

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 5 (Materials and Pipeline Design)**

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 5 of DNV-RP-F104 provides guidance on material selection, guidance on corrosion mechanisms and general requirements for CO2 pipelines.

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 material selection and design approach would result in the HGS pipeline system complying with the guidelines of Section 5 (Materials and Pipeline Design) 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. Note, the list of ongoing activities referenced in Section E is not a comprehensive list of activities required for pipeline design. 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 design approach for NCO2V's HGS pipeline per DNV-RP-F104 Section 5. 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:

- 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

DNV performed a high-level review of the following documents to verify the design approach against Section 5 of DNV-RP-F104. Detailed engineering documents were under development and were not available at the time of this review.

Doc. Type	Doc. Title	Doc. No.	Doc. Rev.	Date
Engineering Specifications	Piping Class Sheet	NCO2V-ENG-101	D	01/20/2023
	Orifice Meters	NCO2V-ENG-103	A	06/07/2022
	Shop Fabricated Pipe Bends	NCO2V-ENG-201	A	08/01/2022
	High Frequency Welded Line Pipe	NCO2V-ENG-203	B	08/01/2022
	Crack Arrestors	NCO2V-ENG-204	A	08/29/2022
	I&E General	NCO2V-ENG-300	A	08/01/2022
	Valve Specification and Application Guidelines for Dense Phase CO ₂ 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)	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
	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
	Flanged Pipe and Equipment Bolting	NCO2V-CONST-2003	A	08/26/2022
	Protective Coatings	NCO2V-CONST-2004	A	08/24/2022



Doc. Type	Doc. Title	Doc. No.	Doc. Rev.	Date
	Field Applied Coating	NCO2V-CONST-2006	A	08/26/2022
	Weld Identification	NCO2V-CONST-2007	A	08/22/2022
	Radiographic and Non-Destructive Testing	NCO2V-CONST-2008	A	08/24/2022
	Mechanical Construction	NCO2V-CONST-2009	A	08/24/2022
	Mechanical Joining by Welding	NCO2V-CONST-2010	A	08/26/2022
	Induction Bends and Welded Fittings- End Preparation for Butt Welding	NCO2V-CONST-2010F	A	08/26/2022
	Handling Pipe	NCO2V-CONST-2011	A	08/22/2022
	Field Applied Powder Coating FBE-Flocking	NCO2V-CONST-2018	A	08/26/2022
	Electrical Construction	NCO2V-CONST-3001	A	08/26/2022
	HGS Design Basis – P2	HGS Design Basis – P2	B	08/24/2022
Supporting Documents	Heartland Greenway System Safety Systems and Considerations (DRAFT)	-	0	10/17/2022
Documents Taken for Information	HGS – CO2 Composition Quality	-	C	02/01/2023

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 material selection and design approach for the HGS CO2 pipeline against the guidelines in Section 5 of DNV-RP-F104.
- The design activities related to material qualification for the specified product, evaluating the impact of impurities including H2S on selected materials, thermohydraulic analysis, structural analysis, water monitoring, and venting/blowdown procedures are ongoing. Completion of these activities is required to satisfy Section 5 of DNV-RP-F104. Details related to these activities are listed below:

Material Selection and Qualification

- Documenting the qualification of all materials for suitability to transport the specified products.
- Finalizing and documenting the metallic and non-metallic material selection and qualification to ensure that all materials meet the requirements of ISO 15156 for any potential H2S containing environment.

Thermohydraulic Analysis

- 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.
- Finalizing the thermohydraulic analysis to determine the range of expected temperatures experienced by the pipeline materials.



Structural Analysis

- Perform detailed structural analysis for the installation, operating, and accidental load conditions, and implement any required design enhancements (e.g., increased pipeline wall thickness).

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 include the effect of product composition on decompression speed, 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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