



# The University of Tulsa



## Multiphase Flow of CO<sub>2</sub> with Impurities in Pipelines and Injection Wells

University of Tulsa CO<sub>2</sub> Transportation and Storage

DE-FE0032322

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2024 FECM/NETL Carbon Management Research Project Review Meeting

# Outline



- 🔹 **Project Overview**
- 🔹 **Introduction**
- 🔹 **Scope**
- 🔹 **Mesoscale Test Bed**
- 🔹 **Expected Outcome**
- 🔹 **Q&A**



# Project Overview

## Key Project Participants



# Project Overview ...

## Key Project Participants



### 💧 Principal Investigators

- Cem Sarica (PI)
- Eduardo Pereyra (Co-PI)

### 💧 Research Associate

- Raphael Viggiano

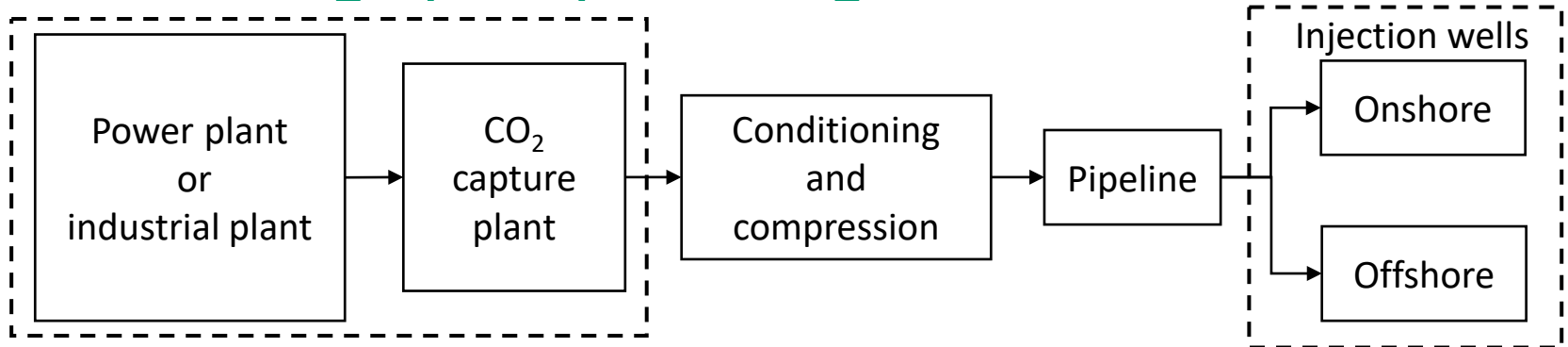
### 💧 Federal Project Manager (FPM)

- Jacob Smith, DOE-NETL

# Introduction

## 💧 Advancing DOE Program Goals

- Addressing Carbon Transport Injection and Storage (CTIS) Challenges

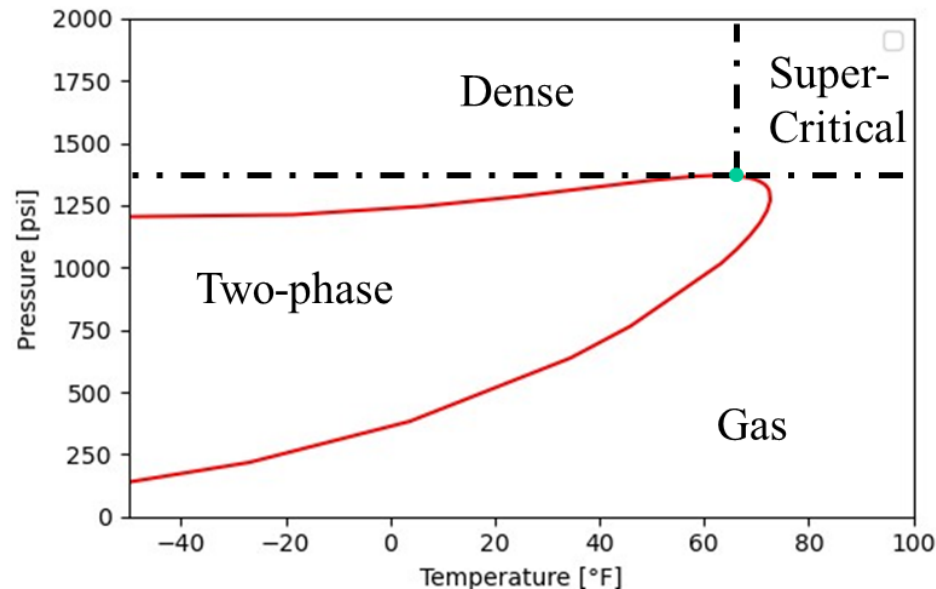


## 💧 Challenges

- CO<sub>2</sub>-Impurity Mixtures have Unique Physical Properties
- Existence of Multiphase Flow
- Potential Hydrate Formation

# Introduction ...

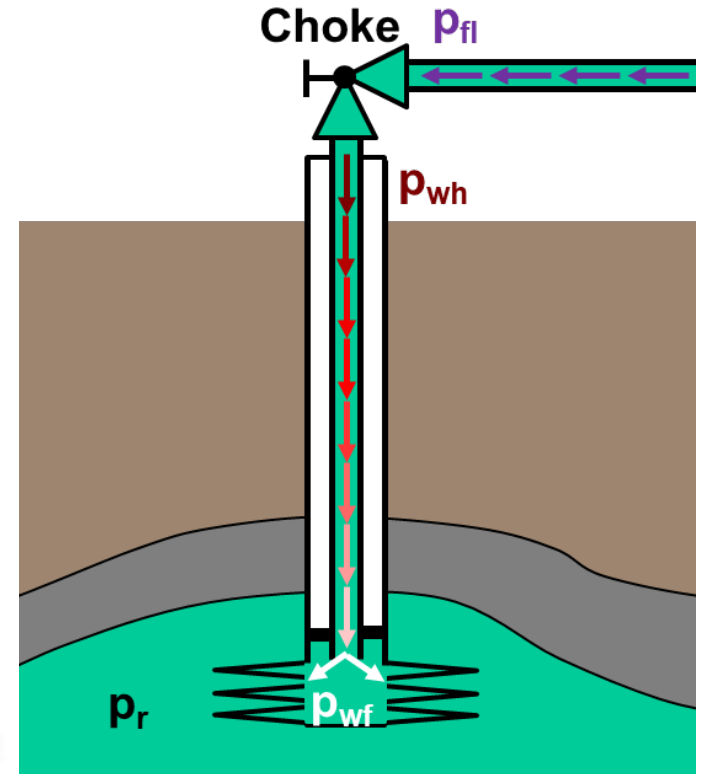
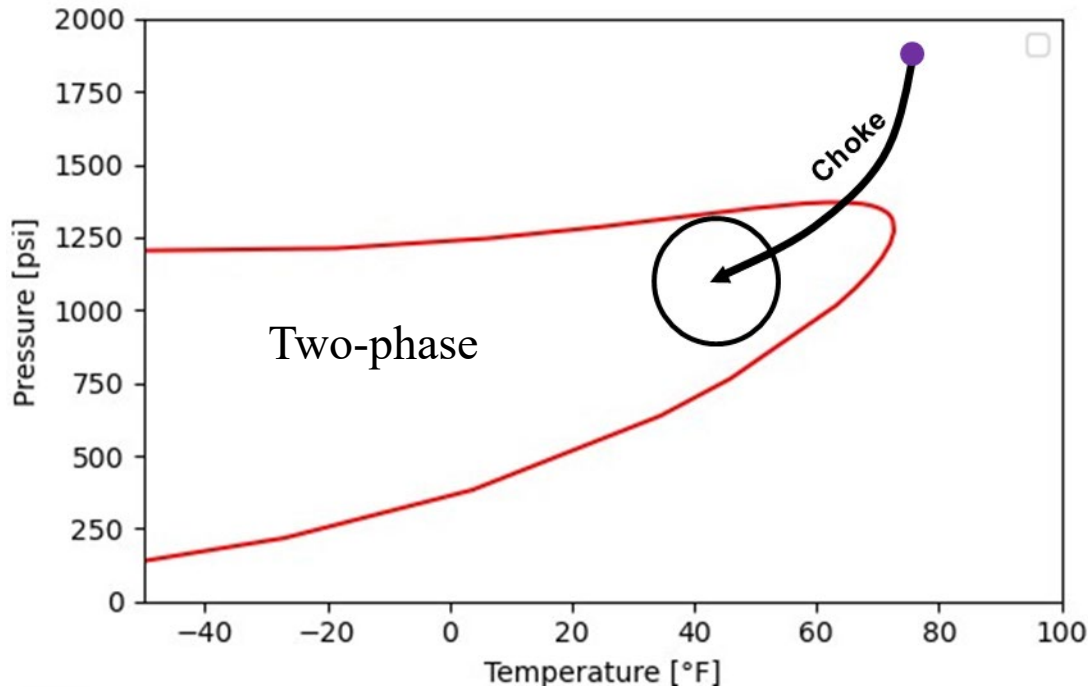
- 💧 **CO<sub>2</sub> is ideally Transported in a Dense or Super-critical State**
  - **Higher Mass Flow Rates with Minimum Pressure Drop**



# Introduction ...

## 💧 Two-phase Flow Can Occur

- Depleted Reservoirs have Lower Pressures
- Pressure Drops
- Joules-Thompson Effect



# Scope of The Work

## General Objectives



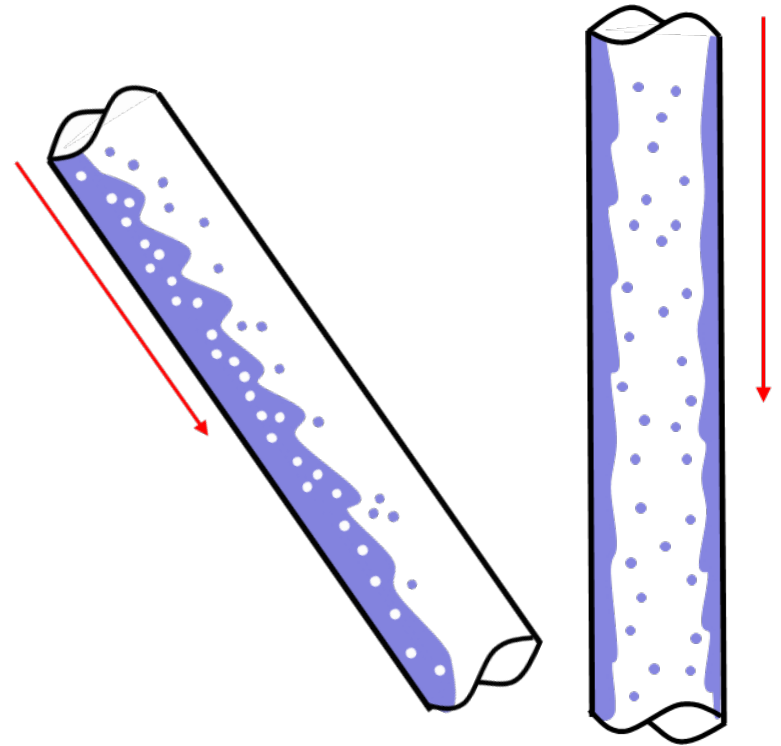
- 💧 **Develop a State-of-the-Art Test Bed**
  - Representative of Wellbores and Pipelines
  - Versatile
- 💧 **Holistically Investigate Multiphase Flow of CO<sub>2</sub> with Impurities (CO<sub>2</sub>-Rich)**
  - Pipeline - Transport
  - Wellbores - Injection
- 💧 **Study Hydrate Formation of CO<sub>2</sub>-Rich Mixtures**
- 💧 **Assess Existing Models**



# Scope of The Work ...

## 💧 Wellbores - Downward Two-phase Flow

- Limited Studies Available in Literature
- Wall Shear (Friction)
- Slip or No-slip?
- Pressure Drop
- Holdup
- Flow Pattern Predictions



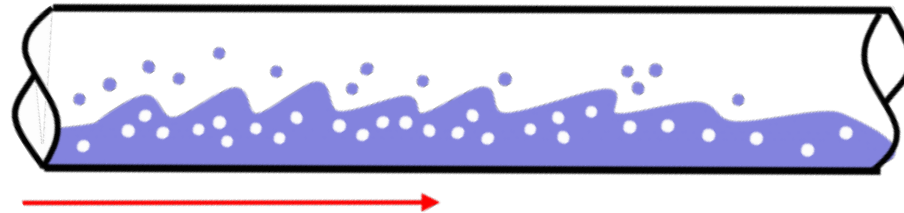
# Scope of The Work ...

## 💧 Causes for Two-phase Flow in Pipelines

- Start-up and Shut-down
- Oscillations in CO<sub>2</sub> Supply
- Depressurization
- Shorter and Lower Pressure Lines

## 💧 Challenges

- Peculiarities of CO<sub>2</sub> Properties
- Changes in Flow Pattern
- Pressure Drop, Holdup, Slip or No-slip, ...



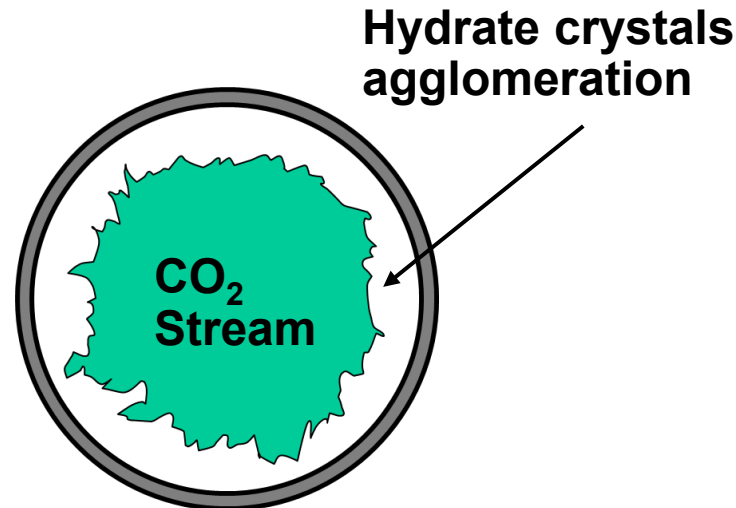
# Scope of The Work ...

## 💧 Investigate Hydrate Formation

### ➤ Flow Through Restrictions

⤴ Simulate Choking Action and Investigate the Effect of Hydrates on Fluid Flow

### ➤ Tests Under Pseudo-one-pass Conditions



# Mesoscale Test Bed



# Mesoscale Test Bed ...

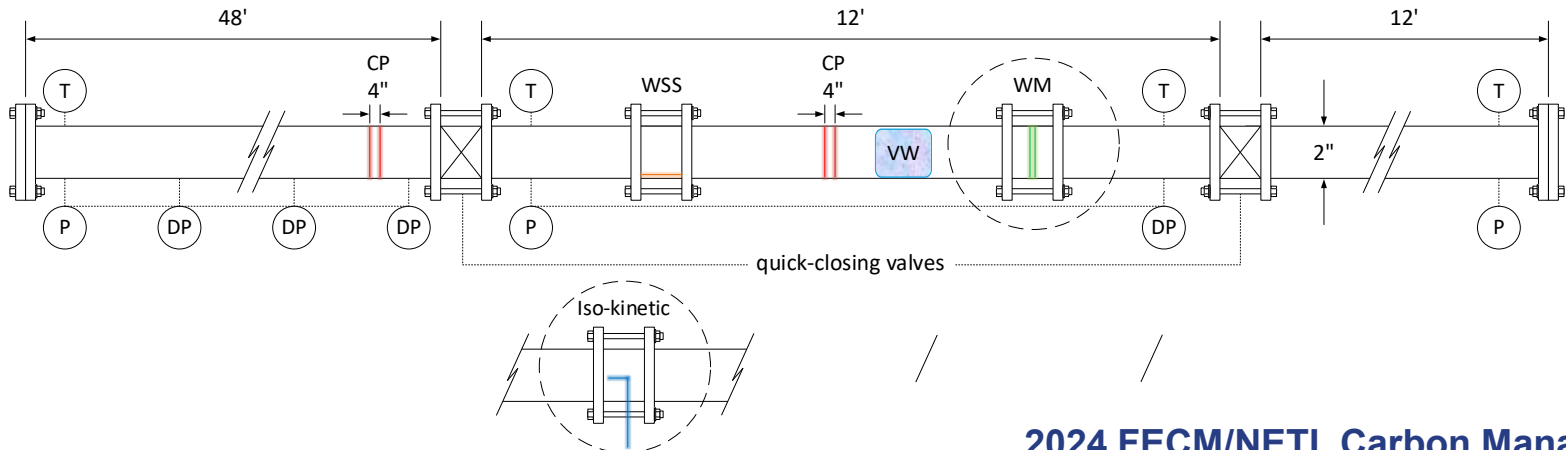
## 💧 TU Test Facility

- Previously Used for Paraffin Deposition
- Temperature Range: 4°C - 82°C (40°F - 180°F)
- Pressure: Up to 69 Bara (1000 Psia)
- Internal Diameter: 50.8 mm (2-in)
- Length: 16.2 m (53 ft)
- Inclinations: -90° to 0°
- Test Fluids: CO<sub>2</sub> and N<sub>2</sub> (N<sub>2</sub> can be Introduced at Different Concentrations to Simulate Impurity Effects)



# Mesoscale Test Bed ...

- 💧 Dynamic  $H_L$  - Capacitance Sensors (CP)
- 💧 Liquid Holdup – Quick Closing Valves
- 💧 Liquid/Gas flow rates– Coriolis Flow Meters
- 💧 Pressure – Absolute Pressure Sensors (P)
- 💧 Temperature – Temperature Sensors (T)
- 💧 Pressure Difference- Differential Pressure Sensors (DP) Boom and Tower
- 💧 Flow Pattern/Visual Observation – Visualization Window (VW)
- 💧 Phase Distribution – Wire Mesh Sensor (WM)
- 💧 Wall Shear Stress – Wall Shear Stress Sensor (WSS)
- 💧 Entrainment – Iso-kinetic Sampling System





# Expected Outcome



- **Experimental Characterization of Two-phase CO<sub>2</sub> Flow**
  - **Injection and Pipeline Transport**
  - **Wide Range of Flow Conditions**
  - **Detailed Measurements (WMS, WSS, Iso-kinetic)**
  - **Capability of Simulating Impurities**
- **Experimental Characterization of Hydrate Formation**
  - **Wide Range of Flow Conditions**
- **Testing of Existing Models and Development of New Ones, If Necessary**

# Q&A



**Thank you!**

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