[redacted]

UIC CLASS VI GEOLOGIC STORAGE OF CO_2 PERMIT APPLICATION

Dusek CCS #2 Well

[redacted]

Upton County, Texas

Section 4: Engineering Design and Operating Strategy

[40 CFR §146.82, §146.86, §146.87]

Prepared for:

EPA Region 6

Underground Injection Control Section

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Acronym / Abbreviation / Term	**Definition / Meaning**
1-D	one-dimensional
2-D	two-dimensional
3-D	three-dimensional
4-D	four-dimensional
ACS	American Community Survey
AES	atomic emission spectrometry
AMA	active monitoring area
AMPP	Association for Materials Protection and Performance
AMS	accelerator mass spectrometry
AoR	area of review
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
AVO	amplitude variation with offset
AZMI	above-zone monitoring interval
bbl(s)	barrel(s)
Bcf	billion cubic feet – standard unit of measurement for natural gas
BEG	Bureau of Economic Geology
BET	Brunauer-Emmett-Teller analysis
BHA	bottomhole assembly
BHP	bottomhole pressure
BHIP	bottomhole injection pressure
BHT	borehole temperature
BNI	BNI Coal, Inc.
BOP	blowout preventer
BOPE	blowout preventer equipment
bpm	barrels per minute
BTC	buttress-thread and coupled
CBL	cement bond log
CBP	Central Basin Platform
CCP	corrosion control program
CCS	carbon capture and storage
CCUS	carbon capture utilization and storage
CFR	Code of Federal Regulations
cm	centimeter
CMG	Computer Modelling Group Ltd.

Glossary of Acronyms, Abbreviations and Terms for All Permit Sections: 1-12	
Acronym / Abbreviation / Term	**Definition / Meaning**
CO_2	carbon dioxide
CRA	corrosion resistant alloys
DAS	distributed acoustic sensing
DIC	dissolved inorganic carbon
DOT	U.S. Department of Transportation
°	degree symbol/glyph used to represent degrees of an arc (i.e., geographic coordinate systems), and degrees of temperature
DST	drill stem test
DTS	distributed temperature sensing
EC	electric conductivity
EJ	environmental justice
EM	electromagnetic
EOR	enhanced oil recovery
EOS	equation of state
EPA	U.S. Environmental Protection Agency
ERCOT	Electric Reliability Council of Texas
ERR	emergency or remedial response
ERRP	emergency and remedial response plan
ESD	Emergency Shutdown
°F	degree Fahrenheit
F/ft	Fahrenheit per foot
FADP	financial assurance demonstration plan
FM	farm-to-market
FMI	formation microimaging
FOC	fiber optic cable
FS	field superintendent
FSP	fault slippage potential
ft	foot
GAU	Groundwater Advisory Unit
GC	gas chromatography
g/cm^3	gram per cubic centimeter
GEM	generalized equation-of-state model
GFCI	ground fault circuit interrupter
GHG	greenhouse gas
GHGRP	Greenhouse Gas Reporting Program
GR	gamma ray
GSDT	Geologic Sequestration Data Tool – EPA's centralized, web-based system
h	hour
H_2S	hydrogen sulfide
HI	health index
HSE	health and safety and the environment
ICP	inductively coupled plasma
ID	inside diameter
in.	inch
Injection Unit	[redacted]
Injection Interval	[redacted]"
km	kilometer
KNN	k-nearest neighbor algorithm (also known as k-NN)
Kv	vertical permeability
L	liter
lb	pound
LUST	leaking underground storage tank
M	magnitude
m	meter

Glossary of Acronyms, Abbreviations and Terms for All Permit Sections: 1-12

Acronym / Abbreviation / Term	Definition / Meaning
m	cementation exponent
MASP	maximum anticipated surface pressure
Mcf	unit of volume equal to one thousand cubic feet
MICP	mercury injection capillary pressure
mD	millidarcy
MD	measured depth
MES	Milestone Environmental Services, LLC
mg	milligram
mg/L	milligram per liter
MICP	mercury injection capillary pressure
Midstream companies	operate the pipeline and gathering or transmission facilities that move the gas from the well (upstream) to our homes and businesses (downstream).
Milestone	Milestone Carbon Midland CCS Hub, LLC
mi	mile(s)
MIT	mechanical integrity test
mm	millimeter
MMscf/d	million standard cubic foot per day
MMt	million metric tonne
MMta	million metric tonne per annum (year)
MMT/yr	million tonne per year
mol%	mole percent
MPa	megapascal
MPSI	million pounds per square inch
MRV	monitoring, reporting, and verification
MS	mass spectrometry
MSIP	maximum surface injection pressure
MVA	monitoring, verification, and accounting
MWD	measurement while drilling
Mya	millions of years ago
n	exponent in the relation to water saturation
nD	nanodarcy
nm	nanometer
NMR	nuclear magnetic resonance
NPL	EPA's Superfund NPL: National Priorities List of sites of national priority among the known releases or threatened releases of hazardous substances, pollutants, or contaminants throughout the United States and its territories
NU	nipple up
NW	northwest
O_2	oxygen
P&A	plug and abandon
PBR	polished borehole receptacle
PEF	photoelectric factor
PISC	post-injection site care
PNL	pulsed neutron log
POD	points of diversion
ppb	parts per billion
ppf	pound per foot
ppg	pound per gallon
ppm	part per million
ppmv	part per million volume
PSD	prevention of significant deterioration
psi	pound per square inch
Psi/ft.	pound per square inch per foot
P/T	pressure/temperature
QA	quality assurance
QASP	quality assurance and surveillance plan
QC	quality control

Glossary of Acronyms, Abbreviations and Terms for All Permit Sections: 1-12	
Acronym / Abbreviation / Term	**Definition / Meaning**
QCSP	quality control and surveillance plan
RCRA	Resource Conservation and Recovery Act
RST	reservoir saturation tool
RRC	Railroad Commission of Texas
RU	rig up
Rw	resistivity of water
RWP	rated working pressure
§	typographical character for referencing individually numbered sections
sc-CO_2	supercritical CO_2
SAU	storage assessment unit, a USGS term related to CO_2 storage resources
SCADA	supervisory control and data acquisition
sDAS	seismic distributed acoustic sensing
SDRDB	Submitted Drillers Reports Database (a TWDB database on water wells)
SGS	sequential gaussian simulation
SIS	sequential indicator simulation
SMEs	subject matter experts
[redacted]	[redacted]
SP	spontaneous potential
Sq. mi	square mile
SWC	sidewall coring
TCEQ	Texas Commission on Environmental Quality
TCEQ Central Registry	provides a centralized location for core information about those TCEQ regulates, such as company names, addresses, and telephone numbers
TD	total depth
TDS	total dissolved solids
TEC	tubing encapsulated conductor
TF	task force
TIC	total inorganic carbon
TIH	trip in hole
TOC	total organic carbon
Top Seal	[redacted]
TRI	toxic release inventory
TSDF	treatment, storage, and disposal facility
TVD	true vertical depth
TVDSS	true vertical depth subsea
TWDB	Texas Water Development Board
uD	microdarcy
UIC	underground injection control
ug/m^3	micrograms per meters cubed
Upper Confining Layer	[redacted]
UCL	Upper Confining Layer
Upper Confining Unit	[redacted]
USD	U.S. Dollar
USDW	underground source of drinking water
USGS	U.S. Geological Survey
USIT	ultrasonic imaging tool
UST	underground storage tank
VCP	vertical proportion concentration
VSP	vertical seismic profile
VTI	vertically transverse isotropy
XRD	x-ray diffraction

4.0 ENGINEERING DESIGN AND OPERATING STRATEGY [40 CFR 146.82(a)(7), (a)(8), (10), (11), (12) 146.86, 146.87]

Milestone's permit **Section 4.0** describes the engineering design details and operational strategies employed during the planning of the Dusk CCS #2 Well proposed by Milestone. Along with the Well, engineering design details and operational strategies of the proposed above-zone monitoring well and USDW monitoring well, respectively named Dusek AZM #2 and Dusek USDW #2, are presented in this section.

This section also features the design and construction of the planned monitoring wells that will be drilled to support injection into the Well. Milestone plans to drill one above-zone monitor well, the Dusek AZM #2, and one USDW monitoring well, the Dusek USDW #2. [redacted]

4.1 Engineering Design [40 CFR 146.82(a)(11), (12), 146.86]

The design of the Well is optimized to permanently sequester CO_2, prevent the movement of CO_2 and subsurface fluids into USDWs, and account for various operational factors, such as injection volume, rate, chemical composition, metallurgical evaluations, physical properties of the injectate fluid, and the corrosive nature of the injectate fluid and its impact on wellbore components. The operation of the well will be managed to ensure efficient use of pore space in the reservoir and to contain the CO_2 within the authorized injection unit both during and post-injection.

The Dusek CCS #2 Well is designed to withstand the corrosiveness of the injectate. [redacted]dditionally, the wellbore cement design and products used to cement the well are designed to create good, reliable bonding between the casing and formations while withstanding the corrosive nature of the injectate. [redacted]

[redacted]**Figure 115** shows the proposed wellbore schematic.

[redacted]

[redacted] See **Section 5** for additional information regarding monitoring plan. The continuous recording devices and pressure gauges are noted as the red lines in **Figure 115**.

[redacted]

[redacted]

4.2 General Outline of Well Design and Completion Schematic

The Dusek CCS #2 Well was designed with the following specifications:

[redacted]

i. See schematic for details (**Figure 120**)

A complete drilling and completion prognosis has been included in **Appendix B**.

4.3 Detailed Discussion of Injection Well Design

[redacted] **Table 32** shows the standard conditions of CO_2 which are used in the modeling and flow calculations.

[redacted]

[redacted] This information is used to properly design the casing, tubing, and wellhead configurations.

[redacted]

The composition specifications for the CO_2 stream to be injected in Well are provided in **Table 33**.

[redacted]

Table 34 shows the calculated injection parameters from the tubing size evaluation based on the inputs described in **Table 32**:

[redacted]

[redacted]

4.3.1 Casing Summary

The Dusek CCS #2 Well will use the following casing sizes and lengths (**Table 35**):

[redacted]

4.3.2 Conductor Pipe

[redacted]

Engineering and design parameters for the conductor pipe are summarized in **Table 36**:

[redacted]

4.3.3 Surface Casing

[redacted]

Engineering and design parameters for the surface casing are summarized in **Tables 37 A-D**:

[redacted]

[redacted]

4.3.4 Intermediate Casing

[redacted]

Engineering and design parameters for the intermediate casing are summarized in **Tables 39-40.**

[redacted]

[redacted]

4.3.5 Production Casing

[redacted]

A comprehensive metallurgical analysis, which considered the chemical composition of the CO_2 injectate and downhole conditions, was conducted and is included in **Appendix A**. The analysis determined that the CO_2 injectate is not corrosive on its own. [redacted]

[redacted]

[redacted]

[redacted]

[redacted] **Figure 115** shows the proposed wellbore schematic.

Engineering and design parameters for the production casing are summarized in **Tables 41-42**:

[redacted]

[redacted]

4.3.6 Centralizers

Centralizer selection and installation for the referenced well will have two (2) separate functions. [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]

4.3.7 Injection Tubing

As previously mentioned, the size of the injection tubing was chosen based on the injection volume, rate, and injectate composition. It is important to consider the injectate and the potential for a corrosive environment when selecting the material of the tubing, similar to the casing string. [redacted]. A comprehensive summary of the metallurgical analysis is included in **Appendix A** of this application. [redacted]

The tubing and production casing annulus will be filled with a corrosion inhibited fluid as approved by UIC Program Director, prior to setting the packer.

[redacted]

[redacted]

[redacted]

4.3.8 Sub Surface Safety Valve (SSSV)

[redacted]

[redacted]

4.3.9 Wellhead Discussion

The wellhead proposal, similar to the production packer, should be designed to combat working pressures and corrosion complications (**Figure 120**).

[redacted]

[redacted]

4.3.10 Packer Discussion

[redacted]

[redacted]

[redacted]

4.4 Injection Well Operating Strategy

[redacted]. **Table 44** summarizes the maximum wellhead and bottomhole pressures. See relevant figures and tables on changes in pressure over time: **Section 2.5- Figure 98**, **Section 2.5** -**Table 26**, and **Section 3.3 – Figure 105**.

Bottomhole pressure will not exceed 90% of the fracture pressure of the injection interval, which will limit surface injection pressure. The anticipated bottomhole injection pressure (BHIP), frac gradient with 90% safety factor and injection rate plot over time is shown in **Table 45**.

Values in **Table 44** are the proposed operating parameters for the Dusek CCS #2 injection well. Average pressure values are likely to be adjusted once the test well is drilled. Maximum pressure and rate values are not expected to change substantially since they are linked to the fracture gradient and pipe size constraints.

[redacted]

The operating strategy for the Well is as follows:

a[redacted]

The injection units identified in **Table 46** were selected from the type log referenced throughout the evaluation and design of the Well. The actual discrete intervals completed and final staging will be selected based on well specific data obtained during operations.

4.5 Above Zone Monitoring Well

[redacted] The proposed design for Dusek AZM #2 is depicted in **Figure 121**.

[redacted]

4.6 General Outline of Well Design and Completion Schematic

Dusek AZM #2 was designed with the following specifications:

[redacted]

4.7 Above Zone Monitoring Well Operational Strategy

The Dusek AZM #2 well is engineered to be an above zone monitoring well. [redacted]

[redacted] If pressure or temperature anomalies are detected via the pressure gauge, water sampling or wireline logging, injection will be halted, and the incident will be evaluated as detailed in the Emergency and Remedial Response Plan (**Section 8**). After injection has ended in Well and the site has been closed, the monitoring well will be sealed as per the Monitoring Well Plugging Plan (**Section 7**). This Dusek AZM #2 will help ensure the safe storage of CO_2 for an extended period of time.

4.8 USDW Monitor Well

Milestone intends to drill and complete one (1) USDW monitoring well, Dusek USDW #2, to monitor the lowermost USDW intervals. Dusek USDW #2 will be positioned within 500 feet laterally of the Dusek CCS #2 injection well and will monitor for signs of CO_2 escaping from the confinement zone and traveling up into the USDW. [redacted]. The proposed design for Dusek USDW #2 is depicted in **Figure 122**.

4.8.1 USDW Monitoring Well Operational Strategy

The Dusek USDW #2 monitoring well is engineered to be an above zone USDW monitoring well. It will be used to sample water periodically as outlined in **Section 5**. Dusek USDW #2 will be sealed as per the Above Zone Monitoring Well Plugging Plan (**Section 7**).

[redacted]

4.9 Testing and Logging during Drilling and Completion Operations

4.9.1 Ancillary Testing During Drilling Operations, prior to hitting TD

The following tests (**Table 47**) and logs will be conducted during drilling, casing installation and after casing installation in accordance with the testing required under 40 CFR 146.87(a) and (c).

[redacted]

[redacted]

[redacted] This measurement data will also be indispensable for determining core point.

[redacted]

4.9.2 Logging Program

[redacted]

There are a number of logging requirements necessary to meet EPA standards and responsible operation which include standard logs, also known as a Triple Combo, and advanced logs.

- **STANDARD LOGS** include the gamma ray or spectral gamma ray, resistivity, neutron, density, caliper, and spontaneous potential. These data are used for primary reservoir and fluid characterization including lithology, porosity, salinity, fracture identification, indications of permeability, and fluid saturations. Standard logs can answer most of the primary reservoir questions related to storage volume.
- **ADVANCED LOGS** include Monopole and Dipole sonic tools, resistivity imaging, nuclear magnetic resonance (NMR), neutron spectroscopy, formation pressure testing and fluid sampling. These are used to complement the standard logs and give additional formation information such as pore body sizes, detailed chemical and elemental information, and finally geomechanical information. These advanced tools are necessary to meet the requirements of documents 40 CFR 146.87 and 40 CFR 146.86.

The sonic tool is a redundant porosity tool, but is also key in understanding geomechanics, stress direction, and existence of fractures in the reservoir and confining layers. The geomechanical interpretation is bolstered by the image logs which can be interpreted for fracture identification, stratigraphy, stress direction, and dip. The image log can also be used to calculate maximum principal stress magnitude in conjunction with sonic data.

The image log will be critical to identify fracture frequency and fracture aperture and evolve the reservoir model accordingly.

The NMR tool can be used to approximate pore body geometry in conjunction with MICP or BET data. It is very useful for estimating permeability as well since it measures hydrogen precession and pore relaxation effects.

The Neutron spectroscopy tool gives detailed highly accurate measurements of a number of elements such as Si, Ca, Mg, Al etc. and can be used with a mixing model and in conjunction with XRD and XRF data to create a detailed vertically continuous mineral model.

[redacted]

[redacted]

[redacted]

The production hole logging program includes the following logs and their main objectives, as shown in **Table 49**. This is the most comprehensive logging program in the project. [redacted]

4.9.3 Formation Fluid Testing

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

All samples will use rigorous fluid testing programs that include cations, anions, salinity, specific conductance, hydrogen isotopes, oxygen isotopes, and carbon isotopes as well as additional parameters.

4.9.4 Minifrac Testing

[redacted]

4.9.5 Initial Mechanical Integrity Demonstration

In **Table 50** is a summary of the Mechanical Integrity Tests (MIT) and pressure fall-off tests to be performed prior to injection.

Milestone will notify EPA least 30 days prior to conducting the test(s) and provide a detailed description of each 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. All tests will utilize the latest EPA guidelines.

See **Section 5.6** and **Appendix C: QASP** for pressure fall-off testing procedures and guidelines.

[redacted]

Per 40 CFR 146.87 and 40 CFR 146.89, the planned cased-hole logs that will be run include several tools meant to establish baselines for future mechanical integrity monitoring. [redacted] Future logging of this unit, with the same technology, will allow for monitoring of the plume and the mechanical integrity of the wellbore. The logging program is shown in detail in **Figure 123,** and **Tables 48** and **49**.

4.10 Coring Acquisition Program [146.87 (b)]

[redacted] The whole core plan is shown in **Table 51**. Depths may be altered as additional information becomes available from 3D seismic data, up-hole surface logging as well as MWD measurements during drilling. [redacted]. Depths of coring intervals is illustrated in **Figure 123**.

[redacted]

4.10.1 Special Note on Lower Confining Layer

[redacted]

This project is **not** applying for a depth waiver under [40 CFR 146.95] and [40 CFR 146.95a]. Therefore, the requirements under [40 CFR 146.95 and 146.95a] do not apply. [redacted]. See **Section 1.4** for additional information on the base of USDW in the region.

4.10.2 Core Analysis Program

As part of the appraisal well program within the South Midland CCS Hub, core and reservoir fluid analysis programs are planned. The core and fluid analysis programs are meant to help minimize the risk and reduce the uncertainties within the subsurface data and provide a complete dataset for second generation static and dynamic models. The current subsurface model lacks data density in nearby area.

[redacted] The data gathering campaign is designed to:

[redacted]

c) Provide data to calibrate well logs
d) Confirm reasonable similarity with the 1st generation static and dynamic models.
e) Provide Rock Mechanical information
f) Provide information about threshold entry pressures and other SCAL properties
g) Further constrain mineralogy and fracturing

The analytical program will consist of two major phases as follows:

- [redacted]

4.10.3 [redacted]

The main objective of this phase is to evaluate the integrity of the core and characterize both the seal and the main injection Interval along with reservoir fluids. This should yield a breakdown of the different facies that supports sample selection for special core analysis tests. The steps related to this phase are as follows and graphically depicted in **Figure 124**.

- [redacted]

[redacted]

[redacted]

4.10.4 [redacted]

[redacted]

[redacted]

- [redacted]

[redacted]

- [redacted]

[redacted]

[redacted]

4.11 Professional Engineer Certification Letter

LONQUIST SEQUESTRATION LLC

[redacted]

- Section 4.0 ENGINEERING DESIGN AND OPERATING STRATEGY [146.86, 146.87]
- Section 6.0 INJECTION WELL PLUGGING PLAN [40 CFR 146.92]
- Section 7.9 SITE CLOSURE PLAN [146.93 (d) – (h)]

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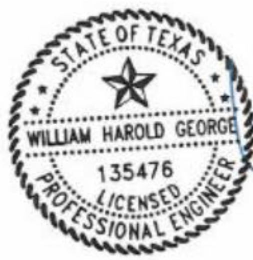

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