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CO2 Transportation

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VP CO2 Supply and Pipelines
CO₂ Transportation - Overview

- CO₂ Pipelines - Present state
- CO₂ Pipelines – Future vision and what needs to occur
- Design
- Construction
- Operations
- Conclusion
CO₂ Properties

Typical Operating Conditions
Pressure: 1,070 - 3,500 psi
Temperature: 75 - 115 F
Density: 30-50 lbs/ft³
Pipeline History

• 1900’s to mid 1900’s
• Oil Pipelines
  ▪ Fragmented
  ▪ Large numbers small suppliers
  ▪ Limited end users
• Natural Gas Pipelines
  ▪ Large number small producers
  ▪ Extensive gathering lines
  ▪ Feed city gates
• A need for transportation to larger markets
Current U.S. CO₂ Sources & Pipelines

- Great Plains Coal Gasification Plant
- LeBarge Ridgeway CO₂ Discovery
- McElmo Dome Sheep Mountain
- Ridgeway CO₂ Discovery
- Bravo Dome Ammonia Plant
- CO₂ to Canada Antrim Gas Plant
- Jackson Dome Gas Plants
CO₂ Pipelines

• First Long-distance CO₂ pipeline 1970’s
• Currently 4,000 miles of CO₂ pipelines in the United States
• 2009 ICF International Study
  ▪ Require 15,000-66,000 miles by 2030
• Pipeline Projects
  ▪ Siting
  ▪ Design
  ▪ Construction
Siting a CO$_2$ Pipeline

- Not regulated by any Federal Agency
- Source of CO$_2$
  - Natural
  - Anthropogenic
- Destination
  - EOR
  - Saline Storage
- Population Density
- Existing Utility Corridors
- Power Availability
- Constructability
CO$_2$ Pipeline Design

- Pipeline Operating Conditions
- MAOP Determination and Design Pressure
- Wall and Diameter
- Fracture Mechanics
- Gas Quality
- Corrosion Control
Internal Design Pressure

- $P = \left( \frac{2St}{D} \right) \times E \times F$
  - $P =$ Internal design pressure in p.s.i.
  - $S =$ Yield strength of steel in pounds per square inch
  - $t =$ nominal wall thickness of the pipe in inches
  - $D =$ Nominal outside diameter of the pipe in inches
  - $E =$ Seam joint factor
  - $F =$ A design factor of 0.72 for onshore

- Assume: 20” O.D., .441” WT, X70, ERW seam.
- Is $P >$ Proposed MAOP of 2,200 psi
  - $P = \left[ 2 \times (70,000 \text{ psi}) \times (0.441”) / 20” \right] \times 1 \times 0.72$
  - $P = 2,222$ psi which is greater than the MAOP.
Fracture Mechanics

• Prevent propagation of a long ductile fracture
• ASME B31.4 requires consideration by the designer
• Physical phenomenon of a ductile fracture
• Steel chemistry for toughness and strength
Crack Arrestors

• General principle – Interrupt the failure mechanism at intervals
• No disruption to flow,
• Does not cause stress concentrations in the wall of the pipe, corrosion by cathodic shielding, interfere with inline inspection and maintenance, or otherwise shorten the life of the pipeline,
• Corrosion resistant, maintenance free, and environmentally safe,
• Facilitates “soft” arrest so that the pipe is not completely severed.
Inline Arrestors

- Short lengths of heavy wall pipe
- Lengths of higher toughness and/or thicker wall line pipe interspersed with low fracture resistant pipe
- Spiral roll pipe with lower toughness across the direction of roll
- Brittle/low ductility girth welds.
Add-on Crack Arrestors

- Loose steel sleeves with or without grout
- Tight steel sleeves with fillet-welded edges to keep water out
- Pre-strained steel sleeve with mastic
- Loose or tight rings of angle iron, channel section, etc., either welded or bolted together and installed with or without grout
- Tight reinforced plastic and fiberglass sleeves
Gas Quality - Impact on Design

- Gas Composition
- Phase behavior upon introduction of additional impurities
- Consider all potential CO$_2$ sources
- Operator gas quality specifications
- Design for worst case
- Gas impurities and the effect of phase boundary and decompression behavior
Influence of Impurities on Phase Envelope of CO₂ Fluid Mixtures

Typical Pipeline Operating Region

Pure CO₂ Phase Boundary

- 95%CO₂+3%N₂+1%H₂+0.5%CH₄+0.5%CO
- 95%CO₂+2%N₂+2%H₂+1%CH₄
- 95%CO₂+5%CH₄
- 95%CO₂+5%CO
- 95%CO₂+5%N₂
- 95%CO₂+3%N₂+2%H₂
- 98%CO₂+2%H₂
- 100%CO₂

Drilling and Production Operations
Corrosion Design

• Internal Corrosion Design
  ▪ Moisture content
  ▪ Dehydration
  ▪ Carbon Steel Pipe, Stainless Steel Pipe, or Liners
  ▪ Internal monitoring

• External Corrosion Design
  ▪ External Coating
  ▪ ARO
  ▪ AC mitigations
  ▪ External monitoring
Various Environmental Acts of Congress

Clean Air Act (1970)
Clean Water Act (1977)
Department of Transportation Act (1966)
Emergency Planning & Community Right-To-Know Act (1986)
Endangered Species Act (1973)
Federal Land Policy and Management Act (1976)
Migratory Bird Treaty Act (1918)
National Environmental Policy Act (1969)
National Historic Preservation Act (1966)
Occupational Safety and Health Act (1970)
Oil Pollution Act of 1990
Resource Conservation and Recovery Act (1976)
Rivers & Harbors Act (1899)
Safe Drinking Water Act (1974)
Superfund Amendments and Reauthorization Act (1986)
Toxic Substances Control Act (1976)
Permitting Process (Example Large Pipeline Cont.)

- Agency Interaction
  - BLM
    - Casper, Wyoming
    - Buffalo, Wyoming
    - Lander, Wyoming
    - Miles City, Montana
  - USFWS
  - COE
    - Cheyenne, Wyoming
    - Billings, Montana
  - MTDEQ
  - WYDEQ
  - SHPO
    - Montana
    - Wyoming
- Project Timeline
  - 2 years
Construction
Construction

• Financing
  ▪ Contributions in aid of construction
  ▪ Ship-or-pay provisions,
  ▪ Project financing,
  ▪ Balance sheet financing
• ROW Acquisition – Eminent Domain
• Qualification of Contractors
• Construction Standards
• Scope Document
• Inspection
Operations

- Safe Operations
- Regulating Body – PHSMA
- Integrity Management Plan
- Public Awareness Programs
- Pipeline Monitoring
Transportation of CO\textsubscript{2}-EOR Potential

**DOE/NELT Report:**

- "CO\textsubscript{2} enhanced oil recovery (CO\textsubscript{2}-EOR) offers the potential for storing significant volumes of carbon dioxide emissions while increasing domestic oil production"

- Approximately 84.8 billion barrels of oil in existing US oilfields could be recovered using state-of-the-art CO\textsubscript{2}-EOR (In a range of $50-$100/barrel, it is economically feasible to recover 39 to 48 billion barrels)

- Next generation technology offers potential for recovering more stranded oil and storing significantly more CO\textsubscript{2}

- Infrastructure for CO\textsubscript{2}-EOR can be used for large-scale carbon capture and sequestration (CCS) projects in underlying saline formations
The Future is Now

- Advancing Energy Production:
  - CO₂-EOR can recover billions of barrels of identified oil from existing oilfields, and offers immediate production without additional exploration and development lead times
  - The environmental impact of every barrel of recovered oil from CO₂-EOR could be offset by carbon capture and storage (CCS), versus no CO₂ reduction for imported oil

- Infrastructure for Future CCS Solutions:
  - CO₂ pipeline networks will enable large-scale CCS during enhanced oil recovery and in post-production utilization of underlying saline formations
  - CO₂ pipeline networks provide the basic infrastructure needed for development of carbon solutions for environmentally-sensitive industrial developments including existing power plants, industrial sites, innovative gasification projects that can produce transportation fuels, power, substitute natural gas, fertilizer and chemicals from plentiful natural resources
Reference Sources

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