6.0 WELL OPERATIONS PLAN
40 CFR 146.82(a)(8) 146.88 146.89

CAPIO MOUNTAINEER SEQUESTRATION PROJECT

Facility Information

Facility name:	MOUNTAINEER GIGASYSTEM
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Well name:	MCCLINTIC SEQUESTRATION 001
Well location:	MASON COUNTY, WEST VIRGINIA Latitude: [redacted] Longitude: [redacted]

Table of Contents

List of Tables

6.0 Well Operation Plan

The Well Operation Plan describes how Fidelis, LLC ("Fidelis") will ensure operating requirements are in place to ensure that injection pressure does not exceed 90 percent of the fracture pressure of the storage formation so as to ensure that the injection does not initiate new fractures or propagate existing fractures in the storage formation. There will be no injection between the outermost casing protecting underground sources of drinking water (USDWs) and the wellbore in accordance with 40 CFR 146.88 (b). The injection well construction is detailed in the Injection Well Construction Plan (Permit Section 4) which addresses 40 CFR 146.88 (c).

The Well Operation Plan describes the source of the carbon dioxide (CO_2) that will be delivered to the storage site, its chemical and physical properties, flow rate, and the anticipated pressure and temperature of the CO_2 at the pipeline outlet. In addition, this section provides the monitoring that will be performed on the injection well to confirm mechanical integrity (40 CFR 146.89).

6.1 Daily Rate, Volumes and Mass of the CO_2 Stream

The design basis of this project is to capture and inject the CO_2 produced at the Mountaineer Gigasytem facility. The maximum injection volume for this project is detailed in **Table 1-3** in the Project Narrative (Permit Section 1) and the planned injection phase of this project is 10 years. Operational parameters of the injection well (**Table 6-1**) are based on modeled and regional data and will be updated using data derived from the injection well as part of the pre-operational testing phase.

[redacted]

Table 6-1: Proposed Operational Procedures.

6.2 Characteristics of CO_2 Delivered to the Storage Site

Prior to injection, the chemical and physical characteristics of the injectant CO_2 will be confirmed using appropriate analytical methods.

6.3 Shutdown Procedure

The shutdown procedure will consist of three parts:

1. The wellhead. In a controlled shutdown situation, the master valve and/or wing valve on the wellhead will be shut trapping the CO_2 in the well. A gauge at the wellhead will allow measurement of the pressure below the valve in the well. This is important so that during re-startup the pressure can be equalized across the valve before opening the valve and continuing injection.

2. The pipeline from horizontal injection pump to wellhead. The wellhead will have at a minimum two shut-off valves and several isolation valves to allow isolation of corrosion coupons, flow meters and other equipment without the need to vent the entire pipeline. During an emergency shutdown both shut-off valves will close automatically due to upset conditions. During a controlled shutdown the valves will be shut in sync with the compressor shutdown and the well head valves to ensure the CO_2 in the pipeline is trapped until injection commences again. During re-startup, the pressure at each end of the pipeline will be equalized across the valve and the valve opened to allow continued injection.

3. The capture and compression system will have the ability to go into recycle mode in case of an emergency shutdown. It will then be able to slowly shut down and vent trapped CO_2 during controlled shutdown, the valve to the pipeline will be shut, trapping the CO_2 in the pipeline and the remaining small amount of CO_2 in the compressor chambers will be vented up a vent stack. During re-startup the compressor will be brought online and compress against the closed pipeline valve until the pressure equalizes and then the valves will be open, and injection will continue.

6.4 Proposed Carbon Dioxide Stream (40 CFR 146.82(a)(7)(iii) and (iv)) and 146.86(b)(1)(v)

6.4.1 Source of the CO_2 Stream

The Mountaineer Gigasytem facility in Mason County, West Virginia, will be the source of the CO_2. The capture, compression and injection of the CO_2 will be operated by Fidelis.

6.4.2 Chemical and Physical Characteristics of the CO_2 Stream and Formation Fluids

Prior to injection, the chemical and physical characteristics of the injectant CO_2 will be confirmed using appropriate analytical methods.

The injection system will be designed with corrosive-resistant materials that contact the injection stream to prevent corrosion of the components caused by the presence of any free water.

The corrosivity of the injection stream should be limited given the anticipated quantities of the minor concentrations of the trace constituents in the injection stream, and a dehydration system will reduce and maintain the water content below the regulated limit of <30 lb/MMscf for CO_2 transport pipeline standards.

Table 6-2 presents the analytical parameters that will be measured in the injection well as part of the pre-operational testing phase, prior to injection, to assess the corrosivity of the formation waters in the storage formation. The pH, conductivity, and total dissolved solids (TDS) data represent analytical results from a commercial laboratory, the oxidation-reduction potential (ORP) data are field measurements made at the time the brine samples are collected, and the temperature value is the temperature measured at the mid-point of the formation through wireline logging.

Parameter	Value
Average pH	TBD
Average Conductivity	TBD
Average TDS	TBD
Average ORP	TBD
Mid-Point Temperature	TBD

Table 6-2: Chemical parameters of storage formation brine to be used for corrosivity assessment.

The data in **Table 6-2** will be used in conjunction with downhole temperature data to assess how corrosive the formation waters will be.

Although neither the CO_2 stream nor formation waters are expected to be highly corrosive, the injection materials that have the ability to come in contact with the CO_2 stream and/or reservoir brines will be constructed of corrosion-resistant materials, such as CO_2 resistant cement, 13CR steel, resistive coatings, or similar. For example, the casing string across the storage formation (and up into the confining zone), cement used, and the packer will be constructed with CO_2 and corrosion-resistant materials. The tubing will be fully lined with a corrosion-resistive material (i.e., fiberglass is commonly used in CO_2 service).

The injection stream will be monitored during the baseline and operational phases of the project. Prior to the start of the injection phase, the CO_2 stream will be sampled for analysis during regular operations to obtain representative CO_2 samples that will serve as a baseline dataset.

Once the injection phase commences, the CO_2 injection stream will be sampled from the CO_2 delivery pipeline on a defined frequency for analysis throughout the life of the injection period.

6.5 Well Annulus Pressure Maintenance System

The purpose of the tubing-casing annulus monitoring and pressure system is to maintain the annular fluid at a prescribed pressure. The automated annulus monitoring system that will be designed for this purpose is part of the comprehensive well annular pressure maintenance system. The well pressure maintenance system includes piping, instrumentation valves, controls, and other equipment to accomplish several functions, including the following:

- Maintain a prescribed pressure on the annular fluid in the well to achieve a positive pressure differential across the packer
- Automatically deliver annular fluid to the well when the fluid volume in the well decreases due to temperature and/or pressure changes
- Automatically remove annular fluid from the wells when the fluid volume in the well increases due to temperature and/or pressure changes
- Monitor parameters (e.g., pressure, temperature, fluid levels, nitrogen pressure) associated with the pressure-maintenance system
- Automatically cease CO_2 injection to the wells when injection pressure or annulus pressure fall outside of prescribed limits.

The annular monitoring system will maintain the wellhead pressure of the annular fluid between the tubing and the long string of casing within the pre-determined levels as specified in the permit. The system will maintain the annular pressure at 100 pounds per square inch (psi) above the pressure of the CO_2 in the injection tubing at the depth of the packer. The annular fluid pressure will be continuously monitored so that CO_2 injection can be halted when the annular fluid pressure falls outside the pre-determined range for a period that exceeds allowable limits. The annular monitoring system consists of a continuous annular pressure gauge, a pressurized annulus fluid reservoir (annulus head tank), pressure regulators, and tank fluid level indication. The annulus system will maintain annulus pressure by controlling the pressure on the annulus head tank using compressed nitrogen. The annulus pressure will be maintained between approximately 150 and 800 psi and will be monitored by the annular pressure gauges and the Supervisory Control and Data Acquisition (SCADA) system. The pressure and fluid level in the annulus head tank will be monitored and recorded continuously. The annulus head tank pressure will be controlled by pressure regulators: one set of regulators to maintain the pressure above 150 psi by adding compressed nitrogen and the other to relieve pressure above 800 psi by venting gas off the annulus head tank. Any changes to the composition of annular fluid will be reported in the next report submitted to the permitting agency. When the injection system is shut down, the annular pressure will be reduced to limit collapse pressure on the tubing string.

6.6 Injection Well Monitoring

Fidelis will install and use continuous recording devices to monitor injection pressure, mass injection rate, and volume (calculated); the pressure on the annulus between the tubing and the long string casing; the backside pressure of all surface and intermediate casing strings; the annulus fluid volume added; and the temperature of the CO_2 stream, as required by 40 CFR 146.88(e)(1), 146.89(b), and 146.90(b). If one of these monitoring devices (except for the mass flow meter) fail, manual readings and recordings of the data will be made daily until the sensor is repaired. If the mass flow meter fails, a secondary or backup flow meter will be used to gather and record the data.

6.7 Monitoring Location and Frequency

Fidelis will perform the activities identified in **Table 6-3** to monitor operational parameters and verify internal mechanical integrity of the injection well. All monitoring will take place at the locations and frequencies shown. All of the data recorded on a continuous basis will be connected to the main facility through a SCADA system.

Parameter	Device(s)	Location	Min. Sampling Frequency	Min. Recording Frequency
CO_2 stream pressure (wellhead)	Pressure Gauge	Injection wellsite	Every 1 min.	Hourly
Mass injection rate	Coriolis Meter	Injection wellsite	Every 10 sec.	Hourly
Annular pressure	Pressure Gauge	Injection wellsite	Every 1 min.	Hourly
Annulus fluid volume	Volume	Injection wellsite	Every 1 min.	Hourly
CO_2 stream temperature	Thermocouple	Injection wellsite	Every 1 min.	Hourly

Notes:

- Sampling frequency refers to how often the monitoring device obtains data from the well for a particular parameter. For example, a recording device might sample a pressure transducer monitoring injection pressure once every two seconds and save this value in memory.
- Recording frequency refers to how often the sampled information gets recorded to digital format (such as a computer hard drive). For example, the data from the injection pressure transducer might be recorded to a hard drive once every minute.

Table 6-3: Sampling devices, locations, and frequencies for continuous monitoring.

6.7.1 Continuous Recording of Injection Pressure

The CO_2 injection pressure will be monitored on a continuous basis to ensure that injection pressures do not exceed 90% of the fracture pressure of the storage formation per 40 CFR 146.88 (a). If injection pressure exceeds 90% of the storage formation fracture pressure, then the injection process will be automatically shut down.

Any changes to the injection pressure outside of the normal operating fluctuations may indicate that an issue has occurred with the well (i.e., loss of mechanical integrity, blockage in the tubing, etc.) or may be caused by a change in injection flowrate. Anomalous pressure measurements would trigger the need for further investigation of the cause of the change (40 CFR 146.89 (b)). The wellhead injection pressure will also be used to calibrate the computational modeling throughout the injection phase of the project. Some of these modeling computations will be used with the reservoir pressure data to provide a calculation correlating the wellhead pressure with the reservoir pressure (Testing and Monitoring Plan, Permit Section 7).

The wellhead pressure of the injected CO_2 will be measured by an electronic pressure transducer with analog output mounted on the CO_2 line associated with the injection well. The transmitter will be electronically connected to the SCADA system, which can instruct shutdown of the system or change the flowrate depending on the pressures measured at the wellhead.

6.7.2 Continuous Recording of Injection Mass Flow Rate

The mass flow rate of CO_2 injected into the well will be measured by a Coriolis mass flow meter. This flow meter will be placed in the CO_2 delivery line near the well and connected to the SCADA system. The meter will have an analog output (Endress & Hauser or Micro Motion Coriolis Flow and Density meter or similar). The meter will be maintained and calibrated according to the manufacturer's specifications.

6.7.3 Continuous Recording of CO_2 Stream Temperature

The temperature of the injected CO_2 will be continuously measured for the well by an electronic thermocouple. The thermocouple will be mounted in a temperature well in the CO_2 line at a location close to the pressure transmitter near the wellhead. The transmitter will be electronically connected to the SCADA system. The thermocouple will be calibrated prior to the start of injection operations, and the calibration will be checked periodically (e.g., quarterly) during regular instrument checks. The thermocouple for measuring surface injection temperature will be recalibrated annually or it will be replaced with a calibrated thermocouple.

6.7.4 Downhole Pressure and Temperature

Downhole pressure and temperature measurement devices are planned to be installed allowing real-time monitoring of storage formation pressures and temperatures. These data will also be used with the mass flow rate to calculate the volume of total injection and confirm plume modeling.

6.8 Control and Alarm System

This section describes the process that will be implemented to safely halt CO_2 injection in the event of an injection well or equipment failure, or if the injection pressure exceeds the predetermined maximum level. The injection process will be monitored by pressure, temperature, and flow measuring devices connected from the capture facility and compression to the injection well over the SCADA system. The monitoring system will be capable of detecting when injection conditions are out of acceptable limits and responding by either adjusting conditions or halting injection. The system is designed to operate automatically with minimal operator intervention. This section presents the following:

- A brief overview of the monitoring and control system
- A description of the automatic shutdown of the capture facility, including the annular pressure, injection pressure, and flow rate that will trigger pump shutdown

The well control system architecture and functionality, including process alarms, plant interlocks, shutdown alarms, and automatic shutdown sequence are described below.

6.8.1 Control System Overview

The proposed control system for the well consists of a SCADA system connected to the pressure, temperature, and flow monitoring systems and controls of the capture facility, pipeline, and injection well. Alarms, run enable, and other critical signals will be passed between the capture facility, system and the injection well through the SCADA system. User privileges and other security measures will be implemented to limit access and control of the SCADA and well control equipment.

Injection pressure will be determined by the pressure of the CO_2 near the wellhead of the injection well. The capture facility will have a variable-speed drive, which will be controlled to limit the CO_2 injection pressure and flow rate within normal operating ranges. A control valve will be installed on the CO_2 pipeline at the well site , immediately upstream of where the pipeline connects to the wellhead. Adjustments to the injection pressure can be made with the control valve if necessary to stay under the injection pressure limit.

6.8.2 Process Alarms and Automatic Shutdown

Alarms will be implemented throughout the injection system and monitored by the SCADA system. Alarms are of three types: process (non-shutdown) flags/alarms, shutdown alarms, and interlock alarms. Process alarms will be used to alert the control room operator whenever process variables are out of the accepted operating range and operator, or maintenance action may be required. Shutdown alarms will indicate critical conditions. An active shutdown alarm and/or plant interlock will trigger an automatic shutdown sequence in which the CO_2 injection process is automatically shut down by the well control procedures.

6.8.2.1 Process Alarms (Non-Shutdown)

Process alarm designations will indicate the relative value of the process variable versus the normal value. For instance, a low-pressure alarm will indicate that the process pressure is lower than the normally expected pressure. Process alarms will include low and/or high alarms that notify if a process variable deviates from the set point or expected value. Discrete inputs from binary devices such as pressure switches, vibration detection, or alarm contacts may require action. Process (non-shutdown) alarms will be used for the parameters listed in **Table 6-4.**

Alarm	Function
1	Wellhead injection pressure
2	Wellhead injection temperature
3	Differential pressure between compressor and wellhead
4	Annular fluid pressure at injection well
5	Annular fluid temperature at injection well
6	Annular fluid level in annular fluid reservoir
7	Annular fluid reservoir volume
8	Vibration detection

Table 6-4: Process (non-shutdown) alarms.

6.8.2.2 Shutdown Alarms

The CO_2 injection process will be automatically shut down under two conditions. One shutdown condition will occur when the annular fluid pressure falls outside the pre-determined range for a period that exceeds allowable limits. The other primary shutdown condition will occur when the CO_2 injection pressure exceeds the maximum allowable injection pressure specified in the permit. Additional automatic shutdowns will be implemented because of plant interlocks, as described below. Operator intervention will be necessary to restart the injection process after an automatic shutdown sequence. Shutdown alarms will be used for the following parameters:

- Annular fluid pressure, injection well (low-low or high-high alarm)
- CO_2 injection pressure (high-high alarm).

6.8.2.3 Plant Interlocks

Plant interlock status signal(s) will be sent from the well control system to the SCADA. The plant interlock will indicate whether conditions in the system are acceptable for the injection process to occur. During injection operations, the plant interlock will be used to initiate an automatic shutdown sequence in the event of equipment malfunctions, critical alarms, or other conditions in the system that warrant a shutdown of the injection process. During startup operations, the plant interlock will act as a run permission command for the injection process to start up. All capture facility operation and operational changes will be tied into the plant (emitter) control room for observation and oversight. Any capture system shutdowns will cause plant emissions to revert to atmospheric discharge until such a time the capture system can be brought back online.