APPENDIX D – PROCESS HAZARD ANALYSIS

Minnkota Project Tundra

PHA / HAZOP Report

Report Issued February 12, 2020

By

Tom L. Hoglin, P.E.
Burns McDonnell Engineering / Hoglin Engineering

Minnkota Project Tundra

PHA / HAZOP Report

Table of Contents

1.0 Executive Summary

A Process Hazard Analysis (PHA) was conducted for the Minnekota Project Tundra. The meetings were held online by MS Teams February 11, 2021 with a team of representatives including engineering, design, management, and operations representing three (3) different operating companies. The project is still in a preliminary stage, operating procedures and some design details were not available at the time of study. Recommendations were made as appropriate.

The PHA study was performed as a structured session using a knowledge-based Hazard and Operability (HazOp) methodology. The team reviewed the project as three (3) nodes to evaluate the potential hazardous or undesirable consequences associated with the proposed equipment and piping. Each identified scenario was assigned a severity and likelihood ranking based on the possible safety, environmental, property damage and/or business interruption consequences identified by the team with the associated safeguards in place to prevent or mitigate the event.

The team developed thirty five (35) recommendations to further help mitigate risk inherent to the process. These recommendations are summarized in Section 6. The HazOp Worksheets that were developed during the review can be found in Appendix A.

2.0 Scope of Study

The following nodes of the site were reviewed during the HAZOP/LOPA study.

Nodes

Node	Type	Design Conditions/Parameters	Drawings / References	Equipment ID	Comment	Session
1. Main Meter Station	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0011 MM0012 MM0013	Orifice Meter, Flow Control Valve, Pig Launcher		1. 2/11/2021
2. Wellpad Meter Station #1	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0014 MM0015	Pig Receiver, Orifice Meter Skid		1. 2/11/2021
3. Wellpad Meter Station #2	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0014 MM0016	Pig Receiver, Orifice Meter Skid		1. 2/11/2021

3.0 Process Description / Design Intent

Dense phase CO2 comes from CCS through the Minnkota facilities and pipelines to the injection wells. The proposed design is detailed on the P&IDs and design drawings.

4.0 Methodology

The HAZOP study is performed using traditional HAZOP study methods.

Study methodology:

1. The facilitator will identify the nodes on the master drawing(s) before the first day of the HAZOP session
2. The design intent for that node/system is defined
3. Each node is reviewed using the process parameters (e.g. Pressure) and selected guidewords (e.g. More of) evaluates deviations (e.g. More Pressure)
4. The team then lists all credible causes and consequences
5. The team evaluates the event severity,and defines what undesirable Health & Safety; Environmental; and Operability consequences may occur. Severity is risk ranked per the 5x5 Risk Matrix in Appendix D.
6. The team then identifies existing safeguards (or independent protection layers) that reduce likelihood or severity, then the likelihood of the event with safeguards in place is risk ranked per the 5x5 Risk Matrix in Appendix D.
7. Recommendations are made if required to reduce the potential risk. If no recommendations are made, this means the PHA Team feels listed safeguards to be sufficient.
8. This process is repeated for different process parameters on the selected node. After exhausting all process parameters, the process is repeated for all other nodes

5.0 HAZOP Team, Roles, Attendance

Team Members

First Name	Last Name	Title	Company	Department	Expertise	Phone #	Extension	Fax #	E-Mail Address	Website Address	Comment
Tom	Hoglin	Facilitator / Engineer	Hoglin Engineering								
Denys	Stavnychi	Pipeline Section Manager	Burns & McDonnell								
Evan	Montz	Project Engineer	Burns & McDonnell								
Boualem	Boudid	Mechanical Lead	Burns & McDonnell								
Joe	Faber	E&I Lead	Burns & McDonnell								
Michael	Istre	Process/Piping Lead	Burns & McDonnell								
Stephanie	Villarreal		Burns & McDonnell								
Naresh	Murthy	Project Manager	Oxy								
Marion	Cole		Hies								
Dylan	Wolf		Minnkota								
Shannon	Mikula		Minnkota								
Kelly	Watson		Oxy								
Angie	Contreras		CCS								
			CCS								
			CCS								

6.0 HAZOP Recommendations

Recommendations

Recommendations	Place(s) Used	Responsibility	Maximum Risk		Rec Pri	Rec Cat	Status	% Complete	Estimated Dates		Actual Dates		Cost		Comments
			Before Action	After Action					Start Date	End Date	Start Date	End Date	Estimated	Actual	
1. Consider consequence number 2 (shutdown resulting in phase change, possible well issues) when developing operation procedures to prevent damage to well perforations.	Causes: 1.1.1														
2. Determine the maximum flow allowed for each wellpad, consider a high flow alarm at appropriate setpoint.	Causes: 1.2.1														
3. Determine what the maximum flow anticipated from the CCS facility is.	Causes: 1.2.1														
4. Assure the RTU building includes a high CO2 alarm with appropriate siren and/or beacon to alert personnel prior to building entry.	Causes: 1.2.2, 1.2.3		6												
5. Assure operating procedures are followed prior to building entry, assure portable CO2 monitors available.	Causes: 1.2.2, 1.2.3		6												
6. Consider adding an additional PCV for another pressure cut on the analyzer line.	Causes: 1.2.2		6												
7. Ensure coordination between operating companies to plan for a CCS unit shutdown which can reduce flow to 40%.	Causes: 1.1.6														
8. Review need for adding a check valve to the meter station with CCS and the well team.	Causes: 1.3.1														
9. Assure operating procedures call for plugs in all valves going to atmosphere, and to not open vents/drains with system in operation.	Causes: 1.4.1		4												
10. Assure operation procedures call for drains and vents closed when system down to prevent moisture entry and corrosion.	Causes: 1.4.2		5												
11. Ensure communication and control occurs between RTUs on CCS, pipeline,	Causes: 1.4.3														

Recommendations	Place(s) Used	Responsibility	Maximum Risk		Rec Pri	Rec Cat	Status	% Complete	Estimated Dates		Actual Dates		Cost		Comments
			Before Action	After Action					Start Date	End Date	Start Date	End Date	Estimated	Actual	
and well team facilities.															
12. Consider using pig trap closures with a physical locking mechanism that prevents opening the closure while under pressure.	Causes: 1.4.4		5												
13. Consider alternate measures of corrosion monitoring (instead of ILI pigs) on pipeline #2 due to the short distance of pipeline	Causes: 1.4.4		5												
14. Assure proper overpressure protection is in place for the system between CCS, pipeline, and wellpads, Assure overpressure protection is set at proper setpoints.	Causes: 1.5.1, 1.5.2		6												
15. Consider adding PAH and PAHH alarms on the station PITs, signal to RTU control.	Causes: 1.5.2		6												
16. Consider adding a PSLL pressure switch to close valve upstream of meter station.	Causes: 1.6.1, 2.6.1														
17. Consider several cases of pressure/temperature on the facility for piping stress analysis, consider potential high temperature from CCS due to cooler failure.	Causes: 1.7.1		6												
18. Consider adding a temperature transmitter with an alarm / shutdown at facility inlet to close on high and low temperatures.	Causes: 1.7.1, 1.8.1		6												
19. Assure proper protection for pipe stress due to high temperature is in place for all parties - CCS, pipeline, and wellpad.	Causes: 1.7.1		6												
20. Determine low temperature safe operating limit, and add a low temperature alarm and/or shutdown at CCS TI-0612, 0613.	Causes: 1.8.1														
21. Revisit the acceptable limits of potential contaminates from CCS for the Pipeline and Wells, assure proper analyzers in place with proper alarm and/or shutdown setpoints.	Causes: 1.11.1														

Recommendations	Place(s) Used	Responsibility	Maximum Risk		Rec Pri	Rec Cat	Status	% Complete	Estimated Dates		Actual Dates		Cost		Comments
			Before Action	After Action					Start Date	End Date	Start Date	End Date	Estimated	Actual	
22. Consider adding ballards and/or flags around aboveground piping to prevent 3rd party impact.	Causes: 1.13.1, 1.14.1, 2.13.1		7												
23. Assure inspection protocols and integrity management plan is in place to meet DOT pipeline requirements.	Causes: 1.13.1, 2.13.1		6												
24. Safeguards for snow removal need to be considered during final design, assure proper training for snow removal personnel.	Causes: 1.14.1		7												
25. Address any potential communication and cyber security breaches between CCS, Pipeline, Wells.	Causes: 1.14.2, 2.14.1		7												
26. Consider adding provisions for a temporary generator.	Causes: 1.16.1														
27. Review the potential for brine coming from the well formation back to the surface equipment causing excessive corrosion and loss of containment, assure proper safeguards are in place.	Causes: 2.3.1		5												
28. Determine what temperature is allowed for the wells and formation, assure proper safeguards are in place to protect wells.	Causes: 1.7.1		6												
29. Assure property owner is informed about the pipeline, potential exposure issues, and trained on how to respond in the event of a release.	Causes: 2.13.1		6												
30. Consider using fiber optic cable along the pipeline for leak detection.	Causes: 2.13.1		6												
31. Consider alternate routes for the pipeline ROW to add additional distance between the pipeline and 3rd party receptors.	Causes: 2.13.1		6												
32. Assure communications are in place with the mining operation and the pipeline group to prevent potential line strikes.	Causes: 2.13.2		6												

Recommendations	Place(s) Used	Responsibility	Maximum Risk		Rec Pri	Rec Cat	Status	% Complete	Estimated Dates		Actual Dates		Cost		Comments
			Before Action	After Action					Start Date	End Date	Start Date	End Date	Estimated	Actual	
33. Confirm MSHA requirements for road crossing during design phase. Review potential mining blasting operations impact on the pipeline.	Causes: 2.13.2		6												
34. Consider more physical security mitigations to prevent entry and/or tampering on remote site location (Wellpad #1).	Causes: 2.14.1		7												
35. Assure the proper failure modes are defined for all the automated valves on the system and identified on P&IDs.	Causes: 1.1.3														

7.0 Appendices

A. **HAZOP Worksheets**
B. **Node List and Definitions**
C. **P&IDs**
D. **Risk Ranking**

Appendix A: HAZOP Worksheets

PHA Worksheet

Node	Deviation	Cause	Consequence	Before Risk Reduction S	Before Risk Reduction L	Before Risk Reduction RR	Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction S	After Risk Reduction L	After Risk Reduction RR
1. Main Meter Station	1. Less/No Flow	1. Shutdown of CCS facility.	1. Loss of flow to meter station and wellpads. Operability issues only. Potential for well shutdown, Operational issues in bringing wells back on.				1. MOV-1001 will close when loss of flow from CCS.	1. Consider consequence number 2 (shutdown resulting in phase change, possible well issues) when developing operation procedures to prevent damage to well perforations.					
			2. If extended shutdown, potential for dense phase CO2 to go more to liquid phase. Possible sand plugging of well tubing perforations downhole. Possible operational difficulties in restarting.				2. MOV-1004, 5 Shutdown valves upstream of wellpads will close on loss of flow.						
							3. Each well will have an automated shutdown valve.						
		2. MOV-1002, 3 malfunctions closed	1. Same scenario as above										
		3. FCV-1001,2 malfunctions closed	1. Same scenario as above					35. Assure the proper failure modes are defined for all the automated valves on the system and identified on P&IDs.					
		4. Any number of manual block valves closed.	1. Same scenario as above										
		5. Well workover or testing as part of permit requirements.	1. Shutdown of system. Same scenario as above										
		6. Intentional reduction of flow, one unit down for cleaning at CCS, when this occurs flow is reduced to 40% of total flow.	1. Operability issues, no hazards.					7. Ensure coordination between operating companies to plan for a CCS unit shutdown which can reduce flow to 40%.					
	2. More Flow	1. CCS system is not able to exceed the pipeline system design capacity.						2. Determine the maximum flow allowed for each wellpad, consider a high flow alarm at appropriate setpoint.					
								3. Determine what the maximum flow anticipated from the CCS facility is.					
		2. PCV-1001 malfunctions open.	1. Potential to overpressure the analyzer. Damage to analyzer, small release rate of CO2. Release is inside of the analyzer building. Possible low O2	A	2	6	1. PSV-1001, set at 80 psig, relieves to a safe location.	4. Assure the RTU building includes a high CO2 alarm with appropriate siren and/or beacon to alert personnel prior to building entry.					
								5. Assure operating procedures are followed prior to building entry, assure portable CO2					

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
			atmosphere and asphyxiation upon building entry.					monitors available.					
								6. Consider adding an additional PCV for another pressure cut on the analyzer line.					
		3. NC 1" vents inadvertently open inside RTU building, or small leaks in building.	1. Un contained release of CO2 from vent. Release is inside of the analyzer building. Possible low O2 atmosphere and asphyxiation upon building entry.	A	2	6	1. Valve is intended to be closed and plugged.	4. Assure the RTU building includes a high CO2 alarm with appropriate siren and/or beacon to alert personnel prior to building entry.					
								5. Assure operating procedures are followed prior to building entry, assure portable CO2 monitors available.					
	3. Reverse Flow	1. With system shutdown, potential reverse flow back to CCS	1. Potential for measurement errors from reverse flow. Minor operability issues.				1. Each compressor has a check valve on the discharge at CCS.	8. Review need for adding a check valve to the meter station with CCS and the well team.					
	4. Misdirected Flow	1. Drains and vents open to atmosphere, release of CO2	1. Un contained release of CO2 from vents and drains.	B	1	4	1. Plugs on all valves to atmosphere.	9. Assure operating procedures call for plugs in all valves going to atmosphere, and to not open vents/drains with system in operation.					
		2. Drains and vents open to atmosphere, entrance of air and moisture/water, etc. into piping.	1. Increased internal corrosion due to water presence.	A	1	5	1. Plugs on all valves to atmosphere. 2. CP may reduce corrosion rate for small amounts of moisture.	10. Assure operation procedures call for drains and vents closed when system down to prevent moisture entry and corrosion.					
		3. 16" manual bypass around FCV-1001 left open.	1. Loss of flow control, possible more flow to one of the well pads. Potential exceed permitted allowable's, formation damage not expected. Operability issues.				1. Flow control devices exist at the well pads. 2. Redundant metering at well pads.	11. Ensure communication and control occurs between RTUs on CCS, pipeline, and well team facilities.					
		4. Opening a pig trap door while under pressure.	1. Potential for injury while opening pig trap.	A	1	5	1. PI-1005 on barrel	12. Consider using pig trap closures with a physical locking mechanism that prevents opening the closure while under pressure.					
							2. Pressure safety indicator on the trap doors 3. Operating procedures. 4. Appropriate drains/vents on pig traps.	13. Consider alternate measures of corrosion monitoring (instead of ILI pigs) on pipeline #2 due to the short distance of pipeline					

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
	5. Higher Pressure	1. CCS compressor discharge overpressure protection failure (PSV, PSHH shutdowns, etc)	1. Possible overpressure of meter station piping and equipment, release and possible injury.	A	2	6	1. PS-1001 on inlet of facility closes MOV-1001 (ANSI 900) 2. PIT monitoring pressure in multiple areas, operator response.	14. Assure proper overpressure protection is in place for the system between CCS, pipeline, and wellpads, Assure overpressure protection is set at proper setpoints.					
		2. Pipeline outlet blockage or closure, continue to feed the pipeline from CCS.	1. Possible overpressure of meter station piping and equipment, release and possible injury.	A	2	6	1. PS-1001 on inlet of facility closes MOV-1001 (ANSI 900)	14. Assure proper overpressure protection is in place for the system between CCS, pipeline, and wellpads, Assure overpressure protection is set at proper setpoints.					
							2. PIT monitoring pressure in multiple areas, operator response.	15. Consider adding PAH and PAHH alarms on the station PITs, signal to RTU control.					
		3. Blocked in thermal expansion on pig trap.	1. Possible slight overpressure of barrel.				1. PSV-1002.						
	6. Lower Pressure	1. Upstream facility upset at CCS.	1. Potential for phase change of the CO2, possible injection issues and operability issues.				1. PIT monitoring pressure in multiple areas, operator response.	16. Consider adding a PSLL pressure switch to close valve upstream of meter station.					
	7. Higher Temperature	1. Cooler failure on downstream of compressors.	1. Potential for compressor discharge temperature CO2 (unknown temperature) coming to the pipeline facilities. Possible piping stress and release.	A	2	6	1. CCS has TSHH-0612, 0613 shutdown, set at 120 F.	17. Consider several cases of pressure/temperature on the facility for piping stress analysis, consider potential high temperature from CCS due to cooler failure.					
			2. Possible for coating damage to the pipeline (180 F limit), possible for increased corrosion and reduced design life.					18. Consider adding a temperature transmitter with an alarm / shutdown at facility inlet to close on high and low temperatures.					
			3. Potential high temp to the wells and formation.					19. Assure proper protection for pipe stress due to high temperature is in place for all parties - CCS, pipeline, and wellpad.					
								28. Determine what temperature is allowed for the wells and formation, assure proper safeguards are in place to protect wells.					

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
	8. Lower Temperature	1. Excessive cooling at CCS, cooling control valve malfunction open.	1. Potential for phase change of the CO2, possible injection issues and operability issues.				1. CCS has TSHH-0612, 0613 shutdown, set at 120 F.	18. Consider adding a temperature transmitter with an alarm / shutdown at facility inlet to close on high and low temperatures. 20. Determine low temperature safe operating limit, and add a low temperature alarm and/or shutdown at CCS TI-0612, 0613.					
		2. System shutdown for extended period of time due to ambient cooling.	1. Potential for phase change of the CO2, possible injection issues and operability issues.										
	9. Higher Level	1. Not applicable.											
	10. Lower Level	1. Not applicable.											
	11. Contamination	1. Failure of dehydration system and/or failure of other scrubbing systems resulting in contaminants to the inlet of the meter station.	1. Potential for corrosion and not meeting injection well specifications. Possible injection issues and reduced life of piping.				1. Moisture analyzers at CCS. 2. Moisture analyzers at main meter station	21. Revisit the acceptable limits of potential contaminates from CCS for the Pipeline and Wells, assure proper analyzers in place with proper alarm and/or shutdown setpoints.					
	12. Wrong Concentration	1. See contamination above.											
	13. Leak/Rupture	1. Corrosion, third party damage, overpressure, pipe stress, valves left open, etc.	1. Possible release and personnel exposure.	A			1. Metering between and wellpad mass balance will detect significant loss 2. Corrosion coupon monitoring 3. Routing inline inspection 4. Steady quality of CO2 5. Cathodic protection 6. Pipeline markers 7. Line is buried additional 12" beyond requirements.	22. Consider adding ballards and/or flags around aboveground piping to prevent 3rd party impact. 23. Assure inspection protocols and integrity management plan is in place to meet DOT pipeline requirements.					
	14. Human Factors	1. Snow accumulation on the site. Snow removal equipment on the site can result in damage to piping systems	1. Possible release and personnel exposure.	A	3	7	1. Site can be controlled and/or shut down remotely. 2. Station is	22. Consider adding ballards and/or flags around aboveground piping to prevent 3rd party impact. 24. Safeguards for snow removal					

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
							designed to be unmanned, routine access is not required.	need to be considered during final design, assure proper training for snow removal personnel.					
		2. Communications to outside entities, potential for hacking / sabotage.	1. Possible release and personnel exposure.	A	2	6		25. Address any potential communication and cyber security breachs between CCS, Pipeline, Wells.					
	15. Startup/Shutdown	1. No new concerns.											
	16. Loss of Utilities	1. Loss of power	1. Loss of communication and loss of flow control to the wells, possible permit violation.				1. For CCS: system has UPS and equipment goes to fail safe condition.	26. Consider adding provisions for a temporary generator.					
							2. For Pipeline: each site has UPS and equipment goes to fail safe condition.						
	17. Miscellaneous	1. No new concerns.											
2. Wellpad Meter Station #1	1. Less/No Flow	1. Same as node 1.											
	2. More Flow	1. Same as node 1.											
	3. Reverse Flow	1. System shutdown, potential reverse flow back to meter stations	1. Potential for measurement errors from reverse flow. Minor operability issues.				1. Each compressor has a check valve on the discharge at CCS.	27. Review the potential for brine coming from the well formation back to the surface equipment causing excessive corrosion and loss of containment, assure proper safeguards are in place.					
			2. Possible reverse flow from wells, possible brine from injection wells into surface equipment, possible increased corrosion.	A	1	5	2. Each wellpad has check valves						
	4. Misdirected Flow	1. Same as node 1.											
		2. One wellpad shutdown, same flow coming from CCS.	1. CCS plant would divert CO2 flow to the vent, compressors do have recycle ability for short term. Operability issues.				1. CCS can divert flow to the CO2 Vent						
							2. 2nd compressor can be shutdown						
							3. Compressor recycle systems						
	5. Higher Pressure	1. Same as node 1.											

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
	6. Lower Pressure	1. Upstream facility upset at CCS, or main meter station.	1. Potential for phase change of the CO2, possible injection issues and operability issues.				1. PIT monitoring pressure in multiple areas, operator response.	16. Consider adding a PSLL pressure switch to close valve upstream of meter station.					
							2. PSLL-1004 will close MOV-1004 stopping flow to well.						
		2. PSLL-1004 fails to close on a low pressure situation.	1. Potential for phase change of the CO2, possible injection issues and operability issues.				1. Wells have shutdown valves for high and low pressure.						
	7. Higher Temperature	1. Same as node 1.											
	8. Lower Temperature	1. Same as node 1.											
	9. Higher Level	1. Not applicable.											
	10. Lower Level	1. Not applicable.											
	11. Contamination	1. Same as node 1.											
	12. Wrong Concentration	1. Same as node 1.											
	13. Leak/Rupture	1. Corrosion, third party damage, overpressure, pipe stress, valves left open, etc.	1. Possible release and personnel exposure. Land owner property for a residence located near the pipeline ROW may experience high levels of CO2, possible fatalities. Note: Dispersion analysis has been completed indicating that high levels may reach 3rd party property line, but not to the 3rd party occupied residence.	A	2	6	1. Metering between and wellpad mass balance will detect significant loss.	22. Consider adding ballards and/or flags around aboveground piping to prevent 3rd party impact.					
							2. Corrosion coupon monitoring	23. Assure inspection protocols and integrity management plan is in place to meet DOT pipeline requirements.					
							3. Routing inline inspection	29. Assure property owner is informed about the pipeline, potential exposure issues, and trained on how to respond in the event of a release.					
							4. Steady quality of CO2	30. Consider using fiber optic cable along the pipeline for leak detection.					
							5. Cathodic protection	31. Consider alternate routes for the pipeline ROW to add additional distance between the pipeline and 3rd party receptors.					
							6. Pipeline markers						
							7. Line is buried additional 12" beyond requirements.						

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
		2. Third party damage in active mine property (line strike, use of explosives in mining activities, etc.)	1. Possible release and personnel exposure. Pipeline goes through an active mine potential increased chance for a line strike. Line goes under an MSHA road.	A	2	6	1. Same as above.	32. Assure communications are in place with the mining operation and the pipeline group to prevent potential line strikes.					
								33. Confirm MSHA requirements for road crossing during design phase. Review potential mining blasting operations impact on the pipeline.					
	14. Human Factors	1. Potential for hacking / sabotage on remote site.	1. Possible release and personnel exposure.	A	3	7		25. Address any potential communication and cyber security breaches between CCS, Pipeline, Wells.					
								34. Consider more physical security mitigations to prevent entry and/or tampering on remote site location (Wellpad #1).					
	15. Startup/Shutdown	1. Same as node 1.											
	16. Loss of Utilities	1. Same as node 1.											
	17. Miscellaneous	1. No new concerns.											
3. Wellpad Meter Station #2	1. Less/No Flow	1. Team discussed that node 3 is identical as node 2, without the public receptors specifically identified in node 2. Deviations cause/consequence/safeguards are the same.											
	2. More Flow												
	3. Reverse Flow												
	4. Misdirected Flow												
	5. Higher Pressure												
	6. Lower Pressure												
	7. Higher Temperature												
	8. Lower Temperature												
	9. Higher Level												
	10. Lower Level												
	11. Contamination												
	12. Wrong Concentration												

Node	Deviation	Cause	Consequence	Before Risk Reduction			Effective Safeguards	Recommendations	Responsibility	Status	After Risk Reduction		
				S	L	RR					S	L	RR
	13. Leak/Rupture												
	14. Human Factors												
	15. Startup/Shutdown												
	16. Loss of Utilities												
	17. Miscellaneous												

Appendix B: Node List and Definitions

Nodes

Node	Type	Design Conditions/Parameters	Drawings / References	Equipment ID	Comment	Session	Revision #	Revision Date
1. Main Meter Station	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0011 MM0012 MM0013	Orifice Meter, Flow Control Valve, Pig Launcher		1. 2/11/2021		
2. Wellpad Meter Station #1	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0014 MM0015	Pig Receiver, Orifice Meter Skid		1. 2/11/2021		
3. Wellpad Meter Station #2	Piping	ANSI Class 900 Flanged Piping, 2160 psig @ 100 F MAWP Pig Trap: 1800 psig @ 200 F	MM0014 MM0016	Pig Receiver, Orifice Meter Skid		1. 2/11/2021		

Appendix C: P&IDs

NOTES:
1. LOCATION OF THE TIE-IN POINT WILL BE AT THE FENCE LIMIT. CO2 PLANT FACILITY CONTRACTOR TO BRING THE PIPING ABOVE GROUND TO THE FENCE LINE. THE PIPING WILL BE KEPT ABOVE GROUND TO THE METER STATION BUILDING.

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

no.	date	by	ckd	description
				MM0010 P&ID SYMBOLS AND LEGEND
				MM0001 METER FLOW STATION PROCESS DIAGRAM
				MM0012 FLOW CONTROL VALVE SKIDS
				MM0017 RTUS & ANALYZER

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
ORIFICE METER SKID MS-1001
MAIN METER STATION

project: 128002
contract:
drawing: MM0011 – rev. A
sheet 1 of 1 sheets
file 128002MM0011.dwg

Scale For Microfilming
Millimeters
Inches

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

no.	date	by	ckd	description
				MM0010 P&ID SYMBOLS AND LEGEND
				MM0001 METER FLOW STATION PROCESS DIAGRAM
				MM0011 ORIFICE METER SKID MS-001
				MM0013 PIG LAUNCHER SKIDS

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
FLOW CONTROL VALVE SKIDS
MAIN METER STATION

project: 128002
contract:
drawing: MM0012 –
rev. A
sheet 1 of 1 sheets
file 128002MM0012.dwg

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description	no.	date	by	ckd	description
									MM0010 P&ID SYMBOLS AND LEGEND
									MM0001 METER FLOW STATION PROCESS DIAGRAM, SHEET 1
									MM0012 FLOW CONTROL VALVE SKIDS
									MM0014 PIG RECEIVER SKIDS
A	01/12/21	MCH	BB	ISSUED FOR REVIEW					

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
PIG LAUNCHER SKIDS
MAIN METER STATION

project: 128002
contract:
drawing: MM0013 –
rev.: A
sheet 1 of 1 sheets
file 128002MM0013.dwg

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

no.	date	by	ckd	description
				MM0010 P&ID SYMBOLS AND LEGEND
				MM0002 METER FLOW STATION PROCESS DIAGRAM, SHEET 2
				MM0013 PIG LAUNCHER SKIDS
				MM0015 ORIFICE METER SKID MS-1002
				MM0016 ORIFICE METER SKID MS-1003

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
PIG RECEIVER SKIDS
WELL PAD #1 & WELL PAD #2

project: 128002
contract:
drawing: MM0014 – rev. A
sheet 1 of 1 sheets
file 128002MM0014.dwg

MS-1002
FLOW METER SKID
TYPE: ORIFICE METER
DESIGN FLOW RATE: 12,980 TON/DAY
DESIGN PRESSURE: 1,800 PSIG
DESIGN TEMPERATURE: 200°F
ORIFICE BORE SIZE: 10"
TYPE: DANIEL SENIOR METER
REDUNDANCY: 2x100%

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

no.	date	by	ckd	description
				MM0010 P&ID SYMBOLS AND LEGEND
				MM0002 METER FLOW STATION PROCESS DIAGRAM, SHEET 2
				MM0014 PIG RECEIVER SKIDS

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
ORIFICE METER SKID MS-1002
WELL PAD #1 & WELL PAD #2

project: 128002
contract:
drawing: MM0015 –
rev.: A
sheet 1 of 1 sheets
file 128002MM0015.dwg

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

Reference drawings:
- MM0010 P&ID SYMBOLS AND LEGEND
- MM0002 METER FLOW STATION PROCESS DIAGRAM, SHEET 2
- MM0014 PIG RECEIVER SKIDS

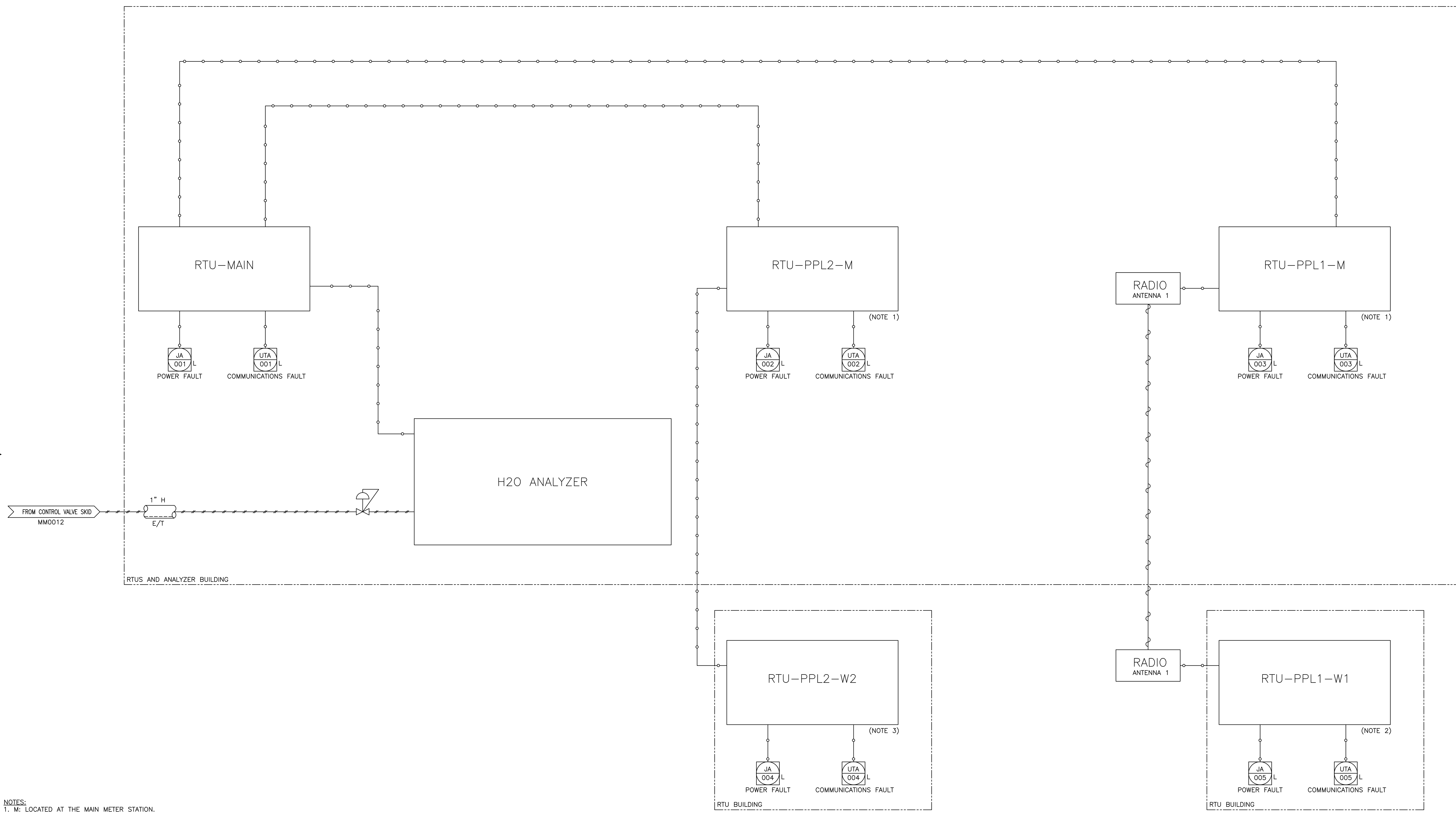
BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.
designed: M. HOOVER
detailed: N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
ORIFICE METER SKID MS-1003
WELL PAD #1 & WELL PAD #2

project	128002
contract	
drawing	MM0016 –
rev.	A
sheet	1 of 1 sheets
file	128002MM0016.dwg



NOTES:
1. M: LOCATED AT THE MAIN METER STATION.
2. W1: LOCATED AT WELL PAD #1.
3. W2: LOCATED AT WELL PAD #2.

PRELIMINARY - NOT FOR CONSTRUCTION

no.	date	by	ckd	description
A	01/12/21	MCH	BB	ISSUED FOR REVIEW

MM0010 P&ID SYMBOLS AND LEGEND
MM0001 METER FLOW STATION PROCESS DIAGRAM, SHEET 1
MM0002 METER FLOW STATION PROCESS DIAGRAM, SHEET 2
MM0012 FLOW CONTROL VALVE SKIDS

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

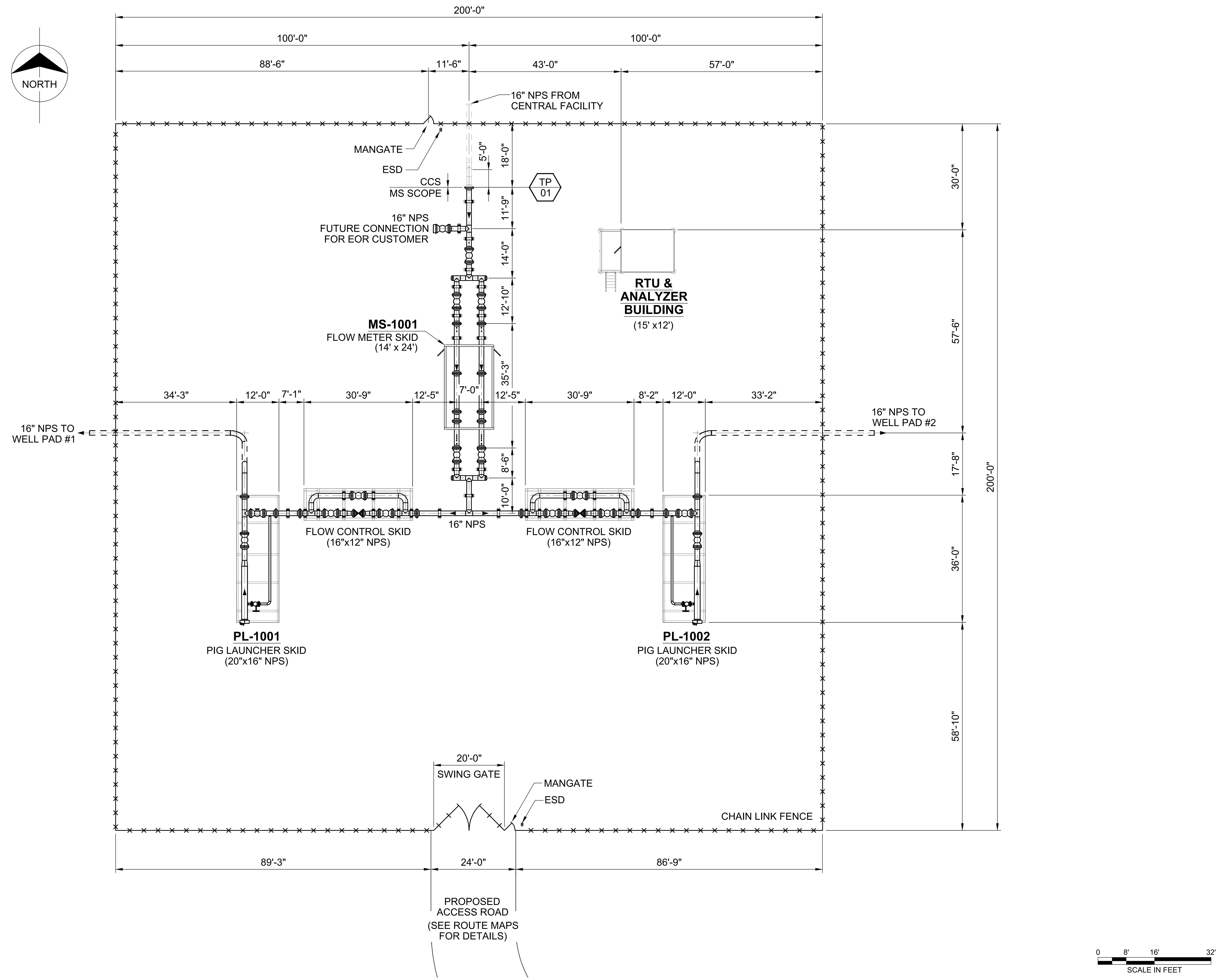
designed M. HOOVER
detailed N. REISER

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PIPING & INSTRUMENTATION DIAGRAM
RTUS & ANALYZER
WELL PAD #1 & WELL PAD #2

project 128002
contract
drawing MM0017 – rev. A
sheet 1 of 1 sheets
file 128002MM0017.dwg



no.	date	by	ckd	description
B	1/12/21	SAR	BB	ISSUED FOR REVIEW
A	12/09/20	SAR	BB	ISSUED FOR BID

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

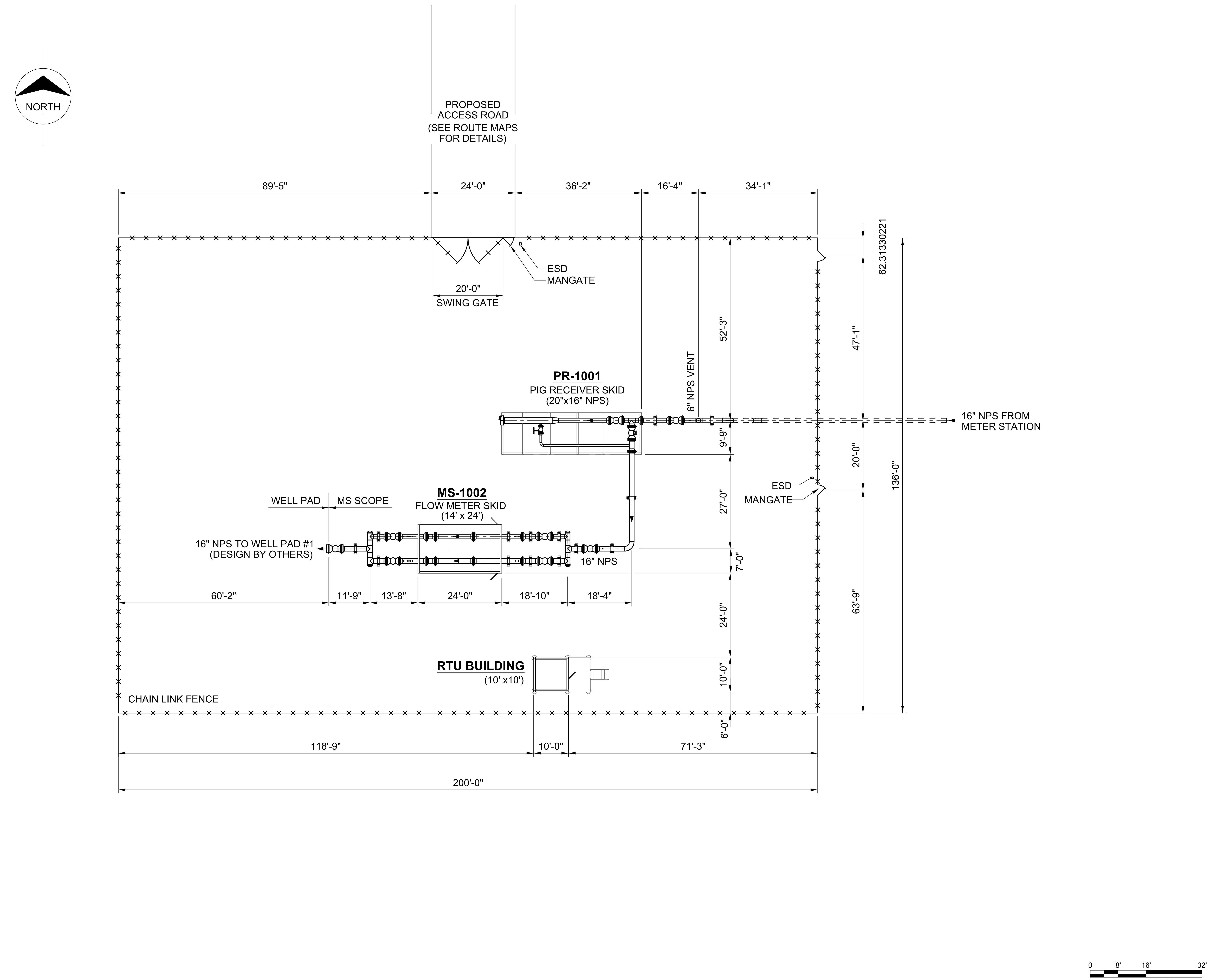
designed: B. BOUDID
detailed: S. RUSSELL

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PROJECT TUNDRA CO2 PIPELINE
MAIN METER STATION
GENERAL ARRANGEMENT

project: 128002
contract:
drawing: MS001 – rev. B
sheet 1 of 3 sheets
file 128002MS001



no.	date	by	ckd	description
B	1/12/21	SAR	BB	ISSUED FOR REVIEW
A	12/09/20	SAR	BB	ISSUED FOR BID

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

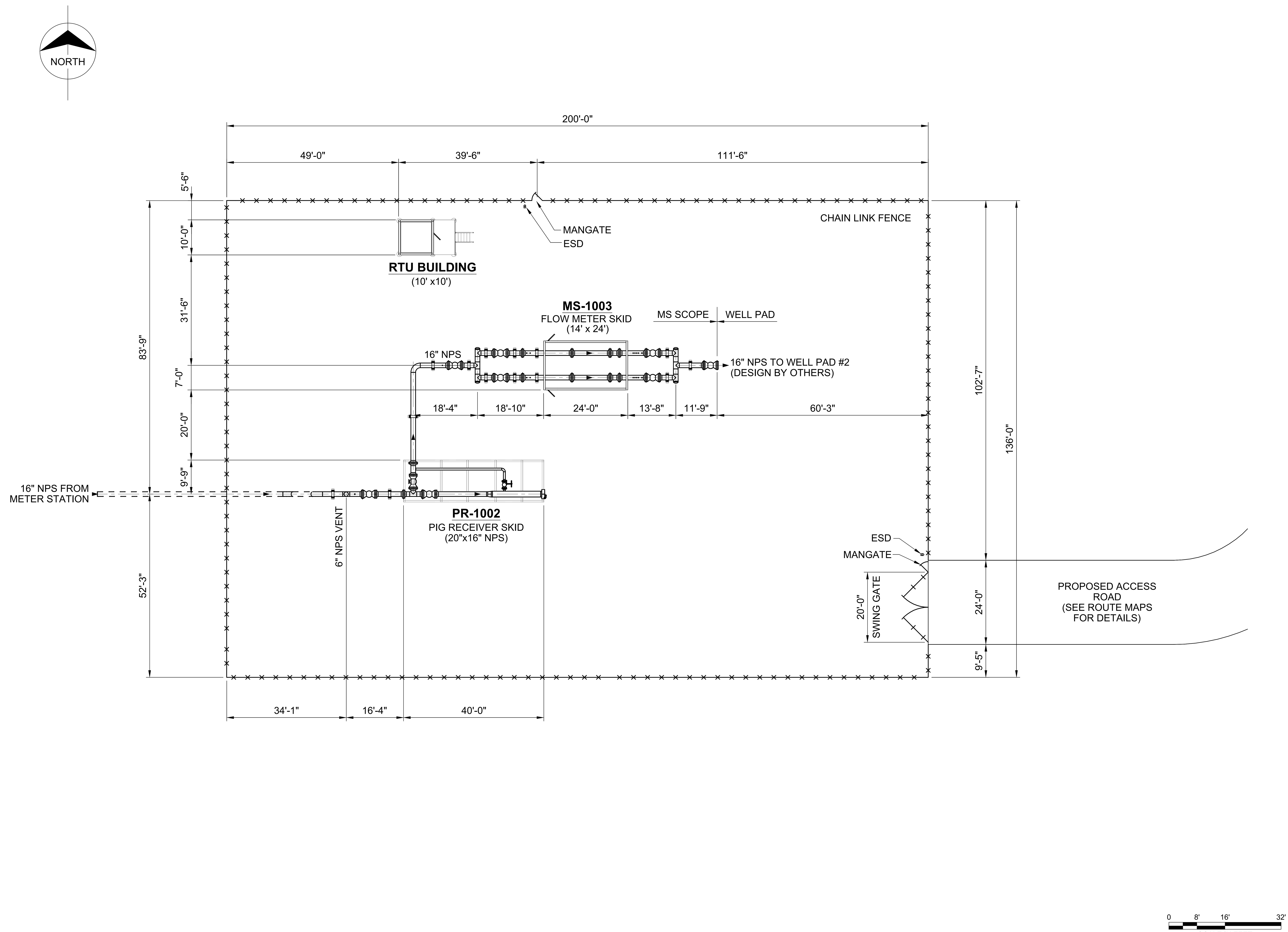
designed: B. BOUDID
detailed: S. RUSSELL

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PROJECT TUNDRA CO2 PIPELINE
WELL PAD 1
GENERAL ARRANGEMENT

project: 128002
contract:
drawing: MS002 – rev. B
sheet 2 of 3 sheets
file 128002MS002



no.	date	by	ckd	description
B	01/12/21	SAR	BB	ISSUED FOR REVIEW
A	12/09/20	SAR	BB	ISSUED FOR BID

no.	date	by	ckd	description

BURNS McDONNELL
9400 WARD PARKWAY
KANSAS CITY, MO 64114
816-333-9400
Burns & McDonnell Engineering Co, Inc.

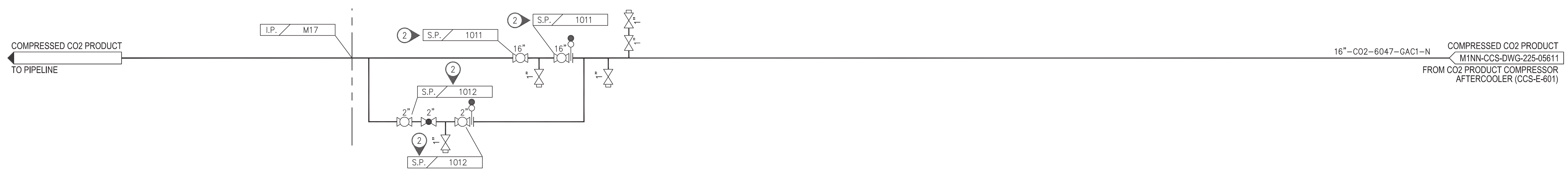
designed: B. BOUDID
detailed: S. RUSSELL

Minnkota Power COOPERATIVE
A Touchstone Energy® Cooperative

OLIVER COUNTY, ND

MINNKOTA POWER COOPERATIVE
PROJECT TUNDRA CO2 PIPELINE
WELL PAD 2
GENERAL ARRANGEMENT

project: 128002
contract:
drawing: MS003 – rev. B
sheet 3 of 3 sheets
file 128002MS003



NOTES:

2. CO2 PRODUCT BATTERY LIMIT ISOLATION VALVES ARE CLASS VI SHUT–OFF.

REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REFERENCE DWG NUMBER	REFERENCE DRAWINGS
A	N/A	INTERNAL ISSUE (NOT USED)	---	---	---								
B	21AUG20	ISSUED FOR CLIENT REVIEW	MKS	KA	SR								
C	02OCT20	ISSUED FOR PHA II	MKS	KA	SR								
0	11DEC20	ISSUED FOR DESIGN	MKS	KA	SR								

FLUOR

CONTRACT M1NN

NOTICE: RESTRICTED, TRADE SECRET INFORMATION AND BACKGROUND INTELLECTUAL PROPERTY OF FLUOR, SUBJECT TO THE TERMS OF THE PARTIES' EXECUTED AGREEMENTS FOR MINNKOTA POWER COOPERATIVE, INC. PROJECT TUNDRA.

CONTRACT M1NN
DESIGNED BY M. STILLMAN
CHECKED BY K. AFSHAR
PROCESS TECHNOLOGY S. REDDY — APP DATE
LEAD ENGR/SPEC. K. AFSHAR — APP DATE
FLUOR R. GRAEBE — APP DATE
CLIENT D. WOLF — APP DATE

MINNKOTA POWER COOPERATIVE

PROJECT TUNDRA

CARBON CAPTURE AND SEQUESTRATION

PIPING AND INSTRUMENTATION DIAGRAM

ECONAMINE FG PLUS℠ PROCESS

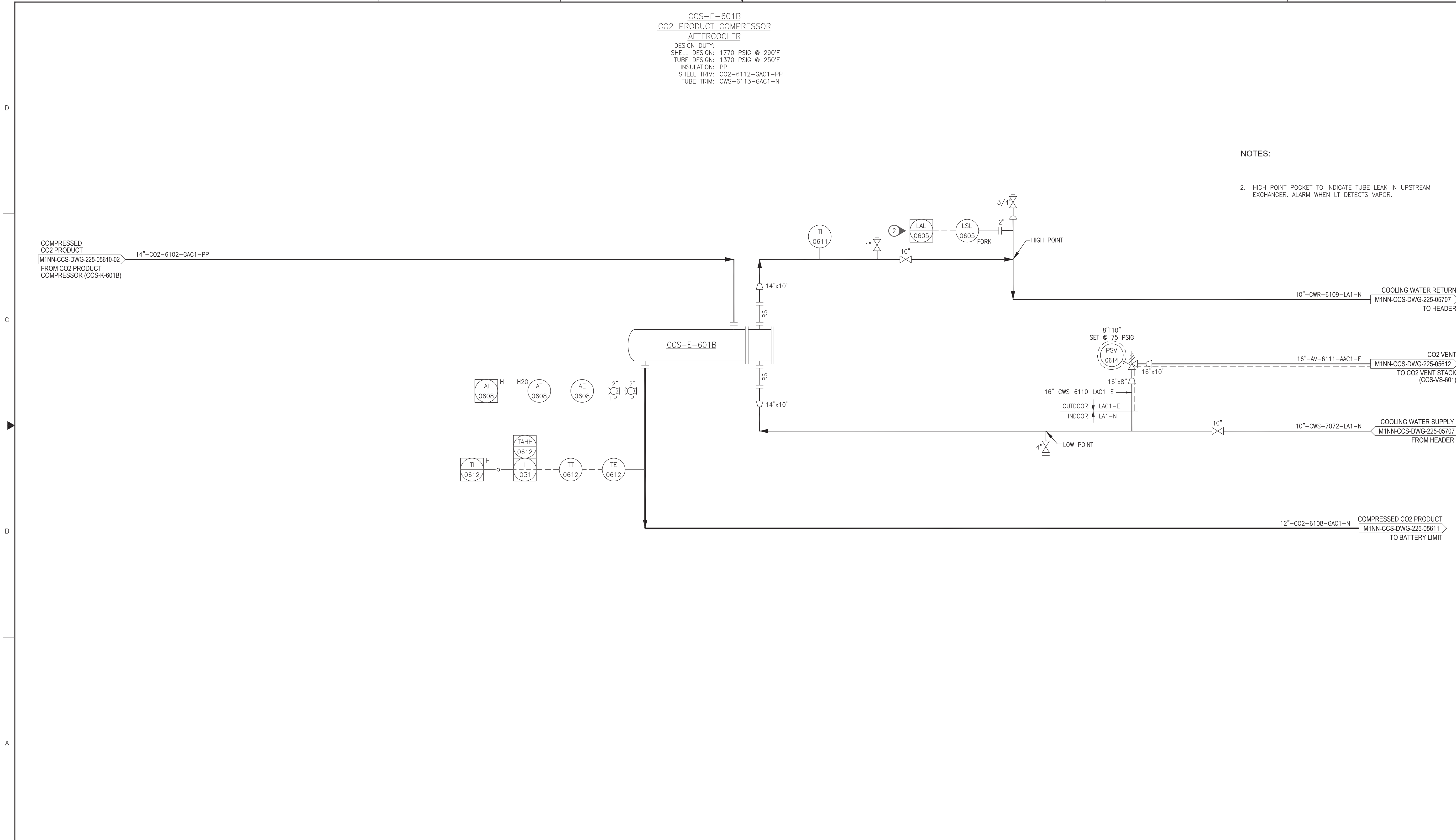
BATTERY LIMIT

SCALE NONE | DRAWING NUMBER M1NN–CCS–DWG–225–05101 | REV 0

CAD FILE NAME M1NN–CCS–DWG–225–05101.dwg

PLOT DATE: \\fdnet.com\av_depts\WRK090\225\Proprietary Equipment\MPC Project Tundra_Process Graphics\PROCESS GRAPHICS Transfer_NATIVES Files – Tundra__PIDs\M1NN–CCS–DWG–225–05101.dwg 12–17–20 8:28 am Printed By: sco57212

F–022.DWG 01JUL09



REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REFERENCE DWG NUMBER	REFERENCE DRAWINGS
A	N/A	INTERNAL ISSUE	---	---	---								
B	21AUG20	ISSUED FOR CLIENT REVIEW	MKS	KA	SR								
C	02OCT20	ISSUED FOR PHA II	MKS	KA	SR								
0	11DEC20	ISSUED FOR DESIGN	MKS	KA	SR								

FLUOR®

CONTRACT M1NN

CONTRACT: M1NN
DESIGNED BY: M. STILLMAN
CHECKED BY: K. AFSHAR
PROCESS TECHNOLOGY: S. REDDY — APP DATE
LEAD ENGR/SPEC.: K. AFSHAR — APP DATE
FLUOR: R. GRAEBE — APP DATE
CLIENT: D. WOLF — APP DATE

MINNKOTA POWER COOPERATIVE

PROJECT TUNDRA

CARBON CAPTURE AND SEQUESTRATION

PIPING AND INSTRUMENTATION DIAGRAM
ECONAMINE FG PLUS℠ PROCESS
CO2 PRODUCT COMPRESSOR AFTERCOOLER

SCALE	DRAWING NUMBER	REV
NONE	M1NN-CCS-DWG-225-05611-02	0

CAD FILE NAME M1NN-CCS-DWG-225-05611-02.dwg

F-022.DWG 01JUL09

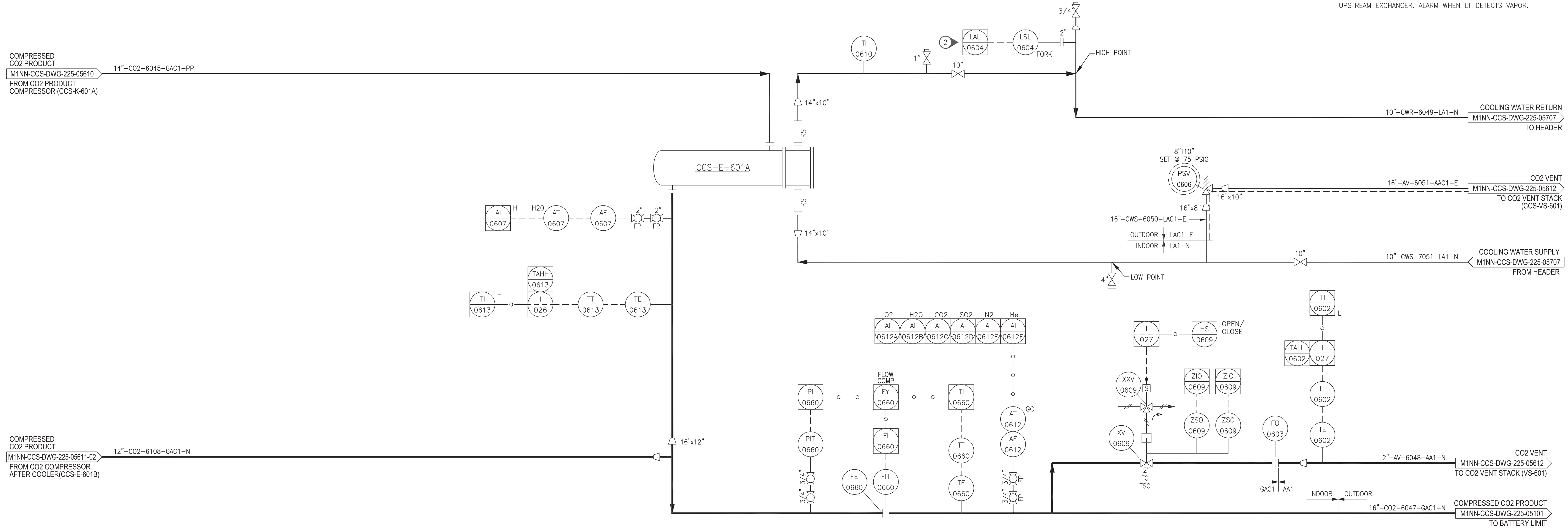
PLOT DATE: \\fdnet.com\av_depts\WRK090\225\Proprietary Equipment\MPC Project Tundra_Process Graphics\PROCESS GRAPHICS Transfer_NATIVES Files – Tundra__PIDs\M1NN-CCS-DWG-225-05611-02.dwg 12-10-20 10:45 am Printed By: sco57212

CCS-E-601A
CO2 PRODUCT COMPRESSOR
AFTERCOOLER

DESIGN DUTY:
SHELL DESIGN: 1770 PSIG @ 290°F
TUBE DESIGN: 1370 PSIG @ 250°F
INSULATION: PP
SHELL TRIM: CO2-6052-GAC1-PP
TUBE TRIM: CWS-6053-GAC1-N

NOTES:

2. HIGH POINT VAPOR POCKET TO INDICATE TUBE LEAK IN UPSTREAM EXCHANGER. ALARM WHEN LT DETECTS VAPOR.



REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REV	DATE	REVISION DESCRIPTION	BY	CHK	APPV	REFERENCE DWG NUMBER	REFERENCE DRAWINGS
A	N/A	INTERNAL ISSUE	---	---	---								
B	21AUG20	ISSUED FOR CLIENT REVIEW	MKS	KA	SR								
C	02OCT20	ISSUED FOR PHA II	MKS	KA	SR								
0	11DEC20	ISSUED FOR DESIGN	MKS	KA	SR								

FLUOR®

CONTRACT M1NN

CONTRACT: M1NN
DESIGNED BY: M. STILLMAN
CHECKED BY: K. AFSHAR
PROCESS TECHNOLOGY: S. REDDY — APP DATE
LEAD ENGR/SPEC.: K. AFSHAR — APP DATE
FLUOR: R. GRAEBE — APP DATE
CLIENT: D. WOLF — APP DATE

MINNKOTA POWER COOPERATIVE
PROJECT TUNDRA
CARBON CAPTURE AND SEQUESTRATION

PIPING AND INSTRUMENTATION DIAGRAM
ECONAMINE FG PLUS℠ PROCESS
CO2 PRODUCT COMPRESSOR AFTERCOOLER

SCALE: NONE
DRAWING NUMBER: M1NN-CCS-DWG-225-05611
REV: 0
CAD FILE NAME M1NN-CCS-DWG-225-05611.dwg

F-022.DWG 01JUL09

PLOT DATE: \\fdnet.com\av_depts\WRK090\225\Proprietary Equipment\MPC Project Tundra_Process Graphics\PROCESS GRAPHICS Transfer_NATIVES Files - Tundra__PIDs\M1NN-CCS-DWG-225-05611.dwg 12-10-20 10:43 am Printed By: sco57212

Appendix D: Risk Ranking

RISK MATRIX

		LIKELIHOOD				
		1	2	3	4	5
SEVERITY	A	5	6	7	8	9
	B	4	5	6	7	8
	C	3	4	5	6	7
	D	2	3	4	5	6
	E	1	2	3	4	5

SEVERITY RANKING

Severity	Description
A	One or More Fatalities, Catastrophic Burns / Serious Public Health and Environmental Impact / Major Property Damage
B	Serious Injury or Multiple Injured Personnel / Limited Public Health and Environmental Impact / Significant Property Damage
C	Medical Treatment for Personnel / No Public Health Impact / Moderate Property Damage and Environmental Impact
D	First Aid Injury / No Public Health Impact / Possible Incipient Fire, Minor Property Damage and Environmental Impact
E	No Injury or Health Impact / Minimal or No Property Damage or Environmental Impact

LIKELIHOOD

Frequency /Likelihood	Description	Frequency
5	Likely to occur several times in facility, possibly annually	>10^-1 to 1 / yr
4	Likely to occur once or twice within facility lifetime	>10^-2 to 10^-1
3	Likely to occur within the lifetime of 10 similar facilities	>10^-3 to 10^-2
2	Not likely, but similar Event has occurred in similar facilities	>10^-4 to 10^-3
1	Not likely, but similar Event has occurred in industry	>10^-5 to 10^-4

APPENDIX E – PROJECT TUNDRA INITIAL LIFE CYCLE ANALYSIS CALCULATIONS

Project Tundra LCA Data Inputs and Assumptions

Data	Source	Notes and Assumptions
Surface Mines CO2 Emission Factor	Equation 4.1.7A (New) Average Global Emission Factor IPCCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2: Energy Retrieved April 25, 2023, From https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf	
Post- Mining Activities CO2 Emission Factor	From IPCC Guidelines "While no default method is provided for estimating Post-mining emissions of CO2, countries may choose to provide their own country-specific emission estimate."	IPCC Guidelines do not provide an emission factor. The CO_2 emission factor for surface mines is between the NTEC provided emission factors for No. 6 and PRB Coal and is therefore a reasonable estimation. If an emission factor for post-mining activities is identified then calculations will be updated.
N2O Emission Factor	Table 5: Raw Material Acquisition Inventory PRB Coal DOE/NETL Upstream Dashboard Tool Documentation (Aug, 2016). Retrieved April 25, 2023, From https://netl.doe.gov/energy-analysis/details?id=a79a1cff-c7a6-43e0-ae57-16dcc806840d	N_2O Emission Factor specific to lignite coal or North Dakota unavailable. Emission Factor for PBR coal from the NETL provided database substituted. NETL Upstream Tool defines Raw Material Acquisition as "starts when material or energy has been drawn from the environment without previous human transformation and includes the extraction of raw feedstocks from the earth and any partial processing of the raw materials that may occur before transport to the energy conversion facility" so emission factor is inclusive of post-mining activities
Surface Mining CH4 Emission Factor	Equation 4.1.7 (New) Average Global Emission Factor IPCCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2: Energy Retrieved April 25, 2023, From https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf	
Post-Mining Activities CH4 Emission Factor	Equation 4.1.8 Average Global Emission Factor IPCCC 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 2: Energy Retrieved April 25, 2023, From https://www.ipcc-nggip.iges.or.jp/public/2019rf/pdf/2_Volume2/19R_V2_4_Ch04_Fugitive_Emissions.pdf	
Emission Factors (CO_2, N_2O, CH_4)	Table 5: Raw Material Acquisition Inventory Domestic Petroleum DOE/NETL Upstream Dashboard Tool Documentation (Aug, 2016).Retrieved April 25, 2023, From https://netl.doe.gov/energy-analysis/details?id=a79a1cff-c7a6-43e0-ae57-16dcc806840d	
FO Consumption	Annual FO consumption projection of MRY Boiler 1 and Boiler 2 provided by Minnkota	
Truck Type	https://insideenergy.org/2016/08/15/why-north-dakota-coal-is-the-last-man-standing/lignite-mine-haul-truck/	Haul Truck Type assumed from research into typically equipment at North Dakota Mining Facilities. Aligns with haul capacity provided by client.
Engine HP	Kress 200C III Coal Hauler Spec Sheet https://www.heavyequipments.org/blog/398-kress-200c-iii-mining-truck-coal-hauler-specifications	
Haul Capacity (short tons)	Kress 200C III Coal Hauler Spec Sheet : https://www.heavyequipments.org/blog/398-kress-200c-iii-mining-truck-coal-hauler-specifications Confirmed by Dylan Wolf (Minnkota) via email	
Average Speed	Kress 200C III Coal Hauler Spec Sheet https://www.heavyequipments.org/blog/398-kress-200c-iii-mining-truck-coal-hauler-specifications	Assumes that the trucks typically travels in Gears 1-4 with mph
Max Coal Consumption (short ton per year)	Coal Consumption Projections MRY Boiler 1 and Boiler 2 Years: 2032-2043 Provided by Minnkota	
Max Roundtrip Distance (miles)	Provided by Minnkota	
Max Trips per Year	Calculated: Maximum Coal Consumption divided by Haul Capacity	Assumes trucks are carrying full loads equivalent to haul capacity every trip
GHG Emission Factors	Greenhouse gas emissions from 40 CFR 98, Table C-1 and C-2	Conversion of 2544.43 Btu/hp-hr. is assumed
Load Factor	Conservative Estimate based on similar equipment	

Project Tundra LCA Data Inputs and Assumptions

Data	Source	Notes and Assumptions
Emission Factors (CO_2, N_2O, CH_4)	Table 5: Raw Material Acquisition Inventory Domestic Petroleum DOE/NETL Upstream Dashboard Tool Documentation (Aug, 2016).Retrieved April 25, 2023, From https://netl.doe.gov/energy-analysis/details?id=a79a1cff-c7a6-43e0-ae57-16dcc806840d	
FO Consumption	Annual FO consumption projections of MRY Boiler 1 and Boiler 2 provided by Minnkota	
CO2 Emission Factor	Based on past actuals submitted to the Acid Rain Program (ARP) years 2018-2021	Emission Factor reflects both Coal and FO combustion
N2O and CH4 Emission Factors	GHG Emission Data 40 CFR, Part 98, Subpart C (Emission Factors)	
Coal HHV	Based on Past Actuals reported to ARP for MRY Boiler 1 and Boiler 2	
Fuel Oil HHV	Based on Past Actuals reported to ARP for MRY Boiler 1 and Boiler 2	
FO Consumption	Annual FO consumption projection of MRY Boiler 1 and Boiler 2 provided by Minnkota	
Max Coal Consumption	Coal Consumption Projections MRY Boiler 1 and Boiler 2 Years: 2032-2043 Provided by Minnkota	
Maximum Heat Input	Calculated based on fuel consumption expectations and previous actual HHV values	
Annual Amount CO_2 Stored	Calculated : Annual amount of CO_2 processed minus processing emissions and transportation emissions.	
CO2 Emissions	Provided by Minnkota Based on preliminary engineering estimations	
Amount of CO_2 processed at the plant on an annual basis	Calculated from the Daily Amount of CO_2 processed by the Plant, Based on operating scenarios Provided by Minnkota	Assumes operation 365/days per year Minnkota's operation scenario is based on a 99% capture efficiency
Pipeline Loss	Provided by Minnkota CO_2 loss from pipeline calculated by Sargent and Lundy	CCS Island to JROC Pipeline (0.25 miles) + Operational Fugitive Losses Sargent and Lundy included a 10% safety factor
Amount of CO2 processed at the plant on an annual basis	Calculated from the Daily Amount of CO_2 processed by the Plant, Based on operating scenarios Provided by Minnkota	Assumes operation 365/days per year Minnkota's operation scenario is based on a 99% capture efficiency
Amount of CO_2 Transported Annually	Calculated: Annual amount of CO_2 processed minus processing emissions.	
SF6 Emission Factor	From DE-FOE-0002962 Appendix J	This emission factor is published in Appendix J with units "kg SF_6 / kg CO_2 stored" updated to "kg SF_6 / Mwh" based on consultation with NETL

Revised Initial LCA
Functional Unit: kg CO_2e per kg CO_2 Stored

Project Tundra LCA Data Inputs and Assumptions

Project Tundra Initial Life Cycle Analysis Results
REVISED

Table 1: Updated Initial LCA Results to incorporate CO_2 sequestered from Coal Plant Emissions

Emissions Source	kg of Emissions per CO2 Sequestered				
	CO_2	N_2O	CH_4	SF_6	CO_2e
Upstream					
Coal Mining	**7.52E-04**	**5.94E-06**	**8.09E-04**	-	**3.16E-02**
FO Extraction	**8.87E-05**	**2.68E-09**	**4.76E-07**	-	**1.07E-04**
Coal Transportation	**9.35E-04**	**3.79E-08**	**7.59E-09**	-	**9.47E-04**
FO Transportation	5.53E-07	1.42E-11	1.11E-11	-	5.58E-07
Coal Electricity Plant	**0.34**	2.15E-05	1.47E-05	-	**0.34**
Proposed Project					
CO2 Capture Plant	**8.15E-03**	-	-	-	**8.15E-03**
Electricity Consumption	**0.04**	**1.81E-06**	**1.24E-06**	--	**0.04**
Downstream					
CO2 transportation	8.58E-05	-	-	-	8.58E-05
CO2 storage*	-		-	-	-
Electricity Transmission	-	-	-	**9.25E-08**	**2.17E-03**
TOTAL LCA	**0.39**	**2.93E-05**	**8.26E-04**	**9.25E-08**	**0.43**

*Assuming there are no measurable losses at the wellhead to the reservoir

****Bold Numbers** indicate numbers that have been updated from previous iterations

Contribution Analysis - kg CO_2 Equivalents per kg CO_2 Sequestered

Appendix J Category	**CO_2**	**N_2O**	**CH_4**	**SF6**	**Total**	**%**
Fuel Extraction and Delivery	**0.34**	0.01	**0.03**	-	**0.37**	**97.30%**
Plant Direct Emissions	0.01	-	-	-	0.01	**2.11%**
CO2 Transport and Storage	8.58E-05	-	-	-	**8.58E-05**	**0.02%**
Electricity Transportation	-	-	-	**2.17E-03**	**2.17E-03**	**0.56%**
Total	**0.35**	0.01	**2.97E-02**	**2.17E-03**	**0.39**	

*Fuel is defined as the CO_2 utilized at the CO_2 Separation and Purification Plant

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Extraction: Coal Mining

Summary

GHG	kg emissions / metric tonne coal extracted	BUILD kg emissions / kg CO_2 stored
CO_2	0.81	7.52E-04
N_2O	6.40E-03	5.94E-06
CH_4	8.71E-01	8.09E-04
SF_6	-	-
CO_2e	34.07	3.16E-02

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change

	Emission Factor	Units
Surface Mines CO_2	0.44	m3 CO2 / metric tonne lignite Coal
	8.10E-01	kg CO2 / metric tonne lignite Coal
Post- Mining Activities CO_2		
	0.00	kg CO_2 / metric tonne Lignite Coal
N_2O	6.40E-06	kg N2O / kg PBR Coal
	6.40E-03	kg N2O / metric tonne PBR Coal
Mining CH_4	1.2	m3 CH4 / metric tonne lignite Coal
	8.04E-01	kg CH4 / metric tonne Lignite Coal
Post-Mining Activities CH_4	0.1	m3 CH4 / metric tonne Lignite Coal
	6.70E-02	kg CH4 / metric tonne Lignite Coal

Conversions

CO_2 Density	1.84	kg/m^3
CH_4 Density	0.67	kg/m^3
1 tonne =	1000	kg
1 M^3 =	35.3147	ft^3
1 tonne =	1.10231	short ton

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Fuel Delivery: Coal Transportation

Summary		
GHG	kg emissions / metric tonnes coal transported	kg emissions / kg CO_2 stored
CO_2	1.01	9.35E-04
N_2O	4.08E-05	3.79E-08
CH_4	8.17E-06	7.59E-09
SF_6	-	-
CO2e	1.02	9.47E-04

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Equipment	Fuel	Engine Horsepower	Load Factor	Loaded Horsepower	Hours Operated per Year	GHG Emission Factors (g/hp-hr)[a]			GHG Emissions kg per Year			
						CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO2e
Semi-Truck	Diesel	2100	0.8	1680	15361	188.19	7.63E-03	1.53E-03	4,856,423.67	1.97E+02	3.94E+01	1,448,147,191.36

(a) Greenhouse gas emissions from 40 CFR 98, Table C-1 and C-2; conversion of 2544.43 Btu/hp-hr is assumed

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Fuel Delivery: Coal Transportation

Assumptions and Data

	YOUNG Boiler 1		YOUNG Boiler 2		Total facility
Year	Megawatt Hours Net	Tons Lignite	Megawatt Hours Net	Tons Lignite	Tons Lignite
2023	1,789,638	1,571,510	3,241,042	2,804,620	4,376,130
2024	1,627,779	1,429,480	3,217,477	2,784,300	4,213,780
2025	1,796,587	1,577,720	2,897,224	2,507,210	4,084,930
2026	1,794,703	1,576,090	3,188,853	2,759,520	4,335,610
2027	1,497,859	1,315,400	3,226,215	2,791,880	4,107,280
2028	1,822,299	1,600,320	2,988,707	2,586,360	4,186,680
2029	1,799,645	1,580,410	3,218,132	2,784,870	4,365,280
2030	1,617,994	1,420,870	3,213,750	2,781,100	4,201,970
2031	1,805,975	1,585,960	2,964,249	2,565,170	4,151,130
2032	1,811,105	1,590,460	3,213,792	2,781,100	4,371,560
2033	1,616,142	1,419,260	3,253,285	2,815,270	4,234,530
2034	1,811,105	1,590,460	2,851,496	2,467,600	4,058,060
2035	1,811,105	1,590,460	3,205,522	2,773,970	4,364,430
2036	1,616,141	1,419,250	3,218,950	2,785,570	4,204,820
2037	1,811,105	1,590,460	2,843,919	2,461,030	4,051,490
2038	1,811,104	1,590,460	3,213,704	2,781,040	4,371,500
2039	1,611,011	1,414,750	3,195,077	2,764,910	4,179,660
2040	1,811,105	1,590,460	2,879,342	2,491,680	4,082,140
2041	1,795,712	1,576,960	3,216,135	2,783,140	4,360,100
2042	1,616,141	1,419,260	3,218,400	2,785,090	4,204,350
2043	1,811,105	1,590,460	2,884,162	2,495,860	4,086,320

Transport Assumptions	
Truck Type	Kress 200C III Coal Hauler
Enginer HP	2,100
Haul Capacity (short tons)	240
Average Speed	15.55
Max Coal (short ton per year)	4,376,130
Max Coal (metric tonnes per	4,823,852
Max trips per year	18234
Max Roundtrip Distance (miles)	13.1
Max Distance Traveled per year (miles)	238,864
Hours per year	15361

Table 1: Maximum Travel Speed

Gear	mph
1	9.4
2	12.6
3	17.1
4	23.1
5	31.4
6	42.3

Conversions		
1 metric tonne =	1.10231	short ton

Haul Distances	
Year	Round Trip Haul Distance (miles)
2028	9.7
2029	10.4
2030	11
2031	11.6
2032	11.7
2033	11.8
2034	12.1
2035	12.4
2036	12.7
2037	12.8
2038	13.1
2039	12.9
2040	12.8

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Extraction: Fuel Oil #2

Summary		
GHG	**kg emissions / gallon FO extracted**	**kg emissions / kg CO_2 stored**
CO_2	5.051E-01	8.874E-05
N_2O	1.524E-05	2.677E-09
CH_4	2.707E-03	4.755E-07
SF_6	-	-
CO2e	0.61	1.067E-04

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New Yo

Assumptions and Data

Projected Annual FO Consumption

MRY Boiler 1	350,000	gal/year
MRY Boiler 2	400,000	gal/year

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Delivery: Fuel Oil Transportation

Summary		
GHG	**kg emissions / gallons FO transported**	**kg emissions / kg CO_2 stored**
CO_2	3.149E-03	5.531E-07
N_2O	8.097E-08	1.422E-11
CH_4	6.301E-08	1.107E-11
SF_6	-	-
CO2e	3.18E-03	5.578E-07

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Projected Annual FO Consumption

MRY Boiler 1	350,000	gal/year
MRY Boiler 2	400,000	gal/year

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Plant Direct Emissions: Coal Electricity Generation Plant

Includes Unit 1 and 2 (boilers) ONLY does not include auxillary equipment on site

Summary		
GHG	**kg emissions / year**	**kg emissions / kg CO_2 stored**
CO_2	1.43E+09	0.34
N_2O	9.16E+04	2.15E-05
CH_4	6.28E+04	1.47E-05
SF_6	-	-
CO2e	1.46E+09	0.34

Functional Unit: CO_2 Stored

Normalize Emissions to Functional Unit		
Operation Period	1.00	year
Annual Amount CO2 stored	4.27E+09	kg
Normalizing Factor	2.34E-10	time operation / kg CO_2 stored

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Plant Direct Emissions: Coal Electricity Generation Plant

Includes Unit 1 and 2 (boilers) ONLY does not include auxillary equipment on site

Assumptions and Data

Emission Calcs

Unit ID	CO2		NO2		CH4	
	lb/year	kg/year	lb/year	kg/year	lb/year	kg/year
Unit 1 Coal	4.54E+09	2.06E+09	72866.92	33051.92	49965.89	22,664
Unit 1 FO #2	[redacted]		169.075	76.691	115.937	53
Unit 2 Coal	8.02E+09	3.64E+09	128,778.84	58413.17	88305.49	40,055
Unit 2 FO #2	[redacted]		193.228	87.647	132.499	60
Total	1.26E+10	5.70E+09	202008.06	91629.42	138519.81	62,832

Operation Data Unit 1

Coal HHV	13.09	MMBtu/ short ton
Fuel Oil HHV	0.13802	MMBtu/gal
Usage	350,000	gal/year
Maximum Heat Input	20,867,428.40	MMBtu/yr

Operation Data Unit 2

Coal HHV	13.23	MMBtu/ short ton
Fuel Oil HHV	0.13802	MMBtu/gal
Usage	400,000	gal/year
Maximum Heat Input	36,849,161.00	MMBtu/yr

Emission Factors

Unit	Fuel	GHG	Emission Factor	Units	Source
U1 and U2	Coal	CO2	217.74	lb/MMBtu	ARP Data
		NO2	0.0035	lb/MMBtu	GHG Emission Data 40 CFR, Part 98,
		CH4	0.0024	lb/MMBtu	GHG Emission Data 40 CFR, Part 98,
	FO #2	NO2	0.0013	lb/MMBtu	GHG Emission Data 40 CFR, Part 98,
		CH4	0.0066	lb/MMBtu	GHG Emission Data 40 CFR, Part 98

Conversions

1 kg =	2.20462	lbs
1 short ton =	2000	lbs

	YOUNG Boiler 1		YOUNG Boiler 2		Total facility	
Year	**Megawatt Hours Net**	**Short Tons Lignite**	**Megawatt Hours Net**	**Short Tons Lignite**	**Megawatt Hours Net**	**Short Tons Lignite**
2023	1,789,638	1,571,510	3,241,042	2,804,620	5,030,680	4,376,130
2024	1,627,779	1,429,480	3,217,477	2,784,300	4,845,256	4,213,780
2025	1,796,587	1,577,720	2,897,224	2,507,210	4,693,811	4,084,930
2026	1,794,703	1,576,090	3,188,853	2,759,520	4,983,556	4,335,610
2027	1,497,859	1,315,400	3,226,215	2,791,880	4,724,074	4,107,280
2028	1,822,299	1,600,320	2,988,707	2,586,360	4,811,006	4,186,680
2029	1,799,645	1,580,410	3,218,132	2,784,870	5,017,777	4,365,280
2030	1,617,994	1,420,870	3,213,750	2,781,100	4,831,744	4,201,970
2031	1,805,975	1,585,960	2,964,249	2,565,170	4,770,224	4,151,130
2032	1,811,105	1,590,460	3,213,792	2,781,100	5,024,897	4,371,560
2033	1,616,142	1,419,260	3,253,285	2,815,270	4,869,427	4,234,530
2034	1,811,105	1,590,460	2,851,496	2,467,600	4,662,601	4,058,060
2035	1,811,105	1,590,460	3,205,522	2,773,970	5,016,627	4,364,430
2036	1,616,141	1,419,250	3,218,950	2,785,570	4,835,091	4,204,820
2037	1,811,105	1,590,460	2,843,919	2,461,030	4,655,024	4,051,490
2038	1,811,104	1,590,460	3,213,704	2,781,040	5,024,808	4,371,500
2039	1,611,011	1,414,750	3,195,077	2,764,910	4,806,088	4,179,660
2040	1,811,105	1,590,460	2,879,342	2,491,680	4,690,447	4,082,140
2041	1,795,712	1,576,960	3,216,135	2,783,140	5,011,847	4,360,100
2042	1,616,141	1,419,260	3,218,400	2,785,090	4,834,541	4,204,350
2043	1,811,105	1,590,460	2,884,162	2,495,860	4,695,267	4,086,320

Project Tundra Initial Life Cycle Analysis

Proposed Project - CO_2 Separation and Purification Plant

Includes CO2 compressor ONLY based on old supplier values, excludes auxilary equipment on

Summary		
GHG	**kg emissions / metric tonnes CO2 Processed**	**kg emissions / kg CO_2 stored**
CO_2	8.08	0.01
N_2O	0	0
CH_4	0	0
SF_6	0	0
CO2e	8.08	0.01

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Emissions from CO2 compressor startups and discharge		
CO2	38,338	short tons per year
	34,779,690	kg / yr
Amount of CO2 Processed by the Plant		
Total CO2 Capture Target	13,000	short tons per day
	4,745,000	short tons per year
	4,304,597	metric tonnes per year

Conversions		
1 metric tonne =	1.10231	short ton
1 metric tonne =	1000	kg

Project Tundra Initial Life Cycle Analysis
CO_2 Separation and Purification Plant Power Consumption

Electricty Summary			
GHG	Electricity	Steam	Total
	kg emissions / kg CO_2 Stored		
CO_2	0.04	0.06	--
N_2O	1.81E-06	0.00	--
CH_4	1.24E-06	0.00	--
SF_6	--	--	--
CO2e	0.04	0.07	0.11

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Functional Unit kg CO_2 Stored		
Normalize Emissions to Functional Unit		
Operation Period	1.00	year
Final Annual Amount CO_2 stored	4.27E+09	kg
Normalizing Factor	2.34E-10	time operation / MWh produced

Assumptions and Data

Electricity Consumption		Emission Factor		Source	Emissions
MW	MWh Annual	Pollutant	**kg** / MWh		**kgs** / Year
77	674,520	CO_2	265	Historical Actuals Three Year Average (2020-2022) of historic Minnkota System	178,832,691
		N_2O	1.15E-02		7,748
		CH_4	7.88E-03		5,313
		CO_2e	269		181,332,843

1848

Steam Consumption		Emission Factor		Source	Emissions
MW	MWh Annual	Pollutant	**kg** / MWh		**kgs**/ Year
110	963,600	CO_2	285	LCA previous calculated CI for MRY based on Future Projected Coal Usage	274,405,641
		N_2O	1.82E-02		17,571
		CH_4	1.25E-02		12,049
		CO_2e	291		280,075,658

Conversions		
1 lb =	0.453592	kg

Project Tundra Initial Life Cycle Analysis
Downstream - CO2 Transportation

Summary		
GHG	kg emissions / tonnes CO2 transported	kg emissions / kg CO_2 stored
CO_2	8.57E-02	8.58E-05
N_2O	0	0
CH_4	0	0
SF_6	0	0
CO2e	8.57E-02	8.58E-05

Functional Unit: CO_2 Stored

Normalize Emissions to Functional Unit		
Amount CO_2 Transported	4269817.02	metric tonnes
Final Annual Amount CO_2 stored	4.27E+09	kg
Normalizing Factor	1.00E-03	Metric tonnes CO2 Transported / kg CO_2 stored

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Pipeline Loss		
Total Released CO2	366.13	metric tonnes per year

Amount of CO2 Processed by the Plant		
Total CO2 Capture Target	13,000	short tons per day
	4,745,000	short tons per year
	4,304,597	metric tonnes per year
Tonnes CO2 Tranported	4269817.021	metric tonnes per year

Conversions		
1 metric tonne =	1.10231	short ton
1 metric tonne =	1000	kg

Project Tundra Initial Life Cycle Analysis
Downstream - Electricity Transmission

Summary	
GHG	kg emissions / kg CO2 stored
CO_2	0
N_2O	0
CH_4	0
SF_6	9.25E-08
CO2e	2.17E-03

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Electricity transmision emissions

GHG	Emission Factor	Unit
SF6	7.85E-05	kg / MWh

Given in FOA Appendix J

Initial LCA
Functional Unit: kg CO_2e per MWh

Project Tundra Initial Life Cycle Analysis Results
REVISED

Table 1-1: Build Scenario, Initial LCA Results Normalized to 1 MWh produced at MRY

Emissions Source	kg of Emissions per MWh produced at MRY				
	CO_2	N_2O	CH_4	SF_6	CO_2e
Upstream					
Coal Mining	0.79	6.25E-03	0.85	-	33.27
FO Extraction	0.09	2.81E-06	5.00E-04	-	0.11
Coal Transportation	0.98	3.99E-05	7.98E-06	-	1.00
FO Transportation	5.81E-04	1.50E-08	1.16E-08	-	5.86E-04
Coal Electricity Plant	352	0.02	0.02	-	360
Proposed Project					
CO_2 Capture Plant	8.56	-	-	-	8.56
Electricty	49.90	1.92E-03	1.32E-03	--	50.52
Downstream					
CO_2 Transportation	0.09	-	-	-	0.09
CO_2 Storage*	-	0.00E+00	-	-	-
Electricity Transmission	-	-	-	7.85E-05	1.84
TOTAL LCA	413	0.03	0.87	7.85E-05	455

*Assuming there are no measurable losses at the wellhead to the reservoir

**Does not account for electricity losses from T&D

Table 1-2: No-Build Scenario, Initial LCA Results Normalized to 1 MWh produced at MRY

Emissions Source	kg of Emissions per MWh produced at MRY				
	CO_2	N_2O	CH_4	SF_6	CO_2e
Upstream					
Coal Mining	0.64	5.05E-03	0.69	-	26.89
FO Extraction	0.08	2.27E-06	4.04E-04	-	0.09
Coal Transportation	0.79	3.22E-05	6.45E-06	-	0.80
FO Transportation	4.70E-04	1.21E-08	9.40E-09	-	4.74E-04
Coal Electricity Plant	1,134	0.02	0.01	-	1,140
Downstream					
Electricity Transmission	-	-	-	7.85E-05	1.84
TOTAL LCA	1,136	0.02	0.70	7.85E-05	1,170

*Assuming there are no measurable losses at the wellhead to the reservoir

**Does not account for electricity losses from T&D

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Extraction: Coal Mining

Summary

GHG	kg emissions / metric tonne coal extracted	BUILD kg emissions / MWh Produced at Mry	NO BUILD kg emissions / MWh Produced at Mry
CO_2	0.81	0.79	0.64
N_2O	0.01	0.01	0.01
CH_4	0.87	0.85	0.69
SF_6	-	-	-
CO_2e	34.07	33.27	26.89

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors
IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

	Emission Factor	Units
Surface Mines CO_2	0.44	m^3 CO_2 / metric tonne lignite Coal
	8.10E-01	kg CO_2 / metric tonne lignite Coal
Post- Mining Activities CO_2		
	0.00	kg CO_2 / metric tonne Lignite Coal
N_2O	6.40E-06	kg N_{2O} / kg PBR Coal
	6.40E-03	kg N_2O / metric tonne PBR Coal
Mining CH_4	1.2	m^3 CH_4 / metric tonne lignite Coal
	8.04E-01	kg CH_4 / metric tonne Lignite Coal
Post-Mining Activities CH_4	0.1	m^3 CH_4 / metric tonne Lignite Coal
	6.70E-02	kg CH_4 / metric tonne Lignite Coal

Conversions		
CO_2 Density	1.84	kg/m^3
CH_4 Density	0.67	kg/m^3
1 tonne =	1000	kg
1 M^3 =	35.3147	ft^3
1 tonne =	1.10231	short ton

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Fuel Delivery: Coal Transportation

Summary			
GHG	kg emissions / metric tonnes coal transported	BUILD kg emissions / MWh Produced at Mry	NO BUILD kg emissions / MWh Produced at Mry
CO_2	1.01	0.98	0.79
N_2O	4.08E-05	3.99E-05	3.22E-05
CH_4	8.17E-06	7.98E-06	6.45E-06
SF_6	-	-	-
CO_2e	1.02	1.00	0.80

Maximu

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Equipment	Fuel	Engine Horsepower	Load Factor	Loaded Horsepower	Hours Operated per Year	GHG Emission Factors (g/hp-hr)[a]			GHG Emissions kg per Year			
						CO_2	CH_4	N_2O	CO_2	CH_4	N_2O	CO2e
Semi-Truck	Diesel	2100	0.8	1680	15345	188.19	7.63E-03	1.53E-03	4,851,352.10	1.97E+02	3.94E+01	1,446,634,888.78

(a) Greenhouse gas emissions from 40 CFR 98, Table C-1 and C-2; conversion of 2544.43 Btu/hp-hr is assumed

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Fuel Delivery: Coal Transportation

Assumptions and Data

	YOUNG Boiler 1		YOUNG Boiler 2		Total facility
	Megawatt	Tons	Megawatt	Tons	Tons
Year	Hours Net	Lignite	Hours Net	Lignite	Lignite
2023	1,789,638	1,571,510	3,241,042	2,804,620	4,376,130
2024	1,627,779	1,429,480	3,217,477	2,784,300	4,213,780
2025	1,796,587	1,577,720	2,897,224	2,507,210	4,084,930
2026	1,794,703	1,576,090	3,188,853	2,759,520	4,335,610
2027	1,497,859	1,315,400	3,226,215	2,791,880	4,107,280
2028	1,822,299	1,600,320	2,988,707	2,586,360	4,186,680
2029	1,799,645	1,580,410	3,218,132	2,784,870	4,365,280
2030	1,617,994	1,420,870	3,213,750	2,781,100	4,201,970
2031	1,805,975	1,585,960	2,964,249	2,565,170	4,151,130
2032	1,811,105	1,590,460	3,213,792	2,781,100	4,371,560
2033	1,616,142	1,419,260	3,253,285	2,815,270	4,234,530
2034	1,811,105	1,590,460	2,851,496	2,467,600	4,058,060
2035	1,811,105	1,590,460	3,205,522	2,773,970	4,364,430
2036	1,616,141	1,419,250	3,218,950	2,785,570	4,204,820
2037	1,811,105	1,590,460	2,843,919	2,461,030	4,051,490
2038	1,811,104	1,590,460	3,213,704	2,781,040	4,371,500
2039	1,611,011	1,414,750	3,195,077	2,764,910	4,179,660
2040	1,811,105	1,590,460	2,879,342	2,491,680	4,082,140
2041	1,795,712	1,576,960	3,216,135	2,783,140	4,360,100
2042	1,616,141	1,419,260	3,218,400	2,785,090	4,204,350
2043	1,811,105	1,590,460	2,884,162	2,495,860	4,086,320

Transport Assumptions	
Truck Type	Kress 200C III Coal Hauler
Enginer HP	2,100
Haul Capacity (short tons)	240
Average Speed	15.55
Max Coal (short ton per year)	4,371,560
Max Coal (metric tonnes per	4,818,814
Max trips per year	18,215
Max Roundtrip Distance (miles)	13
Max Distance Traveled per year (miles)	238,614
Hours per year	15,345

Coal Hauler: Maximum Travel Speed

Gear	mph
1	9.4
2	12.6
3	17.1
4	23.1
5	31.4
6	42.3

Haul Distances	
Year	Round Trip Haul Distance (miles)
2028	9.7
2029	10.4
2030	11
2031	11.6
2032	11.7
2033	11.8
2034	12.1
2035	12.4
2036	12.7
2037	12.8
2038	13.1
2039	12.9
2040	12.8

Conversions		
1 metric tonne =	1.10231	short ton

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Extraction: Fuel Oil #2

Summary			
GHG	kg emissions / gallon FO extracted	BUILD kg emissions / MWh produced at MRY	NO BUILD kg emissions / MWh produced at MRY
CO_2	5.051E-01	9.33E-02	7.54E-02
N_2O	1.524E-05	2.81E-06	2.27E-06
CH_4	2.707E-03	5.00E-04	4.04E-04
SF_6	-	-	-
CO2e	0.61	1.12E-01	9.06E-02

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York:

Assumptions and Data

Projected Annual FO Consumption

MRY Boiler 1	350,000	gal/year
MRY Boiler 2	400,000	gal/year

Project Tundra Initial Life Cycle Analysis
Upstream Emissions - Fuel Delivery: Fuel Oil Transportation

Summary

GHG	kg emissions / gallon FO extracted	BUILD kg emissions / MWh produced at MRY	NO BUILD kg emissions / MWh produced
CO_2	3.149E-03	5.81E-04	4.70E-04
N_2O	8.097E-08	1.50E-08	1.21E-08
CH_4	6.301E-08	1.16E-08	9.40E-09
SF_6	-	-	-
CO2e	3.18E-03	5.86E-04	4.74E-04

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors
IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Projected Annual FO Consumption

MRY Boiler 1	350,000	gal/year
MRY Boiler 2	400,000	gal/year

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Plant Direct Emissions: Coal Electricity Generation Plant

Includes Unit 1 and 2 (boilers) ONLY does not include auxillary equipment on site

Summary (Build Scenario)		
GHG	kg emissions / year	kg emissions / MWh produced at MRY
CO_2	1.43E+09	352.34
N_2O	9.23E+04	0.02
CH_4	6.33E+04	0.02
SF_6	-	-
CO_2e	1.46E+09	359.67

Summary (No-Build Scenario)		
GHG	kg emissions / year	kg emissions / MWh produced at MRY
CO_2	5.70E+09	1134.43
N_2O	9.23E+04	0.02
CH_4	6.33E+04	0.01
SF_6	-	-
CO_2e	5.73E+09	1140.36

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science

Project Tundra Initial Life Cycle Analysis

Upstream Emissions - Plant Direct Emissions: Coal Electricity Generation Plant

Includes Unit 1 and 2 (boilers) ONLY does not include auxillary equipment on site

Assumptions and Data

Emission Calcs

Unit ID - Fuel	CO2		N2O		CH4	
	lb/year	kg/year	lb/year	kg/year	lb/year	kg/year
Unit 1 - Coal	4.54E+09	2.06E+09	72,867	33,052	49,966	22,664
Unit 1 - FO #2	[redacted]		169	77	116	53
Unit 2 - Coal	8.02E+09	3.64E+09	130,361	59,131	89,390	40,547
Unit 2 - FO #2	[redacted]		193	88	132	60
Total	1.26E+10	5.70E+09	203,590	92,347	139,605	63,324

Emission Factors

Unit	Fuel	GHG	Emission Factor	Units	Source
U1 and U2	Coal	CO2	217.74	lb/MMBtu	ARP Data: FO and Coal combined
		N2O	0.0035	lb/MMBtu	GHG Emission Data 40 CFR, Part 98, Subpart C (Emission Factors)
		CH4	0.0024	lb/MMBtu	GHG Emission Data 40 CFR, Part 98, Subpart C (Emission Factors)
	FO #2	N2O	0.0013	lb/MMBtu	GHG Emission Data 40 CFR, Part 98, Subpart C (Emission Factors)
		CH4	0.0066	lb/MMBtu	GHG Emission Data 40 CFR, Part 98, Subpart C (Emission Factors)

	YOUNG Boiler 1		YOUNG Boiler 2		Total facility	
	Megawatt	Short Tons	Megawatt	Short Tons	Megawatt	Short Tons
Year	Hours Net	Lignite	Hours Net	Lignite	Hours Net	Lignite
2023	1,789,638	1,571,510	3,241,042	2,804,620	5,030,680	4,376,130
2024	1,627,779	1,429,480	3,217,477	2,784,300	4,845,256	4,213,780
2025	1,796,587	1,577,720	2,897,224	2,507,210	4,693,811	4,084,930
2026	1,794,703	1,576,090	3,188,853	2,759,520	4,983,556	4,335,610
2027	1,497,859	1,315,400	3,226,215	2,791,880	4,724,074	4,107,280
2028	1,822,299	1,600,320	2,988,707	2,586,360	4,811,006	4,186,680
2029	1,799,645	1,580,410	3,218,132	2,784,870	5,017,777	4,365,280
2030	1,617,994	1,420,870	3,213,750	2,781,100	4,831,744	4,201,970
2031	1,805,975	1,585,960	2,964,249	2,565,170	4,770,224	4,151,130
2032	1,811,105	1,590,460	3,213,792	2,781,100	5,024,897	4,371,560
2033	1,616,142	1,419,260	3,253,285	2,815,270	4,869,427	4,234,530
2034	1,811,105	1,590,460	2,851,496	2,467,600	4,662,601	4,058,060
2035	1,811,105	1,590,460	3,205,522	2,773,970	5,016,627	4,364,430
2036	1,616,141	1,419,250	3,218,950	2,785,570	4,835,091	4,204,820
2037	1,811,105	1,590,460	2,843,919	2,461,030	4,655,024	4,051,490
2038	1,811,104	1,590,460	3,213,704	2,781,040	5,024,808	4,371,500
2039	1,611,011	1,414,750	3,195,077	2,764,910	4,806,088	4,179,660
2040	1,811,105	1,590,460	2,879,342	2,491,680	4,690,447	4,082,140
2041	1,795,712	1,576,960	3,216,135	2,783,140	5,011,847	4,360,100
2042	1,616,141	1,419,260	3,218,400	2,785,090	4,834,541	4,204,350
2043	1,811,105	1,590,460	2,884,162	2,495,860	4,695,267	4,086,320

Operation Data Unit 1

Coal HHV	13.09	MMBtu/ short ton
Fuel Oil HHV	0.13802	MMBtu/gal
Projected Annual Fuel Oil Usage	350,000	gal/year
Maximum Heat Input	20,867,428.40	MMBtu/yr

Operation Data Unit 2

Coal HHV	13.23	MMBtu/ short ton
Fuel Oil HHV	0.13802	MMBtu/gal
Projected Annual Fuel Oil Usage	400,000	gal/year
Maximum Heat Input	36,849,161.00	MMBtu/yr

CO_2 Storage

Annual Amount CO_2 stored	4.27E+09	kg

Conversions

1 kg =	2.20462	lbs
1 short ton =	2000	lbs

Project Tundra Initial Life Cycle Analysis
CO_2 Separation and Purification Plant

Summary

GHG	kg emissions / metric tonnes CO2 Processed	BUILD kg emissions / MWh produced at MPY
CO_2	8.08	8.56
N_2O	0	0.00
CH_4	0	0.00
SF_6	0	0.00
CO2e	8.08	8.56

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors

IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Emissions from CO2 compressor startups and discharge		
CO2	38,338	short tons per year
	34,779,690	kg / yr
Amount of CO2 Processed by the Plant		
Total CO2 Capture Target	13,000	short tons per day
	4,745,000	short tons per year
	4,304,597	metric tonnes per year

Conversions		
1 metric tonne =	1.10231	short ton
1 metric tonne =	1000	kg

Project Tundra Initial Life Cycle Analysis
CO_2 Separation and Purification Plant Power Consumption

Electricty Summary		
GHG	Electricity	Total
	kg emissions / MWh produced at MRY	
CO_2	49.90	49.90
N_2O	1.92E-03	1.92E-03
CH_4	1.32E-03	1.32E-03
SF_6	--	--
CO2e	50.52	50.52

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors
IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data 0.0000

Electricity Consumption		Emission Factor		Source	Emissions
MW	MWh Annual	Pollutant	**kg** / MWh		**kgs** / Year
77	674,520	CO_2	301	Historical Actuals Three Year Average (2020-2022) of historic Minnkota System	202,941,812
		N_2O	1.16E-02		7,801
		CH_4	7.93E-03		5,349
		CO_2e	305		205,459,021

Project Tundra Initial Life Cycle Analysis
Downstream - CO2 Transportation via pipeline

Summary		
GHG	kg emissions / tonnes CO2 transported	BUILD kg emissions / MWh produced at MRY
CO_2	8.57E-02	0.09
N_2O	0	0
CH_4	0	0
SF_6	0	0
CO2e	0.09	0.09

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors
IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from https://www.ipcc.ch/report/ar5/wg1/

Assumptions and Data

Pipeline Loss		
Total Released CO2	366.13	metric tonnes per year

Amount of CO2 Processed by the Plant		
Total CO2 Capture Target	13,000	short tons per day
	4,745,000	short tons per year
	4,304,597	metric tonnes per year
Tonnes CO2 Tranported	4,269,817.02	metric tonnes per year

Conversions		
1 metric tonne =	1.10231	short ton
1 metric tonne =	1000	kg

Project Tundra Initial Life Cycle Analysis
Downstream - Electricity Transmission

Summary	
GHG	**kg emissions / MWh produced at MRY**
CO_2	0
N_2O	0
CH_4	0
SF_6	7.85E-05
CO2e	1.84E+00

AR5 IPCC 2013 GWP Factors - 100 year	
CO_2	1
N_2O	298
CH_4	36
SF_6	23,500

Appendix J Table J.1. GWP Characterization Factors
IPCC. (2013). Climate Change 2013 The Physical Science Basis. New York: Cambridge University Press: Intergovernmental Panel on Climate Change Retrieved December 12, 2013, from

Assumptions and Data

Electricity transmision emissions

GHG	Emission Factor	Unit
SF6	7.85E-05	kg / MWh

Given in FOA Appendix J