The Financial and Regulatory Impact of the New CO_2 Mass Measurement Standards

- CO2 measurement challenges
- New API standards for dense & supercritical CO2 measurement
- Support for financial & regulatory reporting
- Stakeholder benefits

New Mass Measurements Standards for CO2

Establishing a uniform measurement standard for CO_2 across producers, pipelines, and storage operators creates consistency, trust, and efficiency throughout the carbon management value chain.

Ardis Bartle

- Owner, Apex Measurement and Controls (30+ Years)
- 40+ Years in Gas and Liquid Measurement
- American Gas Association (AGA) Standards Member – Received Lifetime Achievement Award
- American Petroleum Institute (API) Standards Member on Committee of Petroleum Measurement (COPM) and Voting Member
- ANSI B109 Voting Member

Background

- Enhanced Oil Recovery used since the 1970s
- Secondary recovery (water or gas injections) can increase recovery by 20-40 percent
- CO_2, chemicals or heat injection can change EOR and increase recovery by 30-60 percent
- US leads world with over 5,300 miles CO_2 pipelines

CO2 Measurement Impact

1% metering bias resulted in an annual error of about 2,671 tCO_2e

Sources: Average carbon credit costs projected around $60/t (metric tons of carbon dioxide) by 2030; compliance carbon prices in some jurisdictions reach $158.8/metric tons of carbon dioxide (t) Carbon Pricing Dashboard.

Credit price (USD/tCO_2e)	Annual impact (USD)
10	**$26,710**
30	**$80,130**
60	**$160,260**
100	**$267,100**
158.8	**$424,155**

Dollar impact of a 1% CO_2 metering error

Dollar impact of a 2% CO_2 metering error

We already calculated that a 1% metering bias in setup corresponds to about 2,671 tCO_2e per year. Doubling that to 2% error gives:

$$\textbf{Annual error} \approx 2 \times 2,671 = 5,342\ \textbf{tCO}_2\textbf{e/year}$$

Apex Measurement & Control

Credit price (USD/tCO_2e)	Annual impact (USD)
10	$53,420
30	$160,260
60	$320,520
100	$534,200
158.8	$847,930

Note: Prices vary widely. Voluntary market averages are often in the $30–$60/t range, while compliance markets (like EU ETS) can exceed $100–$150/t.

CARBON DIOXIDE MEASUREMENT ACROSS A VALUE CHAIN

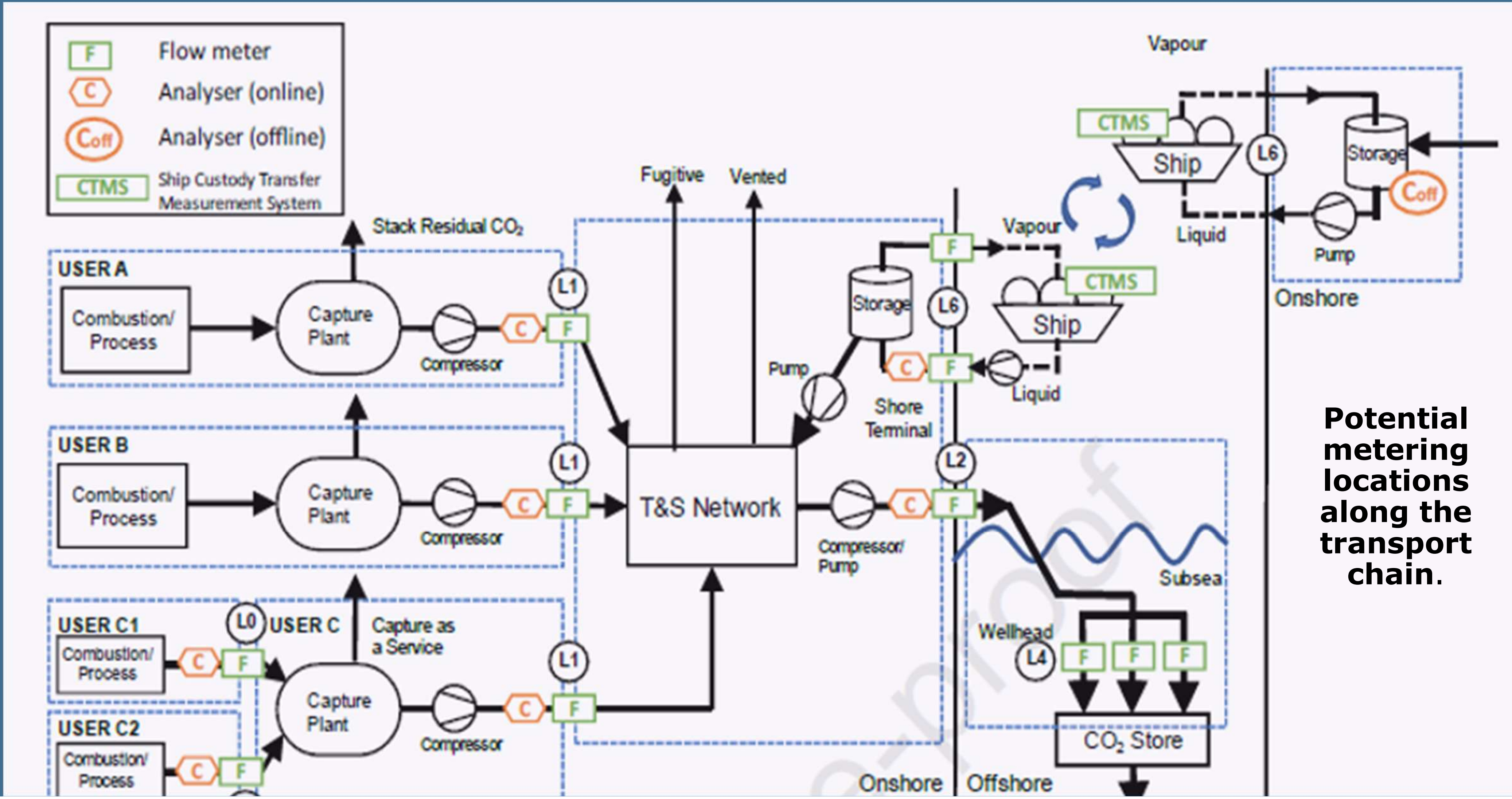
Measurements of the quantity and quality of the transported CO_2 are required at different stages across the value chain:

- Regulatory
- Contractual/custody transfer
- Operations, i.e., leak detection
- Allocation

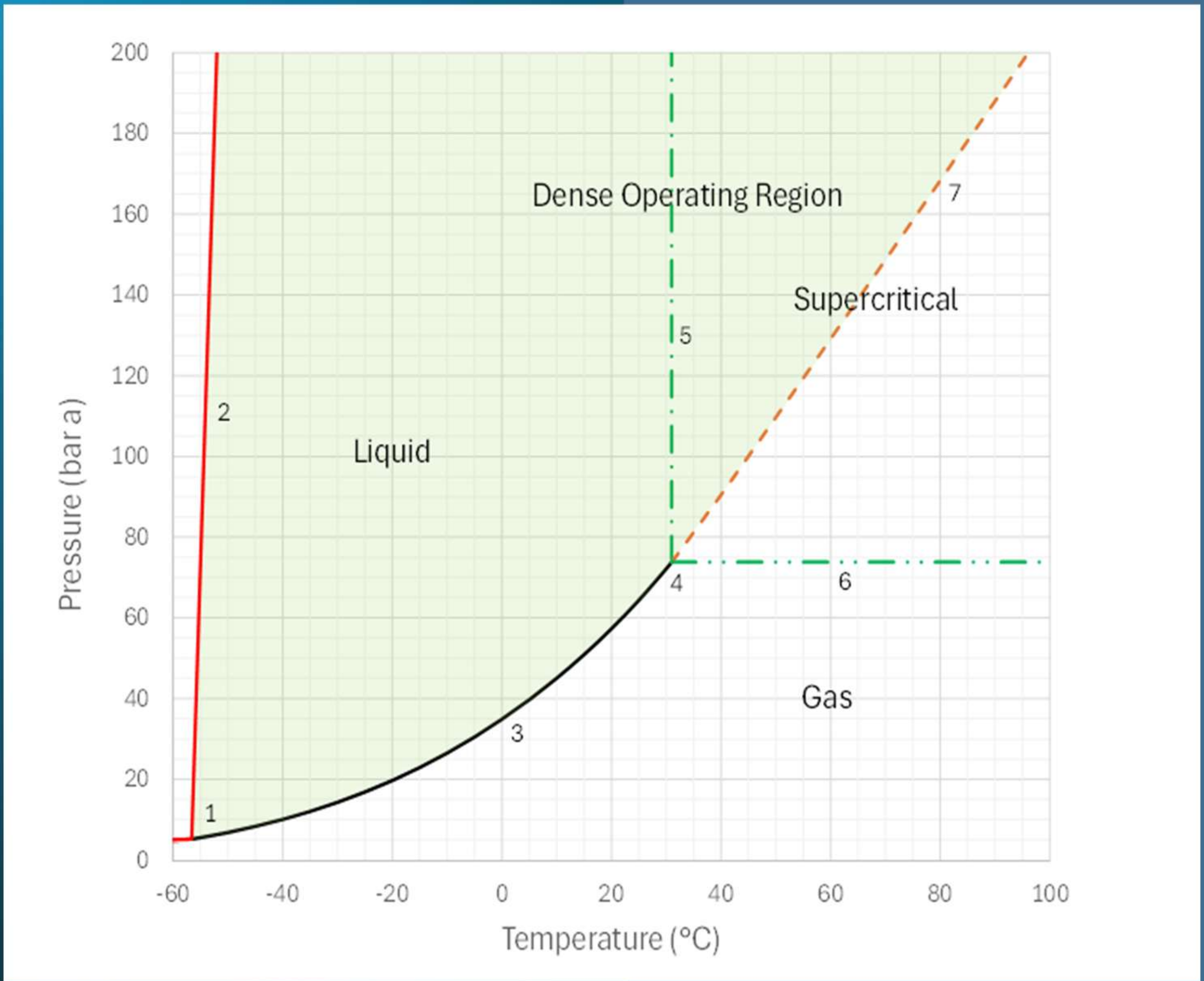
The primary focus here is "custody transfer" where requirements are typically more stringent.

Proposed standards can also be useful for guidance in design and implementation of other applications.

CO2 Value Chain and Possible Measurement Locations



Potential metering locations along the transport chain.



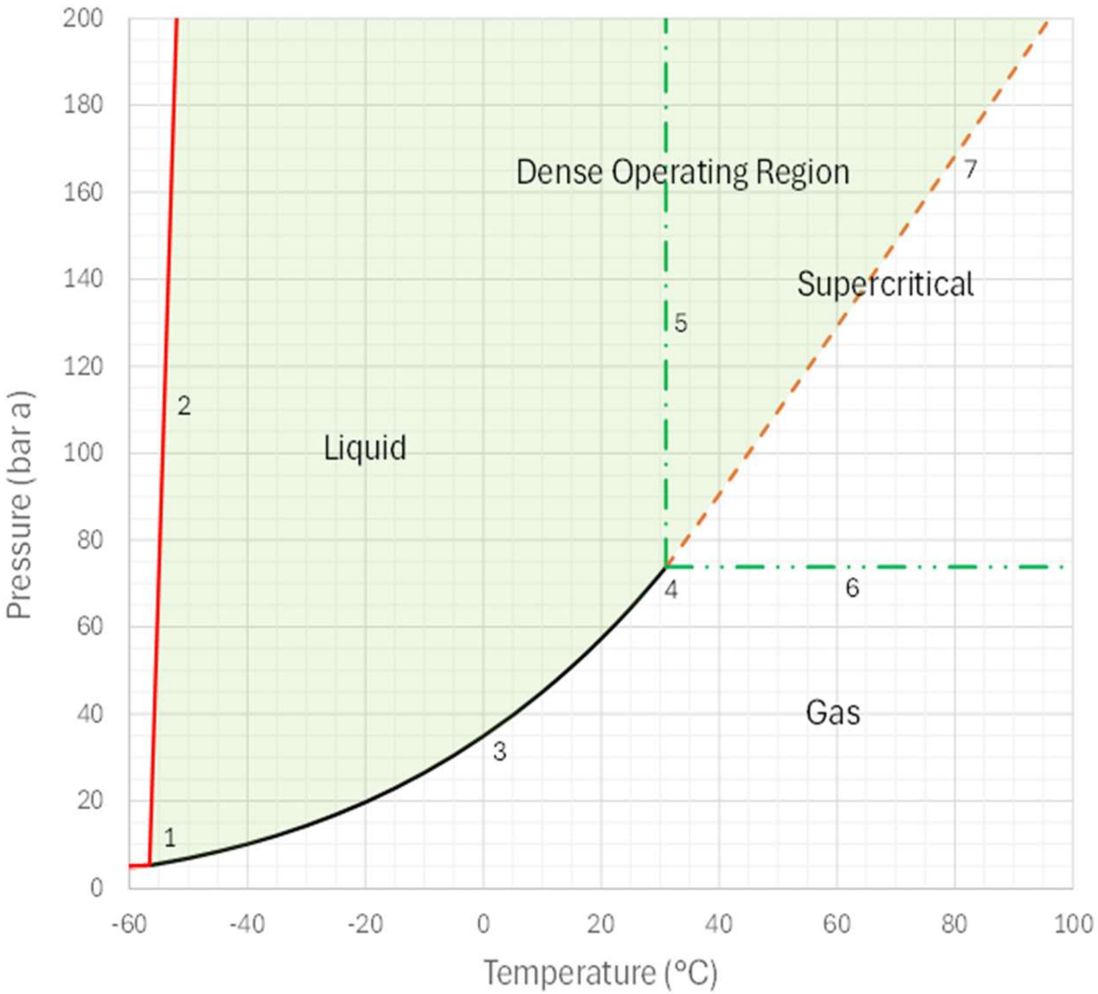
Pure CO_2 Phase Diagram

1. Triple Point
2. Solid/Liquid Phase Boundary
3. Liquid Gas Boundary
4. Critical/Point
5. Liquid/supercritical Phase Boundary
6. Gas/Supercritical Phase Boundary
7. 500 kg/m3 line
8. Dense Operating Region

*CO_2-rich mass quantity, i.e., total stream mass, pure CO_2 and impurities

*CO_2 mass quantity, i.e., the mass of pure CO_2 fraction only

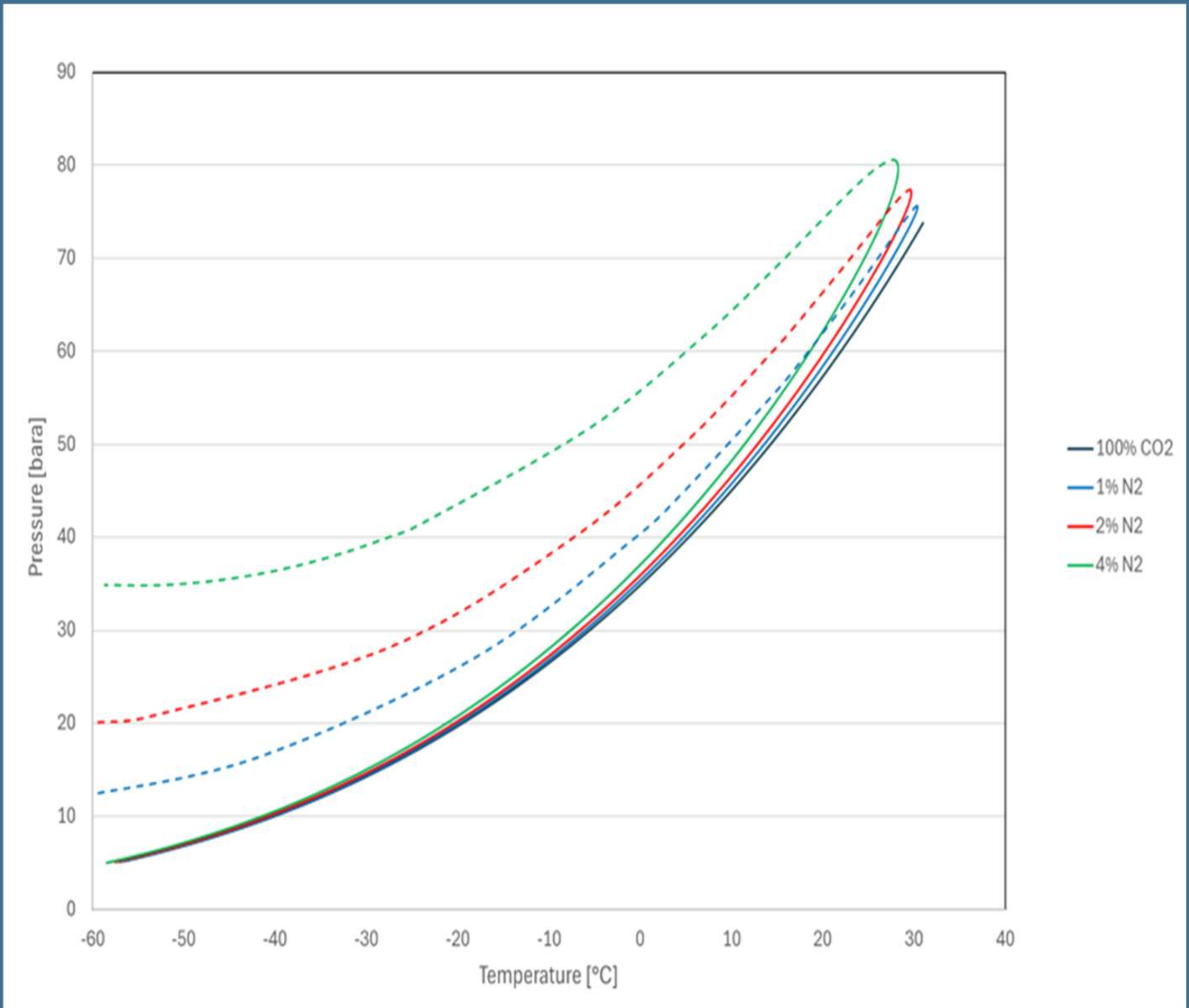
*Impurities concentration in the CO_2 stream



Pure CO_2 Phase Diagram

Notes:

1. Phase: CO2 exists in four phases: solid, liquid, gas or supercritical
2. Supercritical Phase: Fluid state at a temperature and pressure above the critical point where distinct liquid and gas phases do not exist
3. Dense Phase: Not interchangeable with supercritical phase (not used in standard)
4. Dense Operating Region: Std defines operations in liquid and/or supercritical phase with density ≤ 500 kg/m3
5. Phase Diagram: Plot showing material state of function of variables such as temperature & pressure
6. Phase Transition: A change from one state of matter to another



- CO_2 Phase Envelope Impact Due to Impurities (i.e. Nitrogen)
- Note: Operating near the critical point can cause significant problems, as CO_2's critical temperature (30.97°C, 87.76 °F) close to ambient temperature

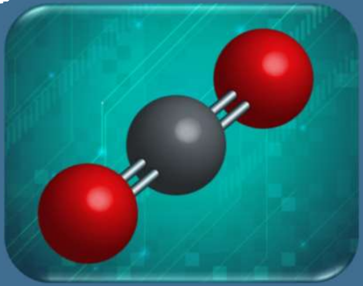
CO2 Meter Challenges

1. Corrosion
2. Two Phase Measurement
3. Custody Transfer: provides quantity and quality information for physical & fiscal documentation of a change in ownership and/or change in responsibility for commodities

NEEDED: DEVELOPMENT OF CO2 MEASUREMENT STANDRARD

Custody Transfer Measurement standard for fluids provides more accurate measurement of CO2 which are compressible when transported in supercritical state:

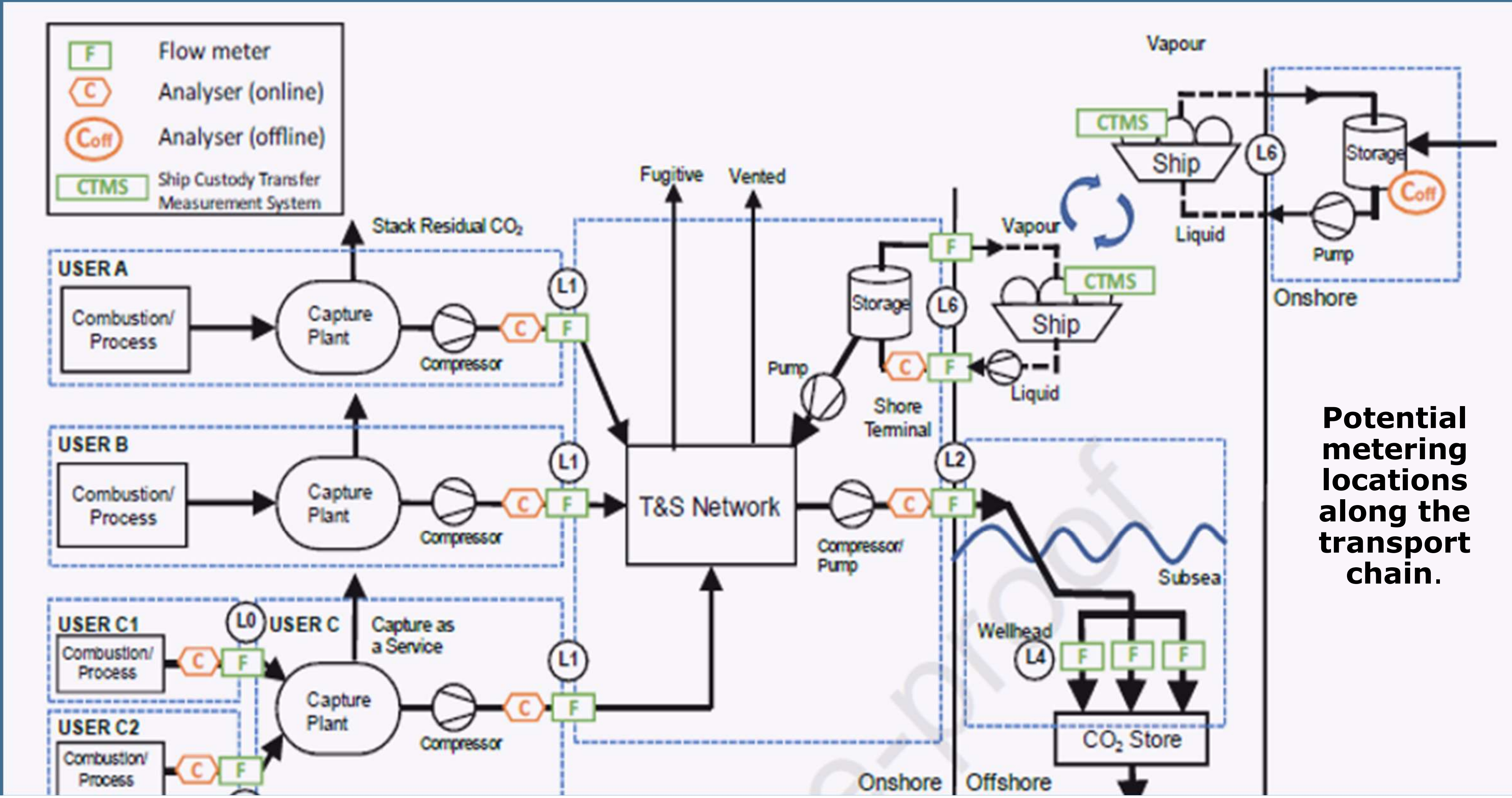
Supercritical fluid is defined as “a fluid is maintained above its critical temperature and critical pressure, such that the fluid has a characteristics of both liquid and gas phases”



Standard Needs to Address: Sampling CO_2 Mixture

As the composition of the CO_2 stream will vary continuously both at the capture plant and throughout the transportation network, continuous sampling should be undertaken.

CO2 Value Chain and Possible Measurement Locations



Potential metering locations along the transport chain.

Standard Needs to Address: Determining Physical Properties

- New equations of state and phase diagrams likely
- Establish validated industry standards and tools, both hardware/software, to minimize result inconsistencies
- Validate physical properties software modelling packages and algorithms for accuracy

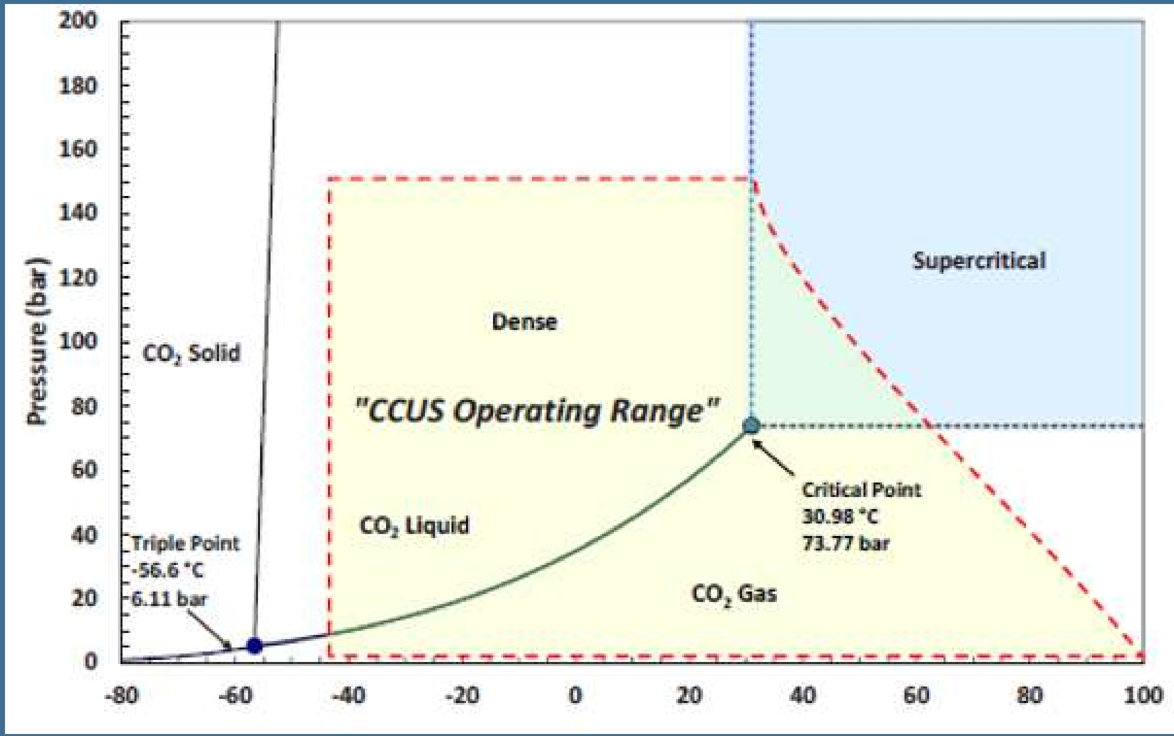
Standard Needs to Address: Flow Measurement

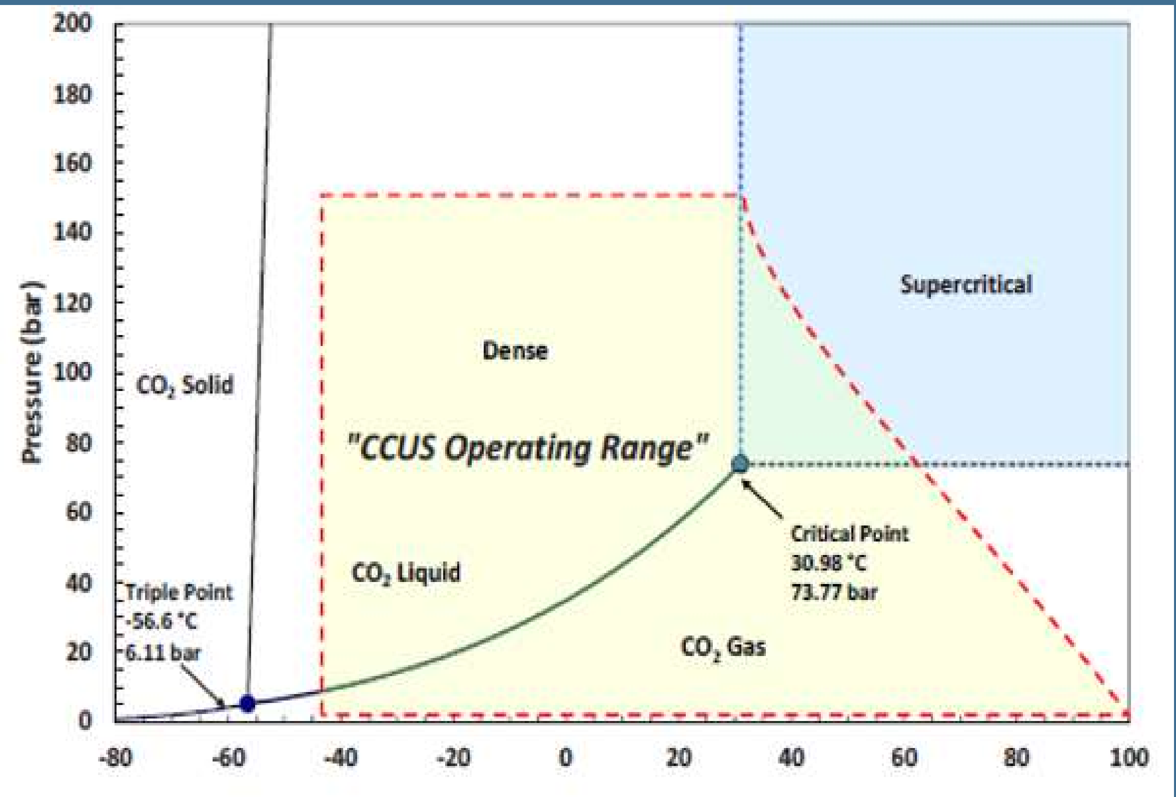
- Recommendations currently target 1.5% flow measurement uncertainty levels
- Standard will outline the design and installation of the correct type of flow meter
- May require both gas and liquid meters
- Special consideration to flow meter selected to measure supercritical phase

DEVELOPMENT OF CO_2 MEASUREMENT STANDARDS

In 2022, API Committee for Liquid Measurement (COLM) recognized that industry guidance was needed regarding custody transfer.

The decision was to develop two complementary standards.

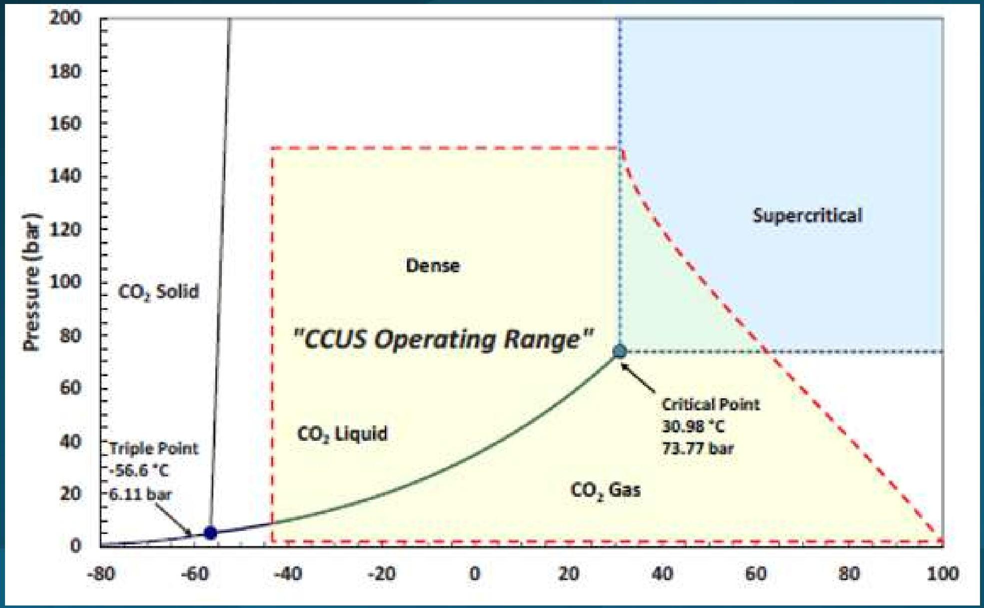




API 6.XA Metering Assemblies for Supercritical and Dense Phase Fluids

Custody transfer measurement standard for fluids provides more accurate measure of CO_2 which are compressible when transported in supercritical state.

- Guidance includes overall design and operation of the measurement system.



API 6.XB Metering Assemblies for Measurement of Liquid, Dense or Supercritical Phase Carbon Dioxide

- For Carbon Capture and Storage (CCS) this standard is essential for all captured CO2 to be accurately measured across the value chain.
- Detect CO2 leaks
- Verification of CO2 quantity accounted under emissions trading/credit scheme

Figure 4: Marine Vessel Loading/Unloading Operating Envelope (Liquid Phase Only)

Ultrasonic meters shall be designed, calibrated, installed, operated, and maintained in accordance with the requirements of API MPMS Chapter 5.8

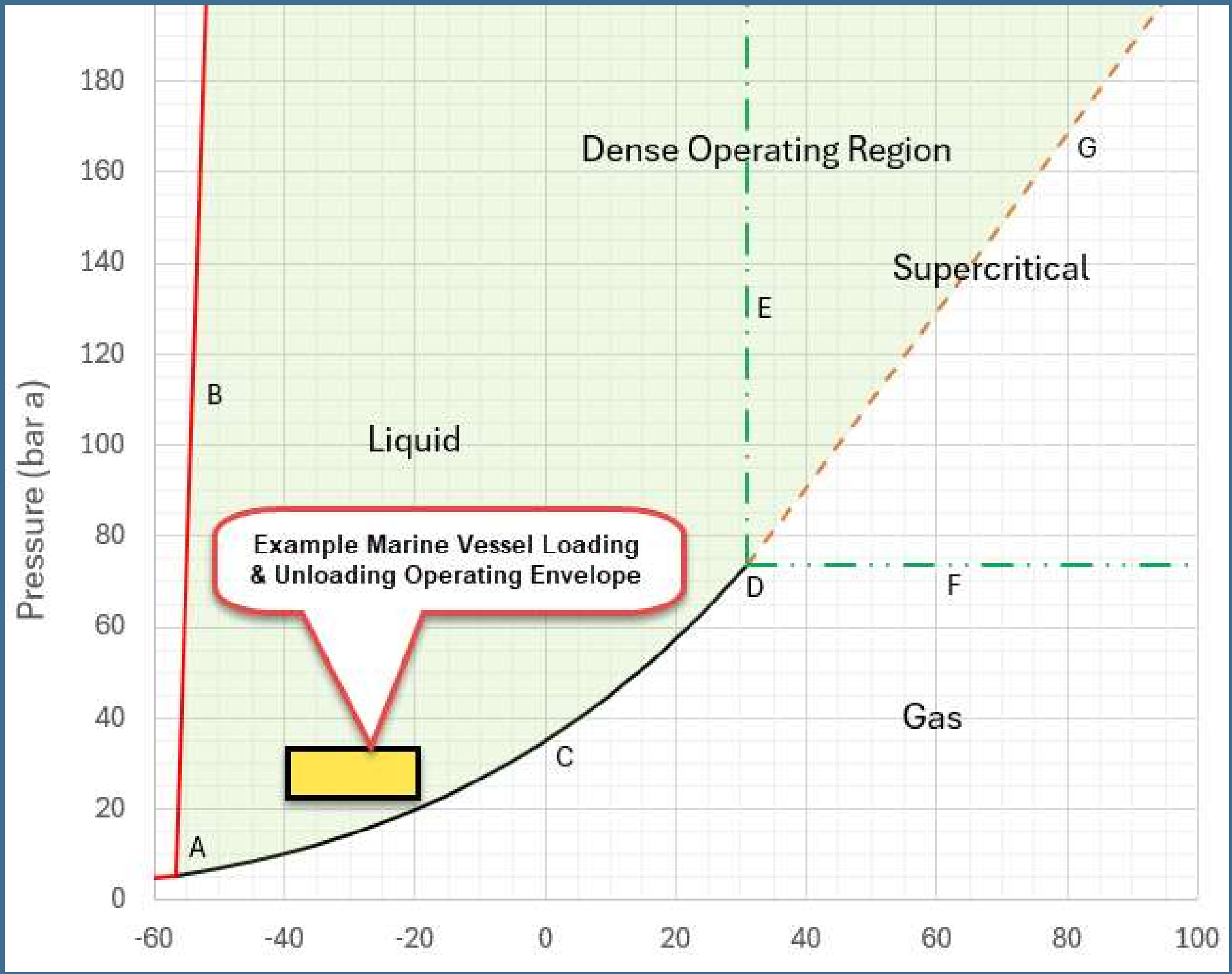


Figure 5: Pipeline Operating Envelope (Gas Phase Only)

Ultrasonic meters shall be designed, calibrated, installed, operated, and maintained in accordance with the requirements of AGA Report No. 9

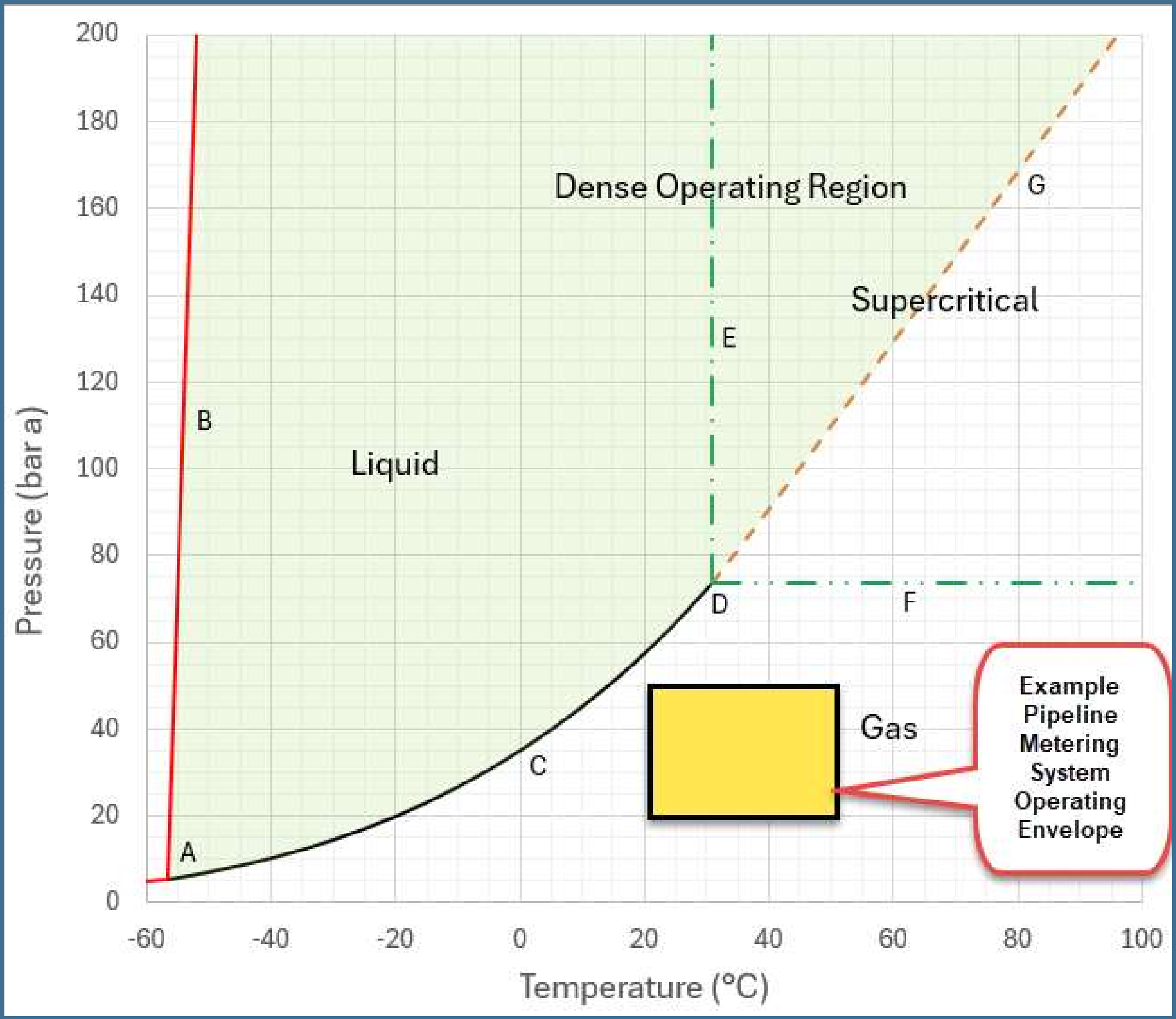
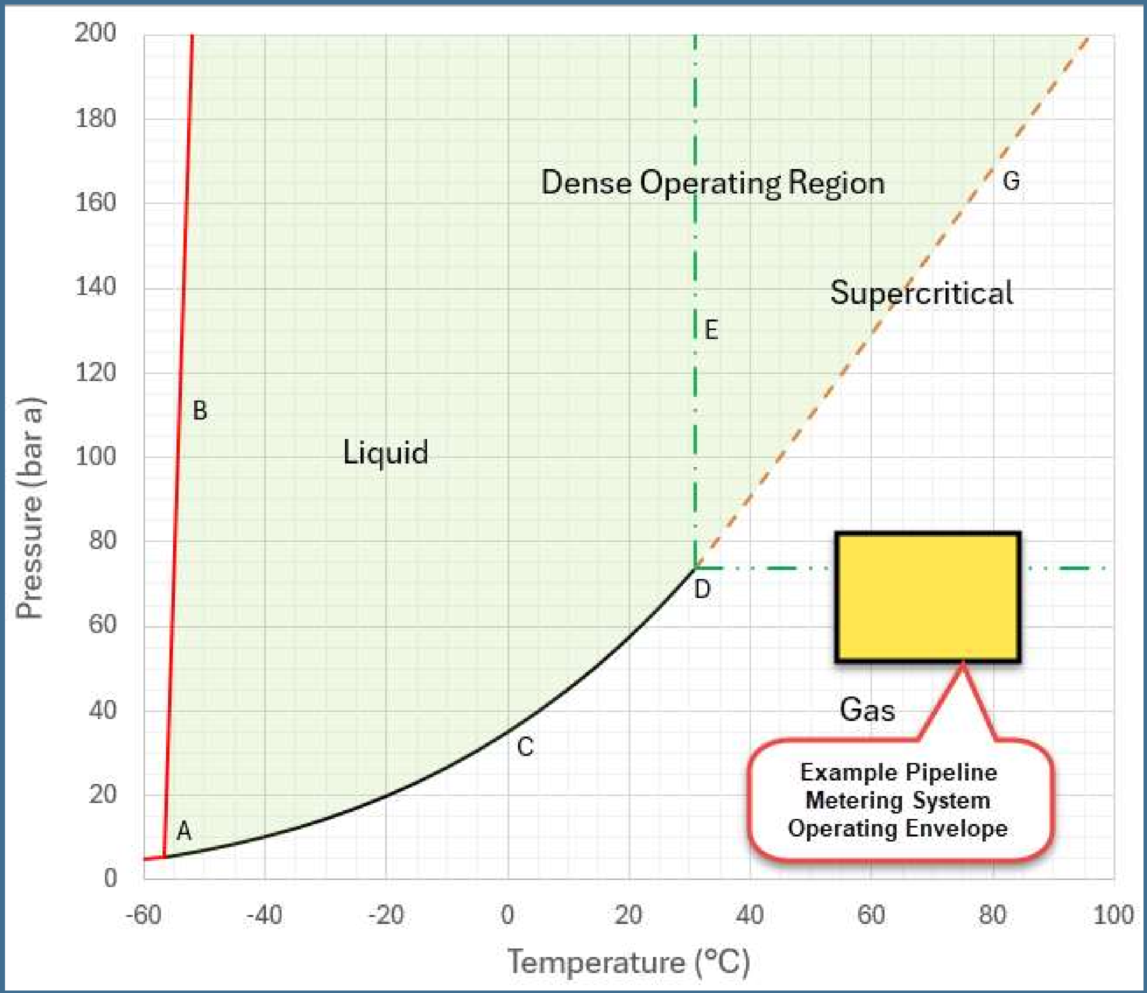


Figure 6: Pipeline Metering Operating Envelope (Gas and Supercritical Phases)



Ultrasonic meters shall be designed, calibrated, installed, operated, and maintained in accordance with the requirements of AGA Report No. 9.

Figure 7: Pipeline Metering Operating Envelope (Liquid and Supercritical Phases)

Ultrasonic meters shall be designed, calibrated, installed, operated, and maintained in accordance with the requirements of API MPMS Chapter 5.8 or AGA Report No. 9. The standard used shall be agreed upon by the contracting parties and largely depends on the measurement uncertainty required, the selected meter calibration/proving method

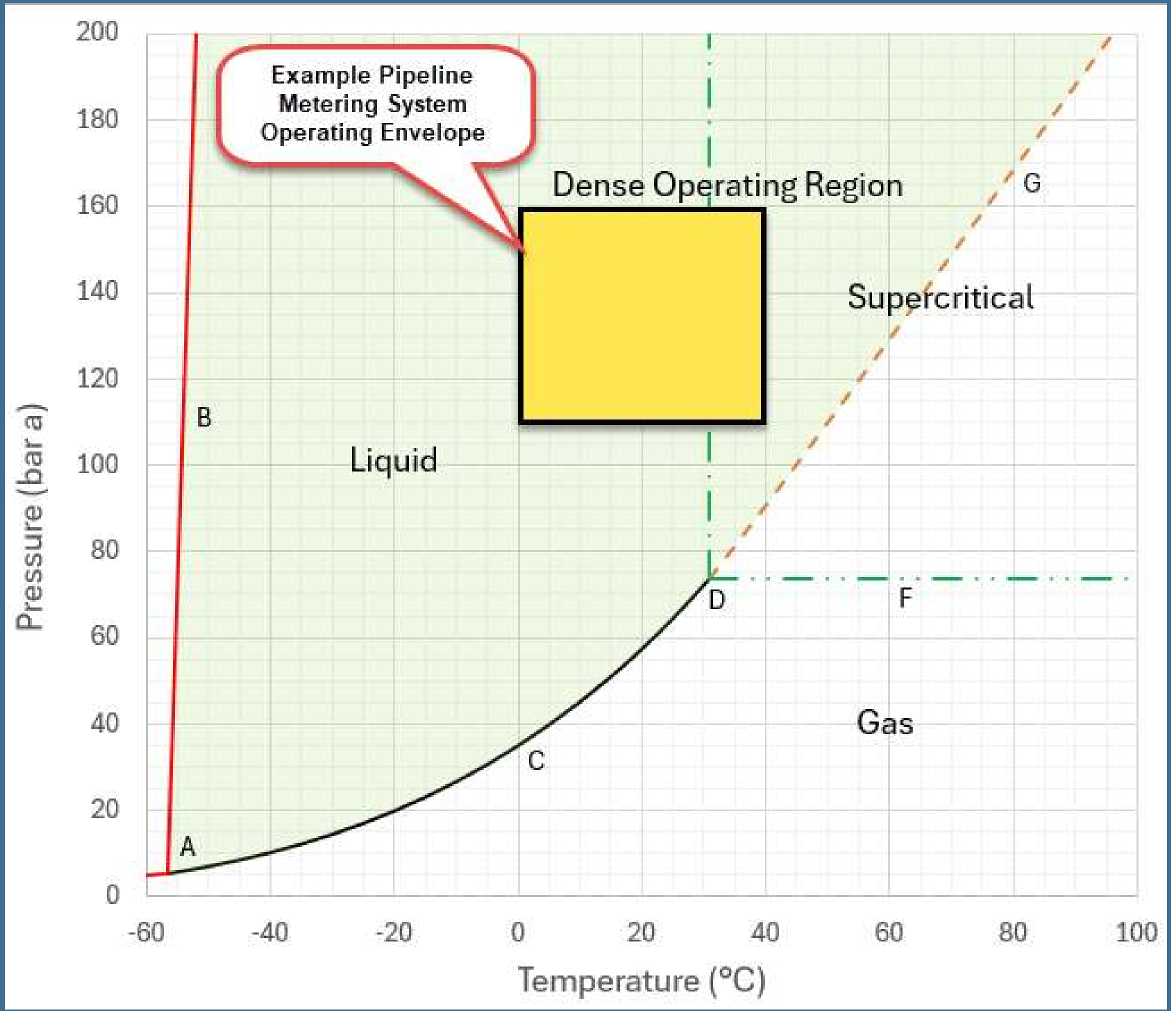
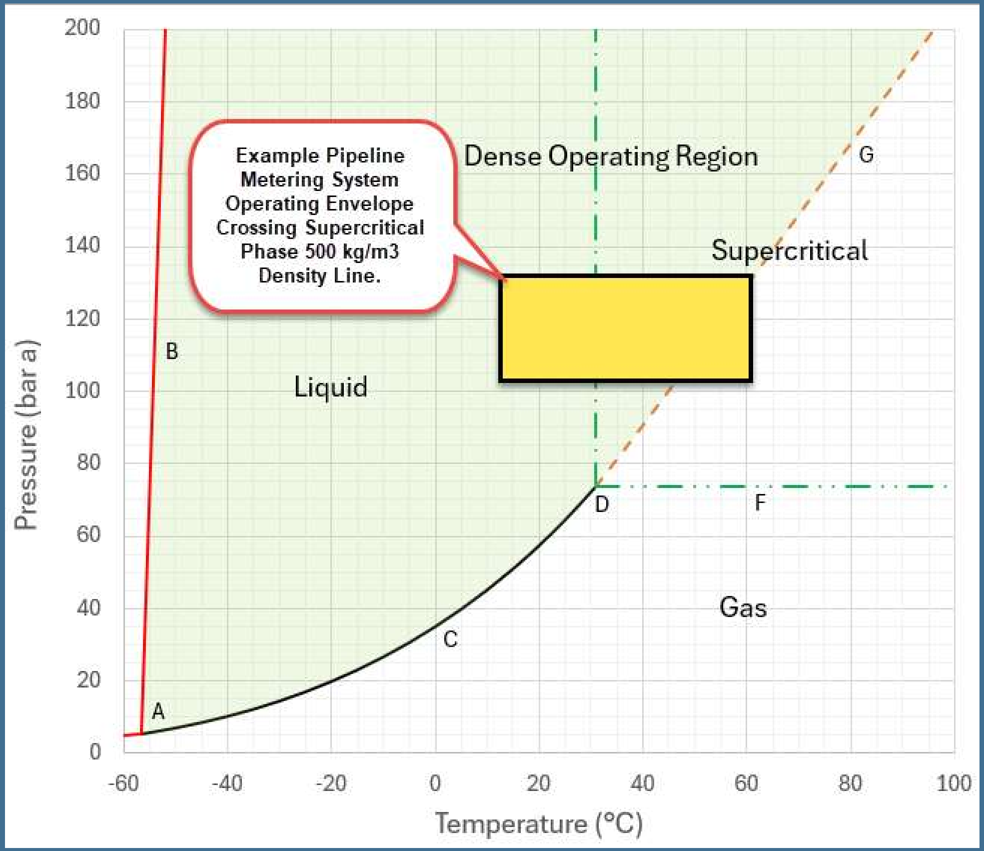


Figure 8: Pipeline Metering Operating Envelope

The standard used shall be agreed upon by the contracting parties and largely depends on the measurement uncertainty required, the selected meter calibration/proving method, operating time within fluid phase and the fluid phase operating envelope's proximity to the triangular portion of the supercritical phase region indicated by the 500 kg/m3 and gas/supercritical phase boundary lines (i.e. lines G, D and F in Figure 8) where AGA Report No. 9 becomes the appropriate industry standard due to fluid compressibility issues

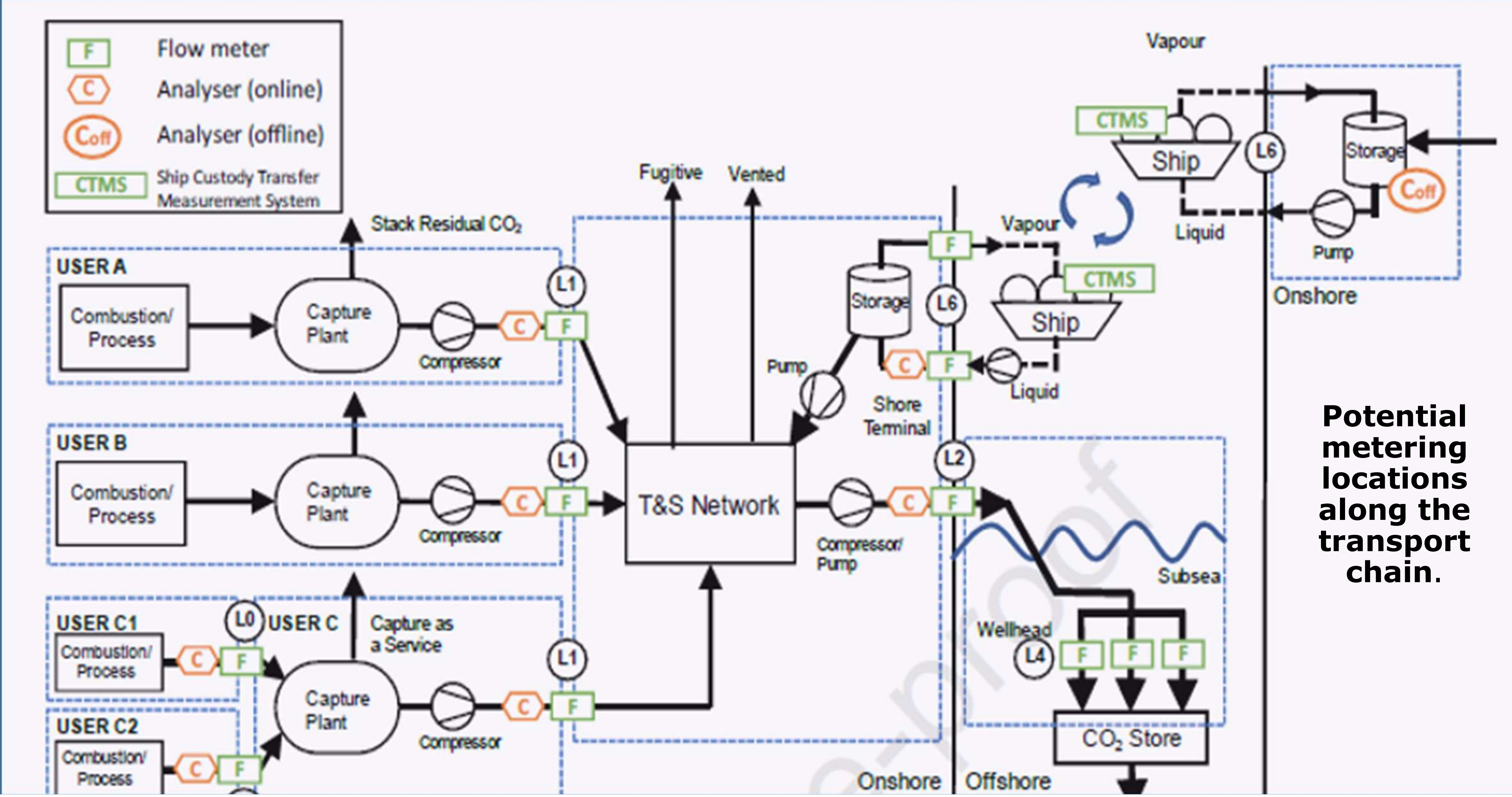


Metering System

Both API 6.XA and 6.XB provide a high-level description of the process or steps for designing mass custody transfer metering systems for carbon dioxide (pure CO_2 and CO_2-rich mixtures) measurement.

- Define operating envelope
- Define meter technology and mass measurement methods
- Select meter technology and mass measurement methods
- Selection meter calibration and field verification method
- Determine meter run configuration
- Determine meter system configuration

CO2 Value Chain and Possible Measurement Locations



Potential metering locations along the transport chain.

Metering Technologies

- Differential Pressure (DP) Flow Meters
  - Orifice Plate Meters (API MPMS 14.3 (AGA Report 3) and API 21.1): Long track record in measuring CO_2 and used widely in stable single phase conditions with uncertainty levels of ±1%.
  - Venturi and V Cone meters – not normally recognized as custody transfer, and not as commonly used with CO_2 applications.
- Volumetric Flow Meters
  - Turbine Meter (AGA Report 7 and API MPMS 5.2)
  - Vortex Meters – Not enough experience with CO_2
  - Ultrasonic Meter (AGA Report 9)
- Mass Flow Meter
  - Coriolis Meter (API 5.6 or AGA Report 11)

Quality Determination

Both API 6.XA and 6.XB recognize that determining the quality of supercritical fluids can be challenging due to their unique properties including:

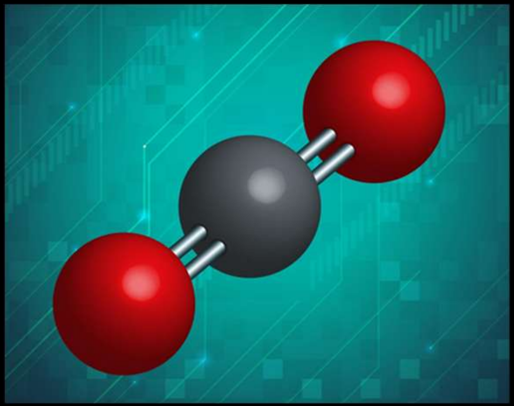
- Highly varying density
- Unusual properties behavior
- Potential for fluid phase transition

Quality Determination

Measurement of supercritical fluids streams

Measurement of supercritical fluids streams must obtain a compositional analysis online or offline representing the homogenous mixture of components being metered.

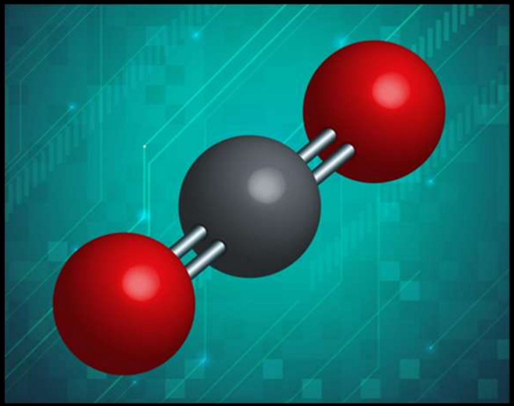
Compositional analysis and impurity analysis of the supercritical fluids within the scope of this standard may be performed using a variety of methods or methods agreed upon by the contracting parties.



Density

Density is required for applications where inferred mass measurement techniques are utilized including orifice meters, ultrasonic meters, turbine meters, etc. Considerations for Density addressed in the standard include:

- Density Design
- Density Determination by On-line Density Meter
- Density Determination by Equation of State
- Density Determination Using a Fixed Value



CASE HISTORY:

SUPPORTING ACCURATE FINANCIAL REPORTING AND REGULATORY COMPLIANCE

Occidental Petroleum (Oxy) – Permian Basin, TX

Project Type: Direct Air Capture (DAC) facility in Ector County, Texas.

How It Works: Giant fans pull CO_2 directly from the atmosphere, then the gas is compressed and either stored underground in saline formations or used in enhanced oil recovery.

Tax Credit Impact:

- For secure geological storage, Oxy earns about $85 per ton of CO_2 captured.
- For utilization in oil recovery, the credit is about $60 per ton.

Continued

CASE HISTORY:

SUPPORTING ACCURATE FINANCIAL REPORTING AND REGULATORY COMPLIANCE

Occidental Petroleum (Oxy) – Permian Basin, TX

- Scale: The facility is designed to capture up to 500,000 tons of CO_2 annually, which translates into tens of millions of dollars in tax credits each year.

- Why It Matters: ***This project is one of the first large-scale DAC plants in the world, and the 45Q credit makes it financially viable.***

Continued

CASE HISTORY:

SUPPORTING ACCURATE FINANCIAL REPORTING AND REGULATORY COMPLIANCE

Occidental Petroleum (Oxy) –
Permian Basin, TX

Credit revenue scenarios for 500,000 **tCO2**/year

Pathway	Credit per ton (USD)	Annual Volume (tCO_2)	Annual Credits (USD)
Secure geological storage	**85**	**500,000**	**42,500,000**
Utilization for EOR	**60**	**500,000**	**30,000,000**

Continued

CASE HISTORY:

SUPPORTING ACCURATE FINANCIAL REPORTING AND REGULATORY COMPLIANCE

Occidental Petroleum (Oxy) – Permian Basin, TX

Impact of metering uncertainty at 1% and 2%:
(Illustrative Purpose)

- Baseline:
  Captured: 500,000 tCO_2/year
  1% uncertainty: ±5,000 tCO_2
  2% uncertainty: ±10,000 tCO_2
- Dollar swing by pathway:
  --Storage at $85/t:
  ±1%: $\pm 5{,}000 \times 85 = \pm \$425{,}000$
  ±2%: $\pm 10{,}000 \times 85 = \pm \$850{,}000$
  --EOR at $60/t:
  ±1%: $\pm 5{,}000 \times 60 = \pm \$300{,}000$
  ±2%: $\pm 10{,}000 \times 60 = \pm \$600{,}000$

New Mass Measurements Standards for CO2

Establishing a uniform measurement standard for CO_2 across producers, pipelines, and storage operators creates consistency, trust, and efficiency throughout the carbon management value chain.

New Mass Measurement Standards for CO2-Specific Stakeholder Benefits

- Revenue Certainty
- Regulatory Compliance
- Market Credibility
- Operational Optimization
- Risk Reduction

Thank you!

- Note: Volunteering for API 6.XX Committee(s) is still open. API can make the API 6.xxx ballot open for comment at request. The API 6.xx standards presently are not published and should be completed and released in 2026. Please reach out to myself, Nick Monchak (MonchakN@api.org) or Chair Joseph Ullman (joseph.w.ullman1@exxonmobil.com) for additional information or to join the committee.

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