLOGY AND RESEARCH	50144.03
DRAWING NUMBER	SCALE
PFD-02	NONE



Dry Fork Station Full-Scale FEED

REVISIONS

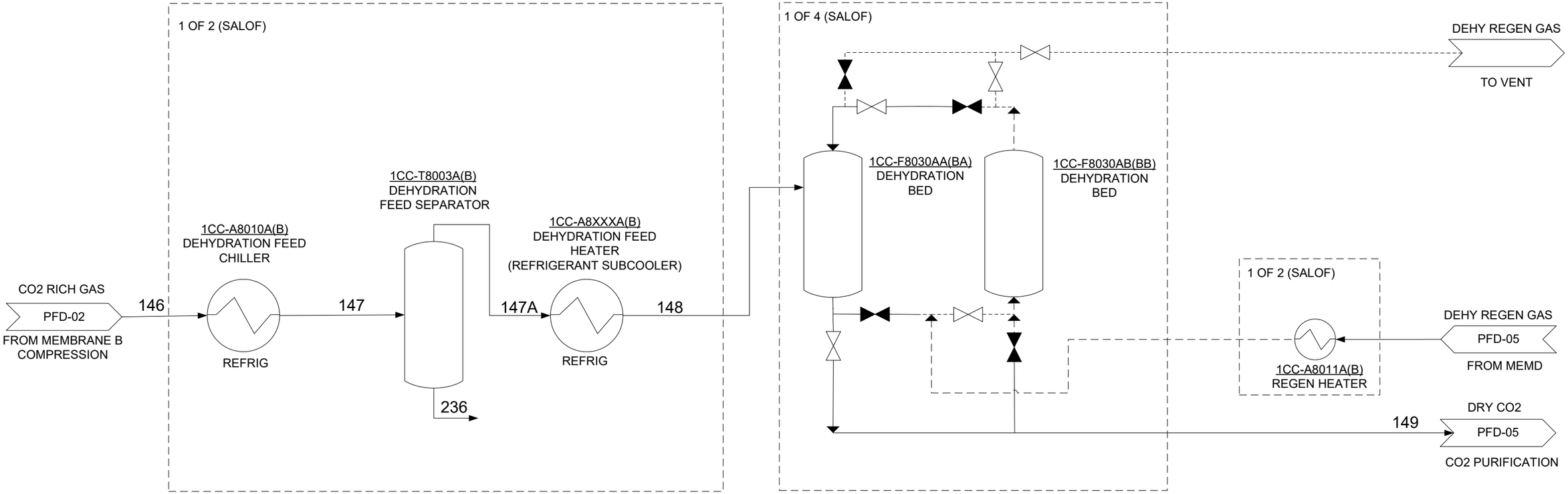
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1	3/24/2021	ISSUE WITH H&MB	AIR	MJM		
2	4/15/2021	REVISE PER EXTERNAL REVIEW	AIR	MJM		
3	9/17/2021	REVISE FOR EQUIPMENT SELECTION	AIR	MJM		

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MTR DFS FULL SCALE
PROCESS FLOW DIAGRAM
MEMB PERMEATE COMPRESSION

FILENAME	DATE		DRAWN BY
MTR DFS FEED PFD REV 3.VSD	August 2,2020		Anne I Ryan

CLIENT/SITE	JOB NUMBER
MEMBRANE TECHNOLOGY AND RESEARCH	50144.03
DRAWING NUMBER	SCALE
PFD-03	NONE



Dry Fork Station Full-Scale FEED

FILENAME	DATE		DRAWN BY
MTR DFS FEED PFD REV 3.VSD	August 2,2020		Anne I Ryan

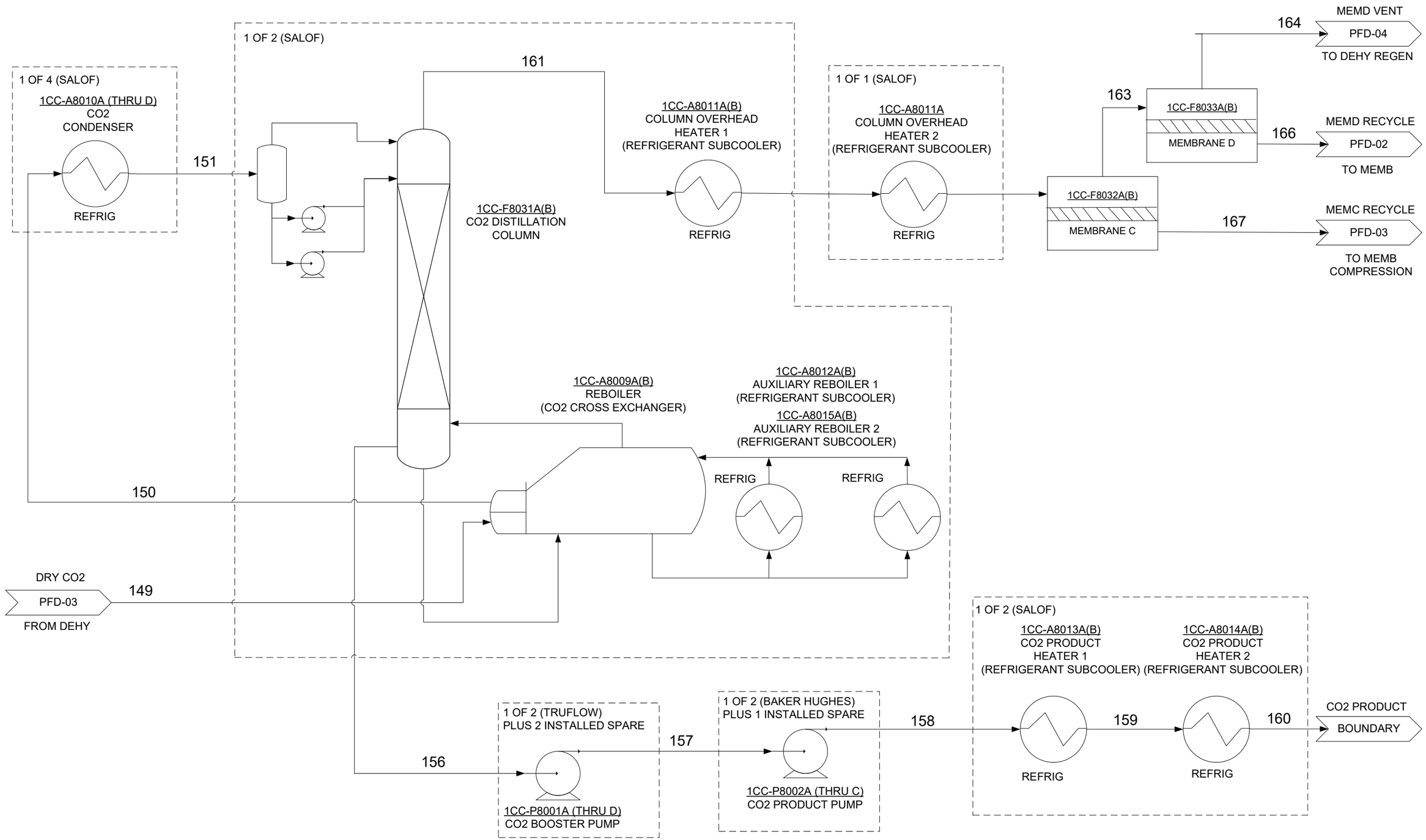
REVISIONS

REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
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1	3/24/2021	ISSUE WITH H&MB	AIR	MJM		
2	4/15/2021	REVISE PER EXTERNAL REVIEW	AIR	MJM		
3	9/17/2021	REVISE FOR EQUIPMENT SELECTION	AIR	MJM		

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MTR DFS FULL SCALE
PROCESS FLOW DIAGRAM
DEHYDRATION

CLIENT/SITE	JOB NUMBER
MEMBRANE TECHNOLOGY AND RESEARCH	50144.03
DRAWING NUMBER	SCALE
PFD-04	NONE



Dry Fork Station Full-Scale FEED

REVISIONS						
REV.	DATE	DESCRIPTION	BY	CHECKED	APPROVED	APPROVED
0	8/3/2020	PRELIMINARY DRAFT	AIR	RWM		
1	3/24/2021	ISSUE WITH H&MB	AIR	MJM		
2	4/15/2021	REVISE PER EXTERNAL REVIEW	AIR	MJM		
3	9/17/2021	REVISE FOR EQUIPMENT SELECTION	AIR	MJM		

FILENAME	DATE		DRAWN BY
MTR DFS FEED PFD REV 3.VSD	August 2,2020		Anne I Ryan

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P.O. Box 826
Buda, Texas 78610

MTR DFS FULL SCALE
PROCESS FLOW DIAGRAM
CO2 PURIFICATION

CLIENT/SITE	JOB NUMBER
MEMBRANE TECHNOLOGY AND RESEARCH	50144.03
DRAWING NUMBER	SCALE
PFD-05	NONE

APPENDIX E. EXISTING ID FAN MODIFICATION STUDY

Membrane Technology & Research

DRY FORK STATION UNIT 1

FULL SCALE CARBON CAPTURE FEED STUDY PROJECT

EXISTING ID FAN MODIFICATION STUDY

Issued for Design Release
Rev. 0

April 28, 2021
Project 13978-002

Prepared by

Sargent & Lundy

55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

ISSUE SUMMARY			
Revision	**Issue Purpose**	**Issue Date**	**Sections Affected**
A	Client Comments	4/14/2021	All
0	Design Release	4/28/2021	All

PREPARED, REVIEWED, AND APPROVED				
Revision	**Discipline**	**Prepared**	**Reviewed**	**Approved**
A	Mechanical	Kelly Gandy	Marion Teslik	Dana B. Pierik S&L Project Manager
0	Mechanical	Kelly Gandy	Marion Teslik	Dana B. Pierik S&L Project Manager

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2.2 NEW DUCTWORK ROUTING AND PRESSURE DROP 3

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ATTACHMENTS

Attachment A: Pressure Loss Calculation

Attachment B: TLT Babcock Fan Curves

Attachment C: Howden Fan Tipping Quote

REFERENCES

Reference A: DFS CO2 Capture Tie-In Design Basis Calculation Rev. 2

Reference B: MES 13.8 – Boiler Fans and Ductwork Systems

1. PROJECT OVERVIEW

As part of the Membrane Technology and Research, Inc. (MTR), full scale, Front End Engineering Design (FEED) study for retrofitting MTR's membrane CO_2 capture technology to the Basin Electric Power Cooperative (Basin) Dry Fork Station (DFS), Sargent & Lundy (S&L) has prepared this existing Induced Draft (ID) fan evaluation for the following main purposes.

1. Determine the capabilities of the existing ID fan.
2. Calculate the pressure drop of the new flue gas duct route from the ID fan outlets to the inlet of the flue gas booster fan (part of the carbon capture system).
3. Evaluate the option of tipping the existing ID fan blades if the ID fan cannot currently overcome the static pressure of the new flue gas duct route.

Currently the existing two ID fans at DFS deliver flue gas from the baghouse to a common stack. For the carbon capture system being developed with MTR's membrane technology, new flue gas ductwork will tie into the existing ductwork downstream of each ID fan and will bypass the existing stack. From the stack bypass, the new ductwork from each ID fan will run eastward to a Direct Contact Cooler (DCC) and exit to a flue gas booster fan.

Without additional heating, the temperature of the flue gas exiting the DCC will be too low for optimal Membrane performance. Placing the booster fan between the DCC outlet and Membrane inlet will take advantage of the expected temperature increase of the flue gas during gas compression. This will avoid purchasing a dedicated heating system to preheat flue gas entering the Membrane and utilize heat that would have been sent to the cooling tower.

There is a strong desire by MTR to maintain a positive pressure throughout the ducting route to the flue gas booster fan to avoid having to design the DCC vessel for vacuum conditions, which can be very costly. The minimum flue gas booster fan inlet pressure required is assumed to be atmospheric pressure. This document considers the static pressure necessary to deliver flue gas to the new booster fans and evaluates the existing fan capability to meet this demand. If the ID fans cannot currently meet this demand, an option of tipping the fan blades will be evaluated.

2. DESIGN INPUT

2.1 EXISTING ID FAN OPERATING CONDITION

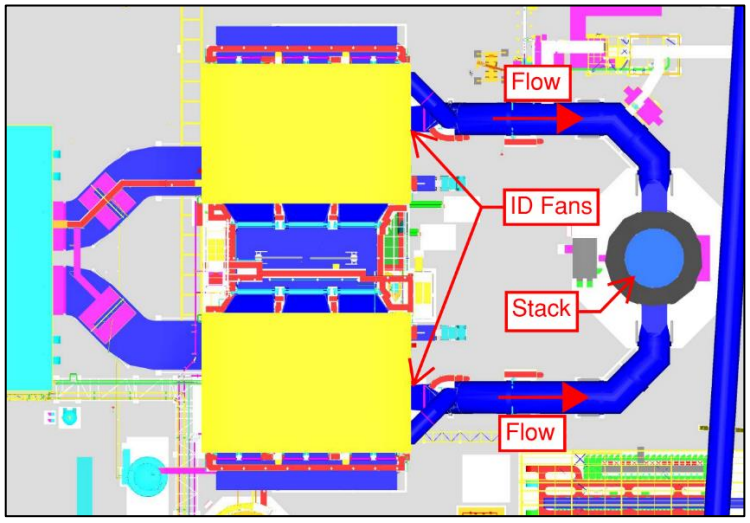
TLT-Babcock manufactured the two existing ID fans operating at DFS. The design conditions provided on their predicted performance and fan curve (Attachment B) do not reflect the current operating conditions of the plant. PI data collected from the plant was analyzed by S&L (Reference A) to determine the actual operating conditions of the plant. Table 2-1 below compares the TLT-Babcock predicted operating conditions to the actual operating conditions of the site.

Table 2-1: Predicted Operating Conditions vs. Actual

Performance Data	Inlet Temp. [°F]	Inlet Press. [in.H2O]	Outlet Press. [in.H2O]	Vol. Flow Rate [acfm]
TLT-Babcock	166	-36.5	0.5	852,263
PI Data	196	-33.2	1.9	832,842

As indicated in Table 2-1 above, the ID fans operate at a lower pressure rise and flow rate than originally predicted by the fan manufacturer. Based on the outlet pressure captured from the PI data, the current flue gas path from the ID fans through the existing duct route and out of the stack, as seen in Figure 2-1 below, requires an outlet pressure of 1.9 in.H2O.

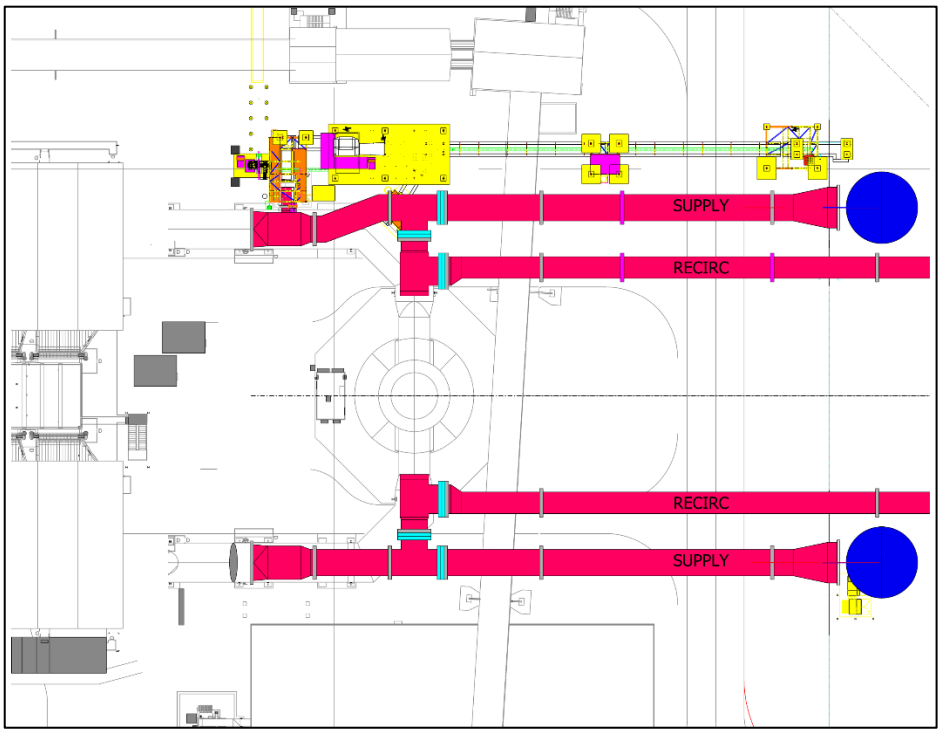
Figure 2-1: Existing Ductwork Plot View



2.2 NEW DUCTWORK ROUTING AND PRESSURE DROP

New ductwork was designed to tie into the existing ductwork downstream of the ID fans to deliver flue gas through the DCC to the flue gas booster fan inlet as shown below in Figure 2-2.

Figure 2-2: Proposed Ductwork Plot View



The ductwork was designed to maintain a velocity of up to 4,500 fpm as recommended by S&L guidelines (Reference B). Rectangular ducting was selected instead of the original site round ducting due to its lower overall installed cost to the project. A hydraulic diameter of at least 15 ft was required to achieve the necessary velocity. Given the space restrictions imposed by existing equipment in the area surrounding the stack, a rectangular supply duct size of 18 ft x 11 ft was selected leading to the DCC. Square 14 ft ducting was selected between the DCC and flue gas booster fan. The pressure drop of the ductwork was calculated (Attachment A) across this route as per Figure 2-3 and Figure 2-4.

Figure 2-3: Existing Ductwork to Carbon Capture (CC) Tie In

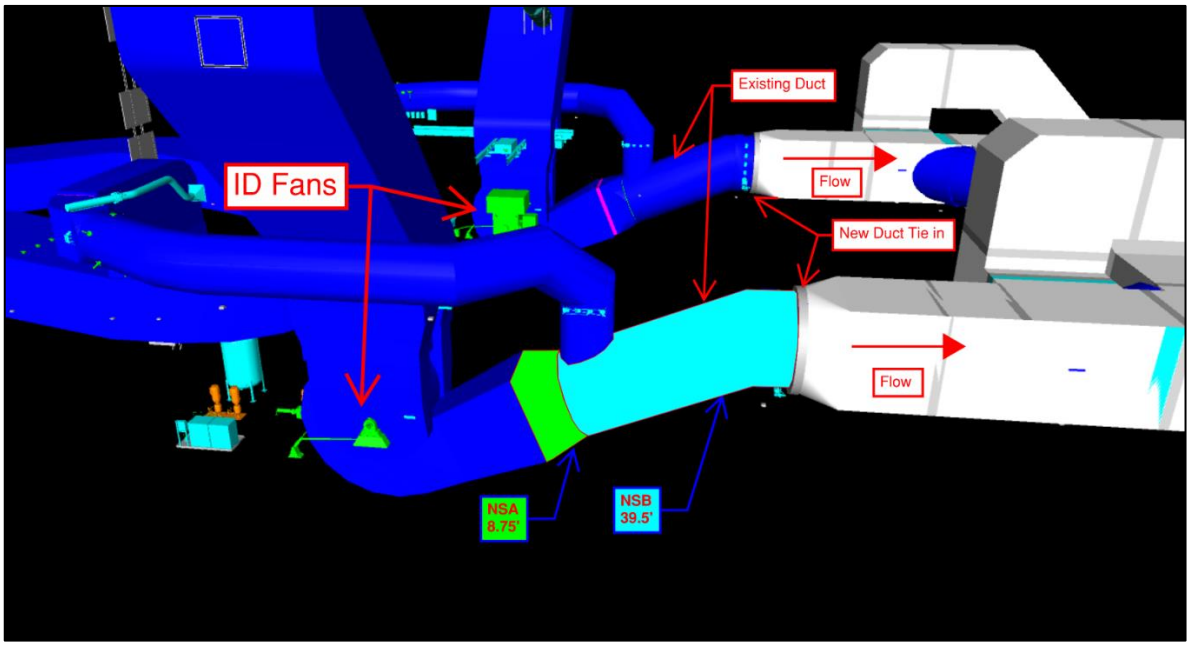


Figure 2-4: Carbon Capture Ductwork to DCC

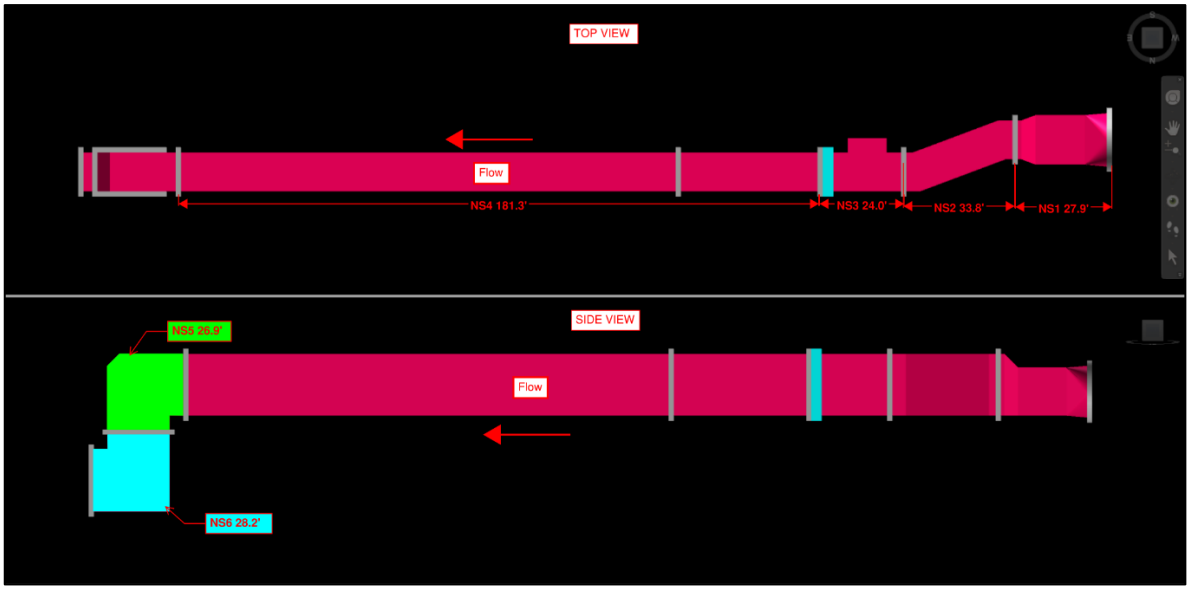


Table 2-2: Pressure Drop Leading to FG Booster Fan

ΔP ID Fan to CC Tie In [in.H2O]	ΔP CC Tie In to DCC [in.H2O]	ΔP Across the DCC [in.H2O]	ΔP DCC to FG Booster [in.H2O]
1.642	2.650	11.000	4.069

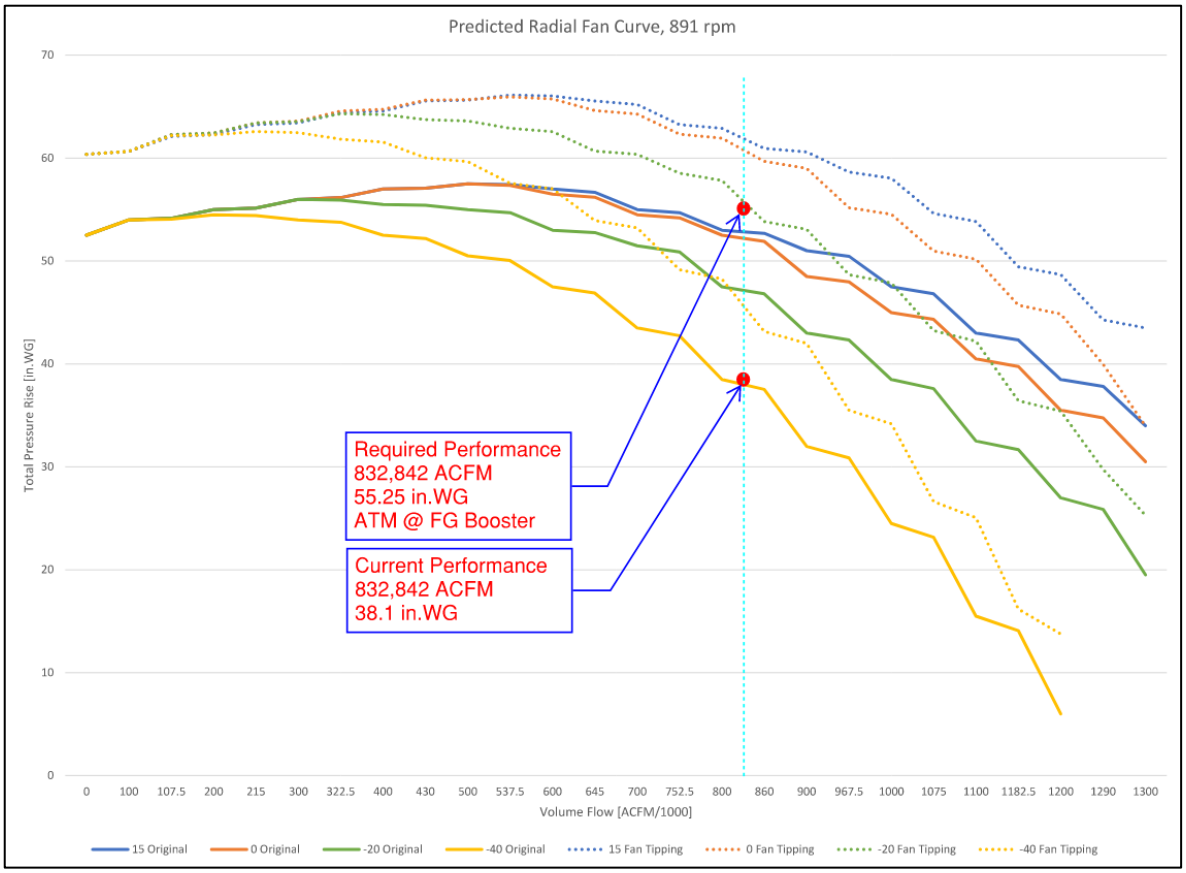
Table 2-2 above lists the calculated pressure drops across each section of ductwork. Assuming atmospheric pressure required at the flue gas booster fan inlet, the ID Fans must overcome a total static pressure of 19.339 in.H2O to deliver flue gas from the ID fan outlet to the inlet of the flue gas booster fan. This static pressure includes the existing ductwork between the ID fan outlet and new carbon capture ductwork tie in, the new carbon capture ductwork leading to the DCC, the DCC, and the ductwork between the DCC and flue gas booster fan. The existing ID Fans cannot meet this pressure requirement.

2.3 ID FAN BLADE TIPPING OPERATING LIMITS

The new outlet static pressure required per fan of 19.339 in.H2O at a flow rate of 832,842 acfm (Table 2-1) is beyond the current capabilities of the ID fans. The common industry practice of tipping the ID Fans for additional performance gains was considered to meet this new static pressure demand. S&L contacted Howden, who merged with TLT-Babcock, for a quote on tipping the fan blades and to establish the expected tipped fan performance. Howden advised that when tipping ID fan blades an increase of 7.5%, 15%, and 25.5% could be seen respectively in the flow rate, static pressure, and motor power consumption (Attachment C). In addition, Howden indicated a Finite Element Analysis (FEA) would have to be conducted to confirm that the existing wheel design can support the blade tipping. Using this information, new predicted fan performance curves were developed and overlayed on top of the original fan curves as seen below in Figure 2-5. The current plant ID fan operating point and the new required ID fan operating point were also plotted. According to the existing motor data sheet provided with the TLT-Babcock fan curves (Attachment B), the existing motor is rated to 9,000 hp and the current design power consumption at the fan shaft is 6,089 bhp. A 25.5% increase to this power consumption due to fan blade tipping would require 7,642 bhp at the fan shaft. Assuming a 15% margin to account for equipment degradation and power loss between the fan shaft and motor shaft would require a motor capable of at least 8,788 hp which is less than the rated 9000 hp of the current motor. The existing motor can therefore support the new demand requirement. In addition,

Sargent and Lundy evaluated the existing electrical infrastructure based on the plant single line diagrams and determined that the electrical infrastructure was designed to support the motor rating of 9000 hp.

Figure 2-5: Predicted Fan Performance Curve



As seen in the fan curve above, tipping the fan blade provides enough of a performance gain to the ID fan to overcome the pressure drop of the new duct route and DCC. The total pressure rise of 55.25 in.WG shown in Figure 2-5 includes an inlet vacuum of -33.2 in.H2O, 19.339 in.H2O pressure needed to overcome the proposed duct route, and allows for internal fan losses up to 2.711 in.H2O. Currently the ID fans, even at the maximum inlet vane configuration, cannot meet the pressure requirements to deliver flue gas to the booster fan at atmospheric pressure. Tipping the fan blades will be required to meet this demand and will provide a conservative pressure margin above the maximum ID fan inlet vane configuration in the event of additional pressure demand or fan degradation.

3. SUMMARY AND CONCLUSIONS

3.1 SUMMARY

The existing ID fans at Dry Fork Station cannot meet the static pressure requirements for the carbon capture retrofit. The static pressure developed by the new duct route and DCC to the flue gas booster fan is beyond the ID fans' current capabilities. To meet the static pressure demands of the carbon capture retrofit fan tipping will be required. This modification also allows for conservative pressure and flow margins to meet additional demands outside of normal operating conditions.

3.2 CONCLUSIONS

- The static pressure produced by the existing ID fans is too low to overcome the proposed duct route to the carbon capture system flue gas booster fans.
- Tipping the ID fan blades will produce enough pressure to overcome the proposed duct routing and deliver flue gas to the booster fan at atmospheric pressure.
- The existing motor and supporting electrical infrastructure can meet the new power consumption requirement due to tipping the fan blades.
- A DCC with a pressure drop of up to 11 in.H2O can be used in the duct routing to the flue gas booster fan when the fan blades are tipped.

ATTACHMENT A.
PRESSURE LOSS CALCULATION

Duct Section / Stream Number	Number of Streams	Mass Flow (lb_m/hr)	Gas Volumetric flow (acfm)	Inlet Gas Total Pressure (psia)	Inlet Gas Static Pressure (psia)	Inlet Gas Static Pressure (in.WC)	Gas Temp (°R)	Gas Temp (°F)	Gas Mol. Weight (g/mol)	Gas Density (lbm/ft^3)	Gas Viscosity (cP)	Gas Viscosity (ft^2/sec)	Duct Geometry (-)	Duct Height/ Duct Diameter (ft)	Duct Width (ft)	Duct Area (ft2)	Duct Perimeter (ft)	Duct Hydraulic Diameter (ft)	Gas Velocity (fpm)	Velocity Pressure (" H_20)	Duct Length (ft)	Reynolds number	Duct Roughness (ft)	Friction factor, f	Total Fitting Loss Coefficients	Duct Pressure Drop (" H20)	Outlet Gas Static Pressure (psia)	Outlet Gas Static Pressure (in.WC)	Outlet Gas Total Pressure (psia)	Outlet Gas Total Pressure (in.WC)	Inlet Gas Total Pressure (in.WC)
[NSA]	2	2,548,495	832,842	13.245	13.217	366.382	681	221.58	28.19	0.0510	0.0219	2.88E-04	Rectangular	15.75	12.38	194.9	56.3	13.9	4,273	0.77	8.8	3.42E+06	0.003	0.0142	0.061	0.054	13.215	366.328	13.243	367.102	367.155
[NSB]	2	2,548,495	832,842	13.249	13.215	366.328	681	221.58	28.19	0.0510	0.0219	2.88E-04	Circular	15.00		176.7	47.1	15.0	4,713	0.94	39.5	4.09E+06	0.003	0.0140	1.650	1.588	13.158	364.740	13.192	365.681	367.269
[NS1]	2	2,548,495	836,120	13.186	13.158	364.740	681	221.58	28.19	0.0508	0.0219	2.90E-04	Rectangular	14.00	14.00	196.0	56.0	14.0	4,266	0.77	27.9	3.44E+06	0.003	0.0142	0.064	0.071	13.155	364.669	13.183	365.437	365.508
[NS2]	2	2,548,495	837,770	13.183	13.155	364.669	681	221.58	28.19	0.0507	0.0219	2.90E-04	Rectangular	18.00	11.00	198.0	58.0	13.7	4,231	0.75	33.8	3.32E+06	0.003	0.0143	0.102	0.104	13.152	364.565	13.179	365.319	365.423
[NS3]	2	2,548,495	837,770	13.179	13.152	364.565	681	221.58	28.19	0.0507	0.0219	2.90E-04	Rectangular	18.00	11.00	198.0	58.0	13.7	4,231	0.75	24.0	3.32E+06	0.003	0.0143	1.500	1.150	13.110	363.415	13.137	364.169	365.319
[NS4]	2	2,548,495	839,425	13.137	13.110	363.415	681	221.58	28.19	0.0506	0.0219	2.91E-04	Rectangular	18.00	11.00	198.0	58.0	13.7	4,240	0.76	181.3	3.32E+06	0.003	0.0143		0.143	13.105	363.271	13.132	364.027	364.171
[NS5]	2	2,548,495	841,087	13.132	13.105	363.271	681	221.58	28.19	0.0505	0.0219	2.91E-04	Rectangular	18.00	11.00	198.0	58.0	13.7	4,248	0.76	26.9	3.32E+06	0.003	0.0143	0.752	0.590	13.084	362.681	13.111	363.438	364.029
[NS6]	2	2,548,495	841,087	13.111	13.084	362.681	681	221.58	28.19	0.0505	0.0219	2.91E-04	Rectangular	18.00	11.00	198.0	58.0	13.7	4,248	0.76	28.2	3.32E+06	0.003	0.0143	0.752	0.591	13.062	362.090	13.090	362.847	363.438
[DCC]	2	2,548,495	842,756	13.062	13.062	362.090	681	221.58	28.19	0.0504	0.0219	2.92E-04	Circular	30.00		706.9	94.2	30.0	1,192		50.0	2.04E+06	0.003	0.0128		11.000	12.666	351.090	12.666	351.090	362.090
[NS7]	2	2,548,495	868,608	12.694	12.666	351.090	681	221.58	28.19	0.0489	0.0219	3.01E-04	Rectangular	14.00	14.00	196.0	56.0	14.0	4,432	0.80	75.0	3.44E+06	0.003	0.0142	1.673	1.396	12.615	349.694	12.644	350.492	351.888
[NS8]	2	2,548,495	872,175	12.644	12.615	349.694	681	221.58	28.19	0.0487	0.0219	3.02E-04	Rectangular	14.00	14.00	196.0	56.0	14.0	4,450	0.80	30.0	3.44E+06	0.003	0.0142	3.305	2.672	12.519	347.021	12.548	347.822	350.495
[SUPPLY FGB]																									Total pressure drop for stream (SUPPLY FGB):	19.361					

ATTACHMENT B.
TLT BABCOCK FAN CURVES AND MOTOR DATA

TLT-BABCOCK, INC.
PREDICTED PERFORMANCE

PROJECT REFERENCES:

Date: 6/4/2007 — Proposal no.: 572-1800
Fan size: 1854AZ/2154/0 (Rbr=90) — Service: Induced Draft

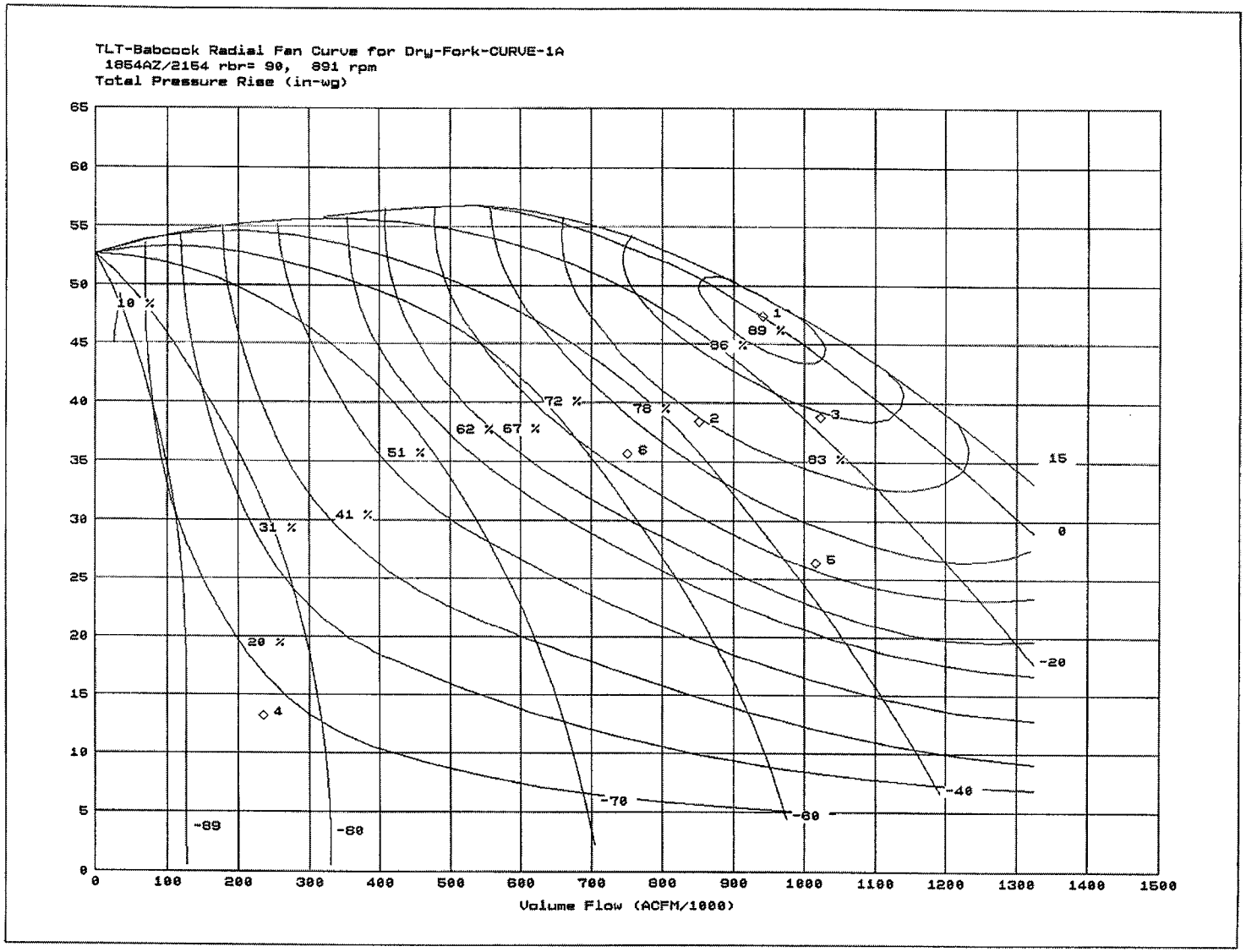
DESIGN CONDITIONS:

Test Block (°F): 166 — Design speed (rpm): 891
Design tip speed (fpm): 36,596 — WR2 (lb ft2): 435,801

OPERATING CONDITIONS (NEW AND CLEAN):

Load	Test Block	Table 1.1 Flue Gas Design	MCR - Perf Coal 44F - 1 BH Compartment Out	NE Calc - 25% Perf Coal - 100F Ambient	1 - Fan in Service NE Calc - 60% Perf Coal - 100F Ambient	HIL - Best Blend 100F Ambient
Curve Number	1A	1A	1A	1A	1A	1A
Point on Curve	1	2	3	4	5	6
Volume flow (acfm)	940,817	852,263	1,022,715	234,565	1,016,672	751,433
Inlet temperature (°F)	166	166	166	166	166	166
Inlet density (lb/acf)	0.0471	0.0480	0.0488	0.0514	0.0499	0.0485
Inlet pressure ("wg)	-44.55	-36.5	-36.5	-14.22	-24.59	-34.69
Static pressure rise ("wg)	44.85	37	37.05	14.27	24.84	35.04
LOSSES ("wg):						
Dynamic pressure rise	0.00	0.00	0.00	0.00	0.00	0.00
Inlet Box	0.66	0.55	0.81	0.04	0.82	0.43
IVC	0.46	0.38	0.56	0.03	0.57	0.30
Inlet Damper	0.19	0.16	0.23	0.01	0.24	0.12
Outlet Damper	0.19	0.16	0.23	0.01	0.24	0.12
Evase	0.75	0.63	0.92	0.05	0.93	0.49
Shaft	0.70	0.59	0.86	0.05	0.87	0.46
Rectangle to Round Adptr	0.05	0.04	0.06	0.00	0.06	0.03
SYSTEM PERFORMANCE:						
Total press. rise ("wg)	47.85	39.51	40.72	14.47	28.55	37.01
Fan total efficiency	89.0%	82.5%	85.7%	----	73.0%	74.2%
Power at fan shaft (bHp)	7473	6089	7213	----	5950	5615
Fan speed (rpm)	891	891	891	891	891	891

NOTES:
Fan Sizing and Performance based on use of Evase with outlet area = 227 ft2.

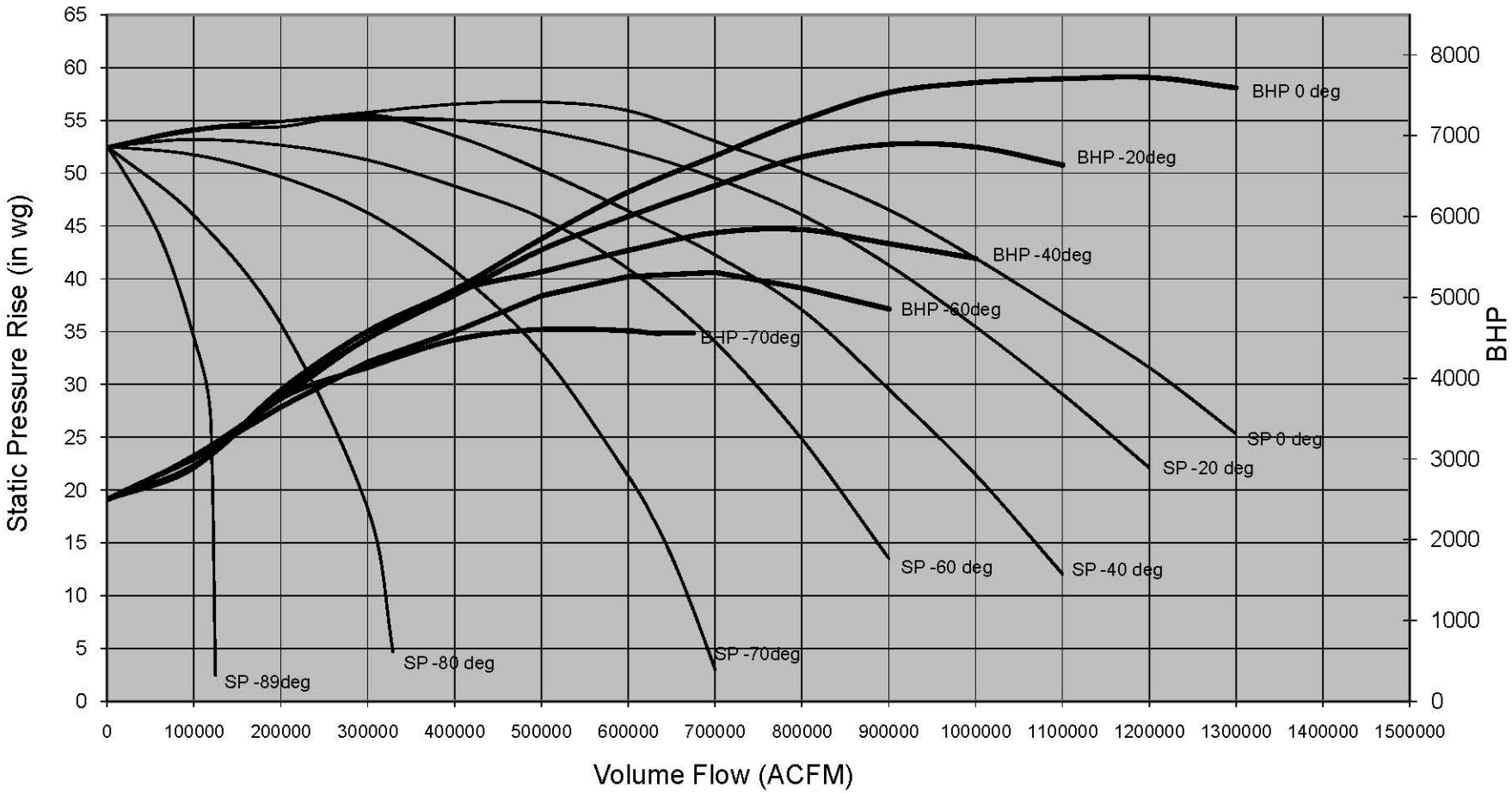

TLT-Babcock Radial Fan Curve for Dry-Fork-CURVE-1A
1854AZ/2154 rbr= 90, 891 rpm
Total Pressure Rise (in-wg)
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
Volume Flow (ACFM/1000)
10 %
31 %
41 %
51 %
62 %
67 %
72 %
78 %
83 %
86 %
89 %
15
0
-20
-40
-60
-70
-80
-89
1
2
3
4
5
6

Nooter Eriksen for Basin
Electric - Dry Fork 1

ID Fan Predicted Performance Curve

Static Pressure Rise and BHP vs. Flow
for Various Inlet Vane Positions
TLT-Babcock Fan Type: 1854AZ/2154/0 rbr=90

TLT-Babcock Inc.
project : 572-1800



DATA	
FRAME SIZE	1120-2500
MOTOR TYPE	INDUCTION
MOUNTING	HORIZONTAL
ENCLOSURE	WP2
HORSEPOWER	9000
VOLTAGE	13200
FULL LOAD AMPS	349
HERTZ	60
PHASE	3
SERVICE FACTOR	1.00
APPLICATION	FAN
LOAD TORQUE CURVE	TLT
LOAD WK^2 LB-FT2	435801
MOTOR WK LB-FT^2	54486
POLES	8
RPM	891
ROTATION	BI-DIRECTIONAL
INSULATION CLASS	F
AMBIENT TEMP	50 DEG C
ALTITUDE FT.	4263
TEMP. RISE C	70 DEG C AT 1.00 BY RESISTANCE
LOCKED ROTOR AMPS	2000A (572%)
STARTING TORQUE (%FLT)	99
PULL-OUT TORQUE (%FLT)	227
ACCEL. TIME 100% VOLTS	22.9 SECONDS
STALL TIME	35.3 SECONDS
MOTOR HEATER RATING	1 PHASE TO 4500W, 480 V, 3 PHASE
STATOR TEMP SENSOR	100 OHM PLATINUM (QTY=6) 3 LEADS
BEARING TEMP SENSOR	100 OHM PLATINUM 3 LEAD(1/BRG)DUAL ELEMENT
NOISE LEVEL	85 dB(a) AT 3 FEET
BRG OIL HEATER RATING	120V, 250W, 1 PHASE
DIFF PRESSURE SWITCH	DYWER 1950-0
VIBRATION	(PROVISIONS FOR ACCELEROMETERS)
DIFF CT RATIO	600:5, C200, QTY = 3

COMPONENT NOTES

A. 1.88 DIA HOLE THRU FRAME FOOT FOR 1.50 DIA HOLD-DOWN BOLTS. (8 PLACES TOTAL).

B. .719 DIA HOLE THRU FRAME FOOT FOR .75 DIA DOWEL. CUSTOMER TO DRILL AND REAM FOR .750 DOWEL PIN IN DIAGONALLY OPPOSITE FEET AFTER FINAL ALLIGNMENT.

C. 1.00-8 TAPPED HOLE IN FRAME FOOT FOR JACKSCREWS (4 PLACES TOTAL)

D. FOUR GROUNDING PADS. EACH PAD HAS TWO .50-13 TAPPED HOLES. HOLES ARE .50 DEEP ON 1.75 CENTERS.

E. REMOVABLE END COVERS FOR ACCESS TO WINDINGS AND UPPER AIR GAP CHECK. (BOTH ENDS)

F. FOUR LUGS FOR LIFTING ENTIRE MOTOR.

G. PROVISION FOR LIFTING ENCLOSURE ONLY.

H. AUX. COND. BOX (NEMA 4X) FOR STATOR/BEARING SENSOR LEADS. BOTTOM CABLE ENTRY SUPPLIED UNDRILLED.

J. AUX. COND. BOX (NEMA 4X) FOR SPACE HEATER LEADS. BOTTOM CABLE ENTRY SUPPLIED UNDRILLED.

K. MAIN CONDUIT BOX IS SUPPORTED BY THE MOTOR FRAME. BOTTOM ENTRY PLATE IS SUPPLIED UNDRILLED. 8.0 X 25.0 DIMENSIONS REPRESENT THE USABLE DRILLING AREA. DIMENSION 101.6 AND 33.1 LOCATE THE CENTER OF THE USABLE DRILLING AREA.

L. ACCESS TO SPACE HEATERS (BOTH SIDES)

M. AUX. COND. BOX (NEMA 4X) FOR CURRENT TRANSFORMER LEADS. BOTTOM CABLE ENTRY SUPPLIED UNDRILLED.

N. DWYER MODEL 1950-0 DIFFERENTIAL PRESSURE SWITCH WITH .50-NPT FEMALE OPENING FOR CUSTOMER CONNECTION.

P. BOTH BEARINGS ARE SUPPLIED WITH (2) .25-18 NPT TAP MOUNTING HOLES ON BEARING HOUSING 45 DEGREE FLATS FOR CUSTOMER (TLT-B) SUPPLIED ACCELEROMETER(S). ⚠

R. BEARING OIL SUMP HEATER (BOTH BEARINGS) (F2 SIDE)

REVIEWED FOR DESIGN INPUT/CONSTRUCTION
BASIN ELECTRIC POWER COOPERATIVE
DRY FORK STATION UNIT 1
SARGENT & LUNDY LLC

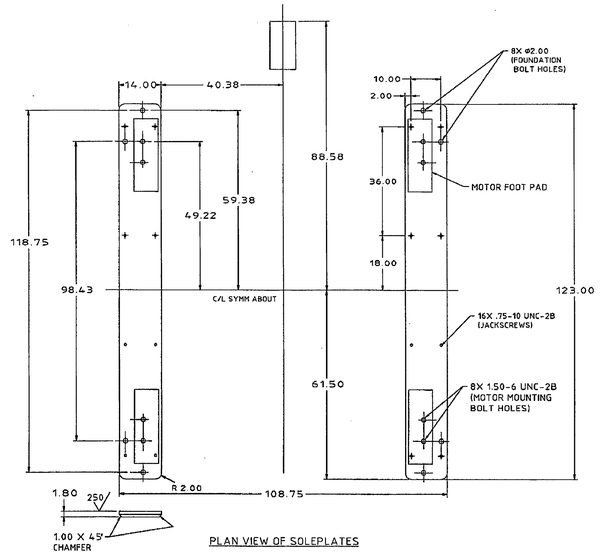
1. ☑ No exception taken. Contractor may proceed with fabrication or construction
2. ☐ Revise as noted and resubmit. Contractor can proceed based on making revisions noted.
3. ☐ Results do not meet specification requirement. Revise and resubmit. Hold Fabrication.
4. ☐ For information only.

ANY ACTION SHOWN ABOVE IS SUBJECT TO THE TERMS OF THE CONTRACT AND DOES NOT RELIEVE CONTRACTOR FROM THE OBLIGATIONS UNDER THE CONTRACT INCLUDING DESIGN AND DETAILING.

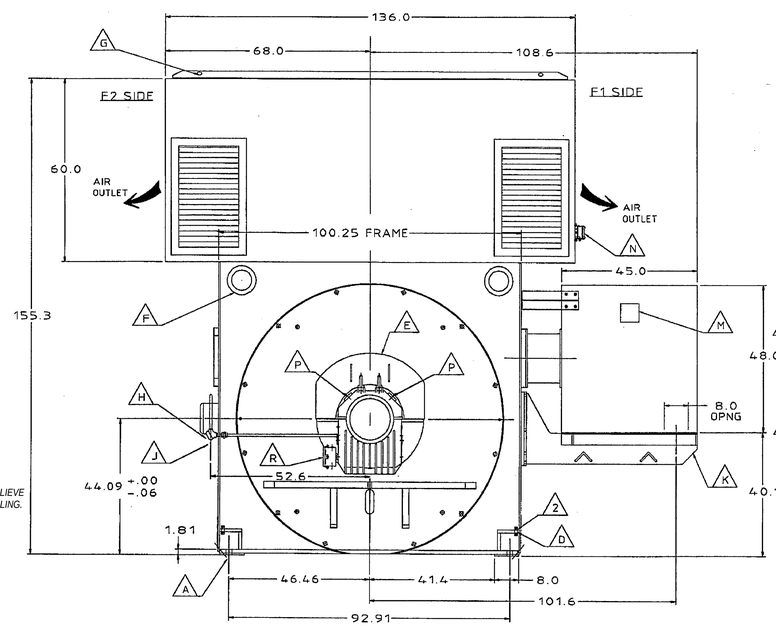
FOR: AQCS DESIGN & SUPPLY
RE: L. BARBIN
SPECIFICATION NO.: B-512266

DATE: DECEMBER 17, 2008
PROJECT NO.: 11786-002

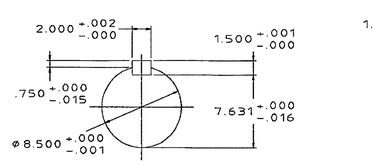
James D Barbin



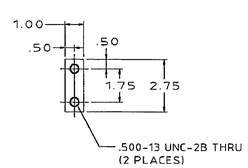
PLAN VIEW OF SOLEPLATES



VIEW FACING NON-DRIVE END

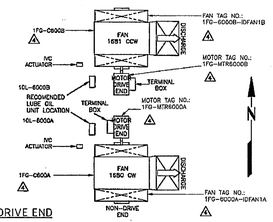


1 SHAFT EXTENSION

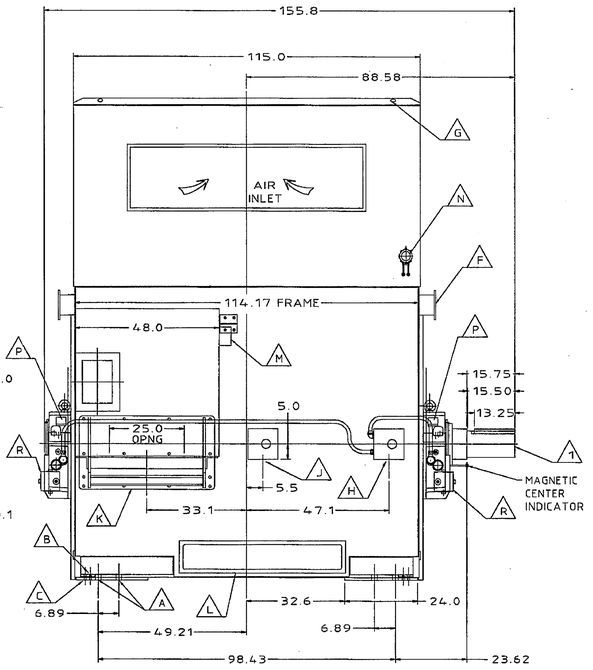


2 FOUR GROUND PADS

LOCATIONS OF STATOR RTDS						
RTD #	1	2	3	4	5	6
PHASE #	A1	C2	B3	A5	C6	B7



NON-DRIVE END DRIVE END



VIEW FACING F1 SIDE

APPROXIMATE WEIGHTS:	POUNDS
FRAME & STATOR	38,000
ROTOR	26,600
BRGS & BRKTS	8,000
CONDUIT BOXES	100
ENCLOSURE	4,800
MAIN CONDUIT BOX	2,000
TOTAL WEIGHT	79,500
SOLEPLATES	1,800

UNLESS OTHERWISE SPECIFIED DIM ARE IN INCHES
INTERPRET DIM AND TOL PER ASME Y14.5M - 1994

ANGLE PROJECTION

MOTOR OUTLINE DATA AND NOTES

TRANSMITTAL DATE:

171265	2924AA	C2924AA
CUSTOMER ORDER NUMBER	SHOP ORDER NUMBER	OUTLINE NUMBER

CUSTOMER: TLT BABCOCK ULTIMATE USER: -

☐ FOR APPROVAL. TO MAINTAIN SHIPPING SCHEDULE APPROVED DRAWINGS MUST BE RECEIVED BY TECO-WESTINGHOUSE ON:

DRAWINGS ARE IN COMPLIANCE WITH YOUR SPECIFIED REQUIREMENTS. DRAWINGS "APPROVED" OR "APPROVED WITH MODIFICATIONS" AUTHORIZE WESTINGHOUSE TO PROCEED WITH MANUFACTURING. MODIFICATIONS NOT IN THE CONTRACT OR MODIFICATIONS MADE DURING OR AFTER DRAWING APPROVAL MAY RESULT IN A PRICE CHANGE AND/OR SHIPMENT DELAY.

☐ FOR CONSTRUCTION OR INSTALLATION. THE EQUIPMENT SHOWN ON THESE DRAWINGS HAS BEEN RELEASED FOR MANUFACTURE. ANY MODIFICATIONS MAY RESULT IN A PRICE CHANGE OR SHIPMENT DELAY.

☐ ⚠ APPROVED BY ⚠

SEND APPROVALS OR INQUIRIES TO THE TECO-WESTINGHOUSE OFFICE WITH WHOM THE ORDER IS PLACED. THESE PRINTS SUPERSEDE PRINTS PREVIOUSLY PROVIDED.

NOTES:

1. GENERAL INSTRUCTIONS
   FOR THE MANUFACTURER'S WARRANTY ON THIS EQUIPMENT TO BE IN EFFECT, THE EQUIPMENT MUST BE INSTALLED IN STRICT ACCORDANCE WITH THIS DRAWING. CONSULT THE INSTRUCTION BOOK THAT HAS BEEN ISSUED FOR INSTALLATION AND OPERATING PROCEDURES. TECO-WESTINGHOUSE MOTOR COMPANY DOES NOT HAVE RESPONSIBILITY FOR LATERAL AND TORSIONAL CRITICAL SPEED PERFORMANCE OF THE INSTALLATION.
2. MOTOR FOUNDATION
   TECO-WESTINGHOUSE MOTOR COMPANY IS NOT RESPONSIBLE FOR THE DESIGN OF THE FOUNDATION. THE MOTOR WEIGHTS AND STATIC/DYNAMIC LOADS ARE LISTED ON THIS DRAWING. TECO-WESTINGHOUSE MOTOR COMPANY IS SUPPLYING SOLEPLATES FOR THIS MOTOR. REFER TO THE GROUTING INSTRUCTIONS ON THIS DRAWING FOR SUGGESTIONS ON THE INSTALLATION OF THESE MOUNTING PLATES. INSTALL THE SOLEPLATES WITH GROUT SUPPORT ALONG THEIR FULL LENGTH AND WITH THE FOUNDATION BOLTS FULLY TORQUED. THE SOLEPLATES SHOULD BE LEVEL AND IN ONE PLANE.
   FOUNDATION REACTIONS (IN POUNDS, VERTICAL DIRECTION, AT CENTERLINE OF EACH HOLD-DOWN BOLT):
   STATIC MOTOR WEIGHT/8
   RATED MOTOR TORQUE MOTOR WEIGHT/8 +/- 1712
   MAXIMUM MOTOR TORQUE MOTOR WEIGHT/8 +/- 15514
3. BEARING and LUBRICATION
   BOTH BEARING LINERS (SHELLS) ARE INSULATED FROM THE HOUSING. METAL CONNECTIONS MADE TO THE BEARING SHELL MUST BE INSULATED TO PREVENT AN INSULATION SHORT CIRCUIT. METAL CONNECTIONS MADE TO THE HOUSING DO NOT NEED TO BE INSULATED. A GROUNDING STRAP HAS BEEN PROVIDED AT THE DRIVE END. THIS GROUNDING STRAP MUST BE CONNECTED AT ALL TIMES WHILE THE MOTOR IS RUNNING. IT SHOULD ONLY BE DISCONNECTED TO MEGGAR THE BEARING INSULATION RESISTANCE.
   USE A GOOD QUALITY OF RUST AND OXIDATION INHIBITED TURBINE OIL WITH A VISCOSITY OF 200-270 SSU @ 100 F (ISO VG-46). THE VISCOSITY INDEX SHOULD NOT BE LESS THAN 95. LUBE OIL MUST HAVE POUR POINT SUFFICIENTLY BELOW LOWEST ANTICIPATED AMBIENT TEMPERATURE.

   NON-DRIVE END BEARING SIZE EMNLB 22-225 (8.858 DIA X 6.634 LENGTH)
   DRIVE END BEARING SIZE EMNLB 22-225 (8.858 DIA X 6.634 LENGTH)
   NON-DRIVE END BEARING OIL SUMP CAPACITY = 6.4 GALLONS
   DRIVE END BEARING OIL SUMP CAPACITY = 6.4 GALLONS

   THE MOTOR ENDPLAY IS 0.5 INCH TOTAL. BEARINGS ARE NOT DESIGNED TO TAKE END THRUST. A LIMITED ENDFLOAT TYPE OF COUPLING IS REQUIRED TO LIMIT THE ENDFLOAT TO 0.19 INCH TOTAL.
4. PHASE SEQUENCE AND ROTATION
   THE MOTOR IS DESIGNED WITH NON-DIRECTIONAL BLOWERS AND MAY BE OPERATED IN EITHER DIRECTION. THE DIRECTION OF ROTATION, FACING THE NON-DRIVE END OF THE MOTOR , IS CW WITH PHASE SEQUENCE T1, T2, T3 AND CCW WITH PHASE SEQUENCE T1, T3, T2.
5. SHIPPING PARTS LISTING
   THIS MOTOR WILL BE SHIPPED WITH THE MAIN LEAD BOX AND VENTILATION ENCLOSURE REMOVED. MOTOR WILL BE SHIPPED WITH THE CUSTOMER'S HALF COUPLING INSTALLED.ITEMS SHIPPED LOOSE: STAINLESS STEEL SHIMS, HOLD-DOWN BOLTS.
6. PARTS NOT SUPPLIED BY TECO-WESTINGHOUSE MOTOR COMPANY ⚠
   FOUNDATION BOLTS, COUPLING GUARDS, LIFTING BEAMS, SLINGS AND SPREADER BARS, LUBRICATING OIL, JACKSCREWS, AND DOWELS.
7. AIRGAP MEASUREMENT
   A PERIODIC PREVENTIVE MAINTENANCE CONSIDERATION IS THE AVERAGE VALUE OF THE ROTOR OD TO STATOR ID (AIRGAP). PROVISION HAS BEEN PROVIDED IN THE AIRSHIELDS OF THE MOTOR FOR MAKING THIS MEASUREMENT. MEASURE THE AIRGAP AT FOUR PLACES 90 DEGREES APART. THE VARIATION OF THE MINIMUM AND MAXIMUM AIRGAP FROM THE AVERAGE OF THESE VALUES MUST NOT BE GREATER THAN +/- 10%.
8. ENCLOSURE -
   AIR INTAKE OPENINGS ARE COVERED WITH #2 MESH STAINLESS STEEL SCREENS. EXHAUST OPENINGS ARE COVERED WITH #2 MESH STAINLESS STEEL SCREENS AND CARBON STEEL LOUVERS.
   AIR INTAKE FILTERS ARE RE-USEABLE GALVANIZED STEEL. TO SERVICE THESE FILTERS, WASH THROUGHLY AND DRAIN. CHARGE FILTERS WITH A COMMERCIAL ADHESIVE OR APPROPRIATE WEIGHT MINERAL OIL AND THEN RE-INSTALL.
9. STARTING DUTY
   WITH RATED VOLTAGE AND FREQUENCY (WITH NEMA TOLERANCE LIMITS) AT THE MOTOR TERMINALS AND WITH A CONNECTED LOAD INERTIA NOT EXCEEDING 435,801 LB-FT2 THE FOLLOWING DUTY SHOULD NOT BE EXCEEDED:
   MOTOR COLD: 2 CONSECUTIVE STARTS
   MOTOR AT OPERATING TEMPERATURE: 1 CONSECUTIVE STARTS
   SUBSEQUENT STARTS WITH THE MOTOR RUNNING BETWEEN STARTS:
   20 MINUTES APART OR WITH THE MOTOR STANDING BETWEEN STARTS 45 MINUTES APART.
   STARTS SHOULD NOT AVERAGE MORE THAN 6 PER DAY THROUGHOUT THE LIFE OF THE MOTOR.
10. TERMINALS
    THE FOLLOWING GROUND TERMINALS ARE BEING SUPPLIED WITH THIS MOTOR.
    FRAME: QUANTITY 1 OF BURNDY TYPE EA28-2N
    MAIN CONDUIT BOX: QUANTITY 1 OF BURNDY TYPE EA28-2N
11. TECO-WESTINGHOUSE MOTOR COMPANY IS SUPPLYING RECOMMENDED INSTRUMENT SETTINGS FOR THIS MOTOR.

REVISION HISTORY

ZONE	REV	DESCRIPTION	DATE	APPROVED
M7	02	R131993.AMBIENT TEMPERATURE WAS 40 . ALTITUDE WAS 4250FT. TEMPERATURE RISE WAS 80 DEG C.	20070821	C. HIDALGO D. MAZZ
	03	R132530. TAPPED HOLE SIZE IN DELTA NOTE P WAS ".375-24 UNF"	20071012	BERKEBILE R.MENDEZ J.PORTOS J.KECK
	04	R135584-ADDED SCHEMATIC DRAWINGS TO SHEET 2, ADDED STAINLESS STEEL SHIMS TO NOTE #5, DELETED TRIP SETTING .25 FROM DIFF PRESS SWITCH, ADDED (NEMA 4X) TO DELTA NOTE H, J & M. ADDED (F2 SIDE) TO DELTA NOTE R. MOTOR HEATER RATING WAS (2X) 1875W, 120V, 1PHASE, BRG OIL HEATER RATING WAS 240V, 250W, 1 PHASE & DIFF CT RATIO WAS 50:5, C100, QTY=3.	20080610	PEREZRAC R.MENDEZ J.PORTOS

REVISIONS

REVISION NO.	DESCRIPTION	DATE	APPROVAL	Z
1	ADDED KEY PLAN, TITLE BLOCKS, AMBIENT 50 DEG C, ELEVATION 4263 FEET ; F8 & M7			
2	ADDED PROJECT NAME & DELETED STATUS & RELEASE DATE FROM NE TITLE BLOCK (B3			
3	MADE CHANGES PER N-E COMMENTS ; SS-SHIMS - CA, MOTOR HEATER RATING 480V ; L7 & CHNGD VERT. PHONE HOLE DIA. -B-B	06/12/08		
4	CHGD FAN ID'S IN KEY PLAN (F6) & INSERTED TLT-B / SUPPLIED ACCELEROMETERS (K2)	10/09/08		

NOOTER/ERIKSEN INC.
VENDOR SUBMITTAL REVIEW

REVIEW OF VENDOR DRAWINGS DOES NOT RELIEVE THE VENDOR OF RESPONSIBILITY FOR ACCURACY OF DIMENSIONS AND CONFORMANCE TO CONTRACT AND/OR OTHER RESTRICTIONS AND NOTES INDICATED ON N-E DRAWINGS.

- X (A) REVIEWED AND ACCEPTED
- (B) REVIEWED WITH COMMENTS (WORK MAY PROCEED)
- (C) REVISE AND RESUBMIT (WORK MAY NOT PROCEED)
- (D) REVIEWED FOR INFORMATION ONLY

DRY FORK STATION # 1 11-28-08 GRL 06

NE DRAWING NO. 074137-DU-004 REV E | X

TLT-BABCOCK INC.

CONTRACT NO.: 572-1800			
CUSTOMER: NOOTER-ERIKSEN			
COMPONENT NO.: 21.00			
PART NO.: 111-8005			
DATE: 10/09/08	SHT: 1/2	DRW NO: 181960D	REV: 4

DRAWINGS

MOTOR CONNECTIONS	SEE SHEET 2
MOTOR SPACE HEATER	
STATOR TEMP SENSOR	
BEARING TEMP SENSOR	
DIFF PRESS SWITCH	
BEARING OIL HEATER	
GROUTING DETAILS	
MAIN CONDUIT BOX	B2924AA
SHAFT PROFILE	MS2924AA

RECOMMENDED INSTRUMENT SETTINGS

SENSOR	ALARM	TRIP
STATOR TEMPERATURE (C)	155	160
BEARING TEMPERATURE (C)	90	95
DIFF AIR PRESS SW. (IN.OF W.C.)	.25	
VIBRATION (HOUSING)	0.18 IPS	0.21 IPS

ALL SHEETS ARE THE SAME REVISION STATUS

DRAFTER	DATE	
BERKEBAT	20070530	
CHECKER	DATE	
FAERBER.K	YYYYMMDD	
MECHANICAL	DATE	
KECK.J	20070523	
ELECTRICAL	DATE	
PORTOS.J	20070523	
MAN.X.	DATE	
MAN.X.	YYYYMMDD	
APPD	DATE	
MENDEZ.R	20070523	
REF		

TECO-Westinghouse
5100 North IH-35
Round Rock, TX 78681

DRAWING TITLE
OUTLINE - DRAWING
AC IND 1120-2500 FRAME WP2
2924AA

SIZE	CAGE CODE	DRAWING NUMBER	REV
J		C2924AA	04
SCALE: NTS		SHEET	1/2

ATTACHMENT C.
HOWDEN FAN TIPPING QUOTE

Quotation (Aftermarket)

ISO 9001:2015 Certified

Attention:	Ms. Marion Teslik	From:	Marc Buchholz
Company/Representative:	Sargent & Lundy	Phone:	7168176989
Plant/Site:	Dry Fork Station	Email:	Marc.Buchholz@howden.com
Your Reference:			
Our Reference:	1854AZ/2154 CW and CCW (572-1800, A0	Fax:	866-810-9419
Market:	Power	Quote #:	HUSASEH.AFM.016129/A
General Assembly Drawing:	431480E-7	Date:	12/07/2020

Howden presents our offer as follows:

Item	Part Number	Description	Qty	Price Each	Lead Time to Ship
1	SPEC	Blade Tipping Performance Upgrade Package Includes: - Predicted Performance Curve - Set of (16) Blade Tips, Enough for One DWDI Fan - Installation Drawing / Instructions - One Package Required per Fan With Maximum Blade Tips They Can Expect the Following Increase Over Their Current Operating Conditions: - 7.5% Increase in the Existing Flow - 15% Increase in the Existing Static Pressure - 25.5% Increase in the Existing Power Consumption - 5% Increase in the Existing Rotary Inertia (WK^2) - Smaller Sized Tips Can be Used for Smaller Increases if Necessary/Required Note: Due to the Age and Condition of the Existing Fan, HUSA Cannot Guarantee the Amount of the Performance Gains Without Performing a Pre and a Post Tipping Performance Test (Price Not Included in This Quotation) - Field Installation is Not Included in This Quote but is Available. - At a Minimum it is Recommend a Howden USA Service Advisor is Hired on a Separate	1	19,575.00	14 Week(s)

		Contract to Supervise the Installation Welding, Balancing and Non Destructive Testing After Installation. See Our Rate Sheets.			
2	SPEC	Finite Element Analysis (FEA) to Determine Additional Stresses Induced by the Addition of Max Blade Tips and Confirm Wheel Design Can Support the Tips	1	15,000.00	6 Week(s)

Prices are in USD

Freight:	EXW (Origin) Incoterms 2020. No Freight Allowed. Failure to pick up or direct shipment of goods within 10 business days after written notice of availability by Howden may result in a $500 storage fee per week until actual pickup or shipment date.

This quote is subject only to Howden USA's Standard Terms and Conditions of Sale, (available at www.howden.com). Unless otherwise negotiated and agreed to by HUSA in writing, no other terms shall apply regardless of any statement on Buyer's documents to the contrary.

Howden Americas does not accept Liquidated Damages or in place warranty as standard business practice.

*If quoted lead time does not meet your requirements, please advise.

For Prepay and Charge orders, there will be a 4% charge of the net selling price applied to Buyer's invoice as a separate item to cover the standard transportation and handling expenses to the first North American destination. This does not apply to overseas or expedited shipments. In addition, any expense incurred by Seller because of special delivery arrangements requested by Buyer shall be billed to Buyer. Howden does not provide copies of freight invoices.

Pricing does not include Federal, State, Local, or Export taxes or duties.

Payment Terms are Net Thirty (30) days from invoice date, which is based on the freight terms quoted above.

Quote expires 30 days from noted and is subject to customer credit approval.

Minimum order value is $500.00.

Non inventory parts are not returnable; returned inventory parts are subject to restocking charges.

Quoted lead time is based upon material availability and factory loading at time of quotation, and may be subject to adjustment at order placement/acknowledgement.

If you have any questions, please contact us.

Sincerely,

Marc Buchholz

Uptime

See how Howden can help you minimise unplanned downtime and maximise efficiencies in your equipment through our Uptime solution.

Tap into remote assistance:
Augmented Reality live annotation technology with real-time communications to connect remote product experts to on-site field technicians.

Get Remote Support

APPENDIX F. NETL CO_2 PRODUCT QUALITY SPECIFICATIONS FOR EOR

Component	Units	Specification for Conceptual Design (Maximum Value unless otherwise stated)
CO_2	vol%	95 (Minimum)
N_2	vol%	1
H_2	vol%	1
Ar	vol%	1
CH_4	vol%	1
H_2O	ppmv	500
O_2	ppmv	10
CO	ppmv	35
H_2S	ppmv	100
SO_2	ppmv	100
NO_X	ppmv	100
NH_3	ppmv	50
COS	ppmv	5
C_2H_6	vol%	1
C_3^+	vol%	< 1
Particulate	ppmv	1
Glycol	ppbv	46
HCl	ppmv	Insufficient Data
HF	ppmv	Insufficient Data
HCN	ppmv	Trace
Hg	ppmv	Insufficient Data
MEA	ppmv	Insufficient Data
Selexol	ppmv	Insufficient Data

APPENDIX G. WIND ROSE DIAGRAMS

Figure G-1
Wind Rose – Annual (2002)

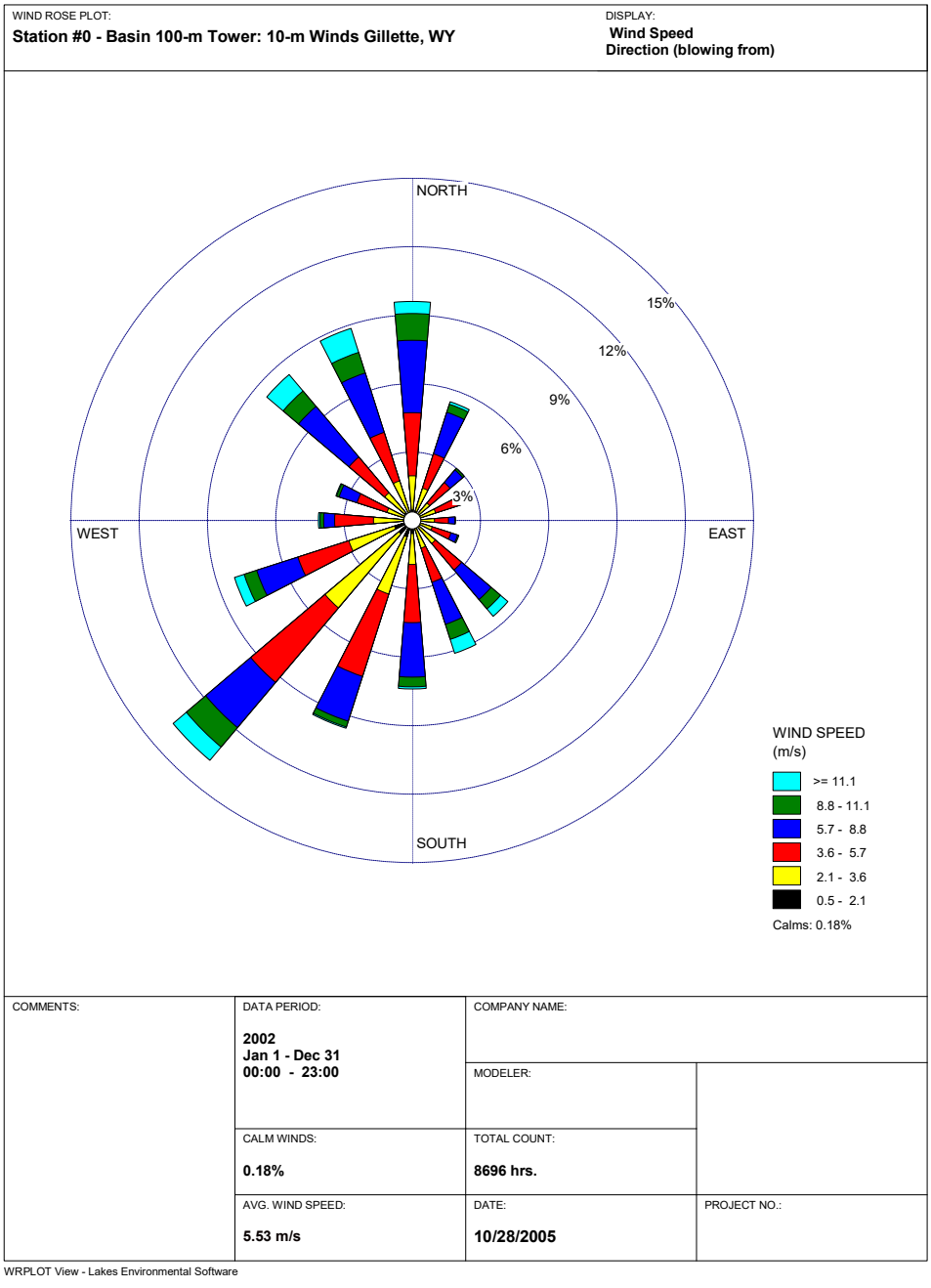


Figure G-2
Wind Rose – Winter Months (January-March 2002)

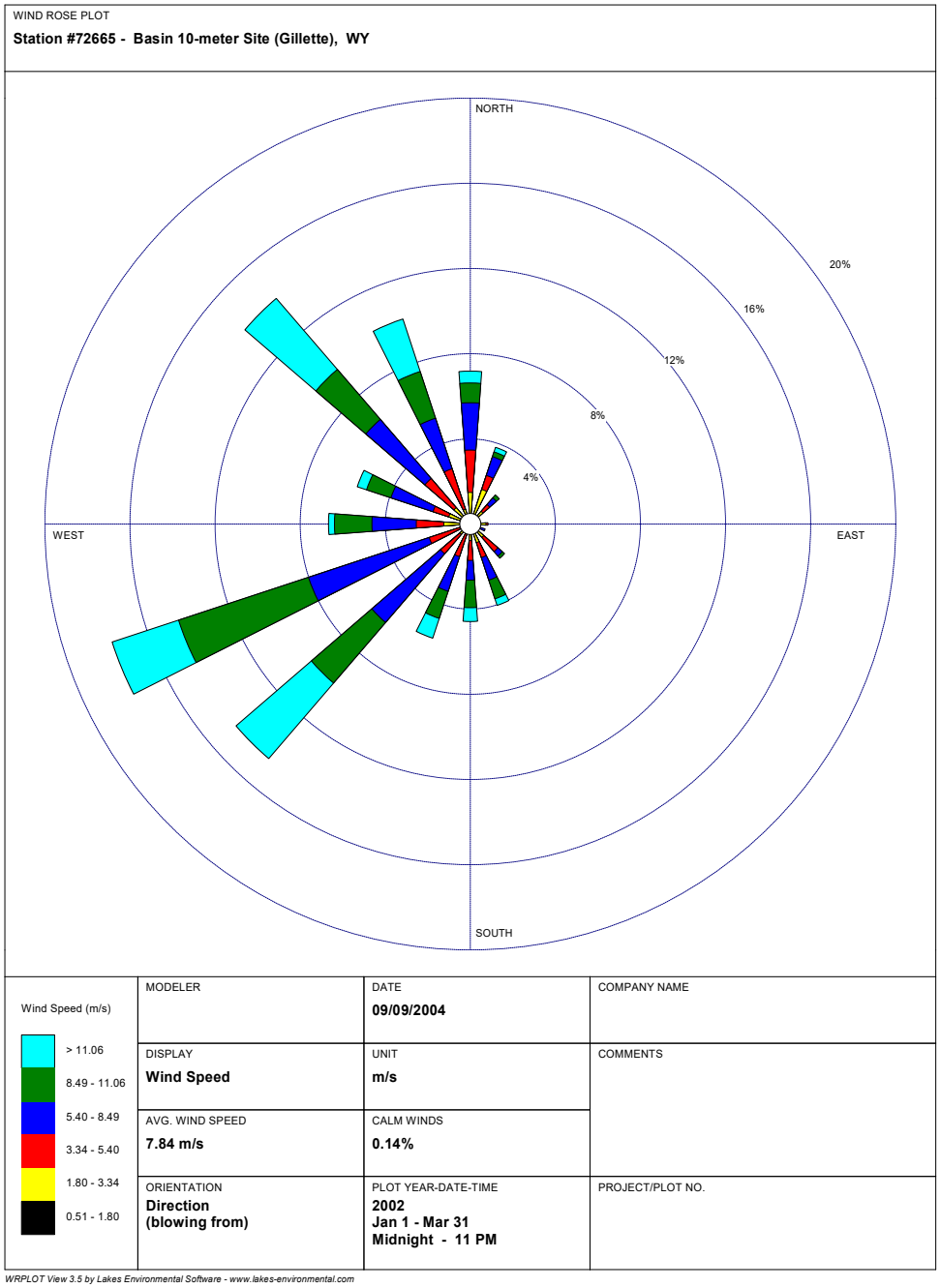


Figure G-3
Wind Rose – Spring Months (April-June 2002)

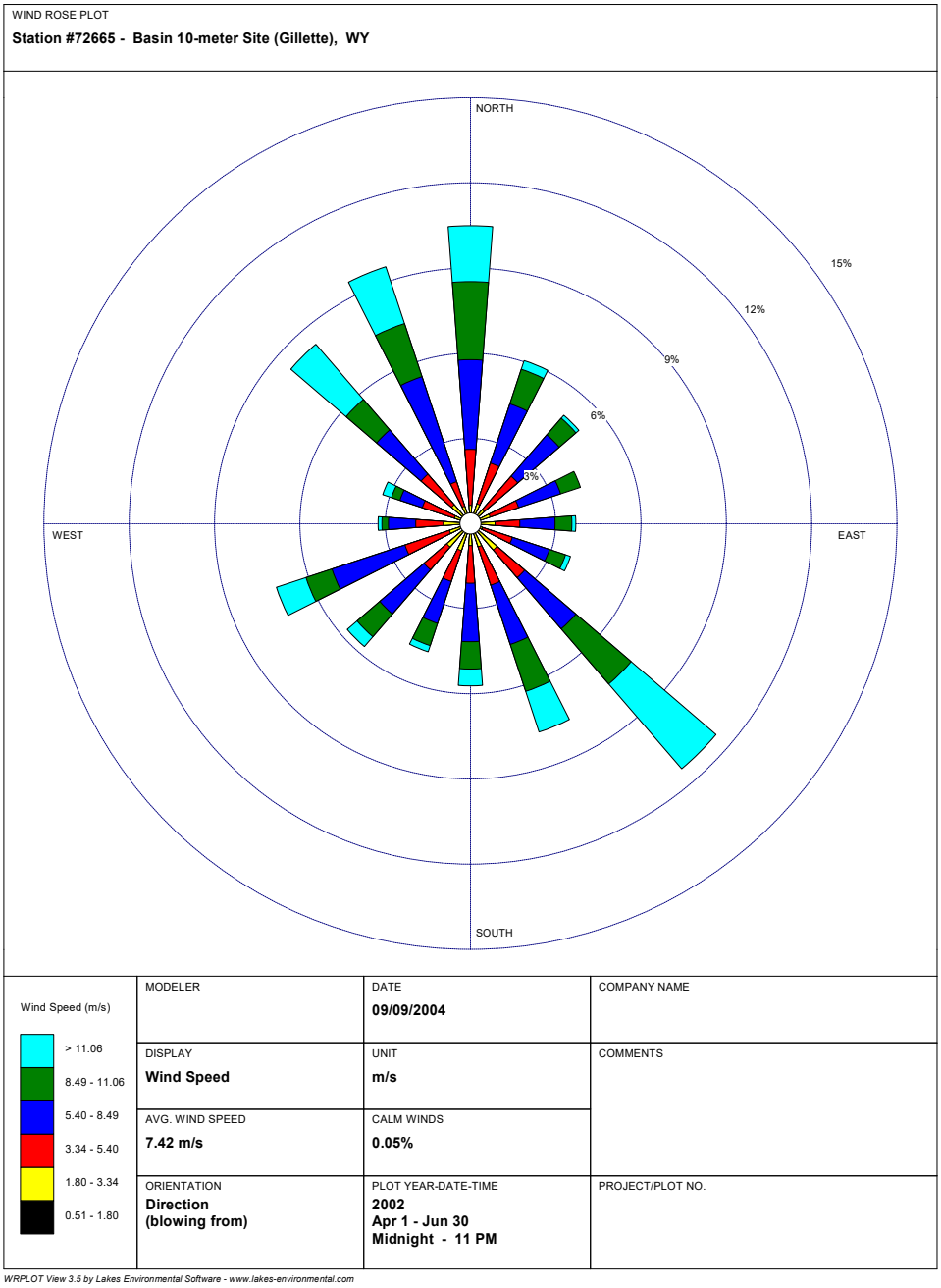


Figure G-4
Wind Rose – Summer Months (July-September 2002)

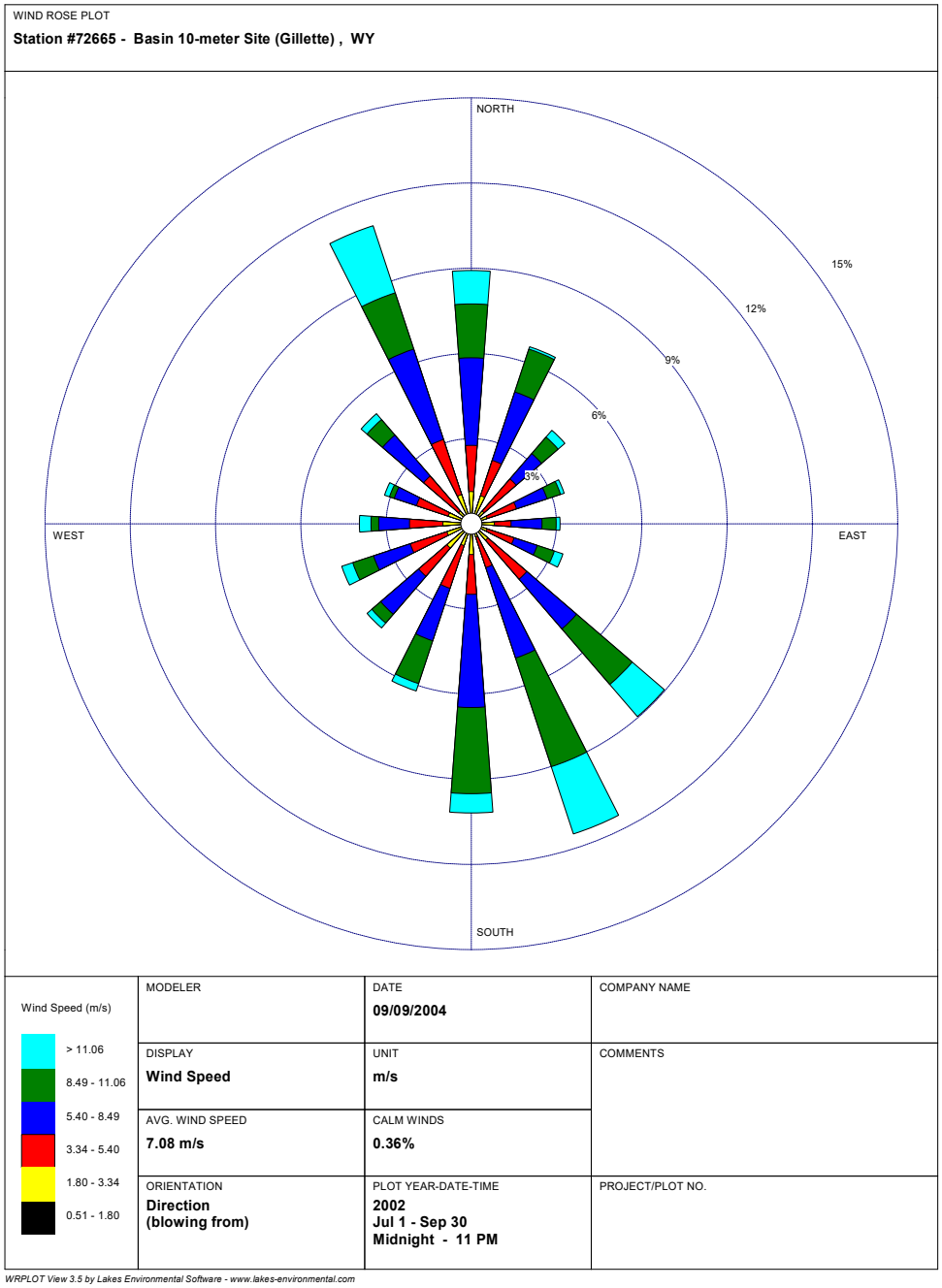


Figure G-5
Wind Rose – Summer Months (June-August 2002)

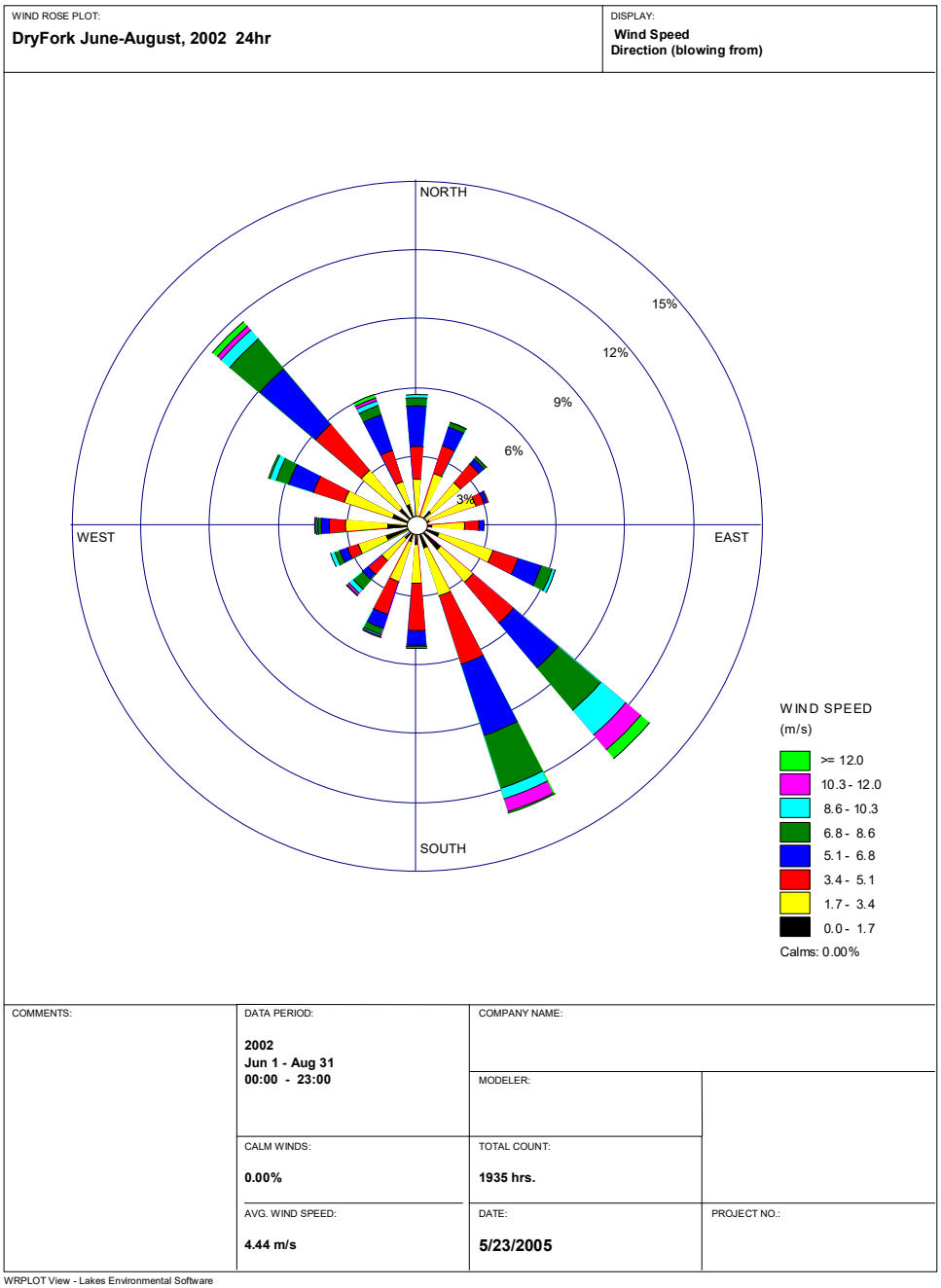


Figure G-6
Wind Rose – Summer Afternoon (Noon-6pm, June-August 2002)

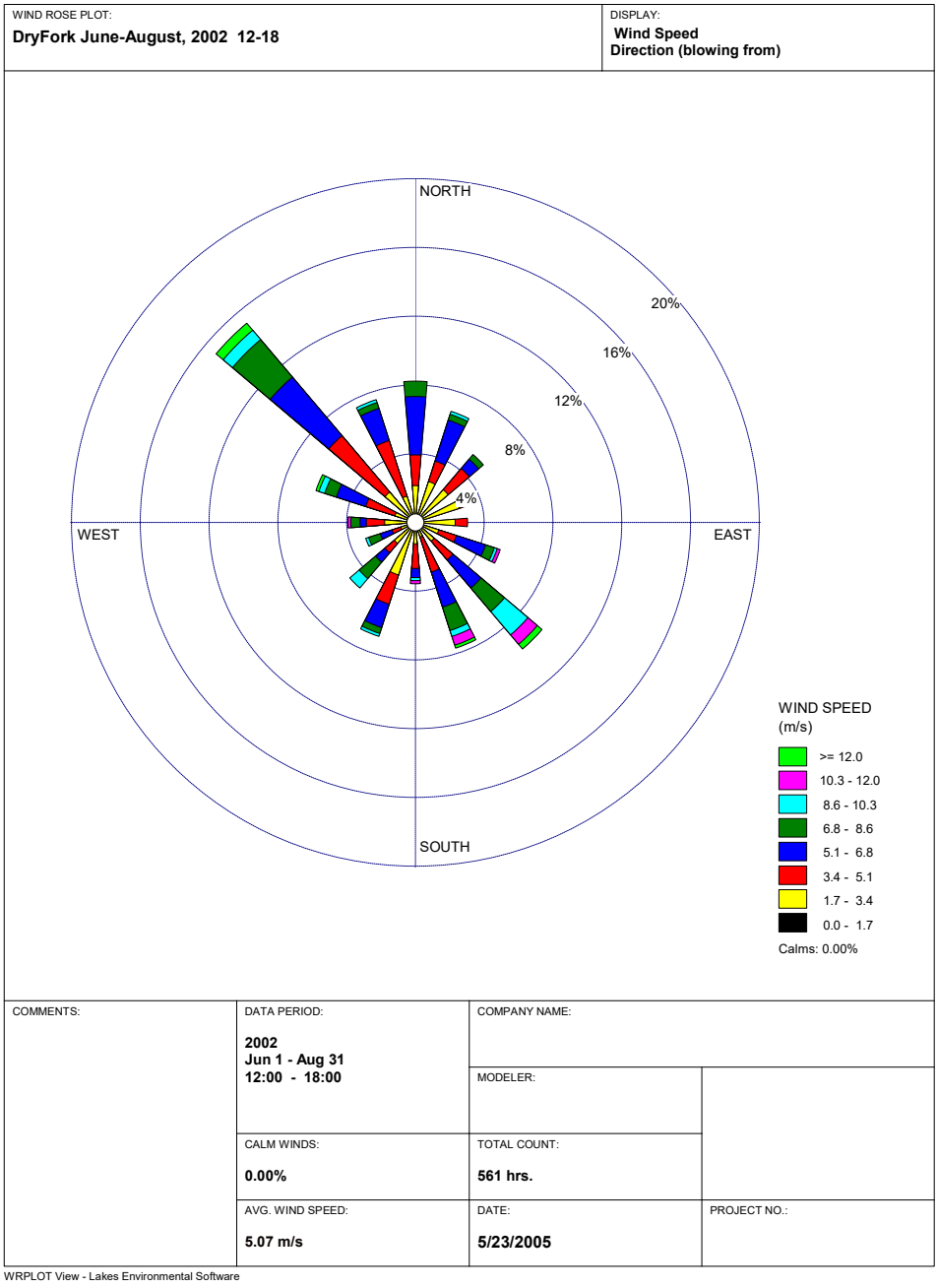


Figure G-7
Wind Rose – Summer Months (June-August 2003)

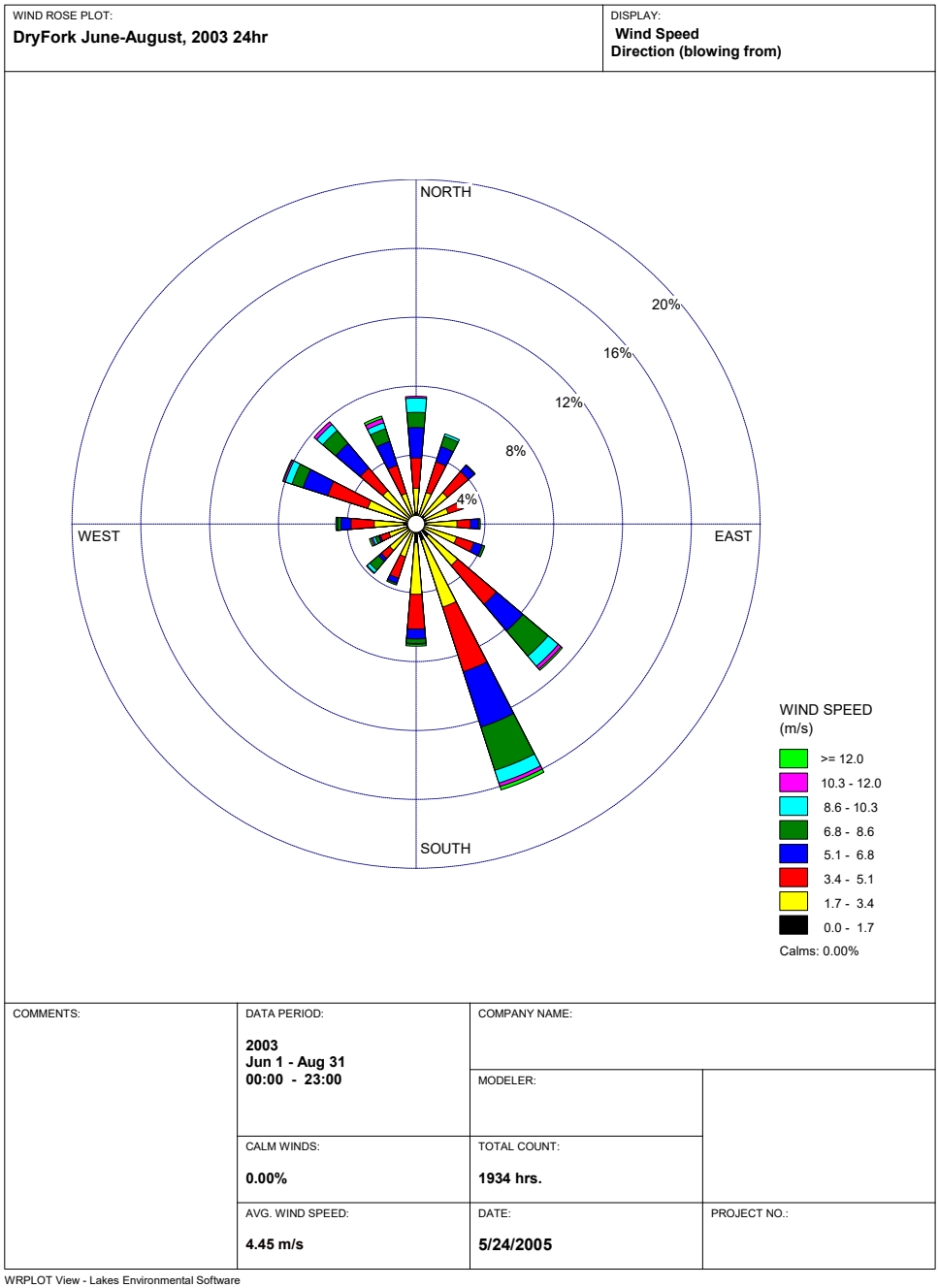


Figure G-8
Wind Rose – Summer Afternoon (Noon-6pm, June-August 2003)

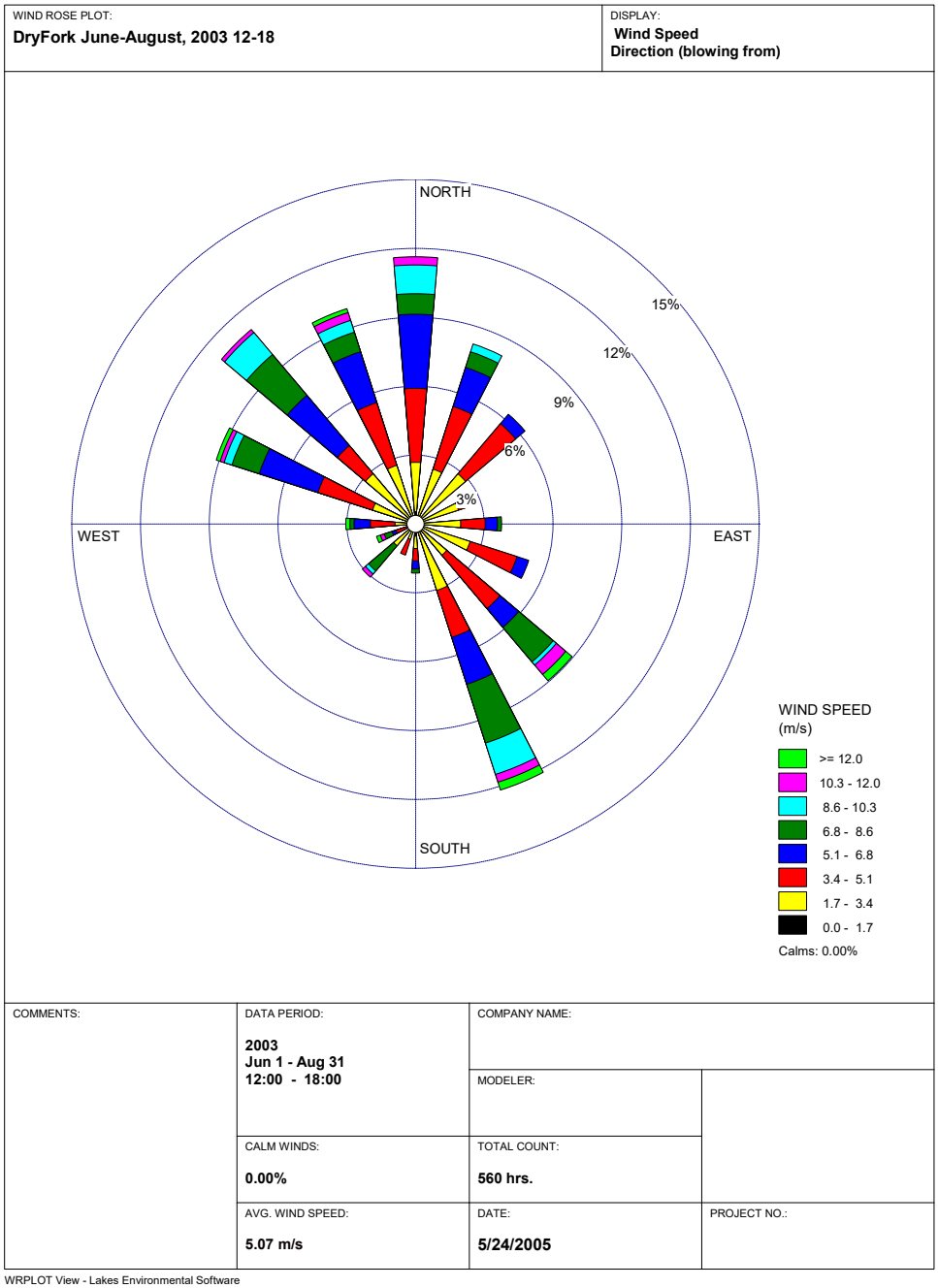


Figure G-9
Wind Rose – Summer Months (June-August 2004)

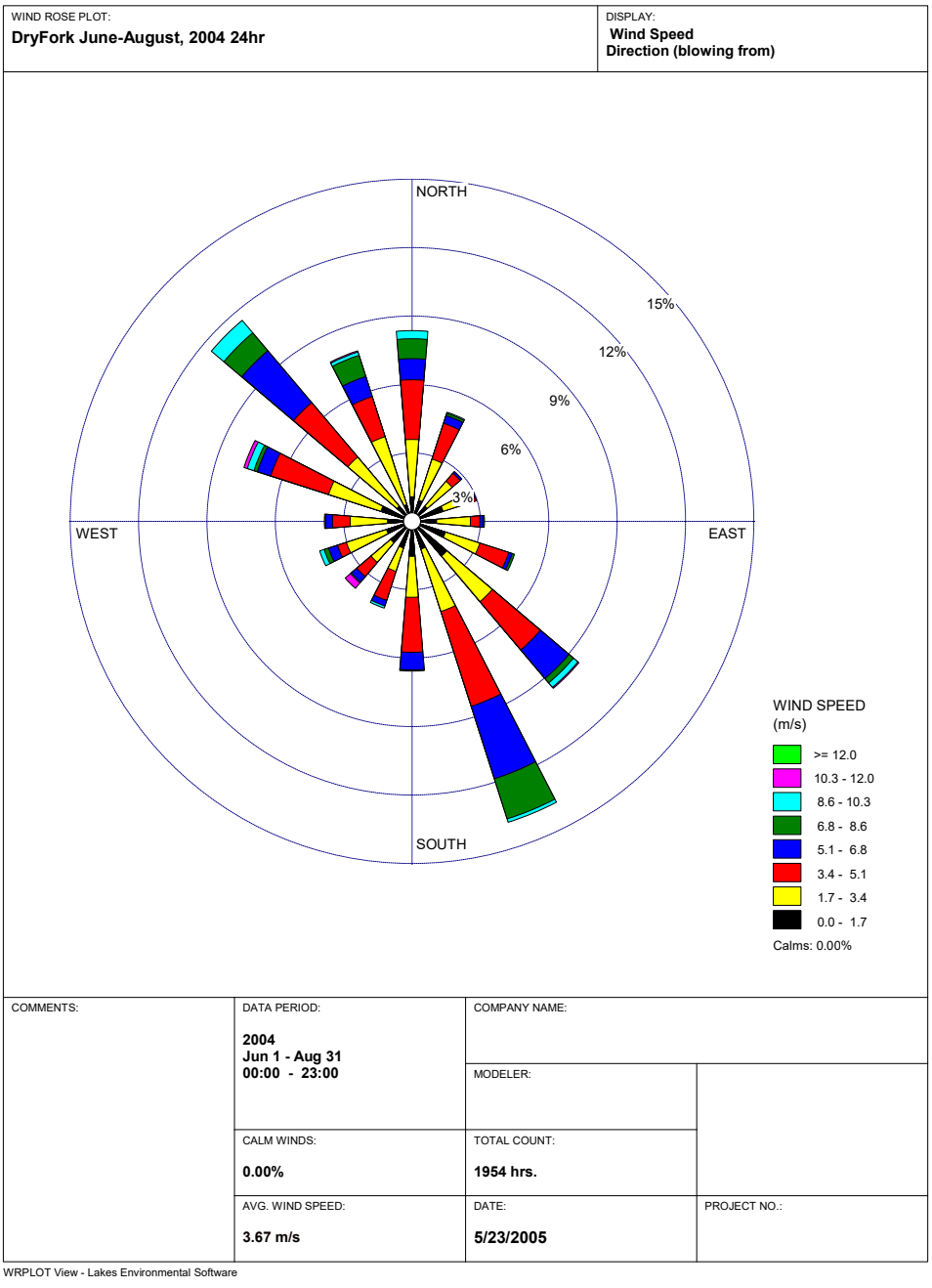


Figure G-10
Wind Rose – Summer Afternoon (Noon-6pm, June-August 2004)

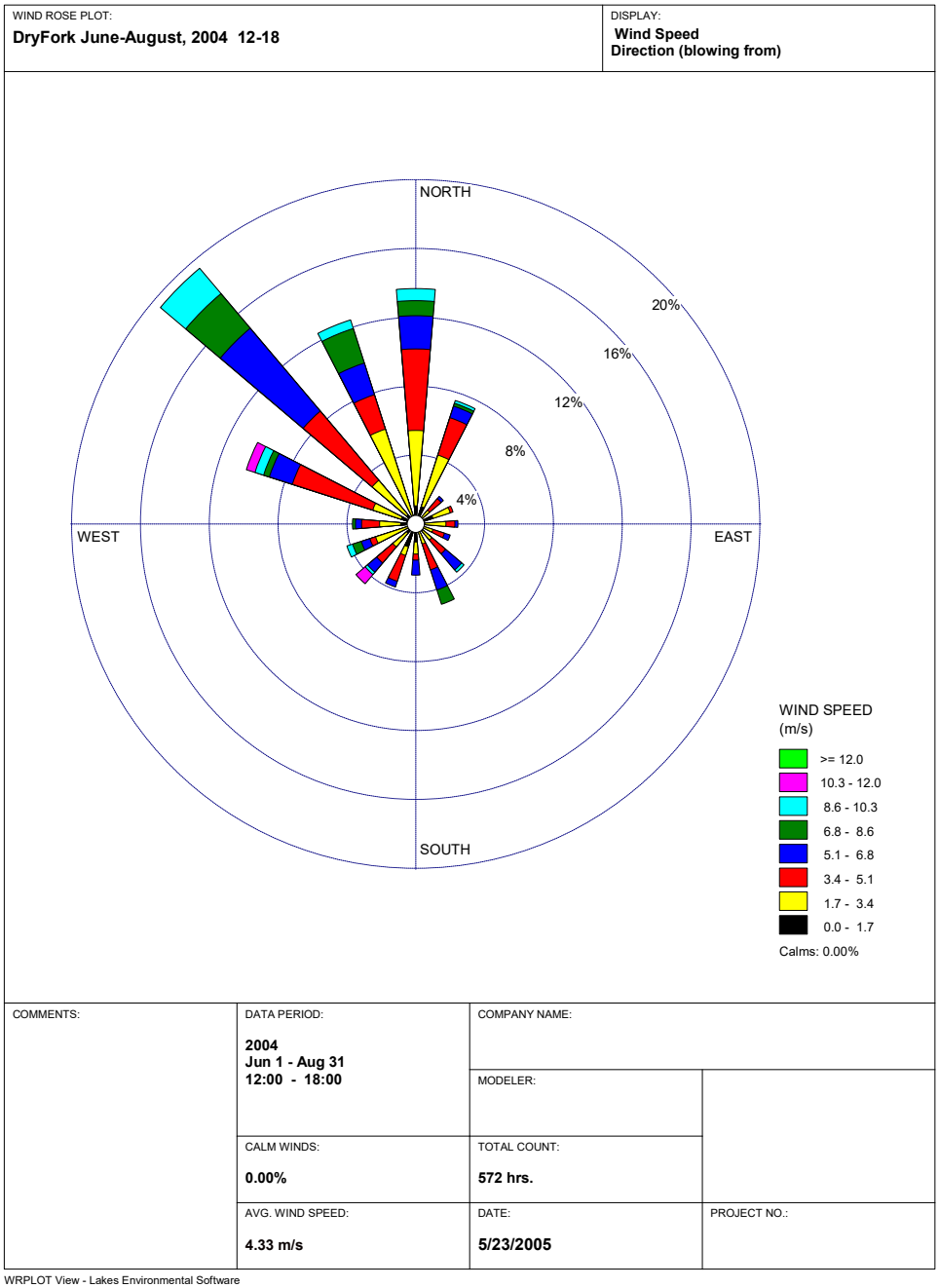
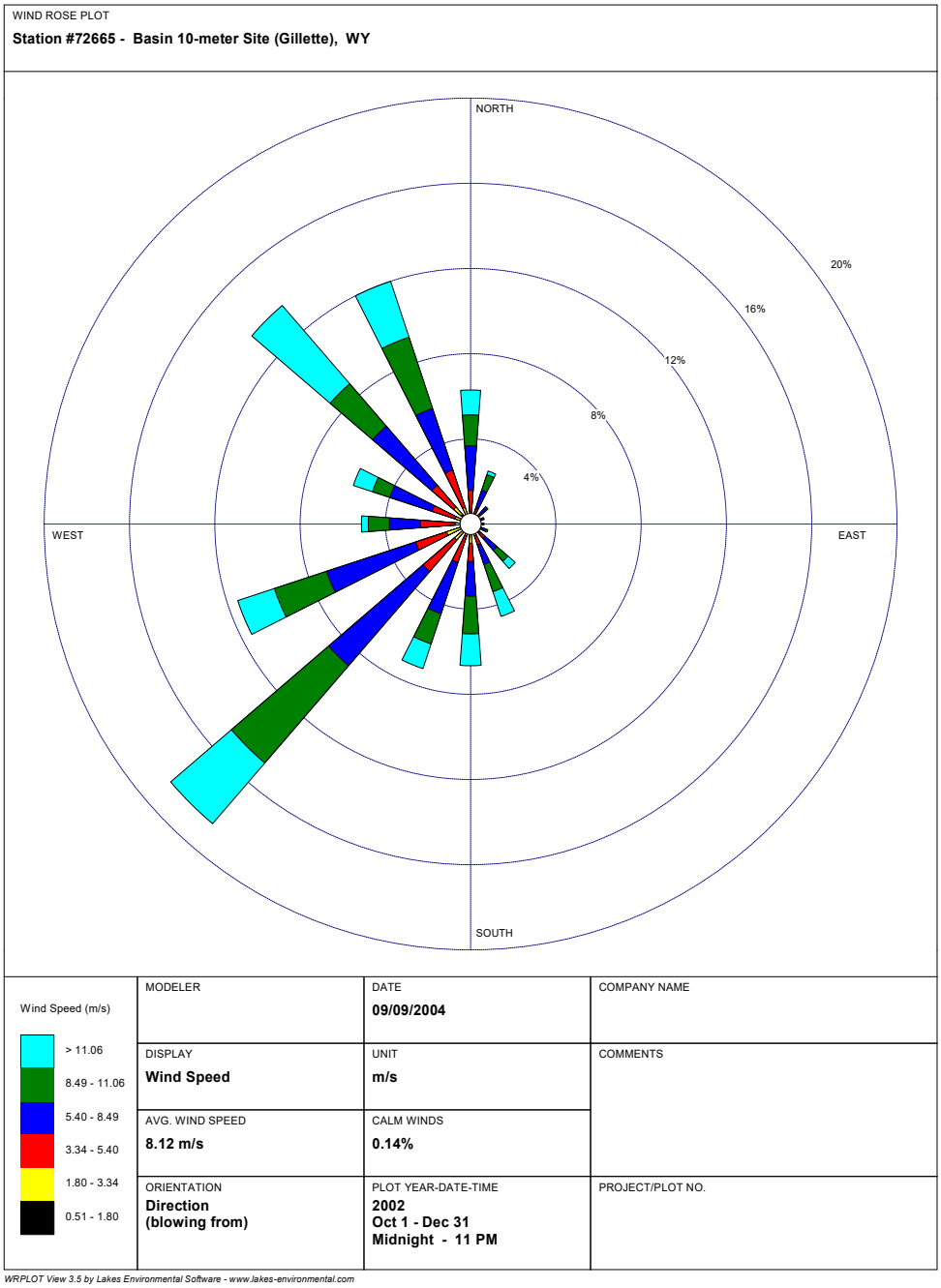


Figure G-11
Wind Rose – Fall Months (October-December 2002)



WIND SPEED UNIT CONVERSION

Meters per Second (m/s)	Miles per Hour (mph)
12.7	28.4
11.06	24.73
8.49	18.99
8.12	18.16
7.42	16.59
7.08	15.83
5.40	12.08
3.34	7.47
1.80	4.03
0.51	1.14

APPENDIX H. ELECTRICAL REQUIREMENTS

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		Substation Transformers		
		Number of Transformers	Ea	2
		MVA Rating	MVA	130 / 173 / 215
		Voltage Rating (Primary-Secondary Windings)	kV	230 / 13.8 / 13.8
		BIL (HV / LV)	kV	825 / 110
		Impedance HV-LV / LV	%Z	LATER
		Cooling	stages	ONAN / ONAF / ONAF
		Insulating Oil		Mineral Oil
		Oil Preservation System		Conservator System
		Temperature rise	Degree C	65C
		Winding Construction		Copper
		Primary connection		Rigid Bus
		Secondary connection		Rigid Bus
		Tap changer	OLTC / DETC	OLTC
		13.8-4.16kV Transformers		
		Number of Transformers	Ea	4 & 2
		MVA Rating	MVA	15 / 20 / 25 & 10 / 13.3
		Voltage Rating (Primary-Secondary Windings)	kV	13.8 / 4.16
		BIL (HV / LV)	kV	110 / 75
		Impedance HV-LV / LV	%Z	TBD
		Cooling	stages	KNAN / KNAF / KNAF
		Insulating Oil		FR3
		Temperature rise	Degree C	65C
		Winding Construction		Copper
		Primary connection		Cable
		Secondary connection		Cable Bus
		Tap changer	OLTC / DETC	DETC
		Neutral Termination		Resistance Grounding
		Secondary Unit Substation Transformers		
		Number of Transformers	Ea	12
		MVA Rating	MVA	2.5 / 3.325 & 2 / 2.67
		Voltage Rating (Primary-Secondary Windings)	kV	13.8-0.48 & 4.16-0.48
		BIL	(Pri / Sec) kV	110 / 30 & 75 / 30
		Impedance	%Z	LATER
		Cooling	stages	AA / FA
		Type		Dry Type - Cast Resin
		Temperature rise	Degree C	65C
		Winding Construction		Copper
		Primary connection		Cable
		Secondary connection		Rigid Bus
		Tap Changer	OLTC / DETC	DETC
		Neutral Termination		High-Resistance Grounding

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		Medium Voltage Switchgear		
		Number of Switchgear Lineups	Ea	10
		Switchgear voltage rating	kV	15 / 5
		Operating Voltage	kV	13.8 / 4.16
		BIL	kV	95 / 60
		Interrupting rating	kA	50
		Main bus rating	A	Varies
		Arc Flash Rating		2C
		Low Voltage Switchgear		
		Number of Switchgear Lineups (Double Bus w/Tie)	Ea	12
		Switchgear voltage rating	V	600
		Operating Voltage	V	480
		Interrupting rating	kA	65
		Main bus rating	A	Varies
		Arc Flash Rating		2B
		Low Voltage Motor Control Centers		
		Number of MCC's	Ea	16
		MCC voltage rating	V	600
		Operating Voltage	V	480
		Interrupting rating	kA	65
		Main bus rating	A	Varies
		Arc Flash Rating		Arc-Resistant
		MV Cable Bus		
		Voltage rating	kV	5
		Operating voltage	kV	4.16
		Current rating	A	Varies
		Momentary rating	kA	50
		Cable Rating		133% Insulation
		MV Non-segregated Phase Bus Duct		
		Voltage rating	V	15
		Operating voltage	V	13.8
		Current rating	A	Varies
		Momentary rating	kA	63
		125VDC System		
		Number of battery banks	Ea	3
		Voltage Ratings of Each System	Vdc	125
		Capacity	Ampere-Hours (AH)	LATER
		Number of Chargers	Ea	6 (2 PER SYSTEM)
		Battery charger rating	A	LATER

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		Inverter (UPS)		
		Number of inverters	Ea	3
		Capacity	kVA	30 / 50
		Output voltage	Vac	120
		Number of phases		1
		Lighting and Receptacles		
		Fixture Type		LED
		Voltage	V	277
		Welding Receptacles		480V Disconnect Switches w/Integrated Receptacles
		Heat Tracing / Freeze Protection		
		Manufacturer		LATER
		Controls		LATER
		Public Address System		
		Manufacturer		GAI-TRONICS
		Type		Extension of existing
		Motors (Non-VFD)		
		0 to 1/2 HP		
		Motor Ratings	Volts/Phase/Hz	120/1/60
		Enclosure		TEFC
		Service factor		1.0
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		High
		3/4 HP to 250 HP		
		Motor Ratings	Volts/Phase/Hz	460/3/60
		Enclosure		TEFC
		Service factor		1.15
		Space heater rating (75 Hp and larger)	Volts/Phase/Hz	240/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		251 HP to 2999 HP		
		Motor Ratings	kV/Phase/Hz	4/3/60
		Enclosure		WP Type 2
		Service factor		1.15
		Space heater rating	Volts/Phase/Hz	240/1/60 or 480/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60 or 480/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		3000 HP and Above		
		Motor Ratings	kV/Phase/Hz	13.2/3/60
		Enclosure		WP Type 2
		Service factor		1.15
		Space heater rating	Volts/Phase/Hz	240/1/60 or 480/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60 or 480/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		Motors (VFD Driven)		
		0 to 1/2 HP		
		Motor Ratings	Volts/Phase/Hz	120/1/60
		Enclosure		TEFC
		Service factor		1.0
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		High
		3/4 HP to 200 HP		
		Motor Ratings	Volts/Phase/Hz	460/3/60
		Enclosure		TEFC
		Service factor		1.15
		Space heater rating (75 Hp and larger)	Volts/Phase/Hz	240/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		Note: Inverter duty motors shall meet the requirements of NEMA MG 1, Part 30 and Part 31.		

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		251 HP to 4499 HP		
		Motor Ratings	kV/Phase/Hz	4/3/60
		Enclosure		WP Type 2
		Service factor		1.15
		Space heater rating	Volts/Phase/Hz	240/1/60 or 480/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60 or 480/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		4500 HP to 9000 HP		
		Motor Ratings	kV/Phase/Hz	6.6/3/60
		Enclosure		WP Type 2
		Service factor		1.15
		Space heater rating	Volts/Phase/Hz	240/1/60 or 480/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60 or 480/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		Note: VFD to be sourced from 13.8 kV bus and provided with 13.8-6.9 kV input transformer.		
		Above 9000HP		
		Motor Ratings	kV/Phase/Hz	13.2/3/60
		Enclosure		WP Type 2
		Service factor		1.15
		Space heater rating	Volts/Phase/Hz	240/1/60 or 480/1/60
		Space heater operating voltage	Volts/Phase/Hz	120/1/60 or 480/1/60
		Insulation Class		F
		Insulation temperature rise basis		Class B
		NEMA Design		B
		Efficiency Class		NEMA Premium
		Medium Voltage Variable Frequency Drives		
		Input voltage Rating	kV	13.8 / 4.16
		Output Voltage Rating	kV	13.8 / 6.9 / 4.16
		Pulses		24 (Minimum)
		Cooling		Air Cooled
		Input Transformer	Y/N	Y
		Low Voltage Variable Frequency Drives		
		Voltage Rating	V	480
		Pulses		12 (Minimum)
		Cooling		Air Cooled
		Note: Drive systems shall be IEEE 519 compliant.		

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		Cabling		
		Medium Voltage Power Cable		15 kV, 100% and 5 kV, 100% insulation level, shielded with CPE jacket and XLPE insulation rated for 105°C with copper conductors and ground wires.
		600V Low Voltage Power Cable		CPE jacket and XLPE insulation rated for 90°C with copper conductors.
		600V Control Cable		CPE jacket and XLPE insulation rated for 90°C with copper conductors and E-2 color coding. Minimum cable size of #12 AWG.
		600V Instrumentation Cable		Individual tape shielded pairs and triads with an overall shield, CPE jacket and EPR or XLPE insulation with copper conductors. Minimum cable size of #16 AWG.
		300V Thermocouple Cable		Individual tape shielded pairs with an overall shield CPE jacket and XLPE insulation. Minimum cable size of #16 AWG.
		Raceway		
		Conduit (Exposed)		Galvanized, rigid steel
		Cable Tray		Ladder type hot dip galvanized after fabrication steel. NEMA Class 20C, peaked covers where required.
		Corrosive Areas		Aluminum
		Duct Banks		Schedule 40 PVC conduit within the duct bank. Rigid Galvanized Steel used for bends.
		Junction / Pull Boxes		NEMA Type 4X outdoors or in washdown area. NEMA 12 indoors.
		Lightning Protection		
		Type		As required per NFPA 780
		Cathodic Protection		
		Type		Impressed Current

		Design Basis Attribute	Unit of Measure	Full Scale Carbon Capture
		Grounding		
		Buried Ground Cable	Type	#4/0, bare copper 500 kcmil, bare copper
		Ground Rods	Type	3/4" copper clad steel, 20' depth
		Depth		Buried ground conductor and top of ground rods to be minimum 18" deep
		Connections	Type	Hyground Compression Type
		Pigtail Size		500 kcmil minimum for transformer and electrical equipment rooms, #4/0 AWG minimum for other equipment

APPENDIX C. S&L DESIGN CALCULATIONS

ISSUE SUMMARY
Form SOP-0402-07, Revision 0

DESIGN CONTROL SUMMARY

CLIENT: Membrane Technology & Research (MTR) UNIT NO.: 1 PAGE NO.: 1

PROJECT NAME: MTR Full Scale Membrane CO_2 Capture FEED Study

PROJECT NO.: 13978-002

CALC. NO..: 2020-03849

S&L NUCLEAR QA PROGRAM
APPLICABLE ☐ YES ☒ NO

TITLE: Dry Fork Station Unit 1 Flue Gas Characteristics at CO_2 Capture System Tie-in

EQUIPMENT NO.:

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Initial Draft for Review

INPUTS/ ASSUMPTIONS
☐ VERIFIED
☐ UNVERIFIED

REVIEW METHOD:
REV.: 0
STATUS: ☐ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID
DATE FOR REV.: 6/9/2020
PREPARER: Vrushant Patel DATE:
REVIEWER: Holly Hills DATE:
APPROVER: Holly Hills DATE:

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Updated for Basin Electric feedback/comments and additional operating provided.

INPUTS/ ASSUMPTIONS
☐ VERIFIED
☐ UNVERIFIED

REVIEW METHOD:
REV.: 1
STATUS: ☐ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID
DATE FOR REV.: 8/28/2020
PREPARER: Vrushant Patel DATE:
REVIEWER: Holly Hills DATE:
APPROVER: Holly Hills DATE:

IDENTIFICATION OF PAGES ADDED/REVISED/SUPERSEDED/VOIDED & REVIEW METHOD

Updated for (1) MTR's request to add a mid-load operating case, which required modification to the existing low load operating case; (2) addition of a full load winter operating case at DFS personnel's request to determine fluctuation in Dry FGD humidification water consumption rates during colder ambient conditions; (3) updated site ambient pressure based on most recent 2017 ASHRAE data and (4) estimated future full load design conditions with tipped ID fan operation.

INPUTS/ ASSUMPTIONS
☐ VERIFIED
☐ UNVERIFIED

REVIEW METHOD:
REV.: 2
STATUS: ☐ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID
DATE FOR REV.: 03/19/2021
PREPARER: Vrushant Patel DATE:
REVIEWER: Holly Hills DATE:
APPROVER: Holly Hills DATE:

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INPUTS/ ASSUMPTIONS
☐ VERIFIED
☐ UNVERIFIED

REVIEW METHOD:
REV.:
STATUS: ☐ APPROVED ☐ SUPERSEDED BY CALCULATION NO. ☐ VOID
DATE FOR REV.:
PREPARER: DATE:
REVIEWER: DATE:
APPROVER: DATE:

Design Basis Document

1.0 Purpose and Scope

The purpose of this document is to define the parameters used in preparing the mass balance for the Basin Electric Dry Fork Station (DFS) Unit 1. The defined parameters and the mass balances will be used to establish the flue gas characteristics of the exhaust stream from the DFS Unit which will serve as the design inlet conditions to MTR's membrane CO_2 capture system.

2.0 Design Inputs

The following design inputs were established for (1) full load operation during warmer summer months, (2) full load operation during winter months, (3) mid load operation and (4) low load operation. It should be noted that the (2) full load during winter month operating case was developed to determine the reduction in the dry flue gas desulfurization (FGD) system's humidification water consumption rate as part of the separate water treatment and management study being completed as part of this project. Therefore, the inputs to this operating condition are only summarized in the following table (i.e. not included in detailed discussion in the following sections).

Table 2-1 Dry Fork Station Unit 1 Inputs

Parameter	Units	Full Load - Summer	Full Load - Winter	Mid Load	Low Load	Notes
Gross Load	MWg	445	431	334	275	For full load (summer) and low load cases, per client RFI responses received on May 04, 2020. For mid load case, assuming 75% of full load design case, and for full load (winter) case per avg. of operating data
Heat Input	MMBtu/hr	4,457.9	4,143.9	3,383.7	2,859.5	Attachment 2, 3, and 4
Ambient Pressure	psia	12.53	12.53	12.53	12.53	Attachment 5

Design Basis Document

Parameter	Units	Full Load - Summer	Full Load - Winter	Mid Load	Low Load	Notes
Ambient Temperature	°F	108.2	49.6	108.2	108.2	Attachment 5. For full load (winter case) using avg. of Jan – May ambient high temperature
Ambient Air Humidity Ratio (H_2O)	lb/lb dry air	0.025	0.0024	0.025	0.025	Engineering Judgement. For full load (winter) case based on psychometric chart
Excess Air	%	16.9	14.9	16.2	19.2	Calculated based on economizer outlet O_2 concentration
Air In-Leakage	%	8.0	14.0	7.2	11.4	Calculated based on stack flow
Bottom Ash / Fly Ash	wt.%	20/80	20/80	20/80	20/80	Engineering Judgement
Boiler SO_2 to SO_3 Oxidation	wt.% SO_2	0.4	0.4	0.4	0.4	Engineering Judgement
O_2 at Economizer Outlet	vol.% (wet)	2.6	2.4	2.5	2.9	Attachment 2, 3, and 4
Economizer Outlet / SCR Inlet Temperature	°F	787.8	763.8	724.3	687.3	Attachment 2, 3, and 4
Economizer Outlet / SCR Inlet Pressure	in. w.c.	-9.1	-8.1	-5.4	-4.0	Attachment 2, 3, and 4
NOx at Economizer Outlet	ppm	130.0	104.8	89.9	87.1	Attachment 2, 3, and 4
SCR Outlet Temperature	°F	785.8	764.7	724.4	683.6	Attachment 2, 3, and 4
SCR Outlet Pressure	in. w.c.	-15.9	-12.0	-9.4	-6.9	Attachment 2, 3, and 4
SCR SO_2 to SO_3 Oxidation	wt.% SO_2	3.0	3.0	3.0	3.0	Confirmed by Basin Electric in comments provided on 7-7-20
Air Heater Outlet (CDS Inlet) Pressure	in. w.c.	-19.2	-14.4	-9.8	-6.8	Attachment 2, 3, and 4

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Parameter	Units	Full Load - Summer	Full Load - Winter	Mid Load	Low Load	Notes
CDS Inlet (Air Heater Outlet) Temperature	°F	327.0	296.1	284.8	268.2	Attachment 2, 3, and 4
CDS Outlet Temperature	°F	196.0	194.0	198.9	209.9	Calculated
CDS Outlet Pressure	in. w.c.	-27.8	-22.2	-16.0	-12.6	Attachment 2, 3, and 4
Baghouse Temperature Drop	°F	0.0	0.0	0.0	0.0	Assumed
Baghouse Differential Pressure	in. w.c.	5.4	4.8	4.2	4.1	Attachment 2, 3, and 4
Current ID Fan Outlet Temperature	°F	213.3	208.1	209.5	218.6	Attachment 2, 3, and 4
Current ID Fan Outlet Pressure	in. w.c..	1.9	1.6	1.0	0.8	Assumed PI Data for "Stack Differential Pressure" to be representative of ID Fan Outlet Pressure Attachment 2, 3, and 4
Current ID Fan Static Differential Pressure	in. w.c.	35.1	28.6	21.2	17.5	Calculated
Future ID Fan Static Differential Pressure	in. w.c.	52.25	n/a	n/a	n/a	Only evaluated at Full Load – Summer case
Future ID Fan Outlet Temperature	°F	222	n/a	n/a	n/a	Calculated based on Future ID Fan Outlet Pressure (fan total differential pressure)
Future ID Fan Outlet Pressure	in. w.c.	19.05	n/a	n/a	n/a	Calculated
Current Stack Temperature	°F	213.4	207.9	211.1	211.3	Attachment 2, 3, and 4
Current Stack Flow Rate	scfh	64,892,562	60,106,743	48,833,761	43,092,938	Attachment 2, 3, and 4

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Parameter	Units	Full Load - Summer	Full Load - Winter	Mid Load	Low Load	Notes
Stack SO_2 Emissions	lb/hr	308.6	286.0	233.0	200.0	For full load (summer) case per Attachment 2, while for other load cases, the emissions are calculated based on maintaining 0.069 lb/MMBtu SO_2 emissions

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1) Coal Analysis

DFS fires sub-bituminous coal from the Dry Fork Mine. Dry Fork Mine coal analyses from the original DFS performance guarantee basis coal (DFS-GV-100-0001); previous 2013 & 2016 analyses provided by Basin Electric for the Laramie River Station (LRS) SCR Project; and recent 2019 analyses received from Basin Electric on 05-04-2020 were evaluated to determine the design coal analysis to be used. A comparison of the various coal analyses is included in Attachment 1.

As shown in Attachment 1, the most recent 2019 Dry Fork Mine coal analyses do not include the usual spectrum of parameters analyzed. Therefore, the Dry Fork 2016 (03-14-2016) coal data was chosen as the design coal as it had the most similar characteristics compared to the average of the 2019 coal compositions. The composition of the design fuel chosen is presented below in Table 2-2. In addition to the measured higher heating value (HHV), a theoretical HHV value was calculated for the design fuel, using the Dulong Formula, based upon the ultimate analysis provided (HHV = 14,544 x (%C / 100) + 4,050 x (%S / 100) + 62,028 x [(%H / 100) – (%O / 100 / 8)]).

Table 2-2: Dry Fork Station Unit 1 Design Fuel

Fuel Data Variable	**Units**	**Dry Fork 2016 (03-14-2016)**
Ultimate Analysis (As Received)		
Carbon	wt.%	47.08
Hydrogen	wt.%	3.35
Nitrogen	wt.%	0.66
Sulfur	wt.%	0.39
Oxygen	wt.%	11.54
Chlorine [Note 1]	wt.%	0.01
Fluorine [Note 1]	wt.%	0.01
Proximate Analysis (As Received)		
Moisture	wt.%	32.0
Ash	wt.%	4.97
Measured HHV	Btu/lb	8,071
Calculated HHV	Btu/lb	8,046

Note 1 – Chlorine and Fluorine content was assumed to be 0.01 wt.% for calculations in order to balance the total coal analysis.

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2) Load

Design Full Load

Per Basin Electric personnel correspondence, the design full load condition of DFS is 445 MW gross (MWg). The selective catalytic reactor (SCR) for NOx control has had pluggage issues in 2018 and 2019, which has since been resolved; however, due to the inadequate amount of current 2020 representative operating data PI data provided by Basin Electric from 1-1-2017 to 12-31-2017 (referred to as "Full Load PI Data") was used to define the process conditions of the design full load. The Full Load PI Data is included in Attachment 2.

Mid Load

At MTR's request, S&L developed an additional mid load operating case. The DFS mid load operation was assumed to be 75% of the design full load case, approximately 334 MWg. Therefore, PI data from 1-1-2017 through 5-18-2020 for the load range of 320 – 350 MWg was used to define the process conditions at mid load. The Mid Load PI data in included in Attachment 3.

Low Load

Basin Electric personnel identified the DFS minimum or low load operating condition to be at 275 MWg (i.e. approximately 62% of the design full load case). However, as the station is mainly a base loaded unit (i.e. few occurrences of low load continuous operation or frequent low load cycling), PI data from 1-1-2017 through 5-18-2020 taken at loads from 260 – 290 MWg was used to define the process conditions at low load. The Low Load PI Data is included in Attachment 4.

3) Heat Input

S&L analyzed the Full Load PI data to determine the average of the highest 5% heat input at full load and the average heat input at mid and low load range. The resulting heat input at full load, 4,458 MMBtu/hr, was used to determine the largest volumetric flue gas flow

rate at the design full load conditions. The resulting mid and low load heat input of 3,384 MMBtu/hr and 2,860 MMBtu/hr was used to be representative of the average mid and low load conditions, respectively. A graph of the heat input versus load for Unit 1 is shown in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively.

4) Atmospheric Conditions

The site conditions for DFS was based on the 2017 ASHRAE Handbook Gillette, WY WMO# 726650 data shown in Attachment 5. Based on this, the site elevation is approximately 4,354 ft. above sea level, ambient pressure is 12.53 psia, and the highest annual 50-year occurrence temperature of 108.2°F is used as the site ambient temperature.

5) Excess Air

The excess air used for combustion was calculated using the economizer outlet O_2 concentrations, a graph of the economizer outlet O_2 concentrations versus load is included in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively. The average of the highest 5% of O_2 concentration at full load was determined to be 2.6% and the mid load and low load average O_2 concentration was determined to be 2.5% and 2.9%, respectively.

Using these values, the excess air percentage was calculated at full load to be 16.9%, at mid load to be 16.2%, and at low load to be 19.2%.

6) Air In-Leakages & CO_2 Volumetric Concentration

Air In-Leakages

Air in-leakages to the ductwork can be determined using either the O_2 concentrations at the ID fan outlet or the measured stack flow rate. A graph of ID fan[1] outlet O_2 and stack flow versus load are included in Attachment 2, 3, and 4 for full load, mid load, and low load,

[1] It should be noted that at full load there is wide variation in the O_2 measurements at the ID fan outlets. Measurements above 5% O_2 are either representative of (1) unit trips, and/or startup and shutdown events in which the sensor is exposed to higher O_2 concentration or (2) a measurement error. Therefore, these measurements are not included in the analysis.

respectively. To compare the two methods to determine air in-leakages, the average of the highest 5% of ID fans outlet O_2 concentrations at full load is approximately 4.2% and the average of the highest 5% of stack outlet flow at full load was determined to be 64,892,562 standard ft^3/hour (scfh) (1,727,290 acfm at 213°F). To compare these two methods:

- Using the ID fan outlet O_2 concentrations, ~4.2% at full load, results in approximately 11.5% air in-leakage, correlating to a flue gas flow rate of approximately 1,783,436 acfm at the stack which is approximately 3% higher than the measured stack flue gas flow rates.
- Using the stack flow, 64,892,562 scfh (1,727,290 acfm at 213°F) at full load, results in approximately 8.0% air in-leakage.

A comparison of the flue gas conditions at the tie-in is presented below in Table 2-3 for both methods.

Table 2-3: Dry Fork Unit 1 Air In-Leakage Calculation Options Comparison

		Full Load Using ID Fan Outlet O_2%		**Full Load Using Stack Flow**	
Temperature	°F	213.0		213.0	
Pressure	psia	12.598		12.598	
Air In-Leakage	%	11.5		8.0	
N_2	lb/hr-vol.%	3,434,088	65.70	3,314,559	65.48
O_2	lb/hr-vol.%	250,881	4.20	214,874	3.71
H_2O	lb/hr-vol.%	620,232	18.46	611,545	18.79
CO_2	lb/hr-vol.%	955,692	11.64	955,692	12.01
SO_2	lb/hr-ppmv	309	26	309	27
SO_3	lb/hr-ppmv	11	1	11	1
HCl	lb/hr-ppmv	0	0	0	0
HF	lb/hr-ppmv	0	0	0	0
Total Flow	lb/hr-acfm	5,261,213	1,783,436	5,096,990	1,727,290
Molecular Weight	lb/lbmol	28.185		28.193	
Ash	lb/hr-gr/acf	53	0.004	53	0.004

Using the ID fan outlet O_2 data would result in a slightly more conservative (3% higher) flue gas flow rate that would be used for the design of the CO_2 capture island. However, the variation in the monitor measurements and noted maintenance activities in the past for

calibration issues would result in the highest O_2 vol.% that will also impact CO_2 capture equipment operation.

It's assumed that more regular maintenance is performed on the stack flow rate monitor for meeting EPA QA/QC reporting purposes, which would make this operating data a more reliable reference point, compared to the ID fan outlet O_2 data.

CO_2 Volumetric Concentration

From the results above, it should be noted that the CO_2 vol.% calculated using ID Fan Outlet O_2% and stack flow method is 11.64 and 12.01 vol.%, respectively. A graph of stack CO_2 volumetric percentage versus load from station operating data is included in Attachment 2. The average of the highest 5% of stack CO_2 vol.% at full load was determined to be 13.1 vol.%; however, the accuracy of this monitor cannot be confirmed at this time.

Due to the CO_2 vol.% discrepancy between the two air in-leakage calculation methods and plant operating data, hourly mass CO_2 emissions from the EPA Clean Air Market Data (CAMD) from 2017 was evaluated for comparison. A graph of the CAMD reported CO_2 mass flow rates versus load is included in Attachment 2. The average of the highest 5% of stack CO_2 mass flow was determined to be 933,778 lb/hr CO_2 at full load. As the CAMD CO_2 mass flow rates correlate with the calculated values (within roughly 2% of each other), this would confirm that the station CO_2 13.1 vol.% is representative.

On August 19, 2020, MTR provided feedback on the impacts of the different CO_2 vol.% concentrations. In summary, the lower 11.6 vol.% CO_2 associated with use of the ID fan outlet O_2% for determining air in-leakage (i.e. higher flue gas flow rate, air in-leakage, and outlet O_2%) would result in a 4% increase in membrane area (m^2), 9 kWh increase in energy usage per tonne of CO_2 captured leading to an estimated 3% increase in cost per tonne of CO_2 removed, resulting in potentially an additional $40M increase in plant cost for the CO_2 capture system.

Air In-Leakages & CO_2% Conclusion

Based on the discussion above, S&L recommends using the stack flow rate data to determine the air in-leakages and the resulting CO_2 vol.% for the tie-in conditions. As the stack flow rate monitor is assumed to be more accurate (due to maintenance & EPA QA/QC), and the resulting outlet CO_2 vol.% is reasonable for process design while not adding significant project costs, it was determined that the air in-leakage will be calculated using the measured stack flow rate; use of this method was confirmed by MTR via email on 8-21-20. Therefore, an air in-leakage of 8.0%, 7.2%, and 11.4% was calculated for full, mid, and low load using highest 5% stack flow of 64,892,562 scfh (1,727,290 acfm at 213°F) at full load, 47,833,761 scfh (1,269,302 acfm at 210°F) at mid load, and 43,092,938 scfh (1,159,717 acfm at 219°F) at low load.

7) Temperatures

S&L analyzed temperatures across the flue gas path using station PI Data. Temperatures at full load were calculated based on taking the average of the highest 5% of PI Data and mid and low load temperatures were calculated using the average of the mid and low load range. Graphs of the temperatures versus load for Unit 1 are shown in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively.

Economizer Outlet/ SCR Inlet Temperature

The economizer outlet / SCR inlet temperature was determined to be 788°F at full load, 724°F at mid load, and 687°F at low load conditions..

SCR Outlet Temperature

The SCR outlet temperature was determined to be 786°F at full load, 724°F at mid load, and 684°F at low load conditions..

Air Heater Outlet/ CDS Inlet Temperature

Temperature measurements at the air heater (AH) outlet are higher than the Circulating Dry Scrubber (CDS) inlet temperature. The air heater outlet temperatures were calculated

to be 332°F, 304°F, and 298°F for full load, mid load, and low load, respectively whereas the CDS inlet temperatures were calculated to be 327°F, 285°F, and 268°Ffor full load, mid load, and low load, respectively. This is likely due to the temperature drop caused by the mixing of the recirculated clean (cooler) flue gas at the inlet of the CDS (near the location of the CDS inlet thermocouple). The recirculated flue gas serves to maintain the flow necessary to maintain the suspended fluidized bed in the CDS vessels at lower loads. However, as DFS is mainly base loaded, the recirculation ductwork is not in use, and therefore, the temperature drop is likely caused by seal air that prevents flue gas from entering the recirculation ducts.[2] Therefore, in order to be conservative, the CDS inlet temperature was used as the air heater outlet temperature to be representative of the CDS inlet conditions.

CDS Outlet Temperature

Temperature measurements at the CDS vessel outlets were unavailable in the PI data provided by DFS. Therefore, the CDS outlet temperature was calculated assuming no temperature drop across the baghouse and using the associated heat of compression across the ID fans for the assumed static pressure rise across the fan to achieve the ID fan outlet temperature (both parameters discussed further below). At full load, to achieve the ID fan outlet temperature of 213°F with an ID fan static pressure of 35.1 in. w.c. would require a CDS outlet temperature of 196°F. At mid load, an ID fan static pressure of 21.2 in. w.c. and the outlet temperature of 210°F would require a CDS outlet temperature of 199°F. At low load, an ID fan static pressure of 17.5 in. w.c. and the outlet temperature of 219°F would require a CDS outlet temperature of 210°F.

[2] PI data provided by Basin Electric also included the Dry FGD system recirculated flue gas flow rate measurements. It should be noted that because each damper is equipped with its own control logic, the recirculation flow for Duct A & Duct B can vary at any given time. This information was not used as part of development of the CO_2 capture system inlet conditions, but graphs of this data are included in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively.

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Baghouse Outlet Temperature

It is assumed that the temperature drop across the baghouse is negligible; therefore, the baghouse outlet temperatures are equal to the CDS outlet temperature at each load condition.

Current ID Fan Outlet Temperature

The PI data tags 1FGTT6024 and 1FGTT6025 labeled as the "Duct A" and "Duct B" stack temperatures, respectively, correspond to the ID Fan outlet temperatures, downstream of the recirculation duct branches (i.e. considered as the "stack inlet") per the DFS P&ID (drawing No. 074130-PID-027, rev. H dated 01-23-09). The ID Fan A outlet temperature at this location was determined to be 212.2°F, 209.5°F, and 219.6°F for full load, mid load, and low load, respectively. The ID Fan B outlet temperature at this location was determined to be 213.3°F, 209.5°F and 217.6°F for full load, mid load, and low load, respectively. Since, the outlet temperatures for ID Fan A and B trend very similar, the higher of the two is used for analysis in order to conservatively design the tie-in conditions of the CO_2 capture equipment at full load and average of the two is used for mid and load ranges, i.e. 213.3°F, 209.5°F, and 218.6°F at full load, mid load, and low load, respectively.

Future ID Fan Outlet Temperature

Future operation with the CO_2 capture equipment online will involve increasing the overall differential pressure across the existing ID fans to deliver flue gas at a slightly positive pressure at the new CO_2 capture system booster fan(s) inlet (discussed in more detail in pressure profile discussion below). The future ID fan outlet temperature is calculated based on the new differential pressure across the existing ID fans. This industry used "rule of thumb" equates 1 in.w.c. of pressure rise to 0.5°F of air temperature increase. Given the existing fan outlet temperature of 213°F at 1.9 in.w.c. and the anticipated outlet pressure of 19.1 in. w.c. of the upgraded fan, an outlet temperature increase of 9°F and an ID fan outlet temperature of 222°F at full load (summer conditions) can be expected. This elevated

ID fan outlet temperature was used to adjust the flue gas volumetric flow rate as part of developing the overall tie-in ductwork differential pressure drop.

Current Stack Temperature

It should be noted that stack temperature PI data was also provided at what is assumed to be at the existing plant CEMS level (halfway up the height of the stack) to correlate to the other CEMS readings required for EPA reporting purposes. The resulting stack temperatures of 213.4°F, 211.1°F, and 211.3°F at full load, mid load, and low load, respectively will be used later in the Full Scale FEED Study project when evaluating re-use of the existing stack for the CO_2 capture equipment exhausted flue gas.

8) Static Pressures

S&L analyzed the PI Data to determine the flue gas path pressure profile. Pressures at full load were calculated based on taking the average of the highest 5% of PI Data and mid and low load pressures were calculated using the average of the mid and low load range. Graphs of the pressures versus load for Unit 1 are shown in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively.

Economizer Outlet Pressure / SCR Inlet Pressure

The economizer outlet pressure was determined to be -9.1 in. w.c. at full load, -5.4 in. w.c. at mid load, and -4.0 in. w.c. at low load conditions.

SCR Outlet Pressure

The SCR outlet pressure was determined to be -15.9 in. w.c. at full load, -9.4 in. w.c. at mid load, and -6.9 in. w.c. at low load conditions. In 2016, it was noted that all SCR catalyst previously installed was removed and 2 new catalyst levels were installed in layers 3 and 4 (see Article 8) for additional information on the SCR design).[3] Therefore, the

[3] It should be noted that the maximum SCR pressure drop of 13.5 in. w.c. was experienced in 2016 when 3 catalyst layers were installed, which made operation of downstream equipment difficult.

approximate SCR system pressure drop of 6.8 in. w.c. determined from the PI data is only representative of 2 catalyst layers.

The recent effort to mitigate SCR operational issues mentioned previously involved the installation of two replacement honeycomb catalyst layers (same design as original) during the DFS Fall 2019 outage among other modifications. The facility is on a 3-year catalyst management schedule, with future catalyst changeouts based on installing three layers of plate catalyst. With the installation of plate catalyst and other modifications recommended to mitigate the SCR plugging issues, the future SCR overall pressure drop is expected to be lower than the calculated 2017 PI data pressure drop of 6.8 in. w.c. Therefore, no additional pressure drop, or pressure drop reduction will be assumed for future SCR operation between catalyst change out outages and the procurement of a new type of catalyst.

Air Heater Outlet Pressure

The air heater outlet pressure was determined to be -19.2 in. w.c. at full load, -9.8 in. w.c. at mid load, and -6.8 in. w.c. at low load conditions. For the full load data, it should be noted that the outlet pressure includes “dirty” conditions i.e. higher pressures that develop over time as the air heaters become plugged (“clean conditions” would follow an outage when the air heaters are manually cleaned offline).

CDS Outlet Pressure

The CDS outlet pressure was determined to be -27.8 in. w.c. at full load, -16.0 in. w.c. at mid load, and -12.6 in. w.c. at low load conditions.

Baghouse Outlet Pressure / ID Fan Inlet Pressure

The average baghouse compartment differential pressure for Train A & B at full load conditions was determined to be 5.4 in. w.c. at full load, 4.2 in. w.c. at mid load, and 4.1 in. w.c. at low load conditions. Therefore, using the baghouse pressure drop and the CDS

outlet pressure, the baghouse outlet pressure was calculated to be -33.2 in. w.c. at full load, -20.2 in. w.c. at mid load, and -16.7 in. w.c. at low load conditions.

Current ID Fan Outlet Pressure / Stack Differential Pressure

The PI data recorded for the stack differential pressure was assumed to correlate to the ID fan outlet pressure, and was determined to be +1.9 in. w.c. at full load, +1.0 in. w.c. at mid load, and +0.8 in. w.c. at low load conditions. This differential pressure was used to establish the ID fans' overall differential pressure. It should be noted that the physical location of the differential pressure monitor is downstream of the expansion joint that follows after the Dry FGD recirculation duct take-off points. Therefore, it is possible that there may be some pressure drop missing from these recorded values for the ductwork upstream of this expansion joint. However, S&L has calculated the overall system pressure drop from the ID fan outlet housing, hence the pressure profile will not be impacted in the event these values may be slightly higher at the ID fan outlet housing.

Future ID Fan Outlet Pressure

For future operation with the CO_2 capture equipment online, the existing ID fan blades will be tipped in order to increase the fans' achievable positive outlet pressure. The ID fan outlet pressure will overcome the added pressure drop associated with the new tie-in ductwork to the CO_2 capture island and DCC to provide a slightly positive pressure at new CO_2 capture system booster fan(s). Based on the latest tie-in ductwork configuration and input from ID fan suppliers, the added pressure drop that the fans must overcome (i.e. the required ID fan outlet pressure) is approximately 19.05 in. w.c., increasing the fans static differential pressure from 35.1 to 52.25 in. w.c. This future ID fan outlet pressure was used to adjust the defined CO_2 capture inlet flue gas volumetric flow rate for the expected operating conditions once the ID fans are tipped for use in the flue gas path pressure profile calculations. It should be noted that as the conditions are interdependent, this may be an iterative process that will have to be revisited later as the process design progresses and information is received from potential booster fan suppliers.

9) SCR Design Parameters

NOx Removal

The DFS Unit 1 B&W SCR has been in operation since May 2011 and was designed with a 2+2 catalyst configuration, i.e. 2 initial catalyst layers and two spare layers. Per the B&W SCR O&M Manual (dated October 2010), the original SCR design performance was to achieve 82% NOx reduction with an inlet NOx concentration of 0.21 lb/MMBtu (127.9 ppmv at full load conditions).

S&L analyzed the PI Data to determine the average of the highest 5% of economizer outlet NOx concentrations at full load and an average of the mid and low load NOx concentrations, resulting in 130.0 ppmv at full load, 89.9 ppmv at mid load, and 87.1 ppmv at low load conditions. As the full load NOx concentration from the PI data is similar to the concentration of the original design conditions, 82% NOx removal across the SCR was assumed for the full load conditions.

The SCR ammonia injection is controlled by a feedback control loop using as-measured conditions. Therefore, for lower NOx concentrations experienced at low loads, it is assumed that the SCR will be operated to achieve the same outlet NOx emission at full load (0.038 lb/MMBtu) in order to reduce the amount of ammonia consumed, resulting in 69.6% NOx removal at mid load and 68.6% NOx removal at low load conditions.

Ammonia Slip

The original SCR design ammonia slip performance guarantee was 2 ppmvd @ 3% O_2; in order to be conservative for fluctuations in ammonia slip as the catalyst deactivates over time, an ammonia slip of 5 ppmvd @ 3% O_2 was assumed for the evaluation.

SCR SO_2 to SO_3 oxidation

The original SCR SO_2 oxidation design performance guarantee was not to exceed 4 wt.% SO_2, across all 4 catalyst layers (i.e. 1 wt.% SO_2 to SO_3 oxidation per layer), in order to be conservative, 3 wt.% SO_2 for all 3 future catalyst layers was assumed.

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10) CDS Design Parameters

SO_2 Removal

Graphs of stack SO_2 emissions data with respect to load are included in Attachment 2, 3, and 4 for full load, mid load, and low load, respectively. The average of the highest 5% of the SO_2 emissions at full load results in 309 lb/hr, which correlates to an outlet SO_2 emission concentration of 0.069 lb/MMBtu (note that DFS Title V operating permit SO_2 limit is 0.07 lb/MMBtu on a 12-month rolling average). Based on the emissions at full load and the assumed design coal, Unit 1 currently achieves approximately 92.6% SO_2 removal. Assuming the emissions in terms of lb/MMBtu are maintained at the other load conditions to maintain the station 12-month rolling average, this would result would in approximately 233 lb/hr and 200 lb/hr at mid and low load, respectively.

Particulate Removal

According to the DFS Title V permit, the filterable particulate matter (PM_{10}) emission limit for the unit is 0.012 lb/MMBtu or 45.6 lb/hr. Assuming the permit of 0.012 lb/MMBtu limit will be maintained at all times, Unit 1 currently achieves approximately 99.998% removal of solid particulate resulting in particulate stack emissions of 53 lb/hr, 41 lb/hr, and 35 lb/hr at full load, mid load, and low load, respectively. It should be noted that the calculated full load hourly mass PM emission rate is slightly higher than written in the permit due to the difference in the heat input basis used. As indicated above, the S&L mass balance uses a heat input of 4,458 MMBtu/hr at full load, whereas a heat input of 3,800 MMBtu/hr is calculated from the two emission rates reported in permit, thereby resulting in a slightly higher PM mass emission rate.

11) Mercury Removal

A graph of stack mercury (Hg) emissions data with respect to time are included in Attachment 5. The DFS Title V permit required an Hg optimization study to achieve a target rate of no more than 20 x 10^{-6} lb/MW-hr on a 12-month rolling average after initial startup of the activated carbon injection (ACI) system. Based on an hourly unit load of 445

MW, the permit limit would correlate to a Hg emission rate of 0.0089 lb Hg/hr. The ACI system was designed to achieve 13.0 x 10^{-6} lb/MW-hr to provide additional operating margin for the facility. As shown in Attachment 6, mercury emissions fluctuate with unit load and the ACI rate is likely managed based on staying below the permit limit of ≤ 20 x 10^{-6} lb/MW-hr on a 12-month rolling average. As such, excluding data above the permit limit of 20 x 10^{-6} lb/MW-hr and taking the average of the highest 5% of the Hg emissions at full load below results in 1.42 x 10^{-6} lb/MW-hr which is equivalent to mass flow rate of 0.0084 lb/hr. However, as indicated in the mass emission graph included in Attachment 5, instantaneous hourly Hg readings can range as high of 0.073 lb/hr. When taking the average of the highest 5% of Hg emissions, including data above 20 x 10^{-6} lb/MW-hr, results in 0.0093 lb/hr. Therefore, in order to be conservative for future unknown fluctuations in operating conditions, 0.0093 lb/hr will be used for full load conditions. Due to limited mid and low load operating data, the application of the permit limit, 20 x 10^{-6} lb/MW-hr, with the design mid load, 334 MW, and low load, 275 MW, results in a Hg emission rate of 0.0067 and 0.0055 lb/hr for mid load and low load, respectively, that will be assumed.

12) Engineering Judgment

- The distribution of bottom ash and fly ash was assumed to be 20% / 80%.
- The ambient air humidity was assumed to 0.025 lb H_2O / lb of dry air for full load – summer conditions, mid load and low load conditions. For full load – winter conditions ambient air humidity of 0.0024 lb H_2O / lb of dry air corresponding to ambient temperature of 49.6°F and relative humidity of 35% was assumed from psychometric chart.
- *SO_2 Oxidation*
    - Boiler SO_2 oxidation for PRB coal is typically in the range of 0.4 wt.% SO_2, hence that was used for the calculations.
- *Dry FGD HCl and HF Removal*

  In order to be conservative, it was assumed that the Dry FGD will remove 100% of the HCl and HF in the flue gas.

- *Dry FGD SO_3 Removal*
  - It was assumed that 40% of the SO_3 in the flue gas would be removed by the air heaters.
  - As shown in Attachment 7, the Dry FGD OEM indicated a SO_3 removal of approximately 97.3%. However, it was assumed that 90% of the SO_3 in the flue gas would be removed by the Dry FGD in order to be conservatively high for the tie-in conditions of the CO_2 capture system.

Design Basis Document

3.0 Calculations

Determination of Flue Gas Flow

Fuel Flow

The fuel flow is calculated by dividing the maximum permitted heat input (MMBtu/hr) by the heating value (Btu/lb) of the fuel.

Gas-Phase Reactions

The stoichiometric calculation models the following gas-phase reactions between the coal and combustion air:

$$C_{fuel} + O_2 \rightarrow CO_2$$
$$2\,H_{fuel} + \tfrac{1}{2}O_2 \rightarrow H_2O$$
$$S_{fuel} + O_2 \rightarrow SO_2$$
$$N_{2\ air} \rightarrow N_2 \text{ flue gas}$$
$$H_2O_{air} \rightarrow H_2O \text{ flue gas}$$

The total oxygen requirements for complete oxidation of carbon, hydrogen and sulfur are calculated. A small portion of the oxygen demand is provided by oxygen inherent in the fuel. Combustion air provides the remainder of the oxygen demand. The stoichiometric quantity of dry air is calculated from the remaining oxygen demand and is corrected for relative humidity and excess air (economizer O_2%) to determine the required wet combustion air at the burners. The gas-phase combustion reactions predict the expected flue gas composition and flow rate.

Material balances were developed to determine conditions for Dry Fork Unit 1. The spreadsheet used to determine the mass flows was S&L's validated Dry FGD material balance. Data not relevant to the flue gas characteristics calculation was hidden, but the formulas in the spreadsheet were not altered. The mass balances are included in Attachment 8-11.

Design Basis Document

Humidification Water Consumption in Dry FGD

Upon DFS personnel's request, the fluctuation in Dry FGD humidification water consumption during colder ambient conditions was developed to utilize as part of the separate water treatment and management study being completed as part of this project. Table 3-1 below shows comparison between the humidification water consumption rates for full load summer and winter ambient conditions.

Table 3-1: Dry Fork Unit 1 Dry FGD Humidification Water Consumption Rate

		Full Load – Summer Conditions	**Full Load – Winter Conditions**
Total Flow	gpm	320	236

4.0 Results

Based upon the results of this calculation, the following tables should be used as part of the design basis for the exhaust flue gas characteristics for the Dry Fork. Full results of the calculation are included in Attachment 8-11 for full (summer and winter), mid, and low load conditions. The results are summarized in Table 4-1.

Table 4-1: Dry Fork Unit 1 CO_2 Capture Tie-In Location (Stack Inlet) – English Units

		Full Load – Summer Conditions		Full Load – Winter Conditions		Mid Load		Low Load	
Temperature	°F	213		208		210		219	
Pressure	psia	12.598		12.588		12.566		12.599	
Differential Pressure	in. w.c.	1.9		1.60		1.0		0.8	
N_2	lb/hr-vol.%	3,314,559	65.48	3,216,405	68.60	2,478,333	66.42	2,271,139	67.56
O_2	lb/hr-vol.%	214,874	3.71	240,500	4.49	151,791	3.56	175,190	4.56
H_2O	lb/hr-vol.%	611,545	18.79	447,762	14.85	423,356	17.65	348,488	16.13
CO_2	lb/hr-vol.%	955,692	12.01	888,376	12.06	725,403	12.37	620,742	11.75
SO_2	lb/hr-ppmv	309	27	286	27	233	27	200	26
SO_3	lb/hr-ppmv	11	1	10	1	8	1	7	1
HCl	lb/hr-ppmv	0	0	0	0	0	0	0	0
HF	lb/hr-ppmv	0	0	0	0	0	0	0	0
Total Flow	lb/hr-acfm	5,096,990	1,727,290	4,793,341	1,588,904	3,779,126	1,269,302	3,415,766	1,159,717
Ash	lb/hr-gr/acf	53	0.004	50	0.004	41	0.004	35	0.003
NOx [Note 1]	lb/hr-ppmv	169	33	157	35	128	33	109	33
NO	lb/hr-ppmv	152	31	141	33	115	31	99	31
NO_2	lb/hr-ppmv	17	2	16	2	13	2	11	2
NH_3	lb/hr-ppmv	11.1	5	10.2	5	8.4	5	7.4	5
Hg	lb/hr	0.0093		-		0.0067		0.0055	

Note 1 – 90% NO / 10% NO_2 split is assumed.

Design Basis Document

Table 4-2: Dry Fork Unit 1 CO_2 Capture Tie-In Location (Stack Inlet) – SI Units

		Full Load – Summer Conditions		Full Load – Winter Conditions		Mid Load		Low Load	
Temperature	°C	101		98		99		104	
Pressure	kPa (a)	86.863		86.789		86.640		87.590	
N_2	kg/hr-vol.%	1,503,457	65.48	1,458,936	68.60	1,124,152	66.42	1,030,170	67.56
O_2	kg/hr-vol.%	97,465	3.71	109,089	4.49	68,851	3.56	79,465	4.56
H_2O	kg/hr-vol.%	277,392	18.79	203,101	14.85	192,031	17.65	158,071	16.13
CO_2	kg/hr-vol.%	433,494	12.01	402,960	12.06	329,037	12.37	281,564	11.75
SO_2	kg/hr-ppmv	140	27	130	27	106	27	91	26
SO_3	kg/hr-ppmv	5	1	5	1	4	1	3	1
HCl	kg/hr-ppmv	0	0	0	0	0	0	0	0
HF	kg/hr-ppmv	0	0	0	0	0	0	0	0
Total Flow	kg/hr-m^3/hr	2,311,954	2,934,683	2,174,221	2,699,564	1,714,181	2,156,557	1,549,364	1,970,371
Ash	kg/hr-gr/acf	24	0.004	23	0.004	18	0.004	16	0.003
NOx [Note 1]	kg/hr-ppmv	76	33	71	35	58	33	50	33
NO	kg/hr-ppmv	69	31	64	33	52	31	45	31
NO_2	kg/hr-ppmv	8	2	7	2	6	2	5	2
NH_3	kg/hr-ppmv	5.0	5	4.6	5	3.8	5	3.3	5
Hg	kg/hr	0.0042		-		0.0030		0.0025	

Note 1 – 90% NO / 10% NO_2 split is assumed.

Table 4-3 summarizes the ID fan outlet operating conditions once the ID fans are tipped to transfer flue gas to the CO_2 capture island that was used as part of the establishing the flue gas path pressure profile.

Design Basis Document

Table 4-3: Dry Fork Unit 1 CO_2 Capture Tie-In Location (Tipped ID Fan Outlet) – English Units

		Full Load – Summer Conditions	
Temperature	°F	222	
Pressure	psia	13.216	
	in. w.c.	19.05	
N_2	lb/hr-vol.%	3,314,559	65.48
O_2	lb/hr-vol.%	214,874	3.71
H_2O	lb/hr-vol.%	611,545	18.79
CO_2	lb/hr-vol.%	955,692	12.01
SO_2	lb/hr-ppmv	309	27
SO_3	lb/hr-ppmv	11	1
HCl	lb/hr-ppmv	0	0
HF	lb/hr-ppmv	0	0
Total Flow	lb/hr-acfm	5,096,990	1,667,490
Ash	lb/hr-gr/acf	53	0.004
NOx [Note 1]	lb/hr-ppmv	169	33
NO	lb/hr-ppmv	152	31
NO_2	lb/hr-ppmv	17	2
NH_3	lb/hr-ppmv	11.1	5
Hg	lb/hr	0.0093	

5.0 Attachment

- Attachment 5: 2017 ASHRAE Handbook Data

Attachment 5 – 2017 ASHRAE Handbook Data

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GILLETTE-CAMPBELL CO AP, WY, USA

WMO#: **726650**

Lat: **44.339N** Long: **105.542W** Elev: **4354** StdP: **12.53** Time Zone: **-7.00 (NAM)** Period: **90-14** WBAN: **94023**

Annual Heating and Humidification Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB		
				99.6%			99%			0.4%		1%				
		99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	
(1)	12	-9.3	-2.4	-16.6	2.6	-5.5	-9.5	3.9	-1.7	34.0	38.0	31.1	35.8	6.6	340	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	7	29.1	95.0	61.8	91.5	61.0	88.4	60.7	66.0	84.2	64.5	82.5	63.2	81.4	11.0	170	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	60.9	94.1	70.6	58.7	86.8	70.8	56.7	80.5	70.4	33.0	83.4	31.9	82.7	30.8	81.2	70.9	(3)

Extreme Annual Design Conditions

	Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature								
					Mean		Standard Deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(n)	(o)	(p)		(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	
(4)	28.9	25.9	23.2	DB	-17.9	100.6	6.9	2.9	-22.8	102.7	-26.8	104.4	-30.7	106.1	-35.6	108.2	(4)
(5)				WB	-18.3	68.4	6.7	1.4	-23.2	69.4	-27.1	70.3	-30.9	71.1	-35.7	72.1	(5)

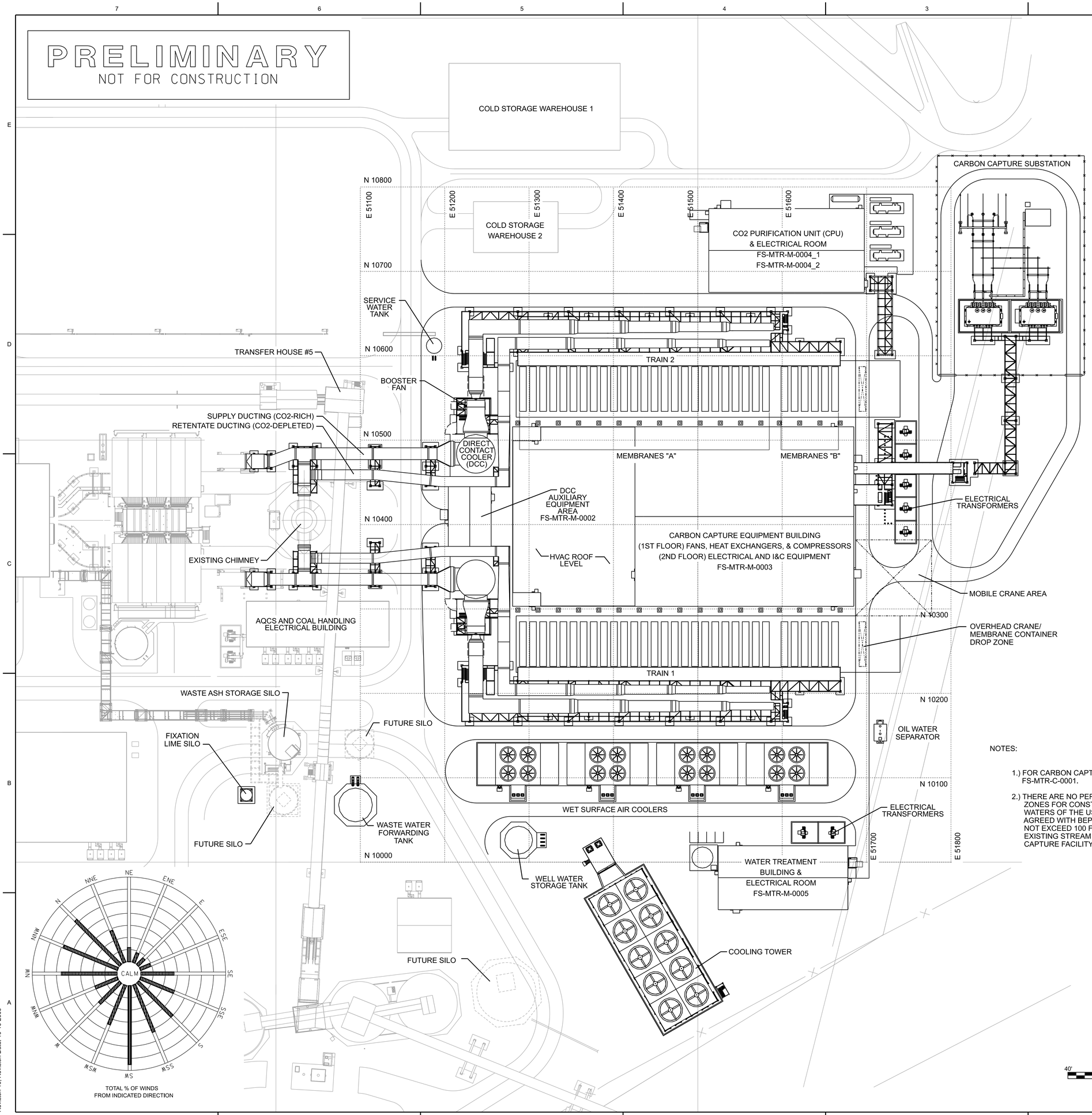
Monthly Climatic Design Conditions

				Annual (d)	Jan (e)	Feb (f)	Mar (g)	Apr (h)	May (i)	Jun (j)	Jul (k)	Aug (l)	Sep (m)	Oct (n)	Nov (o)	Dec (p)	
(6)	Temperatures, Degree-Days and Degree-Hours		DBAvg	46.2	25.6	26.6	35.5	42.9	52.1	62.4	71.4	70.2	60.1	46.1	34.2	25.5	(6)
(7)			DBStd	19.32	12.12	12.63	11.53	9.70	8.59	8.00	6.75	6.82	9.45	10.25	12.16	12.65	(7)
(8)			HDD50	3670	757	656	461	252	78	5	0	1	22	192	484	762	(8)
(9)			HDD65	7417	1222	1075	916	663	405	141	22	32	201	590	924	1226	(9)
(10)			CDD50	2272	0	1	11	40	144	378	664	628	324	71	10	1	(10)
(11)			CDD65	543	0	0	0	1	7	64	221	194	53	3	0	0	(11)
(12)			CDH74	7999	0	0	3	31	174	1026	3053	2666	957	88	1	0	(12)
(13)			CDH80	3642	0	0	0	3	39	420	1529	1259	374	18	0	0	(13)
(14)	Wind		WSAvg	10.3	11.3	10.8	11.0	11.2	10.5	9.6	8.8	9.0	9.4	10.1	11.0	11.2	(14)
(15)	Precipitation		PrecAvg	16.70	0.60	0.60	0.70	1.90	3.00	3.30	1.50	1.30	1.30	1.20	0.70	0.60	(15)
(16)			PrecMax	23.30	1.30	1.50	1.60	4.00	11.10	10.00	3.40	4.00	2.70	3.10	2.10	1.30	(16)
(17)			PrecMin	12.00	0.10	0.10	0.20	0.50	0.20	0.10	0.50	0.00	0.00	0.10	0.20	0.00	(17)
(18)			PrecStd	2.70	0.30	0.40	0.40	1.00	2.30	2.20	0.90	1.20	0.80	0.80	0.40	0.30	(18)
(19)	Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB	54.6	60.1	70.7	78.4	84.7	96.3	100.4	98.0	93.1	82.2	70.2	57.2	(19)	
(20)			MCWB	40.3	43.7	48.3	53.0	57.7	61.6	63.2	62.8	59.7	53.8	47.7	42.8	(20)	
(21)		2%	DB	48.8	53.1	63.9	72.3	79.1	89.7	96.5	93.6	88.6	75.5	62.8	51.3	(21)	
(22)			MCWB	37.6	40.0	45.3	50.6	56.3	61.4	62.8	60.7	58.3	51.2	44.5	39.2	(22)	
(23)		5%	DB	45.4	47.6	58.9	66.2	73.5	84.4	92.6	90.8	84.2	69.9	57.0	46.1	(23)	
(24)			MCWB	36.0	37.2	43.3	48.5	55.6	61.1	62.1	60.5	56.4	49.4	42.0	36.5	(24)	
(25)		10%	DB	42.1	43.1	53.6	61.0	69.4	80.0	89.0	87.8	79.8	63.8	52.2	42.7	(25)	
(26)			MCWB	34.1	34.5	41.1	45.9	53.5	59.9	61.9	60.2	55.5	47.4	40.0	34.4	(26)	
(27)	Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB	41.2	43.9	49.5	54.7	62.0	67.1	68.3	67.0	64.4	55.4	48.3	43.1	(27)	
(28)			MCDB	53.4	59.2	68.3	74.7	76.7	82.4	86.9	88.4	81.4	77.3	67.7	56.6	(28)	
(29)		2%	WB	38.4	40.3	46.2	51.3	59.1	64.6	66.3	65.0	60.6	52.6	45.2	39.5	(29)	
(30)			MCDB	47.8	51.6	62.5	67.7	74.0	82.0	84.8	83.2	80.5	72.4	61.4	49.0	(30)	
(31)		5%	WB	36.2	37.4	44.0	49.1	56.7	62.8	65.0	63.6	58.7	50.3	42.7	37.0	(31)	
(32)			MCDB	44.7	46.5	57.7	64.6	71.2	80.5	83.3	81.3	78.6	67.5	56.2	45.7	(32)	
(33)		10%	WB	34.2	35.0	41.4	46.7	54.3	60.8	63.8	62.1	56.6	48.0	40.3	34.6	(33)	
(34)			MCDB	41.6	42.5	52.8	59.7	67.3	77.5	82.4	80.7	75.9	62.6	51.4	42.3	(34)	
(35)	Mean Daily Temperature Range		MDBR	19.7	20.3	22.8	23.3	23.5	26.6	29.1	29.7	28.6	24.1	22.0	20.2	(35)	
(36)		5% DB	MCDBR	22.0	25.1	30.9	32.8	30.8	33.6	34.2	34.0	34.7	33.7	29.6	23.6	(36)	
(37)			MCWBR	13.9	15.2	16.1	16.0	13.9	13.3	11.2	11.4	13.2	15.5	16.3	14.8	(37)	
(38)		5% WB	MCDBR	21.1	23.3	29.4	30.2	28.0	30.9	30.3	29.6	30.3	30.9	27.9	22.1	(38)	
(39)			MCWBR	13.8	14.7	16.0	15.4	13.8	13.7	11.1	11.0	12.1	14.9	15.8	14.2	(39)	
(40)	Clear-Sky Solar Irradiance		taub	0.245	0.252	0.270	0.295	0.320	0.328	0.350	0.350	0.312	0.281	0.257	0.243	(40)	
(41)			taud	2.581	2.572	2.567	2.486	2.477	2.474	2.435	2.417	2.515	2.581	2.565	2.574	(41)	
(42)			Ebn,noon	291	306	311	308	301	298	289	286	291	290	282	280	(42)	
(43)			Edh,noon	20	24	27	32	34	34	35	34	29	23	20	18	(43)	
(44)	All-Sky Solar Radiation		RadAvg	588	889	1283	1590	1921	2232	2279	1965	1531	1004	652	495	(44)	
(45)			RadStd	36	69	82	93	156	149	82	65	82	84	52	29	(45)	

Nomenclature: See separate page

APPENDIX D. GENERAL ARRANGEMENT AND PIPING ISOMETRIC DRAWINGS

PRELIMINARY
NOT FOR CONSTRUCTION



NOTES:

1.) FOR CARBON CAPTURE RESERVOIR SEE DWG. FS-MTR-C-0001.

2.) THERE ARE NO PERMIT ENFORCEABLE EXCLUSION ZONES FOR CONSTRUCTION CONCERNING THE WATERS OF THE US (WOTUS). HOWEVER, IT WAS AGREED WITH BEPC/DFS THAT CONSTRUCTION SHALL NOT EXCEED 100 FT FROM THE WOTUS, WHICH IS THE EXISTING STREAM TO THE EAST OF THE CARBON CAPTURE FACILITY.

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
A	05/28/2021	FOR CLIENT COMMENT
B	10/12/2021	FOR CLIENT COMMENT
0	02/07/2022	FOR USE

ISSUE PURPOSE: FOR USE

SPECIFICATION:

PROJECT NO.: 13978.002

I HEREBY CERTIFY THAT THIS ENGINEERING DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT PERSONAL SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF ENTER NAME.

ENTER NAME
ENTER DATE

MY LICENSE RENEWAL DATE IS: ENTER DATE
PAGES OR SHEETS COVERED BY THIS SEAL:
THIS DOCUMENT ONLY.

CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-M-0001.DGN

PREPARED BY: RM

REVIEWED BY: RAM

APPROVED BY: DBP

ANY MODIFICATION OR ADDITION TO THIS DRAWING BY AN ORGANIZATION OTHER THAN SARGENT & LUNDY IS NOT THE RESPONSIBILITY OF SARGENT & LUNDY.

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT

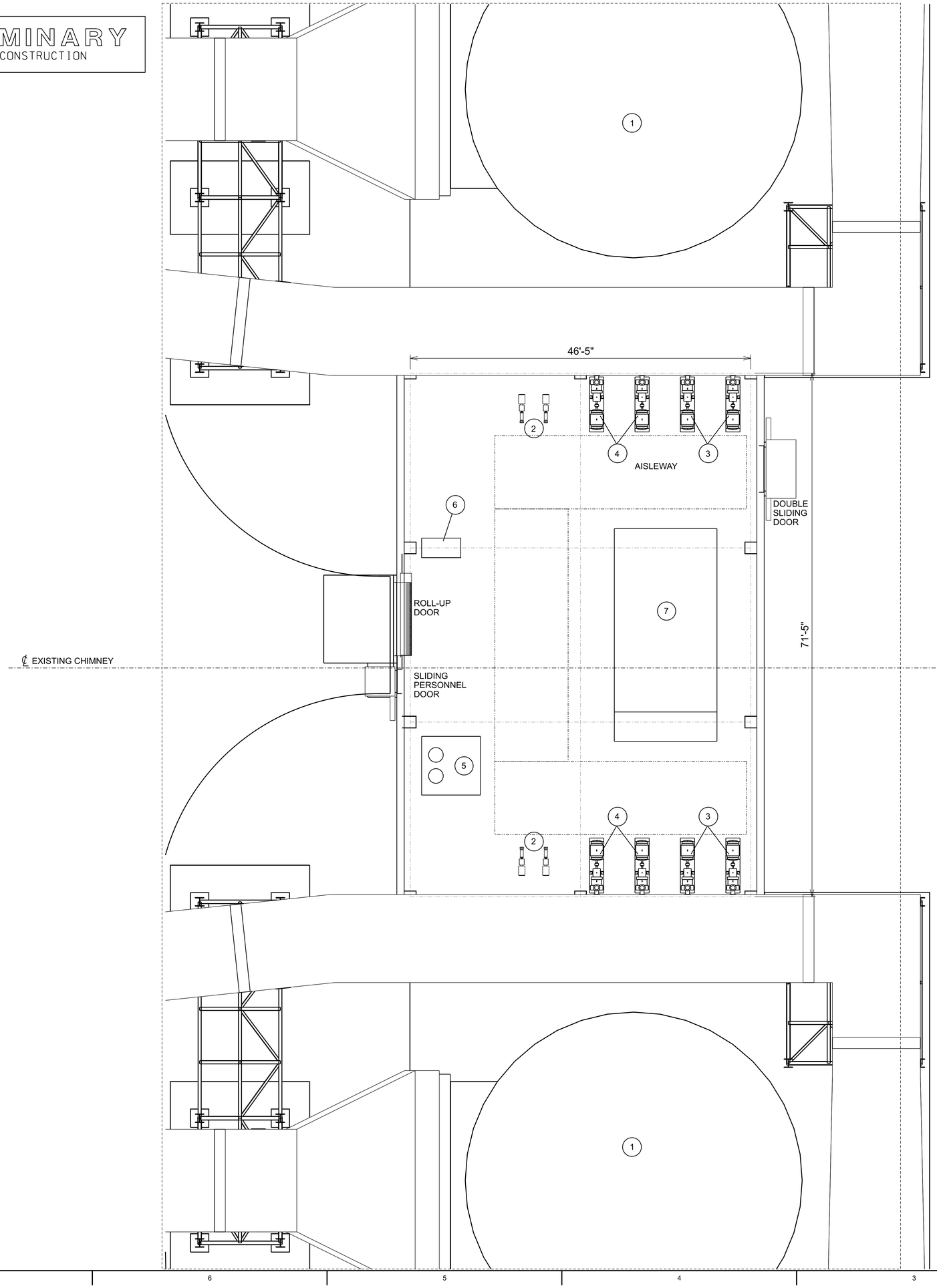
SITE PLAN

DRAWING NUMBER	REVISION
FS-MTR-M-0001	0
SHEET 01 OF 01	

PL:\12849\00M1743\D\DFM\TR\cadms\design\Full Scale\General Arrangements\Site Plan\FS-MTR-M-0001.dgn
Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

2/7/2022 5:04:28 PM ...\Site Plan\FS-MTR-M-0001.dgn

PRELIMINARY
NOT FOR CONSTRUCTION



TRAIN 1 (SOUTH) / TRAIN 2 (NORTH)	
ITEM	DESCRIPTION
1	DIRECT CONTACT COOLER
2	CAUSTIC PUMPS
3	SO2 POLISHING PUMPS
4	DCC CIRCULATING WATER PUMPS
5	BUILDING SUMP & PUMPS
6	ANALYZER CABINET
7	CAUSTIC STORAGE TANK

NOTES:

1.) BUILDING GRADE EL. 4249' - 0"

PLANT NORTH

5' 0 5' 10' 15'
GRAPHIC SCALE

DRAWING SCALE
3/16" = 1'-0"

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

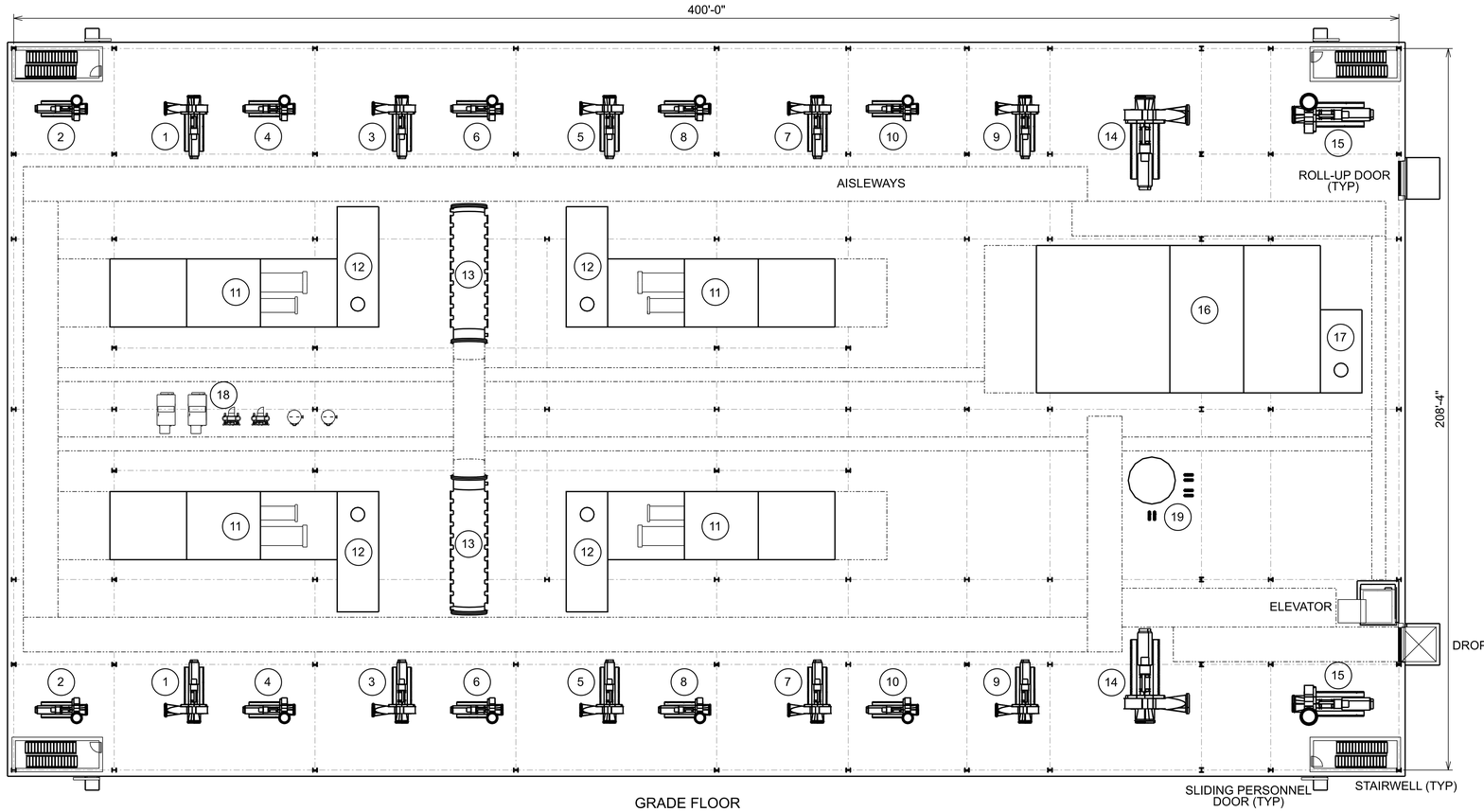
GENERAL ARRANGEMENT
DCC AUXILIARY EQUIPMENT AREA
PLOT PLAN

DRAWING NUMBER	REVISION
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SHEET 01 OF 01

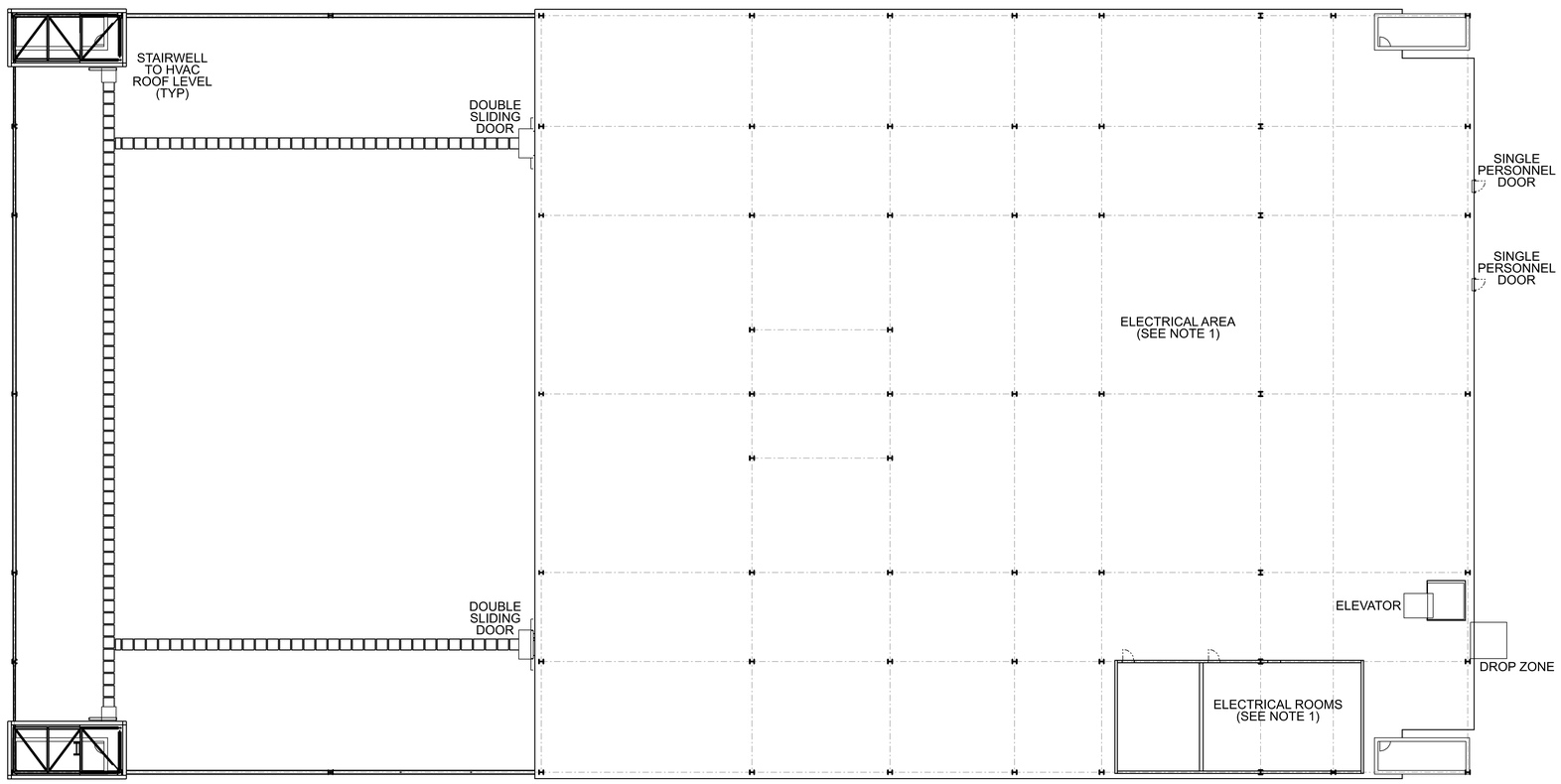
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Revision 10, Revision Date: 10-16-2009

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GRADE FLOOR

EL. 4249' - 0"



HVAC ROOF LEVEL

EL. 4298' - 0"

SECOND FLOOR

EL. 4298' - 8"

TRAIN 1 (SOUTH) / TRAIN 2 (NORTH)	
ITEM	DESCRIPTION
1	MEMA BLOCK 1 FAN 1
2	MEMA BLOCK 1 FAN 2
3	MEMA BLOCK 2 FAN 1
4	MEMA BLOCK 2 FAN 2
5	MEMA BLOCK 3 FAN 1
6	MEMA BLOCK 3 FAN 2
7	MEMA BLOCK 4 FAN 1
8	MEMA BLOCK 4 FAN 2
9	MEMA BLOCK 5 FAN 1
10	MEMA BLOCK 5 FAN 2
11	MEMA COMPRESSOR
12	MEMA COMPRESSOR LUBE OIL
13	MEMA COMP HEAT EXCHANGER
14	MEMB FAN 1
15	MEMB FAN 2
16	MEMB COMPRESSOR
17	MEMB COMPRESSOR LUBE OIL
18	COMPRESSED AIR EQUIPMENT
19	PROCESS CONDENSATE COLLECTION TANK & PUMPS

PRELIMINARY
NOT FOR CONSTRUCTION

NOTES:

1.) FOR ELECTRICAL EQUIPMENT SEE DWGS:
1ST FLOOR - FS-MTR-E-0001_1
2ND FLOOR - FS-MTR-E-0001_2

PLANT NORTH

16' 0 16' 32' 48'

GRAPHIC SCALE

DRAWING SCALE
1/16" = 1'-0"

HOLD INFORMATION	
NO.	DESCRIPTION

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT
CARBON CAPTURE EQUIPMENT BUILDING
PLOT PLAN

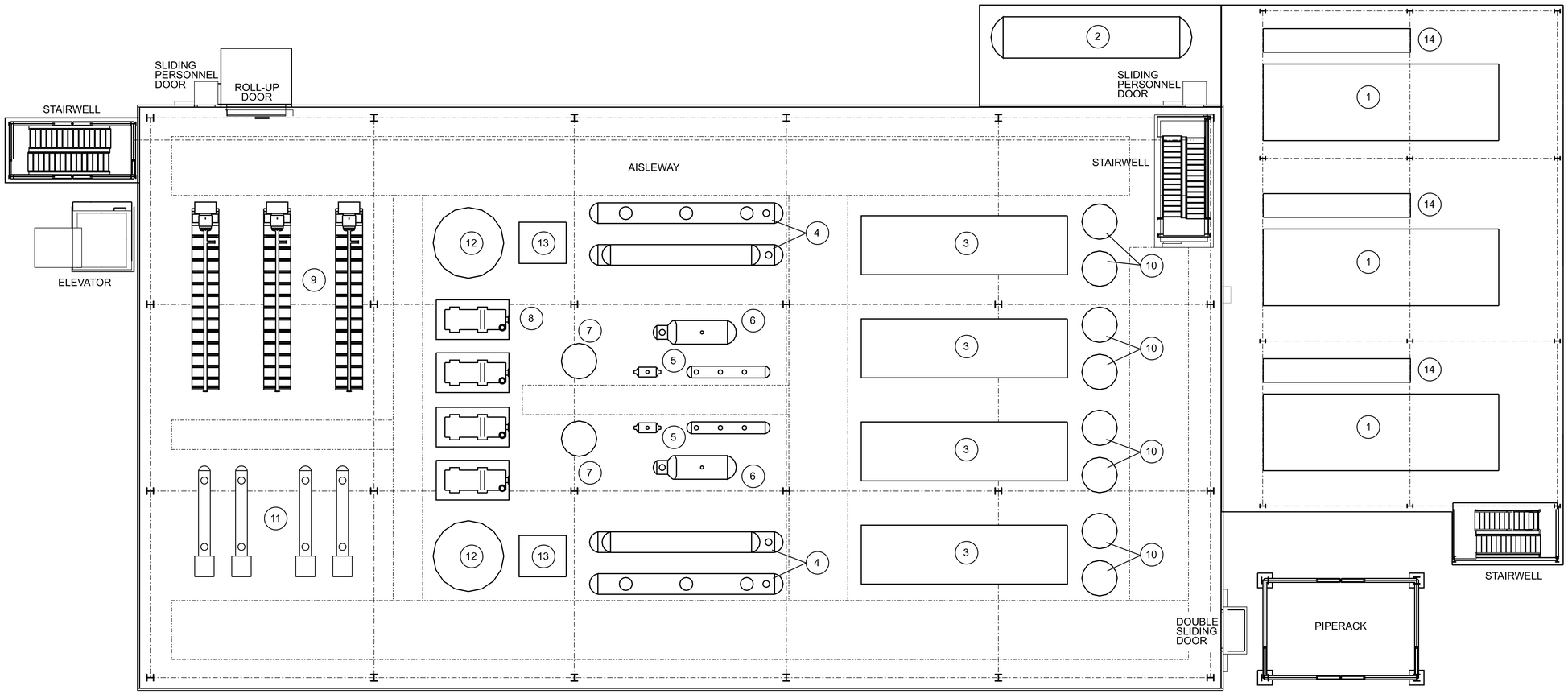
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PRELIMINARY
NOT FOR CONSTRUCTION

ITEM	DESCRIPTION
1	REFRIGERATION COMPRESSOR
2	HIGH PRESSURE REFRIGERANT RECEIVER
3	DHY VALVE SKID
4	PRIMARY CO2 CONDENSER
5	AUX REBOILER
6	REBOILER
7	STRIPPER COLUMN
8	CO2 BOOSTER PUMPS
9	CO2 PRODUCT PUMPS
10	DHY VESSEL
11	CO2 PRODUCT HEATERS
12	REFLUX DRUM
13	REFLUX PUMP SKID
14	COMPRESSOR COOLER



GRADE FLOOR
EL. 4249' - 0"

PLANT NORTH

8' 0 8' 16' 24'
GRAPHIC SCALE

DRAWING SCALE
1/8" = 1'-0"

HOLD INFORMATION	
NO.	DESCRIPTION

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT
CO2 PURIFICATION UNIT (CPU) (1ST FLR)
PLOT PLAN

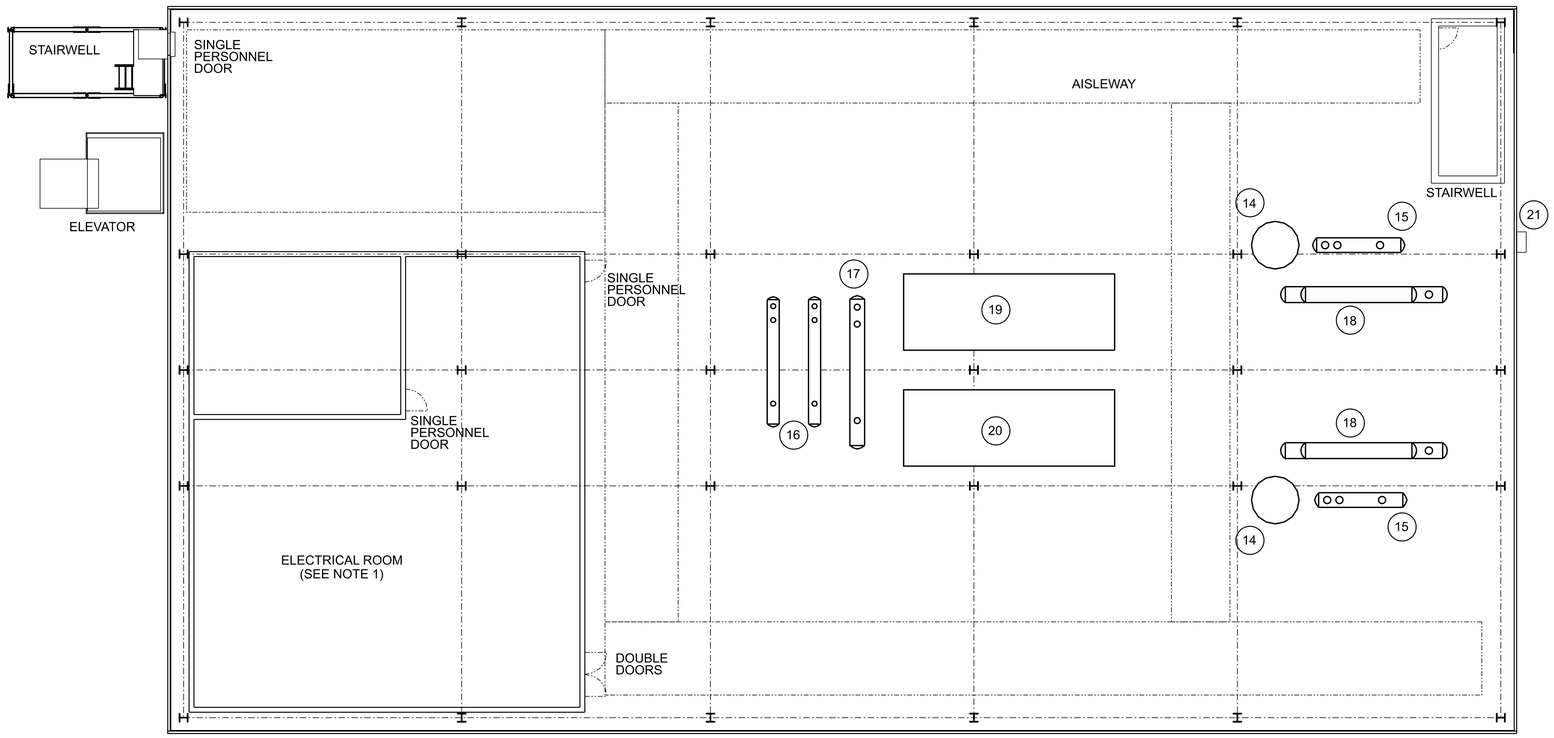
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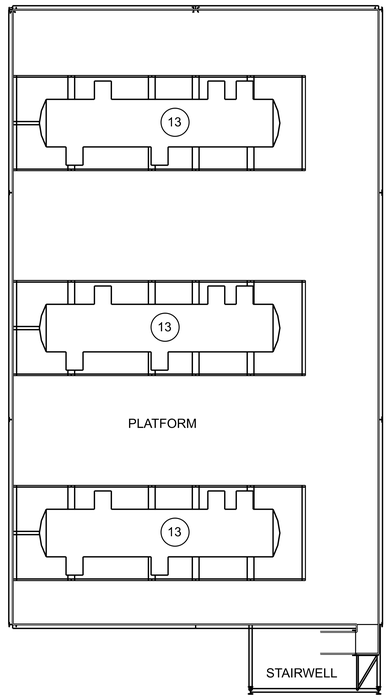
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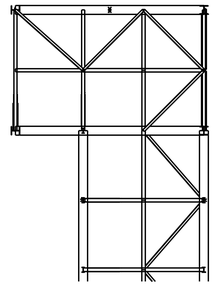
PRELIMINARY
NOT FOR CONSTRUCTION

ITEM	DESCRIPTION
13	REFRIGERANT CONDENSER
14	DHY FEED SEPARATOR
15	SUPERHEATER
16	VENT PREHEATERS
17	VENT HEATER
18	DHY FEED CHILLER
19	MEMBRANE C
20	MEMBRANE D
21	DHY REGENERATION PROCESS VENTS



SECOND FLOOR
EL. 4276' - 8"





PIPERACK FROM PROCESS BUILDING

NOTES:

1). FOR ELECTRICAL EQUIPMENT SEE DWG:
2ND FLOOR - FS-MTR-E-0002

PLANT NORTH

8' 0 8' 16' 24'
GRAPHIC SCALE

DRAWING SCALE
1/8" = 1'-0"

HOLD INFORMATION

NO.	DESCRIPTION

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SPECIFICATION:

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

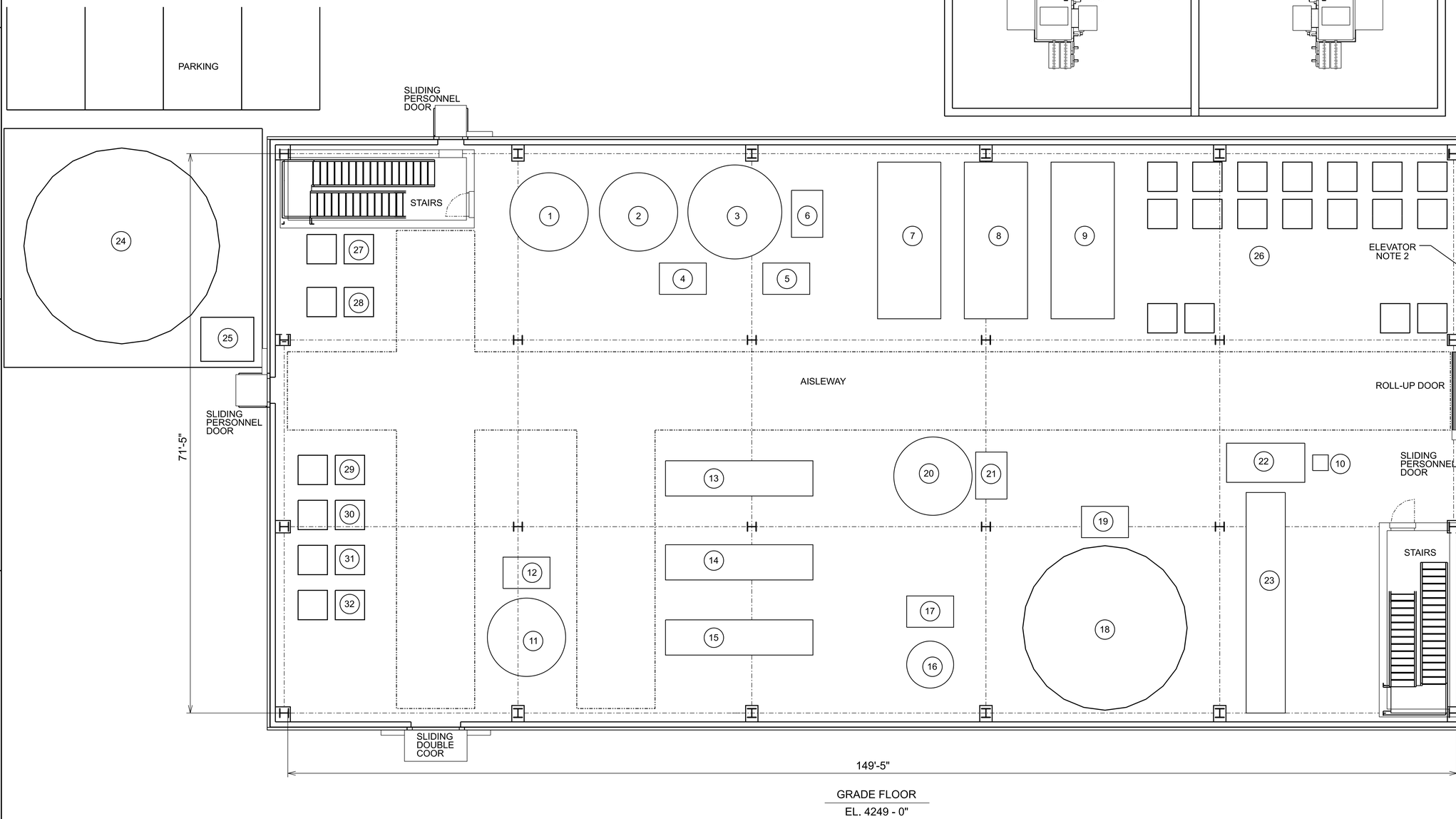
GENERAL ARRANGEMENT
CO2 PURIFICATION UNIT (CPU) (2ND FLR)
PLOT PLAN

DRAWING NUMBER	REVISION
FS-MTR-M-0004	0
SHEET 02 OF 02	

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Revision 10, Revision Date: 10-16-2009

PRELIMINARY
NOT FOR CONSTRUCTION



GRADE FLOOR
EL. 4249 - 0"

ITEM	DESCRIPTION						
1	REACTION TANK 1	11	PH ADJUST TANK	21	FILTER PRESS PUMPS	31	RO ACID TOTE & METERING SKID
2	REACTION TANK 2	12	PH ADJUST FEED PUMPS	22	CONTROL PANEL	32	RO ANTISCALANT TOTE & METERING SKID
3	CONC TANK	13	RO SKID 1	23	FILTER PRESS	33	13800-4160V TRANSFORMER
4	RECYCLE PUMPS	14	RO SKID 2	24	EQUALIZATION TANK		
5	MF FEED PUMPS	15	RO SKID 3	25	EQUALIZATION TANK FORWARDING PUMPS		
6	WASTE PUMPS	16	CIP TANK	26	WSAC/CT CHEMICAL TOTES AND PUMPS		
7	MF SKID 1	17	CIP PUMP SKID	27	MF CAUSTIC TOTE & METERING SKID		
8	MF SKID 2	18	PERMEATE TANK	28	MF HYPOCHLORITE TOTE & METERING SKID		
9	MF SKID 3	19	PERMEATE TANK FORWARDING PUMPS	29	MF FERRIC CHLORIDE TOTE & METERING SKID		
10	HMI STATION	20	THICKENER	30	MF MAGNESIUM OXIDE TOTE & METERING SKID		

NOTES:

1). FOR ELECTRICAL EQUIPMENT SEE DWG: 2ND FLOOR - FS-MTR-E-0003

2.) FIRST FLOOR ELEVATOR ACCESS IS FROM BUILDING EXTERIOR.

PLANT NORTH

5' 0 5' 10' 15'
GRAPHIC SCALE

DRAWING SCALE
3/16" = 1'-0"

HOLD INFORMATION

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1	03/09/2022	FOR USE

ISSUE PURPOSE: FOR USE

SPECIFICATION:

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APPROVED BY: DBP

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT
WATER TREATMENT BUILDING (1ST FLOOR)
PLOT PLAN

DRAWING NUMBER	REVISION
FS-MTR-M-0005	1
SHEET 01 OF 02	

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APPENDIX H. GEOTECHNICAL INVESTIGATION TECHNICAL SPECIFICATIONS

Membrane Technology & Research

DRY FORK STATION UNIT 1

FULL SCALE CARBON CAPTURE FEED STUDY PROJECT SPECIFICATION NO. FSMTR-G-002 GEOTECHNICAL INVESTIGATION

Issued for FEED Study Design
Rev. 0

Oct. 1, 2021
Project 13978-002

Prepared by

Sargent & Lundy

55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

SECTION 000110

TABLE OF CONTENTS

FOR GEOTECHNICAL INVESTIGATION

DIVISION/SECTION	TITLE
Section 000106	Issue Summary and Approval Page
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DIVISION 1 – GENERAL REQUIREMENTS	
Section 011100	Project Summary – Geotechnical Investigation
DIVISION 2 – SITEWORK	
Section 023213	Subsurface Investigation
Section 023126	Soil Resistivity Survey

SECTION 000106

ISSUE SUMMARY AND APPROVAL PAGE

GEOTECHNICAL INVESTIGATION

FOR THE
FULL SCALE CARBON CAPTURE FEED STUDY PROJECT

BASIN ELECTRIC POWER COOPERATIVE (BEPC)

Rev.	Purpose of Issue	Date	Sections Affected
0	FEED Study Design	10/01/2021	All

This is to confirm that this Specification has been prepared, reviewed and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0407, Specifications, which is part of our Quality Management System.

Rev.	Prepared By	Reviewed By	Approved By
0	W. Roger Wu	Daniel Kocunik	Daniel Kocunik

SECTION 011100

PROJECT SUMMARY

GEOTECHNICAL INVESTIGATION

PART 1 - GENERAL

101. PROJECT INFORMATION

101.1	Owner/Purchaser:	Basin Electric Power Cooperative (BEPC)
101.2	Consulting Engineer:	Sargent & Lundy (S&L)
101.3	CO_2 Process Equipment OEM:	Membrane Technology & Research, Inc. (MTR)
101.4	Name of Project:	Full Scale Carbon Capture FEED Study
101.5	Location of Project:	Dry Fork Station, 12460 North Highway 59, Gillette, WY, 82716

102. SCOPE OF WORK

102.1 This specification covers the requirements for performing a geotechnical investigation for the Full Scale FEED study at the Dry Fork Station (DFS) Unit 1 facility. The Contractor shall familiarize itself with the project site and the conditions for performing the Work in the designated areas.

102.2 Contractor shall furnish all necessary labor, material, vehicles and equipment required to perform the Work.

102.3 The Work shall include mobilization and demobilization, buried utility location/avoidance, vacuum excavation (at select locations as required by Owner), boring and test location surveying, soil borings, rock coring, field classification, field sampling and testing, preparing boring logs, sample preparation, laboratory testing, seismic surface wave survey, thermal conductivity tests, electrical soil resistivity tests, and submittal of draft and final reports.

102.4 All field exploration borings shall be advanced and abandoned in strict accordance with all applicable state and local regulations.

102.5 Upon substantial completion of laboratory testing, Contractor shall transmit one electronic copy (PDF format) of the draft report to Purchaser and Engineer for comments. Draft report shall, to the extent practical, contain all items required for the final report.

102.6 Upon incorporation of Purchaser's and Engineer's comments on draft report, provide a geotechnical investigation report sealed by the applicable licensed professional in the state of Wyoming. The report shall include a description of the procedures used, calibration report of SPT hammer energy, final boring logs, reports of seismic surface wave survey, thermal conductivity tests and electrical soil resistivity tests, field and laboratory test results, and the as-drilled boring location diagram.

102.7 Work shall conform to the requirements of these specifications and shall be performed and supervised by personnel who are experienced and knowledgeable in the field of geotechnical investigation work. The work shall be performed by a qualified firm as defined by ASTM D3740.

102.8 All work shall be coordinated through Owner's site representative Mr. Nolan Bray. His telephone number is 307-622-2522.

103. DEFINITIONS

103.1 Whenever the following terms appear in the Contract Documents, they shall mean the following:

a. Engineer - means the firm (S&L) retained by Owner to perform detailed design using the information provided by the Contractor.

b. Contractor - means the firm, company, organization retained by Purchaser to perform the work covered by this Specification.

c. Work - means documentation preparation and submittal, procurement, labor, services, equipment and material as set forth in the Contract Documents.

d. Approved Equal - means a satisfactory equivalent to a specified material or method accepted by Purchaser.

e. Contract Documents - means all Drawings, Exhibits, Specifications, Addenda and Revisions thereto; Purchase Orders and Supplements to the Purchase Order; Supplier's Drawings as accepted by Purchaser; and all documents which are a part of this Contract.

f. Others - means any firm exclusive of the Contractor.

g. Indicated - means as shown, noted, called for, or specified on the Design Drawings and Exhibits.

h. Provide - means furnish, perform and install and when applicable place in successful operation.

i. Per - means in accordance with and/or as required by.

104. SCHEDULE OF WORK

104.1 Intent of Schedule: The Schedule of Work herein specified sets forth activity durations which Contractor is required to meet in order to ensure that the Work by Contractor is properly coordinated with all other work for the Project. However, the stipulation of these activity durations shall not relieve Contractor of the obligation to process the Work, from start to completion, in an orderly and continuous manner during the course of the Work.

104.2 Schedule Durations for Work by Contractor: Contractor shall perform the Work in accordance with the following schedule:

		Weeks After Authorization
a.	Notice to Proceed.....	--------
b.	Commence Subsurface Exploration Work.....	1 week
c.	Complete work to clear underground utilities and stake out boring locations.....	2 weeks
d.	Complete all soil borings, seismic survey and soil resistivity tests	5 weeks
e.	Complete all laboratory testing including thermal conductivity tests	7 weeks
f.	Submit draft report.....	8 weeks

		Weeks After Authorization
g.	Submit final report	1 week after Contractor receives comments related to draft report from Purchaser and Engineer

104.3 The foregoing work period is not guaranteed to Contractor, and it is advised that Work may not be able to be performed continuously between the time durations listed herein, and that its workforce may be required to be increased or decreased as work of others takes precedence.

105. PROTECTION OF PROPERTY

105.1 The Contractor shall take adequate precautions to protect existing structures, fences, pavements, above ground utilities and underground utilities and to avoid damage thereto. The Contractor shall, at its own expense, repair any damage caused by its operations.

105.2 Contractor shall preserve and maintain previously established bench marks and reference points. Should Contractor, during execution of the work, destroy or remove any bench marks and/or reference points, the cost to reestablish these bench marks and/or reference points will be charged to the Contractor.

106. REGULATORY REQUIREMENTS

106.1 Contractor shall at all times be solely responsible for complying with all applicable laws, ordinances, regulations and codes, including those relating to environmental/aquifer protection and safety of all persons, in connection with the Work. No obligation of Owner or Purchaser/Engineer shall impose upon them any duty to review Contractor's compliance with safety measures.

106.2 Obtain, as part of the cost of this project, all permits, licenses and local utility clearances necessary to carry out the Work described herein.

106.3 Permits shall be obtained before commencement of related Work.

106.4 Comply with building code authority regarding permit inspection and approval requirements.

107. SUBMITTALS

107.1 Prior to starting site work, Contractor shall submit a letter certifying that Contractor and all Subcontractors that will perform testing or engineering services comply with ASTM D3740.

107.2 Submit field draft boring logs on a daily basis for Engineer to assign laboratory tests.

107.3 Upon substantial completion of testing, Contractor shall transmit one electronic (PDF format) copy of the draft report to the Purchaser and Engineer for comments.

107.4 Upon implementation of comments made by Purchaser and/or Engineer on the draft report, Contractor shall provide an electronic copy (in PDF format) of the typed final report sealed by a licensed professional in the state of Wyoming. The final report shall include the information as required in Article 102.6.

107.5 Address and submit correspondence, reports and related documents to the following parties:

a. One electronic copy of the final report to:

Mr. Nolan Bray
Tel. 307-622-2522
NBray@bepc.com
Dry Fork Station
12460 North Highway 59
Gillette, WY 82716

b. One electronic copy of the final report to:

Ms. Dana Pierik
Project Manager
Sargent & Lundy
55 E. Monroe Street
Chicago, Illinois 60603-5780
dana.b.pierik@sargentlundy.com

108. SAFETY

108.1 Contractor and Subcontractors are responsible for the safety of their personnel and equipment.

108.2 Site Owner will provide training material for Contractor staff and Subcontractors for the site-specific safety procedures. By providing this training, Site Owner and Purchaser assumes no responsibility for Contractor's safety.

108.3 Contractor shall report all on-site injuries from this Work to the Work Coordinator identified in Article 102.8.

109. BACKFILL, CLEAN-UP AND DISPOSAL OF DEBRIS

109.1 The Contractor shall be responsible for clean-up and disposal of all soil cuttings, drill fluid, debris and other Contractor-generated waste, resulting from the subsurface exploration work. All debris shall be disposed of offsite meeting state and local regulations, unless an onsite location is allowed and as directed by Owner. All boreholes shall be backfilled with grout and surfacing gravel be restored (when applicable) by the Contractor as directed in Section 023213.

109.2 Clean-up, disposal and site restoration shall be in compliance with the applicable requirements of all access permits. If any additional permits are required for disposal of debris, these shall be the responsibility of the Contractor.

109.3 Work areas shall be kept clean and orderly at all times with as little disturbance as possible to existing conditions. Upon completion of work at each site, all tools, equipment, material, and debris shall be completely removed and the area shall be left in a clean condition.

110. CONFLICT

110.1 In the event of variation between Contract Terms and Conditions and the requirements specified herein, Contract documents shall govern.

110.2 In the event of variation between the Engineer's Standards and the Project Specification or the drawings, the Project Specification and the drawings shall govern. In the event of variations between the Project Specification and the drawings, the drawings shall govern.

110.3 The Contractor shall be solely responsible for advising Purchaser and Engineer in writing of any conflicts between the Project Specification and the drawings and the Contractor's methods, including performance and levels of quality. The Contractor agrees that its obligations, liabilities and warranties shall not be diminished or extinguished due to its meeting the requirements of the Project Specification and the drawings.

111. CONTROL AND CHARGE OF CONTRACTOR'S WORK

111.1 The Engineer shall have no authority to stop the Work by the Contractor for any reason. The Engineer, however, reserves the right to request, and Contractor shall supply, detailed information regarding the Work such as procedures or work methods.

112. DRAWINGS AND DATA

112.1 The following design drawings prepared by the Engineer, unless otherwise indicated, form a part hereof:

Drawing No.	Rev.	Title
Exhibit FSMTR-G-002-1	0	Main Carbon Capture Area Soil Boring and Seismic Survey Test Location Plan
Exhibit FSMTR-G-002-2	0	Main Carbon Capture Area Subsurface Investigation Soil Resistivity Test Location Plan

END OF SECTION

SECTION 023213

SUBSURFACE INVESTIGATION

PART 1 - GENERAL

101. EXTENT

101.1 This Section covers the specific requirements for the performance of the subsurface investigation and associated work.

101.2 The Work includes the following:

a. Stake out locations of all borings, seismic surface wave survey lines, and electrical soil resistivity test locations. Survey coordinates and elevations of actual locations after any tests or borings are relocated.

b. Locate and avoid all underground utilities (including stormwater sewer, etc.) in the near vicinity of the boring locations in the Main Carbon Capture Area shown in Exhibit FSMTR-G-002-1. Perform vacuum excavation at select boring locations as required by Owner.

c. At boring locations where surfacing gravel is present, Contractor shall strip and remove the surfacing gravel to the side, perform vacuum excavation (if required by Owner) and record on boring log the soil classification and estimated soil consistency within the vacuum depth (when no SPT is performed). During soil boring operation the soil cuttings and spoil shall be kept separately from the surfacing gravel (do not contaminate the gravel). Measure thickness of gravel and note this on the boring log.

d. Drill 15 borings (BH-1 through BH-15) to the depths specified on Table 1 of this Section and at the locations as depicted on the Exhibit FSMTR-G-002-1 .

e. Obtain Standard Penetration Test (SPT) - N-values, per ASTM D1586.

f. Provide a prior certified report (less than 12 months old) of SPT hammer energy testing for the SPT hammer system used on site, per ASTM D4633.

g. Obtain bulk samples of soils per Article 306.

h. Obtain undisturbed soil samples using Shelby tubes, per ASTM D1587, when cohesive soils are encountered and suitable for sampling using a thin-walled tube sampler.

i. Obtain ring samples in accordance with ASTM D3550, when Shelby tube sampler is not practical.

j. Obtain pocket penetrometer readings (unconfined compressive strength values) on all cohesive soil samples.

k. Continuous rock coring shall be performed in all rock layers as specified in Table 1 in accordance with ASTM D2113 after attaining auger refusal or after SPT refusal when feasible.

l. Obtain groundwater level measurements in each boring during drilling, at completion of drilling, at 24 hours after completion if the borehole is still open, and before grouting the boreholes. Record all of the measurements on the boring logs.

m. Grout the boreholes to the original bottom depth of surfacing gravel (when present) with materials and procedures in accordance with local or state regulations and this Specification. Then cover the borehole up with the original surfacing gravel (when applicable).

n. Perform laboratory testing of selected samples. Soil samples to be tested will be selected by the Engineer (Sargent & Lundy) after receiving the field logs.

o. Soil descriptions shall be in accordance with ASTM D2488.

p. Submit field draft boring logs on a daily basis. Field logs shall be in accordance with ASTM D5434.

q. Perform Soil Thermal Conductivity tests in accordance with Article 310.1 for soil samples taken at the specified boring locations.

r. Perform Seismic Surface Wave Survey in accordance with Article 310.2 of this Section.

s. Perform Soil Resistivity Survey in accordance with the requirements of Section 023126.

t. The Contractor shall be responsible for clean-up and disposal of all debris resulting from the subsurface exploration work. Contractor shall haul the soil cuttings and spoil to offsite meeting state and local regulations unless a designated on-site area is allowed and as directed by Owner.

u. Provide draft and final reports consisting of a description of the procedures used, SPT hammer energy calibration report, final boring logs, field and laboratory test results, including soil resistivity surveys, seismic surface survey, thermal conductivity test results, and the as-drilled boring location diagram.

v. The values stated in either US customary/inch-pound or SI/metric units in this Section are to be regarded separately as the applicable standard. The values stated in each system may not be exact conversion equivalents due to rounding; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformances with the standard.

102. REFERENCE DOCUMENTS

102.1 Standards, Specifications, manuals, codes, and other publications of nationally recognized organizations are referenced herein. References to these documents are to the issue date as indicated by the Adopted Building Code. If the document is not referenced in the Adopted Building Code, then the reference is to the latest issue date of the document together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of the Contract for the Work.

102.2 Abbreviations listed below refer to the applicable organizations or documents.

102.3 ASTM – ASTM International:

a. ASTM C150/C150M – Standard Specification for Portland Cement

b. ASTM C1580 – Standard Test Method for Water-Soluble Sulfate in Soil

c. ASTM D422 – Standard Test Method for Particle-Size Analysis of Soils (Withdrawn 2016)

d. ASTM D854 - Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer

e.	ASTM D1140	– Standard Test Methods for Determining the Amount of Material Finer Than 75 µm (No. 200) Sieve in Soils by Washing
f.	ASTM D1557	– Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort
g.	ASTM D1586	– Standard Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
h.	ASTM D1587	– Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
i.	ASTM D2113	– Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration
j.	ASTM D2166/2166M	– Standard Test Method for Unconfined Compressive Strength of Cohesive Soil
k.	ASTM D2216	– Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
l.	ASTM D2435/2435M	– Standard Test Methods for One-Dimensional Consolidation Properties of Soils Using Incremental Loading
m.	ASTM D2488	– Standard Practice for Description and Identification of Soils (Visual-Manual Procedures)
n.	ASTM D2974	– Standard Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils
o.	ASTM D3550	– Standard Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
p.	ASTM D3740	– Standard Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
q.	ASTM D4220/4220M	– Standard Practices for Preserving and Transporting Soil Samples
r.	ASTM D4318	– Standard Test Methods for Liquid Limit, Plastic Limit and Plasticity Index of Soils
s.	ASTM D4546	– Standard Test Methods for One-Dimensional Swell or Collapse of Soils
t.	ASTM D4633	– Standard Test Method for Energy Measurement for Dynamic Penetrometers
u.	ASTM D5079	– Standard Practices for Preserving and Transporting Rock Core Samples
v.	ASTM D5333	– Standard Test Method for Measurement of Collapse Potential of Soils (Withdrawn 2012)
w.	ASTM D5334	– Standard Test Method for Determination of Thermal Conductivity of Soil and Soft Rock by Thermal Needle Probe Procedure

x.	ASTM D5434	– Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock
y.	ASTM D5777	– Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation
z.	ASTM D5783	– Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geo-environmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
aa.	ASTM D6032	– Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core
bb.	ASTM D6151	– Standard Practice for Using Hollow-Stem Augers for Geotechnical the Exploration and Soil Sampling
cc.	ASTM D6066	- Standard Practice for Determining Normalized Penetration Resistance of Sands for Evaluation of Liquefaction Potential
dd.	ASTM D6913	– Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis
ee.	ASTM D7012	– Standard Test Methods for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures
ff.	ASTM D7263	– Standard Test Methods for Laboratory Determination of Density (Unit Weight) of Soil Specimens
gg.	ASTM D7928	– Standard Test Methods for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis
hh.	ASTM G51	– Standard Test Method for Measuring pH of Soil for Use in Corrosion Testing

102.4 United States Environmental Protection Agency:

a. 0325.3 – Chloride – Titrimetric, Mercuric Nitrate

b. 0375.4 – Sulfate – Turbidimetric

c. 9056 – Inorganic Anions by Ion Chromatography

102.5 IEEE – Institute of Electrical and Electronic Engineers:

a. IEEE Std. 442 – IEEE Guide for Soil Thermal Resistivity Measurement.

PART 2 - PRODUCTS

201. CONTRACTOR'S EQUIPMENT AND SUPPLIES

201.1 The Contractor shall furnish the appropriate equipment and supplies to perform the Work.

201.2 The Contractor is responsible for providing vehicles and equipment capable of reaching the boring locations. All equipment shall be mechanically sound with all safety equipment, including kill switches, maintained in operating condition.

201.3 The Contractor shall provide one or more drill rigs capable of at least 15,000 pounds of down thrust and 7,500 foot pounds of spindle torque.

201.4 Contractor shall furnish rotary wash, drilling equipment per ASTM D5783 if granular soils are encountered below the groundwater level.

201.5 Drill rig shall be equipped with either an automatic hammer system, with automatic release mechanism, or safety hammer with rope and cathead as discussed in ASTM D1586 and ASTM D6066. Hammer systems that include spooling winch mechanisms to lift and drop the SPT hammer shall not be used for any part of this work. A spooling winch system may be used to raise hammer to drive casing, if required.

201.6 Contractor shall furnish watertight jars or equivalent to preserve and transport soil samples in accordance with ASTM D4220/4220M.

201.7 Contractor shall furnish all undisturbed sample tubes and microcrystalline wax or equivalent to preserve samples for laboratory testing in accordance with ASTM D4220/4220M.

201.8 Contractor shall furnish wooden boxes, or equivalent to store and transport rock cores in accordance with ASTM D2113 and D5079.

201.9 Contractor shall provide gravel, asphalt and concrete similar to the materials removed or damaged as directed by the Purchaser.

201.10 It is preferred that sampling devices used in conjunction with the SPTs be an upset wall sampler with an inside diameter of 1 1/2 in., which is now common practice in North America, and all samplers used for SPTs shall conform with the requirements of ASTM D1586.

PART 3 - EXECUTION

301. BORING LOCATIONS

301.1 The soil boring locations are depicted on Exhibit FSMTR-G-002-1. The Contractor shall be responsible for locating/clearing any existing underground structures and utilities. The Contractor shall take the necessary precautions to assure that any buried components are not damaged or disturbed during the drilling.

301.2 The boring locations shall be staked by the Contractor. The Contractor may relocate the borings up to ten feet in any direction due to obstructions following notification of Purchaser or Engineer. Contractor shall survey the as-drilled location and surface elevation of the borings with this information included on the final boring logs. Elevations shall be obtained in reference to NAVD88. Elevations shall be surveyed to the nearest 0.01 foot and the locations shall be surveyed to the nearest 0.1 foot.

301.3 Contractor shall coordinate subsurface utility clearing activities in conjunction with Owner's and Purchaser’s staff and standards.

301.4 Contractor shall anticipate site specific safety training as required by Owner for each field crew member upon initial mobilization.

302. BORING DEPTH AND DRILLING METHODS

302.1 The borings shall be drilled to the depths specified on Table 1 of this Section. Soil drilling auger refusal is defined as the minimal advancement of the drill bit/auger is encountered with reasonable effort of the drill rig and split spoon refusal is observed. Split spoon refusal is defined as the

Standard Penetration Test N-value of 100 blows for 6 inches or after 20 consecutive blows with no observable advance of the sampler.

302.2 Borings shall be made with heavy-duty rotary drilling equipment designed to drill holes of the required sizes and depths in accordance with ASTM D5783/D6151 and as specified herein. Drilling units shall be equipped with an operational pressure gauge to monitor the hydraulic pressure to the feed cylinders.

302.3 The use of drilling fluids other than water may only be permitted with prior approval after Purchaser and Engineer have reviewed and accepted Contractor's written plan for the management, disposal, and clean-up of drill fluids.

302.4 Borings shall be at least four inches in diameter (nominal).

302.5 In fine-grained soil (more than 50 percent finer than No. 200 sieve) and in unsaturated coarse-grained soils (less than 50 percent finer than No. 200 sieve), borings shall be advanced with either hollow-stem auger or rotary drilling with water based drilling fluid in accordance with ASTM D6151 and ASTM D5783, respectively.

302.6 Soil borings shall not be advanced below the groundwater level in granular soils using hollow stem auger. Borings through saturated granular soils shall be advanced with rotary techniques in accordance with ASTM D5783.

302.7 If rock is encountered, it shall be cored in accordance with ASTM D2113 in the borings as indicated on Table 1. Borings shall be terminated after the rock coring per Table 1 notes. All other borings shall be terminated when auger refusal is attained if no rock coring is required.

302.8 Cores recovered shall be stored in wooden boxes or equivalent in accordance with ASTM D2113 and D5079. A description of the rock, core recovery and Rock Quality Designations (RQD) for all coring runs in accordance with ASTM D6032 shall be provided. Orientation of bedding planes in the rock core shall be identified to determine if the core is from a boulder or in-place bedrock.

302.9 Contractor shall inform Purchaser or the Engineer immediately of any unusual conditions that may influence the procedure or method of obtaining the soil data.

302.10 Contractor shall immediately notify Purchaser and Engineer of any observed adverse environmental conditions. These conditions include but are not limited to potentially contaminated soil (based on color or odor), ruptured pipe lines, hydraulic hoses or fittings or any other oil leaks. Contractor shall immediately take reasonable actions to protect the environment.

302.11 The purpose of these borings is to determine the physical properties, arrangement, and thickness of the various soil strata as they exist in the ground. It is necessary to locate and record the elevation at which each change in stratification occurs and to obtain samples truly representative of the material, including its natural water content, comprising each stratum as it exists in the ground. Each sample shall be preserved in accordance with ASTM D4220/4220M as soon as it is removed from the boring and packed so that it will reach the laboratory in as near as possible the condition, in which it was removed from the ground without loss of water by evaporation or damage by freezing, breakage of containers, or other disturbances in transit.

303. PENETRATION TESTS AND SPLIT-SPOON SAMPLING

303.1 Prior to the start of drilling, a report of hammer energy testing based on ASTM D4633 shall be provided for Engineer's review. As an alternative, subject to Engineer's acceptance, such report may be provided after the start of work.

a. Hammer systems with energy efficiencies less than 50 percent or more than 100 percent shall not be used for any portion of this work.

b. The hammer energy report provided shall be signed and sealed by a licensed professional in the State of Wyoming.

c. When an automatic hammer is used, the blows per minute (BPM) during tests shall approximately match the BPM during the hammer energy testing program. It is preferred that automatic hammers operate in the range of 20 to 40 BPM. If the hammer frequency exceeds 40 BPM, the rate shall be reported in the final report.

d. The rod type and size used for SPT tests shall be the same as was used during the hammer energy test program.

303.2 Standard Penetration Tests (SPT) shall be taken at 2 1/2 foot intervals in the upper 10 feet and at intervals of 5 feet or less thereafter. Whenever a strata change is noted during drilling, an additional SPT shall be performed. SPTs shall be performed in accordance with ASTM D1586. Begin the SPT at ground level in all borings.

303.3 Where a change of strata occurs within a sample, each material shall be placed in a separate container.

303.4 Samples shall be sealed, labeled, protected, and transported in accordance with ASTM D4220/4220M.

304. THIN-WALLED TUBE SAMPLES

304.1 Undisturbed samples using a Shelby tube shall be taken when cohesive soils are encountered that are suitable for thin-walled sampling. Thin-walled samples shall be obtained at intervals of not more than 15 feet in homogeneous cohesive soil strata. Samples shall be taken at depths dictated by field conditions to ensure representative sampling of all cohesive layers.

304.2 The purpose of this sampling method is to obtain undisturbed soil samples of a character suitable for laboratory tests. Samples shall be taken with a 3 inch (nominal) thin wall tube according to the requirements of ASTM D1587.

304.3 The length of the sample obtained in each sampling application shall not be less than 12 inches or more than 30 inches. The length of the sampling tube shall be as required by ASTM D1587.

304.4 If no sample is recovered, the Contractor shall clean the borehole to the bottom of the sampling depth and a split spoon sample (or thick-walled, ring-lined, split-barrel sample) shall be obtained immediately at this depth.

304.5 Contractor shall obtain pocket penetrometer readings (unconfined compressive strength values) on all cohesive soil samples.

304.6 Samples shall be retained in sampler tubes, capped, sealed with microcrystalline wax, labeled, protected, and transported according to the requirements of ASTM D1587 and ASTM D4220/4220M. Samples for testing shall not be field extruded.

305. THICK WALLED, RING-LINED, SPLIT-BARREL SAMPLES

305.1 When cohesive soils are encountered that are not conducive to high quality thin-walled tube samples, thick walled ring-lined split barrel samples shall be obtained in accordance with ASTM D3550.

305.2 Ring samples shall not be field extruded.

305.3 Ring samples shall be sealed in moisture-proof plastic tubes to protect the rings from separating and sealed with taped end caps or microcrystalline wax per ASTM D4220/4220M.

305.4 Correlations between SPT N values and ring sampling blow counts shall be provided with reference basis including ring sampler dimensions.

306. BULK SAMPLES

306.1 The Contractor shall obtain bulk samples of soils at designated locations per Table 1 for thermal conductivity testing per Article 310.1. Bulk soil samples shall be obtained at depths between 3 ft and 6 ft.

306.2 Bulk samples shall weigh a minimum of 50 pounds and may be obtained from the drill cuttings.

307. SEALING BORINGS AND SITE CLEANUP

307.1 Following any required 24-hour delayed water level measurements, grout all boreholes and vacuum excavations in accordance with local or state regulations. The borings shall be filled from the bottom upward using the lowest practical pump pressure. When there are no specific state or local requirements for abandoning the boreholes, use the lowest practical water to solids ratio, with a maximum water-cement-bentonite ratio of 4:1:0.4 (45 gallons potable water, 94 pounds Type I Portland cement (conforming to ASTM C150/150M) and 38 pounds of bentonite as required. Additional grout shall be placed following any grout settlement.

307.2 The site shall be cleaned to remove soil cuttings, drill fluid, debris and other Contractor generated waste and restored to pre-investigation conditions. Disposal of all cuttings and debris shall be offsite meeting state and local regulations unless an onsite location is allowed and as directed by Owner.

308. BORING LOGS

308.1 The Contractor will record all data on each boring log and furnish all necessary information as required by this Specification and ASTM D5434, including but not limited to boring diameter, drilling method(s) used, and the SPT hammer used.

308.2 Regardless of drilling and sampling methods, the thickness of asphalt or surfacing gravel (if any), topsoil or upper fill shall be measured and reported on each boring log, as applicable.

308.3 Static water level in each boring shall be measured and recorded by the Contractor during drilling, upon completion of drilling, and just prior to grouting.

308.4 Soil descriptions shall be in accordance with ASTM D2488.

308.5 Contractor shall include details of the SPT hammer used on each boring, either on the boring logs or in the report. Details shall include the hammer type, hammer efficiency and a description of the hammer release system.

308.6 The Contractor shall indicate if an upset wall sampler with an inside diameter of 1-1/2 in. (see ASTM D1586) was used and if sampler liners were used in conjunction with the SPTs on either the boring logs or in the report. Additionally, Contractor shall report the rod type used during the SPTs.

308.7 When thick walled, ring lined, split-barrel samplers or other driven samplers, that do not comply with the sampler dimensions specified by ASTM D1586 are used, the blows to advance the

sampler shall not be reported as "SPT N-value". A correlation to equate blows for non-ASTM D1586 samplers to the equivalent "SPT N-values" shall be provided.

309. LABORATORY TESTING

309.1 All field and laboratory testing shall be performed by a qualified firm as defined by ASTM D3740.

309.2 The number and type of laboratory tests will be determined after the field boring logs have been reviewed by the Engineer. Laboratory testing may consist of, but not be limited to, the following tests:

a. Soil Classification per ASTM D2488.

b. Water Content per ASTM D2216.

c. Dry Density of Soil per ASTM D7263, including water content and visual description.

d. Atterberg Limits per ASTM D4318, including as-received water content.

e. Percent Passing the No. 200 sieve per ASTM D1140.

f. Grain Size Analysis (sieve and/or hydrometer) per ASTM D422, including visual description.

g. Grain Size Analysis (sieve) per ASTM D6913, including visual description.

h. Grain Size Analysis (hydrometer) per ASTM D7928, including visual description.

i. Unconfined Compressive Strength of Cohesive Soils per ASTM D2166/2166M, including water content, dry density, and visual description.

j. Unconfined Compression of Rock per ASTM D7012 (Method C).

k. Consolidation per ASTM D2435/2435M (with loading to 16 tons/sq. foot, including rebound to no load) and including average water content, dry density, and visual description.

l. One-Dimensional Swell or Collapse Potential of Cohesive Soils per ASTM D4546, including initial and final water content, dry density, visual description.

m. Measurement of Collapse Potential of Soils per ASTM D5333.

n. Moisture - Density Relationships per ASTM D1557, including visual description.

o. Organic Content per ASTM D2974, including visual description.

p. Specific Gravity per ASTM D854, including visual description.

q. pH values per ASTM G51.

r. Water-Soluble Sulfates in Soil per ASTM C1580, EPA Method 375.4 or EPA Method 9056. (Test result shall be reported as water-soluble sulfate in soil by weight.)

s. Water-Soluble Chlorides per EPA Method 325.3 or 9056. (Test result shall be reported as water-soluble chloride in soil by weight.)

t. Thermal Conductivity of Soil – ASTM D5334 or IEEE Std. 442, including initial water content, dry density, and percent compaction on reconstituted samples (applicable to bulk samples).

309.3 Contractor shall provide all laboratory tests and incidentals for completing specified test at no additional cost. Pricing provided on the Proposal Pricing Pages (PP pages) shall be inclusive of all incidental testing required to complete the specified test.

309.4 Visual descriptions provided with the laboratory test results shall be completed similar to ASTM D2488 requirements including Unified Soil Classification System (USCS) symbols and local practice. Visual descriptions shall be consistent with the descriptions and symbols provided on the soil boring logs.

309.5 Contractor shall retain untested soil samples for at least 4 months following acceptance of final report by Purchaser and Engineer. After 4 months, prior to disposal, Contractor shall contact Purchaser to determine if samples are to be discarded or transferred to Purchaser.

310. SUPPLEMENTAL TESTING OF SOIL

310.1 Thermal Conductivity of Soil:

a. Bulk samples shall be reconstituted to perform the laboratory thermal tests. The remolded samples shall be compacted to 90% of the maximum dry density as determined per ASTM D1557. The moisture-density relationship test (Proctor) shall be a separate test from the thermal test and shall be billed separately. The thermal conductivity of soil with relation to varying moisture contents shall be developed and reported.

310.2 Seismic Survey:

a. Requirements of the Shear Wave and Compression Wave Velocity Testing:

a1. The shear wave velocity testing is to be performed at the project site using the Multi-Channel Analysis of Surface Waves (MASW) with the active source method. The Refraction Microtremor (ReMi) or approved equivalent method deemed more suitable may be proposed by Contractor and subject to acceptance by Engineer. The purpose of this field testing is to obtain the shear wave velocity and Poisson's ratio profile for a minimum depth of 100 feet of soil and rock below grade for the design analysis of the vibratory equipment foundations. The surveys shall be performed at the locations indicated on Exhibit FSMTR-G-002-1.

a2. In order to obtain the compression wave and thus the Poisson's ratio profile, a seismic refraction survey or equivalent should be performed using instrumentation and field procedures in accordance with ASTM D5777.

a3. At each location, the length of the survey line, the receiver array layout (spacing and quantity) and the positions of the energy source shall be adequate for the data quality and the required depth of soil/rock profile. The coordinates for the end points of the survey lines shall be recorded and included in the reports.

b. Qualification of the Testing Firm and Its Personnel:

b1. The seismic survey shall be performed by, or under the direct field supervision of, a licensed professional in the State of Wyoming with adequate knowledge in the area of geophysics and with a minimum of five (5) years of related experience that demonstrates competency in planning, carrying out the survey, and interpreting the data and in compliance with ASTM D3740. This licensed professional shall be responsible for all activities related to the performance of shear wave velocity and compression wave tests, including, but not limited to, test set up, testing, recording, data analysis and documentation, coordination with other organizations (Consulting Engineer, Contractor, and Purchaser) regarding the testing, preparation, and sealing of the complete testing report.

b2. The experience, qualifications and resumes of the testing firm's personnel who will be involved in this testing project, shall be submitted with the proposal. The licensed professional responsible for the field work and data analysis shall have at least five (5) years of experience with using the proposed testing methods. The document of his/her project experiences for the past five (5) years shall include the name, location and scope of representative projects, methods used and a brief description of the site conditions.

c. Testing Proposal:

c1. Along with the qualifications of the testing personnel mentioned above, the testing firm shall include descriptions of its procedures, test setup, apparatus, discussions on data quality reporting, the interpretations/analysis methods, and the expected contents in the test reports. When the proposed procedures deviate from the requirements in this specification, the testing firm shall provide reasoning with supporting references. The proposed procedures are subject to Purchaser's approval.

d. The results of the seismic survey shall be included in the Draft and Final reports specified in this section.

311. DRAFT REPORT

311.1 Upon substantial completion of laboratory testing, Contractor shall transmit one electronic copy (PDF format) of the draft report to Purchaser and Engineer for comments.

311.2 Draft report shall, to the extent practical, contain all items required for the final report.

312. FINAL REPORT

312.1 Upon incorporation of Purchaser's and Engineer's comments on draft report, provide a geotechnical investigation report sealed by a licensed professional in the state of Wyoming. The report shall include a description of the procedures used, measured and calibrated SPT hammer energy, final boring logs (per Article 308 of this Section), field and laboratory test results, including soil resistivity survey, seismic survey, soil thermal conductivity, and as-drilled boring location coordinates and the diagram.

TABLE 1
BORING SCHEDULE[1]

Boring No.	Boring Total Depth[2] ft	Minimum Rock Core Depth[2] ft	Additional Sampling
BH-1	50	15	
BH-2	50	15	
BH-3	50	15	
BH-4	50	15	
BH-5	50	15	Bulk sample[3]
BH-6	50	15	
BH-7	50	15	
BH-8	50	15	
BH-9	50	15	
BH-10	50	15	
BH-11	50	15	
BH-12	50	15	Bulk sample[3]
BH-13	50	15	
BH-14	50	15	Bulk sample[3]
BH-15	50	15	

Note 1: Coordinates are specified on Exhibit FSMTR-G-002-1 .

Note 2: Perform rock coring when SPT refusal (defined in Article 302) is encountered. Boring shall be extended deeper than the total depth indicated to meet the required minimum rock core depth.

Boring may be terminated at a depth shallower than the total depth indicated only if 30’ rock core depth is achieved.

In case SPT refusal is not encountered within the total depth indicated, additional drilling in soils (without SPT refusal) shall not exceed 50’, which would make 100’ of the maximum total drilling. In no event, the combination of soil drilling and rock coring shall exceed total of 100’.

Note 3: Obtain bulk samples per Article 306.

END OF SECTION 023213

SECTION 023126

SOIL RESISTIVITY SURVEY

PART 1 - GENERAL

101. EXTENT

101.1 This Section covers the requirements for the performance of a soil resistivity survey and associated work.

101.2 The purpose of this task is to investigate the need for corrosion protection and to obtain the data necessary for the design of an adequate grounding system.

101.3 The work includes performing four (4) soil resistivity surveys at the locations shown on the Main Carbon Capture Area Subsurface Investigation Soil Resistivity Test Location Plan (Exhibit FSMTR-G-002-2).

101.4 Soil resistivity is obtained using the Wenner Four Pin Array.

102. REFERENCE DOCUMENTS

102.1 Standards, Specifications, manuals, codes and other publications of nationally recognized organizations are referenced herein. References to these documents are to the issue date as indicated by the Adopted Building Code. If the document is not referenced in the Adopted Building Code, then the reference is to the latest issue date of the document together with the latest additions, addenda, amendments, supplements, etc., thereto, in effect as of the date of the Contract for the Work.

102.2 Methods, equipment and materials specified herein shall comply with the specified and applicable portions of the referenced documents, in addition to federal, state or local codes having jurisdiction.

102.3 Internationally recognized standards equivalent to or more restrictive than those listed may be proposed by the Contractor. Contractor must submit the basis for equivalency for all requested alternative Codes and Standards. Acceptance of alternate Codes and Standards shall be determined by Purchaser and Purchaser's Engineer prior to use/purchase by the Contractor.

102.4 Abbreviations listed below refer to the applicable organizations or documents.

102.5 ASTM – ASTM International:

a. G 57 – Standard Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method.

102.6 IEEE – Institute of Electrical and Electronic Engineers:

a. IEEE Std. 81 – IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System.

b. IEEE Std. 442 – IEEE Guide for Soil Thermal Resistivity Measurement.

103. RELATED WORK SPECIFIED IN OTHER SECTIONS

103.1 The work specified in this Section shall be coordinated with work specified in the following related Sections:

a. Section 011100 – Project Summary

b. Section 023213 – Subsurface Investigation

104. SUBMITTALS

104.1 Submit documents for review in accordance with the submittal requirements of Section 011100.

104.2 Submit the following in accordance with the requirements listed in Article 107 of Section 011100:

a. Prior to starting field work, the Contractor shall submit documentation verifying field equipment conforms to the standardization requirements of Section 6.0 of ASTM G57.

b. A copy of the field data logs from the survey that was performed.

c. Calculation sheets documenting steps taken to calculate Soil Resistivity.

d. The results of the soil resistivity survey that was performed shall be included in the final report.

PART 2 - PRODUCTS

201. CONTRACTOR'S EQUIPMENT AND SUPPLIES

201.1 The Contractor shall furnish the appropriate equipment and supplies to perform the work.

201.2 The Contractor is responsible for providing vehicles and equipment capable of reaching the locations specified for the soil resistivity surveys.

201.3 The Contractor shall provide all testing equipment. All equipment shall be manufactured specifically for soil resistivity testing and shall be in good working order, within the accuracy requirements of ASTM G57.

PART 3 - EXECUTION

301. GENERAL

301.1 The soil resistivity survey locations are indicated on the Main Carbon Capture Area Subsurface Investigation Soil Resistivity Test Location Plan (Exhibit FSMTR-G-002-2). See notes on the exhibit for additional instructions.

302. RESISTIVITY MEASUREMENTS

302.1 General: Specific instructions in this Article describe the tests required to obtain the soil resistivity test results.

302.2 Perform Soil Resistivity Tests:

a. The locations are designated as SR-1 through SR-4 on Exhibit FSMTR-G-002-2.

b. The Soil Resistivity testing shall be performed in accordance with ASTM G57.

c. Each measurement shall be taken with the probes driven in the ground to a depth of 6” to 12” into firm soil. The four probes shall be equally spaced in a straight line with the current probes on the outside and the voltage potential probes on the inside as illustrated in Figure 023126-1.

d. Where the presence of buried metallic structures in the vicinity is suspected, the test probes shall be lined up in a direction perpendicular to that of the buried metallic structure to minimize errors in the measurement results.

e. If rock outcroppings, rugged terrain or other conditions prohibit placement of electrodes in a straight line at any of the required spacings, a sketch shall be included with the report to indicate orientation of electrodes.

f. Six readings shall be taken at each location with spacings of 5, 10, 20, 50, 100 and 250 feet between probes, respectively. A second set of readings at 90° to the first shall also be taken.

g. If the ground is frozen, the probes shall be driven to a depth of 1 foot below the frost line.

302.3 Resistivity Measurements:

a. Resistivity measurements shall accurately represent the soil condition. The locations shown on the measurement layout exhibit were based on the general site details, nearby transmission lines, pipe lines, maximized distance between soil measurements, and other attributes. Measurement points shall be optimized based on the actual field condition. Rock outcroppings, rugged terrain or other conditions should not prevent the probe straight line or spacing measurements. A sketch of the actual measurement location shall be included with the report to indicate the orientation of electrodes. Measurements that do not represent the soil condition shall be re-measured and the results shall be explained and justified based on data. Any technique used to improve a measurement shall be discussed and justified within the report.

302.4 Erratic readings can occur due to poor connections or high contact resistance, background noise at a frequency similar to that used by the measurement equipment, nearby buried metallic structures, equipment failure, operator error, and other factors. Contractor shall immediately graph the measured resistivities in the field to detect any irregular measurements so that corrective action can be taken. Resistivity shall be plotted versus electrode spacing in the final report and a smooth curve is to be expected.

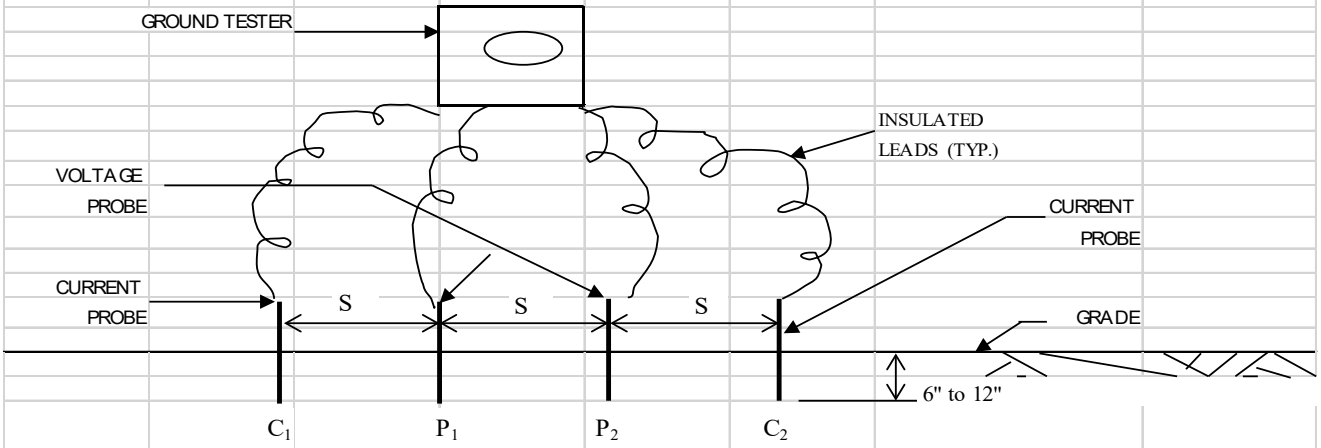
303. SOIL RESISTIVITY CALCULATION

303.1 The readings obtained in all these measurements are values of resistance (R) in ohms. These values shall be converted to values of soil resistivity (ρ) in ohm-meters (or ohm-centimeters) using the following formulae:

a. Top Soil Resistivity (equal probe spacing);

$$\rho = 2\pi RS$$

where S = probe spacing in meters (or centimeters).

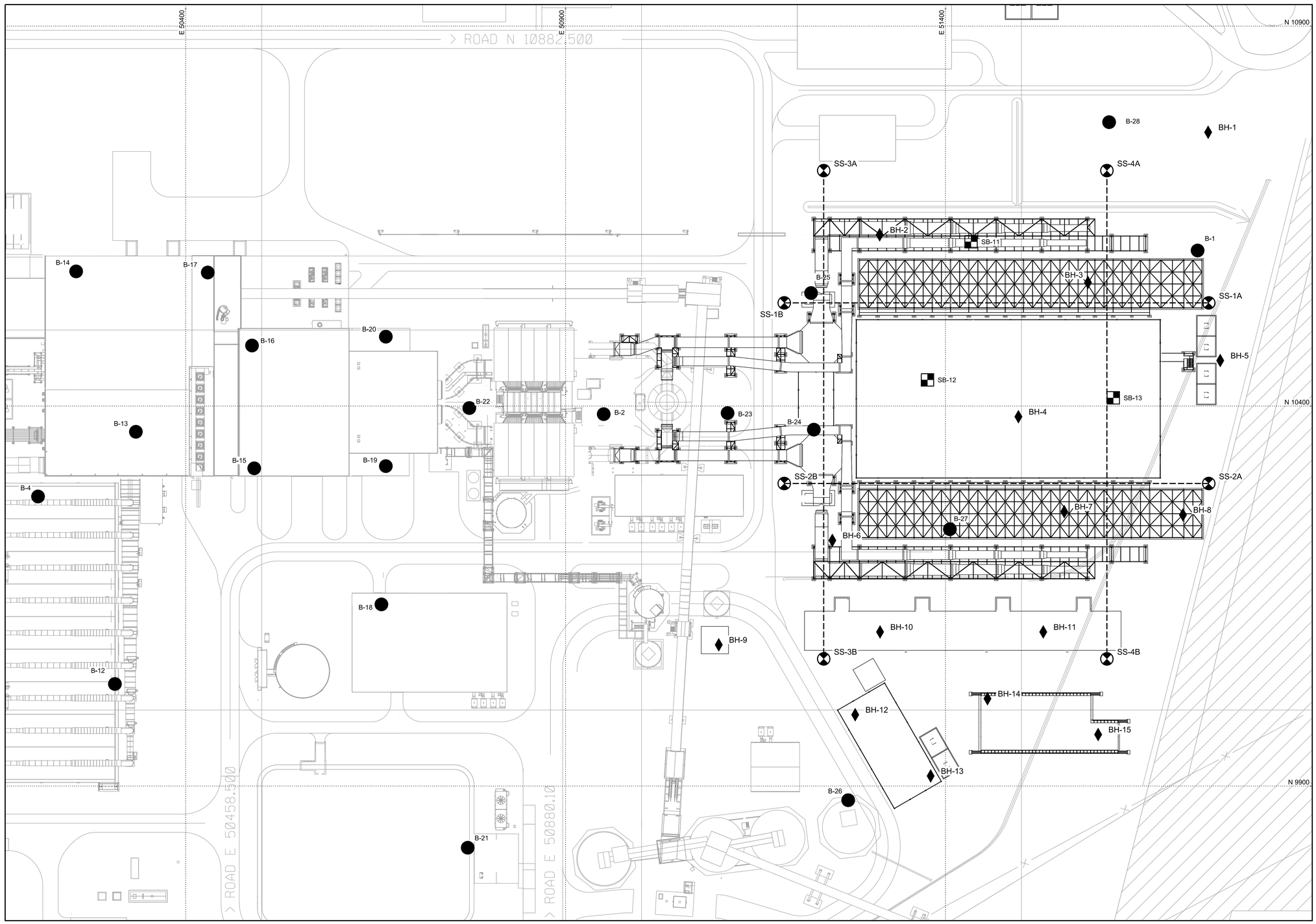


S =5', 10', 20', 50', 100', and 250' RESPECTIVELY FOR SIX CONSECUTIVE READINGS PLUS A SECOND SET OF READINGS AT 90 DEGREES

FIGURE 023126-1. TOP SOIL RESISTIVITY MEASUREMENT - WENNER FOUR PIN METHOD

(NOTE UNITS FOR SPACING)

END OF SECTION 023126



SEISMIC SURVEY SCHEDULE

TEST NO.	NORTH COORDINATE	EAST COORDINATE
SS-1A	10536	51746
SS-1B	10536	51188
SS-2A	10298	51746
SS-2B	10298	51188
SS-3A	10710	51240
SS-3B	10067	51240
SS-4A	10710	51612
SS-4B	10067	51612

SOIL BORING SCHEDULE

TEST NO.	NORTH COORDINATE	EAST COORDINATE
BH-1	10760	51746
BH-2	10625	51313
BH-3	10563	51587
BH-4	10386	51496
BH-5	10460	51762
BH-6	10223	51251
BH-7	10261	51556
BH-8	10257	51713
BH-9	10086	51102
BH-10	10103	51314
BH-11	10103	51529
BH-12	9994	51281
BH-13	9913	51380
BH-14	10015	51455
BH-15	9968	51601

PRELIMINARY
NOT FOR CONSTRUCTION

LEGEND

SB-	SB-11 TO SB-13 AUG 2021 BORINGS
B-26, B-27, ETC.	OLD BORING LOCATIONS
BH-	SOIL BORING LOCATIONS
SS-	SEISMIC SURVEY LOCATIONS

NORTH

50' 0' 50' 100'
GRAPHIC SCALE

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

NOTES

1. COORDINATES SHOWN REFER TO THE PLANT COORDINATE SYSTEM.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	10-01-2021	FOR FEED STUDY DESIGN

ISSUE PURPOSE:	FOR FEED STUDY DESIGN
SPECIFICATION:	FSMTR-G-002
PROJECT NO.:	A13978.002

CAD FILE NAME:	EXHIBIT FSMTR-G-002-1.DGN
PREPARED BY:	M. ROBERTS
REVIEWED BY:	M. TURNER
APPROVED BY:	---

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55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR
MEMBRANE
TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

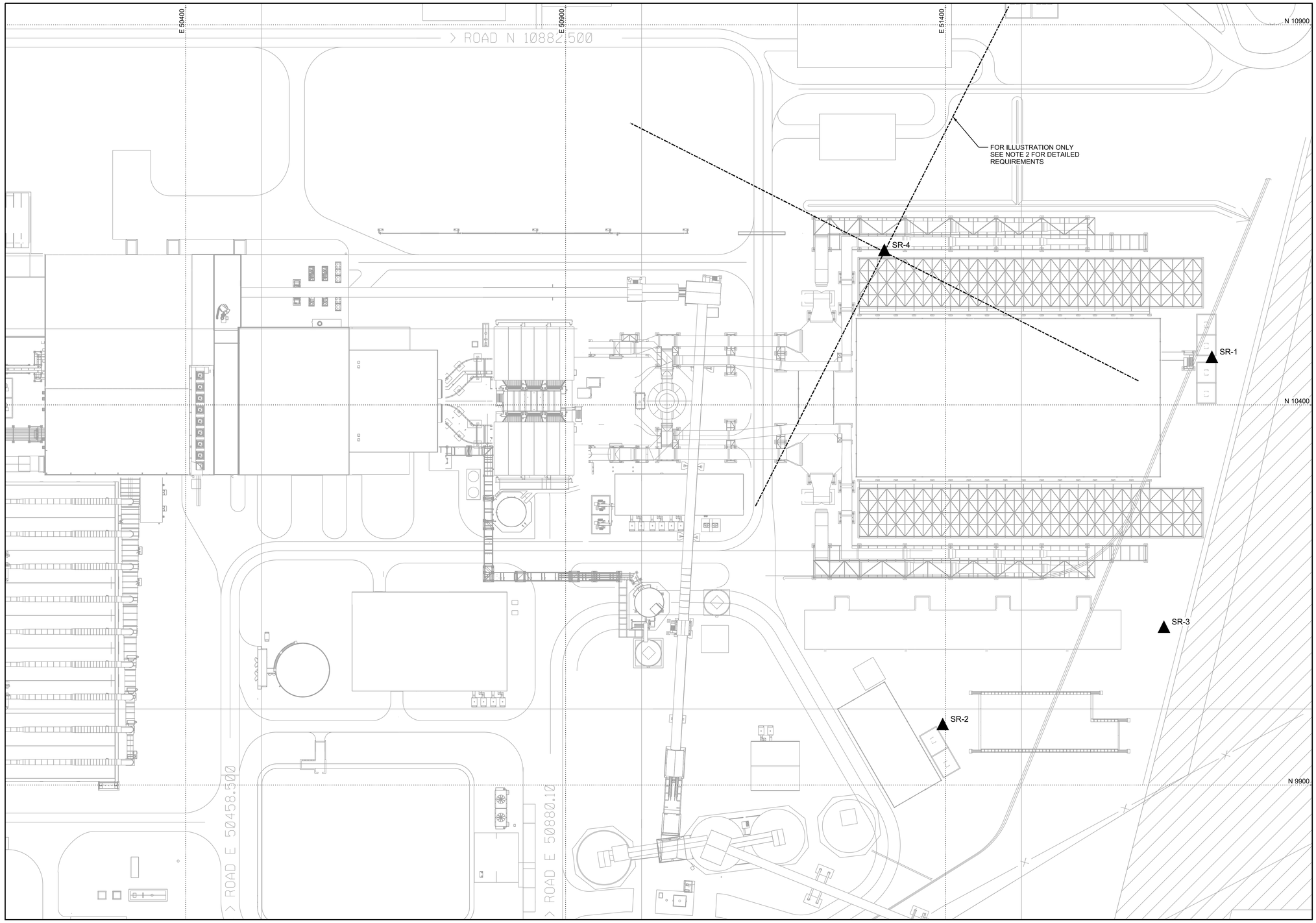
GILLETTE, WYOMING

DRAWING TITLE

MAIN CARBON CAPTURE AREA
SOIL BORING AND SEISMIC SURVEY
TEST LOCATION PLAN

DRAWING NUMBER	REVISION
EXHIBIT FSMTR-G-002-1	0
SHEET 01 OF 01	

PL:10905/0L1144/S:\2-Dry Fork Carbon Capture\Drawings\exhibit fsmtr-g-002-1.dgn
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Revision 10, Revision Date: 10-16-2009
9/30/2021 2:25:13 PM ...\exhibit fsmtr-g-002-1.dgn



LEGEND

▲ SR- ELECTRICAL SOIL RESISTIVITY TEST LOCATION

SOIL RESISTIVITY SCHEDULE

TEST NO.	NORTH COORDINATE	EAST COORDINATE
SR-1	10461	51751
SR-2	9978	51396
SR-3	10106	51688
SR-4	10601	51319

PRELIMINARY
NOT FOR CONSTRUCTION

NORTH

50' 0' 50' 100'
GRAPHIC SCALE

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

NOTES

1. COORDINATES SHOWN REFER TO THE PLANT COORDINATE SYSTEM.
2. MAXIMUM SURVEY LENGTH OF 750 FEET PER ELECTRIC PROBE SPACING OF 250 FEET. EACH SET CONSISTS OF TWO SURVEY LINES PERPENDICULAR TO EACH OTHER. THE SET ORIENTATION IS TO BE FIELD ADJUSTED TO MISS THE EXISTING STRUCTURES.

REFERENCE DRAWINGS

NO.	DESCRIPTION

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	10-01-2021	FOR FEED STUDY DESIGN

ISSUE PURPOSE:	FOR FEED STUDY DESIGN
SPECIFICATION:	FSMTR-G-002
PROJECT NO.:	A13978.002

CAD FILE NAME:	EXHIBIT FSMTR-G-002-1.DGN
PREPARED BY:	M. ROBERTS
REVIEWED BY:	M. TURNER
APPROVED BY:	---

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

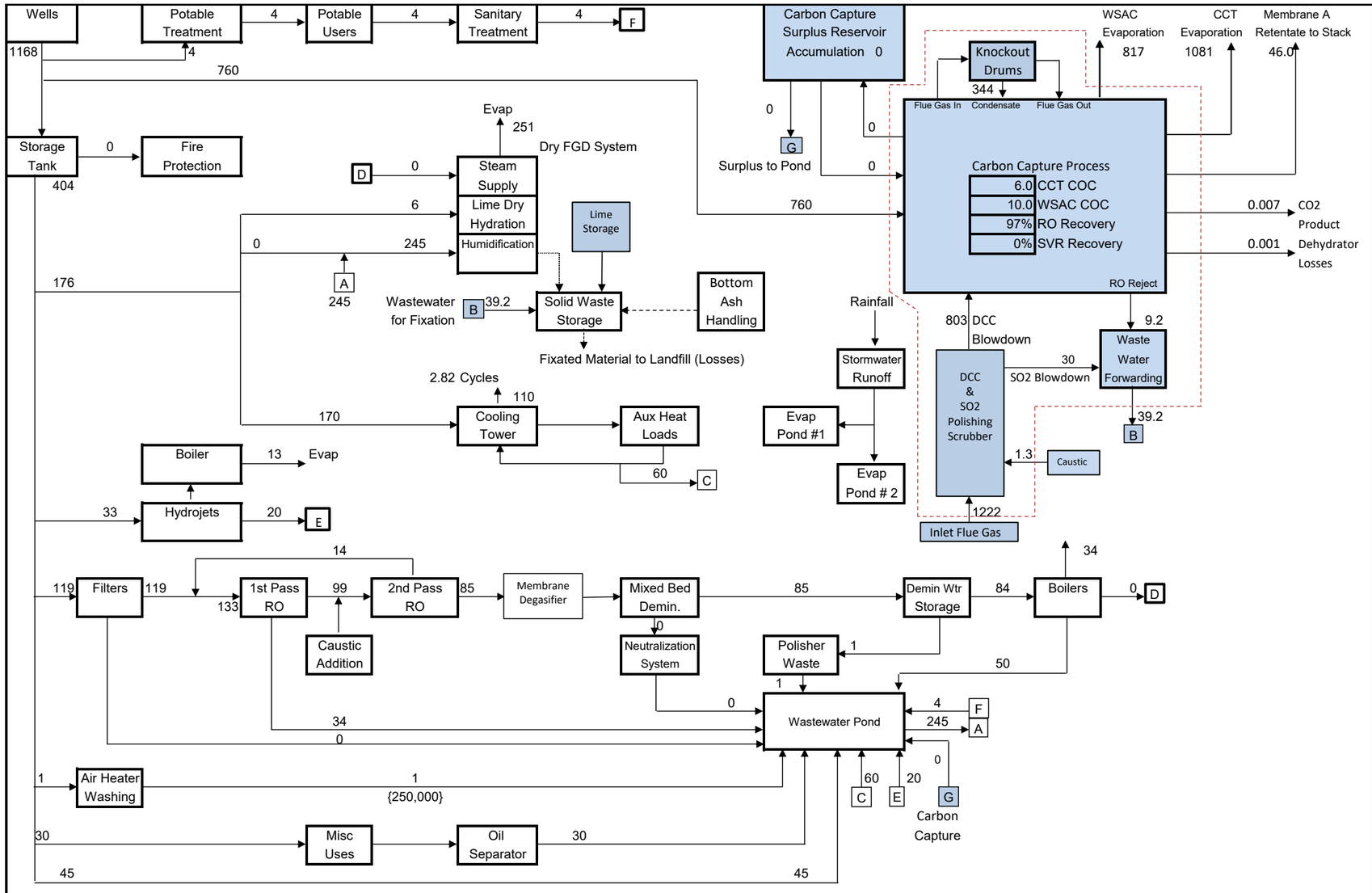
MAIN CARBON CAPTURE AREA
SUBSURFACE INVESTIGATION
SOIL RESISTIVITY TEST LOCATION PLAN

DRAWING NUMBER	REVISION
EXHIBIT FSMTR-G-002-2	0
SHEET 01 OF 01	

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Revision 10, Revision Date: 10-16-2009

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APPENDIX K. WATER BALANCE



Drawing Release Record					
Rev	Date	Prepared	Reviewed	Approved	Purpose
0	5/25/2021	M. Rosen	M. Heerman	D. Pierik	For Use
1	2/11/2022	M. Rosen	M. Heerman	D. Pierik	For Use

Water Balance Notes and Assumptions

1. Unless otherwise specified, all flow rates in gpm.
2. Dry Fork portion of water balance is based on original water balance prepared by S&L in 2006 with minor updates made in 2020 based on comments provided by Basin Electric.
3. Carbon capture portion of the various water balances is based on the Trimeric water balance, MTR DFS-Prelim Watersalt BFD Rev 10A dated April 7, 2021 at 88 F and modified as explained in the notes below.
4. The wastewater pond can accept 45 gpm of wastewater from the carbon capture reservoir. However, the latest surplus model and reservoir simulation show that with a moderate annual deficit that there is 0 gpm of water transferred under normal operating conditions.
5. The net wastewater from the carbon capture process; i.e. RO reject and SO2 polisher blowdown is sent to fixation process.
6. The surplus or deficit will not exactly match those estimated from the Trimeric model due to higher heat rejection and a higher wastewater RO treatment system recovery factory (i.e. 97% vs. 85%) than originally anticipated.
7. Final disposal expected to consist of lime fixation with no recovery of any net process wastewater
8. CCT evaporation rates for each ambient condition were updated for higher heat rejection based on recent quote provided by SPX/Marley. WSAC evaporation rate at 88 F is based on information in Trimeric water balance. WSAC evaporation rates at 62 and 0 F were estimated in previous revision of water balance in order to match results of Trimeric surplus model.
9. DCC blowdown and condenssate drains now estimated based on the difference between water in flue gas inputs and outputs. It is assumed that 70% of the difference is associated with DCC blowdown and the remaining 30% is associated with condensate drains.
10. ----- Denotes material balance boundary lines across carbon capture process.

Project No. 13978-002

CO_2 FEED Study Contractor:

MTR

Owner: BASIN ELECTRIC POWER COOPERATIVE, A Touchstone Energy® Cooperative

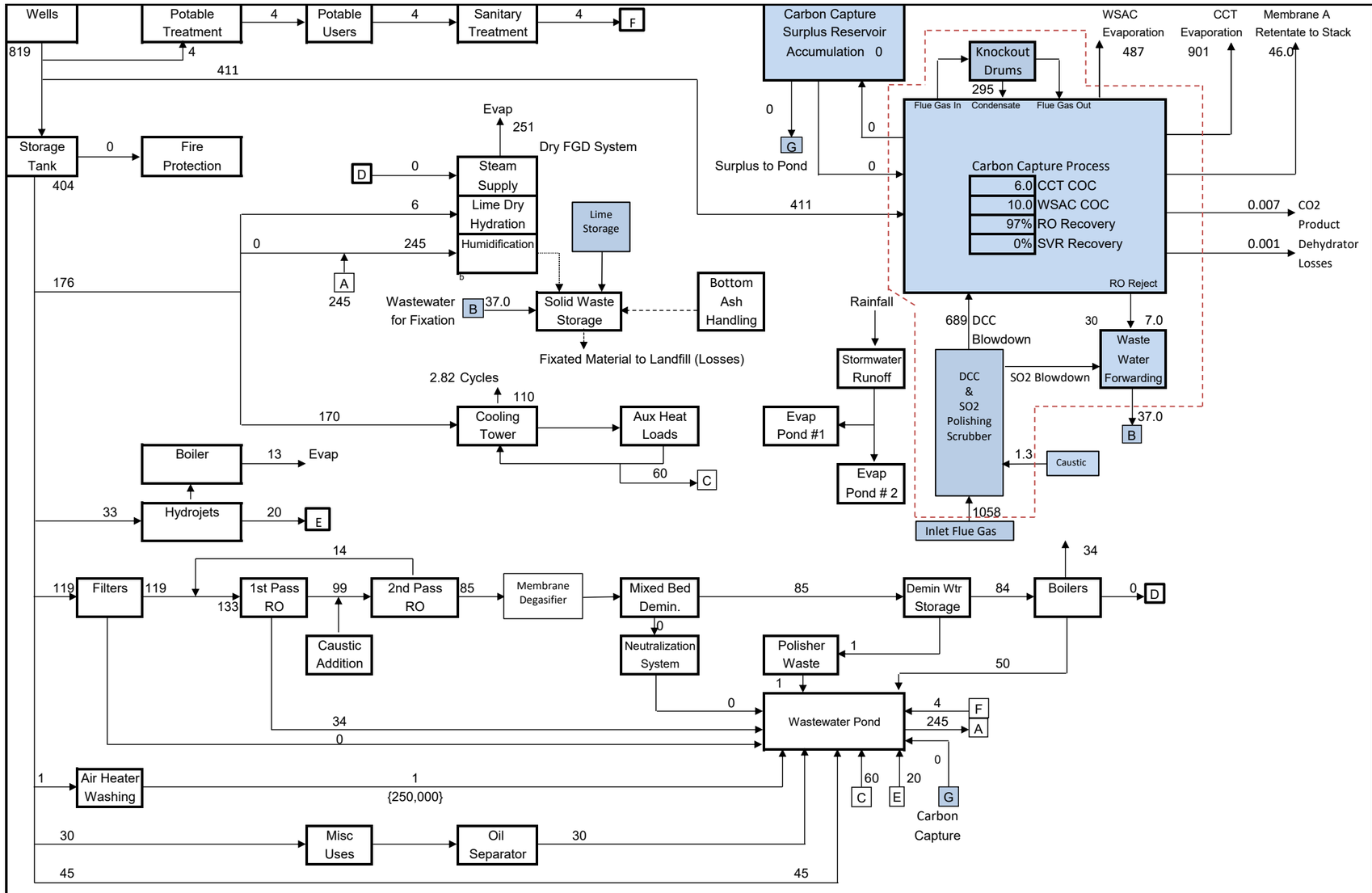
Engineer: Sargent & Lundy

MTR

MTR Full Scale Carbon Capture Project

Plant Water Balance
(88 °F Ambient Condition)

Document No. FS-MTR-M-2000 (Sheet 1)



Water Balance Notes and Assumptions

1. Unless otherwise specified, all flow rates in gpm.
2. Dry Fork portion of water balance is based on original water balance prepared by S&L in 2006 with minor updates made in 2020 based on comments provided by Basin Electric.
3. Carbon capture portion of the various water balances is based on the Trimeric water balance, MTR DFS-Prelim Watersalt BFD Rev 10A dated April 7, 2021 at 88 F and modified as explained in the notes below.
4. The wastewater pond can accept 45 gpm of wastewater from the carbon capture reservoir. However, the latest surplus model and reservoir simulation show that with a moderate annual deficit that there is 0 gpm of water transferred under normal operating conditions.
5. The net wastewater from the carbon capture process; i.e. RO reject and SO2 polisher blowdown is sent to fixation process.
6. The surplus or deficit will not exactly match those estimated from the Trimeric model due to higher heat rejection and a higher wastewater RO treatment system recovery factory (i.e. 97% vs. 85%) than originally anticipated.
7. Final disposal expected to consist of lime fixation with no recovery of any net process wastewater
8. CCT evaporation rates for each ambient condition were updated for higher heat rejection based on recent quote provided by SPX/Marley. WSAC evaporation rate at 88 F is based on information in Trimeric water balance. WSAC evaporation rates at 62 and 0 F were estimated in previous revision of water balance in order to match results of Trimeric surplus model.
9. DCC blowdown and condensate drains now estimated based on the difference between water in flue gas inputs and outputs. It is assumed that 70% of the difference is associated with DCC blowdown and the remaining 30% is associated with condensate drains.
10. ----- Denotes material balance boundary lines across carbon capture process.

Project No. 13978-002

CO_2 FEED Study Contractor:

MTR

Owner: BASIN ELECTRIC POWER COOPERATIVE, A Touchstone Energy® Cooperative

Engineer: Sargent & Lundy

MTR

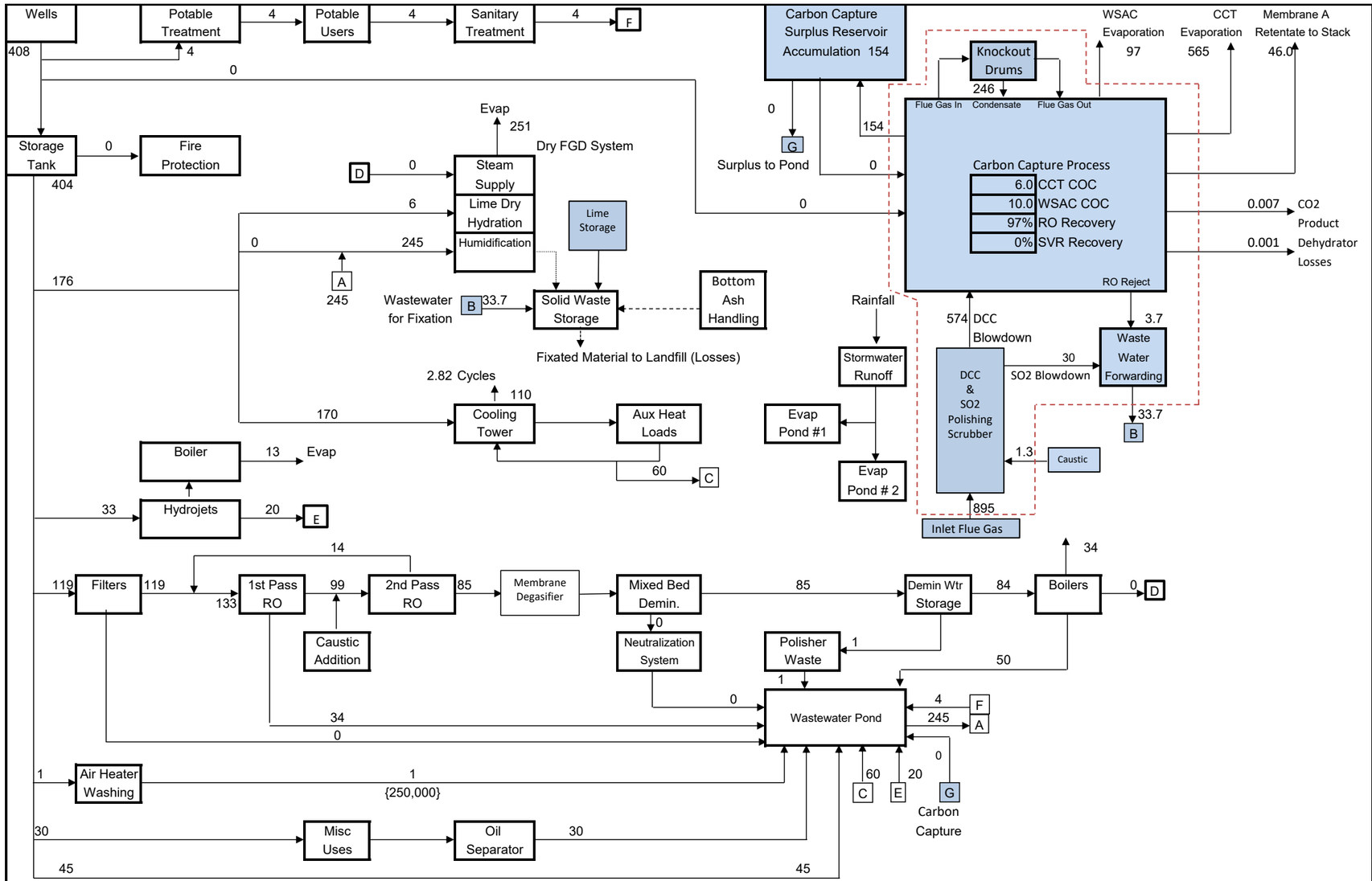
MTR Full Scale Carbon Capture Project

Plant Water Balance
(62 °F Ambient Condition)

Document No. FS-MTR-M-2000 (Sheet 2)

Drawing Release Record

Rev	Date	Prepared	Reviewed	Approved	Purpose
0	5/25/2021	M. Rosen	M. Heerman	D. Pierik	For Use
1	2/11/2022	M. Rosen	M. Heerman	D. Pierik	For Use



Drawing Release Record					
Rev	Date	Prepared	Reviewed	Approved	Purpose
0	5/25/2021	M. Rosen	M. Heerman	D. Pierik	For Use
1	2/11/2022	M. Rosen	M. Heerman	D. Pierik	For Use

Water Balance Notes and Assumptions

1. Unless otherwise specified, all flow rates in gpm.
2. Dry Fork portion of water balance is based on original water balance prepared by S&L in 2006 with minor updates made in 2020 based on comments provided by Basin Electric.
3. Carbon capture portion of the various water balances is based on the Trimeric water balance, MTR DFS-Prelim Watersalt BFD Rev 10A dated April 7, 2021 at 88 F and modified as explained in the notes below.
4. The wastewater pond can accept 45 gpm of wastewater from the carbon capture reservoir. However, the latest surplus model and reservoir simulation show that with a moderate annual deficit that there is 0 gpm of water transferred under normal operating conditions.
5. The net wastewater from the carbon capture process; i.e. RO reject and SO2 polisher blowdown is sent to fixation process.
6. The surplus or deficit will not exactly match those estimated from the Trimeric model due to higher heat rejection and a higher wastewater RO treatment system recovery factory (i.e. 97% vs. 85%) than originally anticipated.
7. Final disposal expected to consist of lime fixation with no recovery of any net process wastewater
8. CCT evaporation rates for each ambient condition were updated for higher heat rejection based on recent quote provided by SPX/Marley. WSAC evaporation rate at 88 F is based on information in Trimeric water balance. WSAC evaporation rates at 62 and 0 F were estimated in previous revision of water balance in order to match results of Trimeric surplus model.
9. DCC blowdown and condensate drains now estimated based on the difference between water in flue gas inputs and outputs. It is assumed that 70% of the difference is associated with DCC blowdown and the remaining 30% is associated with condensate drains.
10. ---- Denotes material balance boundary lines across carbon capture process.

Project No. 13978-002

CO_2 FEED Study Contractor:

MTR

Owner:

BASIN ELECTRIC POWER COOPERATIVE
A Touchstone Energy® Cooperative

Engineer:

Sargent & Lundy

MTR

MTR Full Scale Carbon Capture Project

Plant Water Balance
(0 ° Ambient Condition)

Document No. FS-MTR-M-2000 (Sheet 3)

APPENDIX L. RESERVOIR SIZING

Reservoir Sizing Summary

To support the MTR Full Scale FEED Study at Dry Fork Station (DFS), S&L analyzed the water surplus conditions that result when the CO_2 Capture (CC) Facility is operating in colder months. This document is a chronological summary of the discussions amongst the team regarding the options to handle the surplus water.

S&L and Trimeric prepared several water balances for the CO2 Capture Plant. Then, S&L subsequently prepared an Overall (DFS) Plant Water Balance. Based on the overall plant water balance, S&L investigated several options to consider for the surplus use. These options were presented to MTR and Trimeric in a weekly coordination meeting to brainstorm other possible options. S&L consolidated the options into a presentation that was given at the Weekly Status Meeting on January 27, 2021 to the entire study team, which included: DFS personnel, Basin Electric Power Cooperative (BEPC) participants, Electric Power Research Institute (EPRI) participants, MTR, S&L and Trimeric. The presentation is in Attachment A of this document.

Following the presentation, the team discussed the options for mitigating the surplus; team conclusions are listed below, with the options listed from least to most likely a solution to be implemented:

1. BEPC/DFS was not in favor of sending the excess water back to the aquifer, nor keen on re-introducing it back into the Flue Gas. This option would not be considered further.
2. The irrigation option would be considered: whether on site or a local farm; however, when the water is available from the CC Facility, it is not needed by the users. This option would not be considered further.
3. BEPC/DFS indicated that the municipal project identified is already complete, and the town is drawing water from the new aquifers. Although DFS was not opposed to this option, it is the same as option 2 (water not available from the CC when needed). This option would not be considered further.
4. DFS clarified that the mining industry discharges their excess water to the river (not a user); and DFS is permitted as a ZLD. This is a potential option, but not the best one and would not be considered further.
5. The team agreed the modified hybrid wet surface air cooler (WSAC) would be a good idea, however it is not a 100% solution. Based on Trimeric's calculation, shifting to a 75% capacity WSAC will result in a 50% improvement, decreasing the surplus by 350 gpm, leaving approximately 450 gpm to manage. This option will be considered with a supplemental option.
6. The team agreed a new reservoir would be the best solution (possibly with the hybrid WSAC). DFS indicated there is an area available to the southwest of the plant.

Following this team decision, S&L refined the surplus numbers based on a more detailed set of historical ambient temperature information and the information Trimeric received from Alfa Laval (WSAC vendor). The results and options for Reservoir Sizing were presented at the March 3, 2021 Weekly Status

meeting; see Attachment 2 for the presentation. The team decided on the smaller reservoir size to handle only the surplus would be used. However, the size of the pond would need to be adjusted by S&L to account for the following:

- Due to the unknown nature of the condensate collected in the CC process, BEPC/DFS did not want to hinder the ability to operate the power plant, so they were only comfortable accepting the CC condensate as makeup to the recycle pond to mitigate the risk of contaminating the entire plant. This equates to 55 gpm of the condensate that can be used as makeup to the existing recycle pond.
- BEPC/DFS prefers to not have the containment wall o the reservoir higher than 6 ft above grade, as that would trigger the dam law/permitting process.
- Lastly, BEPC/DFS confirmed that the approximate 700,000 cubic ft of excavated material can be used/stored on site.

At this point in the project S&L estimated a reservoir size of 230 acre-ft would be required.

Later in the year, S&L requested a budgetary quote for the Cooling Tower to support the project. The vendor documentation provided indicated that the evaporation rate in colder ambient temperatures was significantly higher than the original estimate from Trimeric. This results in less water surplus generated from the CC plant. S&L updated the overall water balance and “surplus curve”. These were used as input to update the final size of the reservoir to 160 acre-ft; see Attachment 3. This final size was used to develop the cost estimates for the FEED Study.

ATTACHMENT 1: WATER SURPLUS DISCUSSION PRESENTATION

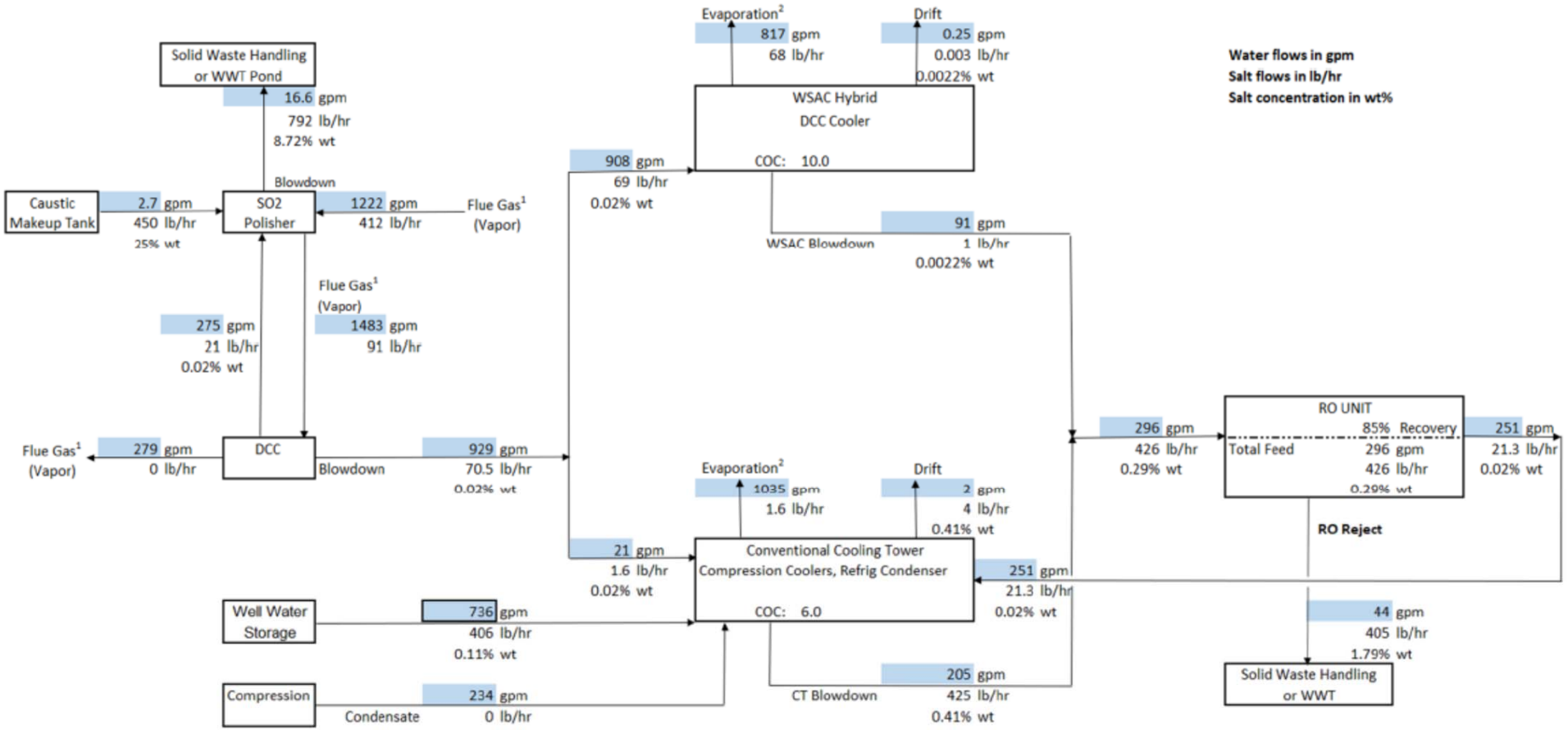
MTR Carbon Capture Project Water Surplus Discussion

S&L: Mike Rosen
Date: 1/27/2021 FS Weekly

- **Background**
  - Initial emphasis on meeting the water budget (610 gpm) during warm summer months
  - MTR/Trimeric develops water balance based on hybrid cooling scheme
  - Water balance at 88 °F exceeds the water budget
  - Favorable water usage profile developed over typical summer day with high of 88 °F
  - Concern raised over potential surplus during cooler months
  - Additional profiles show CC “water neutral” at 62 °F and large surplus (1163 gpm) at 0 °F
  - Subsequent evaluation by S&L to better define water surpluses

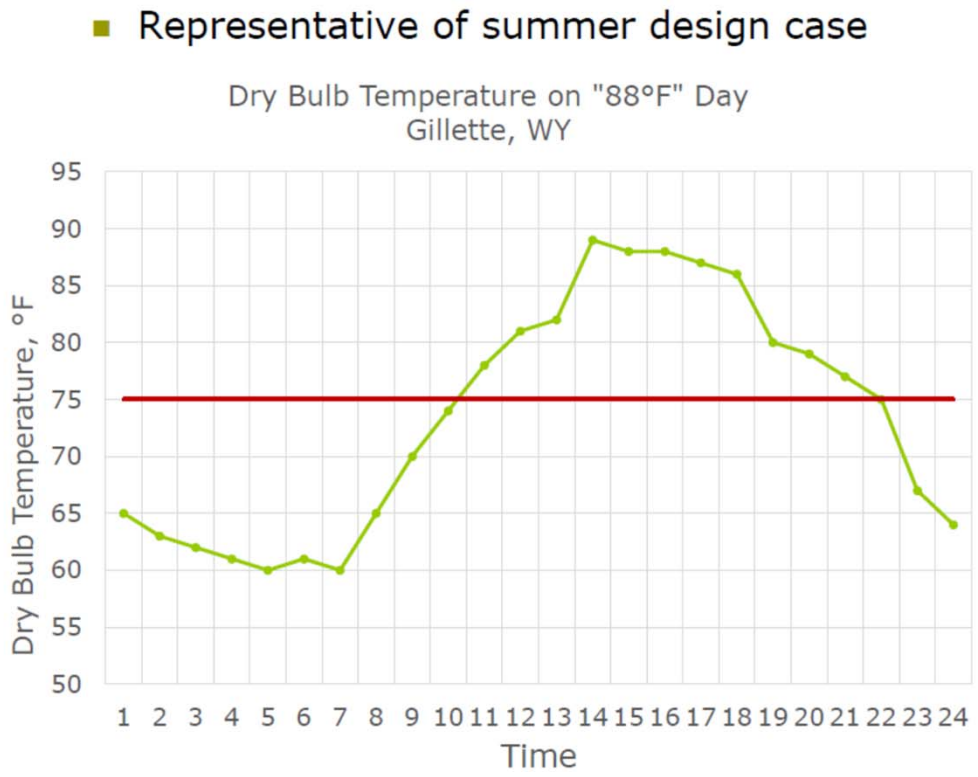
MTR Carbon Capture Project
Water Surplus Discussion

Summer Water Balance at 88 °F



MTR Carbon Capture Project
Water Surplus Discussion

Summer Temperature Profile



Hottest Summer Hour (88°F DB) -> 109 gpm shortfall

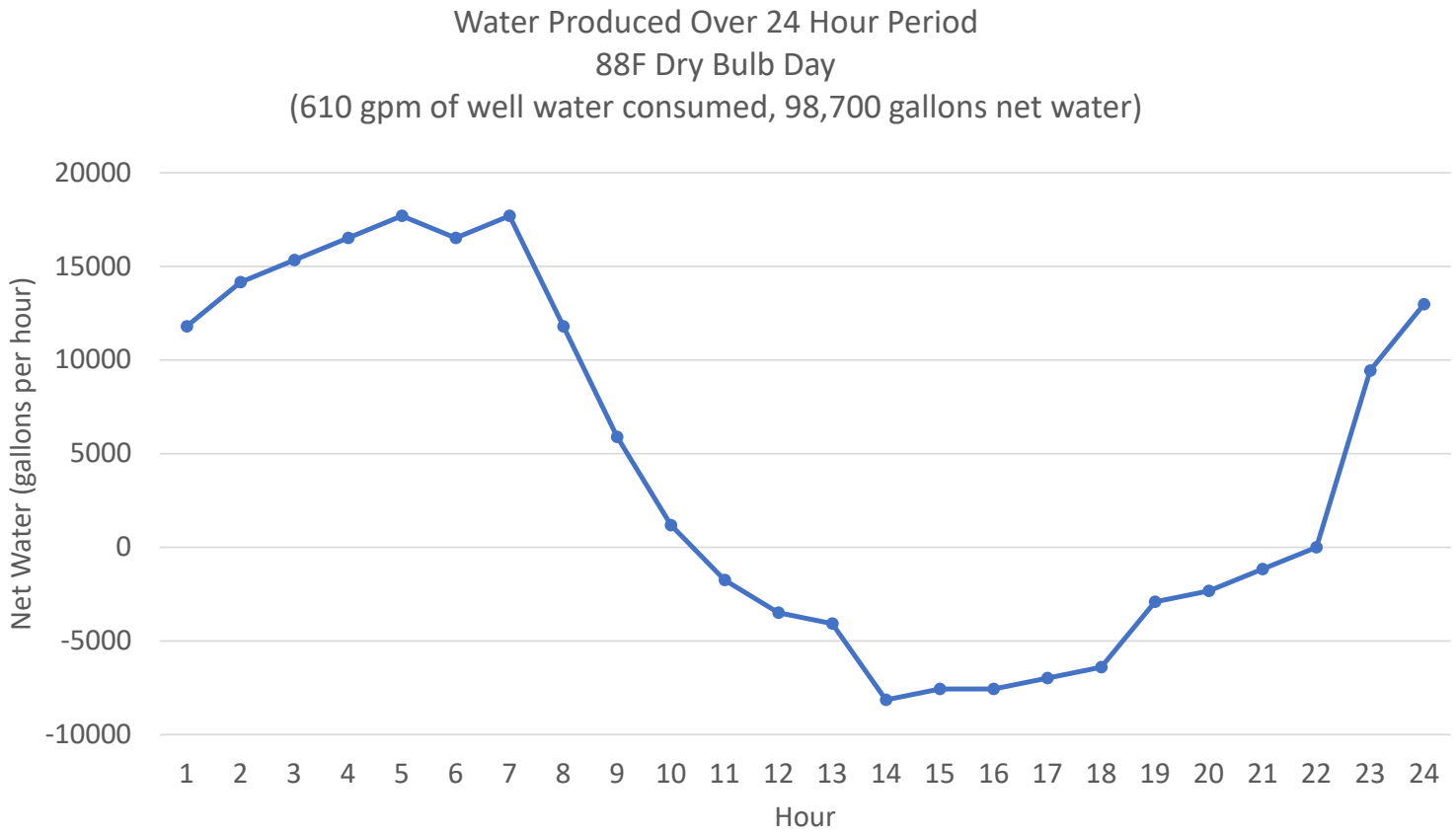
Coolest Summer Hour (60°F DB) -> 308 gpm surplus

Total water shortfall during hot hours: 53,000 gallons

(80,000 gallon tank)

MTR Carbon Capture Project
Water Surplus Discussion

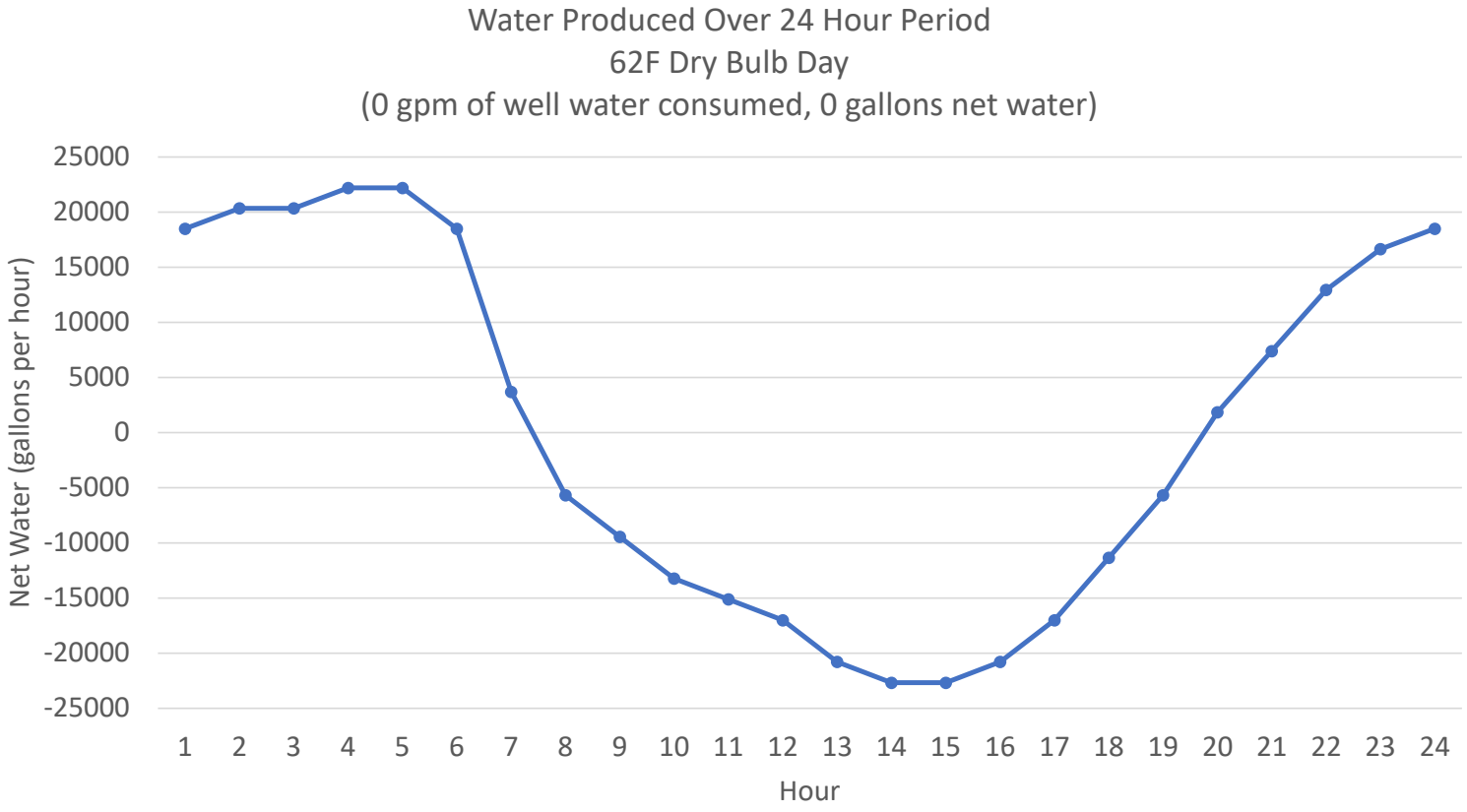
Summer Water Produced: 88F



Note: daily usage 542 gpm, which is under the 610 gpm available

MTR Carbon Capture Project
Water Surplus Discussion

Water Produced: 62F Daily High



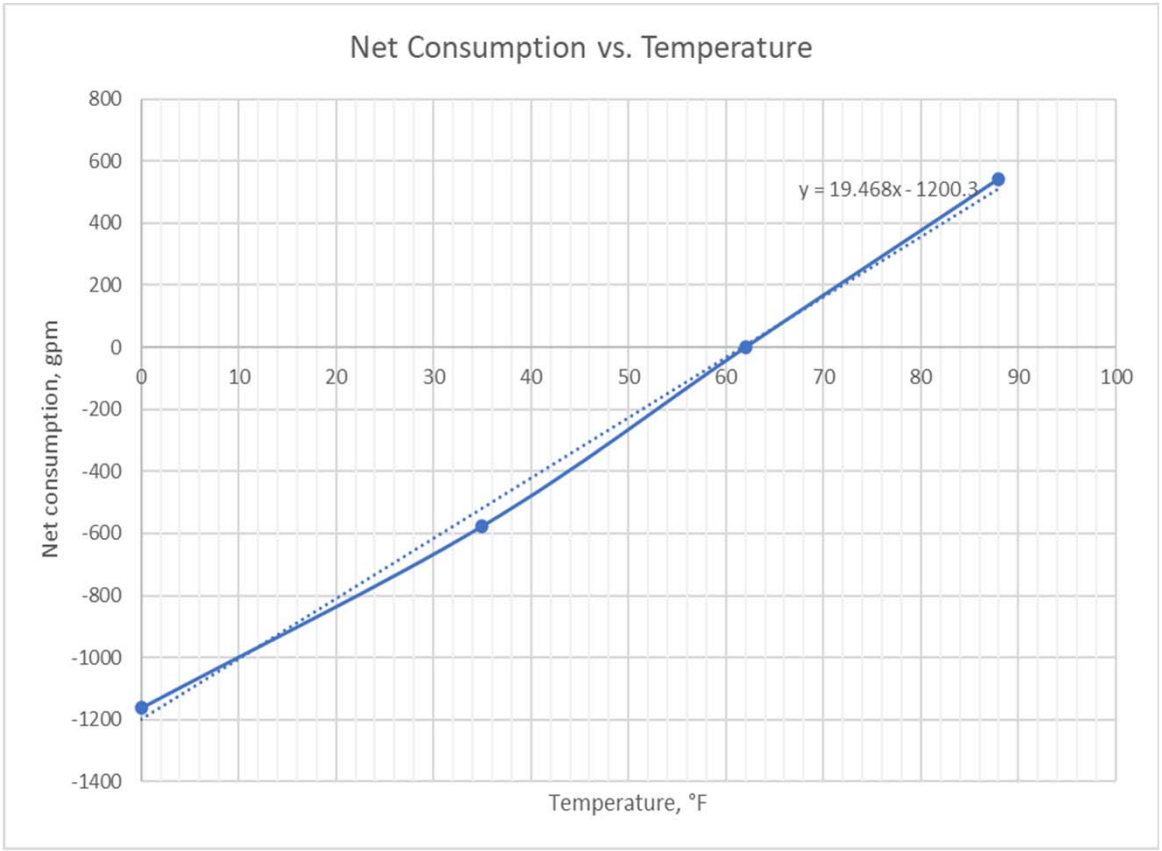
MTR Carbon Capture Project
Water Surplus Discussion

Water Produced: 0F Daily High

			well water	net water	total water			
		DB	(gpm)	(gpm)	gallons			
12:53 AM		-1	0	1163	69780			
1:53 AM		-1	0	1163	69780			
2:53 AM		-1	0	1163	69780			
3:53 AM		-1	0	1163	69780			
4:53 AM		-2	0	1163	69780			
5:53 AM		-3	0	1163	69780			
6:53 AM		-3	0	1163	69780			
7:53 AM		-4	0	1163	69780			
8:53 AM		-3	0	1163	69780			
9:53 AM		-2	0	1163	69780			
10:53 AM		-2	0	1163	69780		total volume gained=	
11:53 AM		-1	0	1163	69780		1674720	gallons
12:53 PM		-2	0	1163	69780			
1:53 PM		-2	0	1163	69780			
2:53 PM		-3	0	1163	69780			
3:53 PM		-3	0	1163	69780			
4:53 PM		-3	0	1163	69780			
5:53 PM		-4	0	1163	69780			
6:53 PM		-4	0	1163	69780			
7:53 PM		-5	0	1163	69780			
8:53 PM		-6	0	1163	69780			
9:53 PM		-6	0	1163	69780			
10:53 PM		-7	0	1163	69780			
11:53 PM		-8	0	1163	69780			

MTR Carbon Capture Project
Water Surplus Discussion

CC Net Consumption vs. Temperature



MTR Carbon Capture Project
Water Surplus Discussion

Water Surplus Evaluation

- Water surplus for 7 months each year: ranges from 32 gpm to 519 gpm
  - During the surplus months, there is no well water consumed by the CO_2 Capture Facility
- DFS requests 420 gpm water rights, but actual consumption is ~360 gpm
  - **At ~43 °F, DFS as a whole w/ CC operating is water neutral**
  - **Under 43 °F, something needs to be done with the excess water**
- 3 months each year: DFS+CC net surplus ranges from 81 gpm to 159 gpm
  - Above evaluation based on *average* ambient conditions
- Net surplus of 1163 gpm – 360 gpm = 803 gpm at 0 °F based on current hybrid cooling design
  - Note: the CC system cannot 'produce' more than 1163 gpm of water

	Avg High (°F)	Consumption (gpm)
January	37	-480
February	39	-441
March	48	-266
April	57	-91
May	67	104
June	77	299
July	87	493
August	86	474
September	74	240
October	60	-32
November	45	-324
December	35	-519

MTR Carbon Capture Project
Water Surplus Discussion

Potential Options to Mitigate Water Surplus

- (Only) Storage tanks will not be practical during very cold weather
- Add a pond or reservoir to “store” the excess water
  - Consider aeration to increase evaporation
- Can we send the water back to the aquifer
- Partial flue gas bypass is technically feasible – potential revenue loss
- Evaluate hybrid system to allow more wet cooling w/o exceeding summer water budget
  - Alfa Laval: 75% air cooler and 75% capacity WSAC configuration being evaluated
- Other options considered:
  - Spray water back into the FG residue stream – would require a second stack – S&L evaluating cost
  - Mining is the main industry in Gillette; it’s a net water producer - where is there water sent/used?
  - Municipal Water project – will not pursue in FEED Study phase
  - Geological/irrigation project on site or nearby – DFS input needed

ATTACHMENT 2: RESERVOIR SIZING OPTIONS PRESENTATION

MTR Full Scale: Reservoir Sizing

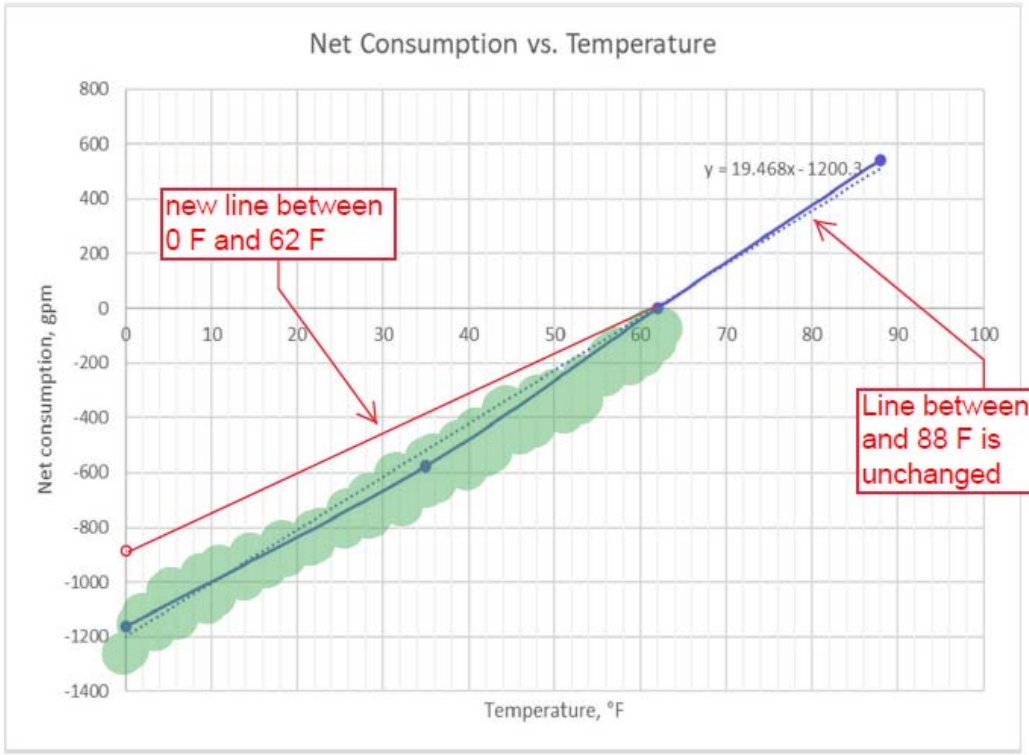
S&L/Mike Rosen

03 MAR 2021

Full Scale Weekly Status

Background

- Updated the water surplus “curve” based on Trimeric input

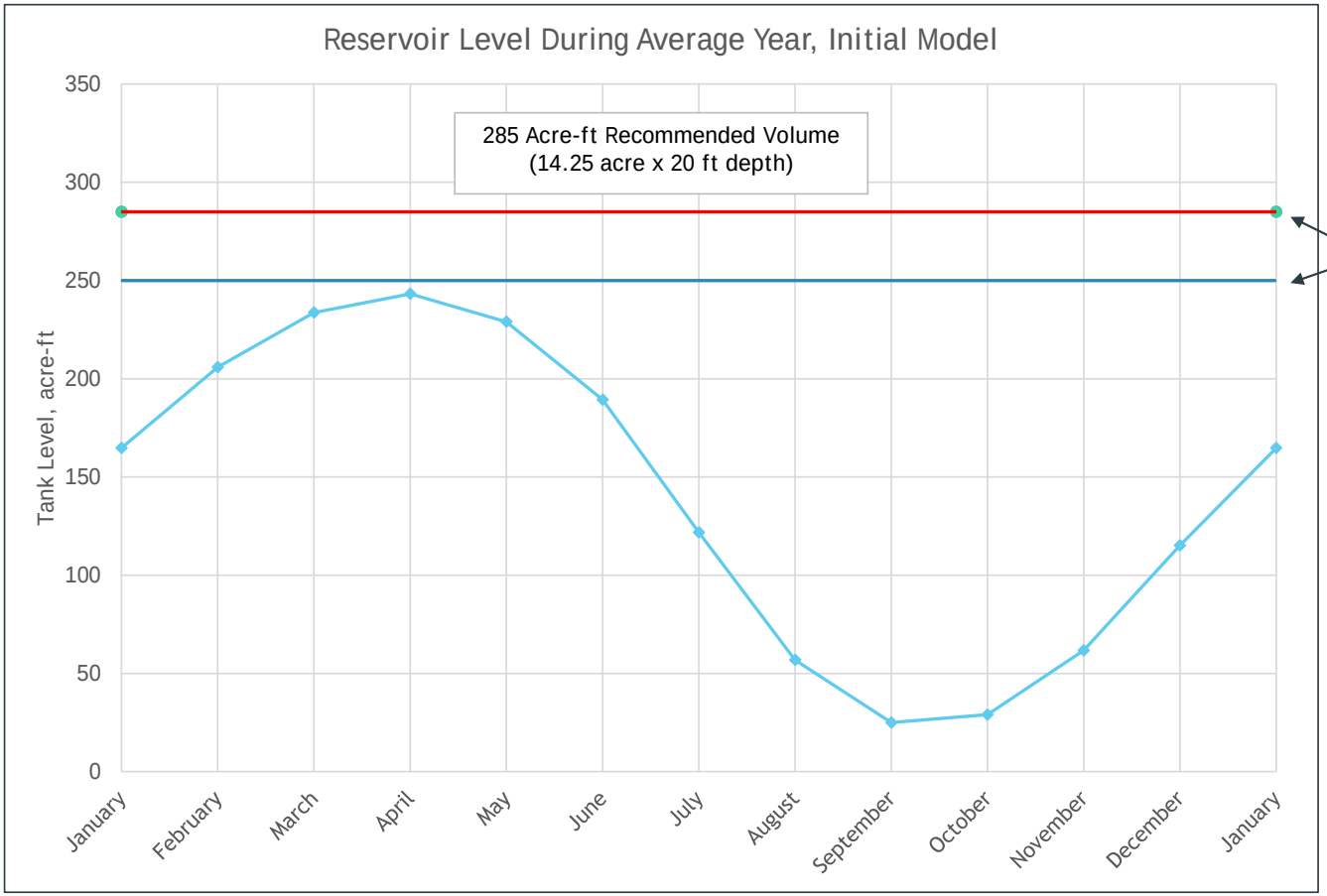


- Above 62 deg F the curve stayed the same
- New curve for temperatures 62 deg F and below
  - Less Surplus generated due to bypass of WSAC Dry Section
  - Previously 1163 gpm max surplus, now 885 gpm

Reservoir Sizing

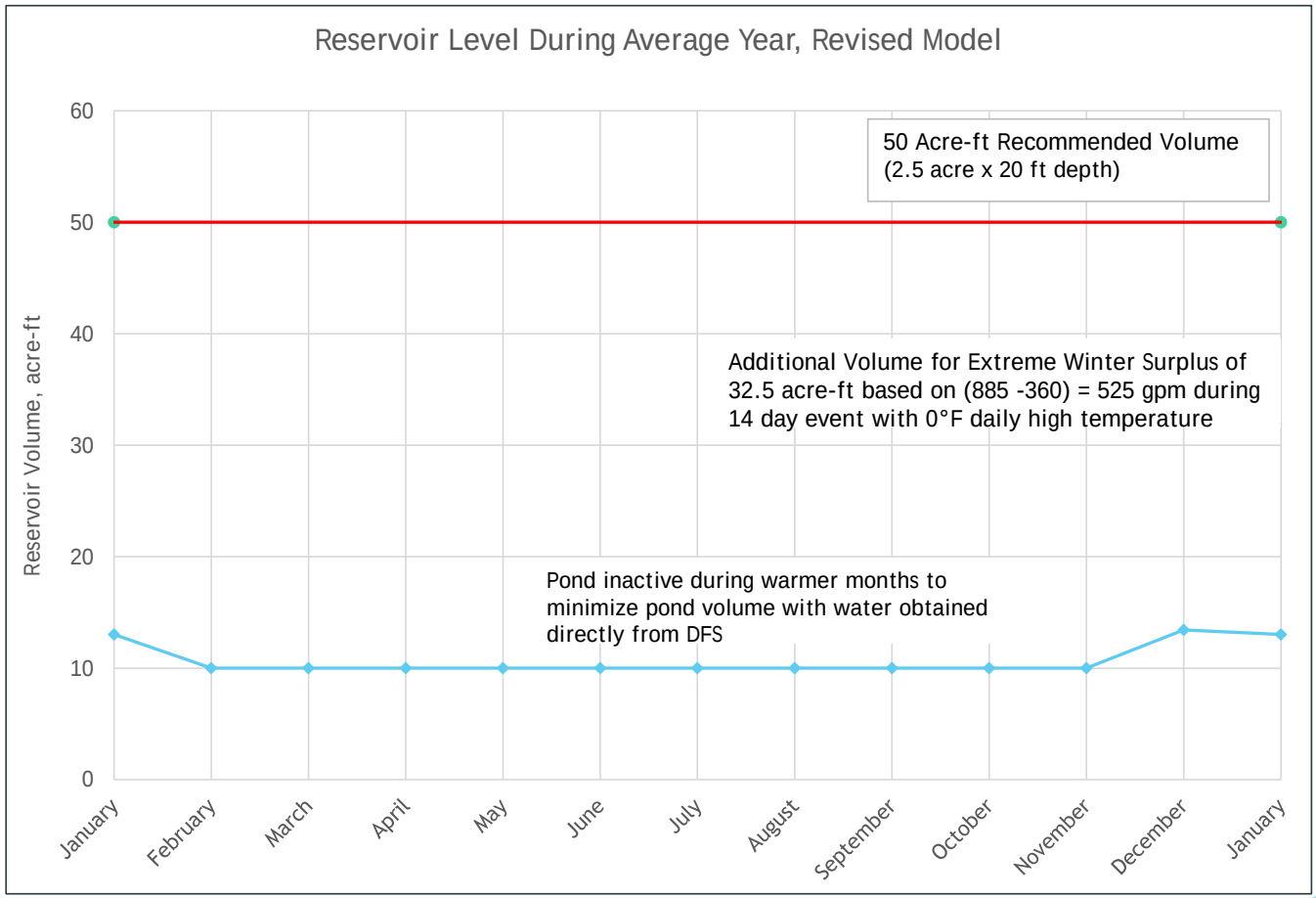
- Reservoir Sizing Simulations
  - Simulation 1: Utilize the reservoir year-round to store surplus & supply the CC facility and DFS
  - Simulation 2: Utilize the reservoir to store the surplus in winter months only
- Calculate the monthly consumption based on the average daily high temperature
- Add margin based on a cold "snap" of 14 days with a 0°F high temperature
  - 32.5 acre-ft based on (885-360 gpm) = 525 gpm during cold snap
- Note: 1 acre-ft x 43,560 ft^2 x 7.48 gal/ft^3 = 325,850 gal

Simulation 1: Year-round Reservoir



Additional Volume for Extreme Winter Surplus of 32.5 acre-ft based on (885 -360) = 525 gpm during 14 day event with 0°F daily high temperature

Simulation 2: Surplus Only Reservoir



Comparison

Simulation 1: Year-round

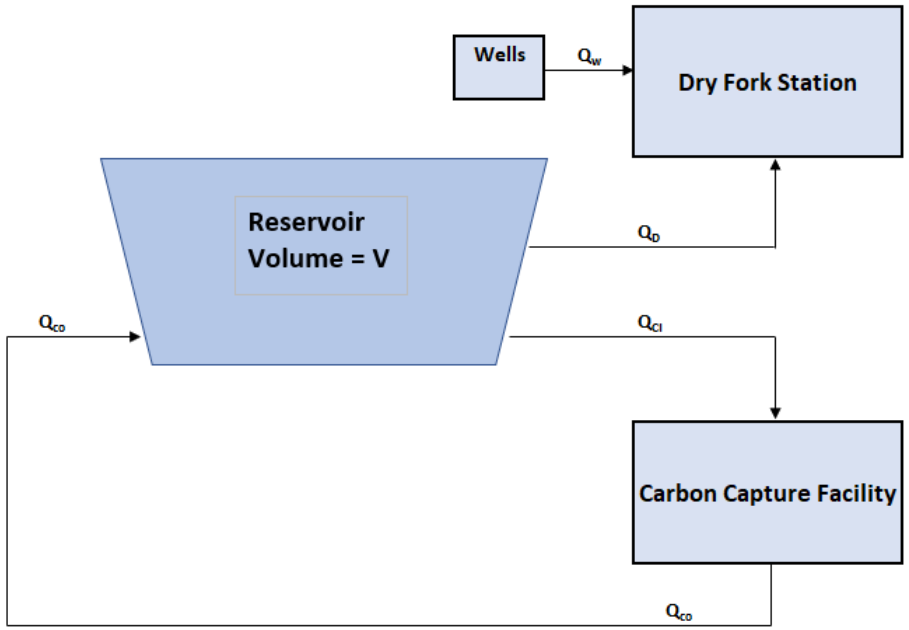
- Pond Size: 285 acre-ft
- 14.25 acre x 20 ft depth
- Cost $360K /acre pond = $5.1M (installed)

Simulation 2: Surplus Only

- Pond Size: 50 acre-ft
- 2.5 acre x 20 ft depth
- Cost $360K /acre pond = $900K (installed)
- **Recommended**

Supplemental Info

Model



Model

$V = V_0 + (Q_{co} - (Q_{CI} + Q_D))(1440D)/(7.48)(43,560)$

$V = V_0 + (Q_{co} - (Q_{CI} + Q_D))(D/226.3)$

$Q_w = 360 - Q_D$

V = Pond Volume, acre-ft

V_0 = Initial Pond Volume, acre-ft

Q_{co} = Flow from carbon capture to reservoir, gpm

Q_{CI} = Flow from reservoir to carbon capture, gpm

Q_D = Flow from reservoir to Dry Fork, gpm

Q_w = Flow from wells to Dry Fork, gpm

D = number of days in month

Simulation 1: Year-round Reservoir

	Q_{CI} (Reservoir to CC)	Q_{CO} (CC to Reservoir)	Q_D (Reservoir to DFS)	V (Volume, acre-ft)	Q_W (Well Water)	D (days per month)
January	0	357	-5.0	164.8	365	31
February	0	328	-4.6	205.9	365	28
March	0	200	-2.8	233.7	363	31
April	0	71	-1.0	243.2	361	30
May	104	0	0	229.0	360	31
June	299	0	0	189.3	360	30
July	493	0	0	121.8	360	31
August	474	0	0	56.9	360	31
September	240	0	0	25.0	360	30
October	0	29	-0.4	29.0	360	31
November	0	243	-3.4	61.7	363	30
December	0	385	-5.4	115.2	365	31

Annual Surplus	-980104	gal
Months with Surplus	7	
Avg days/month	30.3	
Avg gpm	-3.2	
Avg Q_{CO}	230.4	

Q_D = Avg gpm x (Q_{CO}/Avg Q_{CO})

Simulation 2: Surplus Only Reservoir

	Q_{CI} (Reservoir to CC)	Q_{CO} (CC to Reservoir)	Q_D (Reservoir to DFS)	V (Volume, acre-ft)	Q_W (Well Water)	D (days per month)
January	0	357	360	13.0	0	31
February	0	328	352	10.0	8	28
March	0	200	200	10.0	160	31
April	0	71	71	10.0	289	30
May	No water taken from Reservoir during this period			10.0	360	31
June				10.0	360	30
July				10.0	360	31
August				10.0	360	31
September				10.0	360	30
October	0	29	29	10.0	331	31
November	0	243	243	10.0	117	30
December	0	385	360	13.4	0	31
Net Surplus		0	gal			
Months with Surplus		7				
Avg days/month		30.3				
Average gpm		0.0	gpm			

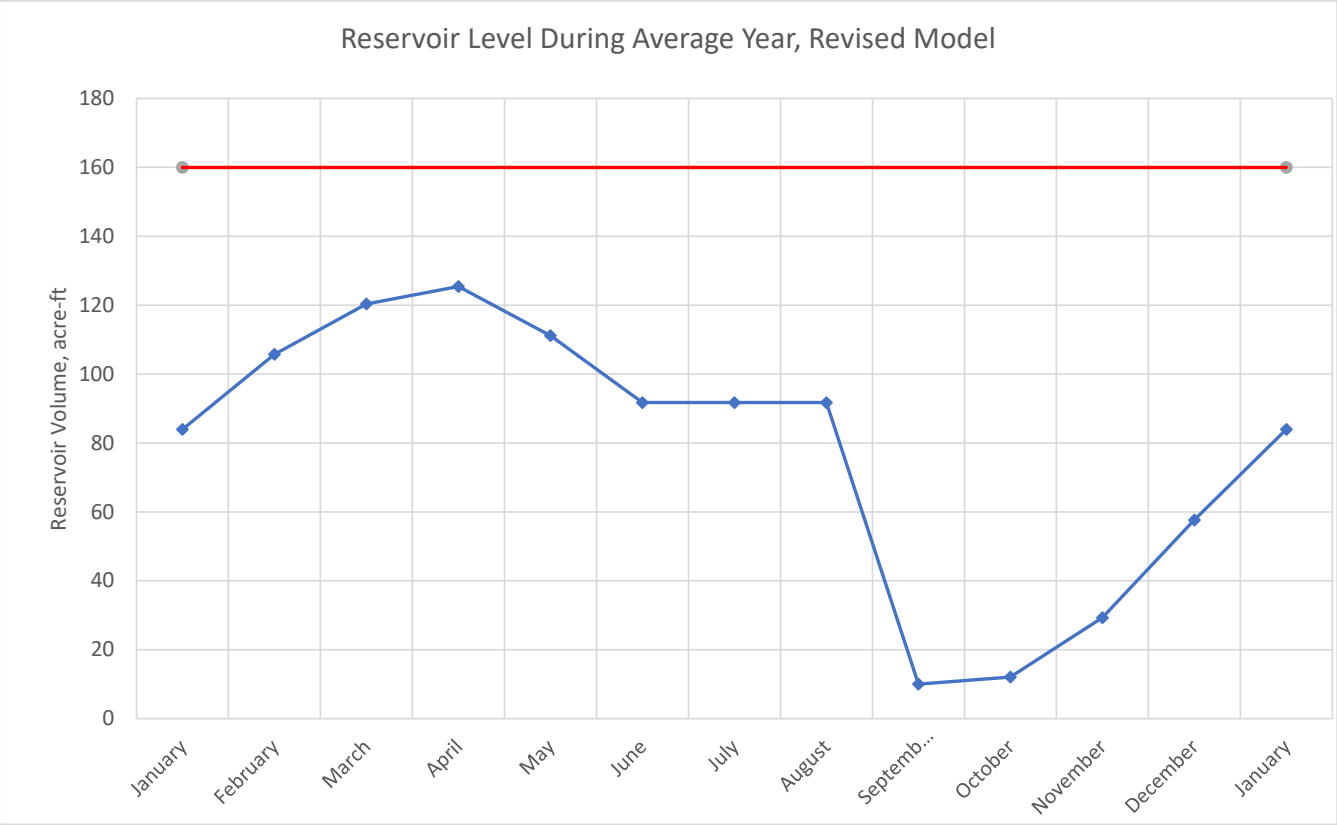
ATTACHMENT 3: REVISED (FINAL) RESERVOIR SIZING SIMULATION

Surplus Only Reservoir Simulation - Revised

(accounts for actual Cooling Tower Evaporation Rate)

	Q_{CI} Reservoir to CC (gpm)	Q_{CO} CC to Reservoir	Q_D Reservoir to DFS (gpm)	V Volume (acre-ft)	Q_W Well Water (gpm)	D (days per month)
January	0	192	0	83.9	360	31
February	0	176	0	105.7	360	28
March	0	107	0	120.4	360	31
April	0	38	0	125.4	360	30
May	104	0	0	111.2	360	31
June	147	0	0	91.7	512	30
July	0	0	0	91.7	853	31
August	0	0	0	91.7	834	31
September	0	0	0	10.0	600	30
October	0	15	0	12.1	360	31
November	0	130	0	29.3	360	30
December	0	207	0	57.6	360	31

Net Surplus	26633866	gal
Months with Surplus	7	
Avg days/month	30	
Average gpm	87	gpm



APPENDIX O. PROJECT PERMITTING MATRIX

Category	Agency	Permit or Approval	Applicability	Permit Needed By	Agency Review Time	Comments
MTR Full Scale Carbon Capture - Dry Fork Station						
Federal Permits						
Risk Management Plan Rule	U.S. Environmental Protection Agency (USEPA)	Risk Management Plan (RMP)	Yes	By date that regulated substance becomes present above a threshold quantity, or within 6 months of a change that requires a revised process hazard analysis or review	7 days from date of Electronic Signature Agreement (ESA) approval through *RMP*eSubmit*	Required by Section 112(r) of the Clean Air Act Amendments. A hazard assessment will be required for the volume of propylene based refrigerant that will be used at the station.
NEPA Compliance	N/A	NEPA Review	No	N/A	N/A	No federal nexus for the project known at this time.
Wetlands	U.S. Army Corps of Engineers (USACE)	Section 404/401	No	N/A	N/A	No impacts to jurisdictional wetlands expected based on a review of past wetland delineation data and preliminary project plans.
State Permits						
Siting	Wyoming Industrial Siting Council (ISC)	Industrial Siting Permit or Certificate of Insufficient Jurisdiction	Yes	Start of construction	185 days	Per the WYDEQ website, facilities with an estimated construction cost of $230,622,000 or more are required to obtain an Industrial Siting Permit. If cost estimates of ITC fall between $184,497,600 and $230,622,000, a Certificate of Insufficient Jurisdiction is required.
Air Emissions	Wyoming Department of Environmental Quality (WYDEQ) Air Quality Division (AQD)	New Source Review -- results in Construction Permit or Authorization Letter (waiver)	Yes	Start of construction	Approximately 45 days if authorization letter issued 120+ days if permit needed	Any new facility or source that will emit regulated air pollutants, or any existing facility or source that will increase the emission of air pollutants, must obtain a construction permit (NSR) before any work is begun on the facility. Dispersion modeling may be required.
	WYDEQ AQD	Administrative Permit Amendment or Permit Modification to existing Title V Permit	Yes	Within 12 months of start up of new/modified equipment	Approximately 12 months	Required if a Construction Permit is required by DEQ AQD after NSR. Amendment vs level of modification would need to be confirmed with WYDEQ.
Stormwater	WYDEQ Water Quality Division (WQD)	Wyoming Pollutant Discharge Elimination System (WYPDES) Construction General Permit	Yes	Start of construction	30 days	A Large Construction General Permit (LCGP) is required since construction will be disturbing more than 5 acres of ground.
Waste Disposal/Storage	WYDEQ Land Quality Division (LQD)	Industrial Solid Waste Landfill Permit	No	N/A	N/A	It is assumed that Project waste will be disposed of at existing permitted Basin landfill, therefore a new permit will not be required.
	WYDEQ Solid and Hazardous Waste Division (SHWD)	Very Small/Small/Large Quantity Generator ID #	No	N/A	N/A	Required if the facility generates hazardous waste for shipment and disposal off-site. Since MTR technology does not generate hazardous waste, a generator ID number will not be required.
	WYDEQ	Participation in Storage Tank Program (STP)	No	N/A	N/A	Required if regulated substance (i.e. CERCLA section 101(14) not including hazardous wastes under subtitle c of RCRA), or petroleum are stored in belowground tanks. Only aboveground tank systems (as defined by W.S. 35-11-14-15) used by a dealer to dispense gasoline or diesel to the public are regulated by the STP. Therefore, participation in the STP is not required.
Wastewater	WYDEQ WQD	WYPDES Discharge Permit	No	N/A	N/A	Wastewater to be treated at Dry Fork which is a zero liquid discharge facility. Therefore, WYPDES Discharge Permit is not required.
Water Use	Wyoming State Engineer	Additional water rights	No	N/A	N/A	Required if using or benefiting from transfers of the state of Wyoming's waters. It is assumed that process water will be obtained from facilities existing water rights; therefore, additional water rights are not required.
Local Permits						
Building Permits	Campbell County	Building Division Permits	No	N/A	N/A	Per phone correspondence with the County Building Division in January 2022, Campbell County does not have jurisdiction on Dry Fork property.

APPENDIX P. EMISSIONS AND WASTE DISPOSAL ESTIMATES

MTR Full Scale Carbon Capture
Emissions Estimates

Table 1. Air Emissions at Existing Main Stack

Pollutant	Current Emissions (lb/hr)	Post-Project Emissions (lb/hr)	Change (lb/hr)
CO_2	955,962	283,073	(672,889)
NO_x	169.0	151.0	(18.0)
CO	107.3	107.3	0
SO_2	309.0	7.81	(301.2)
PM (filterable + condensable)	2.69	2.69	0
PM_{10} (filterable + condensable)	2.41	2.41	0
$PM_{2.5}$ (filterable + condensable)	0.28	0.28	0
VOC	0.57	0.57	0

Note 1. Current CO_2, NO_X, SO_2 emissions obtained from S&L mass balance (DFS Full Scale Feed H&HB Rev 2_Summary).

Note 2. Current CO, PM and VOC emission rates based on 2020 tpy emissions reported to Wyoming DEQ (https://openair.wyo.gov), 2020 annual heat input reported to EPA's CAMD (https://ampd.epa.gov/ampd/), and hourly heat input from design basis document.

Note 3. Post project CO_2, NO_X, SO_2 emissions obtained from S&L mass balance (DFS Full Scale Feed H&HB Rev 2_Summary).

Note 4. Assume no change in CO, PM and VOC emissions due to MTR process.

Table 2. Other Emission Increases from New Emission Points

	Dehydration Vent (lb/hr)	Lime Silo (lb/hr)	Cooling Tower (lb/hr)	Wet Surface Air Cooler (lb/hr)
CO_2	1,040	-	-	-
NO_x	3.3	-	-	-
PM	-	0.069	1.17	0.014

Note 1. Dehydration vent emissions obtained from S&L mass balance (DFS Full Scale Feed H&HB Rev 2_Summary).

Note 2. Lime silo emissions based estimated bin vent exhaust flow rate of 800 cfm and filter grain loading of 0.01 gr/scf.

Note 3. Cooling tower emissions based estimated water circulation rate of 57,250 gpm, drift eliminator efficiency of 0.001% and estimated water TDS level of 4,090 ppm.

Note 4. WSAC emissions based on drift rate of 0.25 gpm (per vendor data) and estimated water TDS level of 109 ppm.

Table 3. Wastewater Discharge

	Current Operation (gpm)	Post-Project Operation (gpm)	Change (gpm)
Off-Site Wastewater Discharge	0	0	0

Note 1. Assume zero offsite wastewater discharge.

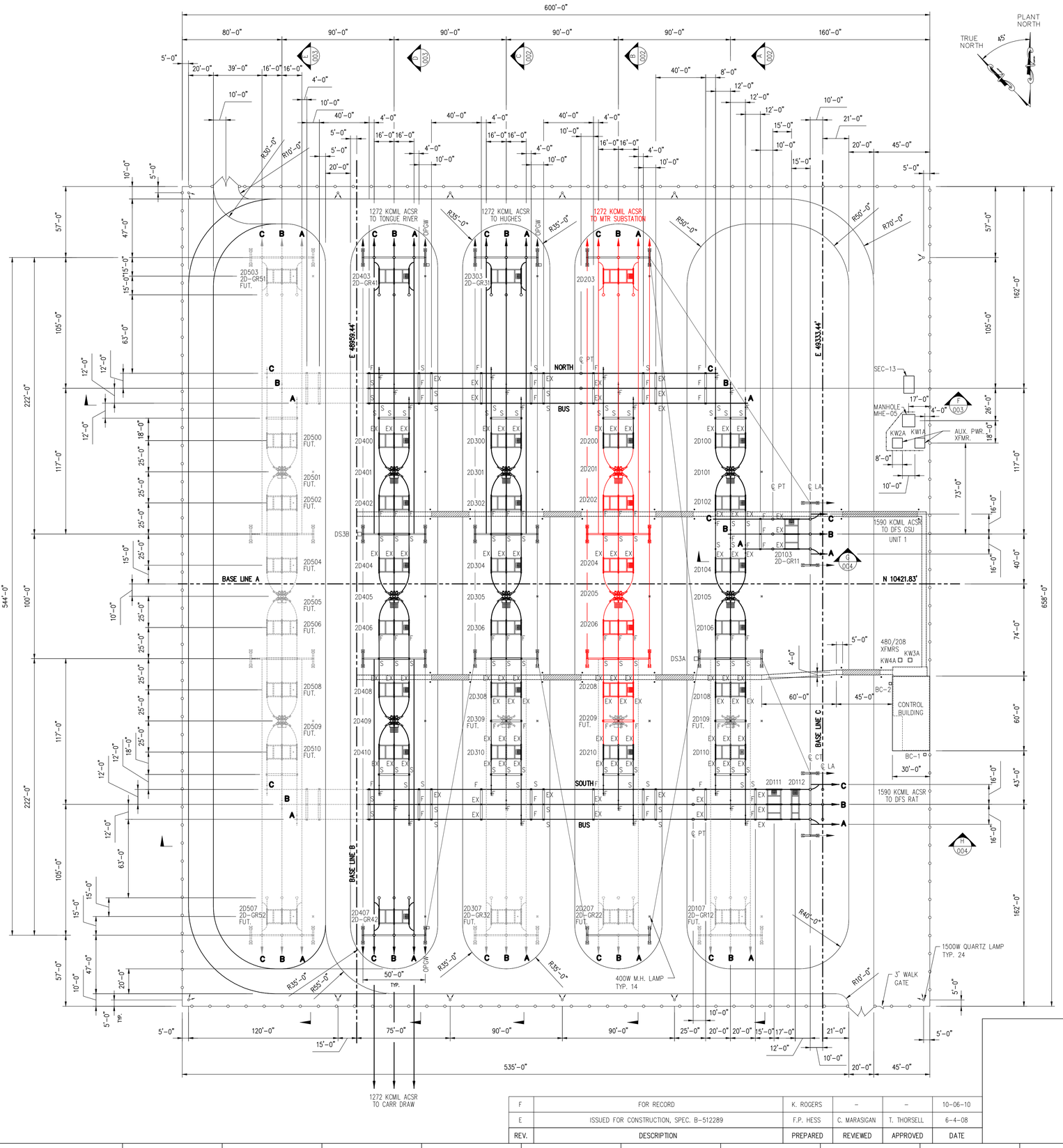
MTR Full Scale Carbon Capture
Emissions Estimates

Table 4. Solid Waste

Source	Current Operation (lb/hr)	Post-Project Operation (lb/hr)	Change (lb/hr)
H_2O Used for Conditioning	5,005	-	
H_2O Forwarded for Fixation	-	18,517	
DFGD Byproduct to Silo	35,141	35,141	
Other Waste Ash	5,507	5,507	
QuickLime	-	1,938	
RO Pretreatment Solid Waste	-	44	
Total	45,652	61,147	15,495

Note 1. Current and post-project values based on S&L mass balance that reflects annual average ambient conditions.

APPENDIX W. SWITCHYARD MODIFICATIONS AND TRANSMISSION LINE REDLINE DRAWINGS



REFERENCE DRAWINGS	
452-054-E3-002	SECTIONS A-A, B-B & C-C
452-054-E3-003	SECTIONS D-D, E-E & F-F
452-054-E3-004	SECTIONS G-G & H-H
452-054-E4-001	230KV SWITCHYARD ELECTRICAL DETAILS
452-062-E3-001	CONDUIT & CABLE PLAN
452-060-C3-001	FOUNDATION PLAN - SHEET 1 OF 2
452-060-C3-002	FOUNDATION PLAN - SHEET 2 OF 2
452-062-E3-001	CONDUIT & CABLE PLAN
452-089-E3-001	GROUNDING PLAN
452-059-E2-050	AC DISTRIBUTION SYSTEM
DFS-EA-100-2002	230KV SWITCHYARD INTERFACE PLAN
DFS-EM-100-0009	SINGLE LINE DIAGRAM, 13.8KV SWGR 1B (PART 3)
DFS-EM-1AP-0018	THRE LINE DIAGRAM, 13.8 KV SWGR 1B, BREAKER 1B16, 1B17, 1B18

LEGEND
F= FIXED CONNECTION
S= SLIDE CONNECTION
EX= EXPANSION CONNECTION

4'x3' GROUND MAT FOR DISCONNECT SWITCH AND CIRCUIT SWITCHER

6'x4' GROUND MAT FOR CIRCUIT BREAKER

NOTES

1. BASELINE COORDINATES SHOWN ARE BASED ON PLANT COORDINATES.
2. DASHED/SHADED EQUIPMENT REPRESENTS FUTURE INSTALLATION
3. ALL 3ø HIGH BUS SUPPORTS AND ALL 1ø LOW BUS SUPPORTS SHALL BE EQUIPPED WITH AN EXTRA-HIGH STRENGTH (LAPP 314161-70) INSULATOR. LOW 3ø BUS SUPPORTS SHALL BE EQUIPPED WITH A HIGH STRENGTH INSULATOR (LAPP 315308-70).
4. HIGH BUS TO BE 5", SCH. 40, 6063-T6 AL. LOW BUS TO BE 4", SCH. 40, 6063-T6 AL. A-FRAMES TO BE 2 1/2", SCH. 40, 6063-T6 AL. DAMPING CABLE TO BE 1272 KCMIL ACSR

40 0 40 80 120
GRAPHIC SCALE

PRELIMINARY

REV.	DESCRIPTION	PREPARED	REVIEWED	APPROVED	DATE
F	FOR RECORD	K. ROGERS	-	-	10-06-10
E	ISSUED FOR CONSTRUCTION, SPEC. B-512289	F.P. HESS	C. MARASIGAN	T. THORSELL	6-4-08

Sargent & Lundy LLC

FILE NAME: 452-054-E3-001

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/ INSTALLER'S PERSONNEL (OR THAT OF IT'S SUBCONTRACTOR(S)) PERFORMING THE WORK.

FACILITY: TRANSMISSION SYSTEM MAINTENANCE
LOCATION/UNIT: 452-230KV DRY FORK SWITCHYARD
CONTRACT/DESIGNATION: S&L PROJECT 11786-004

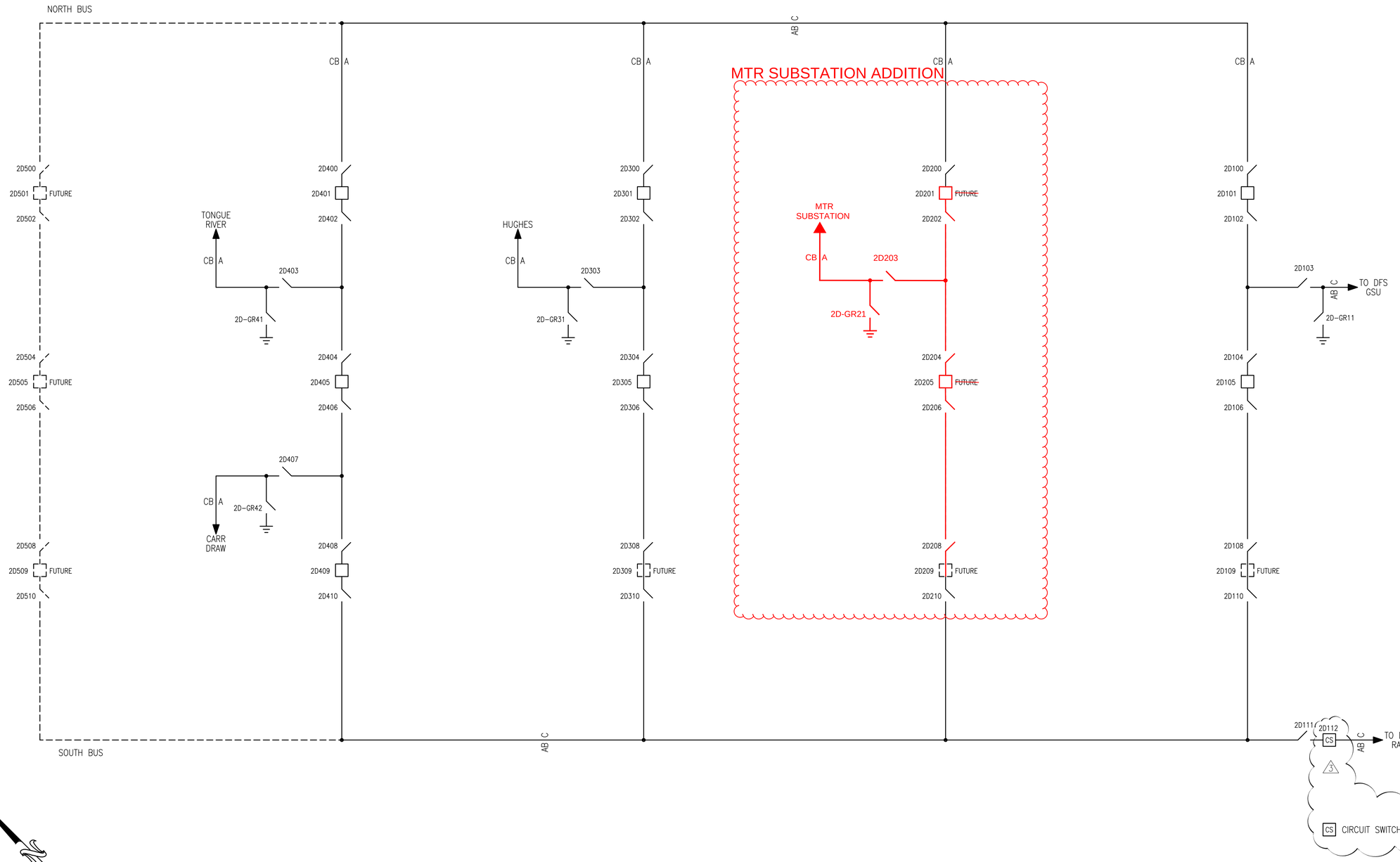
SWITCHYARD GENERAL ARRANGEMENT

BASIN ELECTRIC POWER COOPERATIVE
Your Touchstone Energy Partner

DESIGN BY	F.P. HESS	02/07/07
DRAWN BY	F.P. HESS	02/07/07
DESIGN CHK.	W. JALAFSKY	04/05/07
DRAFT CHK.	C. MARASIGAN	06/04/08
APPROVED	T. THORSELL	06/04/08

SCALE: 1"=40'-0"
VENDOR/ORIGINATED FROM: N/A
VENDOR DRAWING NO. N/A
ORIGINAL REV N/A
BASIN DRAWING NO. 452-054-E3-001
REV. NO. F

03/08/06



REV.	DESCRIPTION	DRWN	DSGN	APPD	DATE
3	ADDED CS 2D112	L. FROEHLICH	D. SWIGOST		11/19/07
2	CHANGED PHASING	L. FROEHLICH	D. SWIGOST		2/2/07
1	ADDED BREAKER AND SWITCH IDENTIFICATION NUMBERS	L. FROEHLICH	D. SWIGOST		11/21/06

REFERENCE DRAWINGS

FACILITY: TRANSMISSION SYSTEM MAINTENANCE
LOCATION/UNIT: 452-DFS 230KV SWITCHYARD
CONTRACT/DESIGNATION:

SWITCHING DIAGRAM

DESIGN BY D. SWIGOST 9/29/06
DRAWN BY L. FROEHLICH 9/29/06
DESGN CHK.
DRFT CHK. B. NELSON 9/29/06
APPROVED
SCALE: NONE
VENDOR/ORIGINATED FROM:
VENDOR DRAWING NO. ORIGINAL REV.

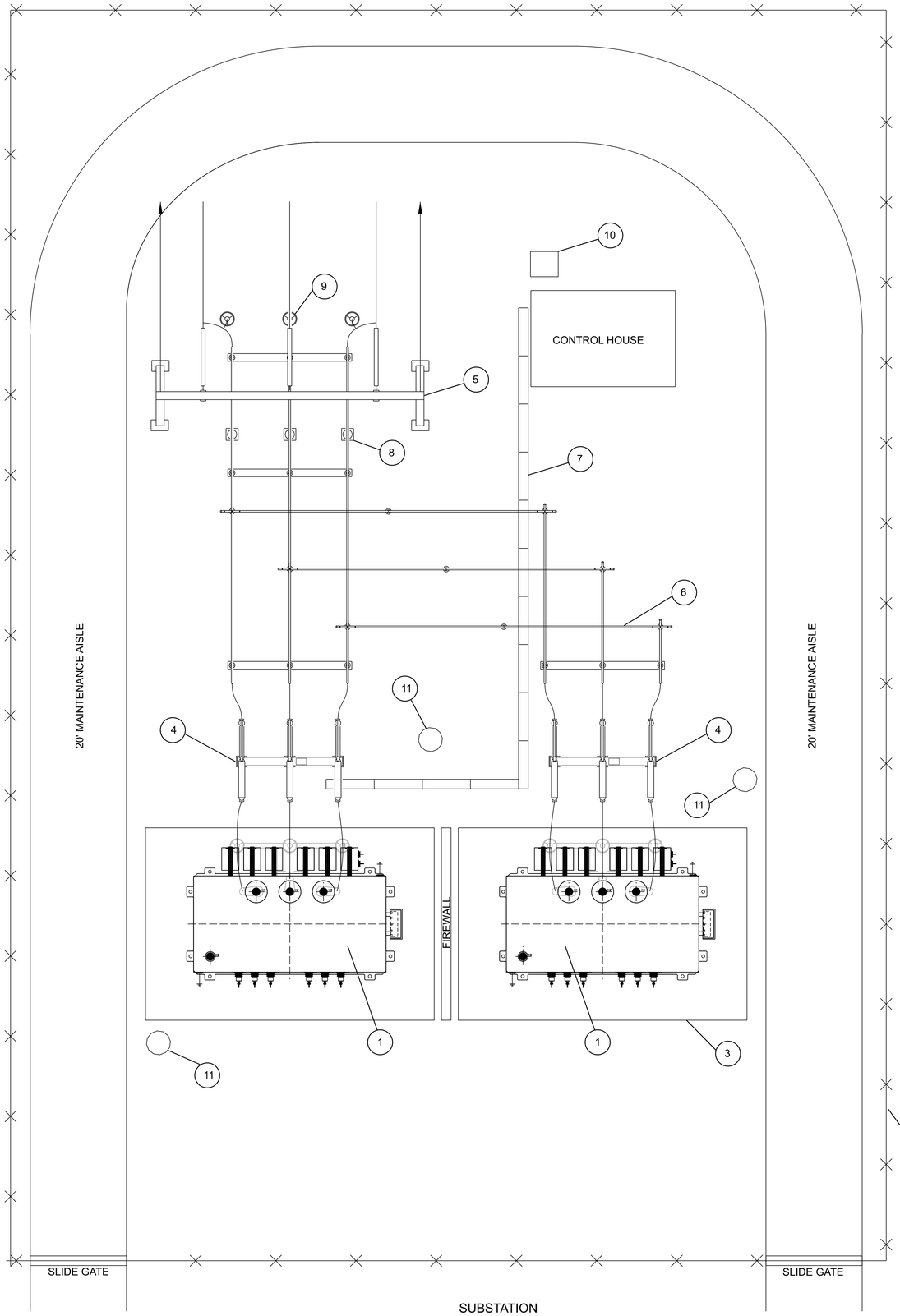
BASIN ELECTRIC POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441

BASIN DRAWING NO. 452-063-E1-001 REV. NO. 3

01/27/04


DRY FORK
DFS GEN STATION

APPENDIX X. CO_2 CAPTURE PLANT SUBSTATION LAYOUT



SUBSTATION

ITEM	DESCRIPTION
1	TRANSFORMER
2	FENCE
3	TRANSFORMER CONTAINMENT
4	CIRCUIT SWITCHERS
5	DEADEND
6	RIGID BUSWORK
7	TRENCH
8	VOLTAGE TRANSFOMER
9	SURGE ARRESTER
10	STATION SERVICE TRANSFORMER
11	SHEILDING MAST

PRELIMINARY
NOT FOR CONSTRUCTION

PLANT NORTH

10' 0 10' 20' 30'
GRAPHIC SCALE

DRAWING SCALE
1" = 10'-0"

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
A	12/29/2021	FOR CLIENT COMMENT
0	03/04/2022	FOR USE
1	03/22/2022	FOR USE

ISSUE PURPOSE: FOR USE

SPECIFICATION:

PROJECT NO.: 13978.002

I HEREBY CERTIFY THAT THIS ENGINEERING DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT PERSONAL SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF ENTER NAME.

ENTER NAME
ENTER DATE

MY LICENSE RENEWAL DATE
IS: ENTER DATE
PAGES OR SHEETS COVERED BY
THIS SEAL:
THIS DOCUMENT ONLY.

CERTIFICATE OF AUTHORIZATION

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT
SUBSTATION
EQUIPMENT LOCATION PLAN

DRAWING NUMBER	REVISION
FS-MTR-E-0004	1

SHEET 01 OF 01

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Form GDG-0401-01-a8, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

APPENDIX DD. CONTROL EQUIPMENT LIST

Ref Dwg: J-0001-01

Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8003	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA DCS CONTROLLER AND LOCAL I/O CABINET	31/81	S&L	VENDOR	GWC	FURNISH WITH CP'S
1CC-CAB8004	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	31/81	S&L	VENDOR	GWC	
1CC-CAB8005	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	31/81	S&L	VENDOR	GWC	
1CC-CAB8006	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	31/81	S&L	VENDOR	GWC	
1CC-ESW8003	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM MEMA COMPRESSOR PLC NETWORK SWITCH	31/81	S&L	VENDOR	GWC	INSTALLED IN DCS LINEUP
1CC-ESW8004	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM MEMA COMPRESSOR PLC NETWORK SWITCH	31/81	S&L	VENDOR	GWC	INSTALLED IN DCS LINEUP
1CC-ESW8005	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	31/81	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
1CC-ESW8006	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	31/81	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
1CC-PLC8001	PLC	TRAIN 1 MEMA PERMEATE COMPRESSOR A PLC	31/81	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1CC-PLC8002	PLC	TRAIN 1 MEMA PERMEATE COMPRESSOR B PLC	31/81	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1CC-PLC8003	PLC	TRAIN 2 MEMA PERMEATE COMPRESSOR A PLC	31/81	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1CC-PLC8004	PLC	TRAIN 2 MEMA PERMEATE COMPRESSOR B PLC	31/81	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8007	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA DCS CONTROLLER AND LOCAL I/O CABINET	32/82	S&L	VENDOR	GWC	FURNISH WITH CP'S
1CC-CAB8008	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	32/82	S&L	VENDOR	GWC	
1CC-CAB8009	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	32/82	S&L	VENDOR	GWC	
1CC-CAB8010	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	32/82	S&L	VENDOR	GWC	
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8011	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA DCS CONTROLLER AND LOCAL I/O CABINET	33/83	S&L	VENDOR	GWC	FURNISH WITH CP'S
1CC-CAB8012	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	33/83	S&L	VENDOR	GWC	
1CC-CAB8013	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	33/83	S&L	VENDOR	GWC	
1CC-CAB8014	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	33/83	S&L	VENDOR	GWC	
1CC-ESW8007	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	33/83	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
1CC-ESW8008	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	33/83	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
1SA-PLC8001	PLC	CO2 CAPTURE PLANT SERVICE AIR COMPRESSOR A PLC	33/83	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1SA-PLC8002	PLC	CO2 CAPTURE PLANT SERVICE AIR COMPRESSOR B PLC	33/83	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8015	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA DCS CONTROLLER AND LOCAL I/O CABINET	34/84	S&L	VENDOR	GWC	FURNISH WITH CP'S
1CC-CAB8016	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	34/84	S&L	VENDOR	GWC	
1CC-CAB8017	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	34/84	S&L	VENDOR	GWC	
1CC-CAB8018	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMA EXTENDED I/O CABINET	34/84	S&L	VENDOR	GWC	
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8019	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMB DCS CONTROLLER AND LOCAL I/O CABINET	35/85	S&L	VENDOR	GWC	FURNISH WITH CP'S
1CC-CAB8020	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMB EXTENDED I/O CABINET	35/85	S&L	VENDOR	GWC	
1CC-CAB8021	DCS CABINET	CO2 PROCESS BUILDING DCS ROOM MEMB EXTENDED I/O CABINET	35/85	S&L	VENDOR	GWC	
1CC-PLC8005	PLC	MEMB PERMEATE COMPRESSOR B PLC	35/85	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR

Ref Dwg: J-0001-01

Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8001	NETWORK CABINET	DCS EQUIPMENT ROOM CO2 PLANT NETWORK CABINET	N/A	S&L	VENDOR	GWC	FURNISH WITH FOPP
1CC-CAB8002	NETWORK CABINET	CO2 PROCESS BUILDING DCS ROOM NETWORK CABINET	N/A	S&L	VENDOR	GWC	FURNISH WITH DCS FANOUTS AND FOPP
1CC-ESW8001	FANOUT SWITCH	CO2 CAPTURE PLANT DCS FANOUT SWITCH	N/A	VENDOR	VENDOR	GWC	INSTALLED IN NETWORK CABINET
1CC-ESW8002	FANOUT SWITCH	CO2 CAPTURE PLANT DCS FANOUT SWITCH	N/A	VENDOR	VENDOR	GWC	INSTALLED IN NETWORK CABINET
1CC-EWS8001	WORKSTATION	CO2 PROCESS BUILDING DCS ROOM DCS ENG/OPS WORKSTATION	N/A	VENDOR	VENDOR	GWC	FURNISH WITH QUAD SCREEN CAPABILITY AND KVM EXT
1CC-HMI8001	HMI	CO2 PROCESS BUILDING DCS ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8002	HMI	CO2 PROCESS BUILDING DCS ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8003	HMI	CO2 PROCESS BUILDING DCS ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8004	HMI	CO2 PROCESS BUILDING DCS ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	

Ref Dwg: J-0001-02

Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-ANZ8001	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA BLOCK 1 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8002	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA BLOCK 2 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8003	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA BLOCK 3 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8004	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA BLOCK 4 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8005	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA BLOCK 5 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8006	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMA FANS & COMP ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8007	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 1 MEMB ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8008	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA BLOCK 1 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8009	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA BLOCK 2 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8010	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA BLOCK 3 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8011	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA BLOCK 4 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8012	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA BLOCK 5 ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8013	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMA FANS & COMP ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8014	ANALYZER CABINET	CO2 PROCESS BUILDING TRAIN 2 MEMB ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ANZ8015	ANALYZER CABINET	CO2 PROCESS BUILDING MEMB FANS & COMP ANALYZER CABINET	35/85	S&L	OTHERS	GWC	
1CC-ESW8009	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM VMS AND ANALYZER NETWORK SWITCH	35/85	S&L	VENDOR	GWC	INSTALLED IN NETWORK CABINET
1CC-ESW8010	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM VMS AND ANALYZER NETWORK SWITCH	35/85	S&L	VENDOR	GWC	INSTALLED IN NETWORK CABINET
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8022	NETWORK CABINET	CO2 PROCESS BUILDING DCS ROOM NETWORK CABINET	N/A	S&L	VENDOR	GWC	FURNISH WITH ENET SWITCHES
1CC-ESW8011	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM VMS WORKSTATION HMI	N/A	S&L	VENDOR	GWC	INSTALLED IN NETWORK CABINET
1CC-ESW8012	NETWORK SWITCH	CO2 PROCESS BUILDING DCS ROOM VMS WORKSTATION HMI	N/A	S&L	VENDOR	GWC	INSTALLED IN NETWORK CABINET
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8023	VMS CABINET	CO2 PROCESS BUILDING MAIN FLOOR VMS REMOTE I/O CABINET	VMS	S&L	VENDOR	GWC	
1CC-CAB8024	VMS CABINET	CO2 PROCESS BUILDING MAIN FLOOR VMS REMOTE I/O CABINET	VMS	S&L	VENDOR	GWC	
1CC-CAB8025	VMS CABINET	CO2 PROCESS BUILDING MAIN FLOOR VMS REMOTE I/O CABINET	VMS	S&L	VENDOR	GWC	
1CC-CAB8026	VMS CABINET	CO2 PROCESS BUILDING MAIN FLOOR VMS REMOTE I/O CABINET	VMS	S&L	VENDOR	GWC	
1CC-EWS8002	WORKSTATION	CO2 PROCESS BUILDING DCS ROOM VMS ENG/OPS WORKSTATION	VMS	VENDOR	VENDOR	GWC	FURNISH WITH QUAD SCREEN CAPABILITY AND KVM EXT
1CC-HMI8005	HMI	CO2 PROCESS BUILDING DCS ROOM VMS ENG/OPS WORKSTATION HMI	VMS	VENDOR	VENDOR	GWC	
1CC-HMI8006	HMI	CO2 PROCESS BUILDING DCS ROOM VMS ENG/OPS WORKSTATION HMI	VMS	VENDOR	VENDOR	GWC	
1CC-HMI8007	HMI	CO2 PROCESS BUILDING DCS ROOM VMS ENG/OPS WORKSTATION HMI	VMS	VENDOR	VENDOR	GWC	
1CC-HMI8008	HMI	CO2 PROCESS BUILDING DCS ROOM VMS ENG/OPS WORKSTATION HMI	VMS	VENDOR	VENDOR	GWC	

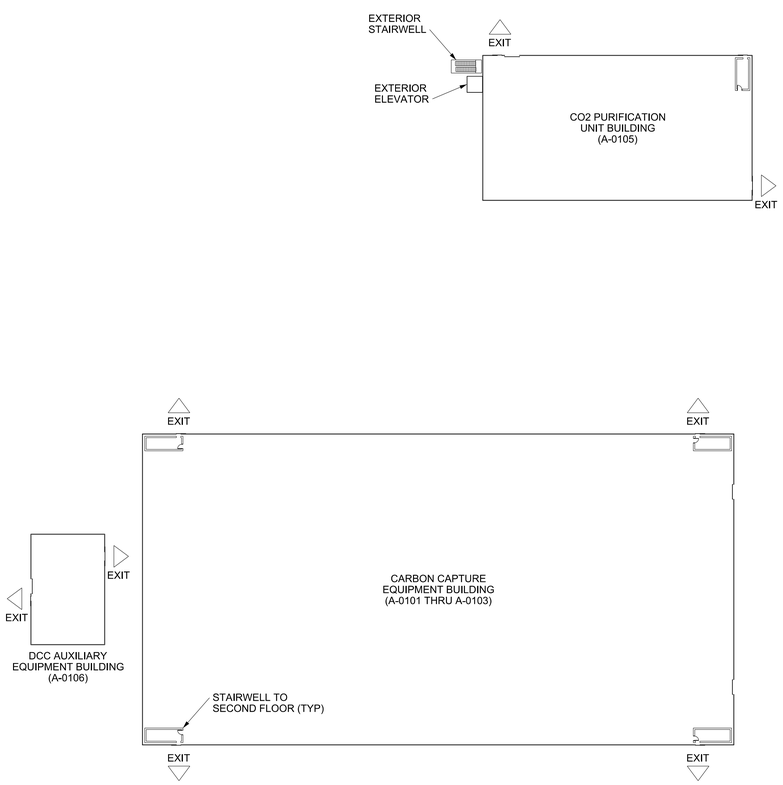
Ref Dwg: J-0001-03

Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-ANZ8016	ANALYZER CABINET	CO2 PURIFICATION UNIT ANALYZER CABINET	36/86	S&L	OTHERS	GWC	
1CC-CAB8028	DCS CABINET	CO2 PURIFICATION UNIT ELECTRICAL ROOM CPU DCS CONTROLLER AND LOCAL I/O CABINET	36/86	S&L	VENDOR	GWC	
1CC-CAB8029	DCS CABINET	CO2 PURIFICATION UNIT ELECTRICAL ROOM CPU EXTENDED I/O CABINET	36/86	S&L	VENDOR	GWC	
1CC-CAB8030	DCS CABINET	CO2 PURIFICATION UNIT ELECTRICAL ROOM CPU EXTENDED I/O CABINET	36/86	S&L	VENDOR	GWC	
1CC-ESW8013	NETWORK SWITCH	CO2 PURIFICATION UNIT ELECTRICAL ROOM RFG COMPRESSOR PLC NETWORK SWITCH	36/86	S&L	VENDOR	GWC	INSTALLED IN DCS LINEUP
1CC-ESW8014	NETWORK SWITCH	CO2 PURIFICATION UNIT ELECTRICAL ROOM RFG COMPRESSOR PLC NETWORK SWITCH	36/86	S&L	VENDOR	GWC	INSTALLED IN DCS LINEUP
1CC-PLC8006	PLC	CO2 REFRIGERATION COMPRESSOR A PLC	36/86	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1CC-PLC8007	PLC	CO2 REFRIGERATION COMPRESSOR B PLC	36/86	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
1CC-PLC8008	PLC	CO2 REFRIGERATION COMPRESSOR C PLC	36/86	OTHERS	OTHERS	GWC	FURNISHED BY EQUIPMENT VENDOR
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1WN-CAB8002	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC DCS CONTROLLER AND LOCAL I/O CABINET	37/87	S&L	VENDOR	GWC	
1WN-CAB8003	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC EXTENDED I/O CABINET	37/87	S&L	VENDOR	GWC	
1WN-CAB8004	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC EXTENDED I/O CABINET	37/87	S&L	VENDOR	GWC	
1WN-CAB8005	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC EXTENDED I/O CABINET	37/87	S&L	VENDOR	GWC	
1WN-ESW8001	NETWORK SWITCH	WATER TREATMENT ELECTRICAL ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	37/87	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
1WN-ESW8002	NETWORK SWITCH	WATER TREATMENT ELECTRICAL ROOM ELECTRICAL EQUIPMENT NETWORK SWITCH	37/87	S&L	VENDOR	GWC	INSTALLED IN SWG LINEUP
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1WN-CAB8006	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC DCS CONTROLLER AND LOCAL I/O CABINET	38/88	S&L	VENDOR	GWC	
1WN-CAB8007	DCS CABINET	WATER TREATMENT ELECTRICAL ROOM MEMC EXTENDED I/O CABINET	38/88	S&L	VENDOR	GWC	
Equipment Tag	Equipment Type	Service Description	Drop	DOR	Furnish By	Install By	Notes
1CC-CAB8027	NETWORK CABINET	CO2 PURIFICATION UNIT ELECTRICAL ROOM NETWORK CABINET	N/A	S&L	VENDOR	GWC	FURNISH WITH FOPP
1CC-EWS8003	WORKSTATION	CO2 PURIFICATION UNIT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION	N/A	VENDOR	VENDOR	GWC	FURNISH WITH QUAD SCREEN CAPABILITY AND KVM EXT
1CC-HMI8009	HMI	CO2 PURIFICATION UNIT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8010	HMI	CO2 PURIFICATION UNIT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8011	HMI	CO2 PURIFICATION UNIT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1CC-HMI8012	HMI	CO2 PURIFICATION UNIT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1WN-CAB8001	NETWORK CABINET	WATER TREATMENT ELECTRICAL ROOM NETWORK CABINET	N/A	S&L	VENDOR	GWC	FURNISH WITH FOPP
1WN-EWS8001	WORKSTATION	WATER TREATMENT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION	N/A	VENDOR	VENDOR	GWC	FURNISH WITH QUAD SCREEN CAPABILITY AND KVM EXT
1WN-HMI8001	HMI	WATER TREATMENT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1WN-HMI8002	HMI	WATER TREATMENT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1WN-HMI8003	HMI	WATER TREATMENT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	
1WN-HMI8004	HMI	WATER TREATMENT ELECTRICAL ROOM DCS ENG/OPS WORKSTATION HMI	N/A	VENDOR	VENDOR	GWC	

Notes:
1) The 'DOR' field indicates the party primarily responsible for the specification and design of the equipment. Ultimately, the DCS supplier will be responsible for providing a complete, fully integrated control system and final control system drawings.
2) By 'VENDOR' refers to the DCS supplier, by 'OTHERS' refers to other equipment suppliers managed under a separate contract.

Prepared By: Harley R. Hudetz Reviewed By: James R. Robeson Approved: Dana B. Pierik

APPENDIX II. ARCHITECTURAL DRAWINGS



BUILDING ARRANGEMENT PLAN
SCALE: 1"=40'

NORTH

CODE ANALYSIS TABLE							
BUILDING	USE GROUP	CONSTRUCTION	BUILDING STORIES	BUILDING AREA	BUILDING HEIGHT	SPRINKLER PROVIDED	FIRE DETECTION
CARBON CAPTURE EQUIPMENT	F-1	TYPE II-B	2	FLOOR 1 = 85,577 SF	87'-0"	PARTIAL (NOTE 1)	YES
				FLOOR 2 = 54,837 SF			
				TOTAL = 140,414 SF			
WATER TREATMENT	F-1	TYPE II-B	2	FLOOR 1 = 11,494 SF	38'-3"	PARTIAL (NOTE 1)	YES
				FLOOR 2 = 11,494 SF			
				TOTAL = 22,988 SF			
CO2 PURIFICATION UNIT	F-1	TYPE II-B	2	FLOOR 1 = 18,122 SF	52'-8"	PARTIAL (NOTE 1)	YES
				FLOOR 2 = 18,122 SF			
				TOTAL = 36,244 SF			
DCC AUXILIARY EQUIPMENT	F-1	TYPE II-B	1	3,760 SF	22'-1"	PARTIAL (NOTE 1)	YES
NOTE 1 - DUE TO THE SPECIFIC HAZARDS PRESENT, SPECIFIC FIRE PROTECTION MEASURES SHALL BE PROVIDED IN ACCORDANCE WITH NFPA 850. NOTE 2 - ALL STAIRWELLS ARE SEPARATED BY A 2 HOUR FIRE-RATED PARTITION.							

ARCHITECTURAL GENERAL NOTES

CONTRACTOR/INSTALLER SAFETY

1. ALL WORK DONE BY CONTRACTOR/INSTALLER PURSUANT TO THIS DRAWING SHALL:
   (A) CONFORM TO THE GOVERNING CONTRACT DOCUMENTS;
   (B) BE PERFORMED EXCLUSIVELY BY TRAINED, COMPETENT PERSONNEL AND
   (C) COMPLY WITH ALL APPLICABLE SAFETY LAWS, REGULATIONS, PROGRAMS AND PRACTICES TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE.
2. UNDERGROUND OR EMBEDDED UTILITIES MAY EXIST WITHIN THE AREA OF AND ADJACENT TO THE LIMITS OF THE WORK. THE LOCATION OR IDENTIFICATION OF SUCH UTILITIES HAS NOT BEEN VERIFIED. FIELD PERSONNEL ARE RESPONSIBLE FOR FIELD LOCATING AND DENTIFYING UNDERGROUND OR EMBEDDED UTILITIES AND ANY OTHER UNDERGROUND OR EMBEDDED UTILITY DIMENSIONS.
3. REFERENCES USED HAVE BEEN IDENTIFIED ON EXCAVATION/ FOUNDATION/DEMOLITION DRAWINGS AND HAVE BEEN PROVIDED TO ASSIST IN FIELD LOCATING EXISITING UTILITIES AND OTHER POTENTIAL UNDERGROUND OR EMBEDDED INTEREFERENCES. THESE REFERENCES ONLY SHOW THE APPROXIMATE LOCATION OF POTENTIAL UNDERGROUND OR EMBEDDED UTILITIES AND MAY NOT INDICATE OR REFLECT ALL EXISITING UNDERGROUND OR EMBEDDED UTILITIES OR THEIR ACTUAL LOCATIONS.
4. REFERENCES IDENTIFIED SHALL NOT SUBSTITUTE FOR THE OBLIGATION TO FIELD LOCATE ANY UNDERGROUND OR EMBEDDED UTILITIES OR INTERFERENCES THAT MAY AFFECT THE WORK.
5. DUE CAUTION SHALL BE TAKEN DURING ANY EXCAVATION/ FOUNDATION/DEMOLITION WORK WITHIN THE AREA OF AND ADJACENT TO THE LIMITS OF THE WORK DUE TO POSSIBLE INTERFERENCES THAT MAY NOT BE REFLECTED ON THE REFERENCES IDENTIFIED.

REFERENCE INFORMATION

1. ALL WORK ON ARCHITECTURAL DRAWINGS SHALL BE DONE IN ACCORDANCE WITH THE ARCHITECTURAL GENERAL NOTES AND TECHNICAL SPECIFICATIONS UNLESS OTHERWISE NOTED.
2. DETAIL & SECTION REFERENCE IS BY THE DRAWING NUMBER ON WHICH THE DETAIL APPEARS PLUS A SEQUENTIAL DETAIL DESIGNATION NUMBER.
3. BUILDING NUMBER REFERENCES FOR ROOM AND DOOR DESIGNATIONS ARE AS FOLLOWS:
   01 CARBON CAPTURE EQUIPMENT BUILDING
   02 WATER TREATMENT BUILDING
   03 CO2 PURIFICATION UNIT BUILDING
   04 DCC AUXILIARY EQUIPMENT BUILDING
   05 CO2 CAPTURE RESERVOIR PUMP HOUSE (PUMP HOUSE NOT SHOWN WILL BE SHOWN DURING DETAILED DESIGN)
4. SIZES FOR DOORS AND OTHER WALL OPENINGS ARE INDICATED IN PLAN AND/OR ELEVATION. GIRT FRAMED OPENINGS SHALL ACCOUNT FOR FRAMES PROVIDED WITH DOORS AND WINDOWS. (LATER)
   SEE THE DOOR SCHEDULES & REFERENCED DETAILS TO CONFIRM WALL OPENING SIZES FOR DOORS & FRAMES. (LATER)
5. BASIC OPENINGS AND PENETRATIONS THROUGH WALLS, PARTITIONS AND ROOFS ARE SHOWN ON THE DRAWINGS. HOWEVER, THE CONTRACTOR SHALL COORDINATE SECONDARY OPENINGS AND PENETRATIONS IN THE FIELD WITH SYSTEM DRAWINGS AND AS SYSTEMS ARE INSTALLED.
6. COLORS FOR ALL MATERIAL AND FINISHES SHALL BE SELECTED AND APPROVED BY THE OWNER. FIELD FINISH PAINTING SHALL INCLUDE HOLLOW METAL DOORS.

PERMIT NOTES

1. THE USE OF THE BUILDINGS IS SPECIAL PURPOSE POWER PLANT EQUIPMENT ENCLOSURE. THE ENCLOSURES ARE REGULARLY UNOCCUPIED. THE ANTICIPATED MAXIMUM NUMBER OF OPERATOR AND/OR MAINTENANCE PERSONNEL UNDER ANY PROBABLE CONDITIONS IS 49 OR FEWER. BY EMPLOYMENT THEY ARE ABLE-BODIED ADULTS.
2. THE ENCLOSURE STRUCTURE IS A NON-COMBUSTIBLE STRUCTURAL STEEL BRACED FRAME DESIGNED TO SUPPORT THE ENCLOSURE AND TO SUPPORT THE POWER PLANT EQUIPMENT THAT IT CONTAINS. THE HEIGHT AND AREA OF THE BUILDING CHARACTERIZED BY OPEN SPACE IS DICTATED BY THE EQUIPMENT & INTERRELATED PROCESSES PLUS ACCOMMODATIONS FOR EQUIPMENT REMOVAL & MAINTENANCE. THERE ARE NO EMPLOYEE WORKPLACES IN THE ENCLOSURES.
3. THE ENCLOSURES DO NOT HAVE A GENERAL AREA AUTOMATIC SPRINKLER SYSTEM. RATHER HAZARD SPECIFIC AUTOMATIC DETECTION AND SUPPRESSION SYSTEMS ARE PROVIDED AT ALL IDENTIFIED FIRE HAZARDS IN ACCORDANCE WITH RECOGNIZED POWER INDUSTRY RECOMMENDED PRACTICES SUBJECT TO THE APPROVAL OF THE LOCAL BUILDING AND FIRE AUTHORITIES.
4. SPECIAL CONSIDERATION & ENGINEERING FIRE RISK ASSESSMENT IN SATISFYING THE INTENT OF THE BUILDING CODE IS APPROPRIATE FOR THIS LOW-HAZARD INDUSTRIAL OCCUPANCY.
5. THE CONSTRUCTION CLASSIFICATION PER THE INTERNATIONAL BUILDING CODE IS TYPE II-B NON-COMBUSTIBLE, UNPROTECTED STEEL FRAME.
6. THE ENCLOSURE OCCUPANCY CLASSIFICATION PER THE INTERNATIONAL BUILDING CODE IS F-1 MODERATE HAZARD FACTORY INDUSTRIAL.

FOUNDATIONS AND CURBS

1. ALL FOUNDATION WORK (CURBS, SLABS, RECESSED SLABS, ETC) SHALL BE DESIGNED, FABRICATED, SUPPLIED AND INSTALLED BY OTHERS UNLESS NOTED.

METAL SIDING & ROOFING

1. METAL SIDING & ROOFING COLORS, PROFILE AND TEXTURE SHALL BE AS SELECTED BY THE OWNER UNLESS NOTED. SEE EXTERIOR ELEVATIONS FOR LAYOUT OF PANEL TYPES. SEE SPECIFICATION FOR CUSTOM COLOR REQUIREMENTS.
2. THE CONTRACTOR SHALL CLOSE AND SEAL ALL EXTERIOR OPENINGS & PENETRATIONS IN METAL SIDING WALLS PROVIDING THE APPROPRIATE FIRE RATINGS WHERE NEEDED AND THE APPROPRIATE MEANS OF ACCOMMODATING HIGH TEMPERATURES AND MOVEMENTS OF PENETRATING ITEMS.
3. OPENINGS IN METAL SIDING AND METAL ROOFING FOR PIPING & CABLE TRAY PENETRATIONS SHALL BE CUT IN THE FIELD AND PROVIDED WITH SHEET METAL FLASHING SLEEVES PROJECTING OUTWARD FROM THE EXTERIOR WALL SURFACE TO ACCOMMODATE CLOSURE FILL AND FLASHING UNIQUE TO THE TYPE OF PENETRATING ITEM. THE SIZE AND SHAPE OF THE SLEEVE SHALL ACCOMMODATE THERMAL EXPANSION AND OTHER ANTICIPATED MOVEMENTS INDICATED ON THE SYSTEM DRAWINGS.
4. BASIC OPENINGS AND PENETRATIONS THROUGH METAL WALLS, PARTITIONS AND ROOFS ARE SHOWN ON THE DRAWINGS. HOWEVER, THE CONTRACTOR SHALL COORDINATE SECONDARY OPENINGS AND PENETRATIONS IN THE FIELD WITH SYSTEM DRAWINGS AND AS SYSTEMS ARE INSTALLED.
5. WHERE INDICATED ON THE DRAWINGS, STEEL GUTTERS & DOWNSPOUTS SHALL BE FABRICATED WITH PRE-COATED SHEET METAL TO MATCH THE SIDING. SUPPLIER SHALL SIZE THE GUTTERS AND DOWNSPOUTS FOR SITE CONDITIONS. CONTRACTOR SHALL DESIGN ALL ANCHORAGE AND FASTENING TO SUIT THE WALL & ROOFING SYSTEMS PROVIDED.
6. CONSTRUCTION OPENINGS ARE TEMPORARY AND SHALL BE CLOSED AT THE DIRECTION OF THE PURCHASER.
7. ALL SPACES BETWEEN METAL SIDING & ROOFING AND OTHER ADJOINING COMPONENTS SHALL BE FLASHED WATERTIGHT AND FILLED WITH INSULATION TO THE GREATEST EXTENT POSSIBLE.
8. FLASH AND SEAL ALL TRANSITIONS AND OPENINGS AS REQUIRED TO MEET SPECIFIED THERMAL AND ACOUSTICAL REQUIREMENTS.
9. PROVIDE CLAMP ON STYLE SNOW GUARDS AT LOW EAVES OF ALL ROOFS.
10. SEE SPECIFICATION FOR FM REQUIREMENTS.

FIRESTOPPING

1. THE CONTRACTOR SHALL PROVIDE FIRESTOPPING USING AN INSTALLER EXPERIENCED IN THE SELECTION AND PROPER INSTALLATION OF FIRESTOPPING ASSEMBLES FOR THE CONDITIONS OF SIMILAR INDUSTRIAL INSTALLATIONS.
2. THE CONTRACTOR SHALL CLOSE AND SEAL ALL TOP AND END JOINTS OF FIRE RATED PARTITION AND FLOOR BARRIERS WITH UL LISTED FIRESTOPPING ASSEMBLIES AND MATERIALS HAVING THE SAME RATING AS THE BARRIER.
3. THE CONTRACTOR SHALL CLOSE AND SEAL ALL OPENINGS / PENETRATIONS THROUGH FIRE RATED PARTITION AND FLOOR BARRIERS WITH UL LISTED FIRESTOPPING ASSEMBLIES AND MATERIALS HAVING THE SAME RATING AS THE BARRIER.
4. THE CONTRACTOR SHALL USE FIRESTOPPING ASSEMBLIES TO AIR SEAL JOINTS & PENETRATIONS IN FLOOR & WALL BOUNDARIES FOR AIR CONDITIONED AREAS.

FIRE RATED ASSEMBLIES

1. FIRE RATED PARTITIONS SHOWN SHALL MEET UL DESIGN REQUIREMENTS FOR ASSEMBLY LISTED. ALL PRODUCTS USED IN THE ASSEMBLY SHALL BEAR UL CERTIFICATION MARKINGS.

GYPSUM BOARD SYSTEMS

1. ALL PARTITIONS SEPARATING ROOMS SHALL BE CONSTRUCTED WITH FIBERGLASS INSULATION FILLING THE ENTIRE WALL CAVITY.
2. GYPSUM BOARD PARTITIONS THAT ARE FIRE RATED OR ARE SPECIFICALLY NOTED ON THE FLOOR PLANS SHALL EXTEND UPWARD TO THE FLOOR OR ROOF DECK ABOVE. OTHER GYPSUM BOARD PARTITIONS SHALL EXTEND TO AN ELEVATION 6" ABOVE THE ADJACENT CEILINGS OR AS SPECIFICALLY NOTED.
3. THE CONTRACTOR SHALL PROVIDE VERTICAL AND HORIZONTAL CONTROL JOINTS IN ACCORDANCE WITH GYPSUM BOARD INDUSTRY RECOMMENDATIONS TO PREVENT GYPSUM BOARD CRACKING. MAXIMUM SPACING IN FIRE RATED PARTITIONS SHALL BE LIMITED TO 30 FEET.
4. ALL REQUIRED PARTITION OPENINGS FOR BUILDING SYSTEM AND/OR POWER PLANT SYSTEMS MAY NOT BE SHOWN ON THE PARTITION DESIGN DRAWINGS. THE CONTRACTOR SHALL REVIEW HVAC, ELECTRICAL AND MECHANICAL DESIGN DRAWINGS BEFORE BEGINNING PARTITION CONSTRUCTION AND ALL NECESSARY OPENINGS AND DETAILS SHALL BE ACCOMMODATED. SEAL OPENINGS IN ACCORDANCE WITH ASTM C840 AND GA-216.

INTERIOR ARCHITECTURAL FINISHES

1. ALL INTERIOR FINISHES SHALL HAVE A FLAME SPREAD RATING PER ASTM E84 OF 0 - 25 AND THE SMOKE DEVELOPMENT RATING SHALL BE LESS THAN 450 UNLESS OTHERWISE NOTED.
2. INSTALL ALL MATERIALS PER MANUFACTURER'S REQUIREMENTS, REFERENCED STANDARDS AND THE APPLICABLE BUILDING, ENERGY AND ACCESSIBILITY CODES.

PRELIMINARY
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HOLD INFORMATION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	02-28-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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REVIEWED BY: B.DEROO

APPROVED BY: -

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PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

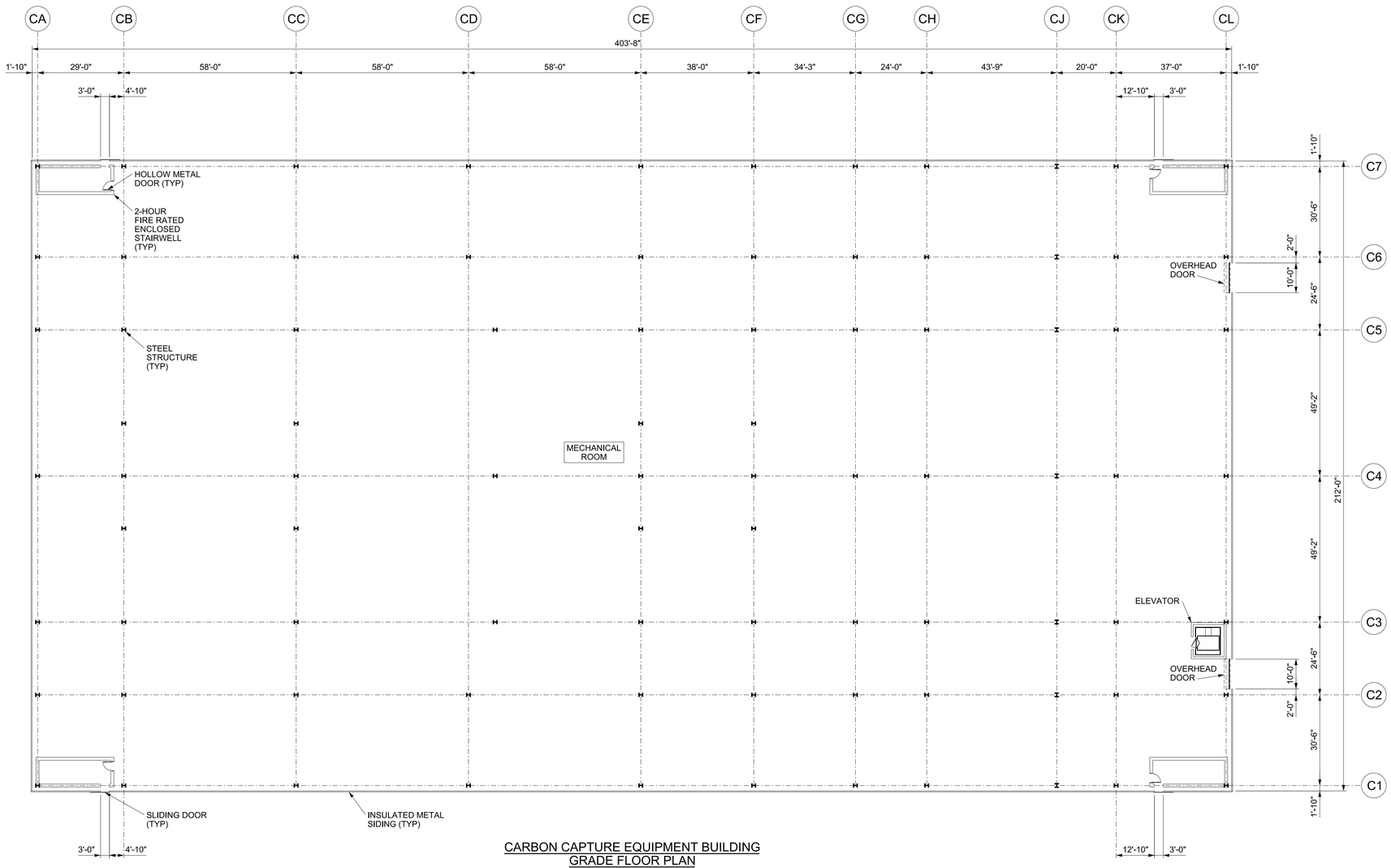
GILLETTE, WYOMING

DRAWING TITLE

ARCHITECTURAL GENERAL NOTES & CODE SUMMARY

DRAWING NUMBER	REVISION
FS-MTR-A-0100	0
SHEET OF	

ZL11463(0L:7267(D:\models\DFMTR\002_FULL_SCALE\mtr-bld-FSarch.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
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CARBON CAPTURE EQUIPMENT BUILDING
GRADE FLOOR PLAN
SCALE: 1/16"=1'-0"

PRELIMINARY
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NOTES

1	FOR ARCHITECTURAL NOTES SEE DRAWING FS-MTR-A-0100.

REFERENCE DRAWINGS

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CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

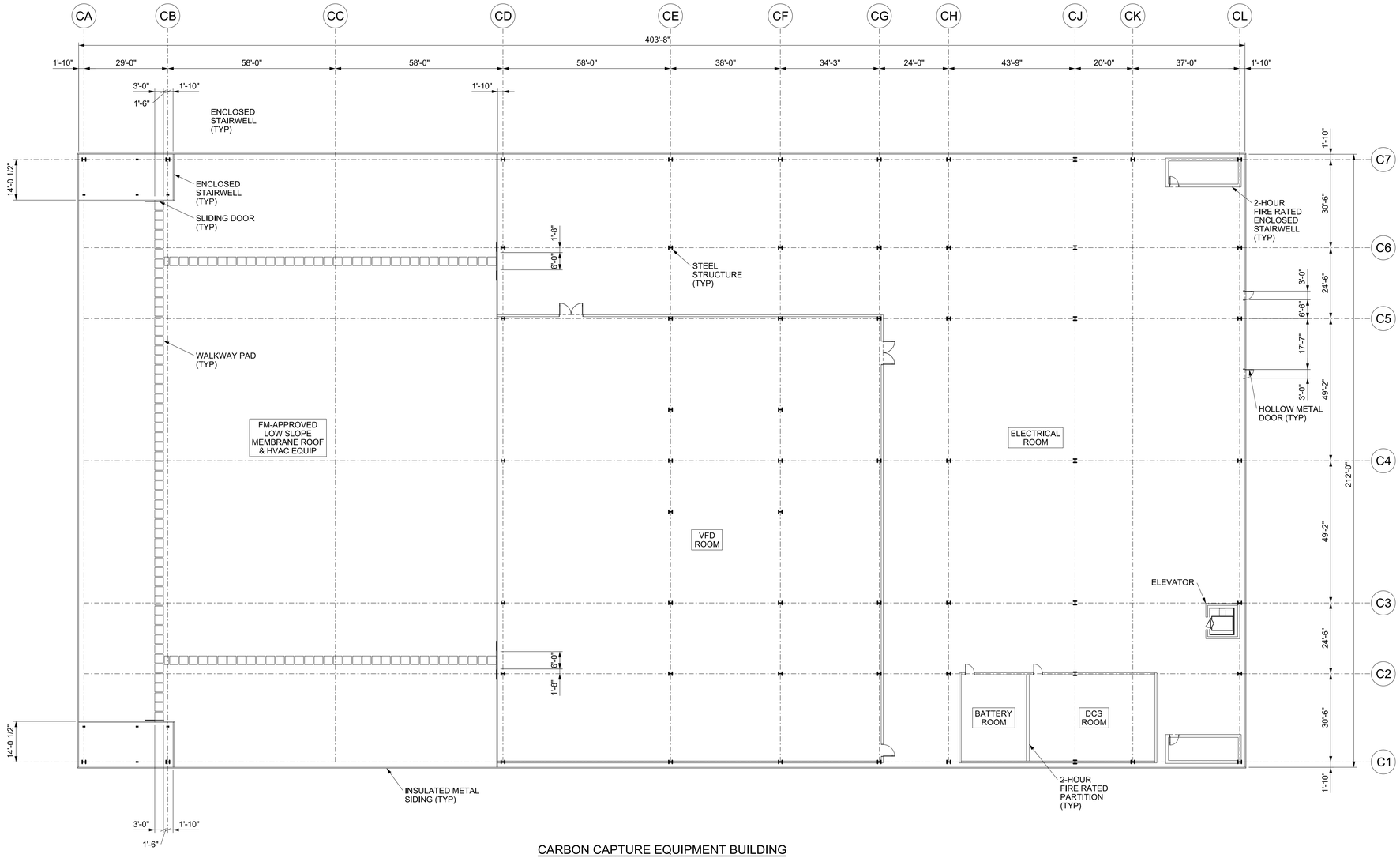
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Revision 10, Revision Date: 10-16-2009



CARBON CAPTURE EQUIPMENT BUILDING
SECOND FLOOR PLAN
SCALE: 1/16"=1'-0"

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NOTES

1	FOR ARCHITECTURAL NOTES SEE DRAWING FS-MTR-A-0100.

REFERENCE DRAWINGS

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CARBON CAPTURE FEED STUDY

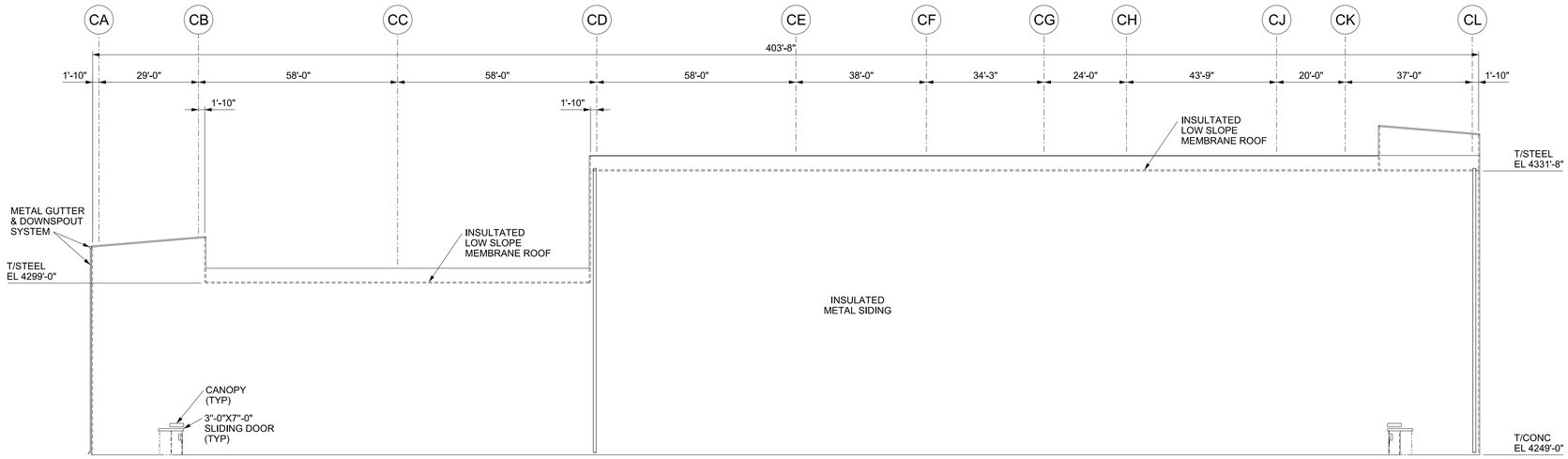
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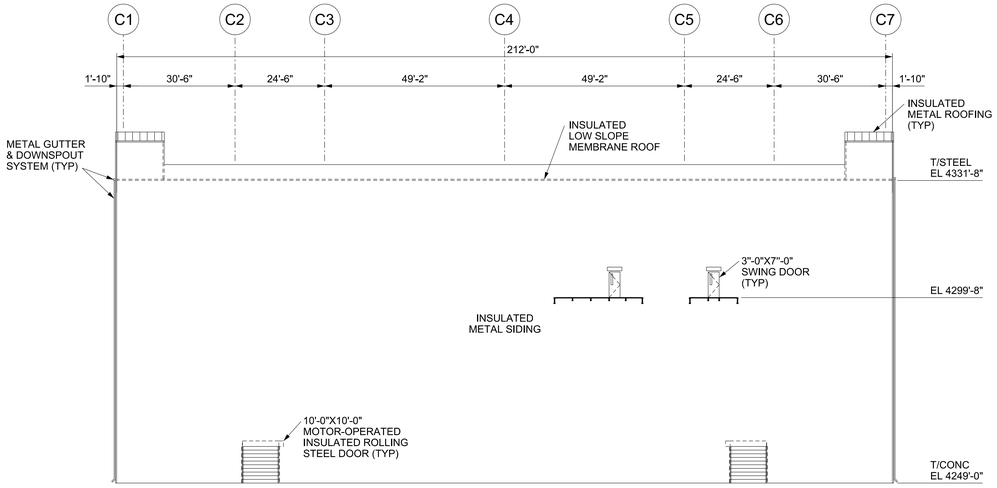
CARBON CAPTURE EQUIPMENT BUILDING SECOND FLOOR PLAN

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SHEET OF	

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Revision 10, Revision Date: 10-16-2009
2/25/2022 9:39:32 AM
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SOUTH ELEVATION
SCALE: 1/16"=1'-0"
LOOKING NORTH



EAST ELEVATION
SCALE: 1/16"=1'-0"
LOOKING WEST

PRELIMINARY
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NOTES

1	FOR ARCHITECTURAL NOTES SEE DRAWING FS-MTR-A-0100.

REFERENCE DRAWINGS

HOLD INFORMATION

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CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

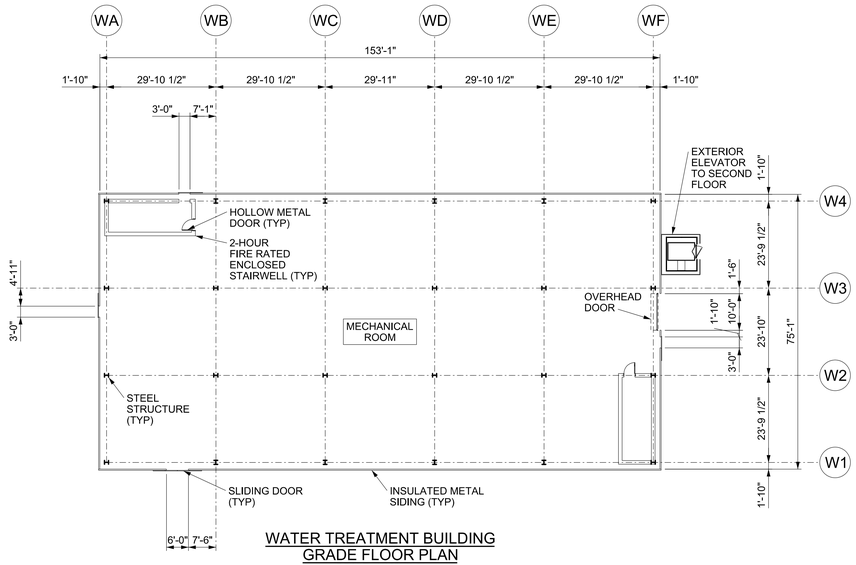
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CARBON CAPTURE EQUIPMENT BUILDING ELEVATIONS

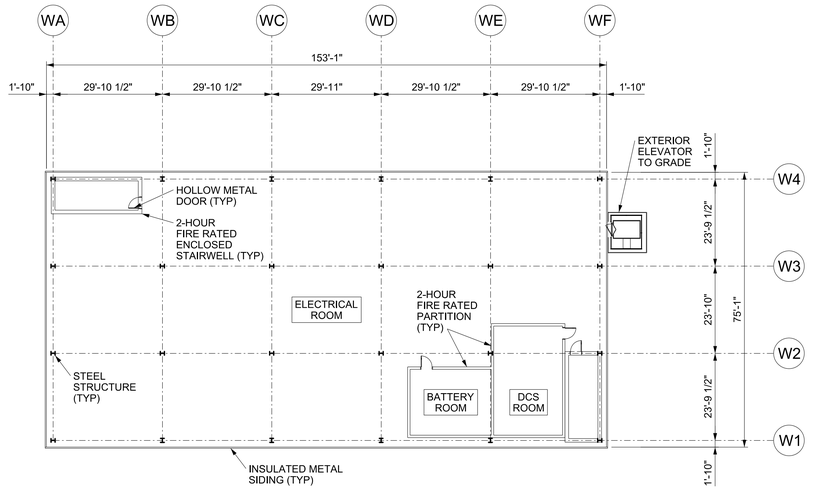
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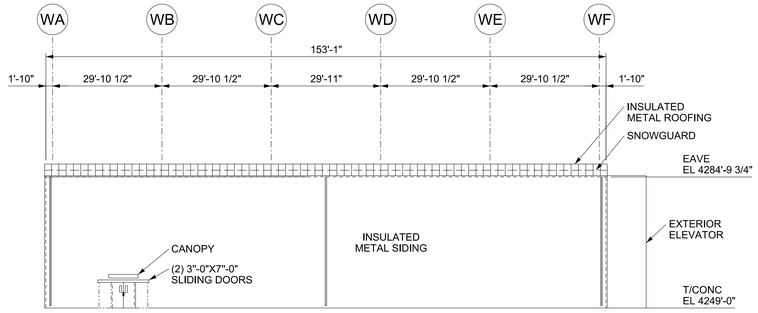
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
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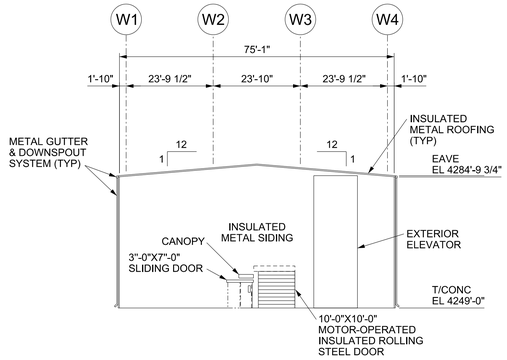
WATER TREATMENT BUILDING
GRADE FLOOR PLAN
SCALE: 1/16"=1'-0"



WATER TREATMENT BUILDING
SECOND FLOOR PLAN
SCALE: 1/16"=1'-0"



SOUTH ELEVATION
SCALE: 1/16"=1'-0"
LOOKING NORTH



EAST ELEVATION
SCALE: 1/16"=1'-0"
LOOKING WEST

PRELIMINARY
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NOTES

1	FOR ARCHITECTURAL NOTES SEE DRAWING FS-MTR-A-0100.

REFERENCE DRAWINGS

NORTH

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MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

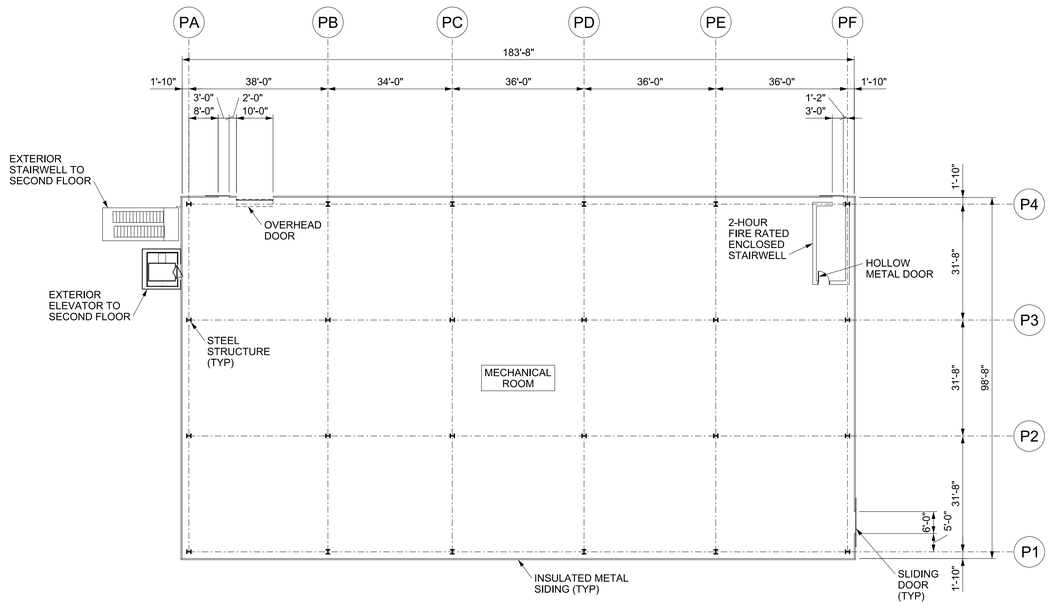
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WATER TREATMENT BUILDING
FLOOR PLAN & ELEVATIONS

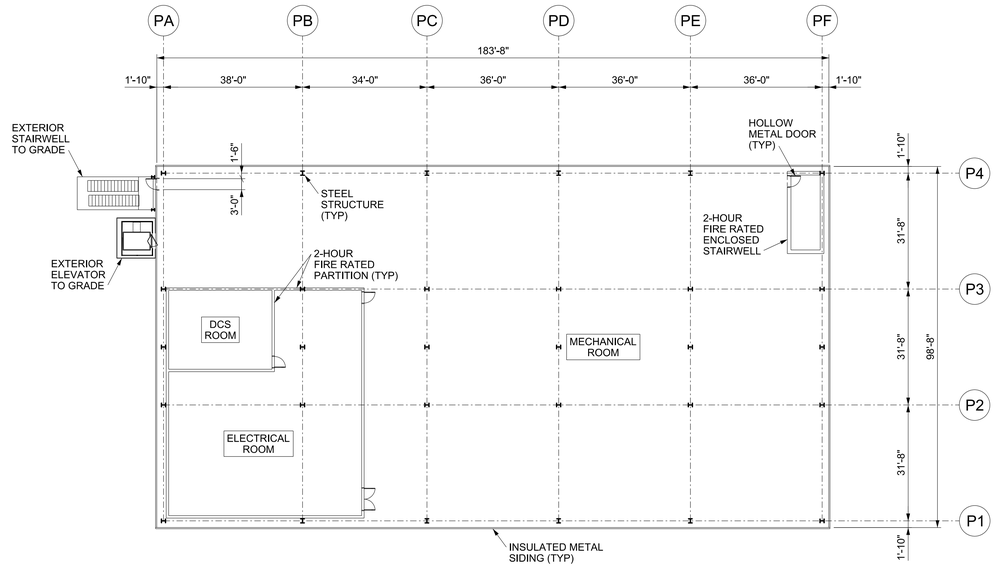
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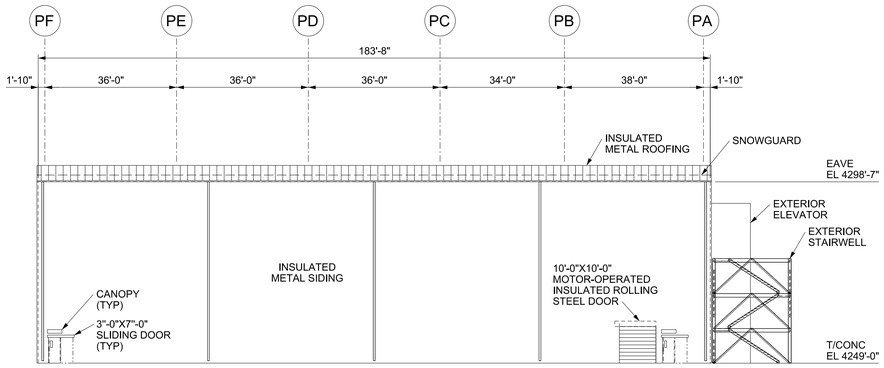
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Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



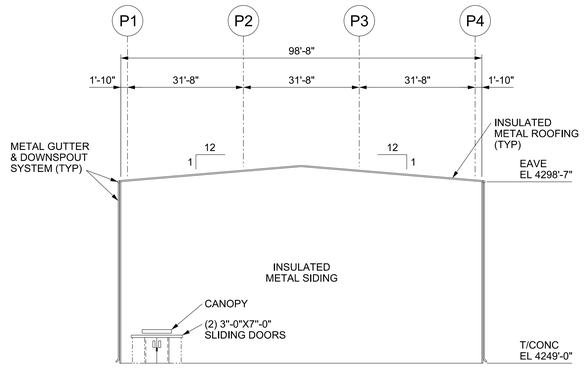
CO2 PURIFICATION UNIT BUILDING
GRADE FLOOR PLAN
SCALE: 1/16"=1'-0"



CO2 PURIFICATION UNIT BUILDING
SECOND FLOOR PLAN
SCALE: 1/16"=1'-0"



NORTH ELEVATION
SCALE: 1/16"=1'-0"
LOOKING SOUTH



EAST ELEVATION
SCALE: 1/16"=1'-0"
LOOKING WEST

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NOTES

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REFERENCE DRAWINGS

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PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

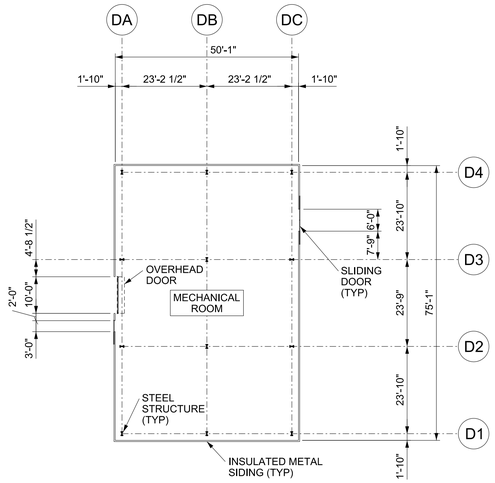
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CO2 PURIFICATION UNIT BUILDING
FLOOR PLAN & ELEVATIONS

DRAWING NUMBER	REVISION
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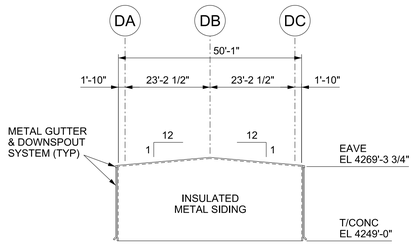
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

2/25/2022 9:40:27 AM
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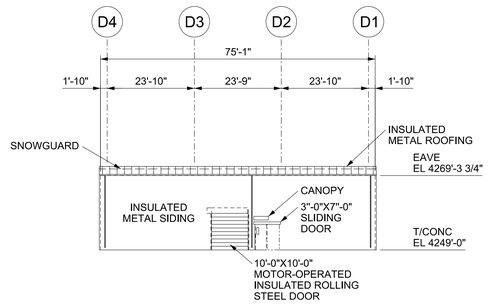
DCC AUXILIARY EQUIPMENT BUILDING FLOOR PLAN

SCALE: 1/16"=1'-0"



SOUTH ELEVATION

SCALE: 1/16"=1'-0"
LOOKING NORTH



WEST ELEVATION

SCALE: 1/16"=1'-0"
LOOKING EAST

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES	
1	FOR ARCHITECTURAL NOTES SEE DRAWING FS-MTR-A-0100.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION	
NO.	DESCRIPTION

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RELEASE INFORMATION		
REV.	DATE	DESCRIPTION
0	02-28-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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CAD FILE NAME:	FS-MTR-A-0106.DGN
PREPARED BY:	D.ZIMA
REVIEWED BY:	B.DEROO
APPROVED BY:	-

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Sargent & Lundy

SARGENT & LUNDY
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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

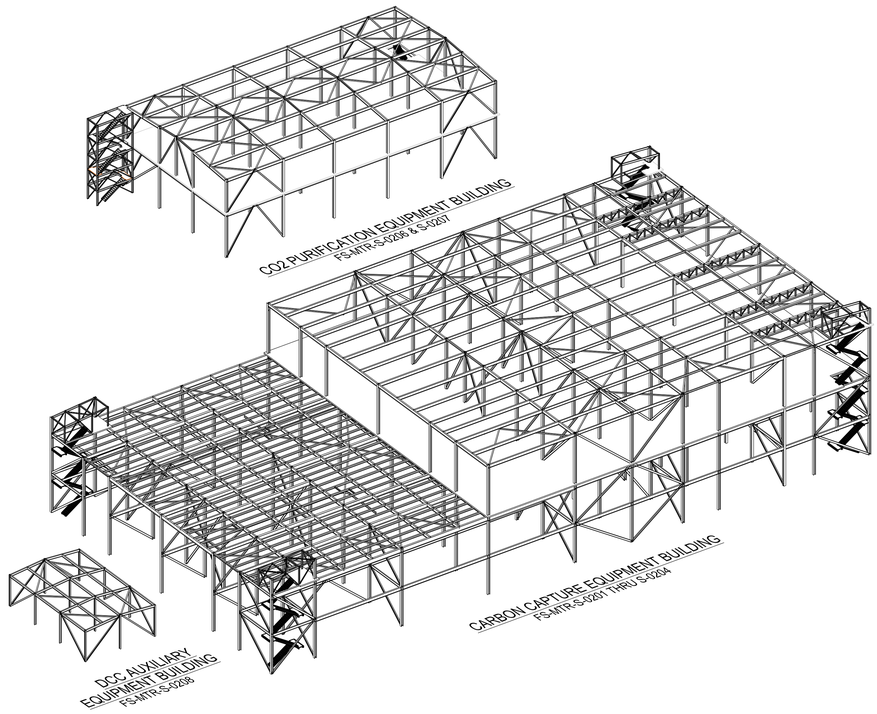
DCC AUXILIARY EQUIPMENT BUILDING FLOOR PLAN & ELEVATIONS

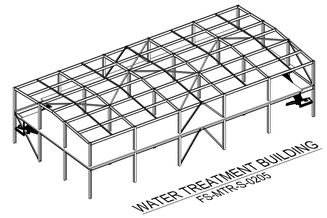
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FS-MTR-A-0106	0
SHEET OF	

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

2/25/2022 9:40:45 AM
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APPENDIX JJ. STRUCTURAL SUPPORT STEEL DRAWINGS





BUILDINGS ISOMETRIC
SCALE: 1/32"=1'-0"
GIRT FRAMING AND ROOF PURLINS NOT SHOWN FOR CLARITY

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. STRUCTURAL STEEL DESIGN IS BASED ON THE APPLICABLE REQUIREMENTS OF THE 2018 INTERNATIONAL BUILDING CODE, AISC 360-16, AWS D1.1 AND PROJECT SPECIFICATIONS.
2. UNLESS NOTED, ALL STEEL MATERIALS SHALL BE AS FOLLOWS:
   - WIDE FLANGE AND WT MEMBERS SHALL BE ASTM A992, GRADE 50
   - GUARD PLATES, LADDERS, LADDER CAGES, CHANNELS, S SHAPES AND MISCELLANEOUS STEEL MEMBERS SHALL BE ASTM A36
   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND EPOXY FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH SHERWIN WILLIAMS 7060 (ATTITUDE GRAY).

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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RELEASE INFORMATION

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ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR
MEMBRANE
TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

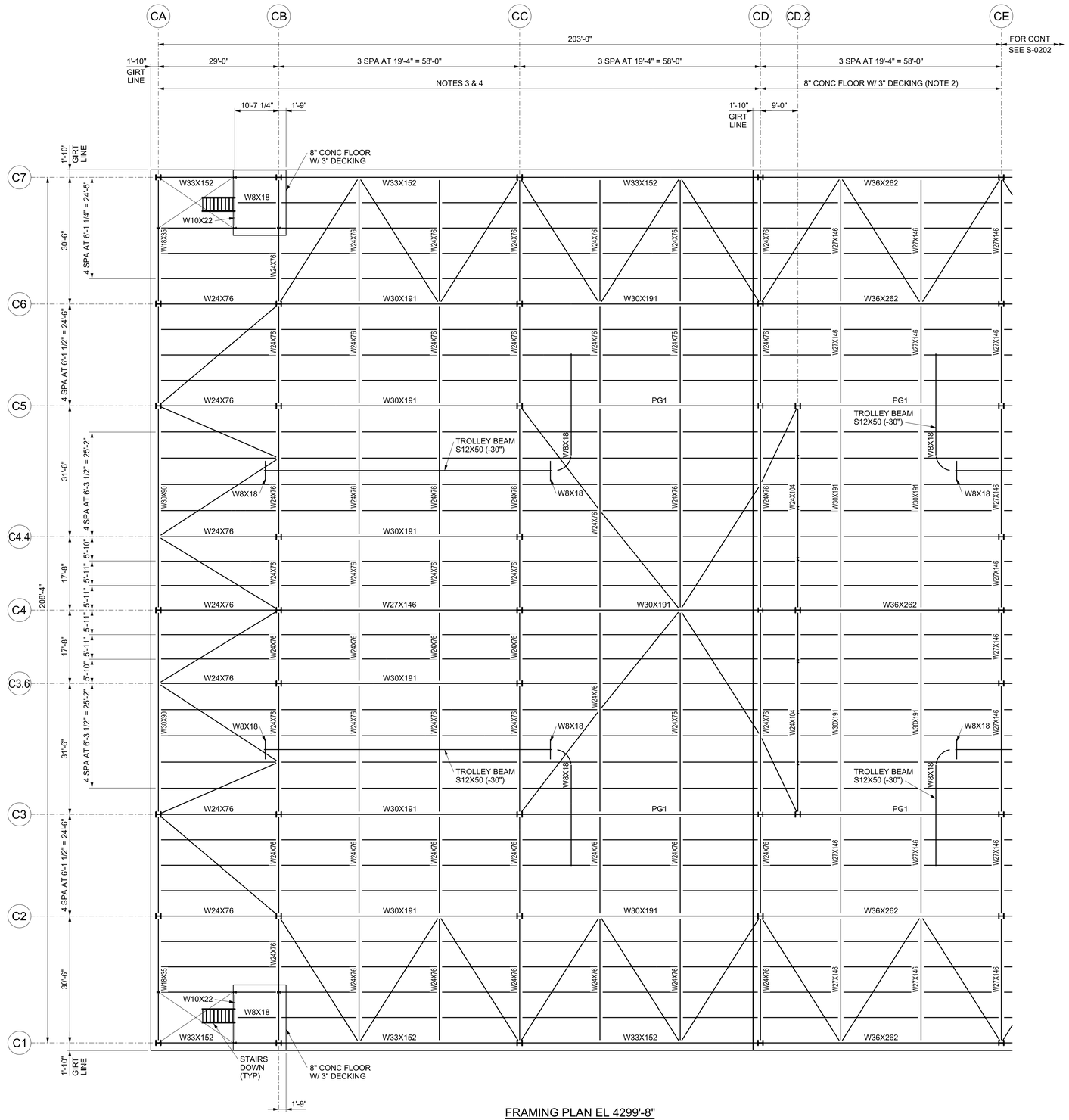
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STEEL BUILDINGS ISOMETRIC

DRAWING NUMBER	REVISION
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SHEET OF	

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/15/2022 9:45:59 AM
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PLATE GIRDER SCHEDULE		
MARK NO.	WEB PL SIZE	FLANGE PL SIZE (TOP & BOTT)
PG1	1"X2'-1"	2 1/2"X1'-2"
PG2	1 1/2"X3'-7"	2 1/2"X1'-4"



FRAMING PLAN EL 4299'-8"

SCALE: 3/32"=1'-0"
T/STEEL EL 4299'-0" UN
T/CONC EL 4299'-8"
BEAMS SHALL BE W12X50 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-12")(T)

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. FLOOR PENETRATIONS AND EQUIPMENT PADS ARE NOT SHOWN. THIS WILL BE SHOWN DURING DETAILED DESIGN. FLOOR DECKING SPAN IS NORTH-SOUTH.
3. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
4. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH METAL DECKING, RIGID POLYISOCYANURATE INSULATION WITH COVERBOARD AND SINGLE-PLY PVC MEMBRANE ROOFING.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION	
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ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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REVIEWED BY:	C.AINGE
APPROVED BY:	-

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

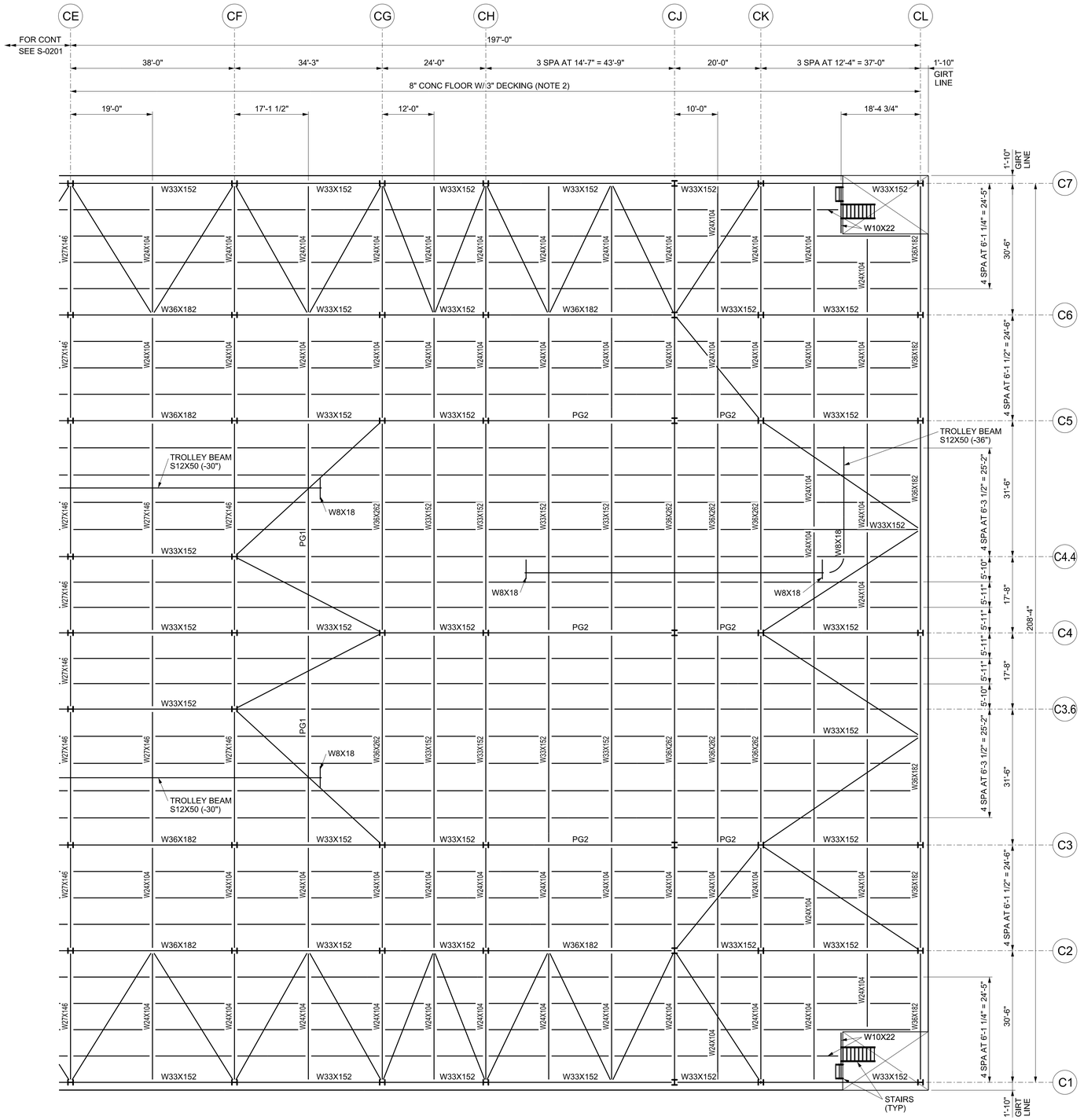
DRAWING TITLE

CARBON CAPTURE EQUIPMENT BUILDING
FRAMING PLAN EL 4299'-8"

DRAWING NUMBER	REVISION
FS-MTR-S-0201	1
SHEET	OF

ZL114630\0L7267\D:\models\DFMTR\mtr-stl-FS\bldgs.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

3/21/2022 1:12:30 PM $FILEABBREV$



FRAMING PLAN EL 4299'-8"

SCALE: 3/32"=1'-0"
T/STEEL EL 4299'-0" UN
T/CONC EL 4299'-8"
BEAMS SHALL BE W12X50 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-12")(T)

HOLD INFORMATION	
NO.	DESCRIPTION

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1	03-21-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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REVIEWED BY:	C.AINGE
APPROVED BY:	-

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CHICAGO, ILLINOIS 60603-5780

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NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. FLOOR PENETRATIONS AND EQUIPMENT PADS ARE NOT SHOWN. THIS WILL BE SHOWN DURING DETAILED DESIGN. FLOOR DECKING SPAN IS NORTH-SOUTH.

REFERENCE DRAWINGS

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

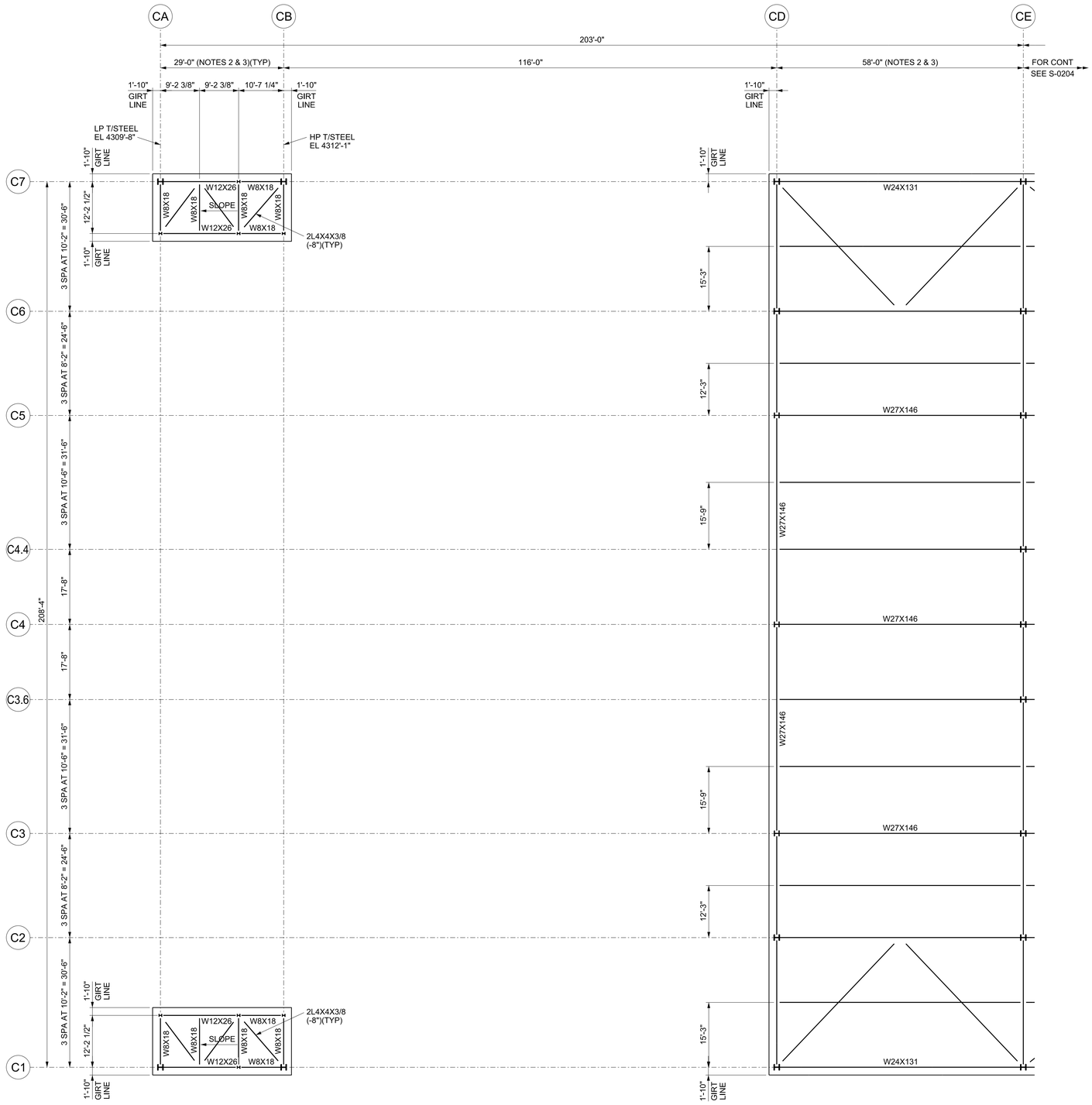
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CARBON CAPTURE EQUIPMENT BUILDING
FRAMING PLAN EL 4299'-8"

DRAWING NUMBER	REVISION
FS-MTR-S-0202	1
SHEET OF	

3/21/2022 1:16:17 PM
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



ROOF FRAMING PLAN

SCALE: 3/32"=1'-0"
T/STEEL EL 4331'-8" UN
BEAMS SHALL BE W24X76 UN
HORIZONTAL BRACING SHALL BE WT9X38 (-24")(T) UN

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
3. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH COMPOSITE, STANDING SEAM, INSULATED METAL PANEL ROOFING.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

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0	03-17-2022	FOR USE
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ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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REVIEWED BY:	C.AINGE
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PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

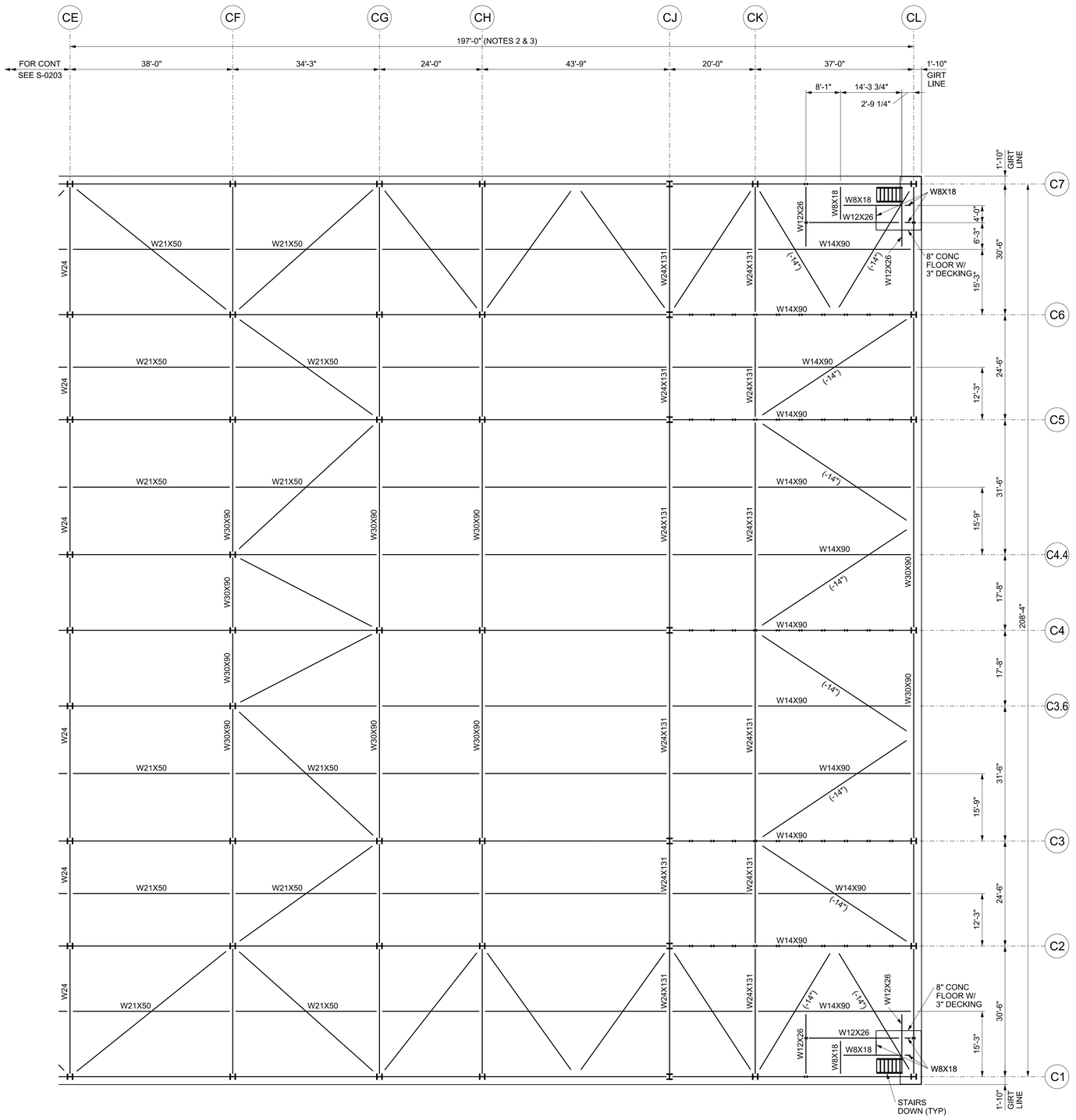
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CARBON CAPTURE EQUIPMENT BUILDING
ROOF FRAMING PLAN

DRAWING NUMBER	REVISION
FS-MTR-S-0203	1
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Revision 10, Revision Date: 10-16-2009
3/21/2022 1:15:48 PM
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ROOF FRAMING PLAN EL 4331'-8"

SCALE: 3/32"=1'-0"
T/STEEL EL 4331'-8" UN
BEAMS SHALL BE W24X76 UN
HORIZONTAL BRACING SHALL BE WT9X38 (-24")(T) UN

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
3. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH COMPOSITE, STANDING SEAM, INSULATED METAL PANEL ROOFING.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

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SPECIFICATION: -

PROJECT NO.: 13978-002

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ENTER DATE

MY LICENSE RENEWAL DATE
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PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

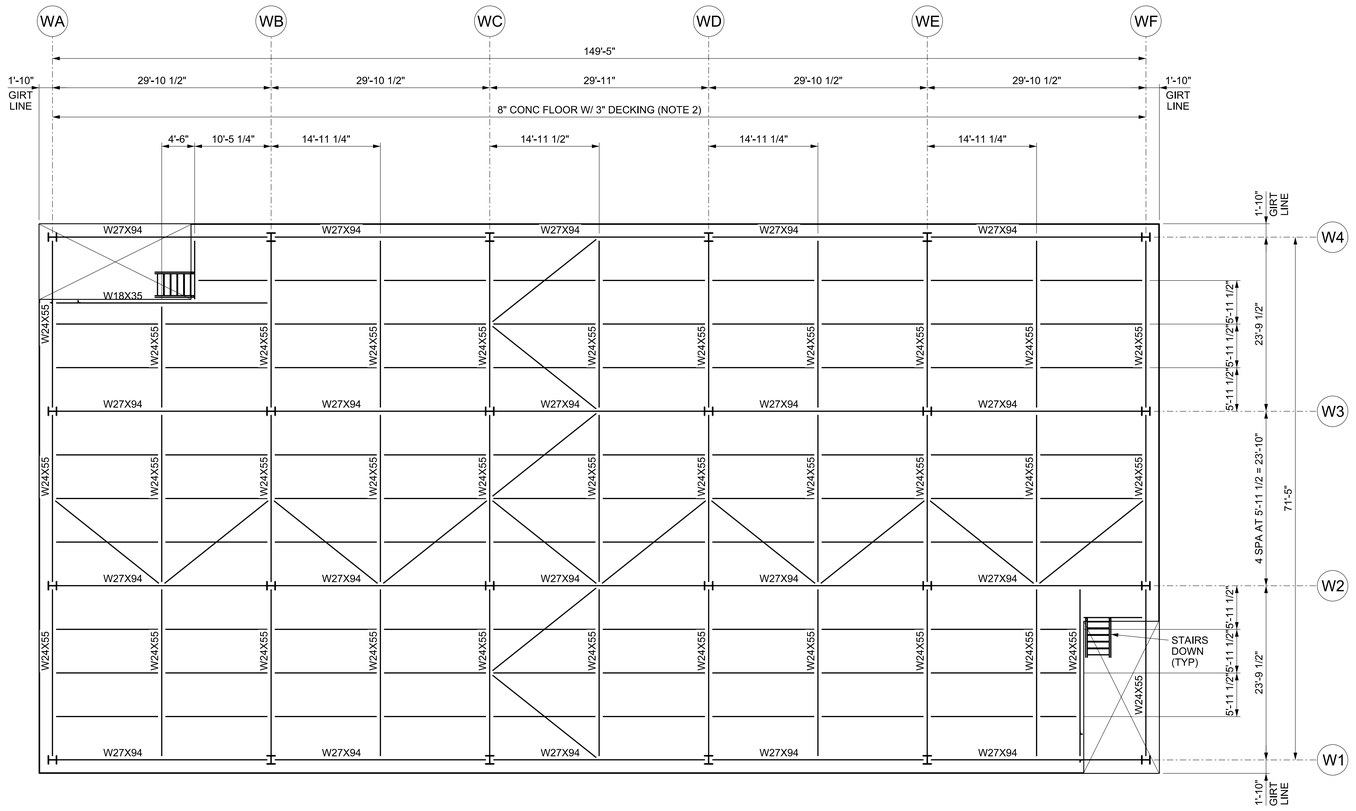
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CARBON CAPTURE EQUIPMENT BUILDING
ROOF FRAMING PLAN

DRAWING NUMBER	REVISION
FS-MTR-S-0204	0
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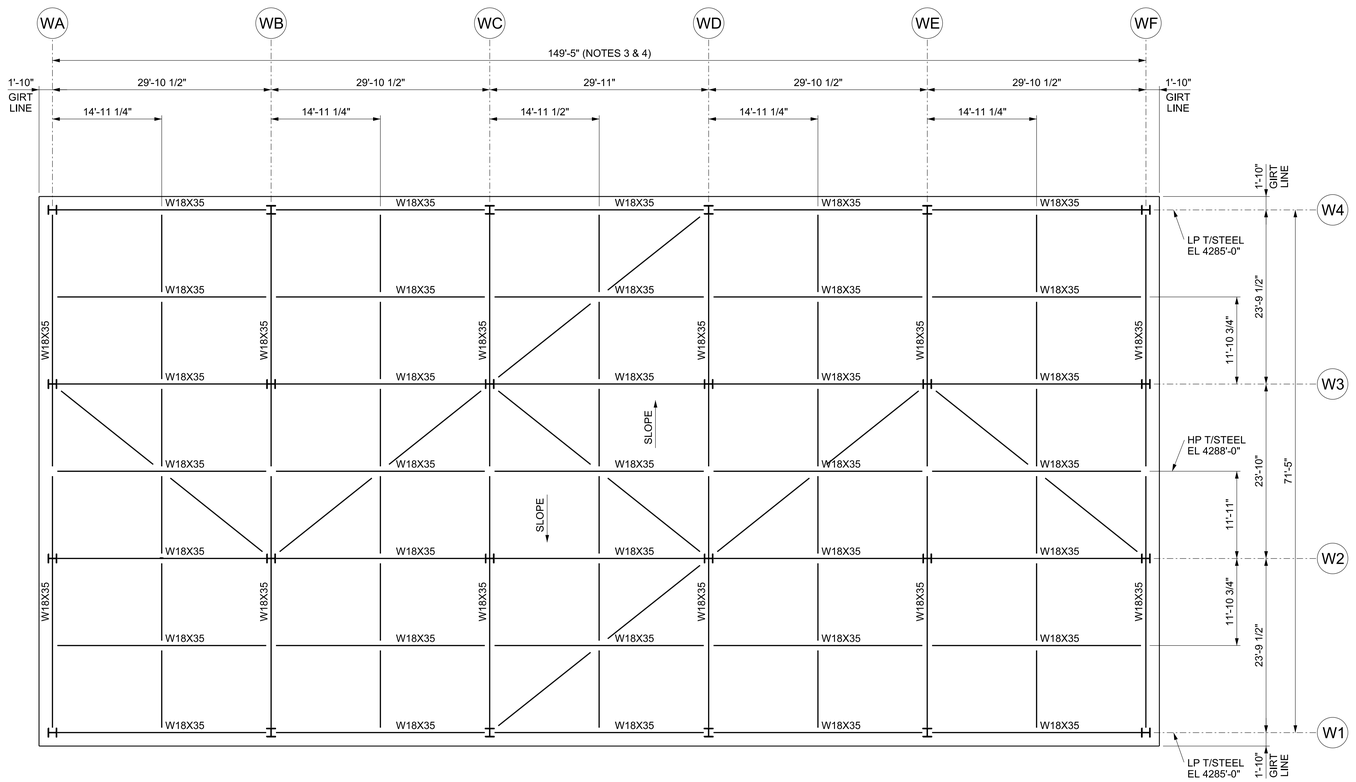
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

3/17/2022 9:44:30 AM
$FILEABREV$



FRAMING PLAN EL 4270'-2"

SCALE: 1/8"=1'-0"
T/STEEL EL 4269'-6" UN
T/CONC EL 4270'-2"
BEAMS SHALL BE W12X50 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-12")(T)



ROOF FRAMING PLAN

SCALE: 1/8"=1'-0"
BEAMS SHALL BE W8X18 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-8")(T)

NORTH

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

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2. FLOOR PENETRATIONS AND EQUIPMENT PADS ARE NOT SHOWN. THIS WILL BE SHOWN DURING DETAILED DESIGN. FLOOR DECKING SPAN IS NORTH-SOUTH.
3. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
4. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH METAL DECKING, RIGID POLYISOCYANURATE INSULATION WITH COVERBOARD AND SINGLE-PLY PVC MEMBRANE ROOFING.

REFERENCE DRAWINGS

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RELEASE INFORMATION

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1	03-21-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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REVIEWED BY:	C.AINGE
APPROVED BY:	-

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SARGENT & LUNDY
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CHICAGO, ILLINOIS 60603-5780

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MTR FULL SCALE

CARBON CAPTURE FEED STUDY

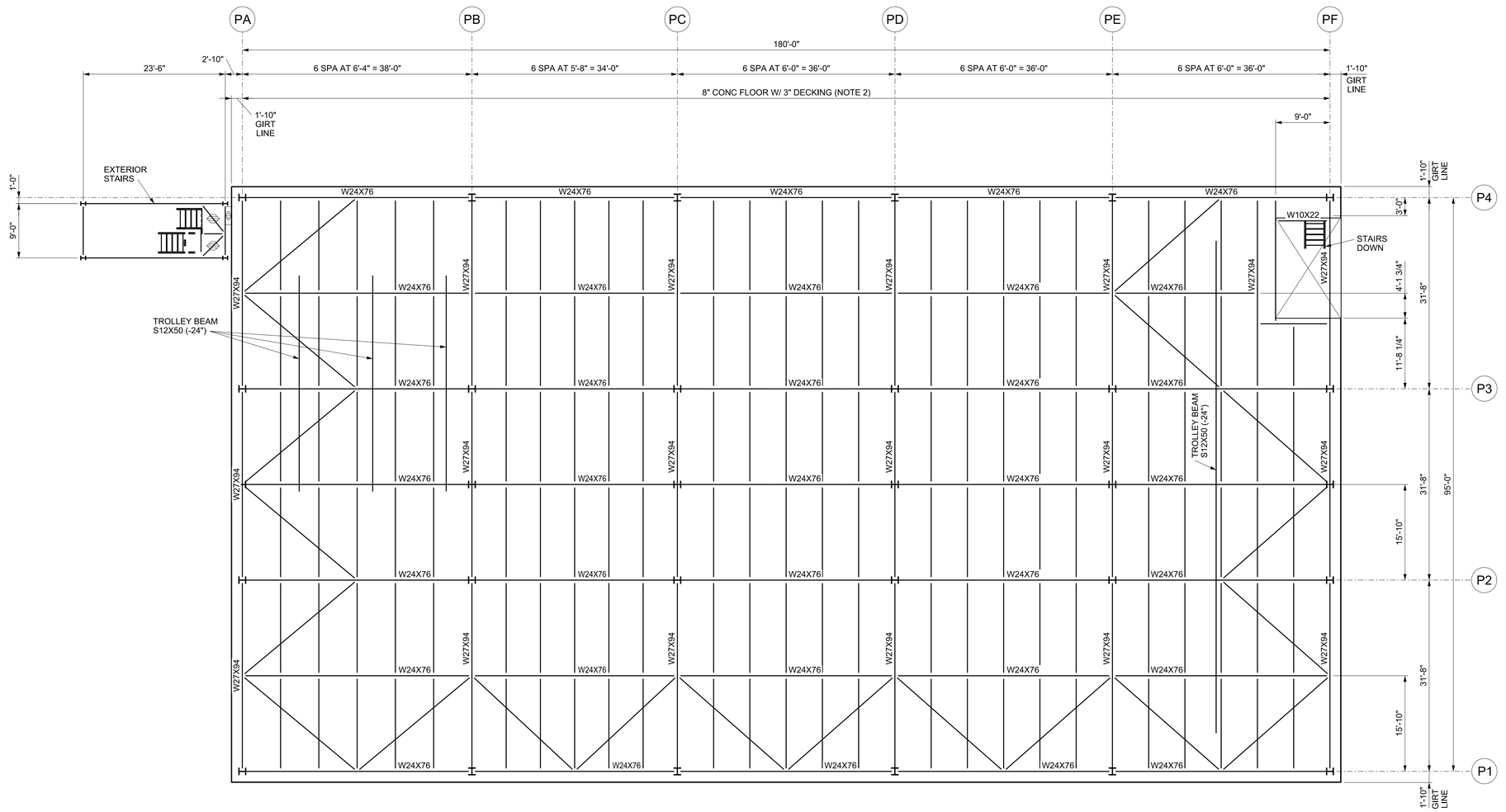
GILLETTE, WYOMING

DRAWING TITLE

WATER TREATMENT BUILDING FRAMING PLANS

DRAWING NUMBER	REVISION
FS-MTR-S-0205	1
SHEET	OF

Z:\114630\L7267\D:\models\DFMTR\mtr-stl-FSbldgs.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/21/2022 1:20:59 PM
$FILEABBREV$



FRAMING PLAN EL 4277'-8"

SCALE: 1/8"=1'-0"
T/STEEL EL 4277'-0" UN
T/CONC EL 4277'-8"
BEAMS SHALL BE W12X50 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-12")(T)

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. FLOOR PENETRATIONS AND EQUIPMENT PADS ARE NOT SHOWN. THIS WILL BE SHOWN DURING DETAILED DESIGN. FLOOR DECKING SPAN IS EAST-WEST.

REFERENCE DRAWINGS

HOLD INFORMATION

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REV.	DATE	DESCRIPTION
0	03-15-2022	FOR USE
1	03-21-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME:	FS-MTR-S-02016.DGN
PREPARED BY:	D.ZIMA
REVIEWED BY:	C.AINGE
APPROVED BY:	-

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

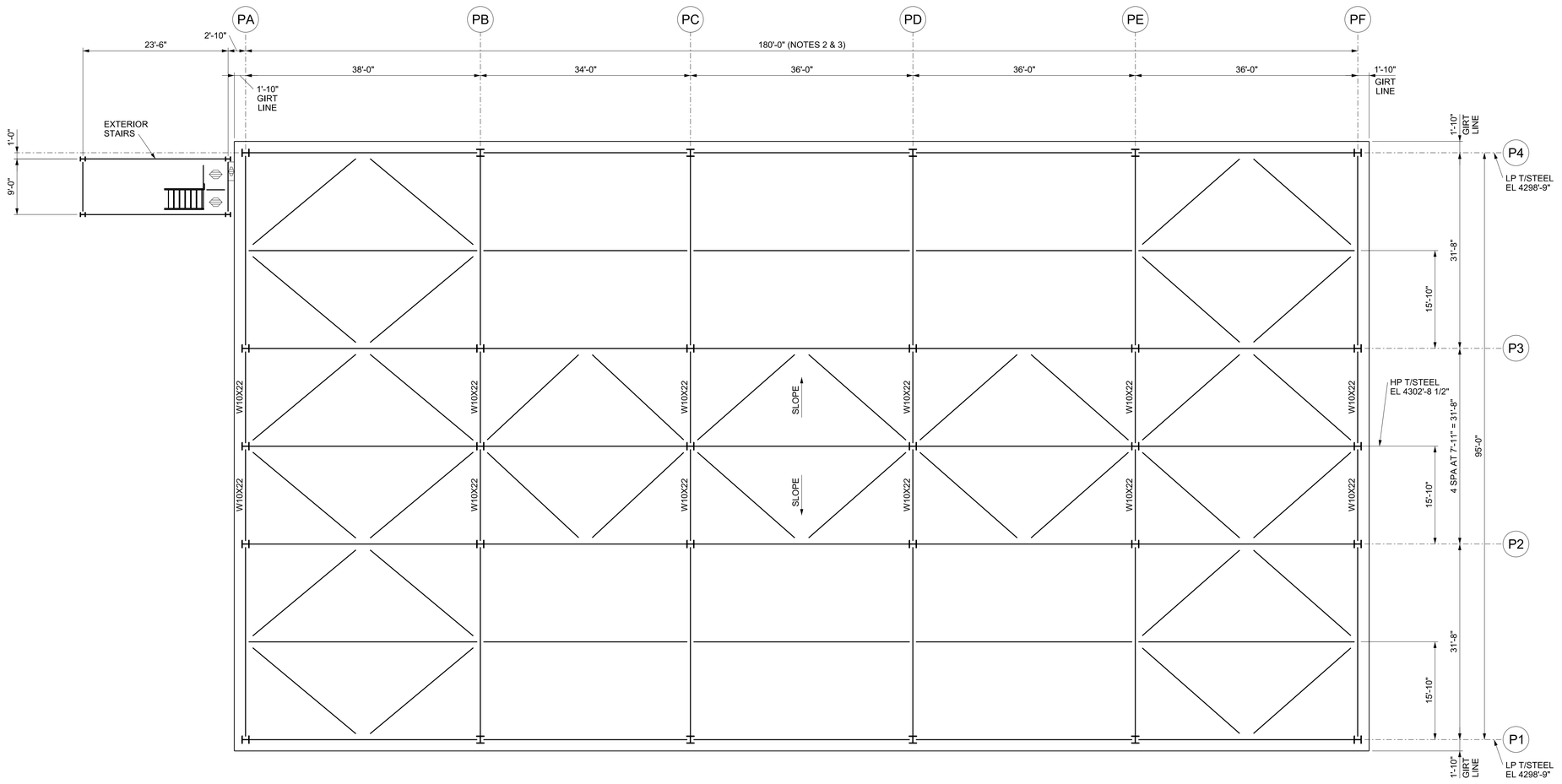
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CO2 PURIFICATION UNIT BUILDING
FRAMING PLAN EL 4277'-8"

DRAWING NUMBER	REVISION
FS-MTR-S-0206	1
SHEET	OF

3/21/2022 11:22:59 PM
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



ROOF FRAMING PLAN

SCALE: 1/8"=1'-0"
T/STEEL VARIES
BEAMS SHALL BE W21X68 UN
HORIZONTAL BRACING SHALL BE WT9X30 (-10")(T)

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
3. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH METAL DECKING, RIGID POLYISOCYANURATE INSULATION WITH COVERBOARD AND SINGLE-PLY PVC MEMBRANE ROOFING.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

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0	03-15-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CAD FILE NAME: FS-MTR-S-0207.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

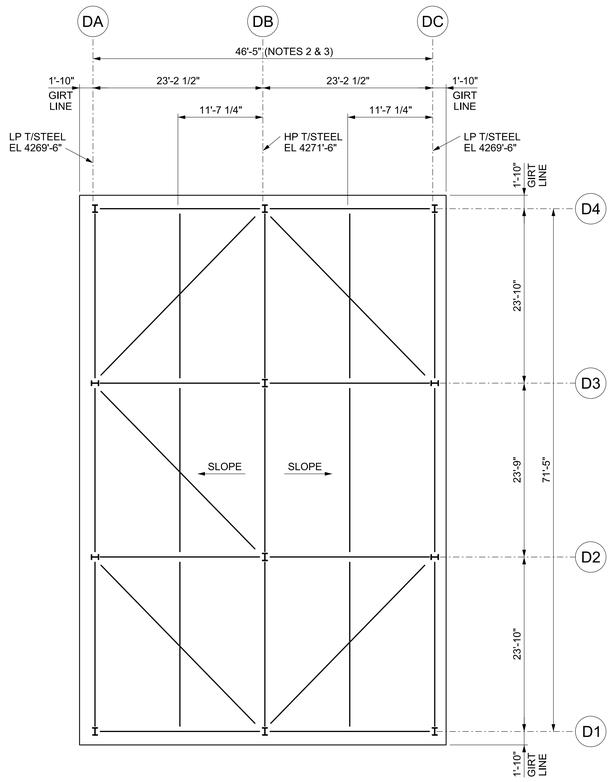
DRAWING TITLE

CO2 PURIFICATION UNIT BUILDING
ROOF FRAMING PLAN

DRAWING NUMBER	REVISION
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SHEET OF	

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Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



ROOF FRAMING PLAN

SCALE: 1/8"=1'-0"
T/STEEL VARIES
BEAMS SHALL BE W16X36
HORIZONTAL BRACING SHALL BE WT9X30 (-16")(T)

HOLD INFORMATION	
NO.	DESCRIPTION

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CAD FILE NAME:	FS-MTR-S-0208.DGN
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MTR MEMBRANE TECHNOLOGY & RESEARCH

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR STEEL BUILDINGS GENERAL NOTES SEE DRAWING FS-MTR-S-0200.
2. ROOF PURLIN FRAMING PLAN DRAWING TO BE DEVELOPED DURING DETAILED DESIGN.
3. FOR FEED STUDY DESIGN, ROOF CONSIDERS W10X22 ROOF PURLINS WITH METAL DECKING, RIGID POLYISOCYANURATE INSULATION WITH COVERBOARD AND SINGLE-PLY PVC MEMBRANE ROOFING.

REFERENCE DRAWINGS

NORTH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

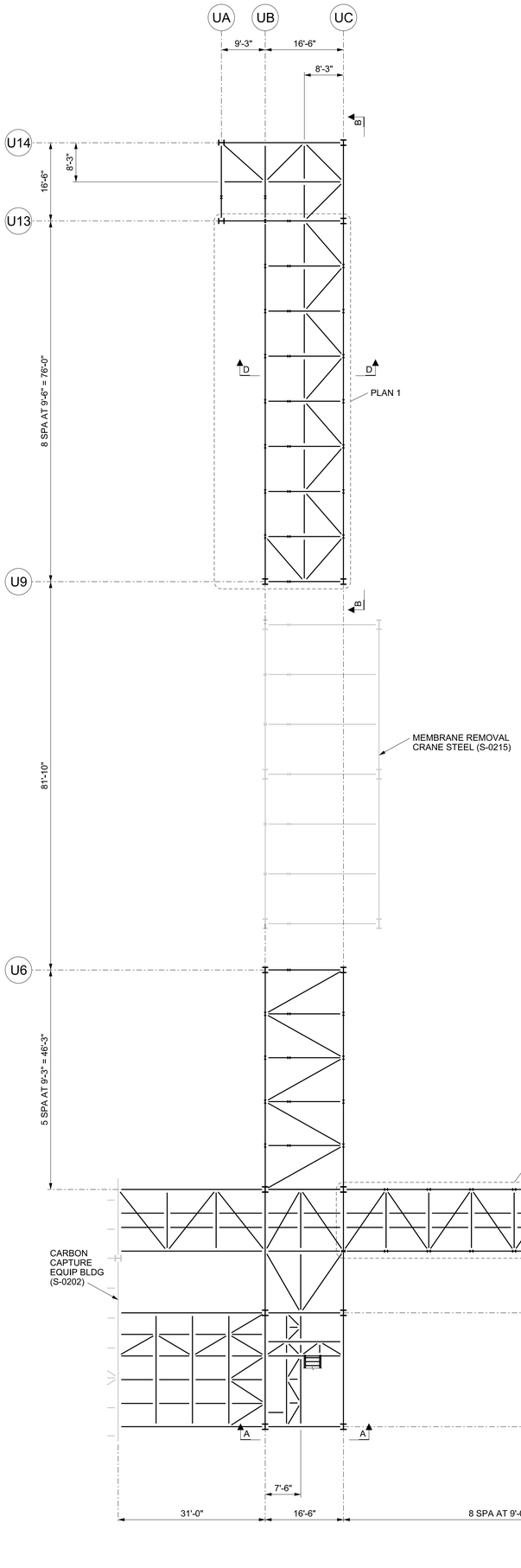
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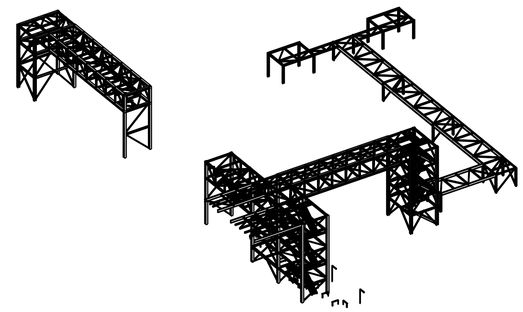
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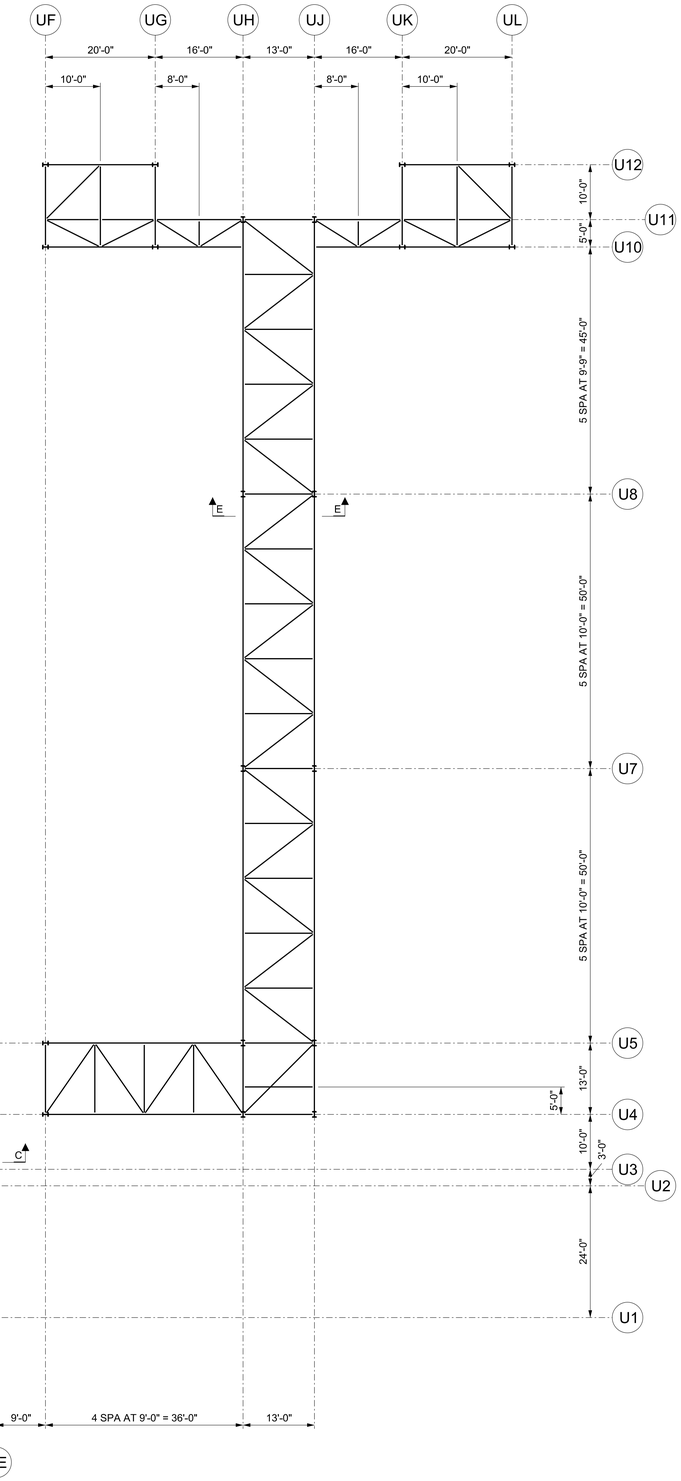
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



UTILITY RACK ARRANGEMENT PLAN
SCALE: 3/32"=1'-0"



UTILITY RACK ISOMETRIC
SCALE: 1/32"=1'-0"



NORTH

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. STRUCTURAL STEEL DESIGN IS BASED ON THE APPLICABLE REQUIREMENTS OF THE 2018 INTERNATIONAL BUILDING CODE, AISC 360-16, AWS D1.1 AND PROJECT SPECIFICATIONS.
2. UNLESS NOTED, ALL STEEL MATERIALS SHALL BE AS FOLLOWS:
   - WIDE FLANGE AND WT MEMBERS SHALL BE ASTM A992, GRADE 50
   - GUARD PLATES, LADDERS, LADDER CAGES, CHANNELS, S SHAPES AND MISCELLANEOUS STEEL MEMBERS SHALL BE ASTM A36
   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND POLYURETHANE FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH FEDERAL STANDARD 595B PAINT SPECIFICATION NUMBER 25526 (BODY BLUE).
4. FOR UTILITY RACK PLANS & SECTIONS SEE DRAWING FS-MTR-S-0210.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-08-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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CAD FILE NAME:	FS-MTR-S-0209.DGN
PREPARED BY:	D.ZIMA
REVIEWED BY:	C.AINGE
APPROVED BY:	-

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

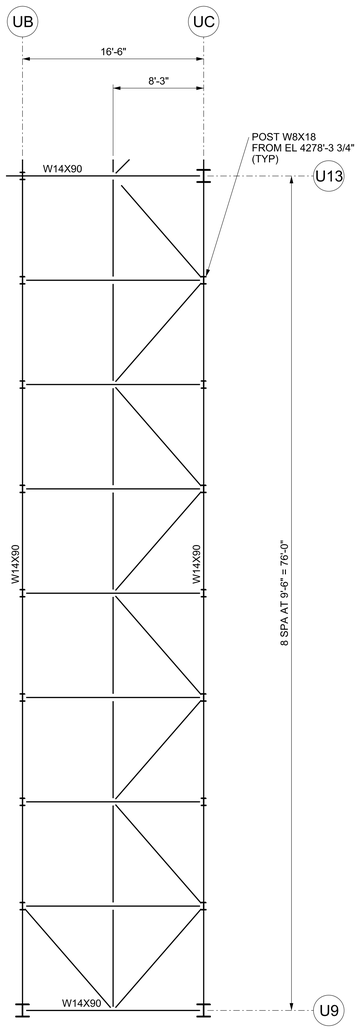
GILLETTE, WYOMING

DRAWING TITLE

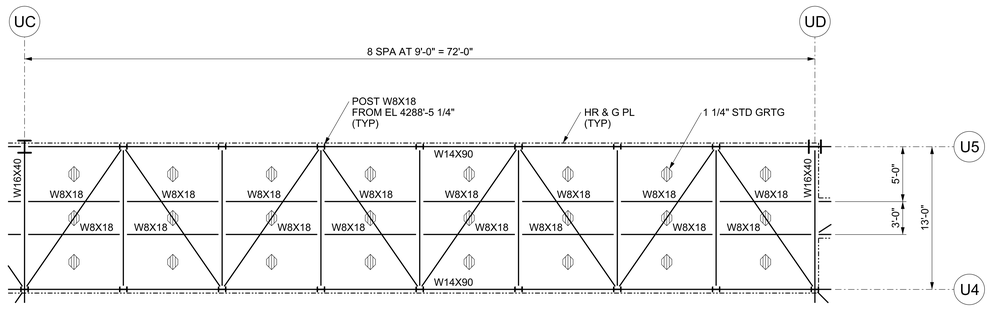
UTILITY RACK
ARRANGEMENT PLAN & ISOMETRIC

DRAWING NUMBER	REVISION
FS-MTR-S-0209	0
SHEET	OF

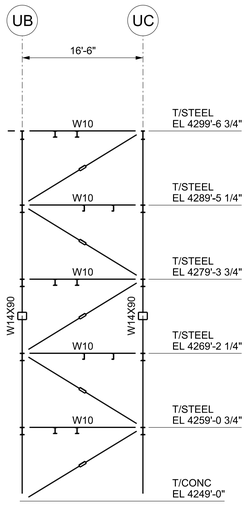
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Form GDG-0401-01-48, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
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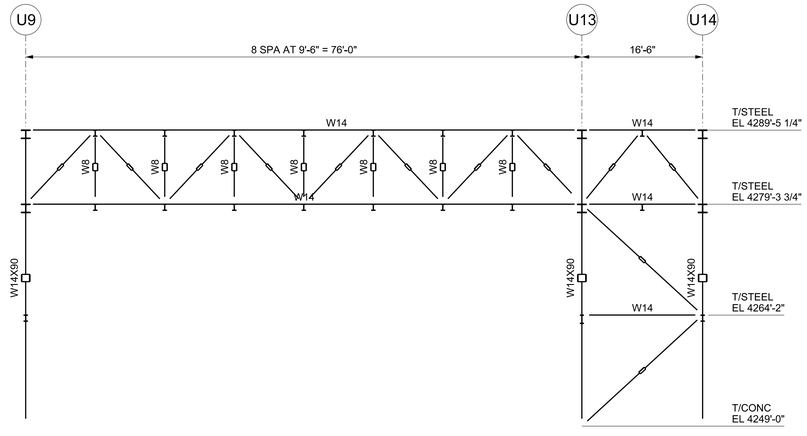
PLAN 1
SCALE: 3/16"=1'-0"
T/STEEL EL 4289'-5 1/4"
BEAMS SHALL BE W10X22 UN
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (-10")



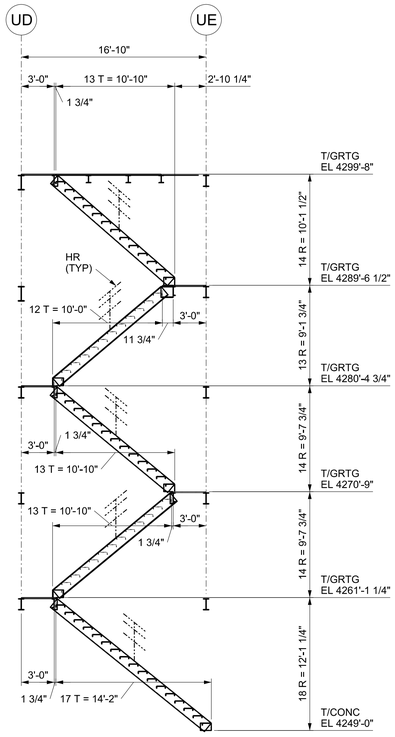
PLAN 2
SCALE: 3/16"=1'-0"
T/GRATING EL 4299'-8"
T/STEEL EL 4299'-6 3/4"
BEAMS SHALL BE W10X22 UN
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (LLV)(-10")



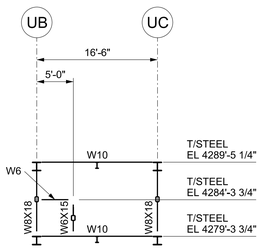
SECTION A
SCALE: 1/8"=1'-0"
VERTICAL BRACING SHALL BE 2L4X4X3/8



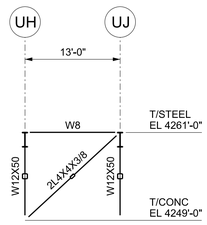
SECTION B
SCALE: 1/8"=1'-0"
VERTICAL BRACING SHALL BE 2L4X4X3/8



SECTION C
SCALE: 3/16"=1'-0"
STAIR STRINGERS SHALL BE C12X20.7



SECTION D
SCALE: 1/8"=1'-0"



SECTION E
SCALE: 1/8"=1'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1	FOR UTILITY RACK GENERAL NOTES SEE DRAWING FS-MTR-S-0209.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-08-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CAD FILE NAME: FS-MTR-S-0210.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

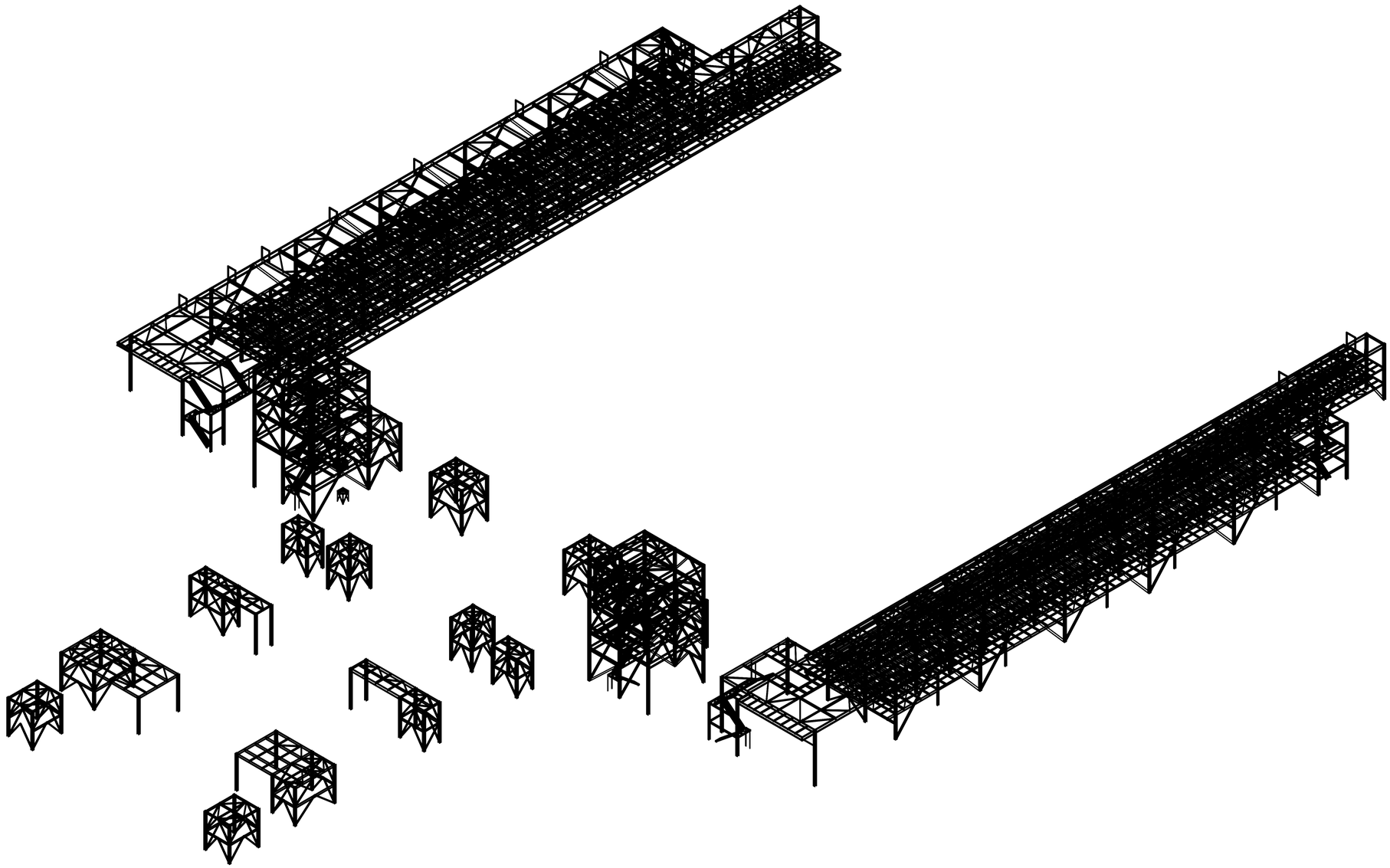
GILLETTE, WYOMING

DRAWING TITLE

UTILITY RACK
PLANS & SECTIONS

DRAWING NUMBER	REVISION
FS-MTR-S-0210	0
SHEET OF	

ZL11463\0L7267\D:\models\DP\MTR\mtr-stl-FSracks.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/7/2022 4:46:44 PM
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DUCT SUPPORT STEEL ISOMETRIC
SCALE: NONE
GRATING & HANDRAIL NOT SHOWN CLARITY

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. STRUCTURAL STEEL DESIGN IS BASED ON THE APPLICABLE REQUIREMENTS OF THE 2018 INTERNATIONAL BUILDING CODE, AISC 360-16, AWS D1.1 AND PROJECT SPECIFICATIONS.
2. UNLESS NOTED, ALL STEEL MATERIALS SHALL BE AS FOLLOWS:
   - WIDE FLANGE AND WT MEMBERS SHALL BE ASTM A992, GRADE 50
   - GUARD PLATES, LADDERS, LADDER CAGES, CHANNELS, S SHAPES AND MISCELLANEOUS STEEL MEMBERS SHALL BE ASTM A36
   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND POLYURETHANE FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH FEDERAL STANDARD 595B PAINT SPECIFICATION NUMBER 25526 (BODY BLUE).

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
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ISSUE PURPOSE: USE

SPECIFICATION: -

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CAD FILE NAME: FS-MTR-S-0211.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

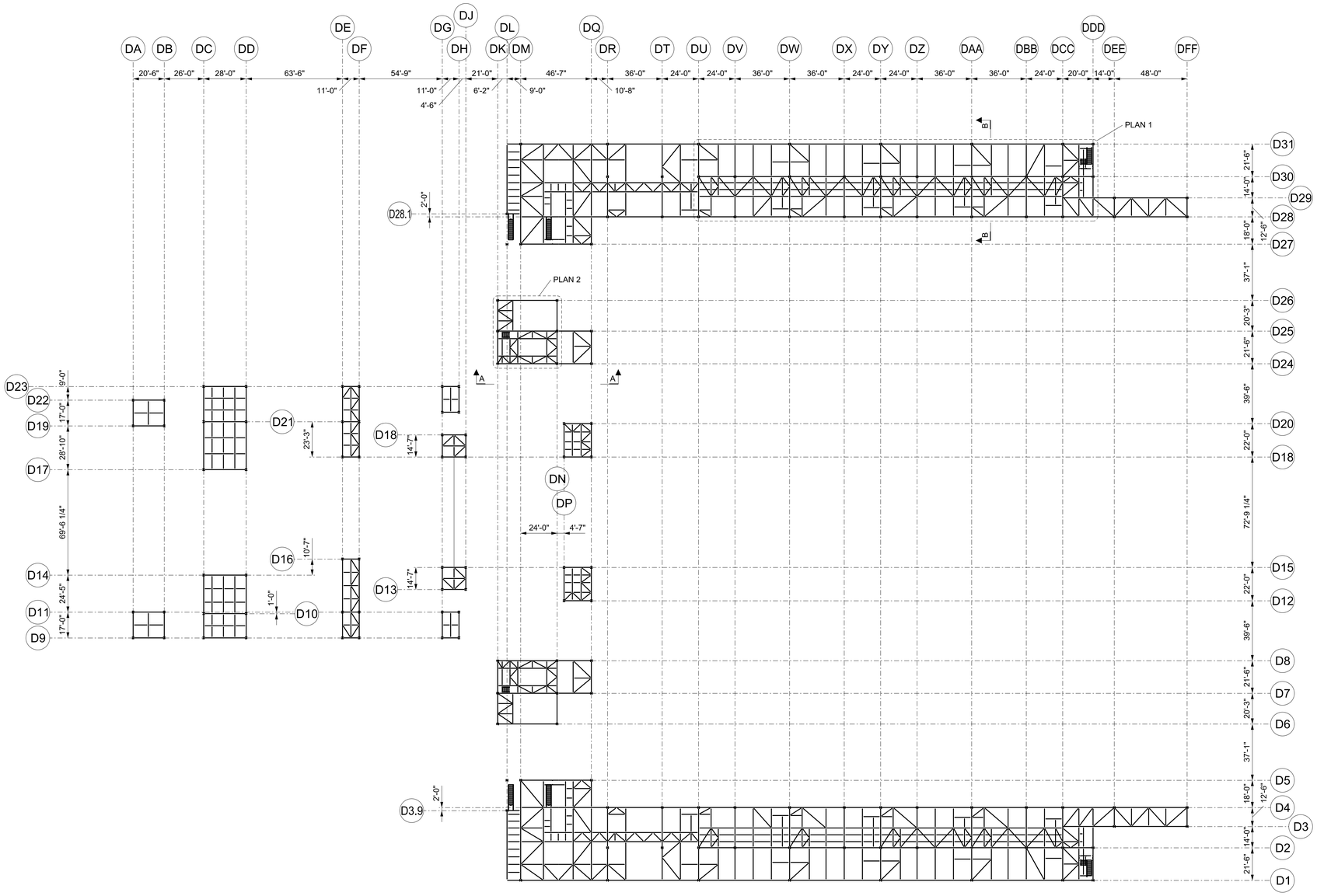
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DUCT SUPPORT STEEL ISOMETRIC

DRAWING NUMBER	REVISION
FS-MTR-S-0211	0
SHEET OF	

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

3/9/2022 11:29:35 AM
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DUCT SUPPORT STEEL ARRANGEMENT PLAN
SCALE: 1"=30'

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR DUCT SUPPORT STEEL GENERAL NOTES SEE DRAWING FS-MTR-S-0211.
2. FOR DUCT SUPPORT STEEL PLANS & SECTIONS SEE DRAWING FS-MTR-S-0213.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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ENTER DATE

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PAGES OR SHEETS COVERED BY THIS SEAL:
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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-S-0212.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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Sargent & Lundy

SARGENT & LUNDY
55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

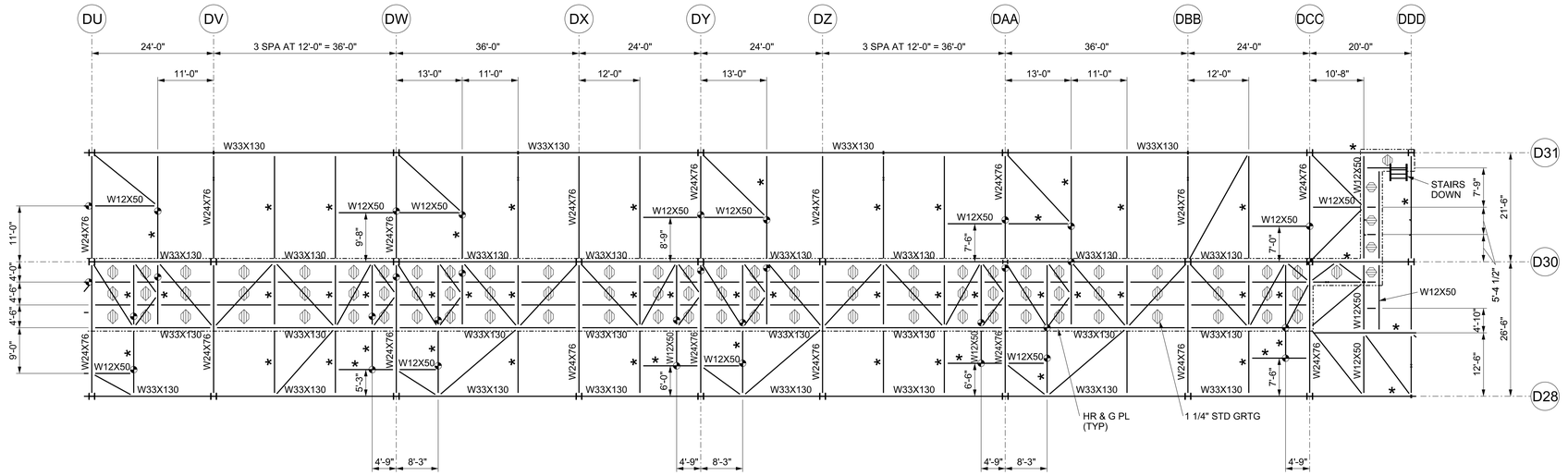
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DUCT SUPPORT STEEL ARRANGEMENT PLAN

DRAWING NUMBER	REVISION
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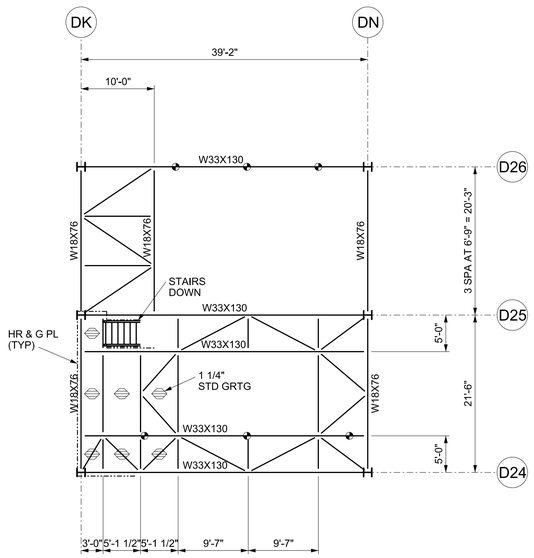
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Form GDG-0401-01-t08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



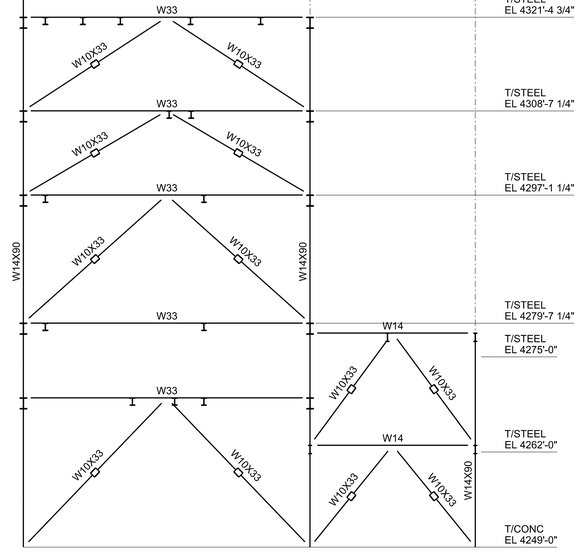
PLAN 1

SCALE: 3/32"=1'-0"
BEAMS SHALL BE W8X18 UN
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (LLV)(-8")
* INDICATES W18X76
INDICATES DUCT SUPPORT LOCATION (NOTE 2)



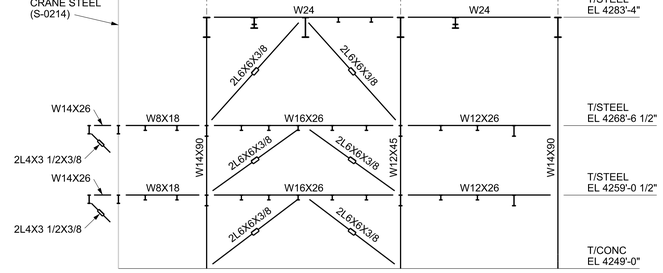
PLAN 2

SCALE: 1/8"=1'-0"
BEAMS SHALL BE W12X50 UN
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (-4")
INDICATES DUCT SUPPORT LOCATION (NOTE 2)



SECTION A

SCALE: 1/8"=1'-0"



SECTION B

SCALE: 1/8"=1'-0"

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR DUCT SUPPORT STEEL GENERAL NOTES SEE DRAWING FS-MTR-S-0211.
2. DUCT SUPPORT LOCATIONS ARE SHOWN PICTORIALLY ONLY FOR THE FEED STUDY.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-10-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CAD FILE NAME: FS-MTR-S-0213.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

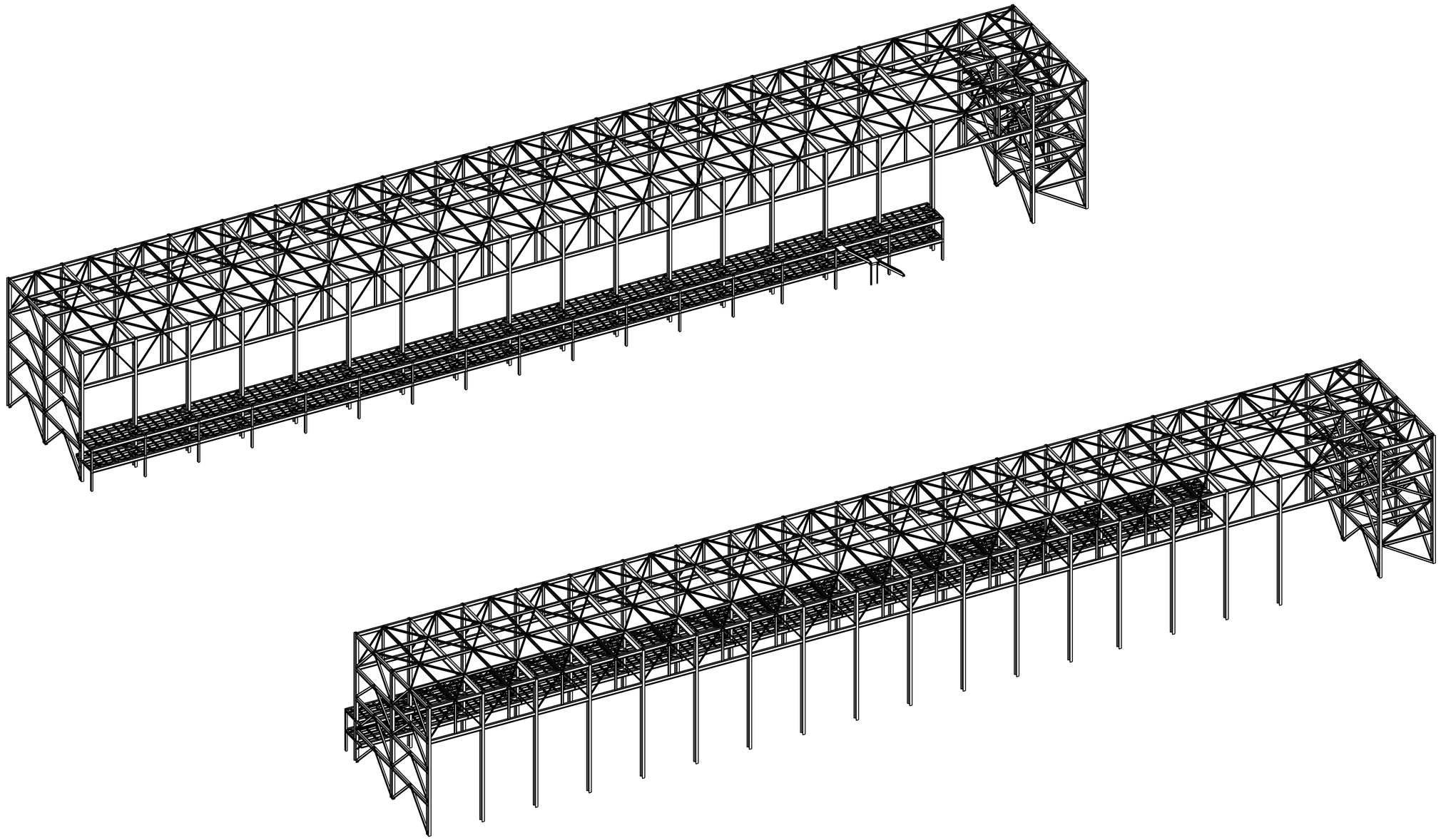
GILLETTE, WYOMING

DRAWING TITLE

DUCT SUPPORT STEEL PLANS & SECTIONS

DRAWING NUMBER	REVISION
FS-MTR-S-0213	0
SHEET OF	

ZL114630\0L7267\D:\models\DFMTR\mtr-stl-FS\ducts.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/9/2022 11:34:15 AM $FILEABBREV$



MEMBRANE REMOVAL CRANE STEEL ISOMETRIC
SCALE: NONE
STEP COLUMNS & CRANE GIRDERS NOT SHOWN FOR CLARITY
GRATING & HANDRAIL NOT SHOWN FOR CLARITY

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. STRUCTURAL STEEL DESIGN IS BASED ON THE APPLICABLE REQUIREMENTS OF THE 2018 INTERNATIONAL BUILDING CODE, AISC 360-16, AWS D1.1 AND PROJECT SPECIFICATIONS.
2. UNLESS NOTED, ALL STEEL MATERIALS SHALL BE AS FOLLOWS:
   - WIDE FLANGE AND WT MEMBERS SHALL BE ASTM A992, GRADE 50
   - GUARD PLATES, LADDERS, LADDER CAGES, CHANNELS, S SHAPES AND MISCELLANEOUS STEEL MEMBERS SHALL BE ASTM A36
   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND POLYURETHANE FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH FEDERAL STANDARD 595B PAINT SPECIFICATION NUMBER 25526 (BODY BLUE).

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
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ISSUE PURPOSE: USE

SPECIFICATION: -

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CAD FILE NAME: FS-MTR-S-0214.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

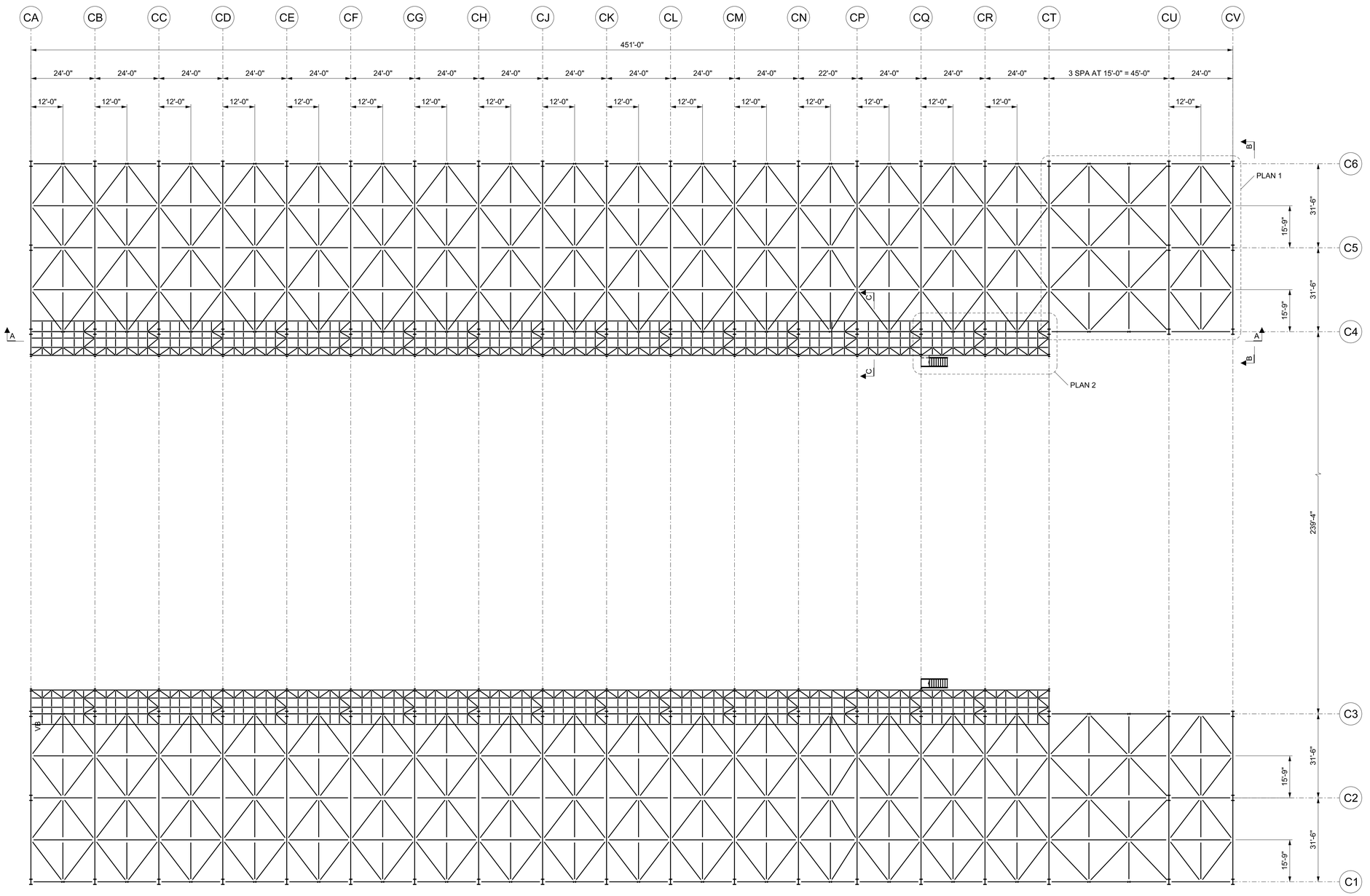
DRAWING TITLE

MEMBRANE REMOVAL CRANE STEEL ISOMETRIC

DRAWING NUMBER	REVISION
FS-MTR-S-0214	0
SHEET OF	

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

3/9/2022 1:00:32 PM
$FILEABBREV$



MEMBRANE REMOVAL CRANE STEEL
ARRANGEMENT PLAN
SCALE: 1/16"=1'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR MEMBRANE REMOVAL CRANE STEEL GENERAL NOTES SEE DRAWING FS-MTR-S-0214.
2. FOR MEMBRANE REMOVAL CRANE STEEL PLANS & SECTIONS SEE DRAWING FS-MTR-S-0216.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

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CAD FILE NAME: FS-MTR-S-0215.DGN

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REVIEWED BY: C.AINGE

APPROVED BY: -

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MTR
MEMBRANE
TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

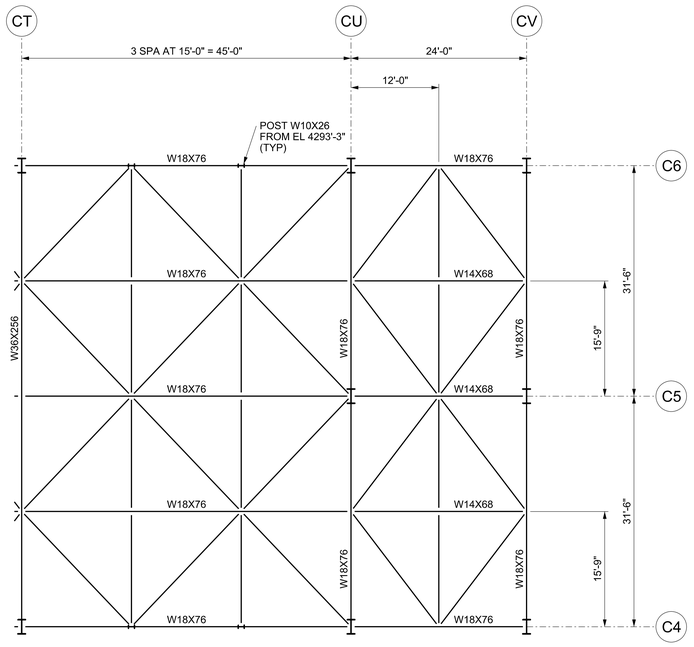
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MEMBRANE REMOVAL CRANE STEEL ARRANGEMENT PLAN

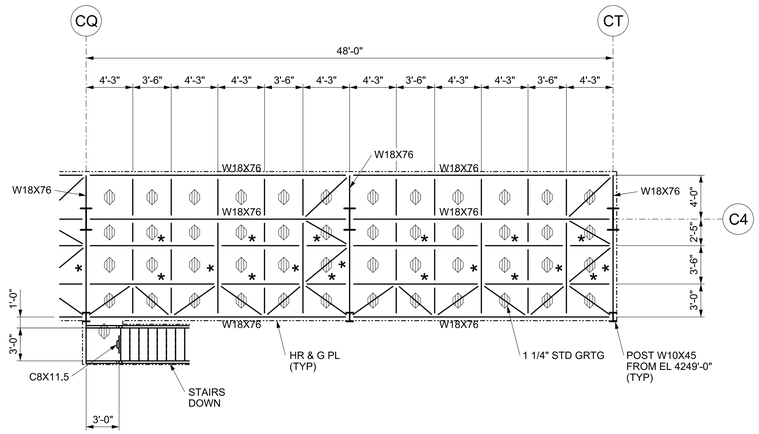
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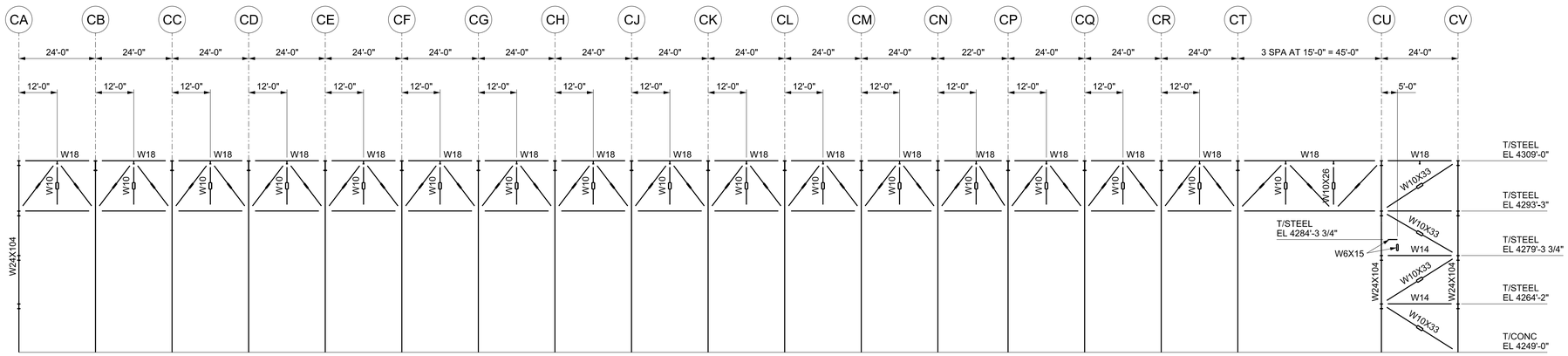
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



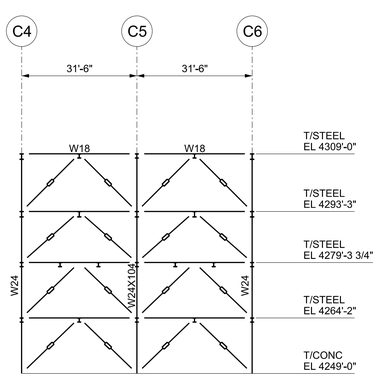
PLAN 1
SCALE: 1/8"=1'-0"
T/STEEL EL 4309'-0"
BEAMS SHALL BE W12X26 UN
HORIZONTAL BRACING SHALL BE 2L5X5X1/2 (-12")



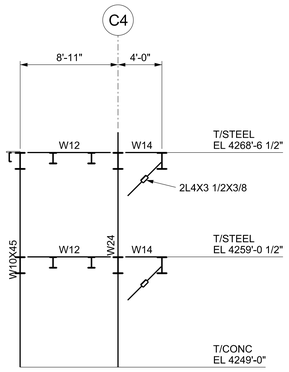
PLAN 2
SCALE: 3/16"=1'-0"
T/GRATING EL 4268'-7 3/4"
T/STEEL EL 4268'-6 1/2"
BEAMS SHALL BE W8X18 UN
* INDICATES W12X50
HORIZONTAL BRACING SHALL BE L3X3X3/8 (-4")



SECTION A
SCALE: 1/16"=1'-0"
BEAMS SHALL BE W18X76 UN
VERTICAL BRACING SHALL BE 2L4X4X3/8 UN
COLUMNS SHALL BE STEP COLUMNS W24X104 & W14X90 UN (NOTE 2)



SECTION B
SCALE: 1/16"=1'-0"
BEAMS SHALL BE W18X76
VERTICAL BRACING SHALL BE W10X33



SECTION C
SCALE: 3/16"=1'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES
1. FOR MEMBRANE REMOVAL CRANE STEEL GENERAL NOTES SEE DRAWING FS-MTR-S-0214.
2. STEP COLUMNS WILL BE DETAILED DURING PHASE III.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-09-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-S-0216.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

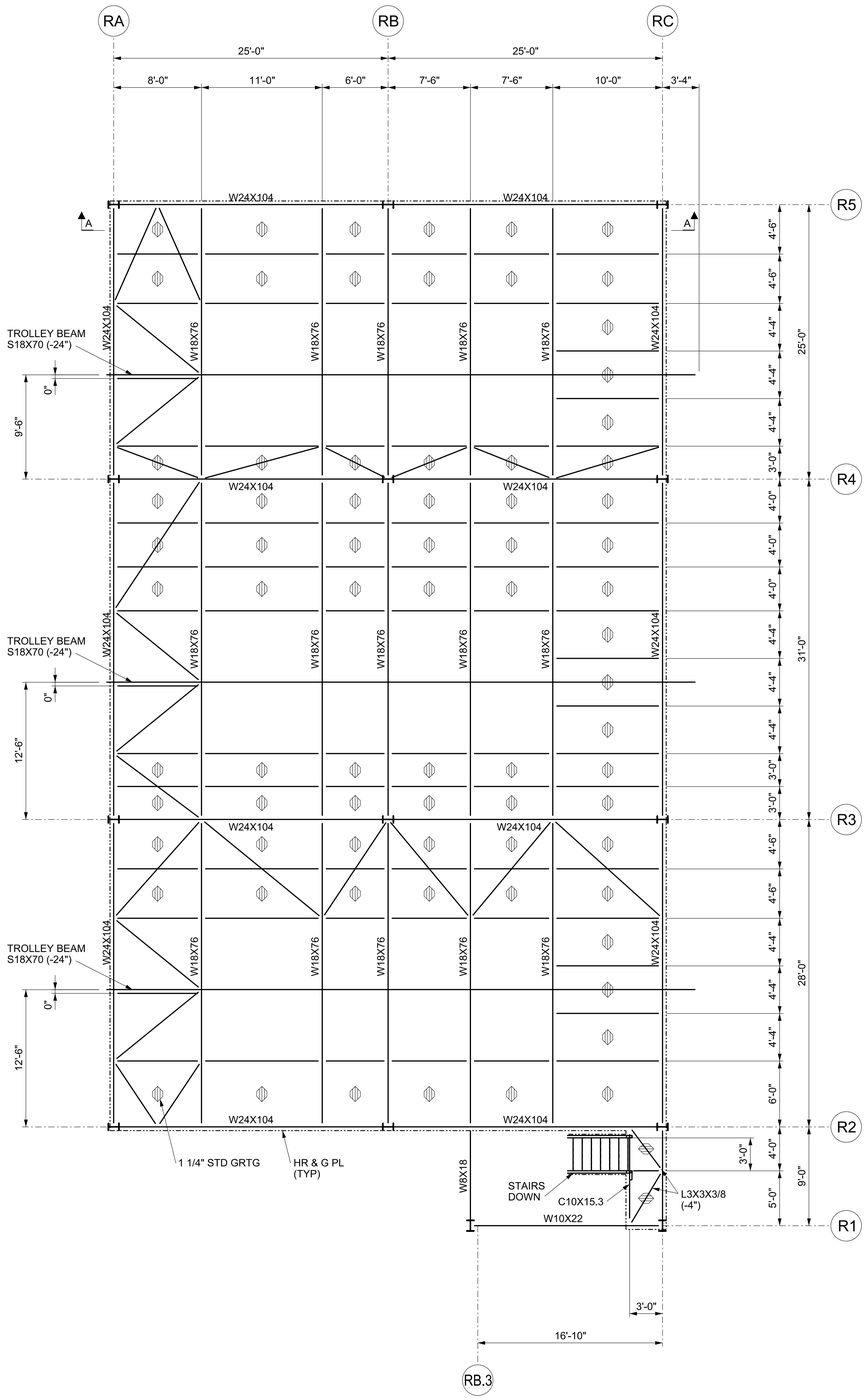
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MEMBRANE REMOVAL CRANE STEEL PLANS & SECTIONS

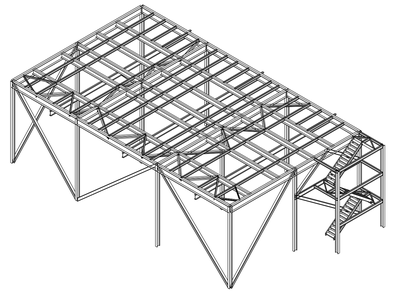
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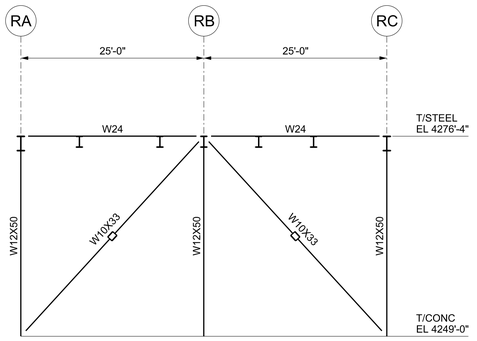
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Form GDG-0401-01-d8, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



FRAMING PLAN EL 4276'-4"
SCALE: 3/16"=1'-0"
T/STEEL EL 4276'-2 3/4" UN
T/GRATING EL 4276'-4"
BEAMS SHALL BE W8X18 UN
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (-8")(LLV) UN



REFRIGERANT STEEL ISOMETRIC
SCALE: 1/16"=1'-0"



SECTION A
SCALE: 1/8"=1'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. STRUCTURAL STEEL DESIGN IS BASED ON THE APPLICABLE REQUIREMENTS OF THE 2018 INTERNATIONAL BUILDING CODE, AISC 360-16, AWS D1.1 AND PROJECT SPECIFICATIONS.
2. UNLESS NOTED, ALL STEEL MATERIALS SHALL BE AS FOLLOWS:
   - WIDE FLANGE AND WT MEMBERS SHALL BE ASTM A992, GRADE 50
   - GUARD PLATES, LADDERS, LADDER CAGES, CHANNELS, S SHAPES AND MISCELLANEOUS STEEL MEMBERS SHALL BE ASTM A36
   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND POLYURETHANE FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH FEDERAL STANDARD 595B PAINT SPECIFICATION NUMBER 25526 (BODY BLUE).

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
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ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

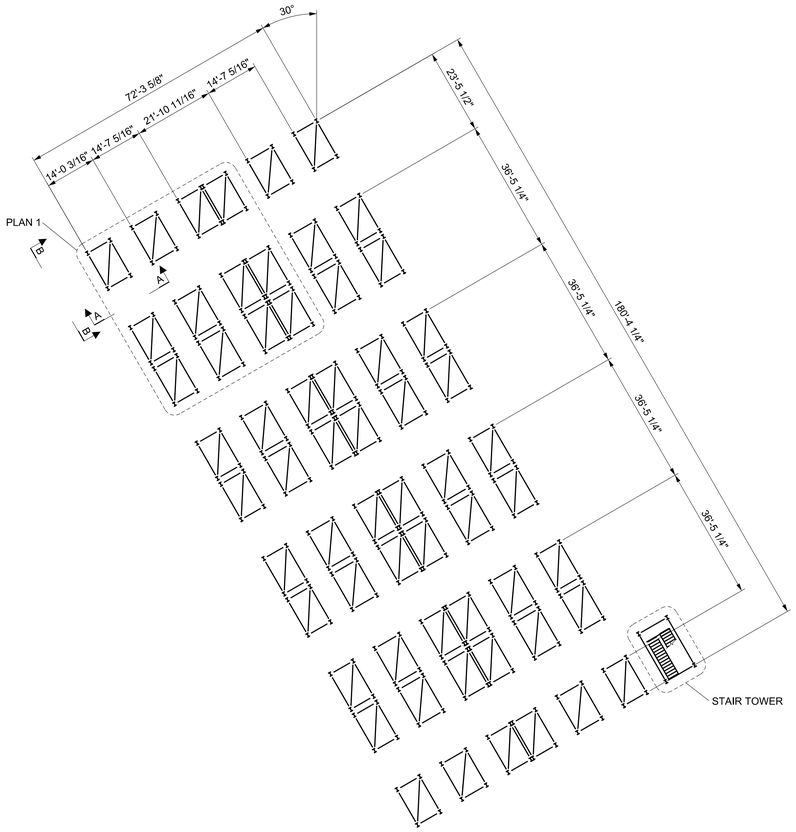
GILLETTE, WYOMING

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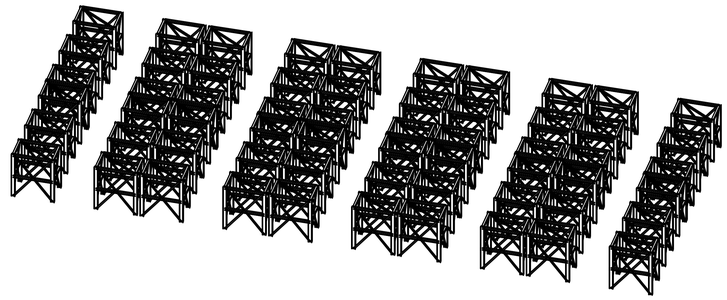
REFRIGERANT COMPRESSOR & CONDENSOR SUPPORT STEEL PLAN & SECTIONS

DRAWING NUMBER	REVISION
FS-MTR-S-0217	0
SHEET OF	

ZL11463\0L7267\D:\models\DFMTR\mtr-stl-FScpu.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/9/2022 1:05:28 PM $FILEABBREV$

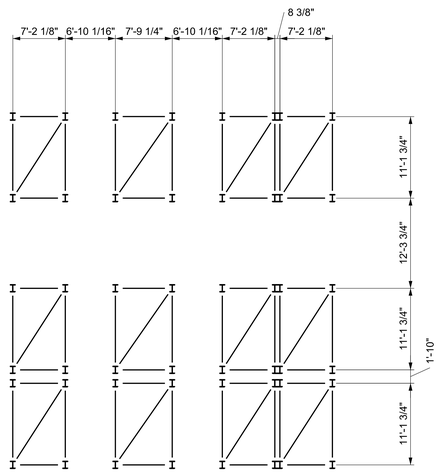


COOLING TOWER STEEL
ARRANGEMENT PLAN
SCALE: 1/16"=1'-0"

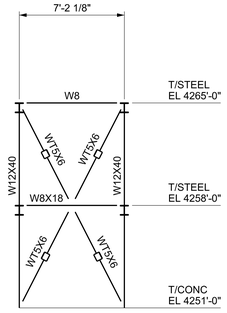


COOLING TOWER STEEL ISOMETRIC
SCALE: 1/16"=1'-0"

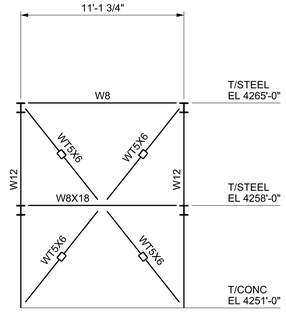
NORTH



PLAN 1
SCALE: 1/8"=1'-0"
BEAMS SHALL BE W8X24
HORIZONTAL BRACING SHALL BE 2L4X4X3/8 (-8")



SECTION A
SCALE: 1/4"=1'-0"



SECTION B
SCALE: 1/4"=1'-0"

NORTH

HOLD INFORMATION	
NO.	DESCRIPTION

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0	03-09-2022	FOR USE

ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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CAD FILE NAME:	FS-MTR-S-0218.DGN
PREPARED BY:	D.ZIMA
REVIEWED BY:	C.AINGE
APPROVED BY:	-

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

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   - PLATE WORK AND ANGLES SHALL BE ASTM A572, GRADE 50
   - ROUND AND RECTANGULAR HOLLOW STRUCTURAL SECTIONS SHALL BE ASTM A500, GRADE C
3. ALL STRUCTURAL STEEL SHALL BE COATED WITH A 3-COAT SYSTEM USING INORGANIC ZINC PRIMER, EPOXY INTERMEDIATE AND POLYURETHANE FINISH. THE COLOR OF THE FINISH COAT SHALL MATCH FEDERAL STANDARD 595B PAINT SPECIFICATION NUMBER 25526 (BODY BLUE).

REFERENCE DRAWINGS

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

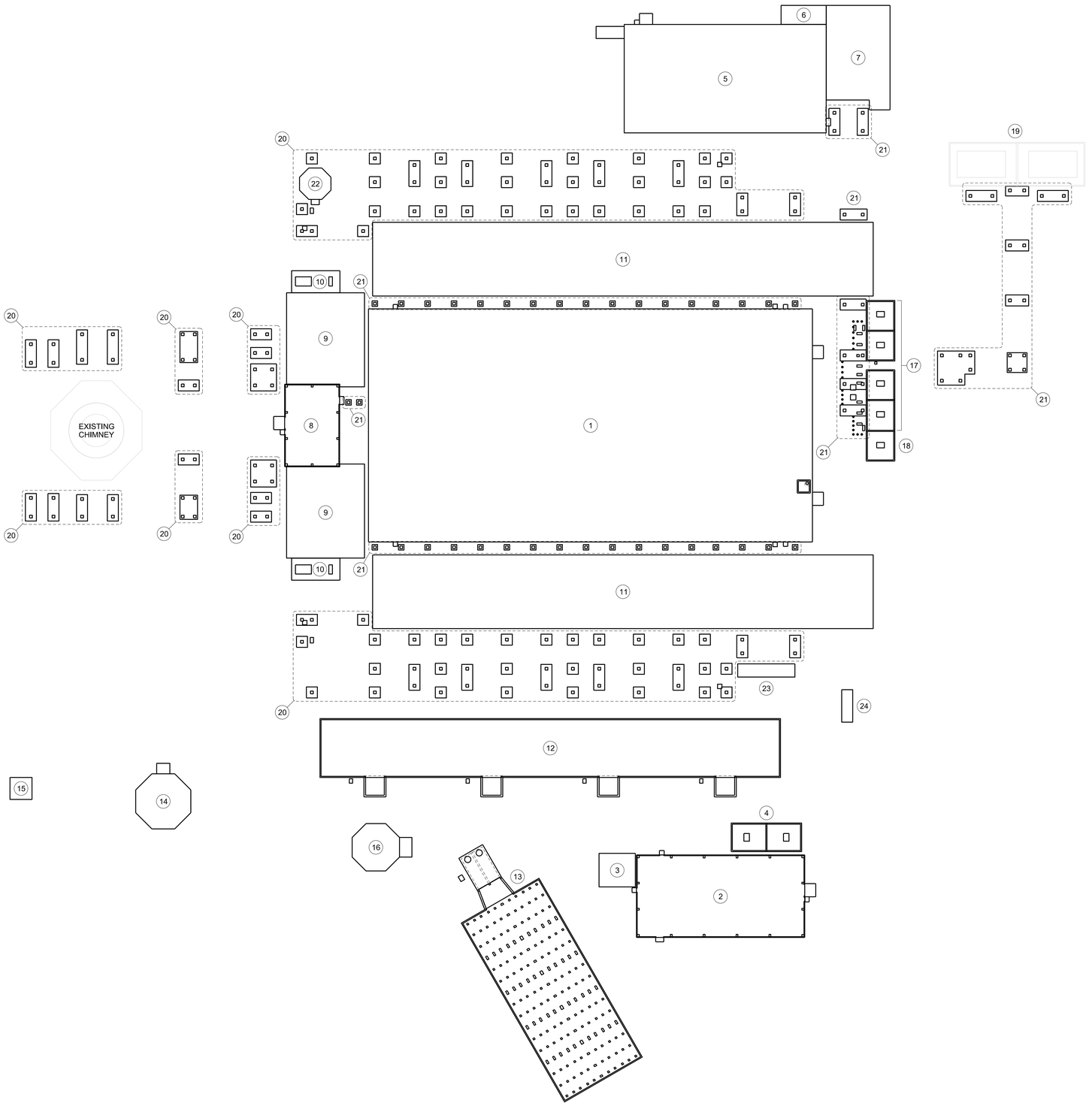
COOLING TOWER STEEL
PLANS & SECTIONS

DRAWING NUMBER	REVISION
FS-MTR-S-0218	0
SHEET	OF

ZL114630L7267D:\models\DFMTR\mtr-stl-FS\cool.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

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APPENDIX KK. FOUNDATION DRAWINGS



FOUNDATION ARRANGEMENT PLAN
SCALE: 1"=40'

FOUNDATION LEGEND (NOTE 3)	
NO.	FOUNDATION DESCRIPTION
1	CARBON CAPTURE EQUIPMENT BUILDING
2	WATER TREATMENT BUILDING
3	WASTEWATER EQUALIZATION TANK
4	13800V - 4160V TRANSFORMERS
5	CO2 PURIFICATION UNIT BUILDING
6	HIGH PRESSURE REFRIGERANT RECEIVER
7	REFRIGERANT COMPRESSORS & CONDENSORS
8	DCC AUXILIARY EQUIPMENT BUILDING
9	DIRECT CONTACT COOLER
10	BOOSTER FAN
11	CARBON CAPTURE MEMBRANES
12	WET SURFACE AIR COOLERS
13	COOLING TOWER
14	WASTE WATER FORWARDING TANK
15	FIXATION LIME SILO
16	WELL WATER STORAGE TANK
17	13800V - 4160V TRANSFORMERS
18	13800V - 13800V TRANSFORMER
19	230kV SUBSTATION TRANSFORMERS
20	DUCT / PIPE SUPPORT STEEL
21	UTILITY RACK STEEL
22	SERVICE WATER TANK
23	EMERGENCY DIESEL GENERATOR
24	OILY WATER SEPARATOR

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR CONCRETE GENERAL NOTES SEE DRAWING FS-MTR-S-0101.
2. FOR TYPICAL FOUNDATION PLANS, SECTIONS AND DETAILS SEE DRAWING FS-MTR-S-0101.
3. CO2 CAPTURE RESERVOIR PUMP HOUSE, PURGE FAN FOUNDATIONS, SCREW CONVEYOR SUPPORT FOUNDATIONS AND DUCTBANKS ARE NOT SHOWN.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-17-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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ENTER NAME
ENTER DATE

MY LICENSE RENEWAL DATE IS: ENTER DATE
PAGES OR SHEETS COVERED BY THIS SEAL:
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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-S-0100.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

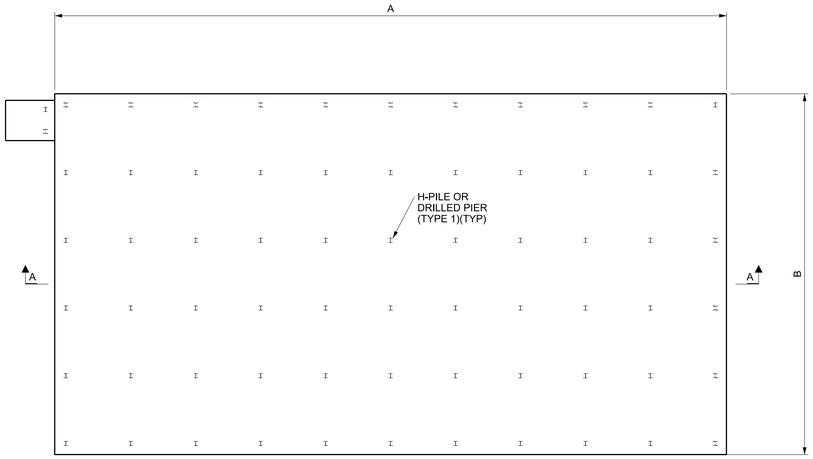
DRAWING TITLE

FOUNDATION ARRANGEMENT PLAN

DRAWING NUMBER	REVISION
FS-MTR-S-0100	0
SHEET OF	

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

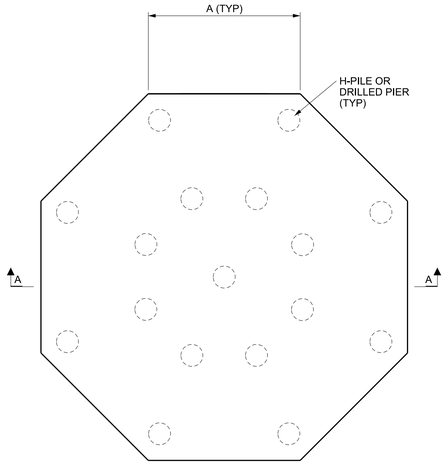
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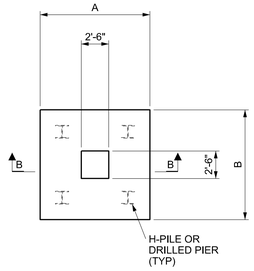
FOUNDATION PLAN TYPE 1 - PILE CAP
FOUNDATION PLAN TYPE 1A- MAT FOUNDATION
SCALE: NONE

FOUNDATION SUMMARY TABLE

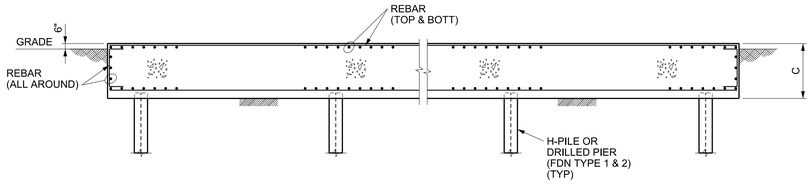
FOUNDATION	FDN TYPE	FDN QUANTITY	A	B	C	D	NO. OF H-PILES PER FDN	NO. OF DRILLED PIERS PER FDN	REMARKS
CARBON CAPTURE EQUIPMENT BUILDING	1	1	403'-7"	211'-11"	5'-0"	-	312	-	TRENCH DET
WATER TREATMENT BUILDING	1	1	75'-0"	153'-0"	4'-0"	-	45	-	CURB DET & TRENCH DET
WASTEWATER EQUALIZATION TANK	1	1	33'-0"	30'-6"	5'-0"	-	9	-	
13800V - 4160V TRANSFORMERS (WATER TREATMENT BUILDING)	1	1	64'-0"	26'-0"	3'-6"	-	8	-	NOTE 13
CO2 PURIFICATION UNIT BUILDING	1	1	183'-7"	98'-7"	5'-0"	-	66	-	TRENCH DET
HIGH PRESSURE REFRIGERANT RECEIVER	1A	1	41'-0"	17'-3"	5'-0"	-	-	-	
REFRIGERANT COMPRESSORS & CONDENSORS	1	1	58'-0"	95'-0"	5'-0"	-	26	-	
DCC AUXILIARY EQUIPMENT BUILDING	1	1	50'-0"	75'-0"	4'-0"	-	20	-	CURB DET
DIRECT CONTACT COOLER	1	2	70'-10"	85'-6"	5'-0"	-	-	30	
BOOSTER FAN	1	2	43'-11"	20'-0"	5'-0"	-	-	6	
CARBON CAPTURE MEMBRANES	1	2	455'-0"	67'-0"	5'-0"	-	130	-	
WET SURFACE AIR COOLERS	1	1	418'-8"	53'-6"	4'-0"	-	96	-	NOTE 17
COOLING TOWER	1	1	81'-6"	239'-11"	VARIES	-	-	61	NOTE 17
WASTE WATER FORWARDING TANK	2	1	20'-9"	-	5'-0"	-	-	17	
FIXATION LIME SILO	1	1	20'-0"	20'-0"	5'-0"	-	-	5	
WELL WATER STORAGE TANK	2	1	17'-10"	-	5'-0"	-	-	17	
13800V - 4160V TRANSFORMERS (CARBON CAPTURE BUILDING)	1	2	26'-0"	55'-0"	3'-6"	-	8	-	NOTE 13
13800V - 13800V TRANSFORMER (CARBON CAPTURE BUILDING)	1	1	26'-0"	28-0"	3'-6"	-	4	-	NOTE 13
DUCT / PIPE SUPPORT STEEL	3	90	VARIES	VARIES	3'-0"	2'-0"	VARIES	VARIES	
UTILITY RACK STEEL	3	48	VARIES	VARIES	3'-0"	2'-0"	VARIES	-	
SERVICE WATER TANK	2	1	11'-10"	-	5'-0"	-	-	9	
EMERGENCY DIESEL GENERATOR	1	1	52'-0"	12'-0"	4'-0"	-	8	-	
OILY WATER SEPARATOR	1	1	10'-0"	29'-6"	4'-0"	-	-	-	



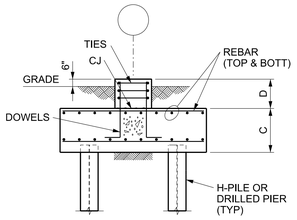
FOUNDATION PLAN - TYPE 2
SCALE: NONE



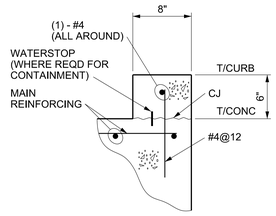
FOUNDATION PLAN - TYPE 3
SCALE: NONE



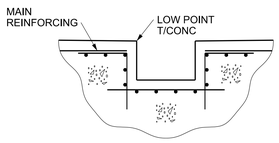
SECTION A
SCALE: NONE



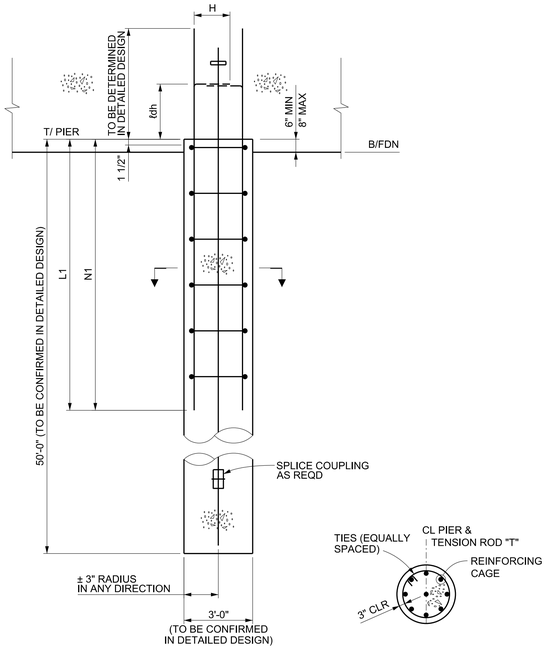
SECTION B
SCALE: NONE



CURB DETAIL
SCALE: NONE

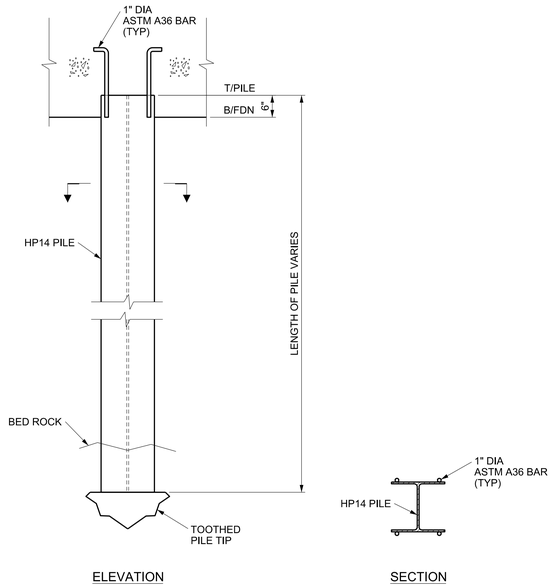


TRENCH DETAIL
NONE



ELEVATION SECTION

DRILLED PIER DETAIL
SCALE: NONE



ELEVATION SECTION

STEEL H-PILE DETAIL
SCALE: NONE

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. ALL CONCRETE FOUNDATIONS SHALL BE DESIGNED IN ACCORDANCE WITH PROJECT DESIGN CRITERIA AND SPECIFICATIONS (TO BE DEVELOPED DURING DETAILED DESIGN).
2. MINIMUM CONCRETE COMPRESSIVE STRENGTH SHALL BE AS FOLLOWS:
   - FOUNDATIONS AND ALL BELOW GRADE STRUCTURES: 4,500 PSI
   - DRILLED PIERS: 5,000 PSI
3. CONCRETE CEMENT SHALL BE PORTLAND CEMENT TYPE II (CONCENTRATION OF SULFATE IN THE SOIL SHALL BE CONFIRMED).
4. DEFORMED REINFORCING BARS SHALL CONFORM TO ASTM A615, GRADE 60, UNCOATED.
5. ANCHOR RODS ARE ASSUMED TO BE ASTM F1554, GRADE 36. GRADE 55 OR GRADE 105 ANCHOR RODS MAY BE USED ON A CASE BY CASE BASIS.
6. FROST DEPTH IS 42" BELOW GRADE.
7. DESIGN OF MAT FOUNDATIONS IS BASED ON FOUNDATION SIZE AND ASSOCIATED ALLOWABLE NET SOIL BEARING PRESSURE FROM EXISTING DRY FORK UNIT 1 GEOTECHNICAL REPORT.
8. DESIGN OF DEEP FOUNDATIONS IS BASED ON STEEL H-PILES HP14X73 ASTM A572 GRADE 50 DRIVEN INTO ROCK WITH THE FOLLOWING SINGLE ISOLATED PILE DESIGN CAPACITIES:
   - COMPRESSION: 150 TON
   - TENSION: 60 TON
   - STRONG-AXIS LATERAL: 10 TON
   - WEAK-AXIS LATERAL: 7 TON
9. FINAL GRADE AROUND EQUIPMENT AND STRUCTURES SHALL BE SET AT LEAST 6" BELOW THE TOP OF FINISHED CONCRETE FOUNDATIONS AND SHALL BE SLOPED AWAY FROM FOUNDATION WITH A MINIMUM SLOPE OF 1 PERCENT FOR TEN FEET.
10. ALL GENERAL AREA FLOORS SHALL BE BROOM FINISHED CONCRETE FLOORS UNLESS NOTED.
11. WHERE POSSIBLE, POST-INSTALLED ANCHOR RODS WILL BE USED FOR DIAMETERS LESS THAN OR EQUAL TO 3/4".
12. FOUNDATIONS SUPPORTING ROTATING MACHINERY OR VIBRATORY EQUIPMENT SHALL BE EVALUATED TO CONFIRM THAT THE INSTALLED RESONANT FREQUENCY OF THE FOUNDATION IS A MINIMUM OF 20% ABOVE THE OPERATING SPEED, OR TO MORE STRINGENT LEVELS AS REQUIRED BY THE EQUIPMENT VENDOR.
13. SECONDARY CONTAINMENT SHALL BE PROVIDED AROUND ALL EQUIPMENT OR STORAGE TANKS THAT CONTAIN OIL EQUAL TO OR GREATER THAN 25 GALLONS. THE SECONDARY CONTAINMENT SHALL MEET THE LOCAL, STATE AND FEDERAL REQUIREMENTS PERTAINING TO OIL STORAGE. ADDITIONALLY, THE CONTAINMENT SHALL BE DESIGNED AT A MINIMUM TO CONTAIN 110% OF THE LARGEST CONTAINER OR EQUIPMENT THAT CONTAINS OIL.
14. BOOSTER FAN INLET AND OUTLET DUCTS AND FAN HOUSING SUPPORT SCHEME ARE NOT SHOWN.
15. EQUIPMENT LOCATIONS ARE IDENTIFIED ON GENERAL ARRANGEMENT DRAWINGS FS-MTR-M-001, FS-MTR-M-002, FS-MTR-M-003, FS-MTR-M-004 AND FS-MTR-M-005.
16. EQUIPMENT PAD FOUNDATIONS, SUMP PITS, TRENCHES, ETC INSIDE THE CO2 CAPTURE BUILDING ARE NOT SHOWN FOR CLARITY.
17. COOLING TOWER BASIN AND WET SURFACE AIR COOLER BASINS NOT SHOWN FOR CLARITY.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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CAD FILE NAME: FS-MTR-S-0101.DGN
PREPARED BY: D.ZIMA
REVIEWED BY: C.AINGE
APPROVED BY: -

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

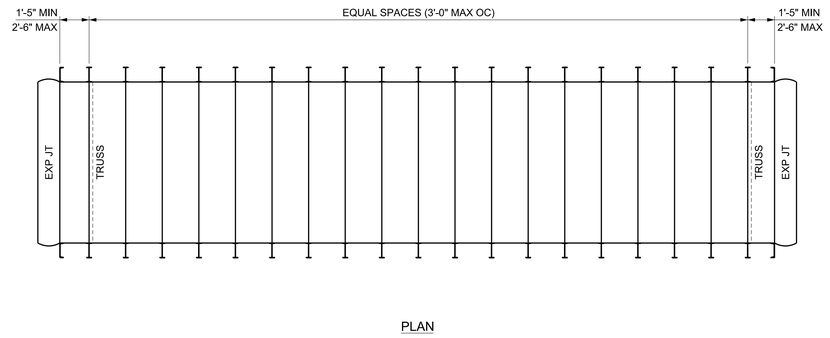
TYPICAL FOUNDATION PLANS, SECTIONS AND DETAILS

DRAWING NUMBER	REVISION
FS-MTR-S-0101	0
SHEET	OF

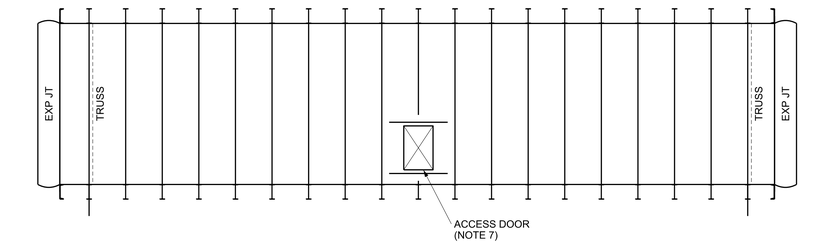
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

APPENDIX LL. FLUE GAS DUCTWORK DRAWINGS

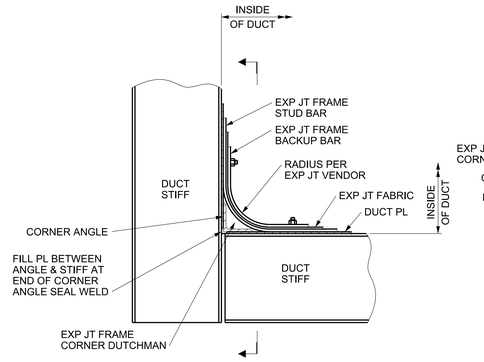


PLAN

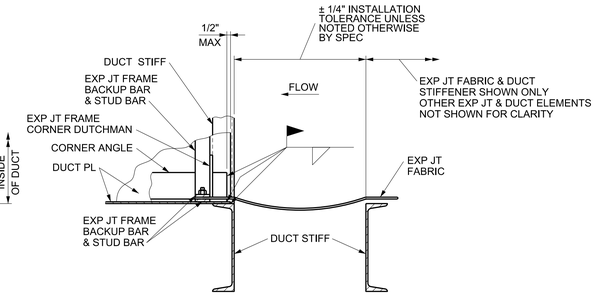


ELEVATION

TYPICAL DUCT STIFFENER ARRANGEMENT
SCALE: NONE

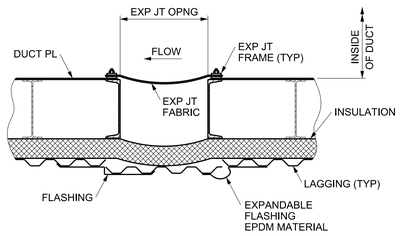


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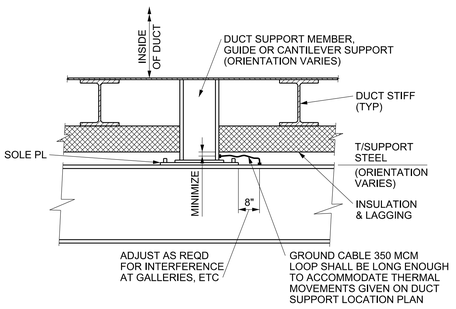
SECTION

DETAIL 1
SCALE: NONE
CONNECTION OF EXPANSION JOINT FRAME
TO DUCT PLATE (NOTE 5)

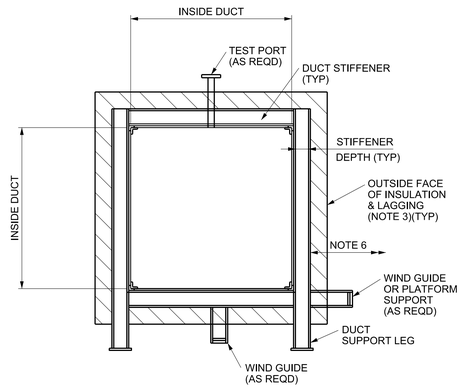


DETAIL 2
SCALE: NONE
EXPANSION JOINT INSULATION DETAIL
LAGGING AUXILIARY SUPPORTS AND ACCESSORIES
NOT SHOWN FOR CLARITY

TYPICAL TRUSS LAYOUT
SCALE: NONE



DETAIL 3
SCALE: NONE
DUCT GROUNDING DETAIL



TYPICAL DUCT CROSS SECTION
SCALE: NONE

MATERIAL (UNLESS NOTED)	
DUCT WALL PLATE	1/4"
DUCT ROOF PLATE	1/4"
DUCT FLOOR PLATE	1/4"
WALL STIFFENERS	W12X19
ROOF STIFFENERS	W12X22
FLOOR STIFFENERS	W12X19
CORNER ANGLES	L4X4X3/8

NOTES

1. ALL DUCTWORK SHALL BE FURNISHED AND INSTALLED PER AISC CODE AND SPECIFICATIONS.
2. DUCT SEGMENTS SHALL HAVE ALL INTERIOR SURFACES COATED USING CARBOLINE PLASITE 4310, VINYL ESTER RESIN WITH SPECIAL CURING SYSTEM AND INERT FLAKE PIGMENT AND PER PROJECT SPECIFICATIONS.
3. DUCTS REQUIRE INSULATION AND LAGGING. INSULATION THICKNESS TO BE DETERMINED DURING DETAILED DESIGN.
4. ALL DUCTWORK EXPANSION JOINTS SHALL BE BY PATHWAY OR APPROVED EQUIVALENT.
5. INSTALL EXPANSION JOINTS AND EXPANSION JOINT FRAMES ACCORDING TO THE VENDOR DRAWINGS. CONTRACTOR SHALL VERIFY THE FACE TO FACE DIMENSION REQUIRED FOR EXPANSION JOINT INSTALLATION FROM THE VENDOR DRAWINGS AND TRIM BACK DUCT PLATE AS REQUIRED.
6. SHOP CLEANING AND PRIME COAT PAINTING IS REQUIRED FOR ALL DUCT STEEL AND APPURTENANCES PROJECTING OUTSIDE OF INSULATION AND LAGGING. PAINT PROJECTIONS TO FACE OF DUCT STIFFENERS.
7. ALL DUCTWORK ACCESS DOORS TO BE 24" WIDE BY 36" TALL. BOTTOM OF DOOR OPENINGS SHALL BE 1'-0" ABOVE DUCTWORK FLOOR ELEVATION.
8. DUCT MATERIALS ARE CONCEPTUAL AND WILL BE DETERMINED DURING DETAILED DESIGN.

REFERENCE DRAWINGS

PRELIMINARY

NOT TO BE USED FOR CONSTRUCTION

HOLD INFORMATION

NO.	DESCRIPTION

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CAD FILE NAME: FS-MTR-S-0300.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

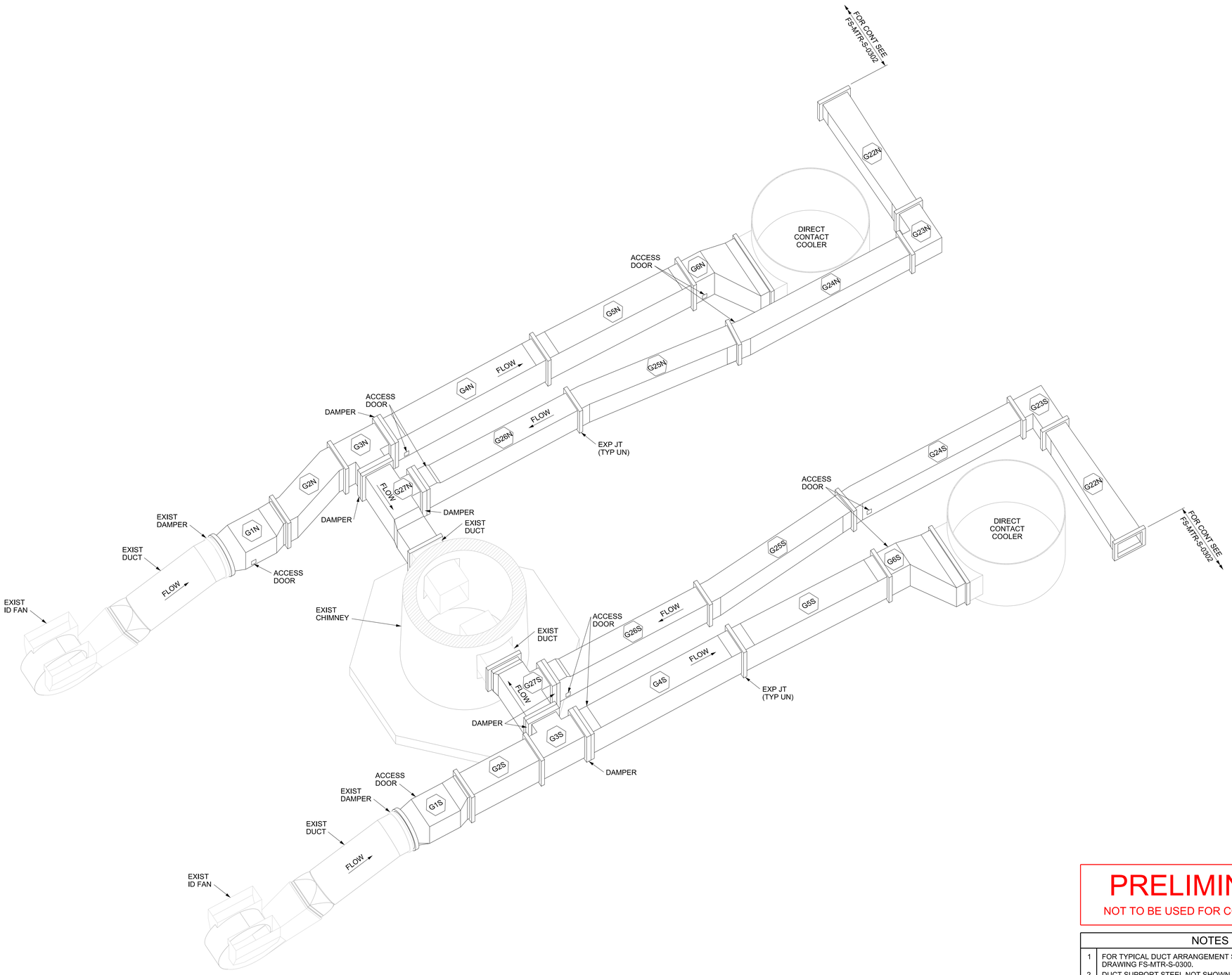
TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS

DRAWING NUMBER	REVISION
FS-MTR-S-0300	0

SHEET OF

ZL11463\0L7267\D:\models\DFMTR\002_FULL_SCALE\mtr-duc-FSducts.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

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DUCT ISOMETRIC
EXISTING ID FANS TO DIRECT CONTACT COOLERS
SCALE: 1/16"=1'-0"

DUCT SEGMENT	AVERAGE CROSS SECTION DIMENSION	
	WIDTH	HEIGHT
G1N / G1S	14'-0"	14'-0"
G2N / G2S	11'-0"	18'-0"
G3N / G3S	11'-0"	18'-0"
G4N / G4S	11'-0"	18'-0"
G5N / G5S	11'-0"	18'-0"
G6N / G6S	27'-0"	16'-0"
G22N / G22S	10'-0"	11'-9"
G23N / G23S	9'-0"	12'-6"
G24N / G24S	9'-0"	12'-6"
G25N / G25S	9'-0"	12'-6"
G26N / G26S	9'-0"	12'-6"
G27N / G27S	11'-0"	18'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS SEE DRAWING FS-MTR-S-0300.
2. DUCT SUPPORT STEEL NOT SHOWN FOR CLARITY.

REFERENCE DRAWINGS

HOLD INFORMATION

NO.	DESCRIPTION

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SPECIFICATION: -

PROJECT NO.: 13978-002

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ENTER NAME
ENTER DATE

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-S-0301.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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Sargent & Lundy

SARGENT & LUNDY
55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

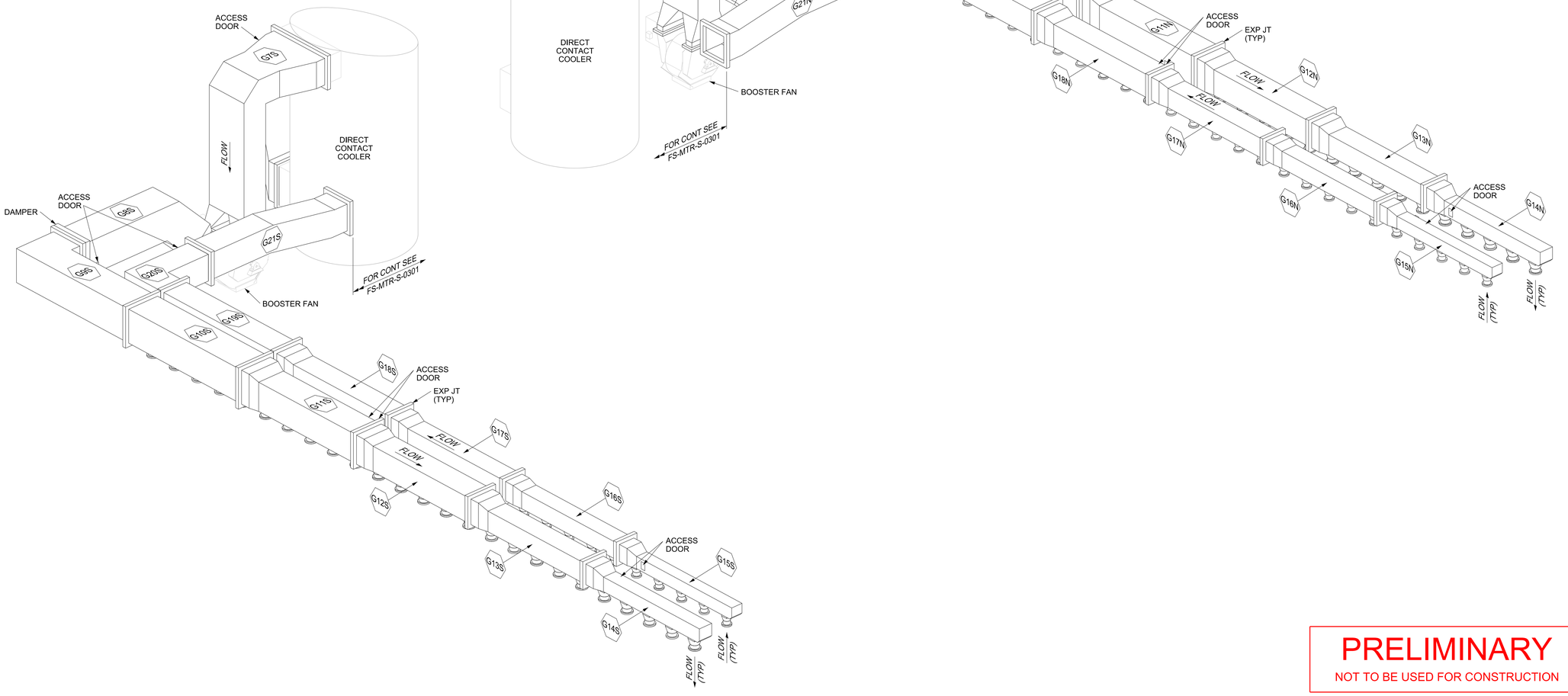
GILLETTE, WYOMING

DRAWING TITLE

DUCT ISOMETRIC
EXISTING ID FANS
TO DIRECT CONTACT COOLERS

DRAWING NUMBER	REVISION
FS-MTR-S-0301	0
SHEET OF	

ZL11463\0L7267\D:\models\DFMTR\002_FULL_SCALE\mtr-duc-FSducts.dgn
Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
2/28/2022 12:19:35 PM
$FILEABBREV$



DUCT ISOMETRIC
DIRECT CONTACT COOLERS TO CARBON CAPTURE MEMBRANES
SCALE: 1/16"=1'-0"

DUCT SEGMENT	AVERAGE CROSS SECTION DIMENSION	
	WIDTH	HEIGHT
G7N / G7S	18'-6"	11'-0"
G8N / G8S	14'-0"	14'-0"
G9N / G9S	14'-0"	14'-0"
G10N / G10S	14'-0"	14'-0"
G11N / G11S	12'-0"	12'-0"
G12N / G12S	10'-6"	10'-6"
G13N / G13S	8'-6"	8'-6"
G14N / G14S	6'-0"	6'-0"
G15N / G15S	5'-0"	5'-0"
G16N / G16S	7'-0"	7'-0"
G17N / G17S	8'-0"	8'-0"
G18N / G18S	9'-6"	9'-6"
G19N / G19S	11'-0"	11'-0"
G20N / G20S	11'-0"	11'-0"
G21N / G21S	11'-0"	11'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS SEE DRAWING FS-MTR-S-0300.
2. DUCT SUPPORT STEEL NOT SHOWN FOR CLARITY.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTOR'S/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	02-28-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-S-0302.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

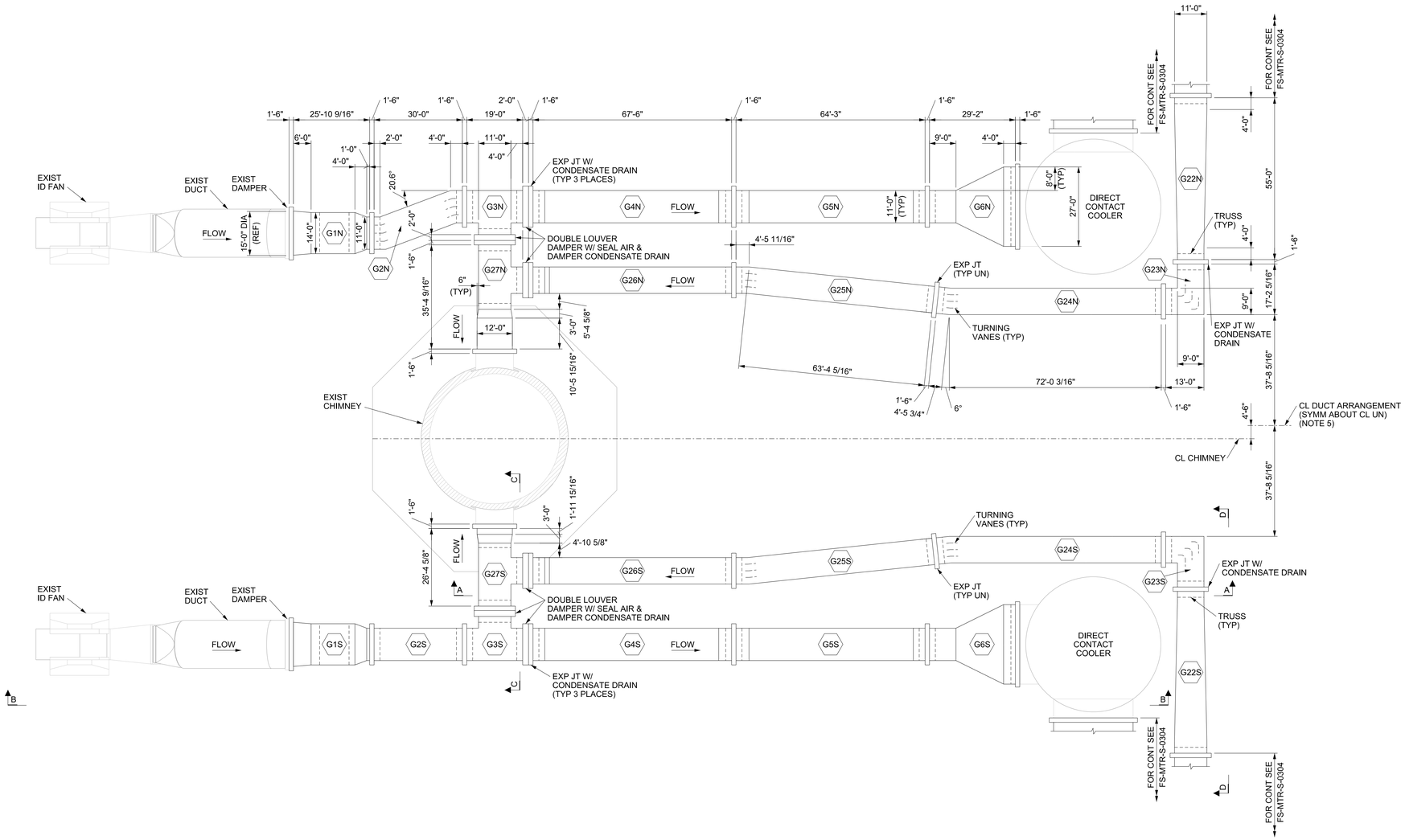
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DUCT ISOMETRIC
DIRECT CONTACT COOLERS
TO CARBON CAPTURE MEMBRANES

DRAWING NUMBER	REVISION
FS-MTR-S-0302	0
SHEET OF	

ZL11463\0L7267\D:\models\DFMTR\002_FULL_SCALE\mtr-duc-FSducts.dgn
Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

2/28/2022 12:20:33 PM
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DUCT PLAN
EXISTING ID FANS TO DIRECT CONTACT COOLERS
SCALE: 1/16"=1'-0"

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS SEE DRAWING FS-MTR-S-0300.
2. FOR DUCT ELEVATIONS SEE DRAWING FS-MTR-S-0305.
3. TURNING VANES AND FLOW CONTROL DEVICE GEOMETRY SHOWN ARE GENERIC. COMPLETE GEOMETRY TO BE DETERMINED IN DETAILED DESIGN.
4. DUCT SUPPORT STEEL NOT SHOWN FOR CLARITY.
5. NORTH AND SOUTH DUCTWORK ARRANGEMENTS ARE OPPOSITE HAND UNLESS NOTED.

REFERENCE DRAWINGS

NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CAD FILE NAME: FS-MTR-S-0303.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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Sargent & Lundy

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

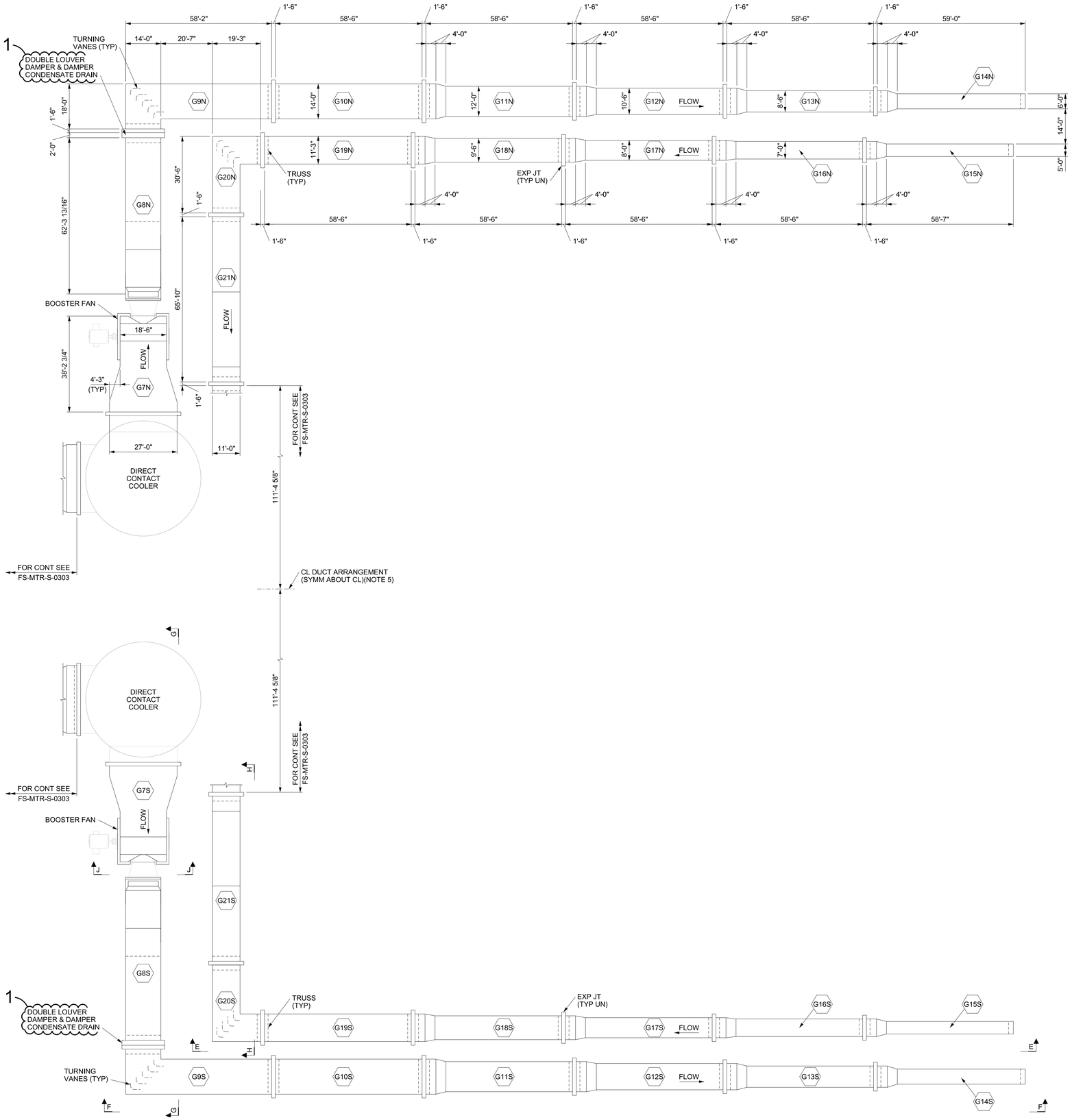
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DUCT PLAN
EXISTING ID FANS
TO DIRECT CONTACT COOLERS

DRAWING NUMBER	REVISION
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SHEET OF	

2/28/2022 12:21:20 PM
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009



DUCT PLAN
DIRECT CONTACT COOLERS TO CARBON CAPTURE MEMBRANES
SCALE: 1/16"=1'-0"

NORTH

HOLD INFORMATION	
NO.	DESCRIPTION

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REV.	DATE	DESCRIPTION
0	02-28-2022	FOR USE
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ISSUE PURPOSE:	USE
SPECIFICATION:	-
PROJECT NO.:	13978-002

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME:	FS-MTR-S-0304.DGN
PREPARED BY:	D.ZIMA
REVIEWED BY:	C.AINGE
APPROVED BY:	-

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CHICAGO, ILLINOIS 60603-5780

MEMBRANE TECHNOLOGY & RESEARCH

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES
1. FOR TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS SEE DRAWING FS-MTR-S-0300.
2. FOR DUCT ELEVATIONS SEE DRAWING FS-MTR-S-0305.
3. TURNING VANES AND FLOW CONTROL DEVICE GEOMETRY SHOWN ARE GENERIC. COMPLETE GEOMETRY TO BE DETERMINED IN DETAILED DESIGN.
4. DUCT SUPPORT STEEL NOT SHOWN FOR CLARITY.
5. NORTH AND SOUTH DUCTWORK ARRANGEMENTS ARE OPPOSITE HAND UNLESS NOTED.

REFERENCE DRAWINGS

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

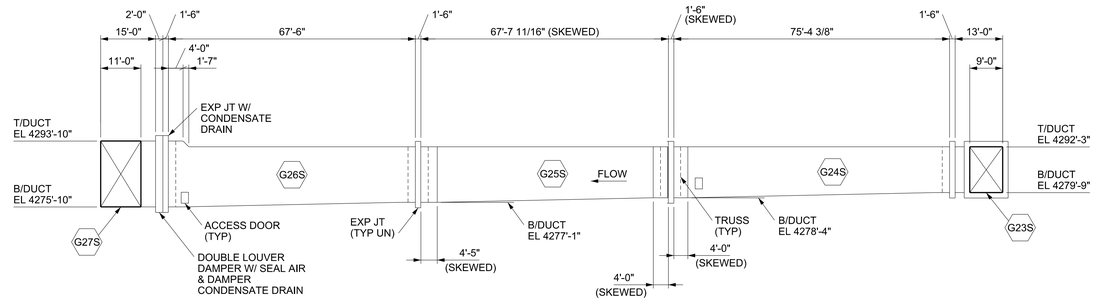
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DUCT PLAN
DIRECT CONTACT COOLERS
TO CARBON CAPTURE MEMBRANES

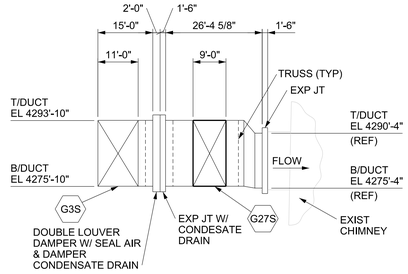
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SHEET	OF

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

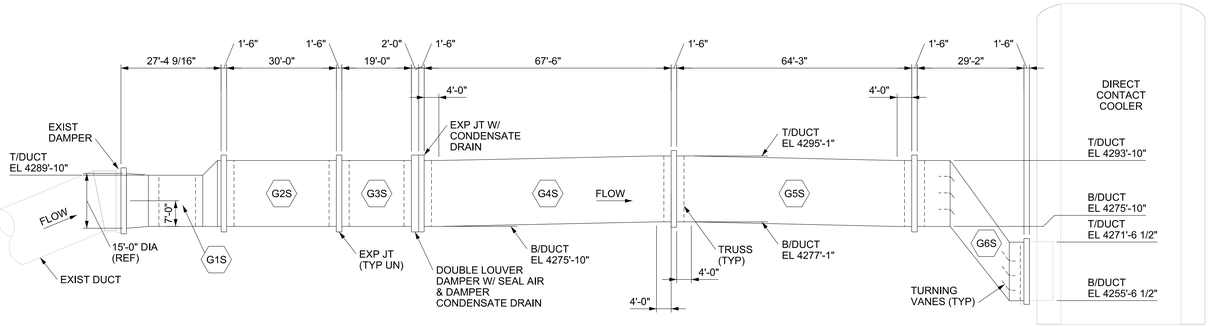
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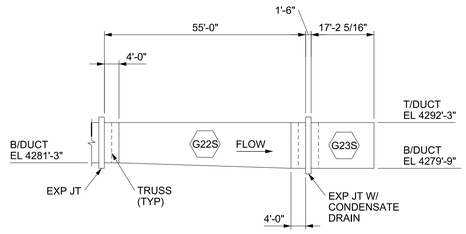
ELEVATION A
SCALE: 1/16"=1'-0"
LOOKING NORTH



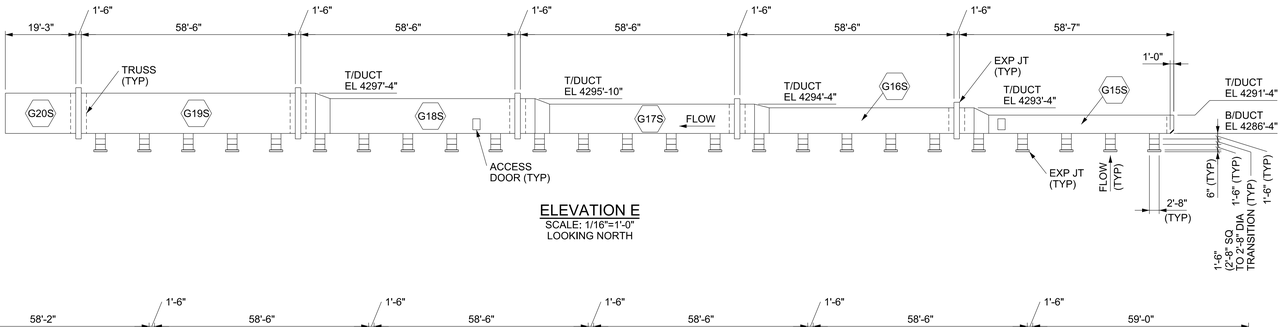
ELEVATION C
SCALE: 1/16"=1'-0"
LOOKING WEST



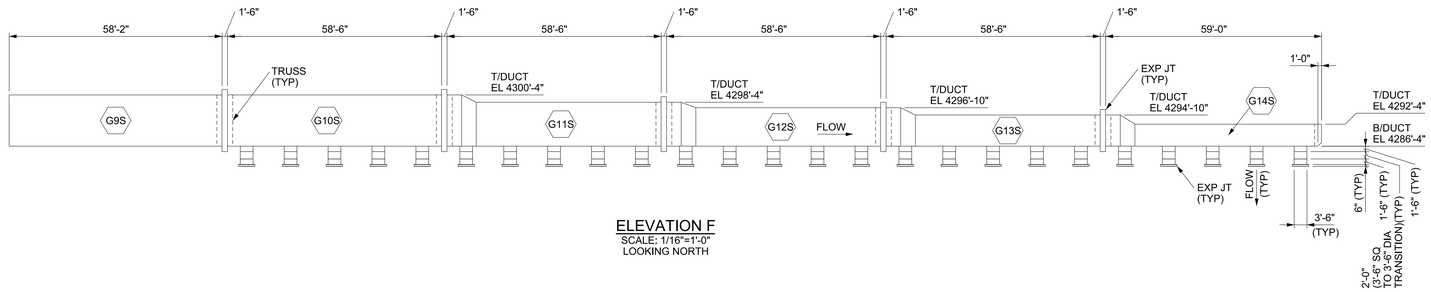
ELEVATION B
SCALE: 1/16"=1'-0"
LOOKING NORTH



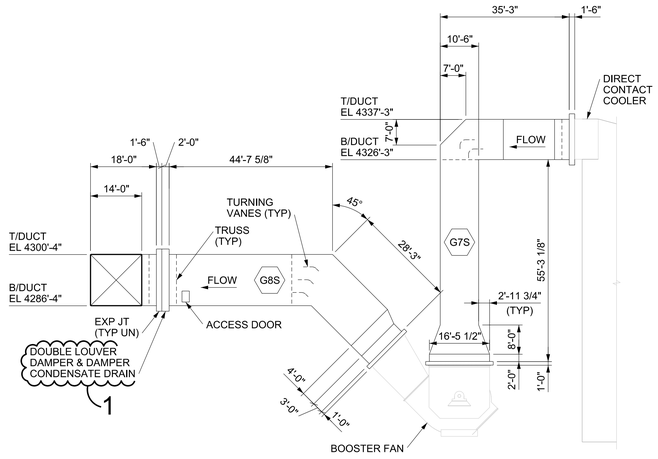
ELEVATION D
SCALE: 1/16"=1'-0"
LOOKING WEST



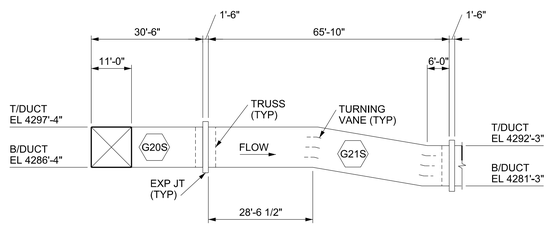
ELEVATION E
SCALE: 1/16"=1'-0"
LOOKING NORTH



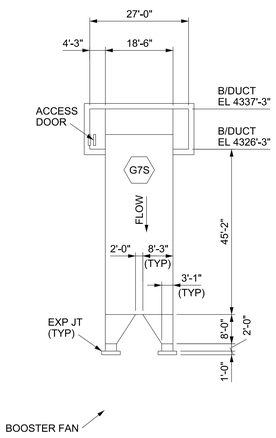
ELEVATION F
SCALE: 1/16"=1'-0"
LOOKING NORTH



ELEVATION G
SCALE: 1/16"=1'-0"
LOOKING WEST



ELEVATION H
SCALE: 1/16"=1'-0"
LOOKING WEST



ELEVATION J
SCALE: 1/16"=1'-0"
LOOKING NORTH

HOLD INFORMATION

NO.	DESCRIPTION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	02-28-2022	FOR USE
1	03-08-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION: -

PROJECT NO.: 13978-002

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CAD FILE NAME: FS-MTR-S-0305.DGN

PREPARED BY: D.ZIMA

REVIEWED BY: C.AINGE

APPROVED BY: -

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CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

1. FOR TYPICAL DUCT ARRANGEMENT SECTIONS & DETAILS SEE DRAWING FS-MTR-S-0300.
2. TURNING VANES AND FLOW CONTROL DEVICE GEOMETRY SHOWN ARE GENERIC. COMPLETE GEOMETRY TO BE DETERMINED IN DETAILED DESIGN.
3. DUCT SUPPORT STEEL NOT SHOWN FOR CLARITY.

REFERENCE DRAWINGS

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

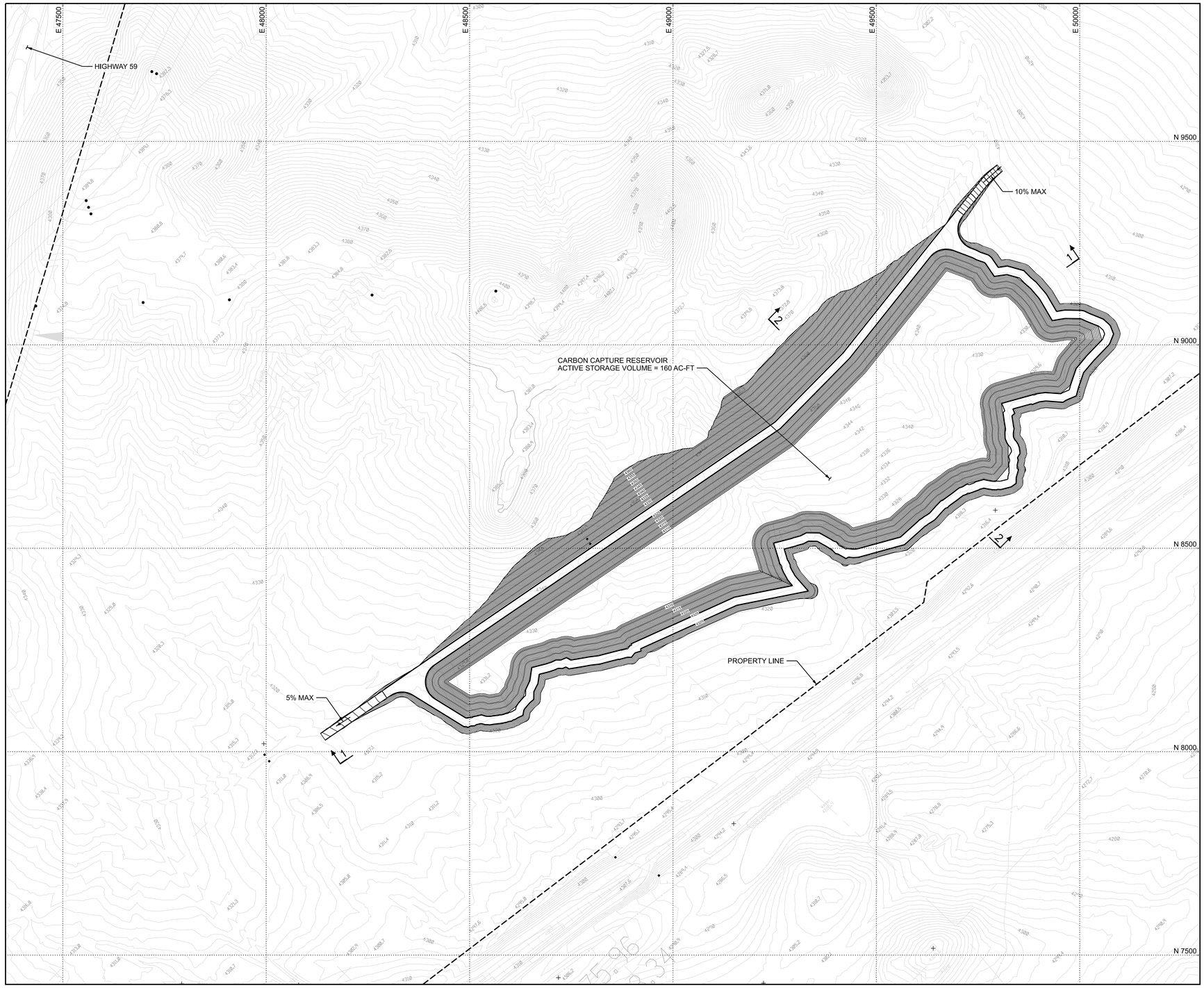
DRAWING TITLE

DUCT ELEVATIONS

DRAWING NUMBER	REVISION
FS-MTR-S-0305	1
SHEET OF	

ZL11463\0L7267\D:\models\DFMTR\mtr-duc-FS\ducts.dgn
Form GDG-0401-01-06, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
3/8/2022 8:44:21 AM
$FILEABBREVS

APPENDIX MM. CIVIL DRAWINGS



PRELIMINARY
NOT FOR CONSTRUCTION

NORTH
100' 0' 100' 200'
GRAPHIC SCALE

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

REFERENCES RELATING TO THE UNDERGROUND OR EMBEDDED UTILITIES ARE PROVIDED TO ASSIST THE CONTRACTOR/INSTALLER IN THE FIELD LOCATING THOSE UTILITIES AND OTHER POSSIBLE UNDERGROUND OR EMBEDDED INTERFERENCES WITH THE WORK.

THE CONTRACTOR/INSTALLER SHALL EXERCISE DUE CAUTION DURING ALL EXCAVATION/FOUNDATION/DEMOLITION WORK.

NOTES

1. AERIAL BACKGROUND SHOWN ON PLAN IS FROM GOOGLE EARTH PRO 7.3. IMAGE DATE JULY 26, 2014.
2. COORDINATES SHOWN REFER TO THE PLANT COORDINATE SYSTEM.
3. EXISTING SITE TOPOGRAPHIC SURVEY PER INITIAL DRY FORK STATION CONSTRUCTION.

REFERENCE DRAWINGS

NO.	DESCRIPTION

HOLD INFORMATION

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RELEASE INFORMATION

REV.	DATE	DESCRIPTION
0	03-01-2022	FOR USE

ISSUE PURPOSE: USE

SPECIFICATION:

PROJECT NO.: A13978.002

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-C-0001.DGN

PREPARED BY: A. PAAPE

REVIEWED BY: M. TURNER

APPROVED BY: D. PIERIK

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CHICAGO, ILLINOIS 60603-5780

MTR
MEMBRANE
TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

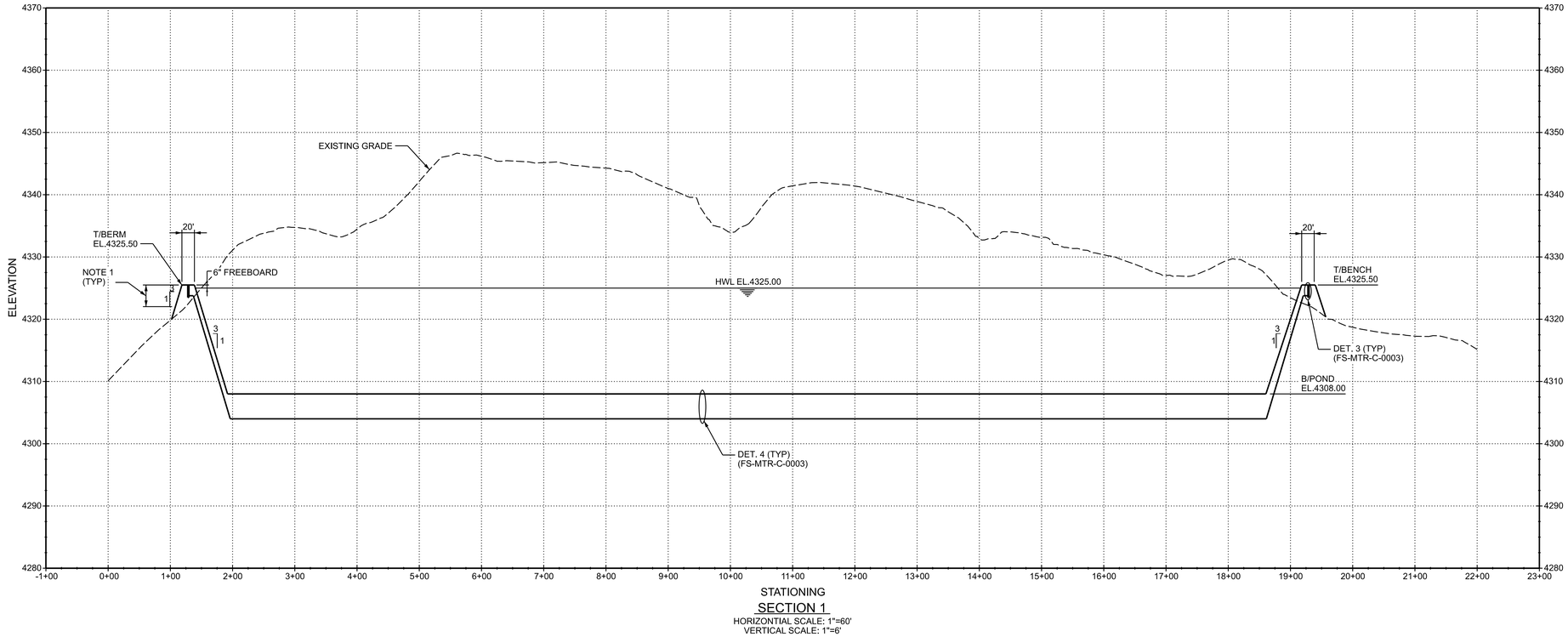
CARBON CAPTURE RESERVOIR PLAN

DRAWING NUMBER	REVISION
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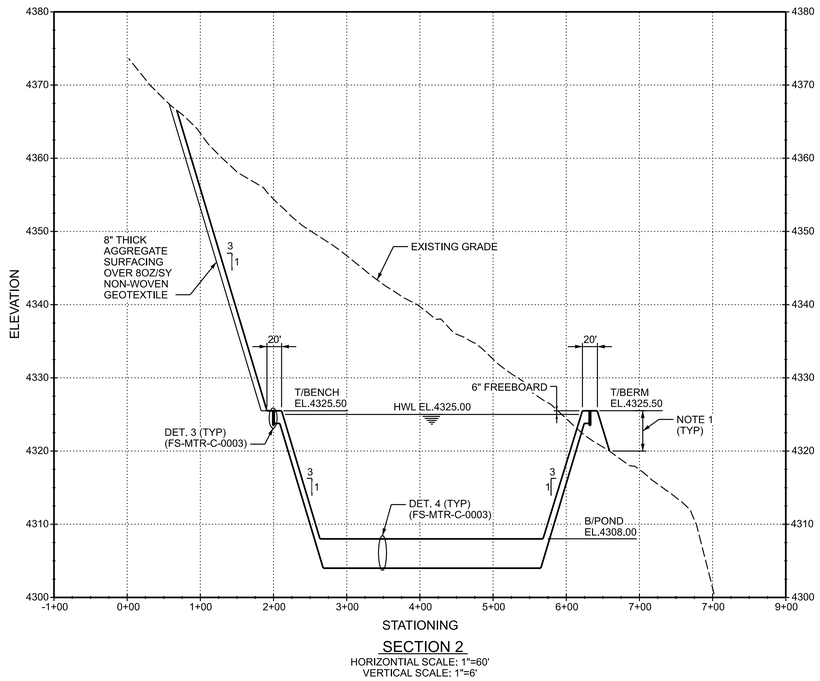
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Revision 10, Revision Date: 10-16-2009

2/28/2022 4:53:24 PM
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SECTION 1

HORIZONTIAL SCALE: 1"=60'
VERTICAL SCALE: 1"=6'



SECTION 2

HORIZONTIAL SCALE: 1"=60'
VERTICAL SCALE: 1"=6'

NOTES

1. MAXIMUM BERM HEIGHT SHALL BE 5.5' FROM EXISTING GRADE TO TOP OF BERM.

REFERENCE DRAWINGS

UNDERGROUND OR EMBEDDED UTILITIES MAY BE LOCATED WITHIN OR ADJACENT TO THE AREA IN WHICH EXCAVATION, DEMOLITION, FOUNDATION, OR MODIFICATION WORK IS TO BE PERFORMED.

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PRELIMINARY
NOT FOR CONSTRUCTION

HOLD INFORMATION

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ISSUE PURPOSE: USE

SPECIFICATION:

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CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-C-0002.DGN

PREPARED BY: A. PAAPE

REVIEWED BY: M. TURNER

APPROVED BY: D. PIERIK

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Sargent & Lundy

SARGENT & LUNDY
55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

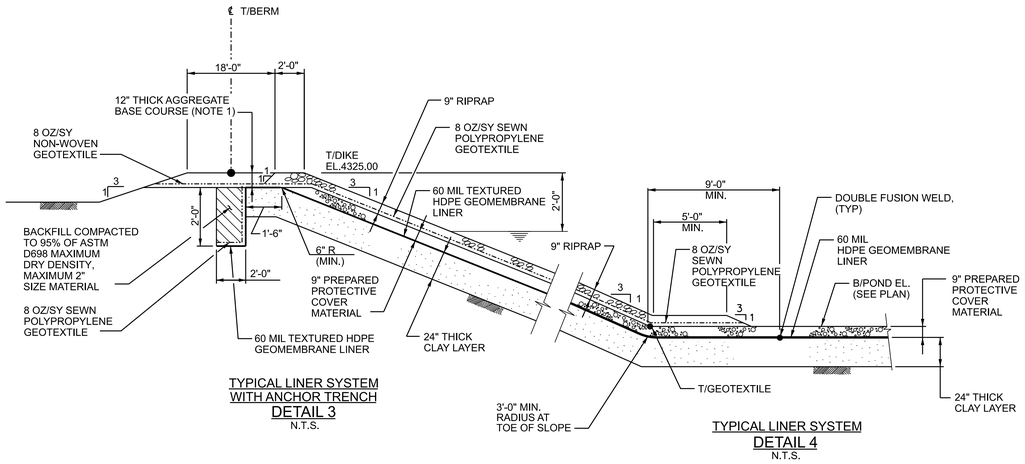
CARBON CAPTURE RESERVOIR CROSS SECTIONS

DRAWING NUMBER	REVISION
FS-MTR-C-0002	0

SHEET 01 OF 01

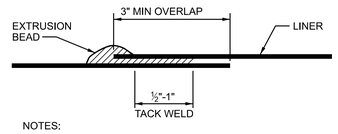
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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009

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TYPICAL LINER SYSTEM
WITH ANCHOR TRENCH
DETAIL 3
N.T.S.

TYPICAL LINER SYSTEM
DETAIL 4
N.T.S.

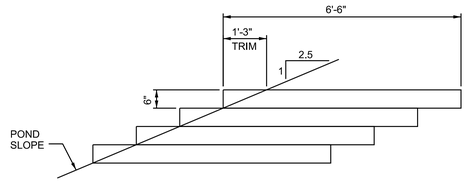


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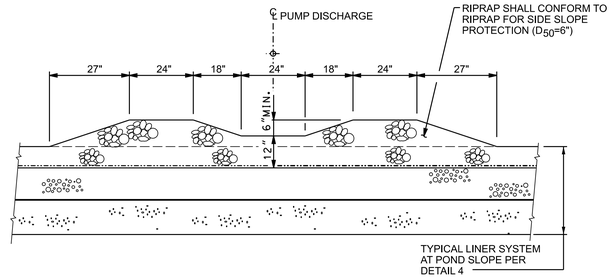
A. LINER SHEETS TACK-WELDED TOGETHER AT OVERLAP PRIOR TO EXTRUDING.

B. EXTRUSION WELDING USED FOR DETAIL WORK AND REPAIR WORK ONLY.

TYPICAL EXTRUSION WELD
DETAIL A
N.T.S.



TYPICAL CLAY PLACEMENT IN HORIZONTAL LIFTS
DETAIL B
N.T.S.



PUMP DISCHARGE RIPRAP DOWNCOMER
DETAIL C
N.T.S.

PRELIMINARY
NOT FOR CONSTRUCTION

NOTES

1. AGGREGATE SHALL BE PLACED IN MAXIMUM 6" LIFTS AND COMPACTED TO 95% PER ASTM D1557.

REFERENCE DRAWINGS

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PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

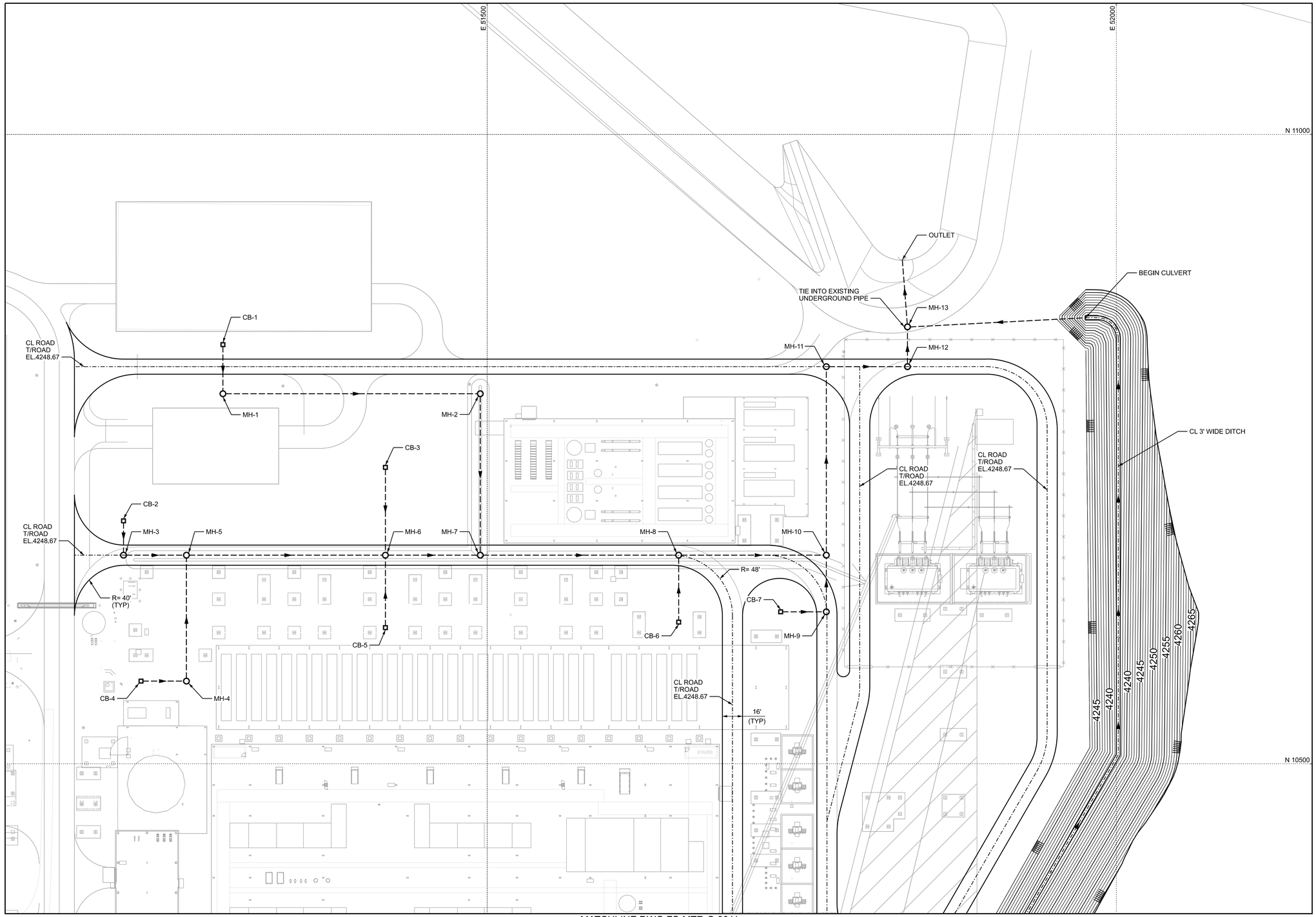
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MATCHLINE DWG FS-MTR-C-0011

NOTES

1. COORDINATES SHOWN REFER TO THE PLANT COORDINATE SYSTEM.
2. EXISTING SITE TOPOGRAPHIC SURVEY PER INITIAL DRY FORK STATION CONSTRUCTION.

NORTH

30' 0' 30' 60'

GRAPHIC SCALE

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REFERENCE DRAWINGS

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CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

CARBON CAPTURE
GRADING AND DRAINAGE PLAN
SHEET 1

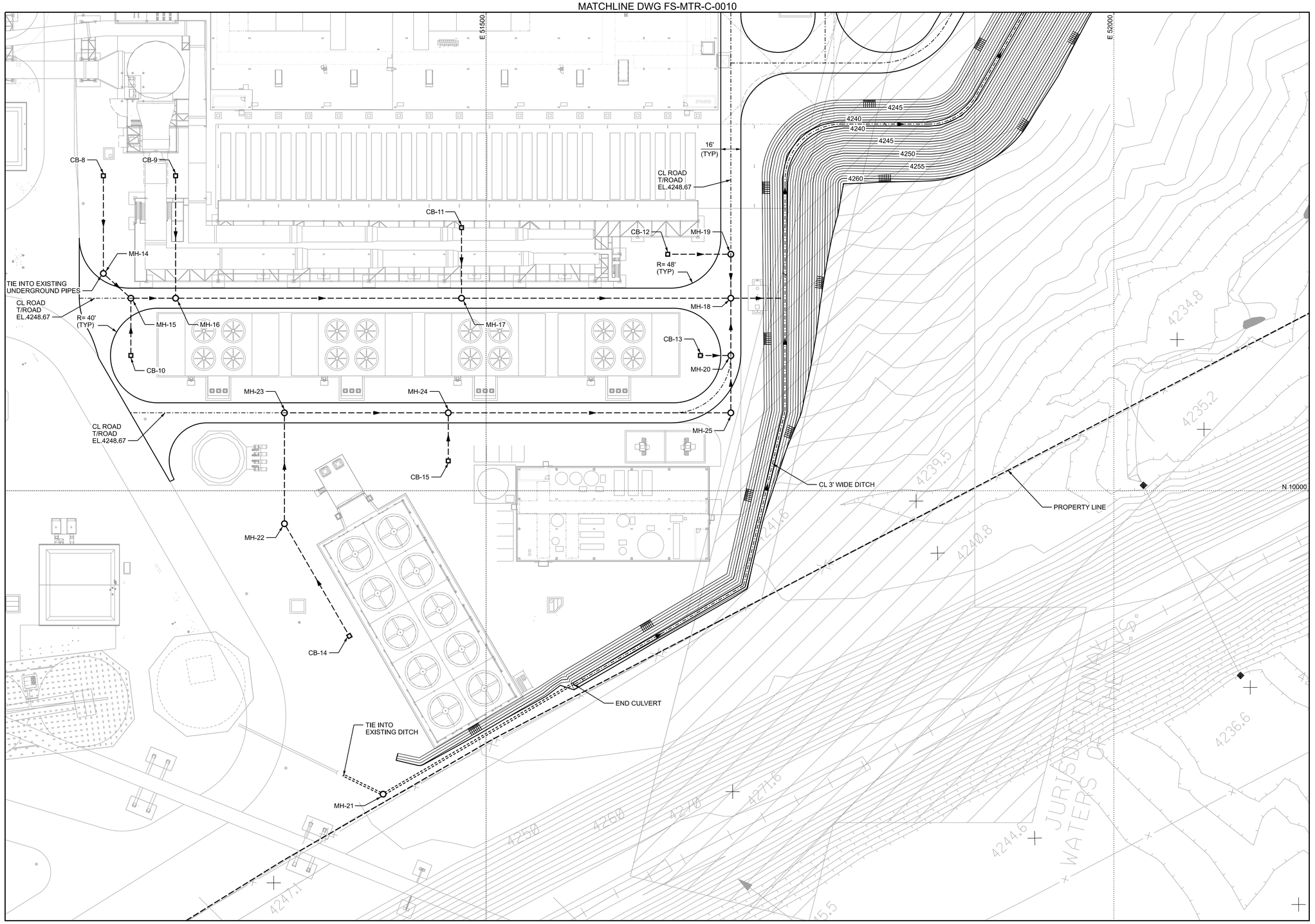
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NOTES

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NORTH

30' 0' 30' 60'

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CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

CARBON CAPTURE
GRADING AND DRAINAGE PLAN
SHEET 2

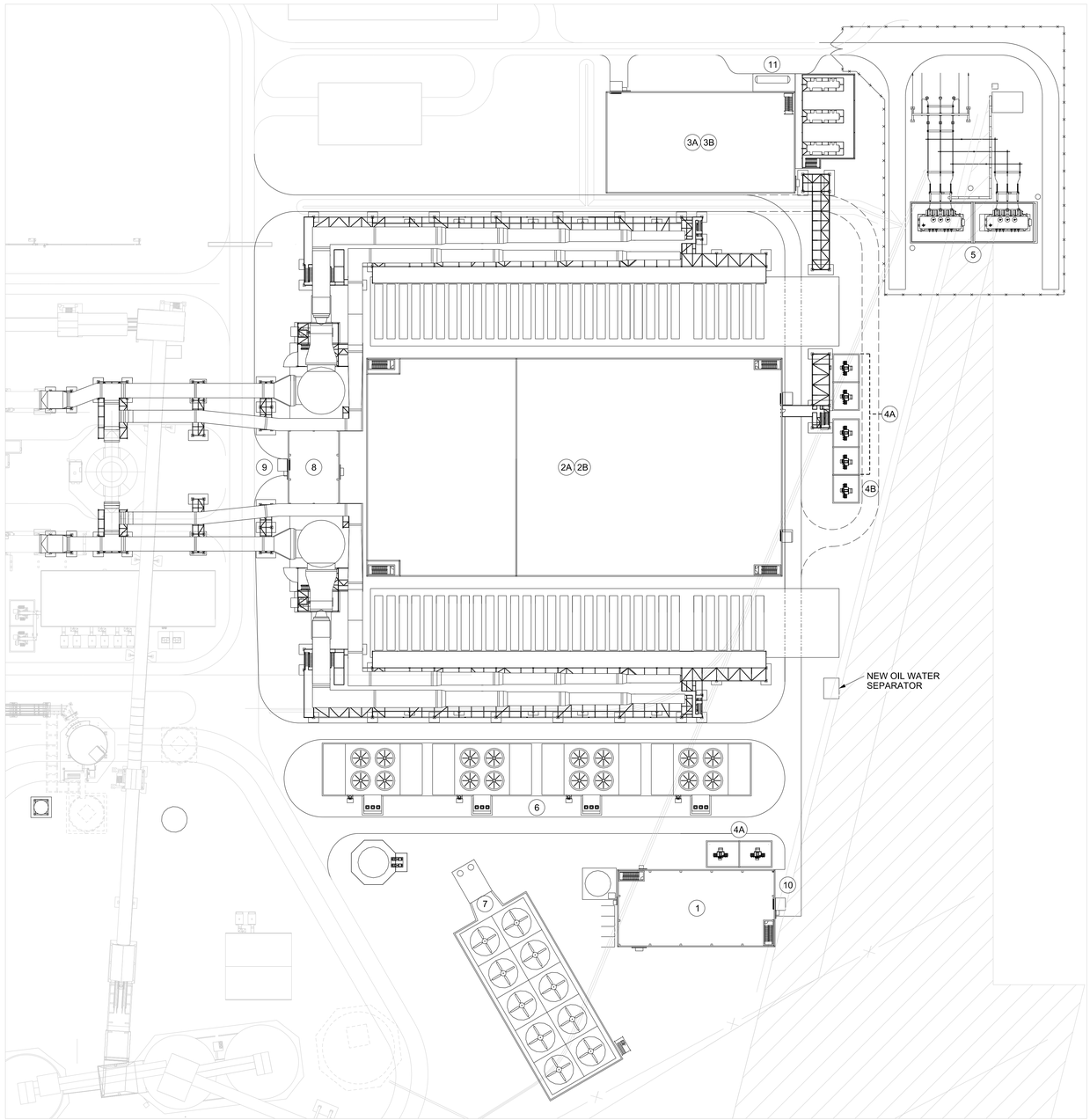
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Revision 10, Revision Date: 10-16-2009

SPIL CONTAINMENT LEGEND				
NO.	CONTAINMENT AREA	EQUIPMENT	POTENTIAL SPILL	CONTAINMENT TYPE
1	WATER TREATMENT BUILDING	WATER TREATMENT EQUIPMENT	MISCELLANEOUS WATER TREATMENT, WSAC & CT CHEMICALS	CONCRETE CURB ALONG BUILDING PERIMETER INTERIOR CONCRETE TRENCHES & BUILDING SUMPS
2A	CARBON CAPTURE EQUIPMENT BUILDING	FAN & CO2 COMPRESSOR LUBE OIL SKIDS, COMPRESSED AIR EQUIPMENT, MISC BOP EQUIPMENT	OIL	FLOOR DRAINS, SUMPS & PIPING TO NEW OIL WATER SEPARATOR
2B	CARBON CAPTURE EQUIPMENT BUILDING	CO2 COMPESSORS, HEAT EXCHANGERS / KNOCKOUT	PROCESS WATER CONDENSATE	FLOOR DRAINS, SUMPS & PIPING TO ABOVE GROUND STORAGE TANK
3A	CO2 PURIFICATION UNIT BUILDING	CO2 PUMPS LUBE OIL SKIDS, MISC BOP EQUIPMENT	OIL	FLOOR DRAINS, SUMPS & PIPING TO NEW OIL WATER SEPARATOR
3B	CO2 PURIFICATION UNIT BUILDING	DEHYDRATION SEPARATORS	PROCESS WATER CONDENSATE	FLOOR DRAINS, SUMPS & PIPING TO ABOVE GROUND STORAGE TANK
4A	13800V - 4160V TRANSFORMERS	OIL-FILLED TRANSFORMERS	OIL	CONCRETE CURBED CONTAINMENT W/ LOCAL GRAVITY DRAIN TO NEW OIL WATER SEPARATOR
4B	13800V - 13800V TRANSFORMER	OIL-FILLED TRANSFORMERS	OIL	CONCRETE CURBED CONTAINMENT W/ LOCAL GRAVITY DRAIN TO NEW OIL WATER SEPARATOR
5	230kV SUBSTATION TRANSFORMERS	OIL-FILLED TRANSFORMERS	OIL	CONCRETE CURBED CONTAINMENT W/ LOCAL GRAVITY DRAIN TO NEW OIL WATER SEPARATOR
6	WET SURFACE AREA COOLERS	WET SURFACE AIR COOLERS	PROCESS WATER	CONCRETE BASIN BELOW EQUIPMENT (PROCESS WATER IS RECIRCULATED INTO PROCESS)
7	COOLING TOWER	COOLING TOWER	PROCESS WATER	CONCRETE BASIN BELOW EQUIPMENT (PROCESS WATER IS RECIRCULATED INTO PROCESS)
8	DCC AUXILIARY EQUIPMENT BUILDING	CAUSTIC STORAGE TANK, CHEMICAL PUMPS, DCC PUMPS	OIL, CAUSTIC	CONCRETE CURB AROUND CAUSTIC STORAGE & CHEMICAL PUMPS, BUILDING SUMP & PIPING TO NEW OIL WATER SEPARATOR
9	DCC TRUCK UNLOADING	TRUCK DELIVERIES	DRIPS & DRABS FROM TRUCK UNLOADING (CAUSTIC)	CONCRETE PAD W/ LOCAL SUMP TO STORM SEWER W/ ISOLATION VALVE FOR TRUCK DELIVERIES
10	WASTEWATER TREATMENT TRUCK UNLOADING	TRUCK DELIVERIES	DRIPS & DRABS FROM TRUCK UNLOADING (MISC CHEMICALS)	CONCRETE PAD W/ LOCAL SUMP TO STORM SEWER W/ ISOLATION VALVE FOR TRUCK DELIVERIES
11	CPU BUILDING TRUCK UNLOADING	TRUCK DELIVERIES	DRIPS & DRABS FROM TRUCK UNLOADING (REFRIGERANT)	CONCRETE PAD W/ LOCAL SUMP TO STORM SEWER W/ ISOLATION VALVE FOR TRUCK DELIVERIES



SPILL CONTAINMENT PLAN
SCALE: 1"=50'

PRELIMINARY
NOT TO BE USED FOR CONSTRUCTION

NOTES

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MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

SPILL CONTAINMENT PLAN

DRAWING NUMBER	REVISION
FS-MTR-C-0100	0
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Revision 10, Revision Date: 10-16-2009

APPENDIX OO. EXISTING STACK REUSE ASSESSMENT

MTR Dry Fork– Preliminary Evaluation for Re-Using Existing Stack Post Carbon Capture

September 30, 2020
Rev. 1

Variable Inputs for Parametric Evaluation

The following cases were evaluated for the existing 500 ft stack.

Stack Cases	1	2	3	4	5
Description	Current Conditions	Post Carbon Capture	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat
Exhaust Temp (°F)	213.3	75.6	90.6	105.6	125.6
Moisture Rate (lb/hr)	612,433	9,545	9,545	9,545	9,545
Exhaust Velocity (ft/s)	96	55	55[1]	55[1]	55[1]
Results (Visual Impacts)	No visual impacts	No visual impacts	No visual impacts	No visual impacts	No visual impacts

Note 1 - The exhaust velocity for cases 3-5 would increase as the temperature increases (i.e. larger flue gas volume); however, for the purpose of modeling efforts, the velocities were kept artificially low at 55 fps in order to be conservative.

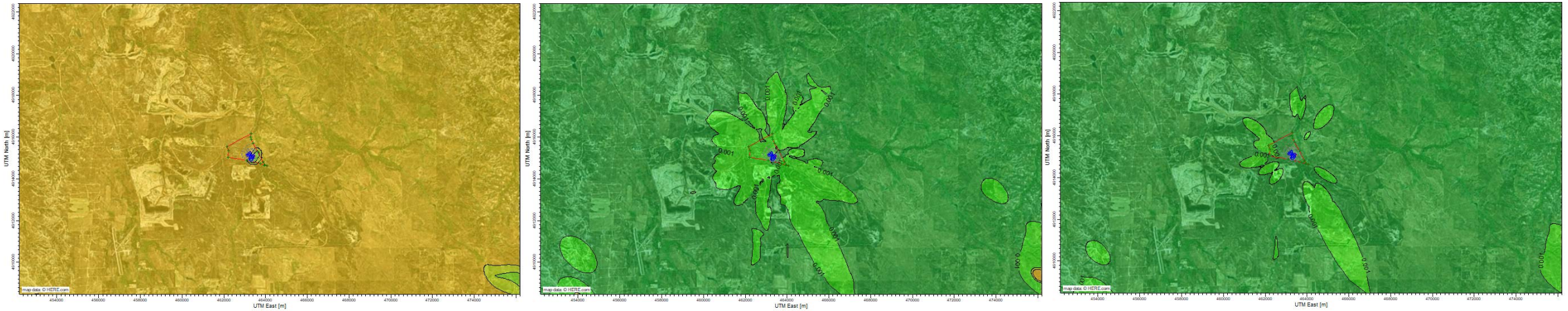
Liquid Water Content Concentration Plots: Stack Condition Comparison

Sargent & Lundy

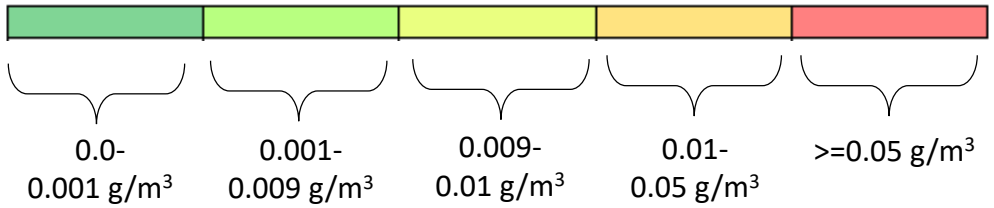
Case 1
Current Conditions

Case 2
Post Carbon Capture

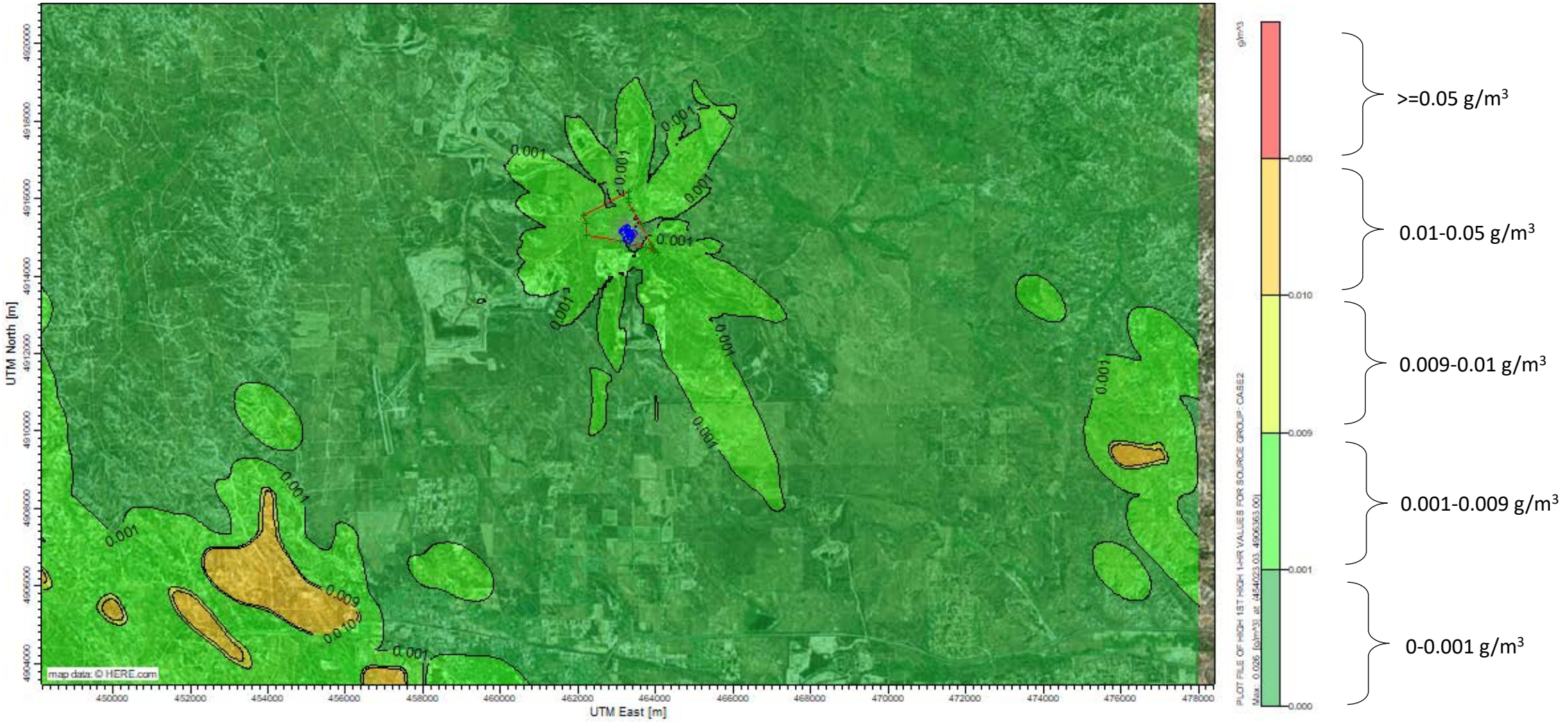
Case 3
Post Carbon Capture w/ Reheat



AERMOD Ground-Level Concentration Plots



Liquid Water Content Concentration Plot: Case 2 Post Carbon Capture without Reheat



AERMOD Ground-Level Concentration Plot

Variable Inputs for SO2 Evaluation

The following cases were evaluated for the existing 500 ft stack.

Stack Cases	1	2	3	4	5
Description	Current Conditions	Post Carbon Capture	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat
Exhaust Temp (°F)	213.3	75.6	90.6	105.6	125.6
SO_2 Rate (lb/hr)	312[1]	50	50	50	50
Exhaust Velocity (ft/s)	96	55	55	55	55

Note 1: SO_2 emissions for current conditions reflect the average of the highest 5% of hourly emissions data at loads ≥ 422 MWg as recorded in the station PI Data, taken from Jan. 1, 2017 through Dec. 31, 2017 in order to be conservative for sizing supporting equipment for the carbon capture system. It should be noted that the facility's existing Operating Air Permit includes a maximum 30-day rolling SO_2 emission limit of 285.1 lb/hr, as such, the SO_2 emission rate reflects the conservative instantaneous hourly rate and is not representative of a 30-day rolling average.

Variable Inputs for NO2 Evaluation

The following cases were evaluated for the existing 500 ft stack.

Stack Cases	1	2	3	4	5
Description	Current Conditions	Post Carbon Capture	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat	Post Carbon Capture w/ Reheat
Exhaust Temp (°F)	213.3	75.6	90.6	105.6	125.6
NO_2 Rate (lb/hr)[1]	196[2]	196	196	196	196
Exhaust Velocity (ft/s)	96	55	55	55	55

Note 1: Tier 1 NO_2 evaluation, assumes all NOx converts to NO_2 (most conservative scenario)
Note 2: NOx emissions. for current conditions reflect the average of the highest 5% of hourly emissions data at loads ≥ 422 MWg as recorded in the station PI Data, taken from Jan. 1, 2017 through Dec. 31, 2017 in order to be conservative for sizing supporting equipment for the carbon capture system. It should be noted that the facility's existing Operating Air Permit includes a maximum 30-day rolling NOx emission limit of 190.1 lb/hr, as such, the NOx emission rate reflects the conservative instantaneous hourly rate and is not representative of a 30-day rolling average.

Preliminary SO2 & NO2 Results[1]

The following cases were evaluated for the existing 500 ft stack.

Stack Cases	1	2	3	4	5
SO_2 Preliminary Results					
SO_2 Max Concentration (ug/m^3)[2]	7.31	18.86	5.38	3.05	2.21
NAAQS 1-hr Standard (ug/m^3)	196.5	196.5	196.5	196.5	196.5
Percent of NAAQS	4%	10%	3%	2%	1%
NO_2 Preliminary Results					
NO_2 Max Concentration (ug/m^3)[3,4]	3.78	32.99	9.44	8.57	7.82
NAAQS 1-hr Standard (ug/m^3)	188	188	188	188	188
Percent of NAAQS	2%	18%	5%	5%	4%

Note 1: Preliminary evaluation, not for regulatory purposes
Note 2: 1-hr 99% Percentile (4th highest) Daily Max
Note 3: 1-hr 98% Percentile (8th highest) Daily Max
Note 4: Tier 1 NO_2 evaluation, assumes all NOx converts to NO_2 (most conservative scenario)

Preliminary Evaluation Summary

- For all post carbon capture cases:
  - The moisture concentration is estimated to be lower than current conditions and, therefore, no visual impacts or plume downwash issues are expected.
  - SO_2 concentrations are not expected to exceed the NAAQS standards.
  - NO_2 concentrations are not expected to exceed the NAAQS standards.
- For all three evaluations, reheat of the plume is not expected to be necessary to mitigate the moisture, SO_2, or NO_2 concentrations.

APPENDIX RR. COMPRESSOR SYSTEM OVERPRESSURE RELIEF STUDY



Membrane Technology & Research

DRY FORK STATION UNIT 1

FULL SCALE CARBON CAPTURE FEED STUDY PROJECT

COMPRESSOR SYSTEM OVERPRESSURE RELIEF STUDY

Issued for Use
Rev. 0

March 23, 2022
Project 13978-002

Prepared by



55 East Monroe Street • Chicago, IL 60603 USA • 312-269-2000

ISSUE SUMMARY			
Revision	**Issue Purpose**	**Issue Date**	**Sections Affected**
0	For Use	03/23/2022	All

PREPARED, REVIEWED, AND APPROVED				
Revision	**Discipline**	**Prepared**	**Reviewed**	**Approved**
0	Mechanical	Digitally signed by Kelly Gandy Date: 2022.03.23 16:10:17-05'00' Kelly Gandy	Digitally signed by Marion Teslik Date: 2022.03.23 16:11:45-05'00' Marion Teslik	Dana B. Pierik

TABLE OF CONTENTS

1. INTRODUCTION 1

2. COMPRESSOR SYSTEM OVERPRESSURIZATION PROTECTION 1

FIGURES

Table 2-1: Compressor System Overpressure Protection Matrix

ATTACHMENTS

Attachment A: Carbon Capture Compressor System Boundaries

1. INTRODUCTION

Membrane Technology and Research, Inc. (MTR) is performing a full scale, Front End Engineering Design (FEED) study, sponsored by the US Department of Energy, for the retrofit of its membrane CO_2 capture technology at the Dry Fork Station (DFS); a coal fired plant located in Gillette, WY and operated by Basin Electric Power Cooperative (BEPC). Carbon dioxide (CO_2) is filtered out of the flue gas stream, purified by distillation, and compressed into pipeline quality CO_2 for transportation and/or storage. This document identifies possible sources of overpressurization within the Carbon Capture Compressor System and what measures will be taken to protect against it.

The process compressor system boundary begins at the "Membrane B" compressor through to the atmospheric vent lines and at the discharge flange to the high pressure CO_2 product. The refrigerant compressor system includes the entire refrigeration loop. Attachment A is a pictorial representation of the compressor systems' boundary. This overpressurization study does not cover the Balance of Plant (BOP) systems providing utilities and consumables to the CO_2 capture system, nor low pressure equipment and pipe/duct segments upstream of the Membrane B compressor.

2. COMPRESSOR SYSTEM OVERPRESSURIZATION PROTECTION

Table 2-1 below is a matrix of the compressor system components, corresponding pressure ratings and overpressure sources; if an overpressure event is possible, the protection method is identified. Overpressure sources listed in table 2-1 are preliminary and shall be evaluated further in the detailed engineering phase, when all vendor information is available. American Petroleum Institute (API) Standard 521: Pressure Relieving and Depressurizing Systems, was consulted for overpressure sources; the list below indicates which API 521 sections apply for each type of equipment:

- Vessels: Sections 4.4.2, 4.4.7, 4.4.12, 4.4.13
- Heat Exchangers: Sections 4.4.2, 4.4.13, 4.4.14
- Pumps: Sections 4.4.2, 4.4.8, 4,4,13, 4.4.15
- Compressors: Sections 4.4.2, 4.4.8, 4.4.13, 4.4.15

Table 2-1: Compressor System Overpressure Protection Matrix

Equipment	P&ID Tag	Pressure Rating [psig]	Overpressure Source (Note 3)	Protection	PSV P&ID Tag
Vessels					
MEMB Compressor KO Drum Header	Later	Later	Closed Drain Valve	PSV	Later
Dehydration Feed Separator	1CC-T8001A/B	Later	DHY Valve Skid Failure	PSV	Later
Dehydration Bed/Vessels	1CC-T8002A/B 1CC-T8003A/B 1CC-T8004A/B 1CC-T8005A/B	Later	DHY Valve Skid Failure	PSV	Later
Dehydration Bed After Filters	1CC-F8094A/B 1CC-F8095A/B	Later	Closed CO2 Outlet	PSV	Later
CO2 Stripper	1CC-T8007A/B	Later	Closed CO2 Outlet	PSV	Later
Reflux Drum	1CC-T8006A/B	Later			Later
Main Reboiler	1CC-A80014A/B	Later	Exothermic Reaction	PSV	Later
Auxiliary Reboilers	1CC-A8017A/B 1CC-A8018A/B	Later	Closed Water Outlet	Open to Atm	Later
Membrane C	1CC-F8096	Later	Closed MEMC Outlet Valve	PSV	Later
Membrane D	1CC-F8097	Later	Closed MEMD Outlet Valve	PSV	Later
Hi Pressure Refrigeration Receiver	1RG-T8001	Later			Later
Heat Exchangers					
MEMB Compressor Aftercooler		Later	Tube Rupture, CO2 Leak to Coolant Side	System Pressure Rating	Later
Dehydration Feed Chiller	1CC-A8012A/B	Later	Tube Rupture, CO2 Leak to Coolant Side	System Pressure Rating	Later
CO2 Condenser	1CC-A8015A/B 1CC-A8016A/B	Later	Closed CO2 Outlet	PSV	Later

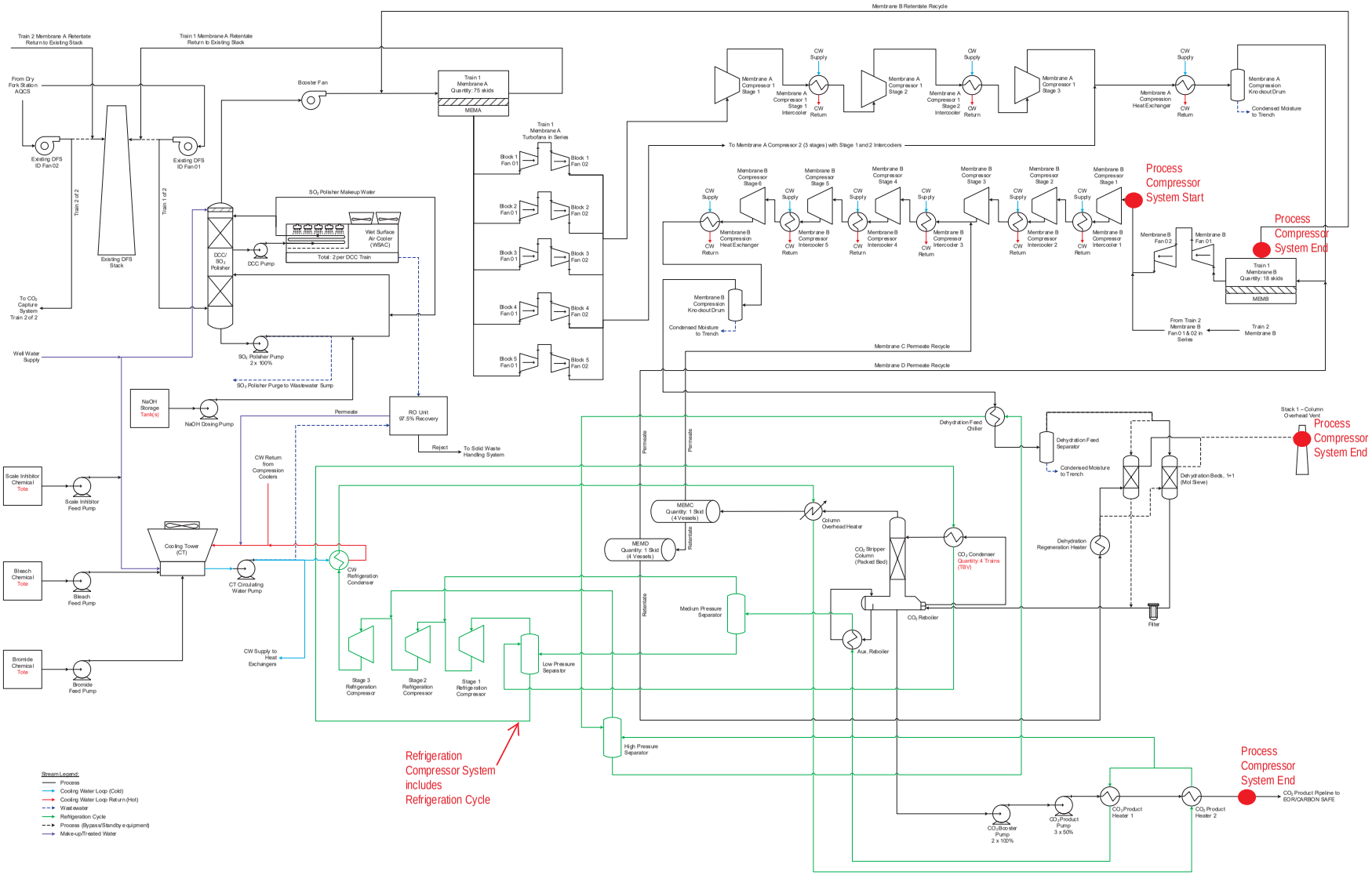
Equipment	P&ID Tag	Pressure Rating [psig]	Overpressure Source (Note 3)	Protection	PSV P&ID Tag
Column Overhead Heater	1CC-A8019A/B	Later	Ruptured CO2 Tube	PSV	Later
CO2 Product Heaters	1CC-A8022A/B 1CC-A8023A/B	Later	Ruptured CO2 Tube	PSV	Later
Vent Gas Heater	Later	Later	Rich Stream CO2 Breakout	PSV	Later
Refrigerant Condenser	1RG-A8001A/B/C	Later	Rich Stream CO2 Breakout	PSV	Later
Pumps (Note 1)					
Reflux Pumps	1CC-P8001A/B 1CC-P8002A/B	Later	Blocked Flow	System Pressure Rating	Later
CO2 Booster Pumps	1CC-P8003A/B 1CC-P8004A/B	Later	Blocked Flow	System Pressure Rating	Later
CO2 Product Pumps	1CC-P8005A/B/C	Later	Blocked Flow	System Pressure Rating	Later
Compressors					
MEMB Compressor (Stages 1-6)	Later	Later	Closed CO2 Outlet	PSV	Later
Refrigeration Compressors	1RG-C8001A 1RG-C8002B 1RG-C8003C	Later			Later
Note 1: Thermal relief valves for pumps, piping, or valves are not considered. TRV's will be required in segments where liquid CO2 can be blocked in; to be addressed in the detailed engineering project phase.					
Note 2: PSV flow, backpressure, and size shall be determined during the detailed engineering project phase.					
Note 3: Refer to API 521 for comprehensive sources of over pressurization.					

ATTACHMENT A.

CARBON CAPTURE COMPRESSOR SYSTEM BOUNDARIES

Dry Fork Station Unit 1
Full-Scale Carbon Capture
Process Flow Diagram

Project: 13978-002
Initial Draft Rev. A
Date: July 30, 2021



APPENDIX SS. PROCESS HAZARD ANALYSIS REPORT

Membrane Technology & Research, Inc
Basin Electric Power Cooperative - Dry Fork Station (DFS)

DFS Full Scale Carbon Capture Preliminary PHA Report

SL – 016601

Revision 0

13 January 2022

Project No.: A13978.002

S&L Nuclear QA Program Applicable:

☐ Yes

☒ No

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(2) information and data provided by others, including Client, may not have been independently verified by S&L; and (3) the information and data contained in this deliverable are time-sensitive and changes in the data, applicable codes, standards, and acceptable engineering practices may invalidate the findings of this deliverable. Any use or reliance upon this deliverable by third parties shall be at their sole risk.

ISSUE SUMMARY PAGE

Rev #	Issue Purpose	Preparer Name & Title	Reviewer Name & Title	Approver Name & Title	Date
0	Issue for Use	Clay Dean, Associate II Clay L Dean Digitally signed by Clay L Dean DN: C=US, E=clay.l.dean@sargentlundy.com, O=S&L, OU=Process Engineering, CN=Clay L Dean Date: 2022.01.13 13:28:08-07'00' Elizabeth A. Berg, Process Safety Advisor Elizabeth Berg Digitally signed by Elizabeth Berg Date: 2022.01.13 13:33:21 -07'00'	Ryan Krone, Project Associate I Ryan Krone Digitally signed by Ryan Krone Date: 2022.01.13 14:58:29 -06'00'	Dana B. Pierik, Project Manager	01/13/2022

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1. PURPOSE & SCOPE

The process hazard analysis (PHA) study is the process that seeks to identify potential operating hazards and risks in systems and processes. This project is in the Front-End Engineering Design (FEED) for scoping and cost estimating. Therefore, not all design parameters and equipment have been finalized, and this Preliminary PHA was conducted at a higher level than what would be typical for a PHA study, in alignment with the preliminary status of the design. Herein, the study plan is referenced as a preliminary PHA. Section 4 outlines the methodologies that were utilized to carry out the analysis.

The project scope includes the installation of Membrane Technology & Research, Inc's (MTR) carbon capture membrane technology at Basin Electric Power Cooperative's (BEPC) Dry Fork Station (DFS) in Gillette, WY. MTR's carbon capture membrane system will be retrofitted onto the existing coal fired power plant to receive the plant's flue gas stream and capture 5,000 tonnes per day (TPD) of carbon dioxide (CO_2). The proposed CO_2 membrane capture system process design by MTR, with support from Electric Power Research Institute (EPRI), Trimeric, and Sargent & Lundy, LLC (S&L) was evaluated during the preliminary PHA.

The Preliminary PHA consisted of a systematic review of the available FEED stage piping & instrumentation diagrams (P&IDs) and process flow diagrams (PFDs) and supporting vendor packages to identify hazardous operating scenarios and potential areas of concern, in accordance with industry guidance, as outlined in Section 4. The Study Team utilized Nodal review for the methodical review of systems (listed in Appendix B). The applicable reference drawings are listed in Design Input (Section 6) and Appendix E. The PHA focused on the carbon capture process systems; the failure(s) of auxiliary systems were discussed with every process node impacted by its improper functioning.

The study was completed in November 2021 using Microsoft Teams and Sphera PHA-Pro 8 Software.

2. OBJECTIVE

The Preliminary PHA study is intended to review the safety and operability of all systems at a facility. Safe operation of these systems is of utmost importance to protect the employees and contractors (personnel), surrounding communities (public), the environment, equipment (asset/property, business interruption), and the company reputation (media). All sessions were based on the detailed design of the subject systems as depicted within the respective system P&IDs and PFDs. It should be noted that the Preliminary PHA was not intended to be a design review nor was it a means to find ways to change the design or create potential rework. The Preliminary PHA was intended to validate the design in its current state and ensure that any potential design gaps, hazards, or risks are mitigated properly, reliably, and safely. However, where necessary, recommendations were made as the Study Team discovered areas of concern with the design.

Changes to the design can be expected as the project progresses through phases to more robust and detailed design. The project team shall incorporate the results and findings of the Preliminary PHA during the finalization of estimating and in commencing and completing detailed design to ensure safe and reliable operations. It is expected that there will be a comprehensive HAZOP during the detailed design of the project.

3. STUDY TEAM

The Preliminary PHA Study Team consisted of numerous participants of various companies, work roles, and disciplines, as is an essential part of quality PHA meetings. The name, company, title, experience, and role of participant of the Preliminary PHA Study are outlined in Table 1, below. Daily attendance was tracked and recorded in Sphera PHA-Pro 8; the log is included in the worksheets in Appendix G.

Table 1: Preliminary PHA Study Team

Name	Company	Title	Experience	Role
Elizabeth Berg	S&L	Process Safety Advisor, Manager	10 years of experience PHA Facilitation. Facilities Engineer in Upstream and Midstream Oil & Gas.	PHA Facilitator
Clay Dean	S&L	Associate II	3 years' experience in oil and gas upstream and midstream operations. Last 2 years with S&L as Process Engineer working on midstream oil and gas facilities.	Scribe
Dana Pierik	S&L	Project Manager	10 years of experience at NASA in Operations. 10 years' experience with S&L in Mechanical engineering department. Currently in Project Management.	Project Management
Holly Hills	S&L	Process Engineering Lead	Environmental/Process Engineering Lead. 10 years S&L environmental	Engineering
Marion Teslik	S&L	Mechanical Engineering Lead	13 years at S&L in mechanical engineering. Worked in industrial industry in chemical processing. Majority of work experience in power plant industry.	Engineering
James Robeson	S&L	I&C Engineer	Worked with S&L for 8 years largely in environmental to start. Has more recently worked on I&C side in CO2 capture projects.	Engineering
Erik Westling	MTR	Engineer	Director of Engineering services at MTR. Chemical engineering background in petrochemical industry, oil and gas, and biofuels. Works largely in commissioning and startup with MTR.	Engineering

Name	Company	Title	Experience	Role
Pingjiao Hao	MTR	Engineer	11 years of experience in CO2 capture field background is in process development and optimization. Primary Process engineer for MTR DFS project.	Engineering
Thomas Hofmann	MTR	Engineer	Former director of engineering. Has worked for MTR for 30 years and has 40 years of membrane technology development. Worked in both development and startup phases. Background in chemical and mechanical engineering.	Engineering
Richard Baker	MTR	Engineer	Principal scientist at MTR and founder. Developer of the membrane technologies at MTR.	Scientist; R&D
Tim Merkel	MTR	Principal Investigator	Co-principal investigator for DOE project. VP of Technology and director of research at MTR. Instrumental in development of MTR's carbon capture membrane technology. 20 years with MTR.	Scientist; R&D
Brice Freeman	MTR	Principal Investigator	Co-principal investigator. Carbon capture product manager. 10 years with MTR. 14 Years with Electric Power Research Institute. Background in environmental.	Engineering
Alicia Breen	MTR	MTR Lead Engineer	28 years experience 13 of which with MTR. Background in screw compressors, pressure vessels, and piping. Director of project engineering in commercial division.	Engineering
Jay Kniep	MTR	Engineer	Chemical engineering. Process Engineer at soybean process and ADM. Been with MTR for 11 years. Senior research manager. Works with membrane research through fuel test operations.	Engineering

Name	Company	Title	Experience	Role
Ray McKaskle	Trimeric	PM/Engineer	Process chemical engineer for 30 years. With Trimeric for 16 years. Experience in oil and gas and semiconductors. Most experience with Trimeric centered around CO2 uses (capture, injection). Currently a PM at Trimeric.	Project Management
Michael Marsh	Trimeric	Engineer	Chemical engineer. 30 years of experience in petrochemical and oil & gas. Most of experience in operations and process control.	Engineer
Will Morris	Carbon Management Strategies	ITC Contract Program Director	Runs WITC. Background in chemical engineering with focus on air pollution control and CO2 capture for last 10+ years. Experience from lab scale through startup.	Engineer

4. APPROACH

4.1. INTRODUCTION

In the Preliminary PHA meetings, a multidisciplinary Study Team, led by the S&L facilitator/scribe, used a structured and systematic approach to review the process. Prior to the meetings, as outlined in the Study Plan and with the help of the design engineer, the facilitator divided the process into nodes to represent individual systems, as given in the list of nodes (Appendix B).

Due to the nature of design (FEED stage), the Study Team considered using a mixture of methodologies for this Preliminary PHA Study based on the detail level of the design documentation available. The Preliminary PHA study was conducted in accordance with American Institute of Chemical Engineers (AIChE) and Center for Chemical Process Safety (CCPS) recommendations for Process Hazard Analysis (PHA) and Hazard Identification and Risk Analysis (HIRA). The Preliminary PHA methodologies meet OSHA 1910.119 Process Safety Management regulatory requirements for Process Hazard Analysis.

Due to a lack of process design information including design parameters, conditions, and equipment information, Nodes 6, 7, and 10 were not analyzed in detail during the Preliminary PHA and should be revisited later in detailed design.

4.2. HAZARD AND OPERABILITY (HAZOP)

For nodes with well-defined systems with P&IDs matching what is proposed for installation at the Plant, the HAZOP methodology was utilized. These portions of the study were conducted in accordance with American Institute of Chemical Engineers (AIChE) and Center for Chemical Process Safety (CCPS) recommendations for Process Hazard Analysis (PHA) and Hazard Identification and Risk Analysis (HIRA) and with IEC 61882 recommendations for HAZOP.

The Preliminary PHA meetings proceeded as follows for each node using HAZOP methodology:

1. The Study Team reviewed documentation to identify Causes (Section 4.2.1) that could result in the exposure of systems and/or personnel or environment to a/many hazard/s.
2. The Study Team considered the initiating cause, developed the consequence scenario (Section 4.2.2) for each potential applicable Consequence Category (4.2.2.1), and assigned a severity level for the worst case in each category (4.2.2.2).
3. The Study Team considered the available effective safeguards (4.2.3) and modifiers that could have an impact on the likelihood of the full scenario transpiring. With consideration of safeguards, the likelihood of the complete incident was then determined (Section 4.2.4).
    a. Presence of effective safeguards and their ability to reduce the likelihood of an event were assessed, but, per guidelines, they did not change the potential magnitude (consequence level).
4. For scenarios with risk ranking in regions not considered broadly manageable/acceptable (Section 4.2.5/4.2.6), the Study Team made recommendations for system improvements. The Study Team made recommendations for the improvement and/or alignment of documentation such that the drawings show the facility systems as they were evaluated and for verification of design.

The proceedings of the meetings, including cause-consequences pairs and general discussions, were

captured within the worksheets, using PHA-Pro 8 software from Sphera, and these are included in Appendix G of this report. Discussions that were not cause-consequences pairs were captured in the “Remarks” column.

4.2.1.Causes

Causes, also called initiating causes or initiating events, are the events that start the process on the path of changing from “normal” operations to “abnormal” operations. The S&L facilitator utilized the list of deviations (Table 9, Appendix A), to identify potential abnormal situations and the Study Team then evaluated the drawings for possible situations that could create this scenario within the given node. Causes were generally system malfunctions (e.g., valve(s) not operating as designed per the control scheme).

4.2.2.Consequence

The consequence is the effect of the deviation. The consequence was considered without the presence of safeguards unless those safeguards are passive and could be considered functional without any action (i.e. secondary containment/berm/dike). The consequence could impact several different entities (consequence categories listed in 4.2.2.1) at varied significance (consequence severity defined in 4.2.2.2). In this Preliminary PHA, the Study Team evaluated the severity and likelihood for all applicable categories to show the wide range of impacts potentially present for each initiating cause. The Study Team determined which categories were applicable and only evaluated those for the given cause-consequence pair; the categories not listed in the worksheets were considered to be not applicable for that scenario.

4.2.2.1. Consequence Categories

People (PER) – impacts to personnel (employees and contractors).

Public (PUB) – impacts to surrounding public.

Environmental (ENV) – impacts to the surroundings – habitat, wildlife, watersheds, etc.

Asset/Property (AST) – monetary impact of repairing/replacing equipment.

Business Interruption (BUI) – runtime impacts due to damage, repair, and/or replacement of equipment.

Media (MED) – impacts to company reputation, ranging from internal to widespread national/international media attention.

4.2.2.2.Consequence Severity

For this Preliminary PHA Study, consequence severity was qualitatively measured on a scale of 1 (low severity) to 5 (high severity), as outlined in Table 2 (following page).

Table 2: Consequence Severity Definitions

		Severity / Consequence Category					
		Severity Description Per Category					
		Personnel	**Public**	**Environmental**	**Asset/Property**	**Business Interruption**	**Media**
Severity	**5**	Multiple Fatalities	Single Fatality	Extensive, persistent, or irreversible damage to ecosystem function	Total or extensive damage to on-site equipment requiring complete replacement (>$50MM). Extensive damage to off-site property (>$1MM) Dwelling(s) off-site damage and uninhabitable	Disruption to dependent operations for more than 1 year	International media attention. Severe adverse public reaction threatening facility operations
	4	Single Fatality	Multiple Injuries to several persons. Hospitalization > 24 hours. Delayed recovery	Widespread moderate-long term ecosystem damage	Major damage to onsite equipment repaired within 4-12 months, requiring significant capex ($25MM-$50MM) Major damage to offsite property (<$1MM).	Disruption to dependent operations for 3 to 12 months	National media attention Moderate public concern/reaction
	3	Multiple Injuries to several persons. Hospitalization > 24 hours. Delayed recovery	Medical treatment injury with rapid recovery Hospitalization < 24 hours	Short term damage impairing local ecosystem	on-site equipment damage repaired within 7-120 days with loss of production (CAPEX: $10MM-$25MM)	Disruption to dependent operations for 70 to 90 days	State media attention. Adverse public reaction
	2	Medical treatment injury with rapid recovery Hospitalization < 24 hours	First Aid Treatment	Minor biological effects across limited area onsite	on-site damage repaired within 7 days with loss of production (CAPEX: $1MM-$10MM)	Disruption to dependent operations for less than 7 days	Local media attention. Possible adverse public reaction
	1	First Aid Treatment	No effect	On-site release immediately contained and readily cleaned up with onsite or locally available tech	On-site equipment damage repaired within 24 hours, without loss of production, CAPEX<$1MM	Disruption to dependent operations for less than one day	No effect

4.2.3.Safeguards

Also referred to as a protection layer, a safeguard is any independent mechanism that acts to prevent the cause from happening or stops the progression/manifestation of the full consequence of an incident by control, prevention, or mitigation [e.g., secondary containment, valve(s), control action(s)].

4.2.4. Likelihood

During this Preliminary PHA, likelihood was considered qualitatively, on a scale of 1 to 5, as outlined in Table 3.

Table 3: Likelihood Description

Likelihood	Frequency Description	Probability
1	Extremely unlikely to be experienced but not physically impossible	less than $1x10^{-4}$/year
2	Unlikely to be experienced, but credible to occur in the life of an item	less than $1x10^{-3}$/year but greater than $1x10^{-4}$/year
3	Unlikely, but reasonably expected to occur in the life of an item	less than $1x10^{-2}$/year but greater than $1x10^{-3}$/year
4	Likely to be experienced more than once in the life of an item	less than $1x10^{-1}$/year but greater than $1x10^{-2}$/year
5	Likely to be experienced often in the life of an item	greater than $1x10^{-1}$/year

4.2.4.1. Event Likelihood

The initiating event likelihood was determined based on CCPS guidelines for initiating events. For standard valve miss-operation, the event frequency was assumed to start at a level 5. For any human error, it is understood that a well-trained and rested operator may err with a frequency of level 4.

Effective safeguards were considered to drop the event likelihood by one level, except in the case of effective overpressure protection (relief valves), which dropped the likelihood by two levels.

4.2.5.Risk Matrix

During this Preliminary PHA, the Study Team utilized the risk matrix that Sphera has built in to their PHA-Pro 8 software (Figure 1). During the meetings, the Study Team identified the severity category(ies), the unmitigated severity level(s) (consequence without any safeguards in place), and the likelihood(s) of occurrence of the full event (with existing safeguards). The risk of an event is the product of unmitigated severity and likelihood.

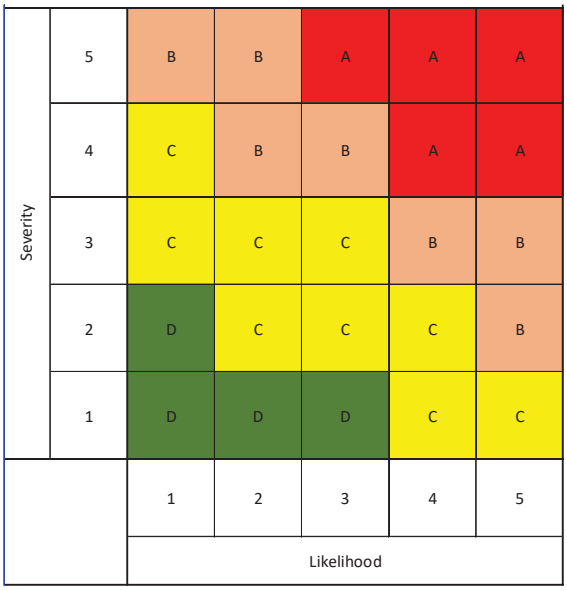


Figure 1: PHA-Pro 8 Standard Risk Matrix

4.2.6.Risk Ranking & Recommendations

Once a scenario was fully developed and risked, the Study Team considered the acceptability of the risk based on the ranking. Each of the 5 risk rankings has a different action level and guidance for resolution. The Study Team proceeded in action/recommendation development per the levels outlined in Table 4.

Table 4: Risk Ranking Description & Action Level

Risk Ranking		Description
A	INTOLERABLE / UNACCEPTABLE	Risk cannot be tolerated or justified unless there are exceptional reasons for the activity to take place. Control measures to be introduced to drive risk downward
B	INTOLERABLE / UNDESIRABLE	Risk may be tolerated but Team should make recommendations/actions to reduce likelihood of the risk scenario
C	TOLERABLE	Risk is tolerated once demonstrated that is As Low As Reasonably Practicable (ALARP), with the endorsement from the HSE department
D	TOLERABLE / BROADLY ACCEPTABLE	Risk is sufficiently low that it may be tolerated with the endorsement of the normal project / plant reviews.
U	UNCLASSIFIED	Interim condition when risk is not yet categorized, or is recorded but is not deemed an equipment safety issue

4.3. WHAT – IF METHODOLOGY

The Study Team considered but did not utilize What-If Methodology for this Preliminary PHA.

“What-If” methodology is a less structured brainstorming approach for the evaluation of hazards and risks in industrial processes. In this methodology, Study Team members identify abnormal operating conditions by asking “What If” questions and seeking out entire scenario hazards, consequences, and existing safeguards, which are then evaluated for severity and likelihood on the risk matrix. The methodology does still align with AIChE and CCPS recommendations for PHA and HIRA and may be utilized at another time.

5. SCHEDULE

The Preliminary PHA proceeded per the following schedule, according to plan:

Table 5: PHA Schedule

Activity	Start Date	Duration	Location
Preliminary PHA Meeting (Day 1 of 4)	11/01/21	10:00 AM – 5:00 PM CDT	Virtual (Microsoft Teams)
Preliminary PHA Meeting (Day 2 of 4)	11/02/21	10:00 AM – 5:00 PM CDT	Virtual (Microsoft Teams)
Preliminary PHA Meeting (Day 3 of 4)	11/03/21	10:00 AM – 5:00 PM CDT	Virtual (Microsoft Teams)
Preliminary PHA Meeting (Day 4 of 4)	11/04/21	10:00 AM – 5:00 PM CDT	Virtual (Microsoft Teams)

Daily Scope is outlined in Appendix G, Table 9.

6. DESIGN INPUTS

The following design inputs were utilized for the study.

- Piping & Instrumentation Diagrams (P&IDs) (primary documents for review within PHA)
- Process Flow Diagrams (PFD) (primary document for review within PHA)
- Design basis/System description documents (for reference only)
- General arrangement drawings (plot plan, site security) (for reference only)

For any P&IDs, PFDs, design basis documents, or others that were not finalized, the most recent revision of the documentation as of October 29, 2021 was utilized. As noted in the rules of engagement (Appendix C), the Study Team assumed that all systems were designed according to applicable industry codes and standards. A detailed list of the primary design inputs is included in Appendix E. All other reference documentation is not tracked within this report.

7. SUMMARY OF FINDINGS

7.1. RISK

The highest Personnel (employees and/or contractors) consequence severity identified in the Preliminary PHA Study was a level 4 based on the presence of potential hypoxic and/or toxic environment and potential for operator exposure. The highest Asset and Business Interruption impacts were also a level 4, due to the cost and potential scope of equipment damage due to abnormal operations, specifically temperature. Additionally, Asset and Business Interruption impacts were the most common consequences, as potential damage to process equipment may result in significant cost/lead times for replacement equipment as well as operational downtime (loss of revenue).

Incident scenario mitigated likelihood ran the entire spectrum of unlikely to likely to occur. As such, the current understanding of process risk scenario rankings ranged from insignificant to high priority to address.

In all, 217 cause-consequence pairs were considered, of which 90 required risk ranking. 1% of the scenarios were considered high priority risk (A-level); 20% of the scenarios were considered medium priority risk (B-level); 68% of the risk-ranked scenarios were considered low priority risk (C-level); the remaining 11% of risk-ranked scenarios were rated insignificant risk (D-level), as shown in the below Figure 2 Risk Heat Map.

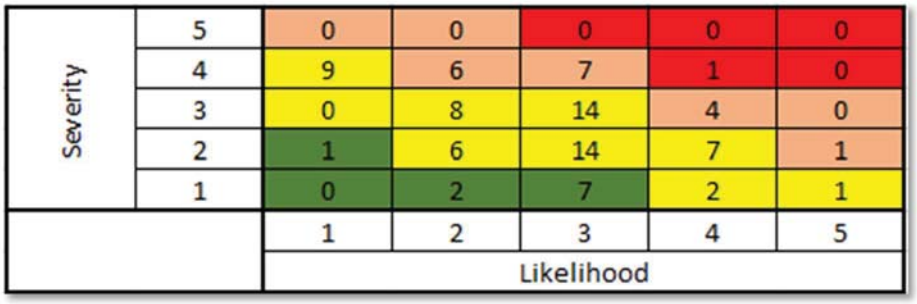


Figure 2: Heat Risk Map

7.2. RECOMMENDATIONS

Table 6, below, outlines the 45 unique recommendations from this Preliminary PHA Study.

Table 6: Recommendation Summary

Risk Ranking	Color	Description	# of recs	Rec #
A	Red	Intolerable/Unacceptable	2	17, 18,
B	Orange	Intolerable/Undesirable	7	2, 3, 8, 9, 35, 36, 41,
C	Yellow	Tolerable	6	1, 4, 27, 39, 43, 45
D	Green	Tolerable/Broadly Acceptable	0	N/A
U	N/A	Unranked / Unclassified	30	5, 6, 7, 10, 11 ,12 ,13, 14, 15, 16, 19, 20, 21, 22, 23, 24, 25, 26, 28, 29, 30 ,31, 32, 33, 34, 37, 38, 40, 42, 44

The Study Team made recommendations:

- To validate and verify that design meets code and operating requirements.
- To update design to match assumptions made during the study.
- To identify potential process improvements for ease of operations.
- To collect additional data and information to ensure the design meets the criteria for safe operations.

Understanding that this project design is still preliminary, the Study Team divided the recommendations for this FEED study Preliminary PHA into two groups: recommendations to be implemented during this phase and those to be addressed in the subsequent phase. Tables 7 and 8 show the breakdown of recommendations by the project's phase and risk ranking.

Table 7: Current Phase Recommendations Summary

Risk Ranking	Color	Description	# of recs	Rec #
A	Red	Intolerable / Unacceptable	0	N/A
B	Orange	Intolerable / Undesirable	6	2, 3, 8, 35, 36, 41
C	Yellow	Tolerable	4	1, 27, 39, 43
D	Green	Tolerable / Broadly Acceptable	0	N/A
N/A	N/A	Unclassified / Miscellaneous	12	5, 6, 11, 13, 14, 15, 21, 23, 25, 26, 40, 44

Table 8: Subsequent Phase Recommendations Summary

Risk Ranking	Color	Description	# of recs	Rec #
A	Red	Intolerable / Unacceptable	2	17, 18
B	Orange	Intolerable / Undesirable	1	9
C	Yellow	Tolerable	2	4, 45
D	Green	Tolerable / Broadly Acceptable	0	N/A
N/A	N/A	Unclassified / Miscellaneous	18	7, 10, 12, 16, 19, 20, 22, 24, 28, 29, 30, 31, 32, 33, 34, 37, 38, 42

The next step is to review the full recommendations list (Appendix H) and resolve/address the recommendations in a timely manner. Note that MTR is the responsible party for all work being performed on the project. S&L can assist with recommendations, tracking progress, and facilitating closure of recommendations as requested by MTR.

8. CONCLUSION

The Study Team successfully completed the Preliminary Process Hazard Analysis study in four (4) sessions in November 2021 following industry best practices for PHA methodologies. The overall conclusion from this FEED-stage PHA is that the systems have generally considered the engineering and processing design elements for this phase of the project. However, there remain outstanding concerns, as documented in the recommendations (Appendix H), to be worked out during detailed design.

In all, the Study resulted in 45 total unique recommendations to improve the design and safety of the project, which will all be addressed prior to construction and start-up.

It is recommended that a PHA Study team reconvenes during the detailed design phase to complete a PHA/HAZOP analysis of the final design proposal of MTR's carbon capture membrane technology at Basin Electric Power Cooperative's Dry Fork Station in Gillette, WY. The PHA Study Team will then update the PHA worksheets, analysis, and/or report as necessary before authorizing facility for construction and commissioning.

APPENDIX A. TERMS & DEFINITIONS

Node – Scope or system to be studied within the PHA/HAZOP study.

Parameter – Result of the function of the system such as flow, pressure, temperature, level, etc.

Guide Word – potential variance in the system parameter, such as No, More, Less, etc.

Deviations – the combination of Guide Word and Parameter such as No Flow, More Flow, Less Flow, etc.

Table 9: Example Table of Deviations

Parameter	Guide Words			
	No/Less	More/High	Reverse/Misdirected	As Well As
Flow	No/Less Flow	More/High Flow	Reverse/Misdirected Flow	
Level	Low/Reduced Level	High Level		
Pressure	Less/Low Pressure	More/High Pressure		
Temperature	Less/Low Temperature	More/High Temperature		
Composition				Contamination
Other	Corrosion/Erosion			
Other	Instrumentation			
Other	Maintenance Hazards			
Other	Start-up/Shutdown			
Other	Temporary Operations			
Other	Utilities			
Other	General Items for Discussion			
Other	What-If			

Causes – reason(s) for the respective deviation to occur; also “initiating cause” and “initiating event”.

Consequences – effect of the deviation on the process, personnel, equipment, and the environment.

Safeguards (Protection Layers) – any independent mechanism that reduces likelihood of a cause or the progression of an incident by control, prevention, or mitigation (e.g. tank, administrative procedure, etc.).

Likelihood - possibility that the hazardous event occurs with the safeguards in place

Severity - the impact associated with the worst hazardous event without considering the safeguards

Risk Rank: the product of unmitigated severity and likelihood

Table 10: Acronyms & Abbreviations

Acronym/Abbreviation	Definition/Clarification
Acfm	Actual Cubic Feet per Minute
AIChE	American Institute of Chemical Engineers
ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
BMS	Burner Management System
CAPEX	Capital Expenditures
CCPS	Center for Chemical Process Safety
CEMS	Continuous Emissions Monitoring System(s)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPU	CO2 Purification Unit
CW	Cooling Water
DCC	Direct Contact Cooler
DCS	Distributed Control System
dP	differential Pressure
EAC	Electrical Area Classification
EPA	U.S. Environmental Protection Agency
FD	Forced Draft
FE	Flow Element (Transmitter)
FG	Flue Gas
HAZOP	Hazard and Operability
HEX	Heat Exchanger
HIRA	Hazard Identification and Risk Analysis
hp	horsepower
hr	hour
IDLH	Immediately Dangerous to Life & Health
IEC	International Electrotechnical Commission
I/O	Input / Output
LIT	Level Indicating Transmitter
MEMA/B/C/D	Membrane A/B/C/D
MMBtu	Million British thermal unit
MOV	Motor-Operated Valve
N_2	Nitrogen gas

Acronym/Abbreviation	Definition/Clarification
NaOH	Sodium Hydroxide (Lye/Caustic)
NFPA	National Fire Protection Association
NG	Natural Gas
NO_x	Nitrogen Oxides
NPSHa/NPSHr	Net Pressure Suction Heat available/required
NTE	Not To Exceed
O&M	Operations and Maintenance
O_2	Oxygen gas
OEM	Original Equipment Manufacturer
OPEX	Operating Expenditures
OPP	Over-Pressure Protection
PHA	Process Hazard Analysis
PID/P&ID	Piping & Instrumentation Diagram
PIT	Pressure Indicating Transmitter
ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
PRB	Powder River Basin
PRV/PSV	Pressure Relief Valve/Pressure Safety Valve
PSIA/G	pounds per square inch absolute/gauge
RO	Reverse Osmosis
scfm	standard cubic feet per minute
SG	Specific Gravity
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SME	Subject Matter Expert
SOPs	Standard Operating Procedures
SO_2	Sulfur Dioxide Gas
T1/T2	Train 1/2
TIT	Temperature Indicating Transmitter
UPS	Uninterruptable Power Supply
US$	U.S. dollars
VFD	Variable Frequency Drive
W.C.	Water Column
WSAC	Wet Surface Air Cooler

APPENDIX B. NODES

Table 11: Node List

Node	Equipment	Intent	Reference (FS-MTR-M-XXXX-XX)	Date
1	DCC, FG Booster Fan, and Membrane A	**Inlet Gas to MEMA** Design Conditions/Parameters: "*12.3-4 PSIA is atmospheric pressure at station (Gilette). Inlet to DCC: 222 Deg F, 13.1 PSIA, 5 MMlb/hr, 1.68 MMACFM (mass and volume flow for both trains). From DCC to Fan: 90 Deg F, 12.71 PSIA, 4.6 MMlb/hr, 1.2 MMACFM. From Booster Fan to MEMA:"	0102-01, 0103-01, 0113-07	11/1/21-11/2/21
2	MEMA Permeate Booster Fan, MEMA Permeate Compression, HX, and Membrane B	**MEMA Permeate to MEMB** Design Conditions/Parameters: "MEMA Outlet: 1.4 PSIA and 106 Deg F; Downstream MEMA Permeate Fan: 3.44 PSIA and 108.5 Deg F; Downstream MEMA Permeate Compressor: 16.5 PSIA and 180.9 Deg F; Outlet of Cooler: 16.25 PSIA and 81.2 Deg F; Composition: 20% Permeate 80 % Retentate"	0103-01, 0104-01, 0104-02, 0104-03, 0105-01, 0105-02, 0109-01	11/2/21
3	N/A	**MEMA Retentate to Stack** Design Conditions/Parameters: "MEM A Retentate Outlet: 12.9 PSIA at 106.3 Deg F"	0102-1, 0103-01	11/2/21
4	MEMB Permeate Booster Fan, MEMB Permeate Compression, HX	**MEMB Permeate to Dehy** Design Conditions: "MEMB Permeate to Permeate Fan: 2.9 PSIA @ 81.2 Deg F; Permeate Fan to Permeate Compressor: ; Compressor to Feed Chiller: 389 PSIA @ 81.2 Deg F ;Composition: 60% Permeate 40% Retentate"	0105-01, 0106-01, 0106-02, 0109-01	11/3/21
5	N/A	**MEMB Retentate to MEMA** Design Conditions: "15.5 PSIA @ 81.2 Deg F"	0103-01, 0105-01, 0105-02	11/3/21
6	Dehy Feed Chiller, Dehy Feed Separator, Dehy Superheater, Dehydration Beds (Normal Operation)	**Dehy Permeate Gas to Feed Chiller** Design Conditions: "Permeate Gas to Feed Chiller: 389 PSIA @ 81.2 Deg F; Feed Chiller Gas to CPU (Post filter): 376 PSIA 60 Deg F"	0107-01	11/3/21
7	CPU, Membrane C	**Permeate Gas to Distillation & MEMC/D**	0108-01, 0108-02, 0109-01	N/A

Node	Equipment	Intent	Reference (FS-MTR-M-XXXX-XX)	Date
8	CO2 Booster Pumps, CO2 Product Pumps, & Product Heaters	**CO2 Product Stream** Design Conditions: "Booster Pump Inlet: 360-370 PSIA @ 10-12 Deg F; Product Pump Outlet: 2213-19 PSIA @ 68 Deg F, Flow: 657,000 lb/hr"	0108-02, 0109-01	11/4/21
9	Membrane C, Dehydration Beds (Regeneration)	**MEMC/D Retentate to Dehy** Design Conditions: "MEMC Retentate to MEMD: 356.3 PSIA @ 81 Deg F; MEMD Retentate to Dehy Beds: 30 PSIG @ 500 Deg F"	0107-01, 0109-01	11/4/21
10	Refrigerant Compressors, Condensers, and Receivers	**Refrigerant System**	0107-01, 0108-01, 108-02, 0110-01, 0110-02, 0110-03	N/A
11	Wet Surface Air Coolers (WSAC), WSAC Pumps	**DCC Cooling System** Design Conditions: "Summer Operating: XXX; Winter Operating: XXX"	0111-03, 0113-01, 0113-02, 0117-01	11/4/21
12	Cooling Tower, Closed Cooling Water Pumps	**Cooling Tower & Closed Cooling Water System** Design Conditions: "Summer Operating (max 108.2 Deg F): XXX; Winter Operating (min -35.6 F): XXX"	0111-05, 0111-06, 0111-07, 0111-08, 0111-09, 0111-10, 0113-03	11/4/21
13	Auxiliary Equipment	**Instrument Air System**	0111-05, 0111-06, 0111-07, 0111-08, 0111-09, 0111-10, 0113-03	N/A
14	Auxiliary Equipment	**Service Water System**	0115-01, 0115-02, 0115-03	N/A
15	Auxiliary Equipment	**Water Treatment System (RO)**	0113-04, 0113-05, 0113-06, 0117-01, 0117-02, 0117-03, 0117-04, 0117-05, 0117-06, 0117-07	N/A
16	Auxiliary Equipment	**Equipment Drain System**	0112-01, 0112-02, 0112-03, 0112-04	N/A

APPENDIX C. RULES OF ENGAGEMENT AND STUDY ASSUMPTIONS

The following rules of engagement will be considered for the Study meetings:

1. Microsoft Teams will be used for conducting the preliminary PHA and all participants must be familiar with the software. Installing the software on the computer / device prior to the first session is essential.

2. Everyone joining the preliminary PHA will be expected to participate using audio and video conferencing.

3. All participants must have familiarized themselves with the project.

The following assumptions will be applied for this study:

1. Causes are to be taken within the node only; however, consequences and safeguards may occur anywhere inside and outside the node.

2. Typical preventive maintenance will be provided. Safety equipment is routinely inspected.

3. Proper sampling methods and procedures are in place to ensure personnel safety and process integrity.

4. Plant personnel are adequately trained to operate and maintain the facility and react to alarm.

5. Unless otherwise specified, it is assumed that all process vessels, piping, and valves are designed and constructed to industry standards.

6. “Poor Design” is not considered a cause of deviation in this study.

7. Effects of extreme environmental events (storms, seismic, wind, etc.), acts of terrorism, and other outside events not controllable by the plant are not considered as valid causes for the purposes of this study.

8. Equipment is designed to meet the applicable seismic, wind, storm, etc. requirements.

9. Start-up, shut-down, transient, and normal operations are considered in this study.

10. Safeguards may either prevent the initiating event (the cause) or may prevent or mitigate event consequence progression. For example, a high-level alarm will not prevent a valve from being inadvertently opened, but it might prevent a vessel downstream from overflowing.

11. A lock-out/tag-out procedure is in effect and strictly enforced by the management. The inadvertent opening of an isolation valve or blind removal during maintenance is not addressed because administrative controls are considered an adequate safeguard to prevent this situation.

12. Manual valves are in the position shown on P&IDs and that the operator is trained to follow procedures to actuate these manual valves. NC valves are normally closed.

13. The text: "inadvertently open/closed" includes failure of the actuated valve by mechanical means, electronic means, failure of the controller, or any individual opening (closing) the valve when it is not desired. The likelihood of the scenario considers the multiple ways that a valve can fail.

14. Check valves are not considered effective safety protection devices. Leakage is assumed.

15. System integration testing and commissioning will reveal software errors; therefore, these are not considered valid causes for deviation in the context of this study.

16. Piping will be cleaned during commissioning (including strainers).

17. If the Study Team determined that a scenario was "improbable for this node," a "minor operational upset," a "minor financial impact," "not a hazard," or "not a problem," then the Team would state so and not spend time determining safeguards or ranking the scenario. Due to either a very low severity or a very low likelihood, the risk is assumed to be minimal from these scenarios.

18. Only single events will be considered as causes, no "double jeopardy."

19. Fire personnel are adequately trained to respond to a fire condition.

20. All documents used in the preliminary PHA shall be the latest revision at the time of the study. Subsequent changes are not considered.

21. Facility is continuously manned.

APPENDIX D. LIST OF POTENTIAL HAZARDS AND CONSEQUENCES

Preliminary List of Potential Hazards for Study

Note that the list of potential hazards is considered preliminary and is a living document. As the list is applied for the preliminary PHA, the Study Team may determine that additional hazards exist and can be added at that time. These hazards are limited to process/system related hazards which may have impact personnel safety, environment, or the equipment.

1. Gases contained in the process equipment at a pressure above atmospheric
2. Gases at elevated temperatures for part(s) of the process.
3. Corrosive/toxic chemicals/fluids
4. Flammable/combustible chemicals/fluids
5. Asphyxiant gas
6. Chemistry/Contamination

Preliminary List of Potential Consequences/Impacts for Study

Note that the list of potential consequences and impacts is considered preliminary and is a living document. As the list is applied for the preliminary PHA, the Study Team may determine that additional consequences and impacts exist and can be utilized during the worksheet development. Process and/or system malfunctions could result in any of the following personnel safety, environmental or asset impacts:

1. Explosion/rupture/breakage (due to over pressure by a fluid or flammable substance)
2. Fire
3. Loss of containment (i.e., spillage of hazardous/non-hazardous fluid by overflow or other)
4. Equipment damage (e.g., pump, valve, etc.)
5. Overheating
6. Scaling/erosion/corrosion of components
7. Reduced output and/or efficiency
8. Personnel injury or fatality
9. Hazardous or damaging effect arising from loss of electrical supply to equipment or system

APPENDIX E. DESIGN INPUTS

Table 12: Design Inputs

No.	Document No.	Rev	Title
1	-	A	MTR Full Scale Design Criteria
2	-	A	MTR Full Scale - PFD
3	FS-MTR-M-0102-01	B	FLUE GAS BOOSTER FAN & DCC TRAIN 1 - P&ID
4	FS-MTR-M-0102-02	A	FLUE GAS BOOSTER FAN & DCC TRAIN 2 - P&ID
5	FS-MTR-M-0103-01	B	MEMBRANE A SKIDS BLOCK 1 TRAIN 1 - P&ID
6	FS-MTR-M-0103-02	B	MEMBRANE A SKIDS BLOCK 1 TRAIN 1 - P&ID
7	FS-MTR-M-0103-03	B	MEMBRANE A SKIDS BLOCK 2 TRAIN 1 - P&ID
8	FS-MTR-M-0103-04	B	MEMBRANE A SKIDS BLOCK 2 TRAIN 1 - P&ID
9	FS-MTR-M-0103-05	B	MEMBRANE A SKIDS BLOCK 3 TRAIN 1 - P&ID
10	FS-MTR-M-0103-06	B	MEMBRANE A SKIDS BLOCK 3 TRAIN 1 - P&ID
11	FS-MTR-M-0103-07	B	MEMBRANE A SKIDS BLOCK 4 TRAIN 1 - P&ID
12	FS-MTR-M-0103-08	B	MEMBRANE A SKIDS BLOCK 4 TRAIN 1 - P&ID
13	FS-MTR-M-0103-09	B	MEMBRANE A SKIDS BLOCK 5 TRAIN 1 - P&ID
14	FS-MTR-M-0103-10	B	MEMBRANE A SKIDS BLOCK 5 TRAIN 1 - P&ID
15	FS-MTR-M-0103-11	A	MEMBRANE A SKIDS BLOCK 1 TRAIN 2 - P&ID
16	FS-MTR-M-0103-12	A	MEMBRANE A SKIDS BLOCK 1 TRAIN 2 - P&ID
17	FS-MTR-M-0103-13	A	MEMBRANE A SKIDS BLOCK 2 TRAIN 2 - P&ID
18	FS-MTR-M-0103-14	A	MEMBRANE A SKIDS BLOCK 2 TRAIN 2 - P&ID
19	FS-MTR-M-0103-15	A	MEMBRANE A SKIDS BLOCK 3 TRAIN 2 - P&ID
20	FS-MTR-M-0103-16	A	MEMBRANE A SKIDS BLOCK 3 TRAIN 2 - P&ID
21	FS-MTR-M-0103-17	A	MEMBRANE A SKIDS BLOCK 4 TRAIN 2 - P&ID
22	FS-MTR-M-0103-18	A	MEMBRANE A SKIDS BLOCK 4 TRAIN 2 - P&ID

No.	Document No.	Rev	Title
23	FS-MTR-M-0103-19	A	MEMBRANE A SKIDS BLOCK 5 TRAIN 2 - P&ID
24	FS-MTR-M-0103-20	A	MEMBRANE A SKIDS BLOCK 5 TRAIN 2 - P&ID
25	FS-MTR-M-0104-01	B	MEMA CO2 PERMEATE COMPRESSION TRAIN 1 - P&ID
26	FS-MTR-M-0104-02	A	MEMA CO2 PERMEATE COMPRESSION TRAIN 1 - P&ID
27	FS-MTR-M-0104-03	B	MEMA CO2 PERMEATE COMPRESSION TRAIN 1 - P&ID
28	FS-MTR-M-0104-04	A	MEMA CO2 PERMEATE COMPRESSION TRAIN 2 - P&ID
29	FS-MTR-M-0104-05	B	MEMA CO2 PERMEATE COMPRESSION TRAIN 2 - P&ID
30	FS-MTR-M-0104-06	A	MEMA CO2 PERMEATE COMPRESSION TRAIN 2 - P&ID
31	FS-MTR-M-0105-01	B	MEMB SKID & CO2 COMPRESSION TRAIN 1 - P&ID
32	FS-MTR-M-0105-02	B	MEMB SKID & CO2 COMPRESSION TRAIN 1 - P&ID
33	FS-MTR-M-0105-03	A	MEMB SKID & CO2 COMPRESSION TRAIN 2 - P&ID
34	FS-MTR-M-0105-04	A	MEMB SKID & CO2 COMPRESSION TRAIN 2 - P&ID
35	FS-MTR-M-0106-01	B	MEMB CO2 PERMEATE COMPRESSION TRAIN 1 & 2 - P&ID
36	FS-MTR-M-0106-02	B	MEMB CO2 PERMEATE COMPRESSION TRAIN 1 & 2 - P&ID
37	FS-MTR-M-0107-01	B	CO2 DEHYDRATION SYSTEM TRAIN 1 - P&ID
38	FS-MTR-M-0107-02	A	CO2 DEHYDRATION SYSTEM TRAIN 2 - P&ID
39	FS-MTR-M-0108-01	B	CO2 PURIFICATION SYSTEM (CPU) TRAIN 1 - P&ID
40	FS-MTR-M-0108-02	A	CO2 PURIFICATION SYSTEM (CPU) TRAIN 1 - P&ID
41	FS-MTR-M-0108-03	A	CO2 PURIFICATION SYSTEM (CPU) TRAIN 2 - P&ID
42	FS-MTR-M-0108-04	A	CO2 PURIFICATION SYSTEM (CPU) TRAIN 2 - P&ID
43	FS-MTR-M-0109-01	B	CO2 RECIRCULATION MEMBRANE C AND D - P&ID
44	FS-MTR-M-0110-01	B	REFRIGERANT SYSTEM RFG - P&ID
45	FS-MTR-M-0110-02	A	REFRIGERANT SYSTEM RFG - P&ID

No.	Document No.	Rev	Title
46	FS-MTR-M-0110-03	A	REFRIGERANT SYSTEM RFG - P&ID
47	FS-MTR-M-0111-01	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
48	FS-MTR-M-0111-02	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
49	FS-MTR-M-0111-03	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
50	FS-MTR-M-0111-04	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
51	FS-MTR-M-0111-05	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
52	FS-MTR-M-0111-06	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
53	FS-MTR-M-0111-07	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
54	FS-MTR-M-0111-08	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
55	FS-MTR-M-0111-09	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
56	FS-MTR-M-0111-10	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
57	FS-MTR-M-0111-11	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
58	FS-MTR-M-0111-12	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
59	FS-MTR-M-0111-13	B	COOLING TOWER AND CLOSED COOLING WATER SYSTEM - P&ID
60	FS-MTR-M-0112-01	B	EQUIPMENT DRAINS - P&ID
61	FS-MTR-M-0112-02	B	EQUIPMENT DRAINS - P&ID
62	FS-MTR-M-0112-03	B	EQUIPMENT DRAINS - P&ID
63	FS-MTR-M-0112-04	B	EQUIPMENT DRAINS - P&ID
64	FS-MTR-M-0113-01	B	CHEMICAL FEED SYSTEM WET SURFACE AIR COOLER - P&ID
65	FS-MTR-M-0113-02	B	CHEMICAL FEED SYSTEM WET SURFACE AIR COOLER - P&ID
66	FS-MTR-M-0113-03	B	CHEMICAL FEED SYSTEM COOLING TOWER - P&ID
67	FS-MTR-M-0113-04	B	CHEMICAL FEED SYSTEM WATER TREATMENT - P&ID
68	FS-MTR-M-0113-05	B	CHEMICAL FEED SYSTEM WATER TREATMENT - P&ID
69	FS-MTR-M-0113-06	B	CHEMICAL FEED SYSTEM WATER TREATMENT - P&ID

No.	Document No.	Rev	Title
70	FS-MTR-M-0113-07	A	CHEMICAL FEED SYSTEM DIRECT CONTACT COOLER - P&ID
71	FS-MTR-M-0114-01	B	COMPRESSED AIR SYSTEM - P&ID
72	FS-MTR-M-0114-02	B	COMPRESSED AIR SYSTEM SERVICE AIR - P&ID
73	FS-MTR-M-0114-03	B	COMPRESSED AIR SYSTEM INSTRUMENT AIR - P&ID
74	FS-MTR-M-0114-04	B	COMPRESSED AIR SYSTEM INSTRUMENT AIR - P&ID
75	FS-MTR-M-0114-05	B	COMPRESSED AIR SYSTEM INSTRUMENT AIR - P&ID
76	FS-MTR-M-0115-01	B	SERVICE WATER SYSTEM - P&ID
77	FS-MTR-M-0115-02	B	SERVICE WATER SYSTEM - P&ID
78	FS-MTR-M-0115-03	B	SERVICE WATER SYSTEM - P&ID
79	FS-MTR-M-0116-01	B	FIRE PROTECTION SYSTEM - P&ID
80	FS-MTR-M-0117-01	B	WATER TREATMENT SYSTEM - P&ID
81	FS-MTR-M-0117-02	B	WATER TREATMENT SYSTEM - P&ID
82	FS-MTR-M-0117-03	B	WATER TREATMENT SYSTEM - P&ID
83	FS-MTR-M-0117-04	B	WATER TREATMENT SYSTEM - P&ID
84	FS-MTR-M-0117-05	B	WATER TREATMENT SYSTEM - P&ID
85	FS-MTR-M-0117-06	B	WATER TREATMENT SYSTEM - P&ID
86	FS-MTR-M-0117-07	B	WATER TREATMENT SYSTEM - P&ID
87	FS-MTR-M-0001	B	Site Plan
88	FS-MTR-M-0002	B	DCC Auxiliary Equipment Area Plot Plan
89	FS-MTR-M-0003	B	Carbon Capture Equipment Building Plot Plan
90	FS-MTR-M-0004-1	A	CO2 Purification Unit (CPU) (1st Floor) Plot Plan
91	FS-MTR-M-0004-2	A	CO2 Purification Unit (CPU) (2nd Floor) Plot Plan
92	FS-MTR-M-0005-1	B	Water Treatment Building (1st Floor) Plot Plan
93	FS-MTR-M-0005-2	B	Water Treatment Building (2nd Floor) Plot Plan

No.	Document No.	Rev	Title
94	-	B	MTR Full Scale Mechanical Equipment List
95	-	1	DFS Full Scale Summer Design HX Summary
96	-	4	Dry Fork CO2 Capture Plant (CPU/Refridge) – Salof PFD
97	-	0	Dry Fork CO2 Capture Plant (CPU/Refridge) – Salof HMB
98	-	0	Dry Fork CO2 Capture Plant (CPU/Refridge) – Salof PFD (for HMB)
99	-	0	Dry Fork CO2 Propylene (CPU/Refridge) – Salof HMB
100	-	1	Refrigeration Compressors DryFork CO2 Plant – Salof Performance runs
101	-	-	Propylene Refrigerant SDS
102	-	0	DFS Full Scale - Preliminary PHA Study Plan

APPENDIX TT. CONSTRUCTABILITY REVIEW REPORT

Membrane Technology & Research

DRY FORK STATION UNIT 1

FEED SCALE CARBON CAPTURE FEED STUDY PROJECT CONSTRUCTABILITY REVIEW

Issued for Use
Rev. 0

March 29, 2022
Project 13978-002

Prepared by

Sargent & Lundy LLC

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Attachment 1: Construction Design Review Meeting Presentation with Notes
Attachment 2: Site Aerial Picture for Laydown Areas, Parking, Trailers, etc.
Attachment 3: Site Grading Sketch
Attachment 4: Feasible Crane Locations

1. INTRODUCTION

1.1. Background

Membrane Technology & research (MTR) is conducting a U.S. Department of Energy (DOE) funded project to complete a front-end engineering and design (FEED) study. In cooperation with Basin Electric Power Cooperative (Basin), Electric Power Research institute (EPRI), Sargent and Lundy (S&L), and Trimeric Corporation, the study investigates the retrofit of MTR's membrane CO_2 capture technology to Basin's existing Dry Fork Station (DFS); which is located in Gillette, Wyoming.

The project includes process design of the CO_2 capture system by MTR and Trimeric; and balance of plant (BOP) integration by S&L. The CO_2 will be filtered through a series of membranes, captured, compressed and purified through a liquefaction system to enhanced oil recovery (EOR) pipeline quality CO_2; it will then be transported to the CarbonSAFE Project at DFS for permanent geologic storage. As part of the overall project to retrofit CO_2 capture at the existing facility, consideration of water usage and power were required in the design and operation of CO_2 capture plant.

1.2. Scope

In this document, S&L will review the constructability for the MTR CO_2 Capture Design and BOP. The constructability review was completed by reviewing the design criteria and systems description, conceptual drawings, and other related project information. A construction design review meeting was held on December 17, 2021 with members of the Full Scale FEED project team: MTR, S&L, BEPC, DFS, and Trimeric; to review the general arrangement, critical construction activities, and preliminary construction sequence, as summarized in this document. The presentation slides with notes from the construction design review meeting are included in Attachment 1. The equipment handling plan and construction sequence developed by S&L as part of this constructability review are a suggested plan and sequence intended to ensure the design is reasonable and to form a basis for the project cost estimate and preliminary schedule. The installation contractor will be responsible for developing a detailed plan and sequence that will be used for the work, including the additional elements not addressed herein, such as protection of plant equipment, the protection of equipment being installed, and construction quality assurance.

2. CONSTRUCTION SITE PLAN

2.1. Laydown and Staging Area

A conceptual construction plan "map" is shown in Attachment 2. It is a satellite image from Google Earth© of DFS with original DFS construction facility areas identified. BEPC/DFS confirmed this project will be able to use the original areas for laydown, parking and trailers. This drawing includes proximity to the final installation area, temporary facility locations, existing structures, access for deliveries, and information based on the construction sequencing. The laydown areas indicated in Attachment 2 will also be utilized by the contractor, as required, for staging, fabrication, equipment and material storage, warehousing, etc.

There are approximately 77,400 sq yds of permanent equipment areas comprised of two (2) trains of: Direct Contact Coolers (DCC), Wet Surface Air Coolers (WSAC), CO_2 Capture Membranes (75 skids each train), Flue Gas Booster Fans, multiple permeate fans, pumps, compressors, ductwork, piping and associate equipment; and a single Cooling Tower (CT). A new Sub-station with Dead End Structure, Switches, Transformers, and associated equipment to provide power to operate the CO_2 Capture Plant occupies about 20,725 sq yds.

The laydown areas will use most of the areas previously utilized for plant laydown, staging, and equipment storage. Construction roads within the assigned laydown areas for access deliveries will be constructed and maintained by the contractor. The equipment will be offloaded and stored in the proper assigned areas. The contractor will be responsible for storing environmentally sensitive components in accordance with manufacturers' recommendations (i.e. HVAC Connex). For the purposes of this study, it is assumed the electrical cable will be fenced in.

2.2. Mass Earth Work & Drainage

Most of the mass earthwork will occur for the new carbon capture reservoir on the Southwest side of the DFS and DFS plant east for the Carbon Capture Train areas with outlying areas for the Carbon Purification Unit (CPU) Building, New CO_2 Capture Sub-station, water treatment and cooling equipment. Overall, there is approximately a 5ft change in elevation across the site. For details regarding site grading and drainage, refer to the Grade Elevation Sketch in Attachment 3.

Earthwork activities will include initial review of existing underground utilities, local excavations for foundations and for new or relocated utilities, as well as grading and site preparation for construction laydown areas. In addition, some new plant access roads may be developed to access construction work areas, ensure traffic separation, and act as heavy load transport routes. At the end of the project these roads will be asphalt paved to provide access to the new equipment as shown on the construction planning general arrangement (GA) drawing (Attachment 2). Other tasks considered during final planning include trenching and excavation, reiterating planned slopes, verifying existing structure protection during excavations, minimizing the number of backfills, verifying adequate storage areas for excavated material, and identifying required compaction requirements are met.

Plant storm water drainage flow paths within the scope of this work at will need to be addressed during site prep and earthwork. All new and existing drainage elevations will be verified. Design of site drainage will consider the spill prevention, control, and countermeasure (SPCC) plans developed for this project during detailed design.

2.3. Construction Equipment

Construction activities are planned to utilize a variety of heavy and light construction equipment. A majority of the heavy lifts will use mobile cranes because of their versatility, maneuverability, and short mobilization and demobilization time. The contractor will be required to prepare and submit a lift plan for all major lifts over the course of construction.

The crane used for erection of the ductwork will be sized to account for the weight and location of the heaviest and farthest reach lift. It is predicted that some portions of the ductwork can be mated together and lifted into place. This will minimize the time required to lift and place many smaller segments one at a time. The contractor's work plan, heaviest weight, and highest lift point will command the size of the cranes that will be required. Generally, a minimum 300-ton crane can handle most lifts for the ductwork. To the greatest extent possible, fabrication of the duct segments should be performed within the lifting reach of the crane dedicated to the ductwork installation. The lifts for the Ductwork will be completed with a Heavy Lift Crane, and CO2 train equipment placement can use smaller mobile cranes for ease of movement and space if the lift will allow.

Reach is a key factor in siting the cranes and the size of crane used. Based on the preliminary constructability review and the proposed crane locations shown in Attachment 4, it has been estimated that a minimum 300-ton capacity heavy lift crane would be required to accommodate both DCC Vessels. In addition, a smaller, mobile crane, estimated up to 90-Ton capacity, would be required for installation of internals for the DCC Vessel and CO2 Capture Island Equipment. Final installation details (final skid sizes, equipment weights, delivery plans, etc. will be available from the vendors in a future design phase; final crane plans will be determined at that time.

2.4. Construction Traffic

Material deliveries will be via WY Highway 59, 7 miles North of Gilette, Wyoming. Craft labor will enter the site from main plant entrance off Highway 59, park in construction parking lot, East of existing Sub-Station, and then enter site through the guardhouse Main Gate. The contractor will need to coordinate shift changes for traffic separation (workers, over-the-road, guardhouse Main Gate, etc.) and with the plant schedule. The parking lot is sized at 16545 sq yds, to accommodate approximately 285 vehicles (based on an estimated 58 sq yds per vehicle and including aisleways, etc.). Signage will indicate direction of travel and parking, and the parking area will be arranged such that traffic congestion will not be a problem at the end of a shift. Public roads to and from the site and the surrounding area are mainly used by local residents and for plant deliveries. The increase in traffic at the construction peak may cause slight backup at the plant intersection but should not adversely affect local traffic or interfere with the surrounding community. Note, plant personnel will be provided priority access, and work hours will be staggered to help eliminate traffic backups. Material and equipment deliveries will generally be by truck. Acceptable traffic patterns for construction workers, material deliveries, and on-site vehicles consider traffic separation and schedules to minimize any obstructed routes.

Note: there is not a rail spur on site, however there is a spur approximately 3 miles away, if a vendor deems transport more economical.

2.5. Construction Power

S&L reviewed the latest set of drawings for Construction Power Loop. The loop is intact, with some modifications near the ITC area. The underground duct bank (2015 ACQS duct bank powers the ITC fans, and there is a tie in from the construction loop that powers the rest of the ITC facility). Currently, the lease

for the ITC is set to end in 2025; it is assumed that the ITC will not be in service during the construction of the Full-Scale Project. Thus, the 8MVA of capacity will be available for construction power from the original construction loop. 480 VAC will be provided for Contractor's use in various locations (to be determined). The Contractor shall be responsible for the distribution transformers, panels and associated disconnect switches.

2.6. Construction Trailer Park with Facilities

For this study, the original construction trailer site will be used to house the Construction / Vender trailers. DFS indicated a secondary trailer area option is available on site near the ITC small test center, as well.

2.7. Construction Waste

BEPC does not have any special requirements for metals (recycle), trash, concrete washout, etc.

2.8. Lighting

Construction lighting will be a mix of Contractor erected temporary lighting fed from construction power sources, as well as mobile generator fed light towers in certain areas.

3. EQUIPMENT ERECTION AND CONSTRUCTION GENERAL GUIDELINES

3.1. Site Safety Plan

Prior to mobilization, the Contractor will be required to prepare and submit a site health and safety plan to be followed by all personnel on site during construction and commissioning activities. This site safety plan shall be reviewed and approved by Dry Fork prior to commencement of construction activities. The Contractor will also be required to retain an on-site Safety Manager during construction to enforce the site safety plan and ensure a safe working environment for all personnel on site.

3.2. Sitework

Sitework activities will be performed to support the specific construction activities and provide/maintain access to the work areas and facilities. These activities will mostly be performed concurrently, based upon available resources, and will define the site development and establish the different construction staging and laydown areas of the site.

3.3. Grading

There is approximately a -0.9% grade slope from east to west across the CO_2 capture area. For details regarding site grading refer to the Grade Elevation Sketch in Attachment 3. In addition, grading will occur during backfilling of equipment foundations and underground as grade elevations are blended to match new and existing elevations. Newly graded areas will be sloped to maintain sufficient drainage and provide vehicular and personnel access to the new facilities.

3.4. Finish Surface and Paving

To finish the CO2 capture area, asphalt will be used for roads, with concrete in the road curves. For areas that are not paved BEPC would like gravel as a road base around equipment or grass as noted in the final site specification. Maintenance areas will be determined later; for the purposes of this study, an allowance for 6 concrete maintenance pads will be captured in the cost estimate.

3.5. Substructure Work

Some underground services may interfere with the associated foundations or other underground apparatus and would need to be relocated before installation begins, this includes stormwater drainage. The existing

duct bank under the Cooling Tower will be straddled with deep foundation piers and the cap set to avoid the duct bank. The excavated material will be separated into general and structural fill, and then stockpiled in locations near the work areas. Excavation for major vessels, buildings, fans, compressor, and duct support foundations will be sequenced in accordance with the construction schedule. Drilled pier and H-pile installation will commence after excavation and follow the same sequence. Foundation pours will be scheduled sequentially, and the concrete will be furnished by an off-site producer or other approved resources.

3.6. Foundations

Foundation footprints will be excavated, drill/H-piles installed (where required), and foundations formed and poured. The foundation pours will be scheduled to allow the Direct Contact Coolers installation to be completed and CO2 absorber trains before erecting the nearby equipment and buildings. (Keep in mind that the Carbon Capture Equipment Building will be somewhat boxed in with the absorber trains and transformers). Electrical conduits, process piping, and drains will be embedded in the foundations; stub ups will be provided for above and below ground connections.

3.7. Electrical Equipment

Transformers, switchgear, VFDs, MCCs and DCS cabinets may be delivered before completion of their assigned buildings. The contractor may elect to rent an off-site warehouse for storage or provide temporary enclosures on site. In addition, power for equipment heaters will be required to prevent condensation. Regardless of the short-term storage method, electrical equipment installation is scheduled to support preoperational startup all of the CO2 Capture and Auxiliary equipment.

3.8. Ductwork

Sections of duct can be shop fabricated off-site and transported by road to the staging area. Sections can also be ground fabricated at the staging area. To improve productivity, duct sections may be insulated and lagged before raising them into position. Installation of the duct support steel and duct sections between the existing duct / stack and the Direct Contact Coolers (DCC) should be erected as soon as underground is finished along with the DCCs. The sections will be raised into position using a dedicated heavy crane in each area. The final duct sections, which are the tie-in spool pieces for the existing breeching ducts, will be installed during the scheduled outage. The new spool pieces will be raised by a heavy crane and welded

into position on the side of each breeching duct. A final expansion joint will be installed between the modified breeching ducts and the new ductwork.

3.9. CO_2 Membrane Skid Installation

The CO_2 Membrane Train 2 (Plant North) installation will be completed before Membrane Train 1 (Plant South), Train 2 can be started simultaneously but not finished until the Carbon Capture Equipment building is completed, this will allow access in between the Membrane Trains. The construction will primarily transpire from Plant North to South and West to East to provide the best access to the construction areas, while minimizing potential interferences with the CO_2 Membrane and Ductwork Construction and existing plant infrastructure.

3.10. Carbon Capture Equipment Building

The structural steel for the Carbon Capture Equipment Building can be preassembled in sections at the staging areas and transported to the erection area by trailer, then raised and set in place. To simplify installation of equipment located at grade level, this equipment should be rough set in place and preserved before starting steel erection, if possible. Once the building steel is erected and major mechanical and electrical equipment are in place, the building siding and roofing will be installed.

3.11. Cooling Equipment and Water Treatment Building

The foundations for all of the new cooling equipment being provided, which will include Direct Contact Coolers, Wet Surface Area Coolers (WSAC), Cooling Towers and heat exchangers, will be set and cured prior to delivery of the cooling equipment such that this equipment does not occupy a significant amount of the laydown area. Sections of the equipment will be set in place via small cranes and lifts. Final dress out of the equipment (piping, valves, etc.) will occur once all the equipment is set, as installing pipe in parallel with equipment can restrict crane movement.

The WSACs and the Water Treatment Building/equipment, located Plant South, can be erected while the Train 1 ducts are being built as long as there is enough room between for crane and construction equipment access.

3.12. Cathodic Protection

Extension of the existing cathodic protection system will be conducted at the site. The existing cathodic protection system will be modified to properly interact with the new cathodic protection equipment. The modification of the existing cathodic protection system design will be in accordance with the governing standards and existing equipment design.

3.13. Grounding

A new ground system will be installed at the site for the new equipment and structures and will be integrated into the existing system.

3.14. Start-up and Commissioning

The startup and commissioning will be consistent with other large projects. Existing MTR or OEM start up procedures can be tailored for the development of the CO_2 capture and auxiliary equipment start up procedures. Testing begins with the systematic transfer of systems and sub systems from construction to start up team. Construction turn over packages developed by the commissioning group identify the systems to be tested and started. The package transferred to the commissioning group will include construction test records. Package content should identify all relevant mechanical and electrical information necessary to safely test and start up equipment and systems.

3.15. Electrical Systems

The auxiliary power distribution system that includes auxiliary power transformers, unit substation transformers, distribution transformers, 230 kV switchyard modifications, switchgear, non-seg bus duct, VFDs, MCCs, UPS, batteries, chargers, panelboards, cable bus and power cables will be detailed in the initial electrical check out packages. Transfer of packages from construction to start up for the auxiliary power transformers, distribution transformers, 230 kV line and conductor structure, 15 kV and 5 kV switchgear, non-seg bus duct, VFDs, 480 V unit substations, MCCs, UPS, batteries, chargers will follow. DCS loops are identified in the turn over packages and loop checks will begin when the DCS panels are energized. System checks, except for fine tuning, will be completed before the unit start-up.

3.16. Mechanical Equipment

Initial mechanical checks will involve auxiliary systems such as station and control air, HVAC systems, sump drains, etc. Process systems involving the CO2 capture system will be checked out sequentially and made operational in an automatic mode. The booster fans will be checked out and run against closed dampers and made ready for automatic control. Pumps will be checked out and operated when process allows. Compressors will be checked out and made ready in automatic mode.

4. SEQUENCE OF CONCEPTUAL CONSTRUCTION

4.1. Inputs & Assumptions

The conceptual construction sequence is based on the following project inputs and assumptions:

- Contractors' equipment deliveries on time with schedule.
- The area needs and restrictions for on-site erection of the major equipment will determine the impact on other construction activities.
- Assume Major Equipment Delivery within the construction schedule dates.
- Unrelated outage work by Dry Fork Station is not included in this evaluation but may have impacts on this work.
- Assume major DFS outage occurs after GWC mobilization to perform the existing FG ducting demo from the ID fan outlet area to the stack & LTC ducting and install the new ducting up to the CC dampers (includes STC tie-in mod); this allows the ductwork to be closed and blanked off while the rest of the construction takes place.
- BOP equipment will be procured and delivered to site to support the construction schedule and installation sequence.
- All permits required for construction will have been obtained.
- Pile Quantities per estimates by Sargent & Lundy.
- Dry Fork Unit 1 plant outage to be used for final tie-ins of new equipment:
    - Ductwork tie-in: demo round duct, install new w/ bypass damper (close/plate isolation to operate DFS) & do a short outage for final tie-in
    - Electrical (BEPC input on switchyard)
    - Mechanical (water)
- Startup, commissioning, and performance testing to support unit operations by consent decree compliance date (at this time a compliance date is not required/known – so schedule will be estimated based on nominal duration).
- Craft is working 6x10-hour days (non-outage), Monday through Saturday (M-S) with additional time for schedule adherence.

- Pipe and electrical work will commence throughout the project when areas become available, scheduled around mechanical progress.
- Construction will build by area until systems are close to 85% complete, then build by system.
- Systems will be turned over to Start-up / Commissioning on time and within schedule allocation.

4.2. Preconstruction Site Prep – 2weeks

The following activities are assumed to be performed prior to starting the main plant construction.

- Grub Access Road(s) for project trailer city, craft parking, and site proper for construction traffic
- Temporary Contractor Shops Setup
- Temporary project Construction Management Office Trailer Setup; including:
    - Site prep to allow trailer setup (level surface, gravel, Parking, any underground, Power, Lighting, Communication, Internet, etc.)
    - Water / sewer for trailers
- Site security considerations
- Signage for site
- Prepare Craft Parking area for traffic
- Silt fencing & berm install, including initial site drainage
- Verify there are no overhead wires in the construction area (currently, there are not any)

4.3. Sequence of Construction

1. Demolition of existing Flue Gas (FG) ducting & supports
2. Install new FG ducting/supports
3. General site grading
4. Scrape and grub for levelness for equipment and foot traffic (storing piles of material to be used later or removed off site)

5. Underground storm sewer & drainage (including construction drainage)
6. Install pilings
7. Install underground piping
8. Install electrical duct banks and other underground conduit or wire: (catholic protection, ground grid, etc.). Note: the primary feed from substation to process transformers have duct bank; plating will be placed over this area until final installation and cable connection
9. Install heavy Civil Foundations, starting with:
    a. Direct Contact Coolers
    b. Train 2 (north) Membrane Modular area
    c. Carbon Capture Process Building
    d. Water Treatment Site Building
    e. CO_2 Purification Building
    f. Train 1 (south) Membrane Modular area (Leave uninstalled area plant east allowing access to Carbon Capture Equipment Building)
    g. Note: Process building transformer foundations installed later to allow for access on east side of the Process building for install (refer to item 8)
10. Erect Direct Contact Coolers, train 1 (south) then train 2 (north)
11. Install support foundations for duct supports, sequencing from present stack to Train 1 (south) then 2 (north)
12. Structural steel for membrane Train 2 then Train 1
13. Install / Stack Membrane containers (3 containers to a stack) set in place for Train 2 and 1 (can start either north or south)
14. Install membrane crane steel (ductwork will box in)
15. Install Duct from Stack to DCC's (1 (south) then 2 (north)) for crane location efficiency
16. Erect / Install DCC Aux Building and equipment

17. Install Duct from membrane back DCC's

18. Mass earth work for New Reservoir, Separating material for disposal. (can start anytime) – assume will be sub-contract to GWC contract at this time, but if GWC does it, Earthwork equipment is now freed up

19. Erect Carbon Capture Building Structure, leaving east side wall off (room to get equipment in & install)

    a. Build entire building structure, leave a crane drop zone (25' x 15') through the roof (southeast side) for electrical & HVAC equipment on 2nd floor

    b. BEPC requested a permanent removable panel on the east wall (2nd floor) to allow for maintenance later; a concrete maintenance pad will be poured at the overhead door area

    c. Note: 2nd floor is a concrete slab

20. Erect CPU building

21. Install Sub-Station foundations, Blast wall, etc.

22. Install Cooling Tower foundations

23. Install foundations for New Limestone Silo and Tank

24. Install Sub-Station Transformer, then dress out

25. Install / Set Equipment in Carbon Capture Process Building

26. Install / Set Equipment in Carbon Purification Building

27. Start dressing out all areas for finished product, Small bore pipe, I&C, DCS, etc. (CPU & Process building)

28. Install Process building transformer foundations, then install Transformers (qty 5), east of Carbon capture building

29. Install new Lime Silo – it will be one piece for the tank (14' diameter & 48' long includes the cone/straight wall length 30')

30. Erect Water Treatment Building structure

31. Install New Wastewater Tank

32. Install/ Set Water Treatment Building equipment

33. Wet Surface Area Cooler & CC Well Water Tank foundations

34. Erection for WSAC & CC Well Water Tank will have to be scheduled after the 1 (south) train Duct is installed from Membrane to Train 1 DCC (need the area for cranes)

35. Walk-down with start-up, Client Reps, etc. for turnover prep for commissioning

36. Install new Lime Silo – it will be one piece for the tank (14’ diameter & 48’ long)

37. Finish all dress out and punch list items that would stop operation of equipment.

38. Turn over to Start-up commissioning

ATTACHMENT 1

Construction Design Review Meeting Presentation with Notes



MTR Full Scale FEED Constructability Review

S&L/ Gene Cellentani & Dana B. Pierik

December 17, 2021

Sargent & Lundy

Overview

- Construction Site Plan
  - Inputs from BEPC/DFS
- Assumptions for Construction
- Conceptual Construction Sequence

Input from BEPC/DFS in Construction Review meeting in ***bright blue text***

Construction Site Plan

- Site Laydown & Staging
  - **BEPC to confirm we can use the original laydown areas, parking, trailers, etc. - *Confirmed***
  - **BEPC input for Traffic**
    - **Material Deliveries – *Main gate; refer to sketch for unloading areas***
    - **Craft Labor Entrance & Parking – *Use original contractor parking area; enter through main gate***
    - **No rail available – *not on site; there is a spur about 3 miles away***
  - **BEPC input for handling of construction waste materials/recycling - *None***
  - *Drawing Reference: Construction Laydown Overlaid on Google Earth*

Construction Site Plan

- Mass Earthwork & Drainage
  - Hill on east side of DFS will be cut into to allow for CO2 Capture facility installation
    - Drainage installed to route to existing stormwater pond on Northwest side of the plant property
    - Note: Construction will not impede on 100 ft from WOTUS
  - CO2 Reservoir on the Southwest side of the plant

  - *Drawing Reference: Dry Fork Civil Sketch*

Construction Site Plan

- Construction Power
  - Existing power loop from original DFS construction is intact w/ some mods near the ITC area
    - U/G duct bank (2015 ACQS powers the ITC fans)
    - Tie-in from the loop powers the remainder of the ITC facility
    - 8MVA total capacity will be available – 480 VAC provided at various locations set up by GWC
    - **Assumption (BEPC/ITC confirm): the ITC will not be in service during CO2 Capture Facility Construction –** ***Lease ends in 2025, but they may renew; will reassess at later phase***
- Lighting
  - Contractor erected temp lighting fed from Construction power loop
  - Mobile generator fed light towers
  - *Drawing Reference: DFS-EH-130-2000 Power Loop*

Construction Site Plan

- Construction Equipment
  - 300-ton Crawler crane(s) – as required for heavy lifts
    - Ductwork segments
    - DCC install
    - Membrane Containers – **MTR confirm container weight –** ***40-ton class A crane estimated***
    - “Reach” support for other installs
  - Mobile cranes – various up to 90-ton
    - Smaller equipment install (maybe Membrane containers)
  - Typical construction equipment - allowance in cost estimate
    - Track hoes
    - Rubber tired forklifts
    - Air Compressors, etc.
  - *Drawing Reference: FS-MTR-M-0001-SitePlan w/ Crane location*

Construction Assumptions

- Deliveries: contractor equipment, major equipment & BOP equipment/materials delivered on time to support construction sequence
- All permits required for construction have been obtained
- Craft working 5–10 hour days (non-outage)
  - **Do we want to consider more to entice craft to the area?** ***6-10's for estimate; per diem***
- "Nominal schedule" – no consent decree
- Pipe & electrical work will commence throughout the project when areas become available
- Construction will build by area until system are close to 85% complete, then transition to system
- Systems will be turned over to start-up & commissioning on time & within schedule

Construction Assumptions

- Outages
  - Unrelated outage work by DFS is not included in this evaluation, but may impact work
  - Assume a major DFS outage occurs after GWC mobilization
    - **For FEED Study Execution Schedule, plan for the 3/8-4/6, 2025 outage** - ***OK***
    - Perform existing FG ducting demo from the ID fan outlet area to the stack & LTC ducting
    - Install new ducting up to the CC dampers (includes STC tie-in mod)
    - Dampers to be closed & blanked for remaining construction
  - Short DFS outage for final tie-in
    - FG Duct
    - Water
    - Electrical
      - **BEPC input on switchyard updates** – ***Due February 11 (on track)***

Conceptual Construction Sequence

- **BEPC Inputs requested:**
  - **For unpaved areas, what is ground cover preference?** ***Gravel for road base near equipment, else grass; reference original final site spec (S&L has)***
  - **Qty 6 maintenance pads acceptable?** ***Yes***
  - **Preference on removable roof or wall panel for process building 2nd floor equipment maintenance** ***- Wall panel***

- Pre-Construction Activities / Site Prep
- Sequence of Construction – (Plant) West to East and North to South

- *Model Review*

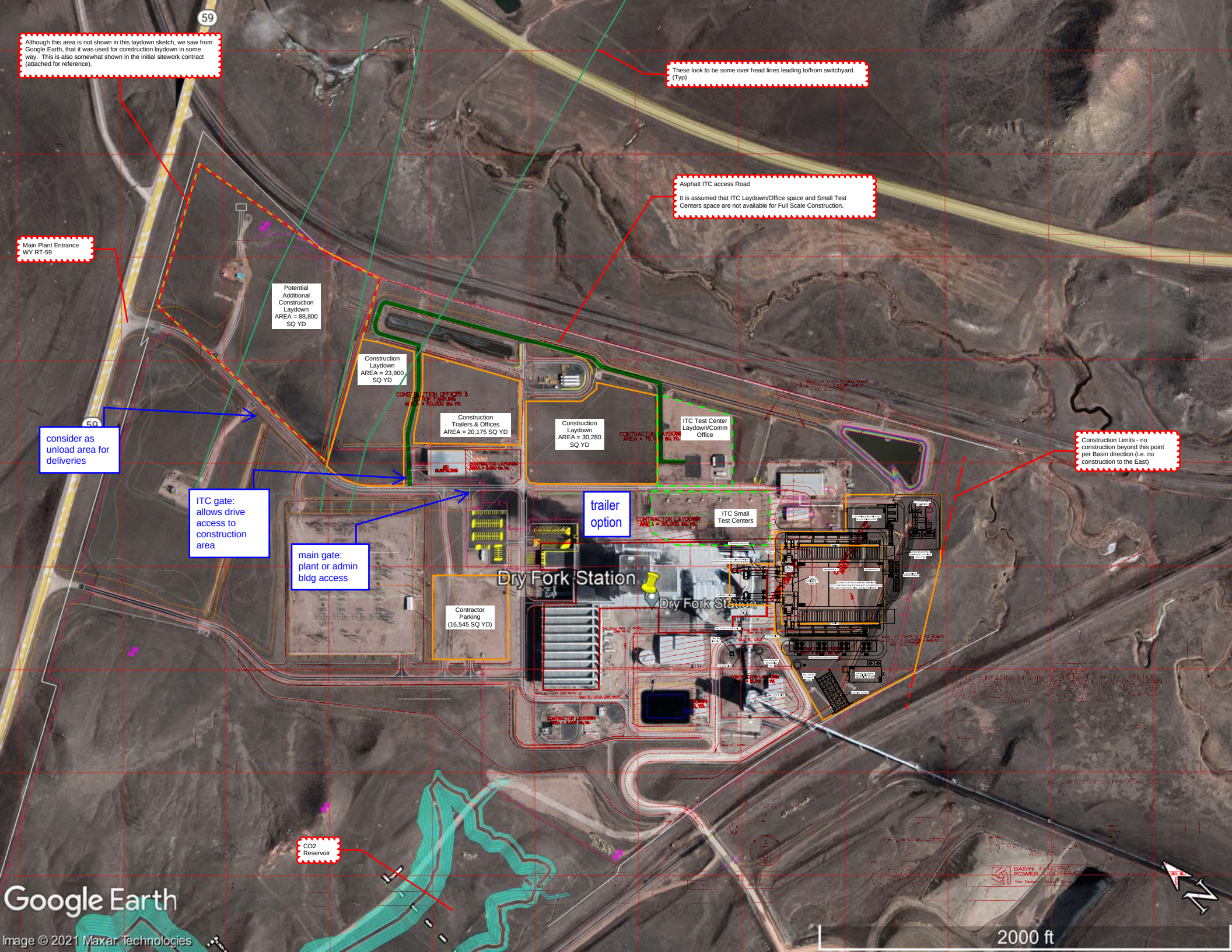
Sargent & Lundy

Thank You

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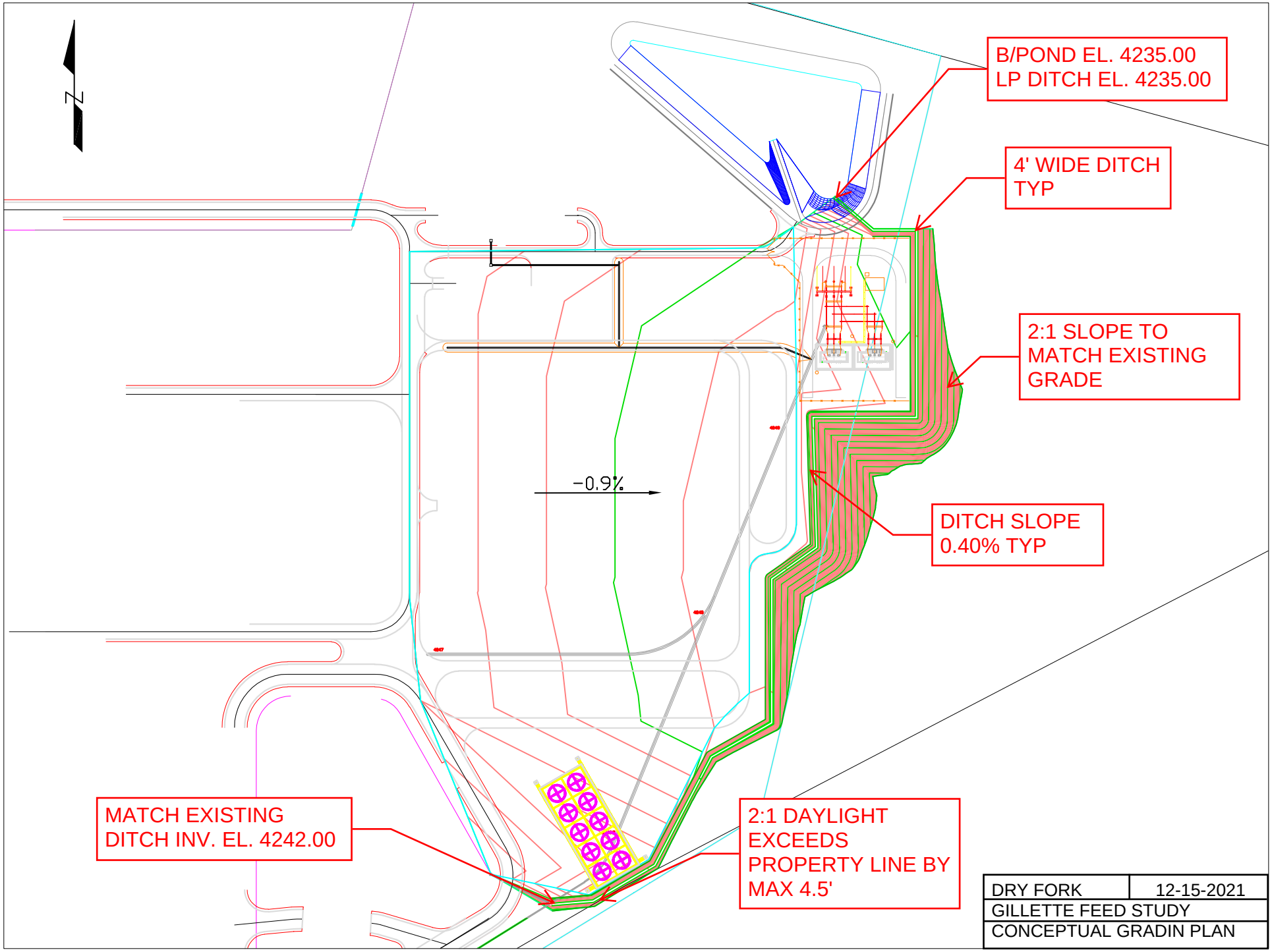
ATTACHMENT 2

Site Aerial Picture for Laydown Areas, Parking, Trailers, etc.


Although this area is not shown in this laydown sketch, we saw from Google Earth, that it was used for construction laydown in some way. This is also somewhat shown in the initial sitework contract (attached for reference).
These look to be some over head lines leading to/from switchyard. (Typ)
Asphalt ITC access Road
It is assumed that ITC Laydown/Office space and Small Test Centers space are not available for Full Scale Construction.
Main Plant Entrance WY RT-59
Potential Additional Construction Laydown AREA = 88,800 SQ YD
Construction Laydown AREA = 23,900 SQ YD
Construction Trailers & Offices AREA = 20,175 SQ YD
Construction Laydown AREA = 30,280 SQ YD
ITC Test Center Laydown/Comm Office
Construction Limits - no construction beyond this point per Basin direction (i.e. no construction to the East)
consider as unload area for deliveries
ITC gate: allows drive access to construction area
main gate: plant or admin bldg access
trailer option
ITC Small Test Centers
Dry Fork Station
Contractor Parking (16,545 SQ YD)
CO2 Reservoir
Google Earth
Image © 2021 Maxar Technologies
2000 ft

ATTACHMENT 3

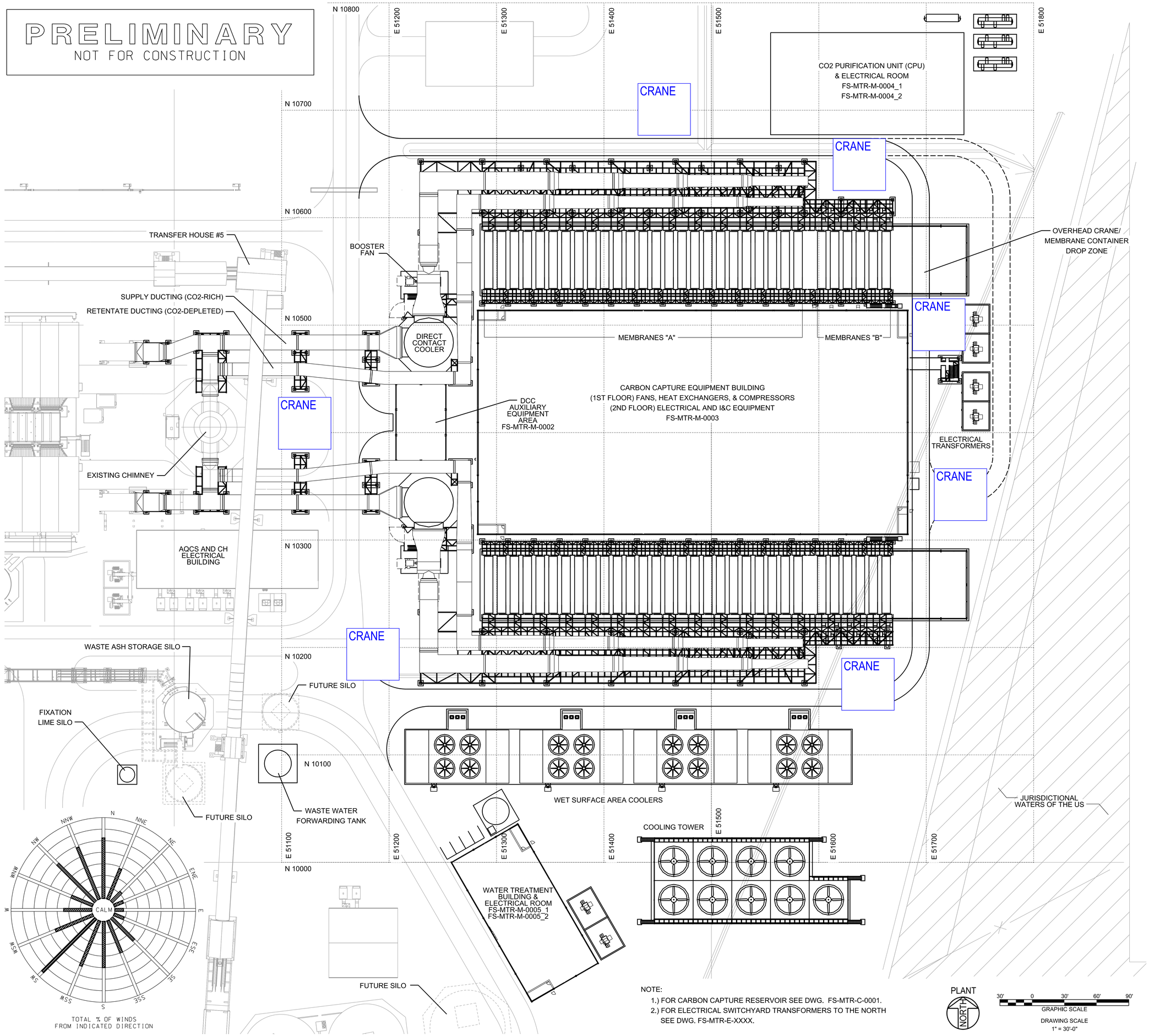
Grade Elevation Sketch


N
B/POND EL. 4235.00
LP DITCH EL. 4235.00
4' WIDE DITCH
TYP
2:1 SLOPE TO
MATCH EXISTING
GRADE
-0.9%
DITCH SLOPE
0.40% TYP
MATCH EXISTING
DITCH INV. EL. 4242.00
2:1 DAYLIGHT
EXCEEDS
PROPERTY LINE BY
MAX 4.5'
DRY FORK
12-15-2021
GILLETTE FEED STUDY
CONCEPTUAL GRADIN PLAN

ATTACHMENT 4

Feasible Crane Locations

PRELIMINARY
NOT FOR CONSTRUCTION



NOTE:
1.) FOR CARBON CAPTURE RESERVOIR SEE DWG. FS-MTR-C-0001.
2.) FOR ELECTRICAL SWITCHYARD TRANSFORMERS TO THE NORTH SEE DWG. FS-MTR-E-XXXX.

PLANT NORTH

30' 0 30' 60' 90'
GRAPHIC SCALE

DRAWING SCALE
1" = 30'-0"

HOLD INFORMATION	
NO.	DESCRIPTION

CONTRACTOR/INSTALLER SHALL TAKE ALL APPROPRIATE PRECAUTIONS TO ENSURE THE SAFETY OF ALL PEOPLE LOCATED ON THE WORK SITE, INCLUDING CONTRACTORS/INSTALLER'S PERSONNEL (OR THAT OF ITS SUB-CONTRACTOR(S)) PERFORMING THE WORK.

RELEASE INFORMATION

REV.	DATE	DESCRIPTION
A	05/28/2021	FOR CLIENT COMMENT
B	10/12/2021	FOR CLIENT COMMENT

ISSUE PURPOSE: FOR CLIENT COMMENT

SPECIFICATION:

PROJECT NO.: A13978.002

I HEREBY CERTIFY THAT THIS ENGINEERING DOCUMENT WAS PREPARED BY ME OR UNDER MY DIRECT PERSONAL SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF ENTER NAME.

ENTER NAME
ENTER DATE

MY LICENSE RENEWAL DATE IS: ENTER DATE
PAGES OR SHEETS COVERED BY THIS SEAL:
THIS DOCUMENT ONLY.

CERTIFICATE OF AUTHORIZATION

CAD FILE NAME: FS-MTR-M-0001.DGN

PREPARED BY: RM

REVIEWED BY: RAM

APPROVED BY: DBP

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55 EAST MONROE STREET
CHICAGO, ILLINOIS 60603-5780

MTR MEMBRANE TECHNOLOGY & RESEARCH

PROJECT

MTR FULL SCALE

CARBON CAPTURE FEED STUDY

GILLETTE, WYOMING

DRAWING TITLE

GENERAL ARRANGEMENT

SITE PLAN

DRAWING NUMBER	REVISION
FS-MTR-M-0001	B

SHEET 01 OF 01

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Form GDG-0401-01-08, ANSI (Imperial) MicroStation Border - Size E - 34 x 44
Revision 10, Revision Date: 10-16-2009
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APPENDIX WW. CAPITAL COST ESTIMATE

MTR
BEPC - DRY FORK STATION
MTR FULL SCALE CARBON CAPTURE PLANT

Estimator	AK/YY/JM
Labor rate table	22WYCHE
Project No.	A13978.002
Estimate Date	04/20/2022
Reviewed By	AK/JM/GA
Approved By	BA
Estimate No.	35837C-Rev. 0
Cost index	WYCHE

MTR
BEPC - DRY FORK STATION
MTR FULL SCALE CARBON CAPTURE PLANT

Sargent & Lundy

Group	Description	Subcontract Cost	Process Equipment Cost	Material Cost	Man Hours	Labor Cost	Equip Amount	Total Cost
11.00.00	DEMOLITION				5,458	312,368	112,239	424,608
21.00.00	CIVIL WORK	13,079,560	100,000	3,493,104	82,168	4,419,559	3,209,903	24,302,126
22.00.00	CONCRETE	200,000		17,132,742	250,009	13,278,744	2,230,432	32,841,918
23.00.00	STEEL			46,485,351	355,465	22,550,476	7,671,306	76,707,133
24.00.00	ARCHITECTURAL	1,530,000		5,418,471	34,041	1,830,377	340,010	9,118,858
27.00.00	PAINTING & COATING	13,733,000		299,525	12,575	575,572	69,363	14,677,459
31.00.00	MECHANICAL EQUIPMENT	11,505,000	322,756,735	1,006,000	284,692	17,989,528	4,812,294	358,069,556
33.00.00	MATERIAL HANDLING EQUIPMENT	286,997	596,974		3,793	234,679	56,133	1,174,784
34.00.00	HVAC	745,928	4,586,710	291,103	15,298	929,836	101,685	6,655,262
35.00.00	PIPING	2,521,560		58,979,566	495,924	32,111,057	8,090,424	101,702,607
36.00.00	INSULATION	1,885,000		2,224,528	54,004	3,199,175	388,551	7,697,254
41.00.00	ELECTRICAL EQUIPMENT	6,874,044	56,281,768	2,085,825	84,148	4,983,621	705,522	70,930,781
42.00.00	RACEWAY, CABLE TRAY & CONDUIT			4,353,501	134,229	8,171,404	172,551	12,697,457
43.00.00	CABLE			11,208,419	130,222	8,009,927	1,843,273	21,061,619
44.00.00	CONTROL & INSTRUMENTATION	5,715,576	3,452,120	918,940	14,600	916,111	55,457	11,058,204
51.00.00	SUBSTATION, SWITCHYARD & TRANSMISSION LINE	4,911,295		303,495	1,360	82,362	7,880	5,305,032
61.00.00	CONSTRUCTION INDIRECT	800,000			57,471	3,616,667		4,416,667
71.00.00	PROJECT INDIRECT	1,596,250						1,596,250
	TOTAL DIRECT	65,384,210	387,774,307	154,200,570	2,015,458	123,211,463	29,867,024	760,437,573

Estimate Totals

Description	Amount	Totals	Hours
Labor	123,211,463		2,015,458
Material	154,200,570		
Subcontract	65,384,210		
Construction Equipment	29,867,024		
Process Equipment	387,774,307		
	760,437,574	**760,437,574**	
General Conditions			
Additional Labor Costs			
90-1 Labor Supervision	7,393,000		
90-2 Show-up Time	2,464,000		
90-3 Cost Due To OT 5-10's	25,860,000		
90-4 Cost Due To OT 6-10's			
90-5 Per Diem	20,155,000		
Site Overheads			
91-1 Construction Management	23,952,000		
91-2 Field Office Expenses	13,307,000		
91-3 Material&Quality Control	4,156,000		
91-4 Site Services	3,413,000		
91-5 Safety	2,629,000		
91-6 Temporary Facilities	2,000,000		
91-7 Temporary Utilities	2,192,000		
91-8 Mobilization/Demob.	2,108,000		
91-9 Legal Expenses/Claims	311,000		
Other Construction Indirects			
92-1 Small Tools & Consumables	3,992,000		
92-2 Scaffolding	6,653,000		
92-3 General Liability Insur.	1,331,000		
92-4 Constr. Equip. Mob/Demob	299,000		
92-5 Freight on Material	7,710,000		
92-6 Freight on Process Equip			
92-7 Sales Tax	19,389,000		
92-8 Contractors G&A	30,491,000		
92-9 Contractors Profit	43,558,000		
	223,363,000	**983,800,574**	
Project Indirect Costs			
93-1 Engineering Services	59,028,000		
93-2 CM Support 3rd Party	14,757,000		
93-3 Start-Up/Comm. 3rd Party	4,919,000		
93-4 Start-Up/Spare Parts	1,221,000		
93-5 Excess Liability Insur.			
93-6 Sales Tax On Indirects			
93-7 Owners Cost	53,186,000		
93-8 EPC Fee			
	133,111,000	**1,116,911,574**	
Contingency			
94-1 Contingency on Const Eq	5,287,000		
94-2 Contingency on Material	28,415,000		
94-3 Contingency on Labor	42,986,000		
94-4 Contingency on Subcontr.	6,471,244		
94-5 Contingency on Process Eq	22,652,109		
94-6 Contingency on Indirect	19,967,000		
	125,778,353	**1,242,689,927**	
Escalation			
96-0 Escalation Supply Chain	23,618,000		
96-1 Escalation on Const Equip	6,490,000		
96-2 Escalation on Material	33,275,000		
96-3 Escalation on Labor	64,581,000		
96-4 Escalation on Subcontract	10,975,000		
96-5 Escalation on Process Eqp	57,104,000		
96-6 Escalation on Indirects	23,564,000		
	219,607,000	**1,462,296,927**	
98 Interest During Constr	96,064,000		
	96,064,000	**1,558,360,927**	
Total		**1,558,360,927**	

APPENDIX XX. O&M COST ESTIMATE

Summary of MTR Full Scale Dry Fork Station (DFS) Carbon Capture O&M Costs

O&M Analysis:	Units	Annual	Source/Notes
DFS Operation:			
Representative Months		Jan - Dec	
Number of Hours	hrs	8,760	Based on 24 hours per day per year, modified for expected operation throughout a year (i.e. Summer Design for 2 months, Winter for 4 months and Annual Average the rest of the year)
Unit Capacity Factor (CF)	%	90	MTR Full Scale Design Criteria Rev. 0 (For Use)
Annual CO_2 Production Rate	tonne/year	2,613,670	Calculated
Capital Cost:			
Subcontract Cost	$	65,384,210	Fixed O&M costs applied to 60% of subcontract costs
Process Equipment Cost	$	387,774,307	
Process Equipment Cost - Excluding Membranes	$	258,853,307	Fixed O&M costs applied to non-membrane costs only as maintenance material and labor are not applicable to the membranes, and costs for membrane replacement is included separately as part of variable O&M costs.
Material Cost	$	154,200,570	Fixed O&M costs applied
Total Direct Cost	$	760,437,574	
Total Project Costs	$	1,558,360,927	
O&M Rates (@ 100% Capacity) & Other Operating Parameters:			
SO_2 Polisher Caustic Consumption Rate, 25% NaOH solution	lb/hr	860	B&W DCC-SO_2 Polisher proposal. Rate represents total for two trains, caustic addition for maintaining pH levels to prevent additional CO_2 removal from occurring in DCC (independent of ambient conditions)
Annual SO_2 Polisher Caustic Consumption Rate	lb/yr	7,533,600	
Annual Fixation Lime Consumption Rate	ton/yr	7,110	
Annual Fixation Incremental Increase in Solid Waste Disposal	ton/yr	64,709	Calculated from current waste disposal from site.
CPU Propylene Refrigerant Annual Makeup Rate	lb/yr	5,000	Per Trimeric input on 2-24-22, assume a 5% makeup rate based on the total amount of refrigerant used in the system, 100,000 lbs. Note that this is considered a maintenance item to occur annually, regardless of unit capacity factor, and therefore is included as a fixed operating cost
Annual RO Water Treatment Inlet Flow	1,000 gal/yr	110,290	
Annual RO Water Treatment Solid Waste Disposal	ton/yr	172	Calculated assuming generation of 150 ppm of dry solids from the RO water treatment process, assuming dewatered sludge is 40 wt% solids.
Membrane System Replacement			
Membrane Replacement Frequency	hours	43,800	MTR input provided on 1-13-2022, membranes will have an average 5 year service life. Specific details of changeout sequence will not be finalized during this study.
Total Changeouts	No./yr	38	Based on 150 MEM A containers (total for Trains 1&2), 36 MEM B containers (total for Trains 1&2), and 1 skid each for MEM C and MEM D
Cooling Tower Chemical Consumption			
Antiscalant Consumption Rate	lb/yr	84,971	Nalco correspondence, proportional to blowdown rate that is subsequentially directly related to evaporation rate, which is dependent on ambient conditions.
Oxidizing Biocide Consumption Rate	lb/yr	31,800	Nalco correspondence (bleach based chemical), dosage is based on the water volume, assume once daily regardless of ambient conditions
Bromine Consumption Rate	lb/yr	3,050	Nalco correspondence, dosage is based on the water volume, assume once daily regardless of ambient conditions

Summary of MTR Full Scale Dry Fork Station (DFS) Carbon Capture O&M Costs

O&M Analysis:	Units	Annual	Source/Notes
Wet Surface Air Cooler (WSAC) Chemical Consumption			
Bleach Consumption Rate	gal/yr	91,250	ChemTreat Correspondence, dosage is based on the water volume, assume once daily regardless of ambient conditions
Sodium Bromide Consumption Rate	lb/yr	14,600	ChemTreat Correspondence, dosage is based on the water volume, assume once daily regardless of ambient conditions
Corrosion Inhibitor Consumption Rate	lb/yr	15,131	ChemTreat Correspondence, proportional to blowdown rate that is subsequently directly related to evaporation rate, which is dependent on ambient conditions.
DBNPA (Microbiocide) Consumption Rate	lb/yr	2,848	ChemTreat Correspondence; note that dosage rate on a monthly basis would continue regardless of unit capacity factor and therefore is considered to be a fixed operating cost
Isothiazolinone (Microbiocide) Consumption Rate	lb/yr	4,295	ChemTreat Correspondence; note that dosage rate on a monthly basis would continue regardless of unit capacity factor and therefore is considered to be a fixed operating cost
Water Consumption			
Annual On-Site Well Water Consumption	1,000 gal/yr	87,621	Calculated, assumed 50/50 split for water supply from Well 1 (on-site) and Well 3 (off-site)
Annual Off-Site Well Water Consumption	1,000 gal/yr	87,621	Calculated, assumed 50/50 split for water supply from Well 1 (on-site) and Well 3 (off-site)
Power Consumption			
Annual CO_2 Capture Island Power Consumption	MW/yr	993,041	
Annual Incremental Increase in Existing ID Fan Power Consumption (Tipping)	MW/yr	19,351	
Annual On-Site Well Water Pump Power Consumption	MW/yr	490	
Total Auxiliary Power Consumption	MW/yr	1,012,882	
Variable & Fixed O&M Costs:			
O&M Unit Pricing ($2022):			
SO_2 Polisher Caustic Price	$/lb	0.30	Hawkins 25% caustic (membrane grade) delivery to Gillette, WY by truck. 10.68 lb/gal, 48,000 lb/4,500 gal per truck, $0.30 per lb, $3.198/gal including FSC
Fixation System - Lime Price	$/ton	165	Based on input from Pete Lien for pebble lime delivery to Gillette, WY
Solid Waste Disposal Price	$/ton	4.62	Basin Electric input based on latest ash haul contract
CPU Refrigerant Price	$/lb	1.95	Airgas Quote: Propylene (Polymer Grade 99.5%) as-delivered price to Salof - New Braunfels, TX, only charged for the amount of product offloaded with each truckload delivered. Although delivered price is not to Gillette, WY, assume that pricing would be provided from a supplier nearby/local to DFS One (1) truck load = ~36,841 lbs propylene (8,400 gallons). Assume (1) purge fees are not required for refrigerant makeup as system will have propylene product already in it, (2) unloading from the truck into storage tank should be ≤ 1 hour and will not require additional demurrage fees and (3) deliveries will not be requested unless required to avoid other non-delivery charges
RO Water Treatment Chemicals Price	$/1,000 gal	0.96	Based on input from Evoqua, 296 gpm inlet should require approximately $150k/yr for chemicals (process and cleaning).
Cooling Tower - Antiscalant Price	$/lb	2.15	Nalco Correspondence
Cooling Tower - Oxidizing Biocide Price	$/lb	0.96	Nalco Correspondence
Cooling Tower - Bromine Price	$/lb	2.18	Nalco Correspondence
WSAC - Bleach Price	$/gal	0.90	ChemTreat Correspondence
WSAC - Sodium Bromide Price	$/lb	4.02	ChemTreat Correspondence
WSAC - Corrosion Inhibitor Price	$/lb	3.59	ChemTreat Correspondence
WSAC - DBNPA (Microbiocide) Price	$/lb	5.90	ChemTreat Correspondence
WSAC - Isothiazolinone (Microbiocide) Price	$/lb	3.75	ChemTreat Correspondence
Raw Water Price	$/1,000 gal	0.00	No additional costs incurred for additional well water consumption
Off-Site Water Aux Power Price	$/1,000 gal	0.77	Well 2 and 3 utilize off-site power. Assumes avg cost of 2020 and 2021 for Well 3 on a $/1,000 gal basis
On-Site Auxiliary Power Price	$/kWh	0.022	Auxiliary power load from DFS switchyard. Basin pricing provided 3-4-22 for aux power pricing at $22/MWh

Summary of MTR Full Scale Dry Fork Station (DFS) Carbon Capture O&M Costs

O&M Analysis:	Units	Annual	Source/Notes
Variable O&M Summary:			
SO_2 Polisher Caustic Cost	$/yr	2,260,000	Calculated
Fixation Lime Consumption Cost	$/yr	1,174,000	Calculated
Fixation - Incremental Increase in Solid Waste Disposal Cost	$/yr	298,000	Calculated
RO Water Treatment System Cost - Chemicals	$/yr	107,000	Calculated
RO Water Treatment - Solid Waste Disposal Cost	$/yr	900	Calculated
Membrane System - Maintenance Replacement Cost	$/yr	15,000,000	Per MTR direction on 2-23-22 $15M/yr, assumed to include spent membrane module disposal costs
Cooling Tower - Antiscalant Cost	$/yr	183,000	Calculated
Cooling Tower - Oxidizing Biocide Cost	$/yr	31,000	Calculated
Cooling Tower - Bromine Cost	$/yr	7,000	Calculated
WSAC - Bleach Cost	$/yr	82,000	Calculated
WSAC - Sodium Bromide Cost	$/yr	59,000	Calculated
WSAC - Corrosion Inhibitor Cost	$/yr	54,000	Calculated
Water Consumption Cost	$/yr	0	Calculated
Off-site Water Power Consumption Cost	$/yr	67,000	Calculated
On-site Auxiliary Power Consumption Cost - CO_2 Capture Island	$/yr	21,847,000	Calculated
On-site Auxiliary Power Consumption Cost - Existing Fan & Well Water Pump	$/yr	436,000	Calculated
Total Variable O&M Cost - at 100% Capacity	**$/yr**	**41,606,000**	
Total Variable O&M Cost - at 90% Capacity	**$/yr**	**37,445,000**	
Fixed O&M Summary:			
Operator Wage	$/hr	72.12	Basin provided operator wage with benefits to be $150k. Assumes 52 weeks, 40 hour work week
Operators Required	#	9.0	Refer to Operating Labor Breakout, number of operators required reflect the total number of personnel (operators, lab technicans, and other support roles) that would be hired as part of retrofit. It should be noted that the number of operators reflects a large degree of oversight that can be provided by existing DFS personnel, as the station staff are familiar with many components of the BOP equipment (based on Basin Electric correspondence).
Operating Labor Cost	$/yr	1,350,000	Refer to Operating Labor Breakout
CPU Propylene Refrigerant Makeup Cost	$/yr	10,000	Calculated
WSAC - DBNPA (Microbiocide) Cost	$/yr	17,000	Calculated
WSAC - Isothiazolinone (Microbiocide) Cost	$/yr	16,000	Calculated
Maintenance Material Cost (Process Equipment - Excluding Membranes)	$/yr	6,784,000	Calculated assuming maintenance costs = 2.5% of the total purchased equipment & material costs and 60% of subcontract costs. Assume cost would be 60% maintenance material costs, 40% maintenance labor.
Maintenance Labor Cost (Process Equipment - Excluding Membranes)	$/yr	0	Operating Labor Breakout includes dedicated maintenance staff for preventative maintenance activities, therefore no additional separate maintenance labor costs are assumed at this time, but will be reviewed further with completion of capital cost estimate.
Total Fixed O&M Cost	**$/yr**	**8,177,000**	

Summary of MTR Full Scale Dry Fork Station (DFS) Carbon Capture O&M Costs

O&M Analysis:	Units	Annual	Source/Notes
Total O&M Cost Summary:			
Total Variable O&M Cost - at 90% Capacity	$/yr	37,445,000	
Total Fixed O&M Cost	$/yr	8,177,000	
Total O&M Cost ($2022)	**$/yr**	**45,622,000**	Sum of Total Variable & Fixed O&M Costs
Current Year for Escalation		2022	
O&M Start Year for Escalation		2029	Construction estimated to be completed & system operational in summer of 2029
Escalation Rate	%	3	Assumed
Escalated Total O&M Cost ($2029)	**$/yr**	**56,109,000**	

Summary of MTR Full Scale Dry Fork Station (DFS) Carbon Capture Retrofit Operating Labor Breakout

Position	Full Time/ Part Time	No. Shifts	No. Personnel/ Shift	Total No. of Staff	Pay Rate	Hours Worked per Year	Total No. of Staff Hired	Annual Salary	Remarks
Shift Supervisor	Full Time	1	1	1	72.12	no increase	0	0	Assume existing shift supervisor at station can provide necessary oversight, as would currently for existing DFS operations - no additional hours
Admin Support	Full Time	1	1	1	72.12	no increase	0	0	Assume existing staff at station can provide necessary oversight, as would currently for existing DFS operations - no additional hours
Support Engineer	Full Time	1	1	1	72.12	2,080	1	150,000	Assume existing responsible engineer for the DFS DFGD system will be able to also take on support of the DCC - no additional hours. However, expect 1 additional support engineer will be required to support all other CO2 capture system components.
Operations Manager	Full Time	1	1	1	72.12	no increase	0	0	Assume existing operations manager at station can provide necessary oversight, as would currently for existing DFS operations - no additional hours
CEMS Technician	Full Time	1	0.25	0.25	72.12	no increase	0	0	Assume that existing CEMS technician staff for the station will be capable of maintaining the additional set of CEMS equipment on the new process vents (stacks) for DHY regeneration exhaust and the existing DFS stack (current operation/CPU shutdown) without any additional increase
Lab Technician (Analyst/Chemist) - Water	Full Time	1	1	1	72.12	2,080	1	150,000	Per Basin Electric input, will require lab technician for monitoring the DCC, cooling tower, WSAC and water treatment system in order to maintain the interconnected chemistry of the DCC and WSAC and cooling water loop with re-injection of condensate water for fans.
Mechanical Maintenance Staff	Full Time	1	1	1	72.12	2,080	1	150,000	Per Basin Electric input
Electrical/ Instrumentation Technician	Full Time	1	1	1	72.12	2,080	1	150,000	Per Basin Electric input
Control Room Operator	Shift Work	4	1	4	72.12	no increase	0	0	Per Basin Electric input, existing control room staff will be capable of overseeing all new equipment associated with CO_2 Capture Island with the assistance of the infield operators.
Cooling Tower and Wet Surface Air Cooler (WSAC) Infield Operator	Shift Work All + Relief	5	0.5	2.5	72.12	no increase	0	0	Per Basin Electric Input, assume other staff/field operators can also provide the oversight needed without any additional increase.
DCC and Flue Gas Booster Fan Infield Operator	Shift Work All + Relief	5	0.25	1.25	72.12	no increase	0	0	Per Basin Electric input, assume other staff/field operators can also provide the oversight needed to facilitate DCC/Booster Fan area maintenance activities, including reagent unloading of caustic solution when required without any additional increase.
MEMA/MEMB Compression Building Infield Operator	Shift Work All + Relief	5	1	5	72.12	10,400	5	750,000	Assume one additional operator required per shift for providing oversight and maintenance support for MEMA and MEMB compression equipment consisting of multi-stage compressors with intercoolers
CPU Building Infield Operator	Shift Work Day & Weekend Only	2	1	2	72.12	no increase	0	0	Assume one field operator on day and weekend to handle trip or upset conditions (2 operators), provide equipment oversight, and minor maintenance as needed to the CO_2 booster pumps. Also assumes that PM work can be covered by other areas' relief staff. Per Basin Electric input, assume other staff/field operators can also provide the oversight needed without any additional increase.
Water Treatment System Infield Operator	Shift Work Day & Weekend Only	2	0.87	1.73	72.12	no increase	0	0	Per Evoqua (RO Supplier) input 2-10-22, approximately 3,600 hours estimated to be required per year to maintain equipment (total no. staff x 40 hour work week x 52 weeks per year = 3,600 hrs). Per Basin Electric Input, assume other staff/field operators can also provide the oversight needed for chemical feeding system and maintenance support of the microfiltration and RO water system without any additional increase.
Wastewater Lime Fixation Infield Operator	Shift Work Day & Weekend Only	2	0.25	0.5	72.12	no increase	0	0	Assume that existing operator(s) and relief staff that oversee the waste ash silo can also accomodate maintenance activities required for new pebble lime storage silo, including pebble lime unloading activities and oversight of pug mill loadout process without any additional increase. Note that incremental increase in waste disposal/truck traffic as part of loadout process is assumed to be covered by waste disposal costs.

Notes
Four (4) shifts per week include Day, Evening, Graveyard, and Weekend.
+ (1) Relief Shift, which consists of personnel on-site for four (4), eight (8) hour days or 32 hours total to complete majority of the preventative maintenance (PM) activities (i.e. infield operators are more reactive and only do PM activities when time allows)

Operators Required	
Full-Time Staff Hired	4.0
Typical No. of Operators per Shift (excluding Full-Time Staff & Control Room Operators)	3.9
Total No. of Staff Hired	9.0
Annual Operating Labor Cost, $/yr	**1,350,000**