

# **Design of a CO<sub>2</sub> Injection System for Sequestration and Enhanced Oil and Gas Recovery Testing**

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# Project Objectives

- Design and build CO<sub>2</sub> injection system to support sequestration and enhanced oil and gas recovery testing at multiple sites in the Illinois Basin
  - Coal Bed Methane
  - Huff and Puff
  - Well Conversion
  - New Well / Pattern Flood
  - Deep Saline Reservoir
- Specify and obtain other required equipment
  - CO<sub>2</sub> Storage Tank
  - Line Heater
- Address safety concerns for liquid CO<sub>2</sub> service
- Predict pressures and phases in injection wellbore



# Design Objectives

- Equipment must be portable and suitable for oil field use
- System must have flexibility to deliver CO<sub>2</sub> over a wide range of conditions:
  - 15 Mscf/d (0.9 ton/day) CO<sub>2</sub> vapor for Huff and Puff test
  - 2.2 MMscf/d (129 ton/day) CO<sub>2</sub> liquid for Deep Saline Reservoir test
- CO<sub>2</sub> Storage
  - Maximum capacity required for test flexibility
  - Portable storage tank needed to minimize transportation and site support costs
- Line Heater
  - Must vaporize some or all of CO<sub>2</sub> for tests that require vapor injection
  - Must heat CO<sub>2</sub> up to near ambient temperature for realistic simulation of future CO<sub>2</sub> injection projects



# Equipment Overview

- Pump Skid
  - 3, single piston cylinder pumps in parallel, 7 gpm (69 lb/min) capacity each
  - Pressure regulated bypass valves for constant pressure injection
  - Return line with globe valve for constant flow rate injection over a wide range of flow rates
  - Liquid flow meter with flow transmitter and totalizer
- CO<sub>2</sub> Storage Tank
  - 60 ton capacity
  - Portable tank to reduce transportation and site support costs
- Line Heater
  - Propane fired, 250 MBtu/hr capacity
  - Suitable for water or glycol service
  - Skid and lift lugs added for increased portability

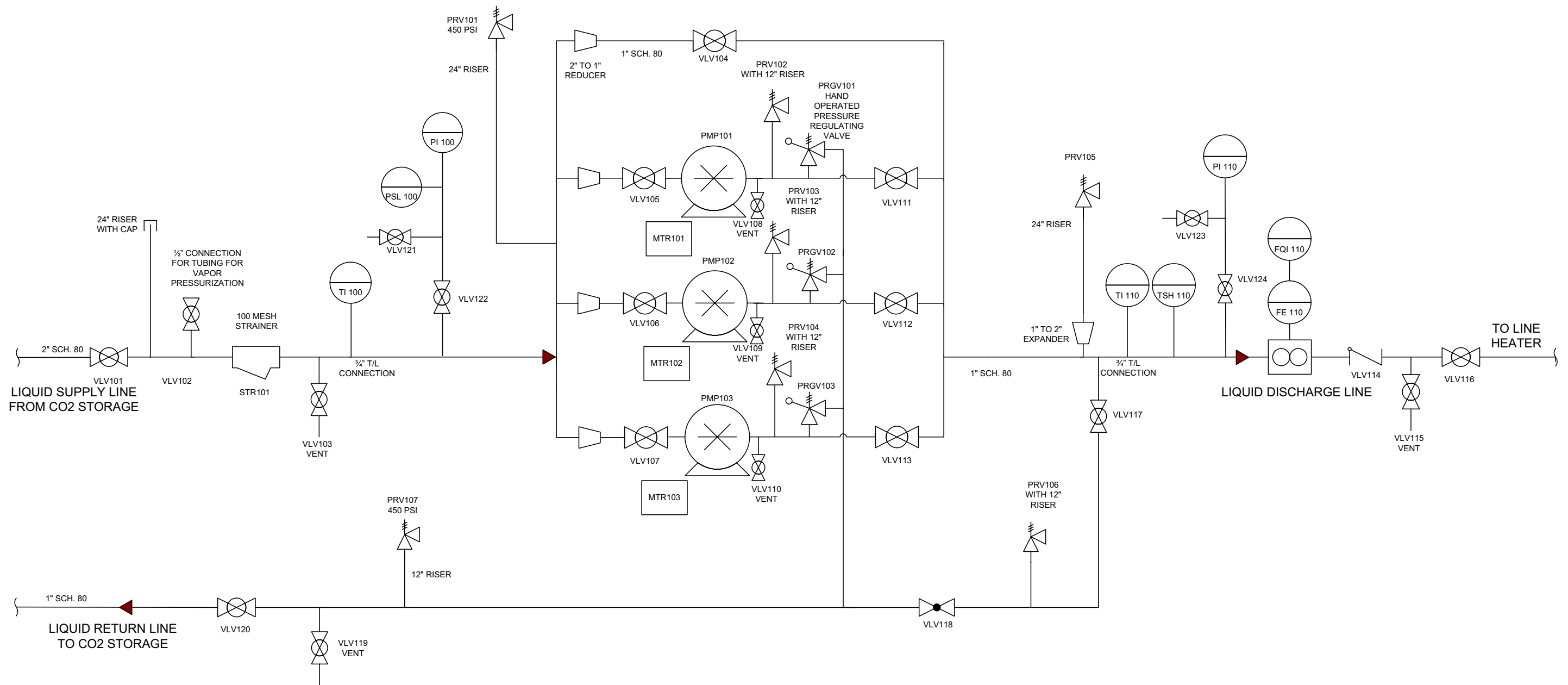


# Safety Design Considerations for Liquid CO<sub>2</sub> Service

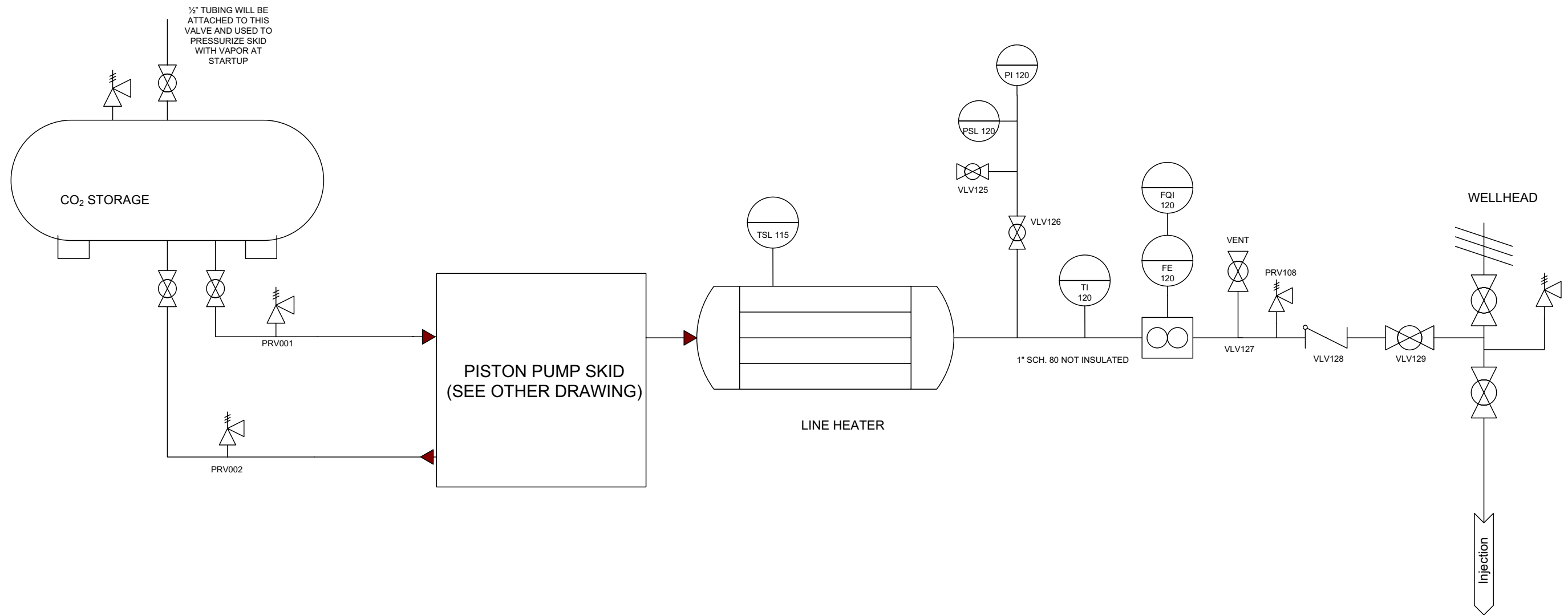
- Liquid CO<sub>2</sub> will be at 0 °F and range from 300 psia to 1,000 psia in the pump skid piping
- If liquid CO<sub>2</sub> becomes trapped in the lines, it will heat rapidly and pressure will rise
  - System is designed with automatic pressure relief valves located every place that liquid CO<sub>2</sub> has the potential to be blocked in
  - PRV discharges will be routed to divert flow of cold vapor CO<sub>2</sub> that would exit the PRV's in order to reduce the risk of personnel exposure
- Normal shutdown procedures will vent liquid CO<sub>2</sub> from bottom of pipes to prevent equipment exposure to temperatures lower than design conditions
- Ambient CO<sub>2</sub> monitors will be installed at four site locations and will alarm if elevated levels of ambient CO<sub>2</sub> are detected



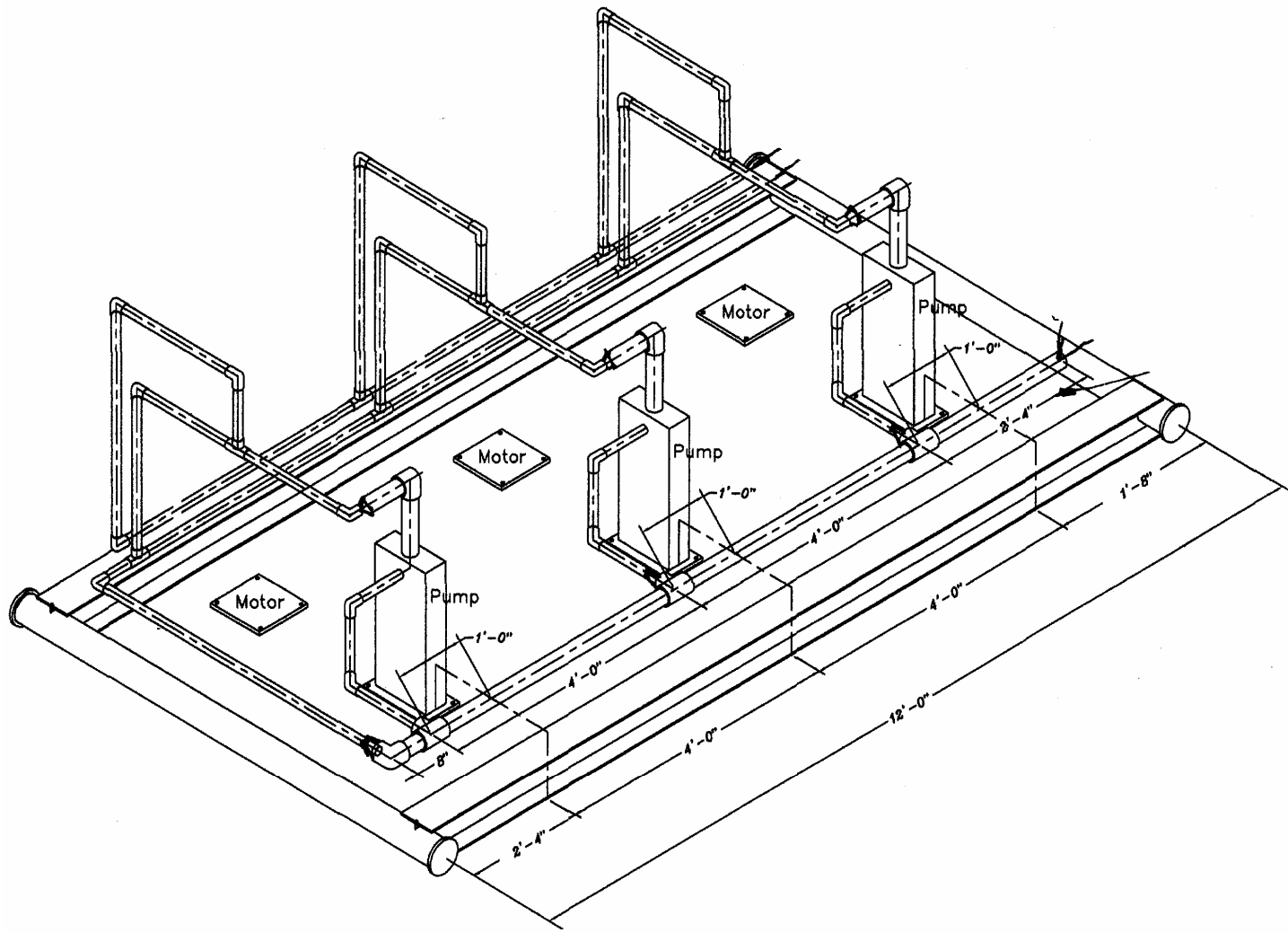
# Pump Skid Process Flow Diagram



# Overall Process Flow Diagram



# Simplified Isometric Pump Skid Drawing



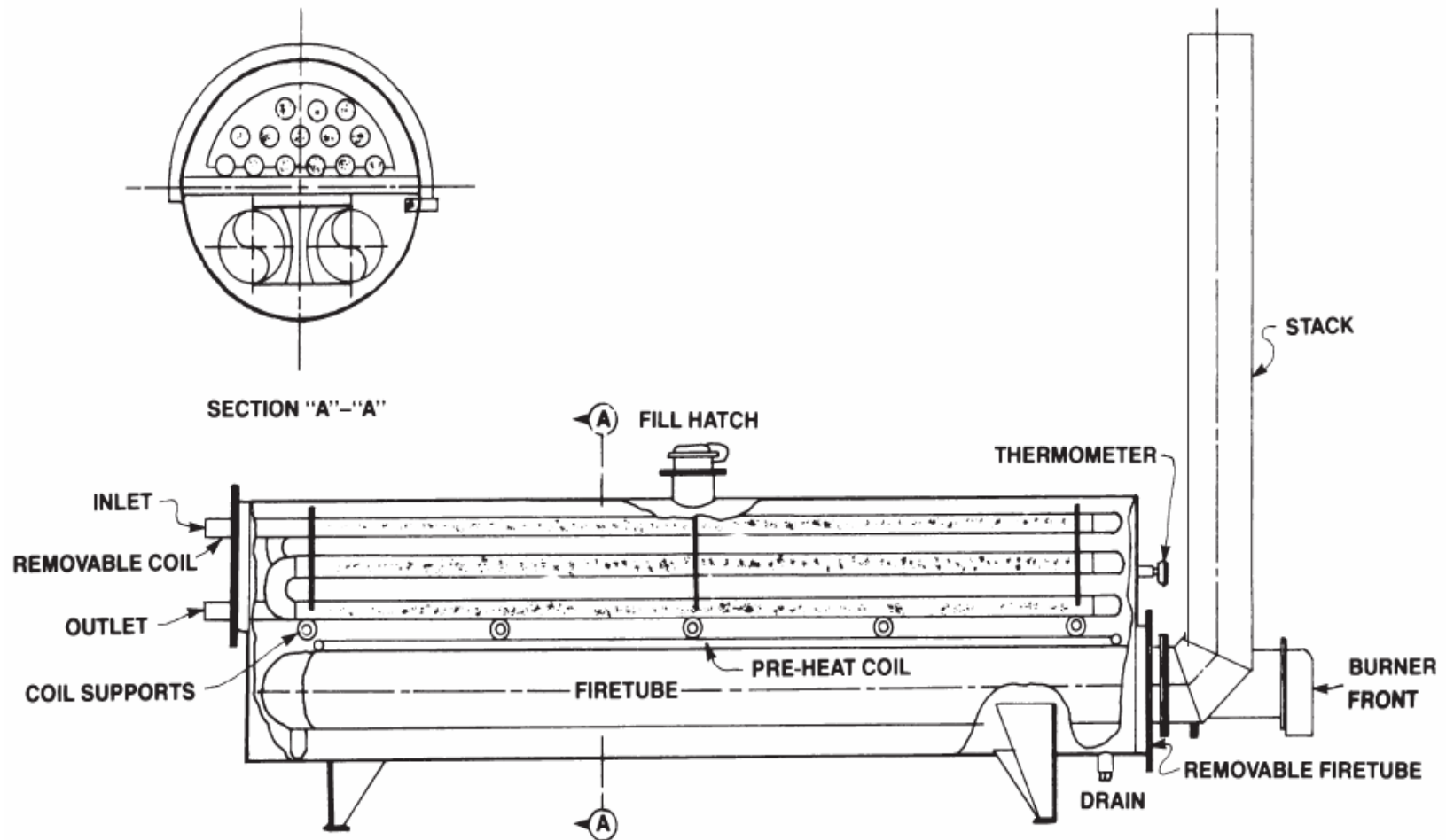
Skid dimensions: 6' wide x 12' long



# 60 Ton Portable CO<sub>2</sub> Storage Tank



# Line Heater Schematic



Source: GPSA Engineering Data Book, 12<sup>th</sup> Ed, Fig. 8-32

# 250 MBtu/hr, Propane Fired Line Heater

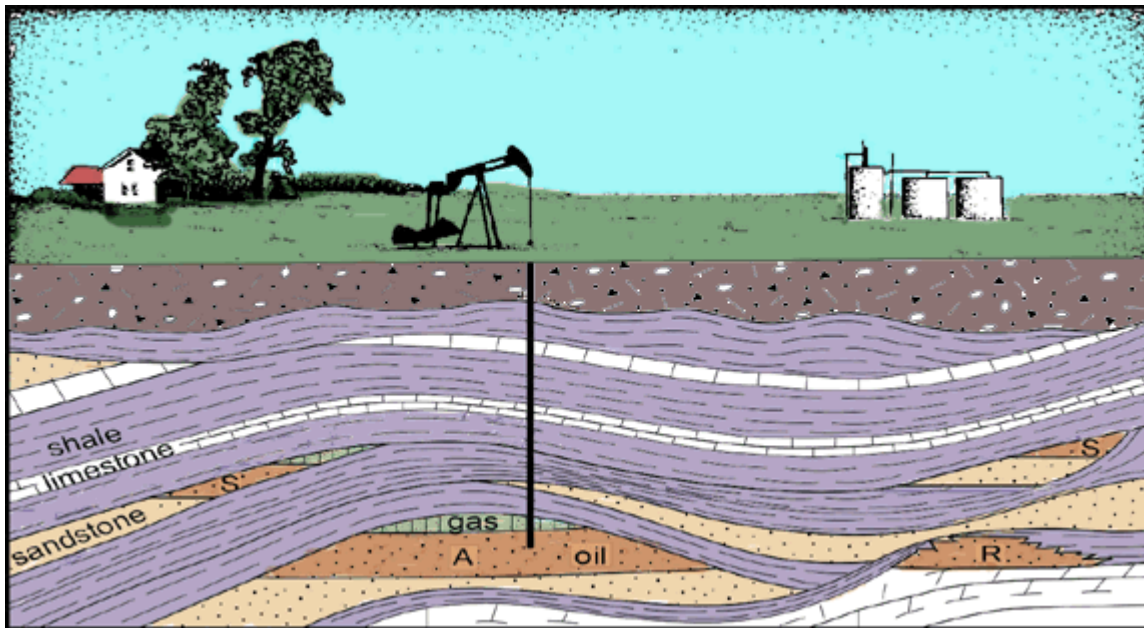


24" diameter, 8' long, 1,800 lb. dry weight on skid

# Wellhead

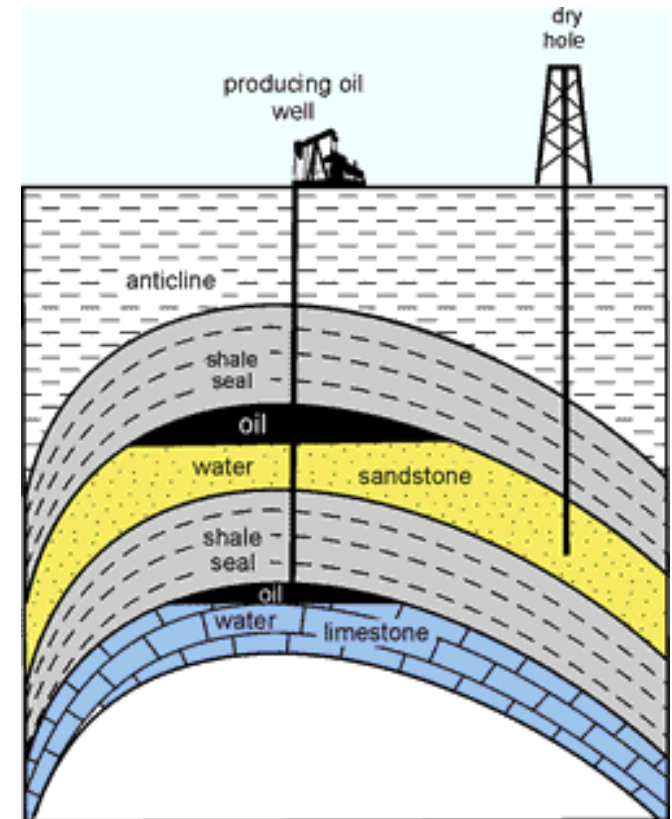


# Reservoir Schematics



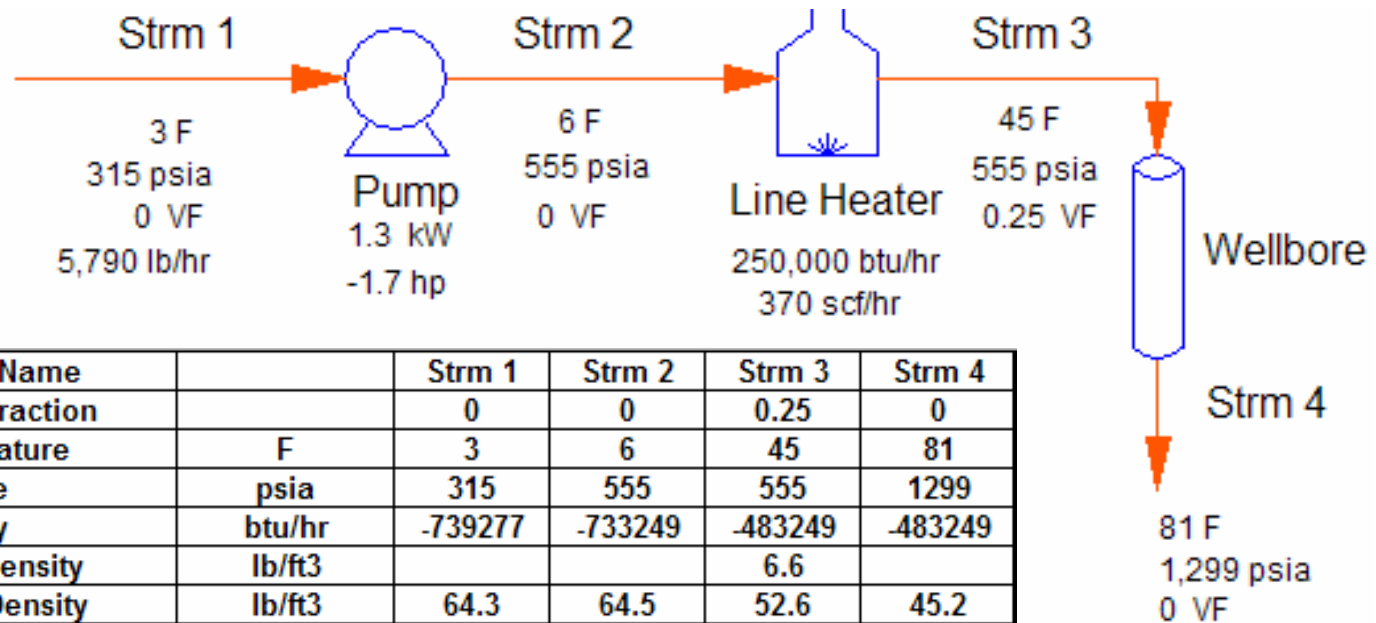
Impervious rocks like shale trap oil and gas in crests or upwarps of rock layers.

A=anticline trap. R=reef trap. S=stratigraphic trap



The folded rock layers trap the oil, which is lighter than water and floats at the top of the reservoir.

# Simulation Results – New Oil Well Case



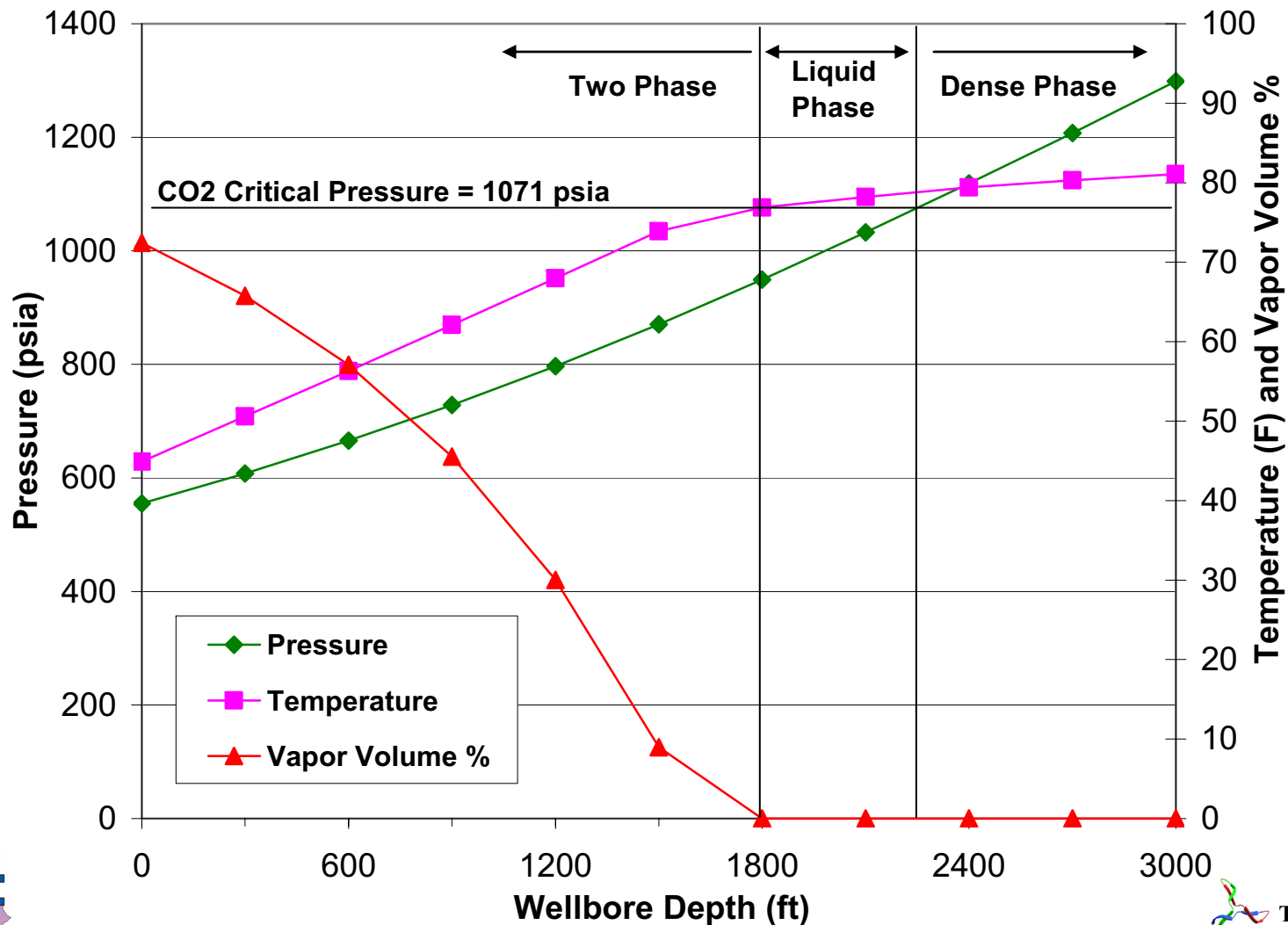
Stream Name		Strm 1	Strm 2	Strm 3	Strm 4
Vapor Fraction		0	0	0.25	0
Temperature	F	3	6	45	81
Pressure	psia	315	555	555	1299
Enthalpy	btu/hr	-739277	-733249	-483249	-483249
Vapor Density	lb/ft3			6.6	
Liquid Density	lb/ft3	64.3	64.5	52.6	45.2
Vapor Cp	btu/lbmol/R			13.9	
Liquid Cp	btu/lbmol/R	21.4	20.9	28.7	55.9
Vapor Viscosity	cP			0.016	
Liquid Viscosity	cP	0.121	0.121	0.086	0.069
Liquid Flowrate	gal/min@STP	14.0	14.0	10.5	14.0
Molecular Weight		44.0	44.0	44.0	44.0
Molar Flowrate	lbmol/hr	131.5	131.5	131.5	131.5
Mass Flowrate	lb/hr	5789	5789	5789	5789



Simulation Package: WinSim Design II v 9.32

# Simulated Wellbore Conditions – New Oil Well Case

Pressure, Temperature and Vapor Volume % vs. Wellbore Depth



# Conclusions

- Pump skid has been designed to provide maximum flexibility over a wide range of operating conditions
- System design incorporates safety requirements for liquid CO<sub>2</sub> service
- Pump skid, CO<sub>2</sub> storage tank, and line heater selections ensure oil field suitability and maximum portability for multi-site, four year project
- Pump skid completion is scheduled for mid-May 2006
- Line heater and CO<sub>2</sub> storage tank will also available by mid-May 2006

