CO_2 TRANSPORTATION AND EOR

The Genesis of the Carbon Highway

INGAA

Houston, Texas

September 21, 2007

Presented by

Ken Havens

Director of Source and Transportation

Kinder Morgan CO2 Company

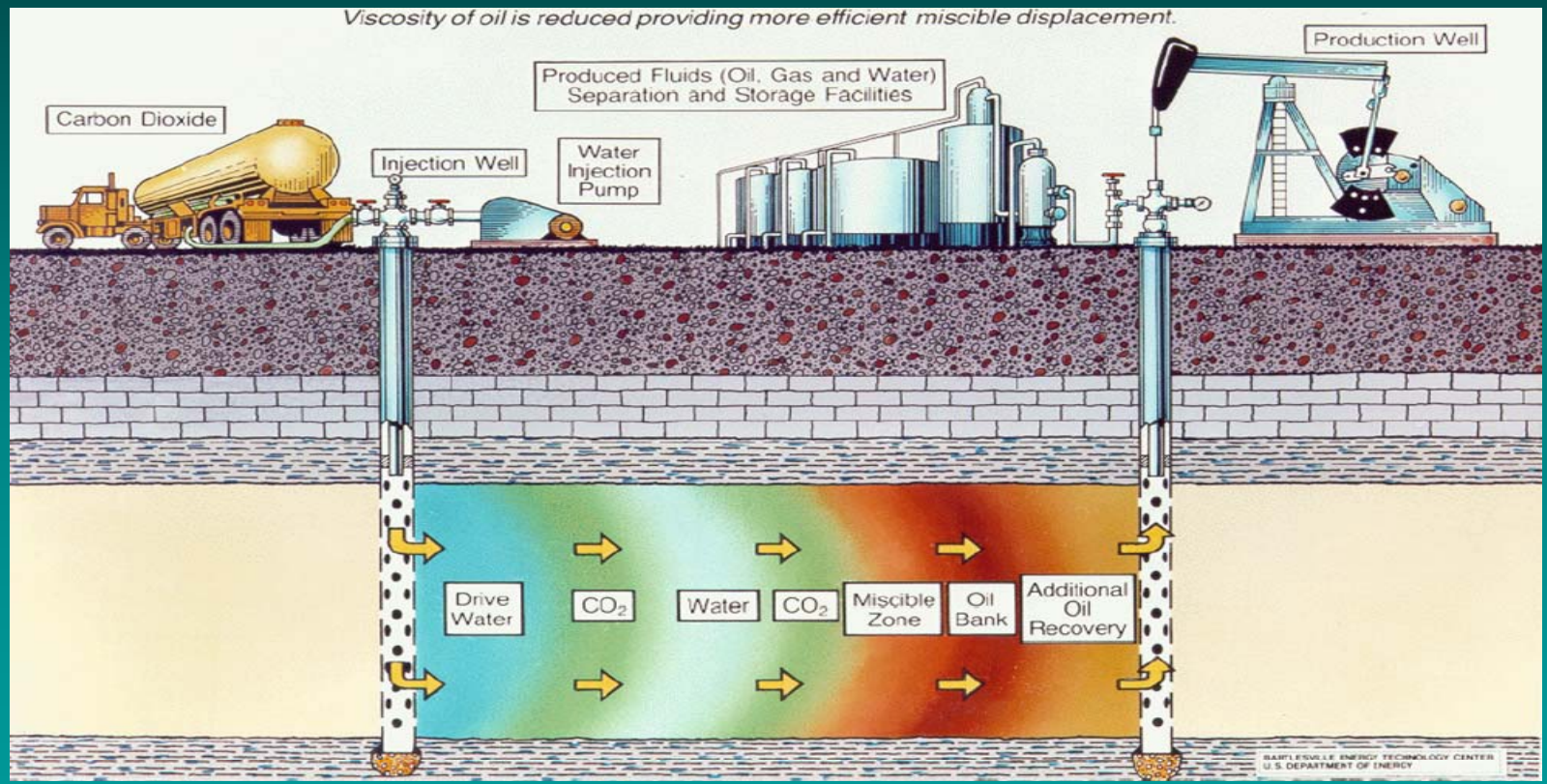
Agenda

- EOR
- Sequestration
- Pipelines

EOR

CO_2 EOR: Process Schematic

- CO_2 mixes with oil much like turpentine cleans paint from a brush
- Inter-phase mass transfer typically yields NGL rich gas production
- Chase water injection helps control mobility and gas recycle



KINDER MORGAN

EOR: Technical Overview

General Performance Characteristics

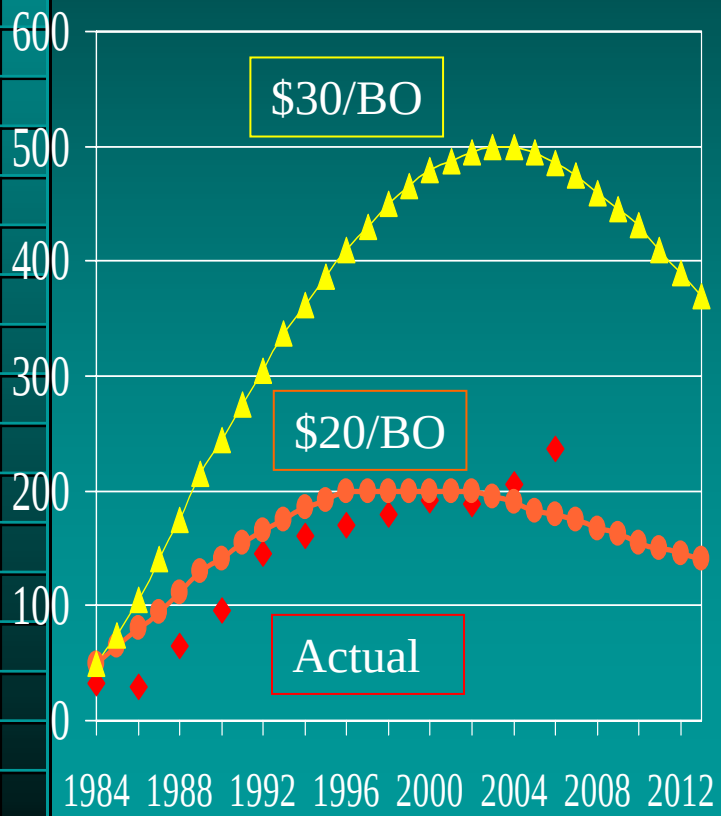
- Recovery efficiency - 10-15% OOIP
- Incremental oil prod. - 20-30% of cum. production (primary and secondary)
- Net utilization factor - 4-6 mcf/bbl oil
- Gross utilization factor - 8-15 mcf/bbl oil

Reservoir Criteria

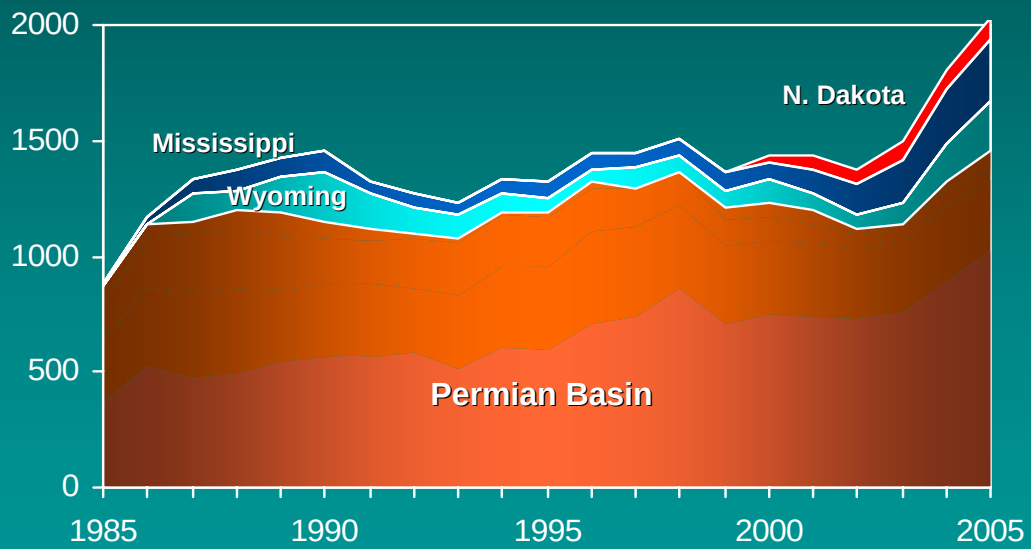
- Reservoir depth - 2000 ft or greater
- Oil gravity (API°) - 25 or greater
- High residual oil saturations
- Favorable waterflood characteristics
  - Homogeneous reservoir
  - No fractures or thief zones

U.S. CO_2 Enhanced Oil Recovery Actual vs Prediction

Actual CO2 Flood Oil Production vs. 1984 NPC Study MBbl/d



CO2 Deliveries by Region



KINDER MORGAN

Source: Oil and Gas Journal, 1984 NPC EOR Study

Domestic CO_2 EOR Operational Achievements

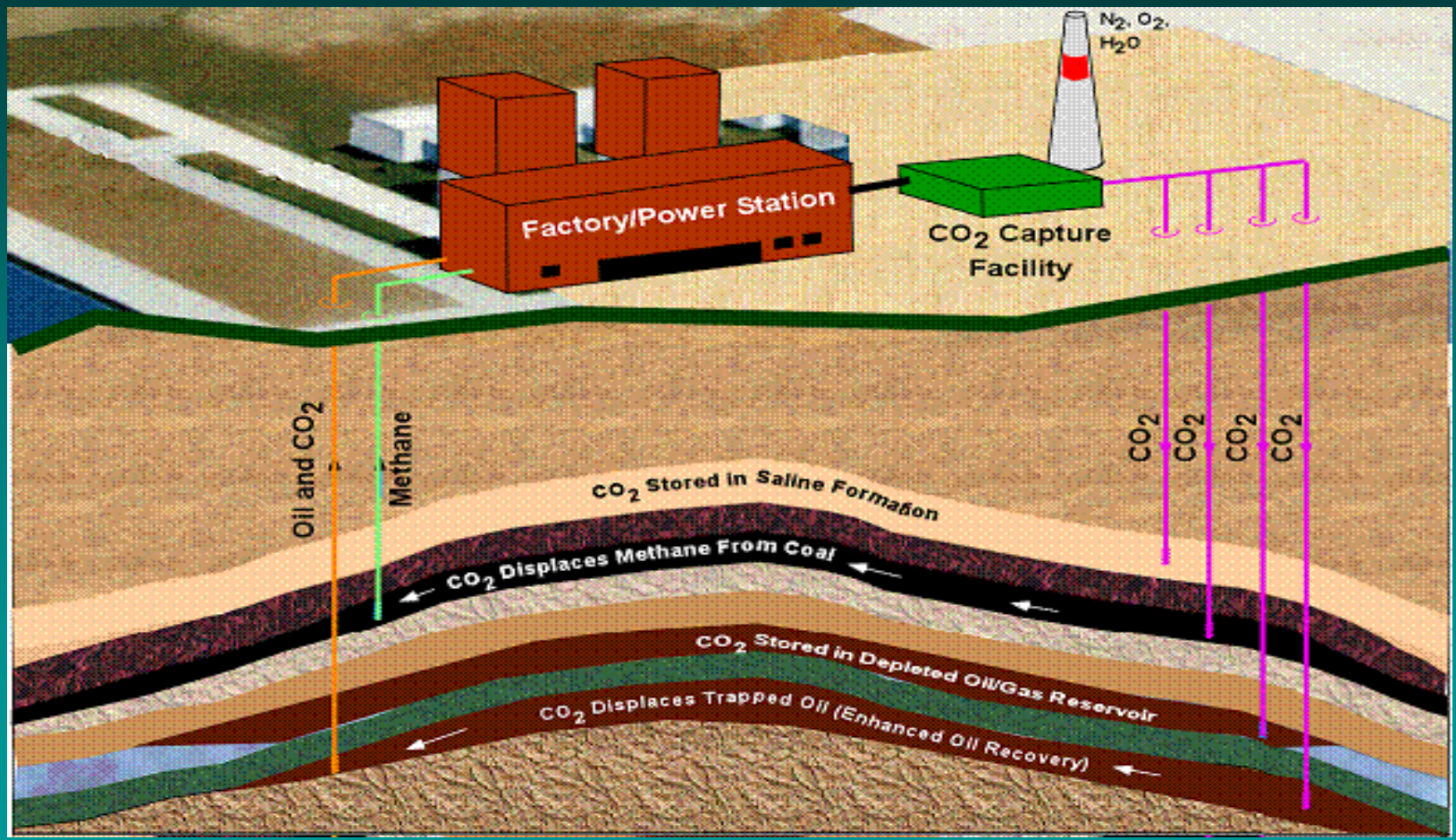
Over the past 30+ years, the oil and gas industry has:

- Produced and injected more than 10.8 TCF of CO2 from 7 sources.
  - 1.2 TCF of which came from sources that otherwise would have been vented.
- Constructed over 3500 miles of CO2 mainline pipeline systems.
- Produced in excess of 1.2 billion barrels of incremental oil.
- Secured operating practices of:
  - Corrosion management, Metallurgies, Elastomers
  - Separation, Dehydration and Hydrocarbon extraction
  - Compression/pumping
  - Injection and production well completion and operation

KINDER MORGAN

Sequestration

Sequestration: The Simple View



KINDER MORGAN

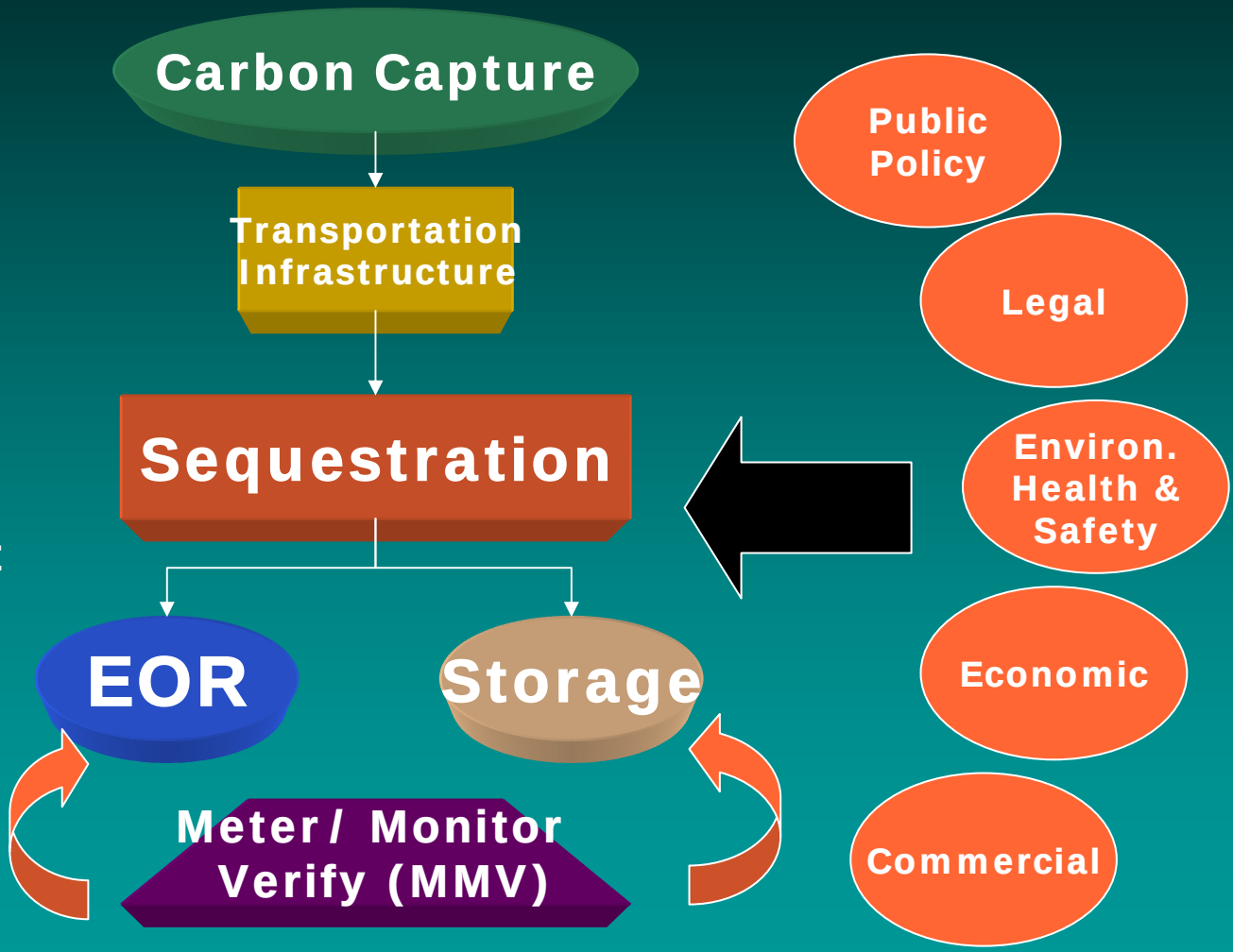
Geologic Sequestration Dynamics

Step 1:
Get it.

Step 2:
Move it.

Step 3:
Store / Use it

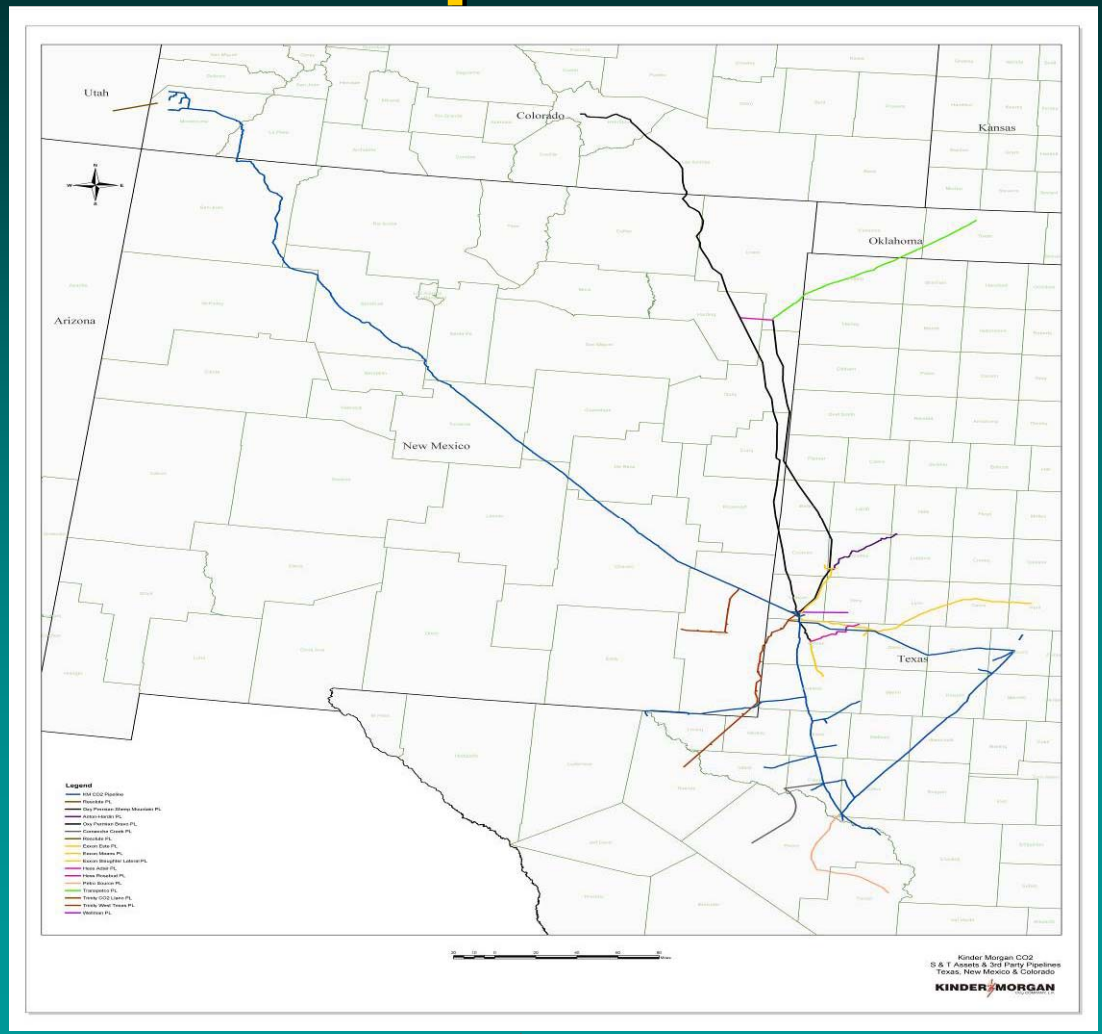
Step 4:
Control it



KINDER MORGAN

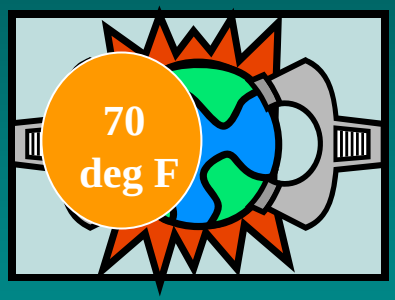
Pipelines

McElmo Dome and Cortez Pipeline



CO_2 Properties – Compressible Fluid

Increase the pressure of CO_2, Methane or Water in the Cortez PL from 1,800 psig to 1,900psig



Additions to inventory:
CO_2 – 19,842 klbs
Water – 882 klbs
Methane – 17,637 klbs

Isothermal Compressiblity:

CO_2 –	77 E-6/psi
Water –	630 E-6/psi
Methane –	3 E-6/psi

Increase the temperature of 1,800 psig CO_2, Methane or Water in the Cortez PL From 70 deg F to 80 deg F

Pressures increase to :
CO_2 – 2,300 psig
Water – 2,263 psig
Methane – 1,915 psig

Sometimes CO_2 acts more like a liquid and sometimes more like a gas

KINDER MORGAN

CO_2 Pipelines – Gas Pipelines

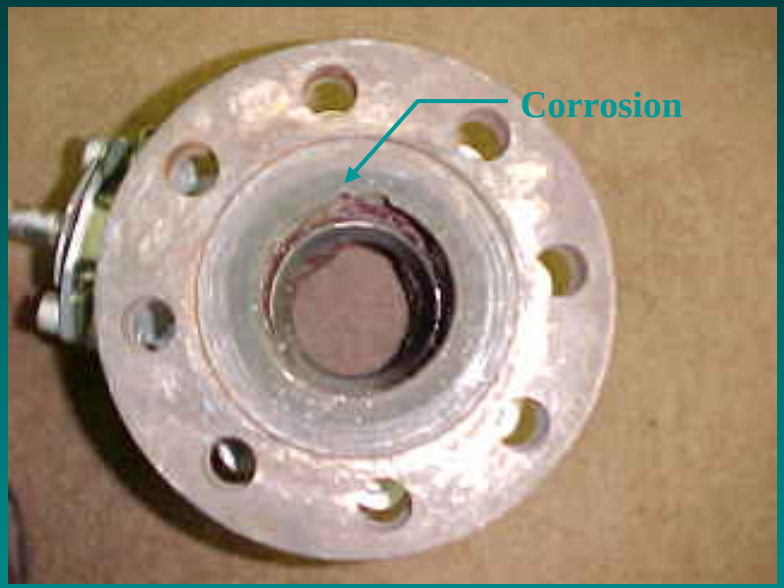
- Use same steel metallurgy as Natural Gas Pipelines
  - Keep CO_2 dry
  - Little or no H2S (<20 ppm)
- Higher operating pressures
  - Gas – 600 psig to 1200 psig
  - CO_2 – 2000 to 3000 psig
  - Why? Maintain CO_2 in dense phase (>1300 psig) to allow pumping rather than compression.
- Pumps rather than compression
  - Energy savings
- CO_2 - PHMSA regulated under CFR Part 195, “Transportation of Hazardous Liquids by Pipeline”
- Natural Gas – PHMSA regulated under CFR Part 192, “Transportation of Natural and Other Gas by Pipeline”

KINDER MORGAN

U.S. Quality Specifications

CO_2	95%	Min	MMP Concern
Nitrogen	4%	Max	MMP Concern
Hydrocarbons	5%	Max	MMP Concern
Water	30 lbs/MMSCF	Max	Corrosion
Oxygen	10 ppm	Max	Corrosion
H_2S	10 – 20 ppm	Max	Safety and PL Metallurgy
Glycol	0.3 gal/MMcf	Max	Operations – protect pump seals
Temperature	120 deg F	Max	Materials

Corrosion



This doesn't happen in pipeline transportation of CO_2. Shown: Valve from McElmo Dome CO_2 Source field salt water disposal system which experienced corrosion over 15 years of service.

- Corrosion has not been a problem in CO_2 transportation
- Corrosion can be a problem in oil field production; however, operators have learned to control it by using corrosion inhibitors

KINDER MORGAN

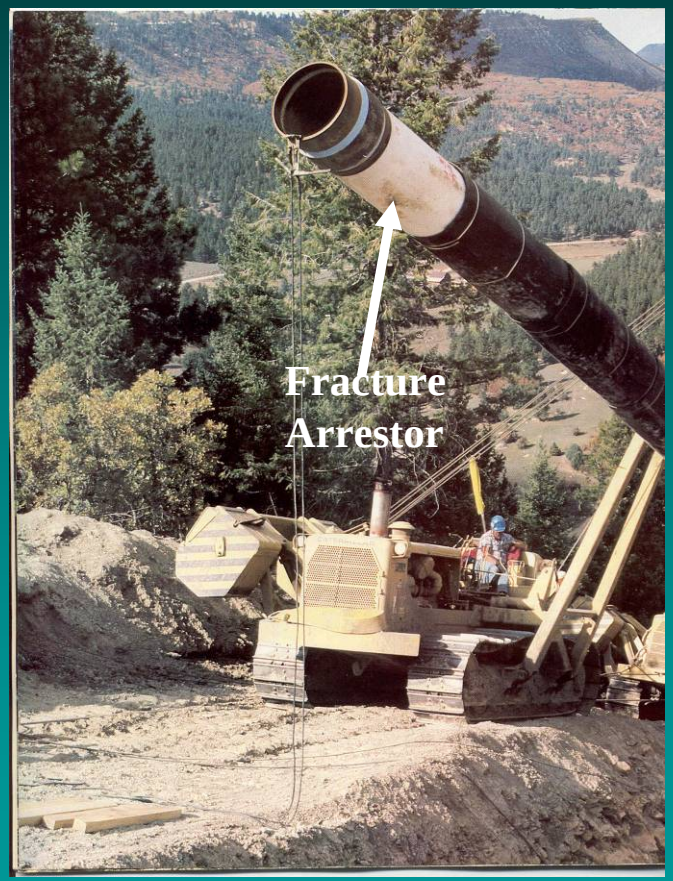
Case History: Centerline Pipeline

Centerline Pipeline

- In Service 4/15/03
- Total Cost $30.0 MM
- 113 miles of 16” pipeline
- MOP – 2,160 psig
- Capacity 300 MMSCFD

KINDER MORGAN

Safety Design: Fracture Propagation



Construction of the Cortez PL

- Propagating ductile fractures are possible
- CO_2 undergoes slow decompression therefore fractures are more likely to propagate
- Fracture arrestors are installed every 1,000 ft.

KINDER MORGAN

Case History CRC Pipeline Hydrotest

- Project Cost $2.35 MM
- Out of service 5/16/2003
- In Service 6/21/2003
- 36 days out of service

- Tested 131 miles of 16” pipeline
- Two hydrotest failures
- Raised MOP 1792 to 2025

KINDER MORGAN

CRC Pipeline Inside

KINDER MORGAN

Pumping vs. Compression

A happy KMCO_2 employee stands in front of a 4000 hp CO_2 pump at Cortez Station. This pump increases pressure from 1,800 psig to 2,100 psig at the inlet of the Cortez PL mainline.

- Centrifugal pumps are used to transport CO_2 at supercritical conditions.
- Advantages:
  - Lower cost
  - Better efficiency
  - Higher reliability
  - Better operating flexibility

Three Things to Remember

- Carbon capture and underground injection for EOR and/or Sequestration is a proven technology. But its not cheap and its not easy.
- EOR operations, when applied in suitable reservoirs, create a source of domestic energy that partially offsets the cost of capture, and is a net consumer of CO2.
- Carbon capture and underground **storage injection** operations will require cooperation and mutual understanding by policy makers, industry, the Public, and other stakeholders for this technology to be a part of the carbon management solution.

KINDER MORGAN