



DESIGN VERIFICATION REPORT

DVR: 1919587
Rev.: 0

Particulars of Design

Customer:	Navigator CO2 Ventures LLC (NCO2V)
Location:	Illinois, Iowa, Minnesota, Nebraska, and South Dakota
Asset:	Heartland Greenway System (HGS) CO2 Pipeline Phase 1

Navigator CO2 Ventures LLC (NCO2V) has requested DNV GL USA Inc. (DNV) to perform a design verification for NCO2V's proposed Heartland Greenway System (HGS), a 1350-mile CO2 pipeline system spanning five states (Illinois, Iowa, Minnesota, Nebraska, and South Dakota). DNV's overall involvement in the verification of NCO2V's HGS pipeline is detailed in the enclosed document (Doc. No. 1907045).

DNV has developed an industry recommended practice document, DNV-RP-F104 (for CO2 pipelines) and unique elements associated with the transportation of CO2 are addressed within this document. For technical assurance of assets, DNV offers a suite of services, including certification and verification of pipeline systems. The Scope of Work was defined between NCO2V and DNV and includes verification in different stages via a Design Verification Report (DVR). The purpose of the Design Verification Report (DVR) is to provide documentation that objective evidence has been presented, to confirm compliance with the requirements, and to document the work performed by DNV.

This is to verify that the design philosophy of

Navigator's Heartland Greenway System CO2 pipeline

has been reviewed against the requirements of

Design and Operation of Carbon Dioxide Pipelines (DNV-RP-F104), Section 4 (Concept Development and Design Premises)

DNV-RP-F104 provides a framework for the design, construction and operation of offshore and onshore CO2 pipelines, with a focus on structural assessment and with the aim of obtaining an appropriate and consistent level of safety. Section 4 of the DNV-RP-F104 provides a basis for definition of relevant field development characteristics for CO2 pipelines. Further, key issues required for design, construction, operation, and abandonment of CO2 pipeline systems are identified.

The design of the NCO2V Heartland Greenway CO2 pipeline system at the time of this assessment is in the P2 phase, which is the second of four progressive design cycles as defined by NCO2V, namely P1 (30%), P2 (60%), P3 (90%/IFB) and IFC (100%).

DNV finds that NCO2V's proposed design concept and premise would result in the HGS pipeline system complying with the requirements of Section 4 (Concept Development and Design Premises) of DNV-RP-F104, subject to adherence to the applicable codes, standards, specifications, and project specific plans/documents planned to be developed or finalized as noted in Section E of the DVR. Defining the acceptable risk profile is the responsibility of the pipeline operator and DNV did not participate in evaluating the risk profile for the HGS pipeline.



The verification is based on the following

A. DNV Scope of Work and Key Activities

The scope of work covered in this DVR is limited to verification of DNV-RP-F104 Section 4 requirements for NCO2V's HGS pipeline. DNV's overall involvement in the verification of NCO2V's HGS pipeline is detailed in the enclosed document (Doc. No. 1907045).

B. Design codes/standards used as references:

1. Design and operation of carbon dioxide pipelines, DNV-RP-F104, 2021

C. Design Specification

Design Codes and Standards	49 CFR 195, ASME B31.4
Pipe Material	API 5L PSL-2
Pipe Grade	X60 M/X65 M
Maximum Operating Pressure (psig)	2,200
Design Temperature (°F)	120
Nominal Pipe Sizes (inch)	6, 8, 12, 16, 20
Proposed D/t for Nominal Pipe Sizes	6-inch: 26.50 8-inch: 31.14 12-inch: 37.06 16-inch: 37.30 20-inch: 37.38
Pipeline System Length (mile)	1350

D. Documents Reviewed

Doc. Type	Doc. Title	Doc. No.	Doc. Rev.	Date
Engineering Specifications	Facility Design - General	NCO2V-ENG-100	A	08/01/2022
	Piping Class Sheet	NCO2V-ENG-101	D	01/20/2023
	Orifice Meters	NCO2V-ENG-103	A	06/07/2022
	Pipeline Systems Design	NCO2V-ENG-200	A	05/19/2022
	Shop Fabricated Pipe Bends	NCO2V-ENG-201	A	08/01/2022
	Pipeline Survey	NCO2V-ENG-202	A	12/15/2021
	I&E General	NCO2V-ENG-300	A	08/01/2022
	Medium Voltage Motors	NCO2V-ENG-301	A	05/02/2022
	PCR Building	NCO2V-ENG-302	A	05/02/2022
	MCC Building	NCO2V-ENG-303	A	05/02/2022
	Medium Voltage Switchgear & Motor Control Center	NCO2V-ENG-304	A	05/02/2022
	Medium Voltage Variable Frequency Drive	NCO2V-ENG-305	A	05/02/2022
	Distribution Transformers	NCO2V-ENG-306	A	05/02/2022
	Valve Specification and Application Guidelines for Dense Phase CO2 Service	NCO2V-ENG-401	A	08/29/2022
	API 610 Centrifugal Pumps	NCO2V-ENG-800	A	08/15/2022
	Packaged Reciprocating Compressors	NCO2V-ENG-801	A	06/07/2022
	Packaged Centrifugal Blowers	NCO2V-ENG-802	A	08/11/2022
	Glycol Dehydration Packages	NCO2V-ENG-803	A	08/11/2022
Geotechnical Engineering Investigation (For Station)	Geotechnical Engineering Investigation (For Station)	NCO2V-ENG-910	A	06/07/2022
	Geotechnical Engineering Investigation (For HDD)	NCO2V-ENG-920	A	05/02/2022
Construction Standards	Pipeline Construction	NCO2V-CONST-1001	A	08/26/2022
	Facility Construction	NCO2V-CONST-1002	A	08/24/2022

Doc. Type	Doc. Title	Doc. No.	Doc. Rev.	Date
	Commissioning of Steel Line Pipe	NCO2V-CONST-1003	A	08/19/2022
	Pressure Testing	NCO2V-CONST-1004	A	08/22/2022
	Pipeline Bending	NCO2V-CONST-2001	A	08/11/2022
	Piping Construction	NCO2V-CONST-2002	A	08/25/2022
	Excavating for Pipelines	NCO2V-CONST-2005	A	08/26/2022
	Mechanical Construction	NCO2V-CONST-2009	A	08/24/2022
	Concrete Construction	NCO2V-CONST-2016	A	08/26/2022
	Drainage Tile	NCO2V-CONST-2017	A	08/29/2022
Supporting Documents	Electrical Construction	NCO2V-CONST-3001	A	08/26/2022
	Environmental Construction Guidance	-	0	09/2022
	HGS DESIGN BASIS – P2	HGS Design Basis – P2	B	08/24/2022
	Heartland Greenway System Routing Philosophy	HGS Routing Philosophy	B	09/09/2022
	Heartland Greenway System Safety Systems and Considerations (DRAFT)	-	0	10/17/2022
Documents Taken for Information	Vent Discussion – Process Schematic	-	A	07/22/2022
	HGS Design Report (without Appendices)	1147-1009	2	01/12/2023
	HGS – CO2 Composition Quality	-	C	02/01/2023
	HCA Impact Summary	-	0	10/17/2022
	HGS Execution Resources	-	-	11/2022
	SP1 - Bentley - 4 (Topography Heat Map)	-	N/A	N/A

E. Comments

- Scope and Limits of Verification:
 - DNV verification is limited to the pipeline components and the booster pumping stations.
 - Scope of the current DVR is verification of Design Concept and Premise for HGS CO2 transport pipeline against requirements in Section 4 of DNV RP F104.
- The design activities related to thermohydraulic analysis, structural analysis, water monitoring, and venting/blowdown procedures are ongoing. Completion of these activities is required to satisfy the requirements of Section 4 DNV-RP-F104. Details related to these activities are listed below:

Thermohydraulic Analysis

- Developing the line packing strategy and commissioning plan to smooth out transient/dynamic flow conditions.
- Finalizing the thermohydraulic analysis to determine the water drop out potential for the following operational modes:
 - Normal operation pressure and temperature envelope.
 - Pipeline shut-in pressure combined with minimum ambient temperature.
 - Pipeline depressurization scenario.
- Determining the safety factor between the specified maximum allowable water content and the calculated minimum water content that may cause water drop within the operational envelope. A minimum safety factor of 2 is recommended by DNV-RP-F104.
- Determining the safety factor for pressure during shut-in to minimize the risk of water drop out. NCO2V has committed to a minimum safety factor of 2.

- Finalizing the dynamic flow and surge analysis for full parameter safety envelope.

Structural Analysis

- Performing the detailed structural analysis for installation, operating, and accidental load conditions.

Monitoring

- Defining the safety integrity level (SIL) for the water monitoring system to ensure sufficient level of reliability

Venting

- Finalizing the venting and blowdown procedures and the associated monitoring instrumentation to prevent solid CO₂ formation during venting, operate within set parameter safety envelope, and minimize occupational health and third-party risks

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for DNV

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