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Ultrasonic Flowmeters up to the Challenges of Measuring Carbon Dioxide

1. CO_2 Phases and applications
2. UFM measurement Test Results
3. Conclusions

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Topics

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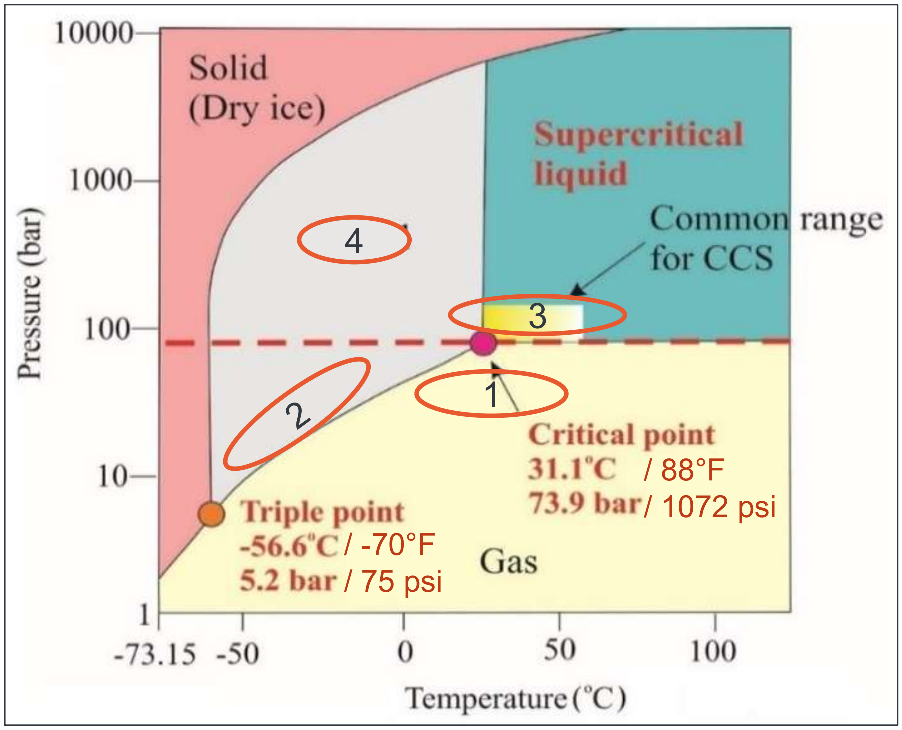
Ultrasonic Flowmeters up to the Challenges of Measuring Carbon Dioxide

CO_2 phase and measurement application

To what extend can ultrasonic flowmeters be used for measuring carbon dioxide?

1. Pressurized gas phase CO2 (pipelines up to 70 bar / 1015 psi)
2. Liquid (cryogenic) CO2, not pressurized
3. High dense (supercritical) CO2 (pipeline transport and injection), pressurized up to 150 bar / 2175 psi
4. High pressure liquid CO2 (injection), up to 450 Bar / 6526 psi



CO_2 measurement
Phase and application

Phases of CO_2 for measurement:

Gas phase:

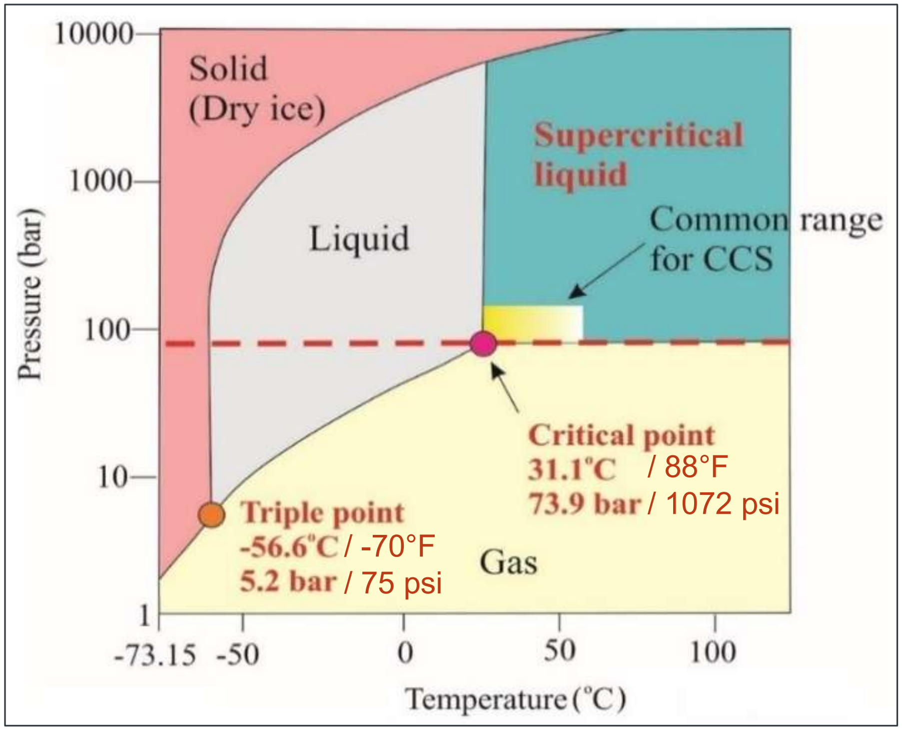
- Short distance pipeline transport
- Large pipeline diameter, low pressure

Liquid phase:

- Tank storage, transport by ship, truck and or railcar
- Low pressure, cryogenic

Dense / Supercritical phase

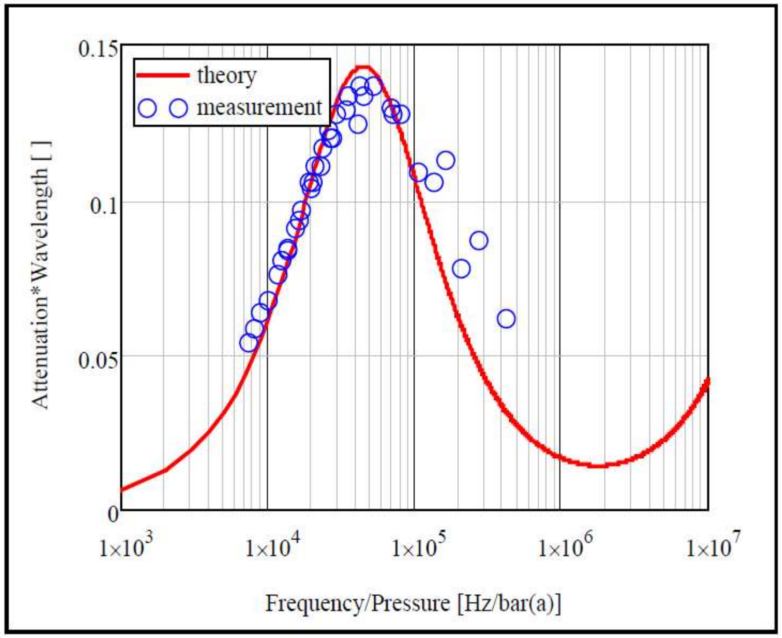
- Long distance pipeline transport and storage
- Complex relation between temperature, pressure and properties like density, speed of sound and acoustic attenuation



CO_2 flow measurement
Gas flow measurement

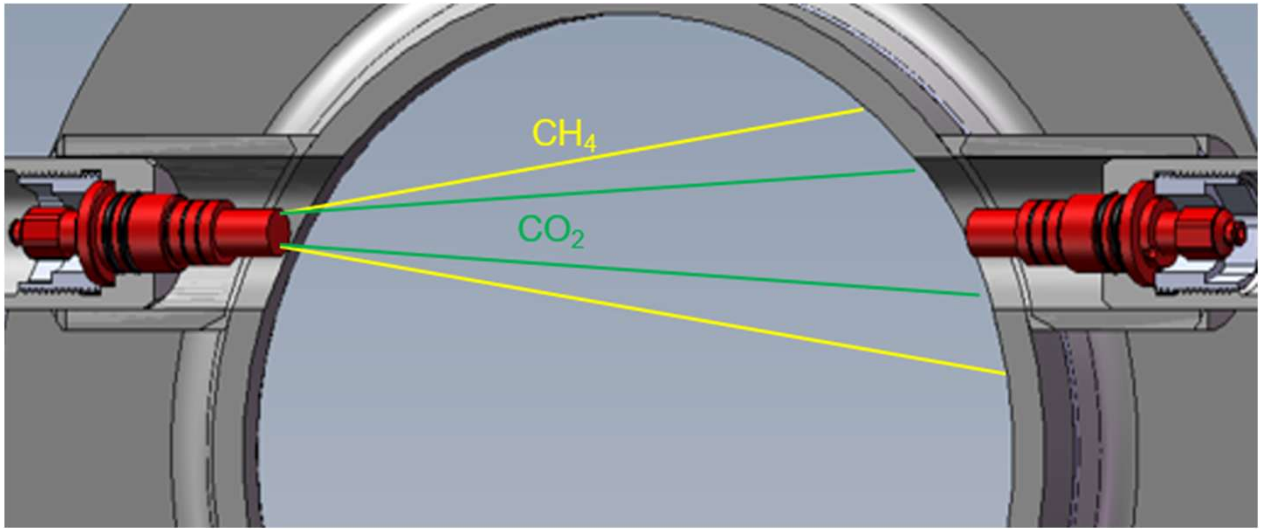
Gas CO_2:

- High acoustic damping due to molecule relaxation, molecules act like a “spring”
- To keep away from attenuation peek
  - Increase pressure (difficult due to phase properties)
  - Lower measurement frequency



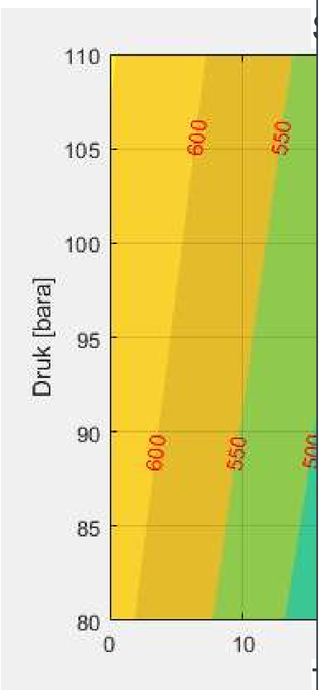
CO_2 flow measurement
Gas flow measurement

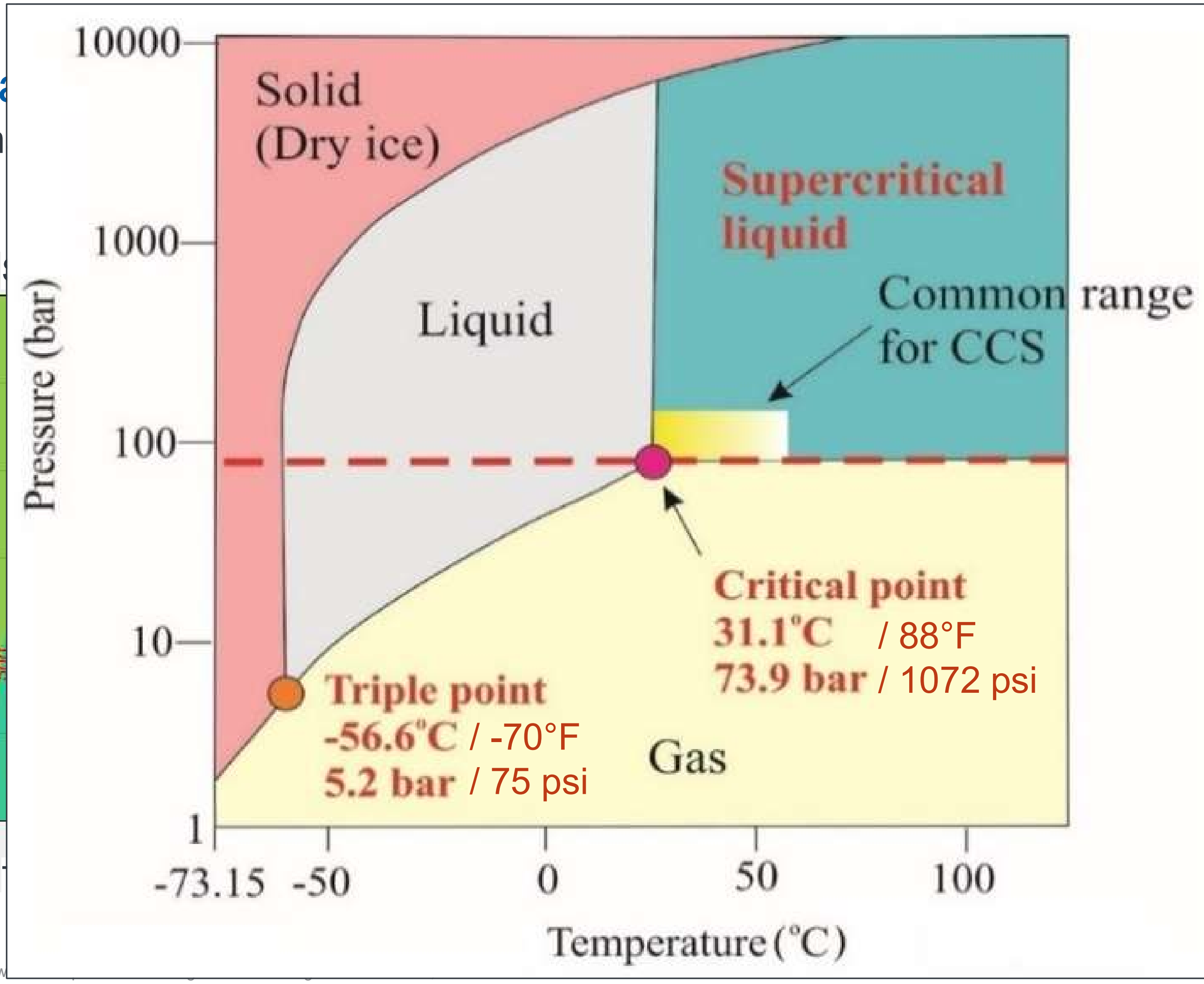
- High molecular weight: 44 g/mol
  - Propagation of the acoustic signal in the gas at a small beam angle
  - Limits flow range due to “beam blow”
- Generally, a lower transducer frequency required
  - To reduce damping
  - To widen acoustic beam

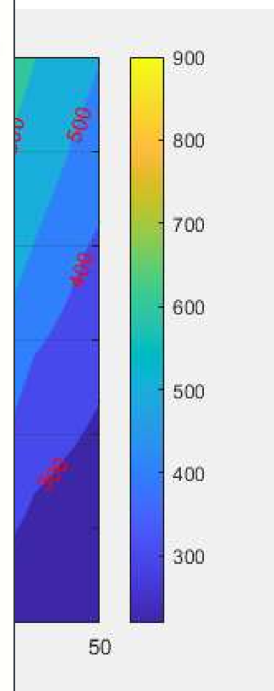


CO_2 flow mea

Supercritical ph







CO_2 flow measurement
Supercritical phase

Speed of sound low: from below 200 m/s to max 350 m/s (656 ft/s to 1148 ft/s)

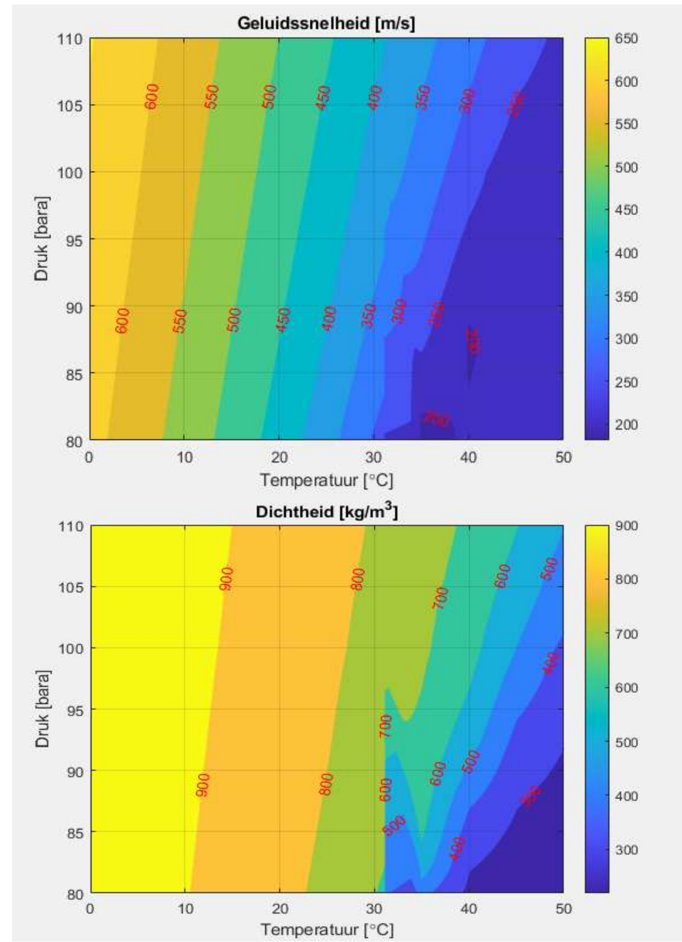
Density: 300 to 700 kg/m3. (18.3 lbs/ft^3 to 43.7 lbs/ft^3)

Specific behavior:

- Large SOS and Density change ratio on change of pressure and temperature
- High acoustic damping expected

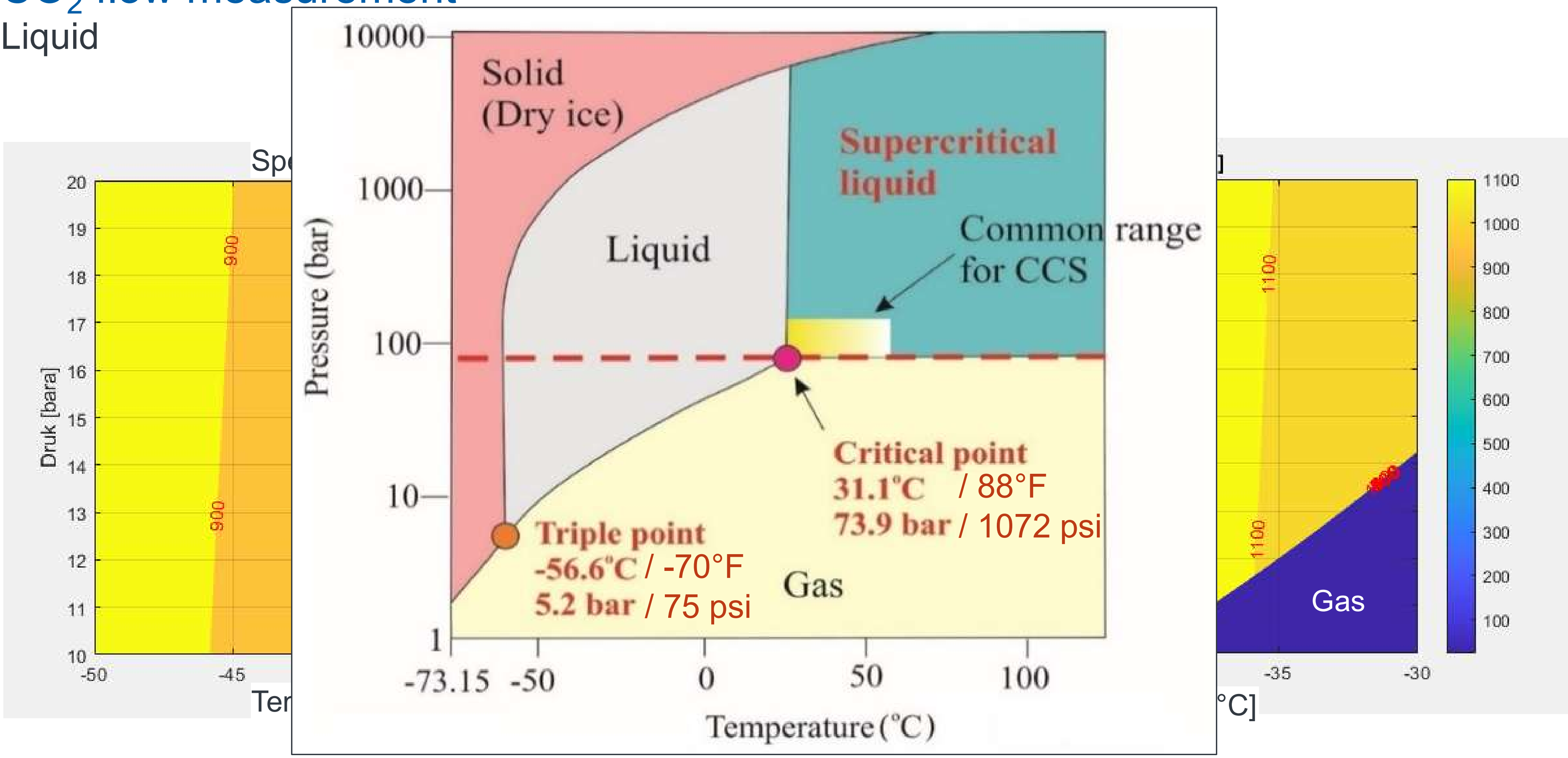
Flowmeter requirement:

- Must have short measurement interval and fast processing.
- Must adapt to fast changes in acoustic damping and density which will have a strong impact on acoustic signal strength.



CO_2 flow measurement

Liquid



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CO_2 flow measurement
Liquid phase

Speed of sound low: from 800 m/s (2625 feet/s) to 900 m/s (2953 feet/s)

Density: Around 1100 kg/m3 (968,67 $lb/ft^{3)}$

Specific behavior

- High acoustic damping expected, which will reduce at higher pressure.
- Application range close to the vapor line
- Boiling/vapor line is unclear as CO_2 is not pure

making the phase transition of liquid to gas unsure (gas bubbles may occur)

CO2 flow measurement

What instruments to use?

High dense supercritical and gas

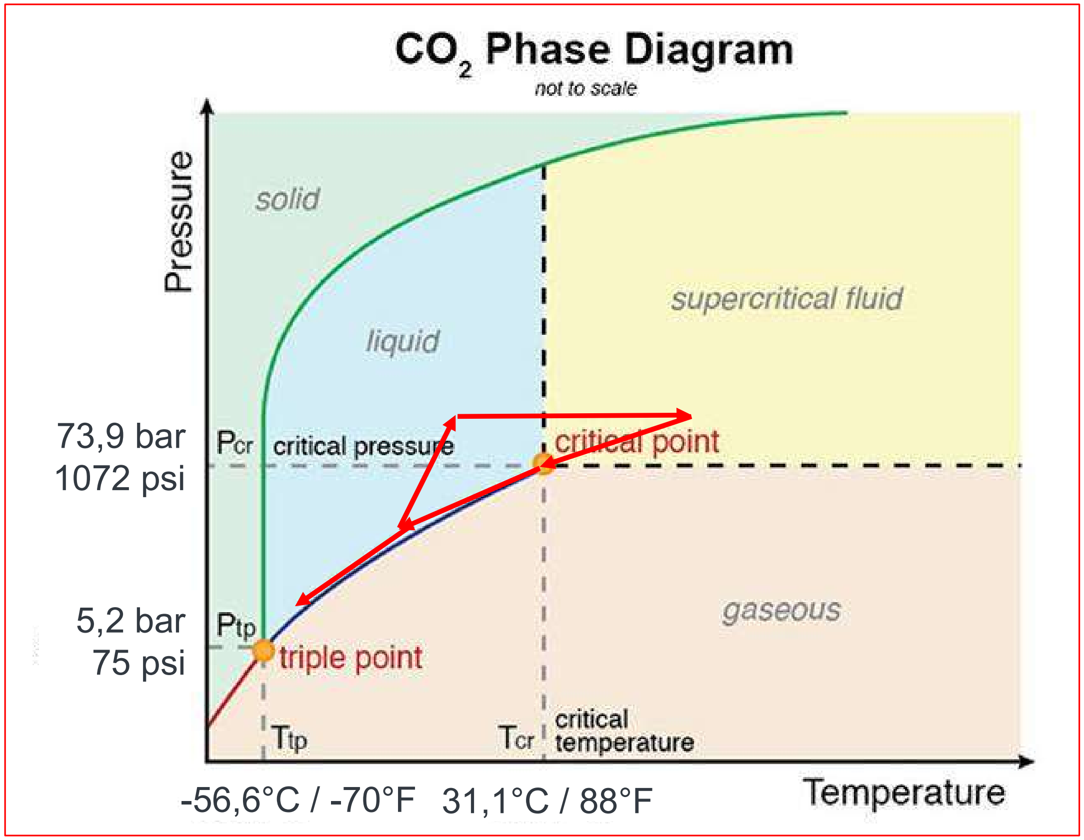
- ALTOSONIC V12 with direct paths
- Standard flowmeter

Liquid:

- ALTOSONIC 5
- Transducer for high damping fluids (lower frequency)
  (normally used for heavy crude oil)
- Challenge: CO_2 is not pure, making the phase transition of liquid to gas unsure (gas bubbles may occur)

Static CO_2 test at DNV

1. High dense / supercritical phase
2. Liquid / low temperature phase



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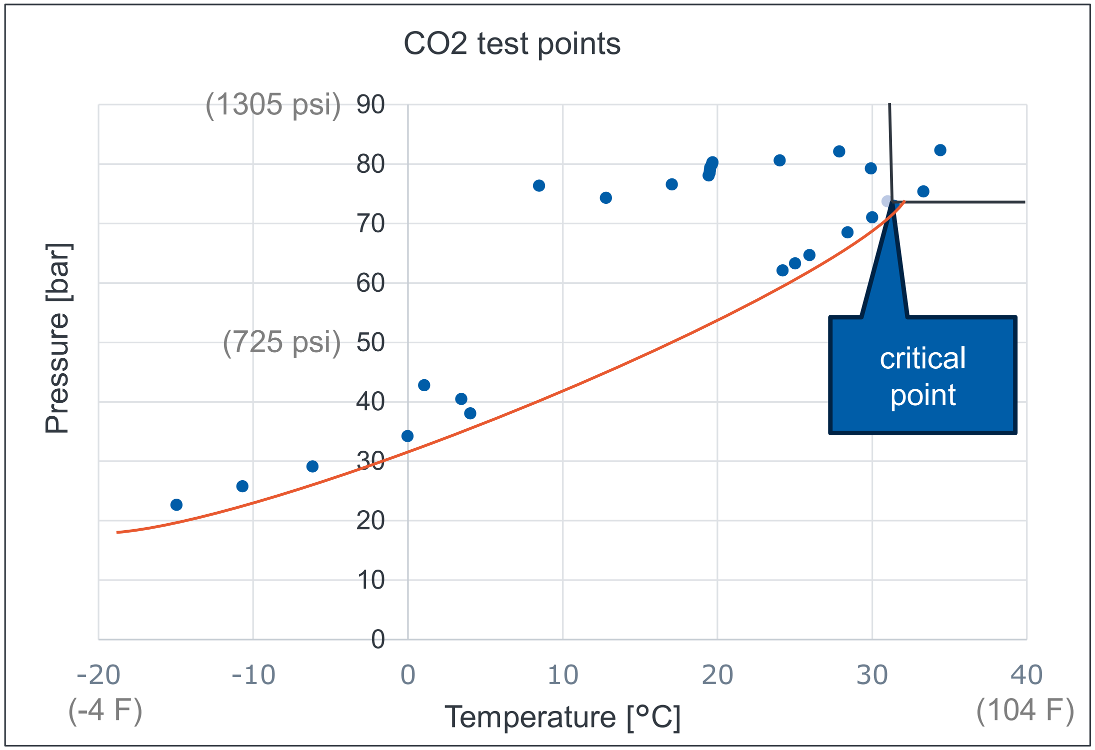
CO_2 static testing at DNV

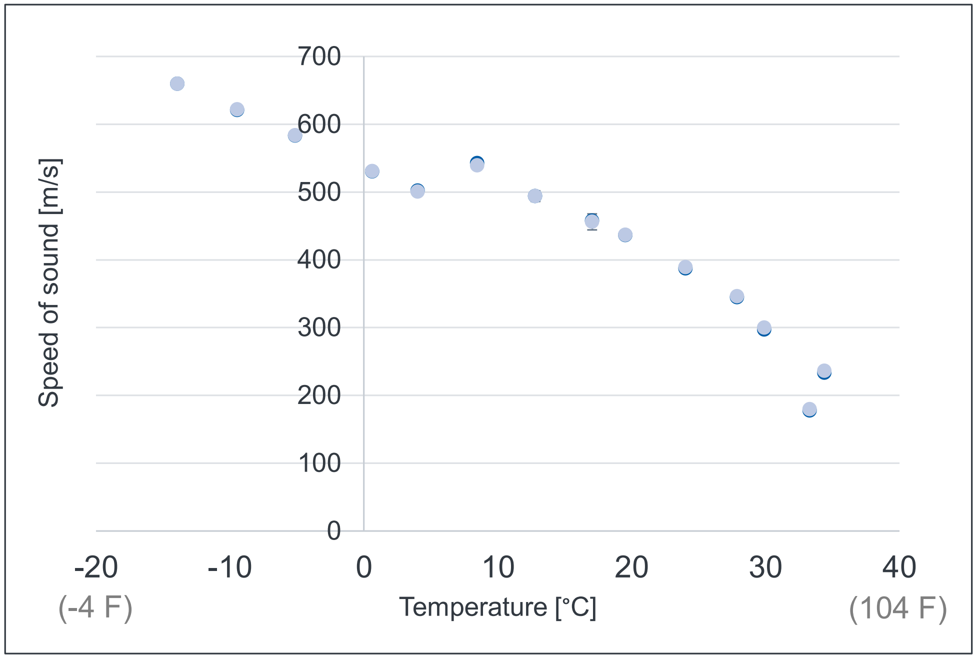
Temperature and pressure of the test points of the DNV static tests.



CO_2 static testing at DNV

SOS measurement

Calculated and measured speed of sound of CO_2.



Speed of sound results of ultrasonic measurement and EOS-CG as function of temperature. Error bars indicate the uncertainty in the reference speed of sound

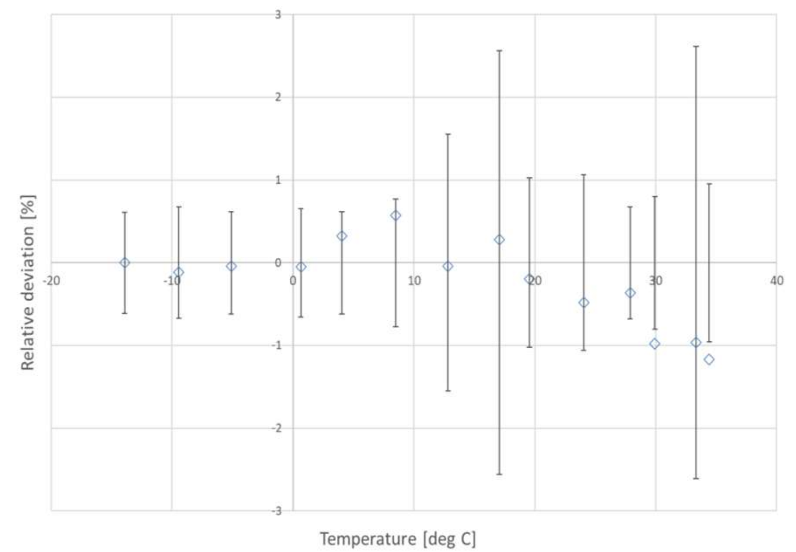


Figure 4 : Speed of sound results of ultrasonic measurement and EOS-CG as function of temperature. Error bars indicate the uncertainty in the reference speed of sound

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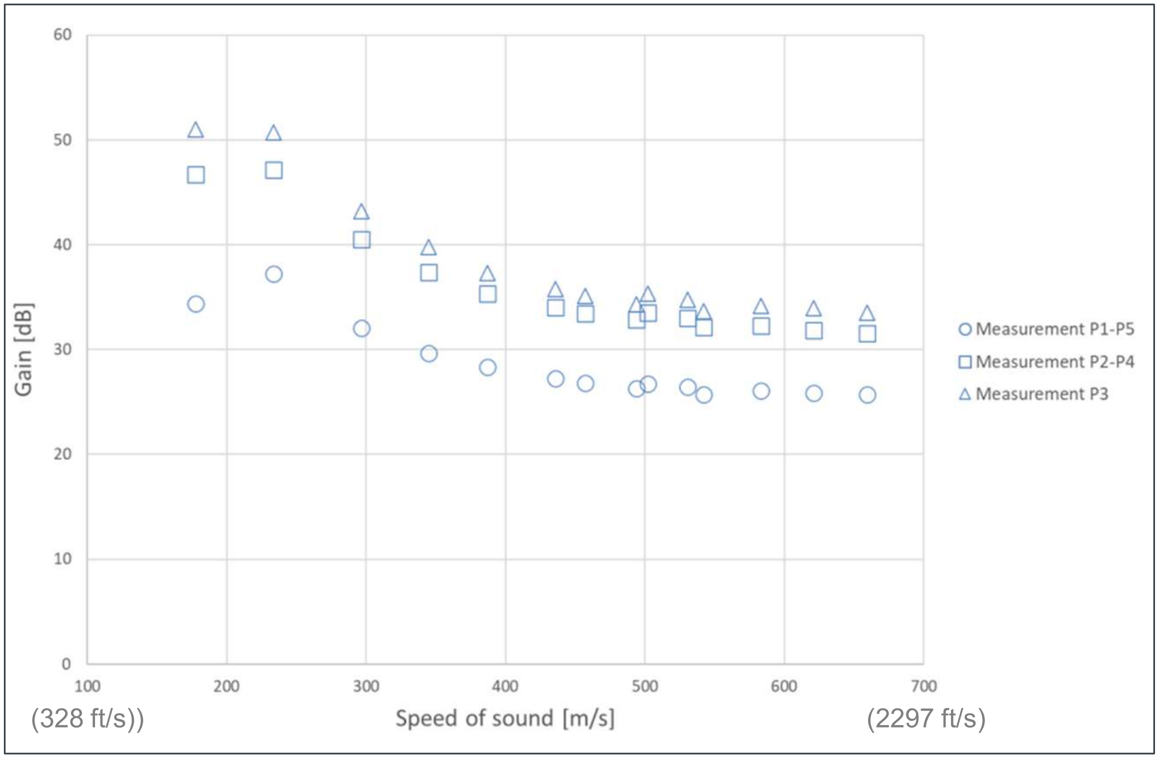
CO_2 static testing at DNV

Acoustic signal strength (gain)



Quality and attenuation of acoustic signals in supercritical CO2:

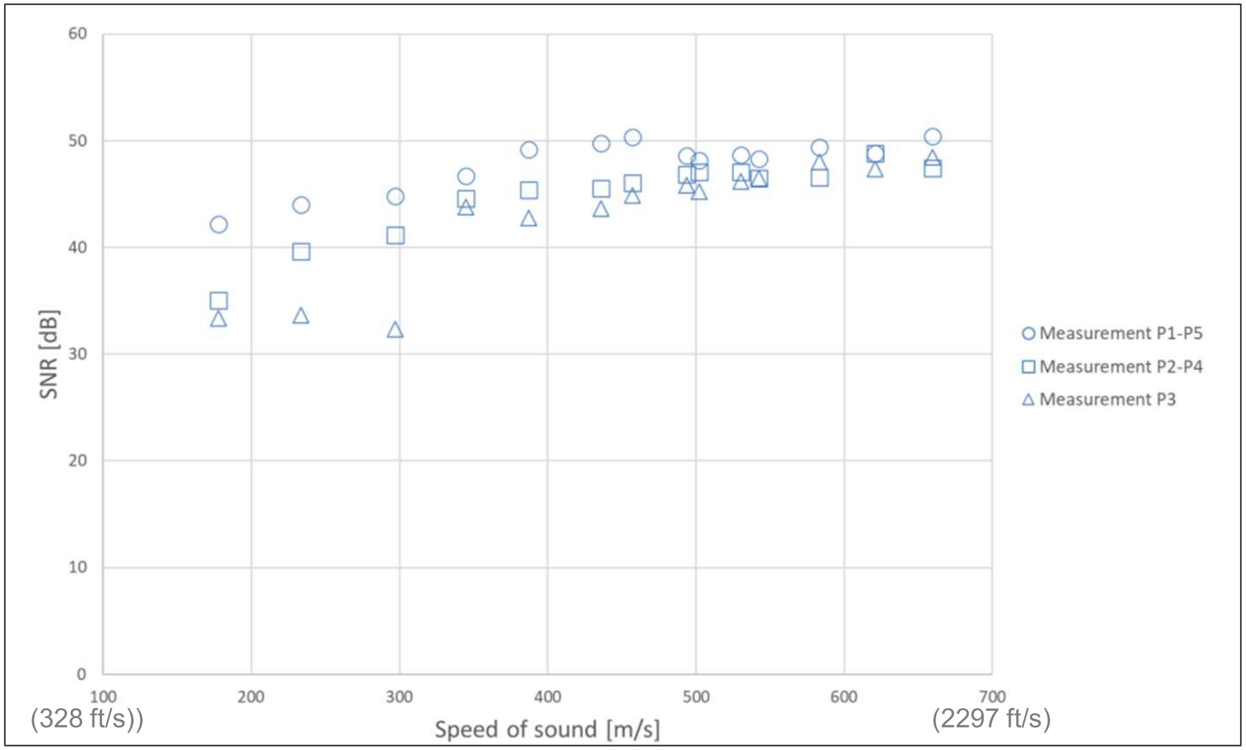
Acoustic attenuation, indicated by gain of receiving transducer should be below 70 dB

- Test result: Gain <= 52dB
- At higher temperature (towards 40°C), a higher acoustic attenuation may be expected.

Dynamic measurement performance are being demonstrated at a flow test

CO_2 static testing at DNV

Acoustic signal quality, signal to noise ratio (SNR)



Quality is determined by signal to noise ratio (SNR) and should be above 20 dB

- Test result: SNR > 30 dB

Dynamic measurement performance are being demonstrated at a flow test

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Conclusions

1. Pressurized gas phase CO2 (pipelines up to 70 Bar)

   An ultrasonic gas meter can be used with low frequency transducers
   For example, a standard 8” direct path ALTOSONIC V12 can be used on gas CO2 with a minimum pressure of 40 Barg/725 psi

2. Liquid (cryogenic) CO2, not pressurized

   A standard, direct path ALTOSONIC V12 may be used when sufficient pressure is available

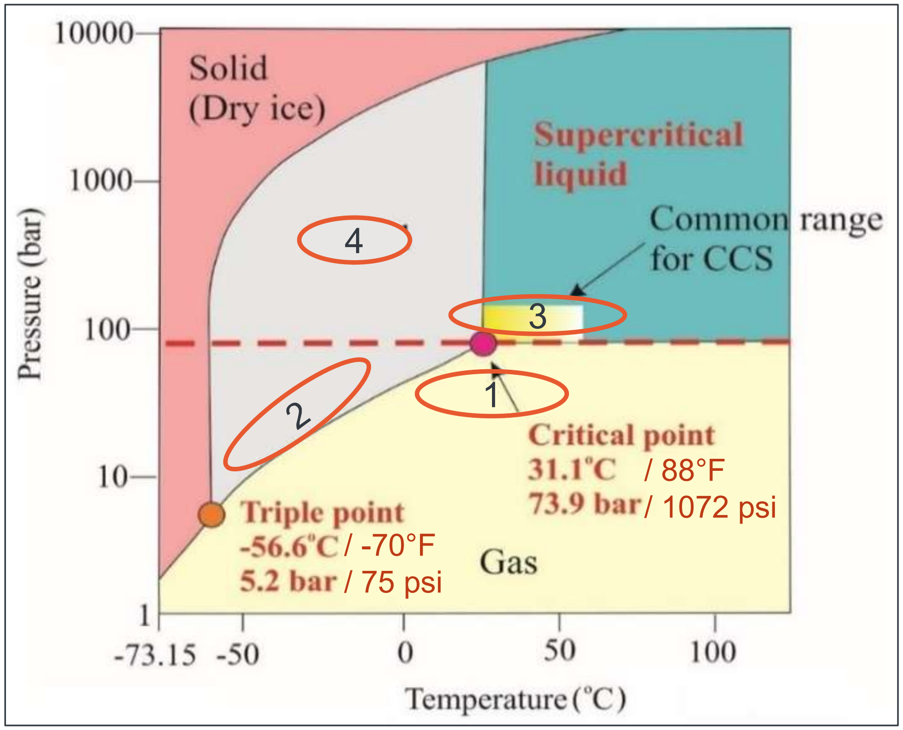
3. High dense (supercritical) CO2 (pipeline transport and injection), pressurized up to 150 bar

   A standard, direct path ALTOSONIC V12 can be used

4. High pressure liquid CO2 (injection), up to 450 Bar/6.526 psi

   A standard, direct path ALTOSONIC V12 with high pressure transducers, can be used.

Static tests with an ALTOSONIC 5 liquid UFM did not provide any suitable results



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Thank you for your attention!