Underground Injection Control
Carbon Sequestration
Class VI Permit Application

PRE-OPERATIONAL TESTING PROGRAM
40 CFR 146.85
Section 6.0

NexGen Carbon Oklahoma, LLC
Vanguard CCS Hub

June 2025

6.0 PRE-OPERATIONAL TESTING PROGRAM

VANGUARD CCS HUB

INSTRUCTIONS

This template provides a suggested outline and recommendations for the pre-operational testing program for a Class VI well. Permit applicants are not required to use this template. This document does not substitute for promulgated provisions or regulations, nor is it a regulation itself, and it does not impose legally-binding requirements on the U.S. Environmental Protection Agency (EPA), states, or the regulated community.

Note that references to EPA's Class VI Rule in the code of federal regulations (CFR) are provided in this template. States with Class VI primacy have requirements that are at least as stringent as EPA's. If your Class VI well is in a primacy state, consult your permitting authority about any additional requirements for what must be included in the plan.

In this template, instructions or suggestions appear in ***blue text***. These are provided to assist with site- and project-specific plan development. These are recommendations and are not required elements of the federal Class VI Rule.

Please delete the ***blue text*** and replace the yellow highlighted text before submitting your document. Similarly, please adjust the example text and tables throughout as necessary (e.g., by adding or removing rows or columns). Appropriate figures, references, etc. should also be included to support the text of the plan.

For more information, see EPA's Class VI guidance documents at https://www.epa.gov/uic/class-vi-guidance-documents. It is the responsibility of the owner or operator to maintain records of previous revisions to this plan.

Facility Information

Facility name: Vanguard CCS Hub
Vanguard I-1
Vanguard I-2
Vanguard I-3
Vanguard I-4
Vanguard I-5
Vanguard I-6
Vanguard I-8
Vanguard I-9
Vanguard I-10
Vanguard I-12

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Well locations: Osage County, Oklahoma

Vanguard I-1: Lat 36.633288°N, Lon -96.571029°W (NAD 83)
Vanguard I-2: Lat 36.660083°N, Lon -96.534652°W (NAD 83)
Vanguard I-3: Lat 36.664329°N, Lon -96.586951°W (NAD 83)
Vanguard I-4: Lat 36.710244°N, Lon -96.542370°W (NAD 83)
Vanguard I-5: Lat 36.744047°N, Lon -96.533843°W (NAD 83)
Vanguard I-6: Lat 36.724157°N, Lon -96.489526°W (NAD 83)
Vanguard I-8: Lat 36.823356°N, Lon -96.620496°W (NAD 83)
Vanguard I-9: Lat 36.849167°N, Lon -96.592912°W (NAD 83)
Vanguard I-10: Lat 36.893849°N, Lon -96.578026°W (NAD 83)
Vanguard I-12: Lat 36.785641°N, Lon -96.594085°W (NAD 83)

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Acronyms and Abbreviations

3D	three-dimensional
°	degree
A	
AoR	area of review
B	
BHL	bottom hole location
C	
CFR	Code of Federal Regulations
CO_2	carbon dioxide
E	

EOS	equation-of-state
EPA	U.S. Environmental Protection Agency
F	
ft	feet/foot
°F/ft	Fahrenheit per foot
G	
GR	gamma ray
GSDT	Geologic Sequestration Data Tool
L	
lbm/ft^3	pound mass per cubic foot
M	
mD	millidarcy
MDT	Modular Formation Dynamics Tester
mg/L	milligrams per liter
MEM	mechanical earth model
MICP	mercury injection capillary pressure
MIT	mechanical integrities
MMSFC	million standard cubic feet
MMSFD/D	million standard cubic feet per day
N	
NMR	nuclear magnetic resonance
O	
P	
PEF	photoelectric factor
psi	pounds per square inch
psi/ft	pounds per square foot
R	
RCA	routine core analyses
S	
SCAL	special core analysis
SHmin	minimum horizontal stress
SP	spontaneous potential
T	
TCS	triaxial compressive strength
TD	total depth
TVD	true vertical depth
TVDSS	true vertical depth sub sea
U	
UIC	Underground Injection Control
USDW	underground source of drinking water
USIT	ultra sonic imager tool

6.0 PRE-OPERATIONAL TESTING PROGRAM

6.1 Introduction

This document outlines the pre-injection testing activities for the proposed stratigraphic test well, as well as the injection and monitoring wells planned for the Vanguard CCS Hub. Testing and monitoring operations during the injection and post-injection phases are detailed separately in the Testing and Monitoring Plan section (*Section 8*). This includes non-well-related baseline activities, such as geochemical analysis.

Additional site-specific data will be collected during the drilling and installation of ten (10) injection wells (Vanguard I-1, Vanguard I-2, Vanguard I-3, Vanguard I-4, Vanguard I-5, Vanguard I-6, Vanguard I-8, Vanguard I-9, Vanguard I-10, Vanguard I-12). The project also includes ten (10) above-zone injection wells (Vanguard AZM-1, Vanguard AZM-2, Vanguard AZM-3, Vanguard AZM-4, Vanguard AZM-5, Vanguard AZM-6, Vanguard AZM-8, Vanguard AZM-9, Vanguard AZM-10, Vanguard AZM-12) to be drilled and completed above the upper confining zone and seven (7) in-zone monitoring (Vanguard IZM-1 through Vanguard IZM-7) wells targeting the single injection zone within the upper Arbuckle. This plan is designed to comply with the standards outlined in 40 CFR 146.87(a)-(d).

Coring operations described in this program will be adjusted based on spatial variability, core quality, and recovery during the drilling process. All wells will undergo mechanical integrity testing prior to injection approval. The data collected will be used to update the Area of Review and Corrective Action Plan section (*Section 3*), refine the site characterization, revise the Testing and Monitoring Plan section (*Section 8*), and define the final operational limits and procedures.

6.2 Pre-Injection Testing Plan—Injection Well

To comply with the requirements of 40 CFR 146.87(a)-(d), the following testing and logging activities will be carried out during drilling, casing installation, and post-casing installation phases. These procedures are further outlined in the in *Section 5.0* (Proposed Injection Well Construction Information) of the permit application.

A detailed schedule of testing operations will be submitted to the UIC Director at least 30 days before the planned start date. The UIC Director will have the opportunity to observe all testing operations associated with the injection wells, as specified under 40 CFR 146.87(f).

6.2.1 Deviation Checks

At the Vanguard CCS Hub, ten (10) injection wells will be drilled and completed, with each well situated on a separate pad. All wells are designed as vertical completions. Deviation measurements will be recorded at regular intervals during drilling to ensure the creation of accurate and comprehensive deviation surveys.

6.2.2 Tests and Logs

6.2.2.1 *To be performed during drilling*

The logging plan for the injection wells will encompass both open-hole and cased-hole phases during all stages of drilling. The program will comply with EPA Class VI requirements and will evaluate in-situ formation characteristics, including thickness, porosity, permeability, lithology, formation fluid salinity, and reservoir pressure, as specified under 40 CFR 146.87.

A comprehensive mud logging program will be tailored to the target depths of each injection well. Formation cuttings will be collected from the surface to the total depth, with more frequent sampling intervals concentrated around the proposed injection zones. Gas sampling will be incorporated into the process and cross-referenced with cutting data and drilling parameters for onsite analysis.

Details of the logging procedures for both open-hole and cased-hole sections of the wells are outlined in subsequent sections. Each injection well will be drilled and completed in two primary phases: the surface casing and the long-string casing, with the logging program adjusted to align with these completion stages.

6.2.2.2 *Surface String Logging Program*

These wireline logging techniques outlined will be utilized to evaluate the surface hole of the twelve injection wells once the casing point is reached at approximately 150 feet below the Vamoosa Formation in Osage County, OK. These depths range from 700-1,100 feet deep for ten (10) planned injection wells. The planned geophysical logs will provide essential data for site characterization. The surface casing will be set below the lowermost freshwater zone and cemented to the surface, as specified in **Table 6.1.**

Table 6.1 - Well Log Details – Surface Casing

Open Hole – 12 1/4 in		
Well Log	**Measurement**	**Data Acquisition Profile**
Spontaneous Potential	Electrical Potential	Permeability, shale volume and formation fluid salinity
Resistivity	Ohm-meters	Porosity, water saturation and the presence of hydrocarbons
Gamma Ray	API Units	Lithology
Open Hole Caliper	Inches	Borehole diameter and log correction. Account for washouts
Cased Hole – 9 5/8 in		
Well Log	**Measurement**	**Data Acquisition Profile**
Cement Bond	Acoustic	Determine the integrity of the cement between formation and cement
Ultrasonic Imaging	Acoustic	Well completion quality – bond quality between casing and cement
Temperature	Degrees Fahrenheit	Develop temperature profile & establish baseline

6.2.2.3 *Long String Logging Program*

Wireline logging methods will be employed to analyze the long-string casing upon reaching TD. The logging program includes both open and cased hole geophysical logs. For all injection wells, the long-string casing will be cemented to the surface, as detailed in **Table 6.2**.

Table 6.2 - Well Log Details – Long String

Open Hole – 8 ½ in		
Well Log	**Measurement**	**Data Acquisition Profile**
Spontaneous Potential	Electrical Potential	Permeability and formation fluid salinity
Resistivity	Ohm-meters	Porosity, water saturation and the presence of hydrocarbons
Gamma Ray	API Units	Lithology
Open Hole Caliper	Inches	Borehole diameter and log correction. Account for washouts
Density/Neutron	Bulk Density (gm/cc), Porosity (Phi)	Porosity
Fracture Finder	Resistivity Image Log	Formation Imaging for breakouts and fractures
Sonic Scanner	Borehole imaging using sound waves	When combined with Resistivity image can differentiate if fracture networks are permeable
Dipole Sonic	Sonic Compressional and Shear velocities	Porosity, Mechanical Properties
NMR	Nuclear Magnetic Resonance	Fluid Properties, Porosity, Permeability
Cased Hole – 7 in		
Well Log	**Measurement**	**Data Acquisition Profile**
Cement Bond	Acoustic	Determine the integrity of the cement between formation and cement
Ultrasonic Imaging	Acoustic	Well completion quality – bond quality between casing and cement
Temperature	Degrees Fahrenheit	Develop temperature profile & establish baseline

6.2.2.4 *Open Hole / Injection Interval Section*

Wireline logging methods will be employed to analyze the openhole injection interval section upon reaching the total depth of the well. The logging program includes open hole geophysical logs **Table 6.3**.

Table 6.3 - Well Log Details – Open Hole / Injection Interval

Open Hole – 6 1/8 in		
Well Log	**Measurement**	**Data Acquisition Profile**
Spontaneous Potential	Electrical Potential	Permeability, shale volume and formation fluid salinity
Resistivity	Ohm-meters	Porosity, water saturation and the presence of hydrocarbons
Gamma Ray	API Units	Lithology
Open Hole Caliper	Inches	Borehole diameter and log correction. Account for washouts
Density/Neutron	Bulk Density (gm/cc), Porosity (Phi)	Porosity
Fracture Finder	Resistivity Image Log	Formation Imaging for breakouts and fractures
Sonic Scanner	Borehole imaging using sound waves	When combined with Resistivity image can differentiate if fracture networks are permeable
Dipole Sonic	Sonic Compressional and Shear veolocities	Porosity, Mechanical Properties
NMR	Nuclear Magnetic Resonance	Fluid Properties, Porosity, Permeability

6.2.2.5 *Analysis and Reporting*

Upon completing the open and cased hole logging activities, NexGen will compile a comprehensive interpretation report prepared by an experienced log analyst, as required under 40 CFR 146.87(a). The report will include the following key elements:

- Log and Well Details: Documentation of the date and time of each test, wellbore completion date, and installation dates for all casing strings and cement types.
- Graphical and Data Outputs: Charted results of each geophysical log, along with any supplemental data collected during the logging process.
- Personnel Information: The name of the logging service provider, the log analyst, and a summary of their qualifications.
- Log Interpretations: Detailed interpretations of the geophysical logs provided by the log analyst. This includes assumptions made and determinations related to porosity, permeability, lithology, thickness, depth, and formation fluid salinity for relevant geological formations.
- Revised Stratigraphy: Identification and explanation of any changes in the site stratigraphy based on insights gained from formation testing and logging.

All reports will be submitted to the authorized UIC Program Director for review and approval.

6.2.2.6 *Core Program*

Developing an accurate reservoir model relies heavily on petrophysical data and interpretation, which is strengthened by incorporating core analysis to correlate with geophysical log results. NexGen has implemented a comprehensive coring program that adheres to the requirements outlined in 40 CFR 146.87(b).

A detailed strategy has been established for collecting whole core samples from both the confining and injection zones at the Vanguard CCS Hub. Core samples will be obtained from the NexGen I-5 well (see **Table 6.4**). The collected core will represent the geological conditions of the primary confining unit and injection zone within the AoR.

The coring program's objective is to extract approximately 900 feet of whole core from the stratigraphic test well which will be repurposed as an injection well designated as the Vanguard I-5, providing a representative dataset for the primary confining layer and injection zone. Site-specific analysis indicates low structural dip, the absence of faulting, and no significant structural disturbances within the site.

Table 6.4 - Coring details for Vanguard I-5 – Note: the stratigraphic test well will be repurposed for injection and designated Vanguard I-5

Formation	Regulatory Intervals	Core Acquisition Intervals
Lower Mississippi - Arbuckle	Confining Zone	2,906 – 3,012 (106 ft.)
Upper Arbuckle	Injection Zone	3,012 – 3,476 (464 ft.)
Lower Arbuckle	Injection Zone	3,476 – 3,770 (294 ft.)

The specific core sampling intervals during well drilling will be determined in real-time based on the actual subsurface conditions encountered. If core recovery from any run is inadequate, the geological advisor may opt to repeat the coring process or utilize sidewall coring techniques to obtain the required formation samples. Core collection depths will also be adjusted to align with the actual drilling depths observed.

Should the UIC Director find that the cores obtained are not adequately representative or the quality is insufficient, NexGen will implement an alternative coring plan to rectify these shortcomings. NexGen may, if deemed necessary, core one or multiple of the additional twelve injection wells within the same stratigraphic interval.

Additionally, formations with permeability above the injection zones may be sampled if deemed beneficial. These samples could provide valuable data to enhance the "Testing and Monitoring Plan" detailed in *Section 8* throughout the lifecycle of the project. The decision to sample these additional formations will be guided by the project's specific requirements at the time the injection wells are being drilled.

6.2.2.7 *Analysis*

Comprehensive core sample analyses will be conducted by a certified laboratory, which will be selected by NexGen at a later date. The primary objective of these analyses is to characterize the injection and confining zones by evaluating a broad spectrum of rock properties. These include petrological and mineralogical characteristics, petrophysical attributes such as porosity and permeability, and assessments of capillary pressure (**Table 6.5**). All analyses will adhere to the requirements set forth in 40 CFR 146.82(a). Additionally, geomechanical tests will be performed to evaluate the fracture gradient and pore volume compressibility for both the injection and confining zones.

The data derived from these analyses will play a critical role in minimizing uncertainties within the reservoir models. This information will allow for adjustments to input parameters and enhance the overall accuracy of the model. Furthermore, the analyses will validate the integrity of the caprock seal and provide insights to optimize operational procedures for injection activities. Core samples obtained from the stratigraphic test well are expected to reliably represent the conditions of the injection site.

Key evaluations will include lithologic core descriptions, thin section analysis, and X-ray-based techniques such as XRD and XRF. These tests will help address uncertainties regarding the depositional and flow properties of the formations. Depending on the quality of the collected core samples and the specific needs of the injection project, additional specialized tests—such as electrical property evaluations and relative permeability measurements—may also be performed.

Table 6.5 - Core Analysis Details

Parameter	Measurement	Units
Porosity	Total Porosity Diffuse Porosity	Percent
Permeability	Vertical Permeability Horizontal Permeability	mD
Relative Permeability	Relative Gas Permeability Relative Aqueous Permeability	mD
Saturation	Fluid Saturation Residual Aqueous Saturation Residual Gas Saturation	Percent
Resistivity		Ohm-meters
Compressibility	Bulk Compressibility Pore Compressibility	1/Pa
Physical Properties	Rock Strength Ductility Elastic Properties	UCS % Pa
Lithology	Description	
Rock/Soil Type	Petrology	SEM
	Mineralogy	Thin Sections
Capillary Pressure		Pc

6.2.2.8 *Reporting*

NexGen will provide a detailed report prepared by a qualified log analyst, presenting the findings from the core analyses in compliance with 40 CFR 146.87(b). This report will include comprehensive information on the core collection and testing methodologies, descriptions of the samples, and calibration details for any instruments used in the process. Results will be presented in a clear and accessible format, using tables, graphs, and photographs where relevant. The final report will be submitted to the UIC Director for review.

6.2.2.9 *Formation Pressure and Fluid Sampling*

Formation brine samples will be obtained from the Arbuckle injection zone using a wireline reservoir sampling tool. These samples will be analyzed for temperature, pH, conductivity, and static fluid pressures in accordance with 40 CFR 146.87(c).

Collected fluids will be sent to a certified laboratory (to be determined by NexGen) for detailed analysis of their physical and chemical characteristics. Although minimal drilling mud contamination is anticipated, it will be evaluated as part of the analysis. The results will help determine the compatibility of the injected CO_2 with the native formation fluids.

Additionally, baseline downhole pressure conditions for each injection interval will be recorded during the drilling and completion phases of the injection wells. These measurements, taken with wireline gauges and sensors, will be used to calculate injection rates and volumes. Further details regarding formation testing procedures are outlined in **Table 6.9**. Pressure data will be collected from each injection well for its designated injection interval.

6.2.2.10 *Analysis*

Geochemical analysis will be conducted on all fluid samples obtained from the injection interval to evaluate their physical and chemical properties. The specific parameters to be measured are outlined in **Table 6.6.**

Table 6.6 - Physical and chemical testing parameters

Parameter	Methodology
Reservoir Pressure	DAS Fiber Optics
Fluid Temperature	TBD
pH	TBD
Conductivity	APHA 2510
Fracture Pressure	Step-rate test, core analysis, MDT, log analysis
Static Fluid Level	Fluid level ultrasonic transmitter

Solubility and compatibility analyses will be conducted for the following purposes:

1. Determining salinity levels.
2. Reducing uncertainties in viscosity calculations.
3. Assessing the compatibility of the CO_2 injectate with formation fluids.

4. Evaluating the interaction between formation fluids and injection materials.

Formation fluid samples will also serve as baseline references for the injection interval, providing critical initial data for monitoring changes in reservoir conditions during injection operations and throughout the post-injection site closure phase.

Formation pressures collected at this stage may not fully reflect static reservoir conditions due to the influence of drilling activities. These discrepancies will be addressed through interval-specific formation testing conducted after the completion of each injection well. Initial downhole formation pressures will represent the static reservoir conditions, forming a baseline for monitoring pressure changes during injection and post-injection operations.

6.2.2.11 *Reporting*

Following the collection and analysis of formation fluid samples, a comprehensive report will be compiled in accordance with 40 CFR 146.87(b). The report will include the following details:

- **Sampling Equipment and Procedures:** Description of the equipment utilized for sample collection and the field procedures employed.
- **Pumped Samples:** If a pump was used, the report will specify the flow rate, type of pump, its location, and geochemical modeling results indicating the anticipated geochemical composition of fluids under downhole conditions.
- **Field Data:** Measurements for parameters such as pH, conductivity, temperature, and pressure obtained during field sampling.
- **Laboratory Results:** Results of the laboratory analyses, including data from quality assurance samples.
- **Anomalies:** Observations or notes addressing any unusual or unexpected data encountered during analysis.

The finalized report will be submitted to the authorized regulatory UIC Director.

6.2.3 Fracture Pressure Analysis

In accordance with 40 CFR 146.87(d)(1), the fracture pressures of the injection and confining zones will be calculated or determined. These values, along with the injection zone's pore pressures, will help establish suitable injection pressures for the wells. NexGen plans to analyze vertical stress (Sv) by utilizing density logs recorded in each injection well. Additionally, image logs, such as fracture identification logs, will be used to detect any fractures or borehole breakouts.

Fracture and reservoir pressures will also be assessed through the evaluation of core samples and log data. The outcomes of these analyses will ensure that injection rates and pressures remain within limits defined by the fracture pressure of the injection zone(s). With a fracture pressure gradient of 0.706 psi/ft and a depth of approximately 3,000 feet, the calculated fracture pressure at the upper boundary of the Arbuckle Formation is estimated to be approximately 2,118 psi.

6.2.4 Injection Well Mechanical Integrity Testing

The in-zone and above-zone injection wells at the Vanguard CCS Hub will undergo a series of MITs following installation and prior to initiating CO_2 injection activities. **Table 6.10** outlines the tests designed to evaluate the mechanical integrity of the wells.

The MITs will include a pressure test conducted using fluid or gas to confirm the absence of any leaks within the well structure. Additionally, a tracer survey or noise log will be conducted to verify that no fluid migration is occurring behind the casing. These assessments are critical to ensuring the mechanical integrity of the wells and preventing unintended movement of formation fluids along the wellbore.

If a well fails to meet mechanical integrity standards, necessary repairs will be made before progressing to the next phase of drilling or construction activities.

Table 6.7—Pre-Operational Testing Schedule

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR 146.89(a)(1)	MIT - Internal	Pressure test using liquid or gas to determine that there is no significant leak in the casing, tubing or packer	After construction
40 CFR 146.87(a)(4)	MIT - External	Pressure test using liquid or gas and a casing inspection log to demonstrate the internal and external mechanical integrity of the well	
40 CFR 146.87(a)(4)	MIT - External		
40 CFR 146.87(e)(1)	Testing prior to operating	Pressure fall-off test, pump test and injectivity test to verify the hydrogeologic characteristics of the injection zone	Prior to operation

NexGen will notify EPA least 30 days prior to conducting the test and provide a detailed description of the testing procedure. Notice and the opportunity to witness these tests/logs shall be provided to EPA at least 48 hours in advance of a given test/log.

Table 6.8 - Wireline Logs and Description

Test	Description
Casing Inspection Log (Internal MIT)	To detect deformation, physical wear and or corrosion
Cement Bond Log (External MIT)	To evaluate integrity of cement job between the casing and the formation
Temperature or Noise Log (External MIT)	To detect thermal anomalies that deviate from the baseline gradient

An APT will be performed following the completion of injection wells construction and prior to initiating injection activities to verify the structural integrity of the well. The test will confirm that the well can maintain its integrity under operational conditions. To pass the test, the annular pressure must remain at a minimum of 500 psig for at least 60 minutes, with no more than a 5% deviation from the starting pressure. Throughout the test, a differential annular pressure of at least 100 psi will be maintained.

Pressure data will be logged using a time-driven recorder for no less than 60 minutes. The recorded data, either in chart or digital format, will be verified as accurate and reliable. The recording scale will be designed to clearly display any 5% change from the initial pressure value. The test procedure includes the following steps:

1. Attach a high-resolution pressure transducer to the annulus. Increase the annular pressure to at least 500 psig or maintain a minimum of 100 psi above the tubing pressure. Hold this pressure for at least 60 minutes, ensuring a differential pressure of no less than 100 psi above the maximum allowable surface injection pressure.

2. Once the APT is complete, reduce the annular pressure to a safe, normal operating differential pressure. Disconnect the pressure monitoring equipment from the well system.

The test will be deemed successful "PASS" if the pressure remains stable for the entire duration. A failure to sustain pressure during the test timeframe will result in a "FAIL" designation, suggesting that the well's structural integrity may be compromised. Ongoing monitoring of the annular pressure system will be conducted to detect any indications of leaks and assist in identifying possible causes of integrity issues.

6.2.5 Formation Testing

Before injection operations commence, a hydrogeologic test will be conducted on the injection wells. The testing may include procedures such as a pressure fall-off test or an injectivity test. These evaluations will rely on parameters like porosity, permeability, and connectivity, which were previously evaluated during the site characterization phase. Following the cementing of the casing and the perforation of the formation, a straddle packer will be positioned within the cased interval of the well to enable testing.

Outlined below are the potential steps for conducting these tests. The final design for well-specific tests will be developed based on the completed construction of the well and the identified injection zone. These finalized procedures will be submitted to the EPA or the designated UIC Director for review at least 30 days before the planned testing date.

6.2.5.1 *Ambient Pressure Fall-off Testing*

To evaluate reservoir permeability, assess injection capacity, and examine wellbore efficiency—specifically for completion-related factors, such as skin damage, a short-term injection and fall-off test will be performed for each well after construction but prior to initiating CO_2 injection per 40 CFR 146.87(e)(1). This testing will establish baseline data for each well, which will serve as a reference to monitor the effects of CO_2 injection in the near-wellbore area.

The test procedure involves an extended injection phase followed by a shut-in period. During the test, pressure data will be recorded before, during, and after injection as pressures gradually return to static equilibrium. The testing methodology will align with the "USEPA Region 6 UIC Pressure Fall-Off Testing Guidance (Third Revision – August 8, 2002)." Before initiating the test, the well will remain idle to ensure static pressure conditions, with no ongoing injection operations. Two pressure gauges will be placed at designated depths within the injection intervals to capture accurate initial static bottomhole pressure measurements.

Following the collection of static pressure data, injection will begin at a consistent, predefined rate and will continue for a duration sufficient to generate pressure transients. These transients will provide critical data for fall-off test analysis. Downhole DAS fiber optic cable will continuously monitor flowing bottomhole pressures throughout the injection period. The well will then be closed at the surface to minimize the influence of wellbore storage, allowing pressure to decline naturally. This decline will be tracked until the reservoir reaches radial flow conditions, and final bottomhole pressure measurements are recorded. During this time, no injections will occur in nearby wells to ensure pressure responses remain isolated to the specific well and interval under testing.

Analysis of the fall-off test will involve preparing comprehensive calculations and data plots to verify the test, define flow regimes, and evaluate well completion and reservoir characteristics. Parameters such as transmissivity and skin factor will be analyzed to identify changes over time. The impact of drilling or completion activities, such as perforation-related damage, will also be assessed, along with determining whether future well cleanouts may be required. In CO_2-specific scenarios, pressure variations might indicate the presence of multiple fluid phases. The test design will account for such conditions to ensure accurate analysis.

All findings and supporting documentation will be compiled into a detailed report, which will be submitted to the EPA within 30 days of completing the test (40 CFR 146.91(e) and 146.91(b)(3)).

6.2.5.2 *Step-Rate Test*

A step-rate test will be conducted to determine the Maximum Allowable Surface Injection Pressure (MASP), which must remain below 90% of the measured fracture closure pressure for the injection interval. Each well will have a custom-designed step-rate test specific to its injection interval and completion parameters. The test will encompass a range of injection rates, starting from minimum pressures and gradually increasing toward the estimated fracture pressure.

The step-rate test involves incremental fluid injection, during which injection pressure is plotted against injection rate. For unconsolidated formations, a tubing/packer setup may be required. Each step will maintain a consistent injection rate and duration, with at least five steps involving 20% rate increases. However, step design may vary for each well to optimize data collection, potentially including more steps or smaller rate increases over time.

Both downhole and surface rates and pressures will be recorded throughout the test. At the conclusion of each step, data will be analyzed by plotting injection pressure against rate. A consistent slope indicates elastic formation behavior, while a reduced slope suggests fracture initiation and pressure dissipation. The general procedure includes the following steps:

1. **Pre-Test Stabilization**: Shut the well in long enough to allow bottomhole pressure to stabilize.
2. **Incremental Injection**: Inject fluid at progressively higher rates, maintaining a constant duration for each step. Record the corresponding pressure at the wellhead using a calibrated pressure gauge, with adjustments made for friction losses.
3. **Flow Rate Control**: Use a pre-tested constant flow regulator to ensure consistent injection rates.
4. **Flow Rate Measurement**: Measure injection rates using a calibrated turbine flow meter and document the readings.
5. **Pressure Measurement**: Measure bottomhole pressure with a downhole pressure bomb.
6. **Graphical Analysis**: Plot stabilized injection pressures against flow rates. Identify the formation's fracture pressure as the point where the slope decreases, indicating a loss of pressure retention.
7. **Post-Test Stabilization**: Cease injection, allowing pressure to dissipate into the formation. Record the instantaneous shut-in pressure (ISIP), representing the minimum pressure needed to keep a fracture open.
8. **Formation Behavior Assessment**: If the maximum test injection pressure fails to reach fracture pressure, results may suggest that the formation can accommodate fluid without fracturing.

All findings and associated documentation will be submitted to the EPA within 30 days of completing the test (40 CFR 146.91(e) and 146.91(b)(3)).

6.3 Pre-Injection Testing Plan—Monitoring Wells

NexGen plans to drill ten (10) above-zone monitoring wells (Vanguard AZM-1, Vanguard AZM-2, Vanguard AZM-3, Vanguard AZM-4, Vanguard AZM-5, Vanguard AZM-6, Vanguard AZM-8, Vanguard AZM-9, Vanguard AZM-10 and Vanguard AZM-12) and seven (7) in-zone monitoring wells (Vanguard IZM-1 through Vanguard IZM-7) equipped to track temperature and pressure above and within the injection zone. These wells will also provide critical data to validate site characterization parameters for both the confining and injection zones.

Although the EPA does not impose the same testing requirements for monitoring wells as it does for injection wells, NexGen has developed a testing plan to mitigate uncertainties, fill any data gaps, and establish robust baseline conditions. The following subsections detail the logging and testing procedures designed specifically for the in-zone monitoring well.

This above-zone and in-zone monitoring wells will be constructed to allow for testing operations, including the deployment of downhole tools and workover equipment, while also enabling assessments of the well's mechanical integrity. Testing and logging activities will be conducted in stages, addressing both open-hole and cased-hole phases, based on the finalized well design.

6.3.1 Deviation Checks

The ten (10) above-zone monitoring wells are planned for vertical drilling and completion and will be located approximately 250 ft east of the proposed injection wells. The seven (s) in-zone monitoring wells will be located along the periphery of the AoR and within the NexGen-controlled land position. Deviation from the vertical trajectories are expected to be minimal or negligible. Deviation measurements will be taken at regular and adequate intervals during each phase of the drilling process to ensure precise well placement.

Similarly, the in-zone monitoring wells, situated approximately 2 miles east of the injection site, is also designed as a vertical completion. This well will undergo regular deviation monitoring at consistent intervals throughout the drilling phases to confirm alignment with the planned trajectory. Both sets of monitoring wells are engineered to maintain accuracy and integrity in their vertical configurations.

6.3.2 Tests and Logs

The logging program has been tailored to enhance site characterization for both the confining and injection zones. It follows a methodology similar to the logging operations described for the injection wells. This program will include a range of logging runs, as outlined below. Please note, the table provides examples of potential logs NexGen may utilize, subject to the specific requirements of the project and permitting process for injection well construction.

Table 6.9 – Summary of tests and logs to be run

Logging Run	Logging Tools	Data Acquisition
Triple Combo	Gamma Ray (GR), Caliper, Spontaneous Potential (SP), Resistivity, Density, Neutron	Correlation, Porosity, Saturations, Hole Size, Resistive Anisotropy
Dipole Sonic	Sonic compressional and shear	Porosity, Mechanical Properties
Formation Images	Formation Micro-imager borehole images	Structure, Env. Deposition, Fractures
Magnetic Resonance	Magnetic Resonance	Porosity, free and bound fluids, Permeability
Elemental Spectroscopy	Elemental Capture Spectroscopy	Lithology
Natural Gamma Ray Spectroscopy	Spectral GR	Clay Minerals
MDT Tool	Modular formation dynamics tester	*In situ* Fracture Pressure Fluid Samples
Sidewall Cores	Sidewall Coring Tool	Porosity, Permeability
Temperature Survey	Temperature Log	Geothermal Gradient Baseline for Fluid Migration
VSP	Vertical Seismic Profile	Tie in to 2D regional profile or be used for future monitoring techniques (if applicable)
CBL/VDL, CCL	Cement Bond Log, Variable Density Log, Casing Collar Locator	Casing cement integrity

Data collected during the drilling of the monitoring well will offer additional insight into the properties of the confining and injection zones, contributing to refinements of the Area of Review and Corrective Action Plan detailed in *Section 3*. The program's flexibility allows for adjustments to align with project needs and regulatory objectives.

6.3.3 Core Programs

Coring is described above.

6.3.4 Formation Fluid Samples

Formation fluid samples will be obtained using a wireline sampling chamber for each targeted injection zone during the drilling of each well within the project scope.

6.3.5 Formation Testing

This well has been designed and engineered in a manner that does not necessitate formation testing at this specific location.

6.3.6 Demonstration of Well Mechanical Integrity

A detailed summary of the Mechanical Integrity Tests (MITs) planned for the wells is outlined in **Table 9**. These tests will verify the mechanical integrity of the well and include pressure testing using fluid or gas to confirm the absence of leaks. Furthermore, tracer surveys or noise logs will be conducted to detect any potential fluid movement behind the casing. These tests are essential to ensure the structural integrity of the well and to confirm that formation fluids are not migrating along the wellbore. If a well is unable to demonstrate mechanical integrity, necessary repairs will be performed before proceeding to subsequent phases of drilling and construction.

Table 6.10 – Mechanical Integrity Tests

Class VI Rule Citation	Rule Description	Test Description	Program Period
40 CFR 146.89(a)(l)	MIT - Internal	Pressure test using liquid or gas to determine that there is no significant leak in the casing, tubing or packer	After construction
40 CFR 146.87(a)(4)	MIT - External	Pressure test using liquid or gas and a casing inspection log to demonstrate the internal and external mechanical integrity of the well	
40 CFR 146.87(a)(4)	MIT - External		
40 CFR 146.87(e)(l)	Testing prior to operating	Pressure fall-off test, pump test and injectivity test to verify the hydrogeologic characteristics of the injection zone	Prior to operation

Table 6.11 – Wireline Logging

Test Name	Test Description
Casing Inspection Log (Internal MIT)	To detect deformation, physical wear and / or corrosion
Cement Bond Log (External MIT)	To evaluate integrity of cement job between the casing and the formation
Temperature or Noise Log (External MIT)	To detect thermal anomalies that deviate from the baseline gradient

The pressure will be logged using a time-based recording device for a minimum duration of 60 minutes, and the resulting chart or digital output will be verified as accurate and authentic. The pressure scale on the recorded output will be detailed enough to detect any deviation of 5 percent or more from the initial pressure. The test procedure will generally follow these steps:

1. Attach a high-resolution pressure transducer to the annulus and raise the pressure to at least 500 psig or 100 psi higher than the tubing pressure. Execute the Annulus Pressure Test (APT) by maintaining a pressure level of at least 100 psi above the maximum authorized surface injection pressure of the well for at least 60 minutes. A minimum pressure differential of 100 psi will be maintained during the entire test.

2. Once the test concludes, reduce the annular pressure to the standard and safe operating differential pressure for the well, and then detach the pressure monitoring equipment from the system.

The test will be classified as a "PASS" if the pressure remains stable throughout the test duration. If the pressure drops and fails to remain stable for the required timeframe, the test will be deemed a "FAIL," indicating potential well integrity issues. Continuous annular pressure monitoring will be employed to detect anomalies, identify potential leaks, and support the evaluation of any issues affecting the annulus.

6.4 Annulus Pressure Test Procedures for Injection Wells

Annular pressure testing will be conducted after well completion and before injection begins for all ten (1) injection wells, and following any workover involving tubing and packer removal. If tubing remains in place, testing will be performed at five-year intervals. The annular pressure will be held at least 100 psi above the tubing injection pressure and continuously monitored at the wellhead to detect anomalies indicative of leakage. The procedure is as follows:

1. Operate the well at a stable injection rate for 72 hours to allow thermal equilibrium along the wellbore, confirmed by stable readings from surface and downhole temperature gauges.
2. Close the annular valves to isolate the annulus, and monitor annular pressure and temperature (surface and downhole) for at least 30 minutes. A valid test shows no more than a 10% pressure loss.
3. Submit test results to the UIC program administrator within 30 days of test completion.

6.5 Annulus Pressure Test Procedures for Monitoring Wells

Mechanical integrity will be verified through periodic pressure testing before injection operations begin and every five years thereafter. The test involves pressurizing the casing to 500 psi and monitoring the pressure using a calibrated digital gauge. The procedure is as follows:

1. Apply 500 psi to the casing and record pressure data using a digital monitoring device.
2. Maintain pressure for at least 30 minutes; a valid test shows no more than a 10% decline.
3. Report test outcomes to the UIC administrator within 30 days, or within 24 hours if the well fails to demonstrate mechanical integrity.

6.6 Pressure Fall-Off Test Procedures:

NexGen will perform a baseline pressure fall-off test before the start of injection and repeat the test every five years during the injection period to evaluate injectivity and monitor changes in the near-wellbore environment. The procedure is as follows:

1. Conduct a pressure fall-off test prior to initial CO_2 injection to establish baseline injectivity and skin conditions near the wellbore.
2. Repeat fall-off testing on a five-year interval to assess changes in reservoir pressure and near-wellbore flow efficiency.

3. Use test results to quantify any increase in formation damage or skin effect that could impair injection performance over time.

6.7 Quality Assurance and Surveillance Plan

The Quality Assurance and Surveillance Plan is provided in the standalone document **8.11_QASP_NexGen_Vanguard.pdf**.