BOLD ALLIANCE

Supercritical Carbon Dioxide Pipelines

Technical Issues, Regulatory and Development Issues

Technical Overview

What is supercritical carbon dioxide (CO_2)?

- Supercritical CO_2 is colorless and odorless gas under so much pressure that it has characteristics of both a liquid and a gas
- It can move through porous solids like a gas, but like a liquid can dissolve some other liquids and solids, such as oil and plastics
- Small changes in pressure, temperature and/or contamination may result in dramatic changes in how it behaves
- It is almost as heavy as water

Why is CO_2 transported as a supercritical fluid?

- Much greater amounts of CO_2 can be shipped as a supercritical fluid than as a gas
- Since supercritical CO_2 can flow through porous rock and dissolve into oil and water, it can be pumped underground for sequestration or to dissolve oil in enhanced oil recovery (EOR) operations

Is transporting supercritical CO_2 the same as transporting oil and natural gas?

- No. Because of its hybrid gas/liquid nature, supercritical CO_2 behaves very differently, both during operations and ruptures
- The unusual properties of supercritical CO_2 create unique safety issues
- Almost all CO_2 pipeline safety research appears to be done overseas
- An October 2021 study for European oil and natural gas industry groups identified an number of unresolved safety concerns

Corrosion and Degradation Impacts

- It is well known that trace amounts of water in the CO_2 can cause rapid corrosion, but what is less well known is the corrosion risk where water is combined with other contaminants
- Degradation of seals, coatings, lubricants, and other non-metallic materials due to supercritical CO_2's ability to dissolve hydrocarbons
- Degradation of the pipe steel and other pipeline components by contaminants in the CO_2

Pressure Impacts

- Decompression damage resulting from rapid pressure drops
- Running ductile fractures as a result of a rupture
- The impact of unintended phase changes (formation of CO_2 gas bubbles) causing pressure spikes
- Small changes in the amounts and types of contaminants in a CO_2 stream may have dramatic impacts on operation and safety
- Changes in volume can also create operational challenges, for example from seasonal variations and market cycles

Cryogenic Impacts

- Changes to/from a solid (dry ice) at -109°F (sublimation)
- Rapid depressurization can result in dry ice formation
- Brittle fractures in pipeline components due to low temperatures caused by startups, shutdowns, transient operations, depressurizations, intentional releases, and ruptures
- Possible internal and external coating detachment in low temperature conditions

Risks to Human and Animals

- Asphyxiation and intoxication risk
- Exposure can cause headaches, loss of smell, dizziness, nausea, vomiting, loss of coordination, confusion, loss of consciousness, frostbite, heartbeat irregularities, coma, and death
- Need to determine danger zone for different sizes of pipelines and different types of contaminants, topographies, and weather conditions

Satartia, Mississippi Rupture – Feb 22, 2020

- Rupture of 24” diameter CO_2 pipeline that vented about 9.5 miles of pipe to release 9,532 barrels
- 49 hospitalized
- Over 250 evacuated

Symptoms of Different Exposure Levels[2]

- 10,000 ppm (1.0%) Typically no effects, possible drowsiness
- 15,000 ppm (1.5%) Mild respiratory stimulation for some people
- 30,000 ppm (3.0%) Moderate respiratory stimulation, increased heart rate and blood pressure
- 40,000 ppm (4.0%) Immediately Dangerous to Life or Health (IDLH)
- 50,000 ppm (5.0%) Strong respiratory stimulation, dizziness, confusion, headache, shortness of breath
- 80,000 ppm (8.0%) Dimmed sight, sweating, tremor, unconsciousness, and possible death

- [2] https://www.fsis.usda.gov/sites/default/files/media_file/2020-08/Carbon-Dioxide.pdf

Running Ductile Fractures

- Caused by rapid pressure spikes following a rupture as the fluid supercritical CO_2 changes to a gas
- This phase change happens inside the pipe, and the pressure of the expanding CO_2 created can “unzip” a pipe
- Can be prevented by using either stronger steel or attaching reinforcing sleeves (crack arrestors) at intervals
- Steel strength models used for oil and gas pipelines are not adequate

Figure 8: Test result: overview.

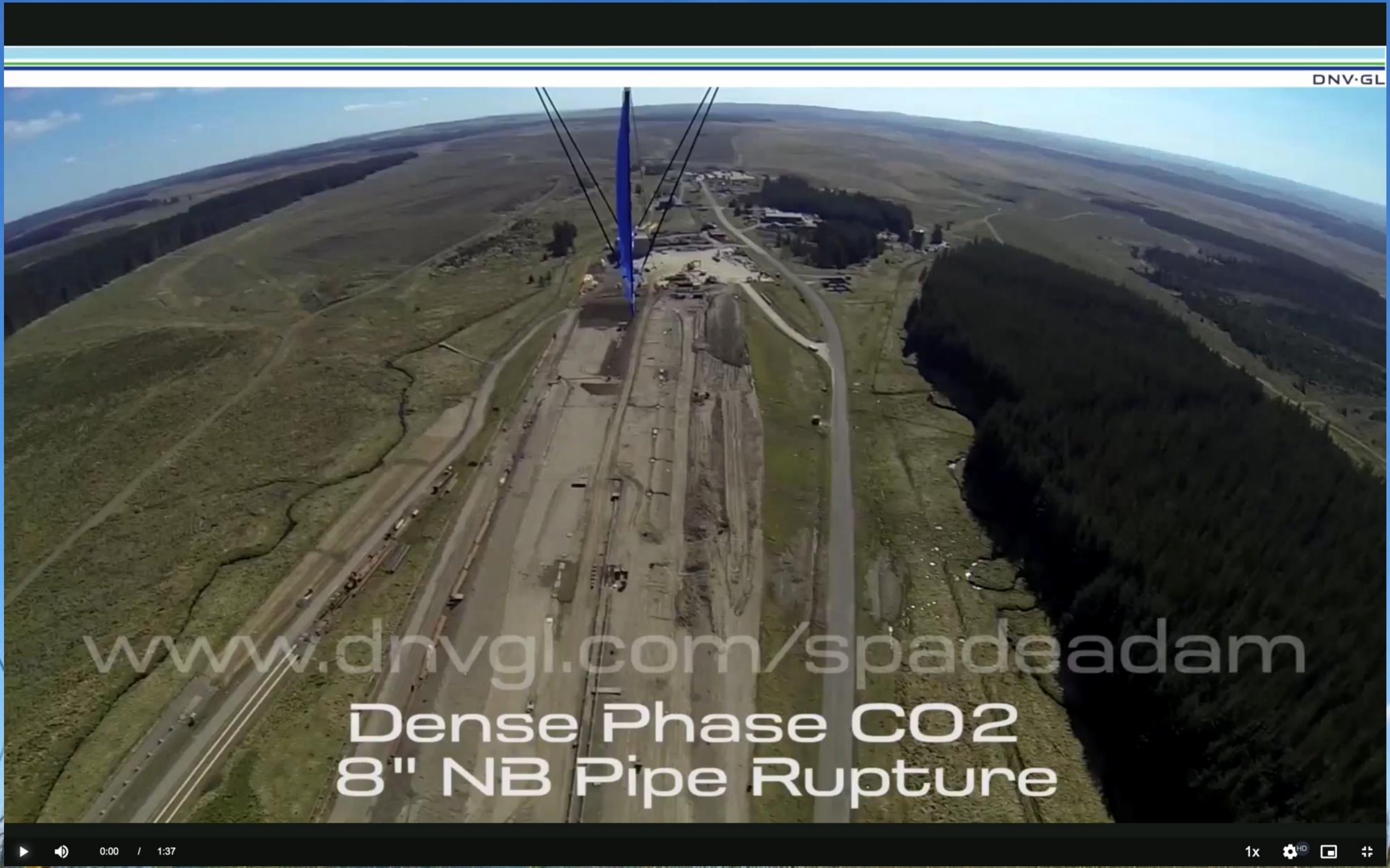
a) Arrest on composite CA

b) Natural arrest

Figure 14: Arrest on composite crack arrestor and natural arrest.

Dispersion Modeling

- Citizens and first responders need to know the danger zone for CO_2 ruptures from different size pipelines in various weather conditions, taking into account contaminants
- Danger zones can be predicted by a number of simple commercial computer models, such as PHAST, EFFECTS and FRED, and more complex computational fluid dynamic models (CFD) that take weather and topography into account
- Regulators and the CO_2 pipeline industry have not defined danger zones for CO_2 pipelines


DNV·GL
www.dnvgl.com/spadeadam
Dense Phase CO2
8" NB Pipe Rupture
0:00 / 1:37
1x

Technical Summary

- The US CO_2 industry appears to believe that its pipeline technology is well understood and safe
- Overseas researchers have identified a number of important unresolved engineering issues
- The scale of Summit and Navigators' proposed pipeline networks will likely create a variety of technical challenges
- US citizens have no knowledge about danger zones, and US safety standards may have fallen behind

Federal, State and Local Permitting Overview

Federal Permits and Regulation

- The federal government does NOT determine the route of hazardous liquid pipelines, just natural gas pipelines
- 49 U.S.C. §60104(e) of the Pipeline Safety Act states: "This chapter does not authorize the Secretary of Transportation to prescribe the location or routing of a pipeline facility."
- Federal law preempts state regulation of safety only as to pipeline design, construction, operation and maintenance
- The US Army Corps of Engineers regulates crossings of federal waters

No Nebraska State Permits or Regulations

- Nebraska may grant private pipeline CO_2 companies the right to eminent domain
- Nebraska may determine CO_2 pipeline route, consider safety information needed for routing and state emergency response, and mitigate construction damage and abandoned pipelines
- Nebraska regulates oil pipeline route (Ch. 15 Art. 14) and oil pipeline construction damage (Ch. 76 Art. 33), but these laws do not apply to CO_2 pipelines

Local Permits and Regulation

- In Nebraska, state law will preempt a local law in three instances:
- 1) when the state explicitly preempts local laws on the same subject; 2) when the state's intention to preempt local law is implied by a comprehensive scheme of legislation on a particular subject; also known as "field preemption" and

  3) where the local law is inconsistent with state law[1]
- Since Nebraska has no state laws related to routing of CO_2 pipelines, counties should have the power to enact ordinances for route permits, setbacks, mitigation, and emergency response

[1] *State ex rel. City of Alma v. Furnas County Farms*, 667 N.W.2d 512, 522-23 (Neb. 2003)

Permitting Summary

- Nebraska has no state routing or construction permitting laws applicable to CO_2 pipelines
- The federal government does not and cannot determine CO_2 pipeline route; regulates safety without any meaningful citizen participation; and Army Corps permitting will likely focus on specific crossings
- Since the state does not regulate CO_2 pipelines, Nebraska's counties may regulate issues such as route, setbacks and post-construction and post-abandonment mitigation

Commercial Overview

Why the Rush to Build?

- The federal 45Q tax credit is so generous that it's created a rush to build CO_2 sequestration facilities and pipelines – ready or not
- The tax credit is owned by the entity that owns the CO_2 capture equipment and ensures sequestration of the CO_2
- In 2026, the tax credit will be $50/metric ton for 12 years
- NE projects alone would generate a total tax credit of up to ~$30 million per year to Summit, and up to ~ $50 million per year to Navigator

BOLD

Few Operating Ethanol CO_2 Capture Plants

- ADM, Decatur, IL: Operates at about half capacity and ships to sequestration site via 1-mile pipeline
- Arkalon, Liberal, KS: Provides CO2 for EOR via a 90-mile pipeline
- Bonanza, Garden City, KS: Provides CO2 for EOR via a 15-mile pipeline
- Little is publicly known about the capital and operating costs for these facilities

Nebraska Ethanol Plant Contracts

Summit Contracts

- Husker Ag – Plainview
- Louis Dreyfus – Norfolk
- Green Plains – Atkinson
- Green Plains – Central City
- Green Plains – Wood River
- Green Plains – York

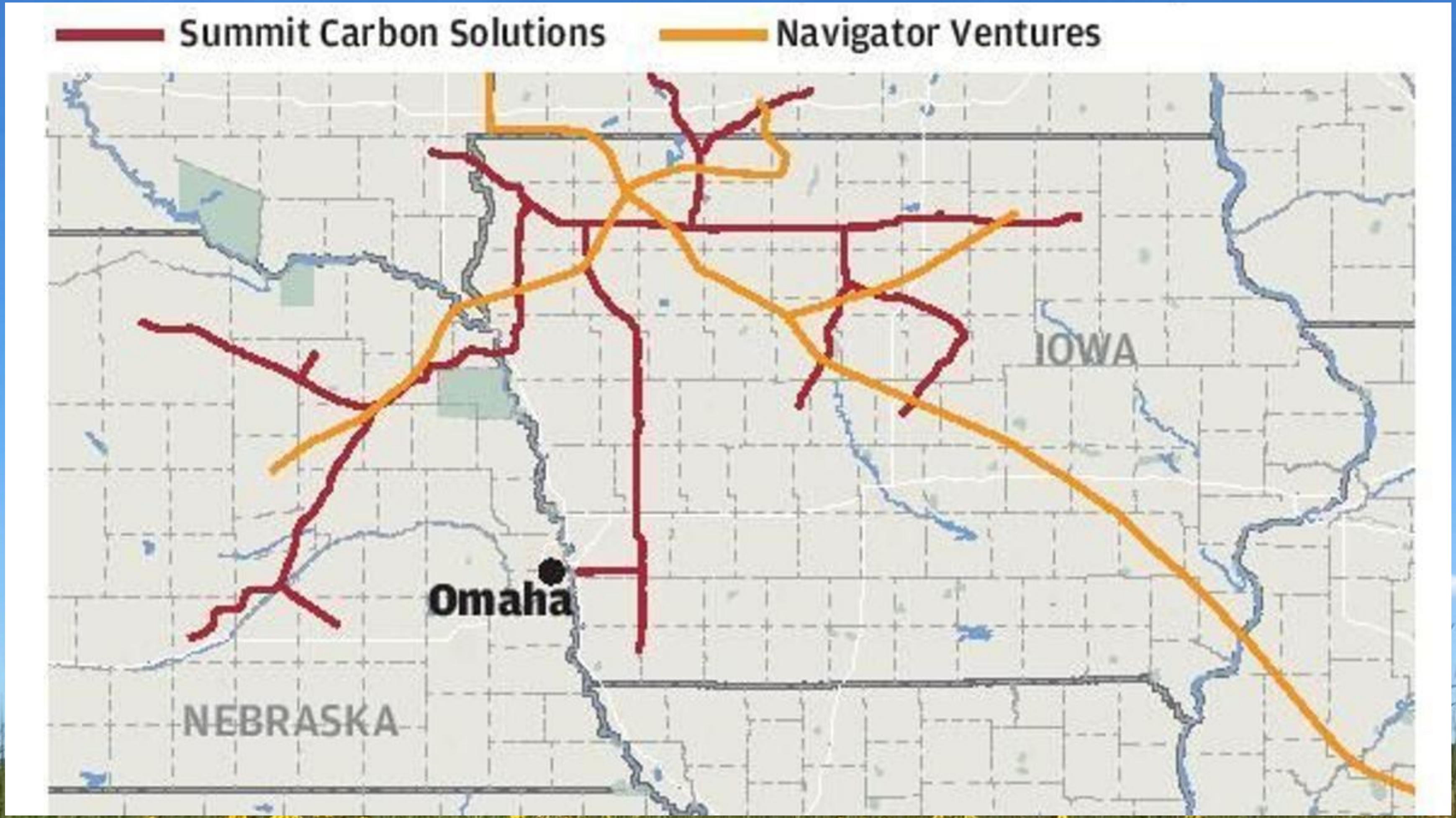
Navigator Contracts

Valero Renewables – Albion

Siouxland Ethanol – Jackson

ADM -- Columbus

A Leap into Massive



The Scale of the Proposed Carbon Capture Facilities and Pipelines Creates Uncertainty

- The industry has experience with CO_2 pipelines, but most are single pipelines from one CO_2 source to EOR facilities, with a very few to sequestration wells
- The Summit and Navigator projects are at a much larger scale and involve many sources and likely many sequestration wells
- This larger scale will likely cause a variety of technical challenges, create new safety risks, require new statutes and regulations, and result in very complex commercial relationships among CO_2 sources, pipelines, and sequestration sites

A Government Triggered Gold Rush

- Just because the Congress is willing to subsidize a massive expansion of carbon capture, transportation, and storage and has put a current deadline for bringing projects online of 2026, does not mean that there is no need for critical safety improvements, needed state and local permitting, and confirmation of commercial viability, or that taking private property for these private commercial ventures is fair

THANK YOU!


BOLD