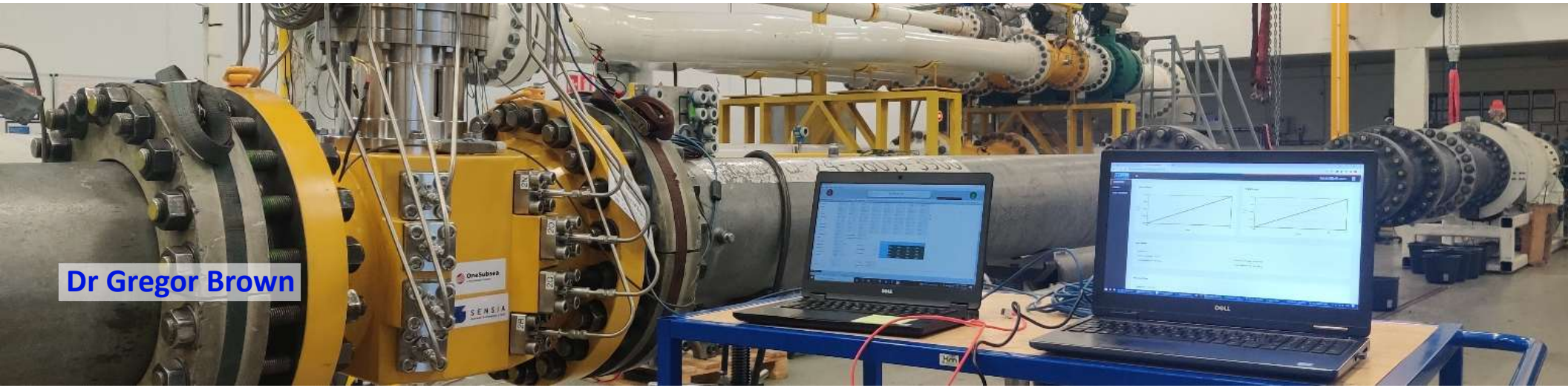
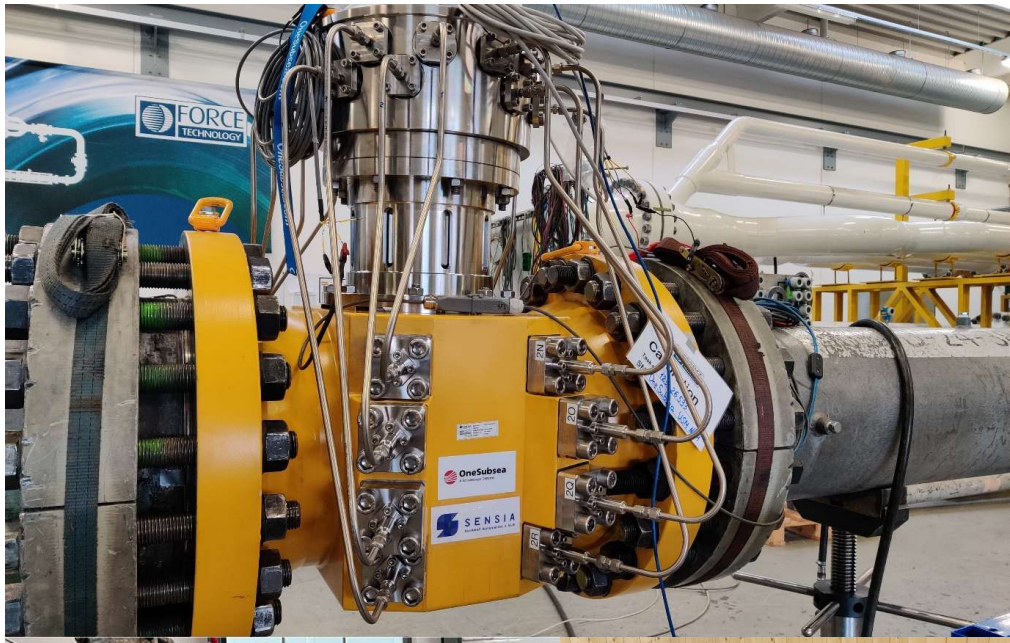
Development of a Subsea Ultrasonic Meter for Natural Gas and CO_2

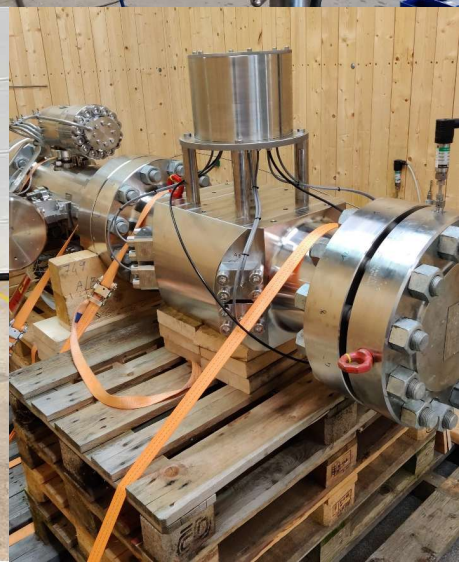


Dr Gregor Brown

Agenda

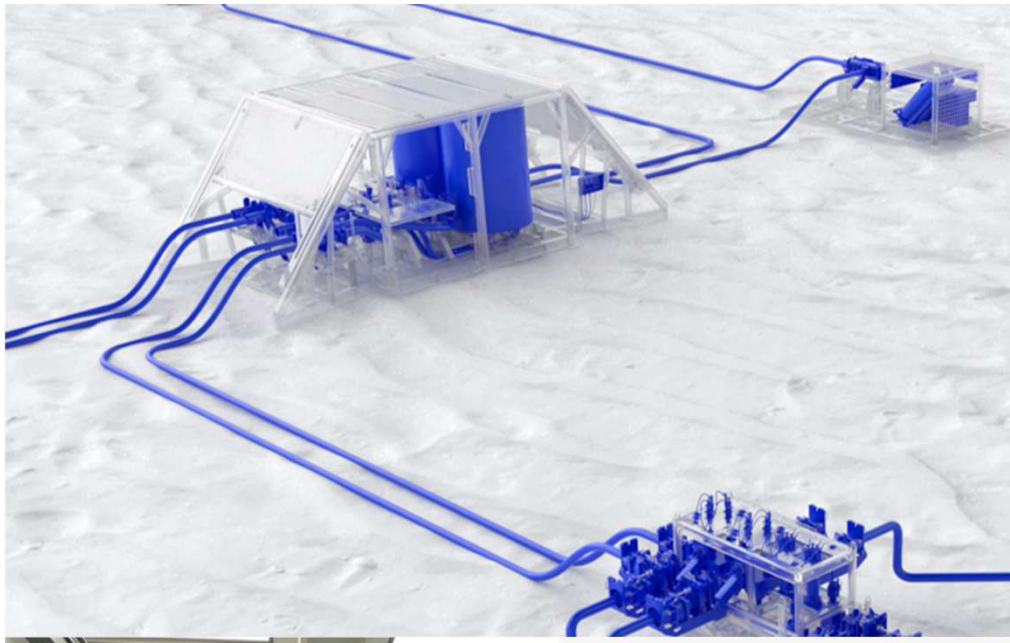
→ Background
→ Technology building blocks
→ Transducer development
→ Testing
→ Applications and prospects
→ Conclusions





Background

- → The development was initially driven by the need for subsea custody transfer metering as an enabler for Equinor's "subsea factory" concept
- → The project was funded by a partnership of SLB OneSubsea, Equinor and Gassco, in cooperation with SLB/Sensia measurement
- → The project scope was later expanded to include subsea measurement of CO_2, with financial support from the Research Council of Norway
- → The development is now in the final stages of commercialisation



slb One Subsea

equinor

GASSCO

The Research Council of Norway

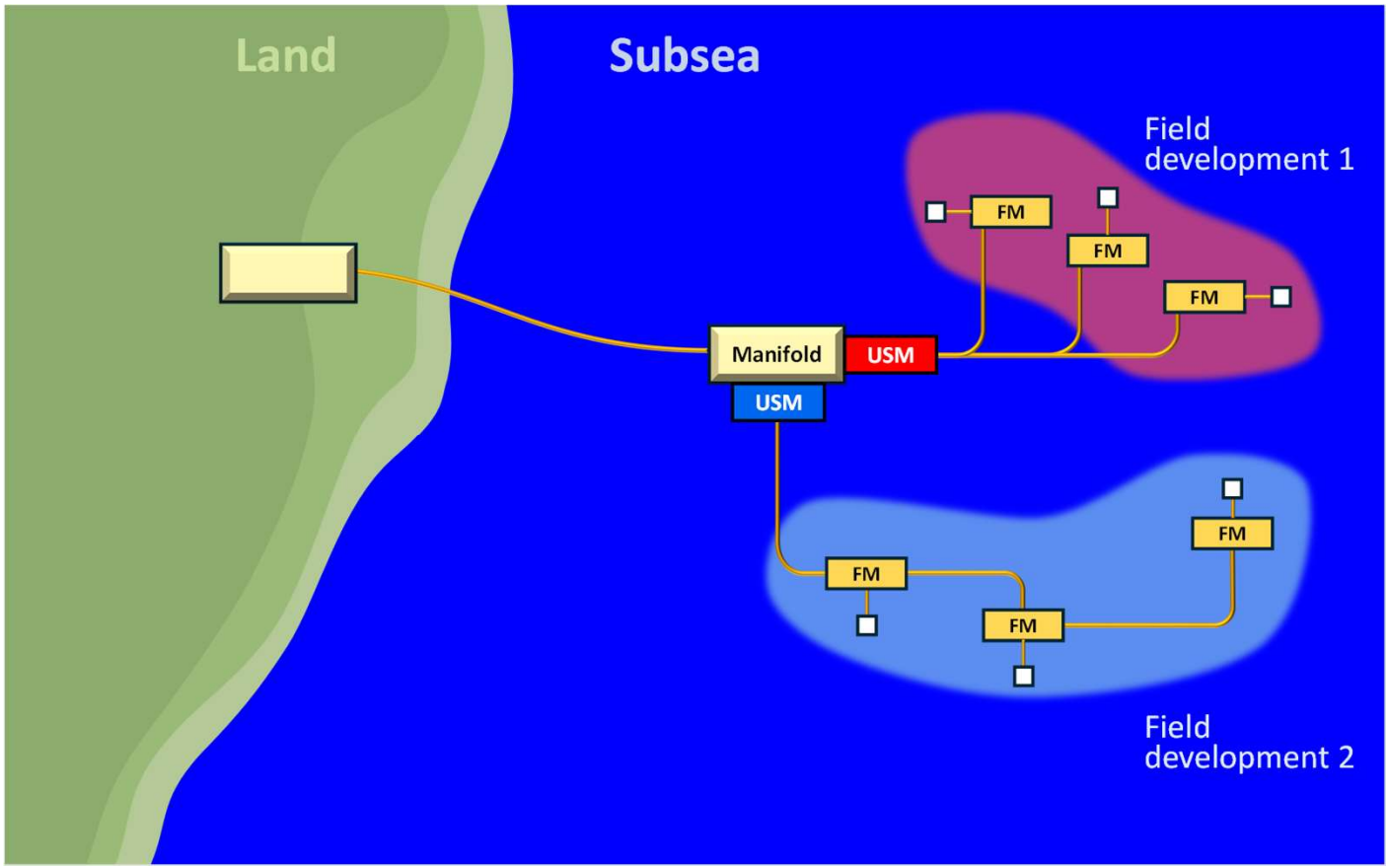
SENSIA
Rockwell Automation + SLB

Subsea gas production

Custody transfer production measurement from different fields

→ Facilitates subsea production tie-in to an existing pipeline

→ Or development of full subsea shared production and transportation



A subsea carbon storage network

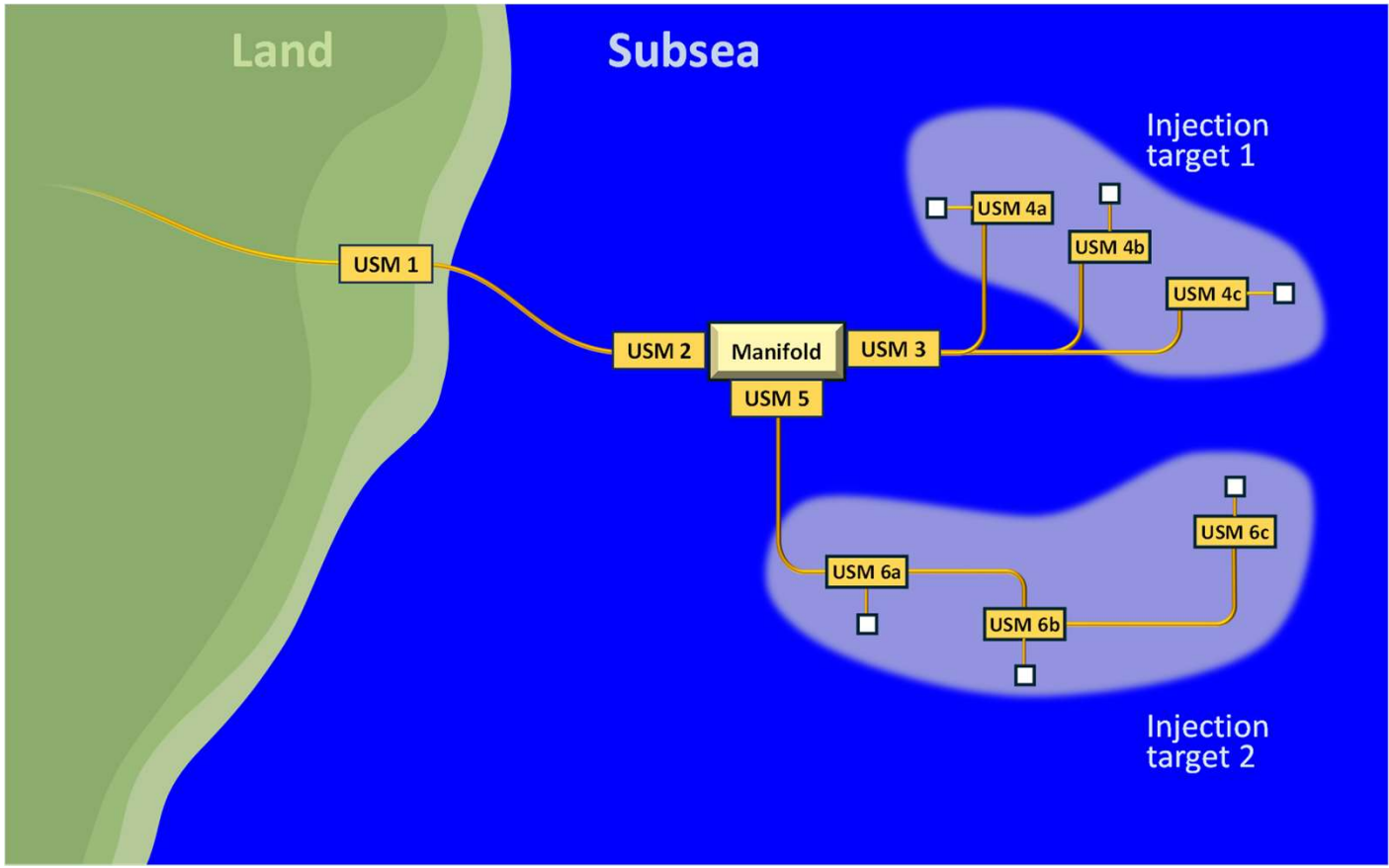
Applications include

→ Onshore export point (1)

→ Pipeline leak detection (2)

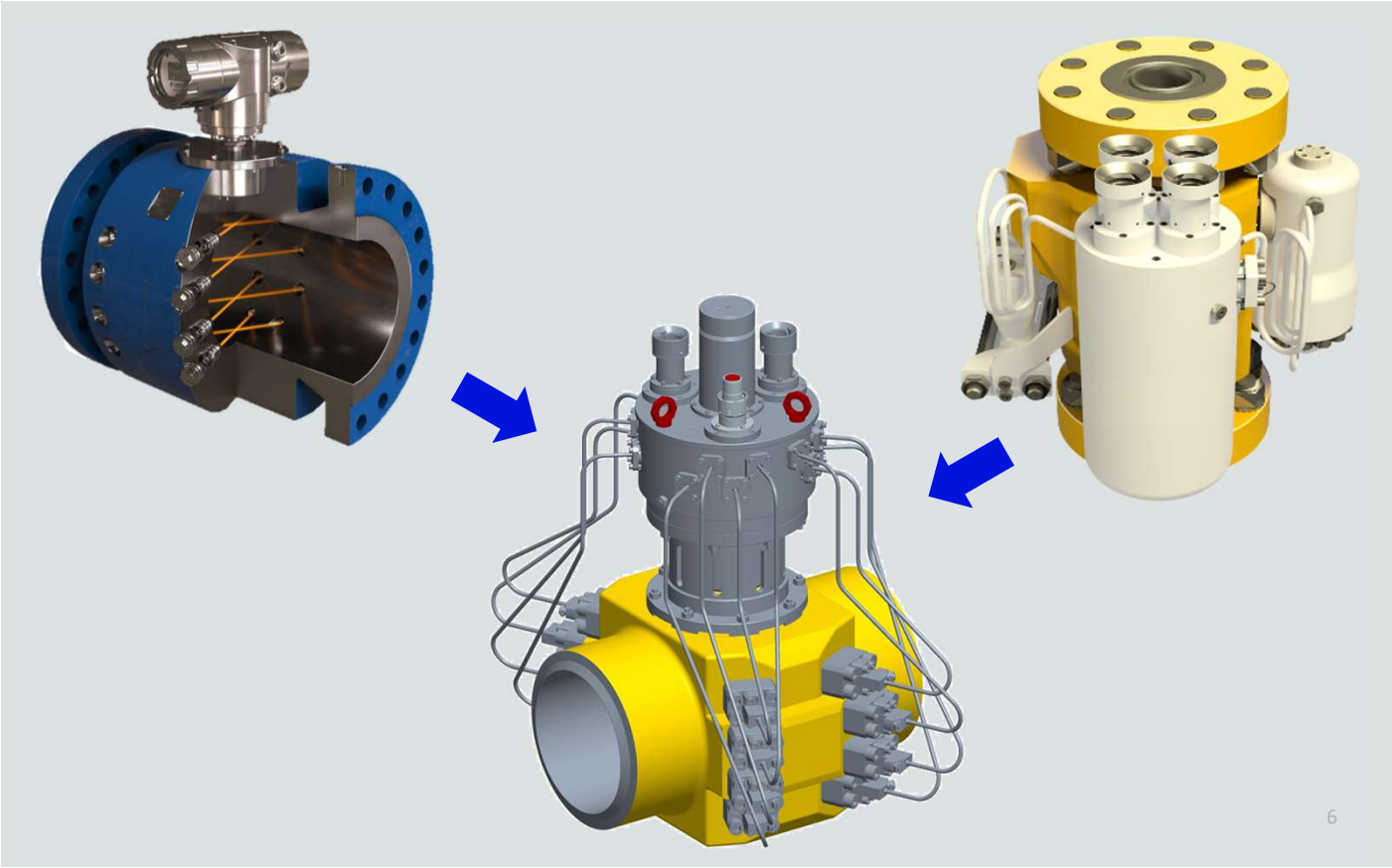
→ Field allocation (3 & 5)

→ Injection wells (4 & 6)



Ultrasonic technology building blocks and benefits

- → CALDON ultrasonic meters
  - More than 50 years of continuous development started in the 1960's by Westinghouse
- → OneSubsea subsea multiphase meters
  - Over 1000 units deployed subsea since 1990
- → Robust, non-intrusive
- → High accuracy and turndown
- → Advanced diagnostics



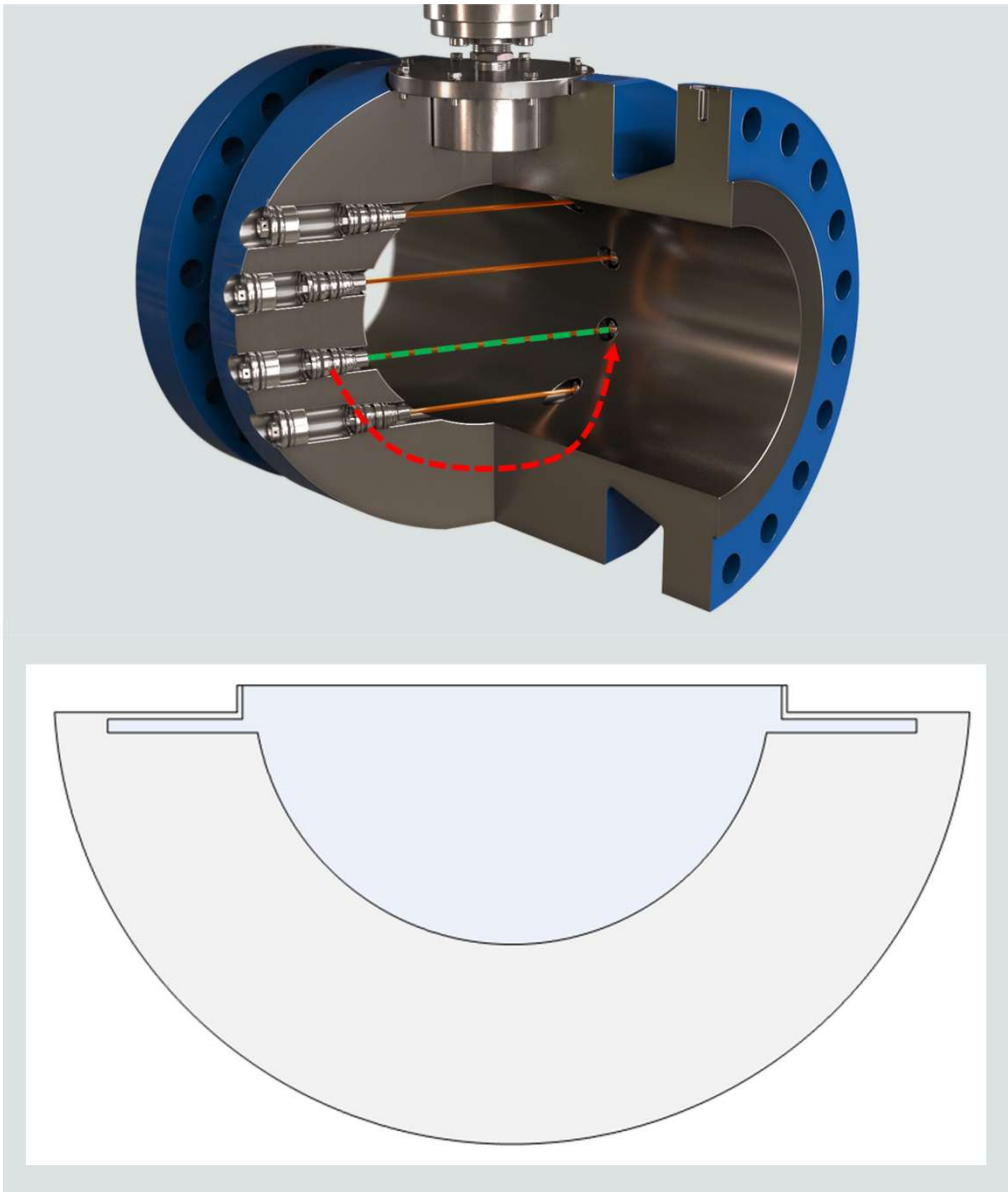
The primary technical challenge

Transducer development

→ Transducers used in land and topsides application do not meet the more stringent sealing requirements for subsea applications

→ Use of elastomeric process seals was ruled out of scope during early discussions with Equinor

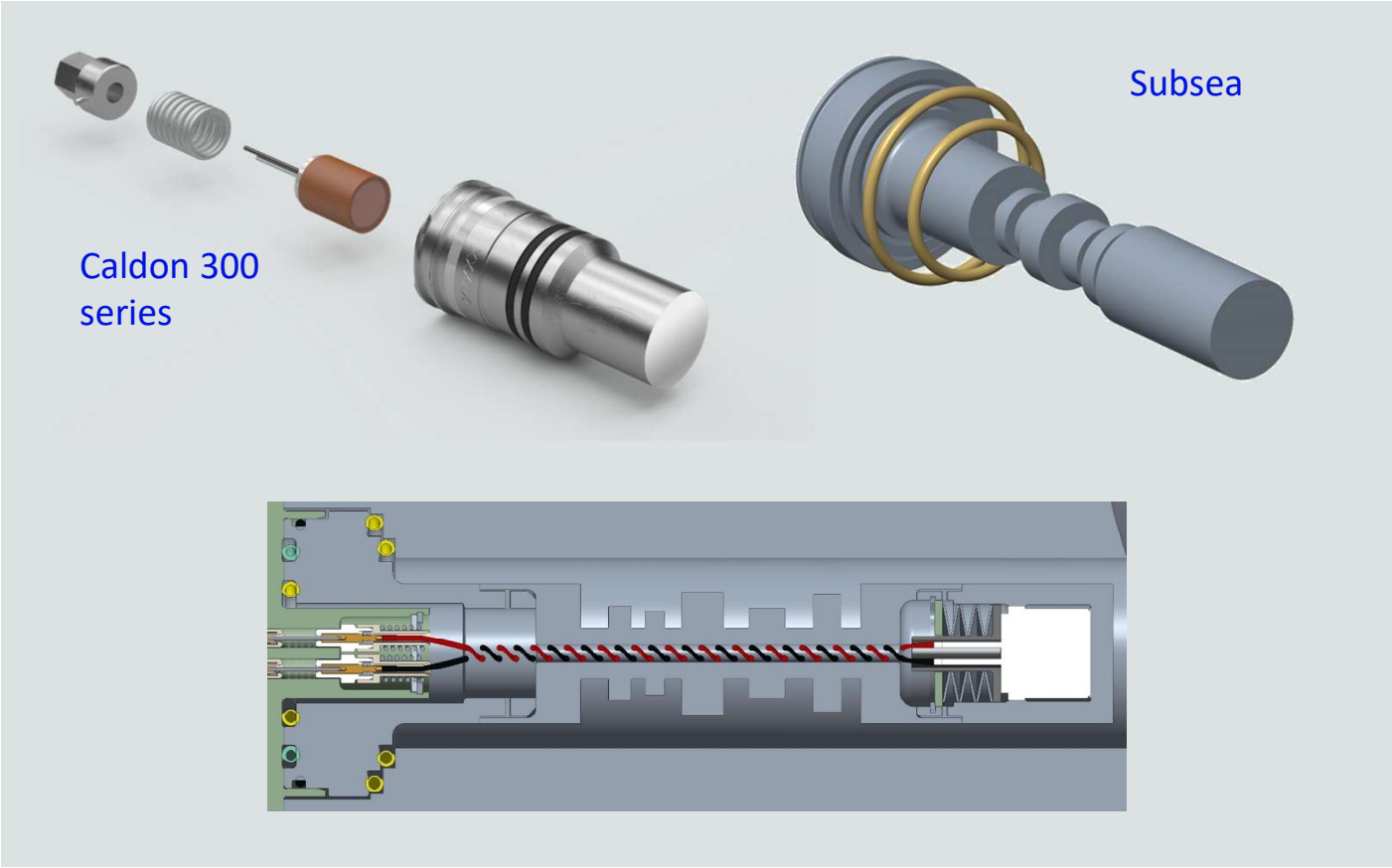
→ Metal-to-metal contact between the transducer housing and meter body can adversely affect signal-to-noise ratio, affecting accuracy



Transducers for land/topsides and subsea

→ Caldon 300 series
  - Transducer module removable from housing under line pressure
  - Elastomer o-ring seals

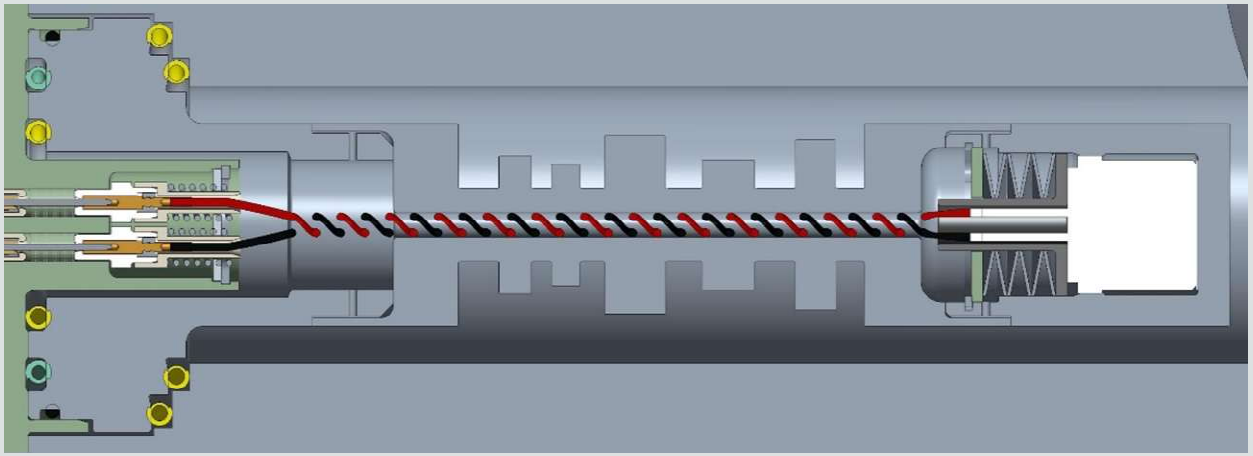
→ Subsea
  - Transducer module seal welded in housing tip
  - Metal c-rings seal transducer housing to meter body

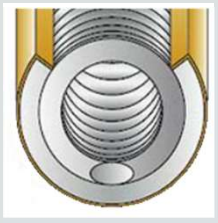


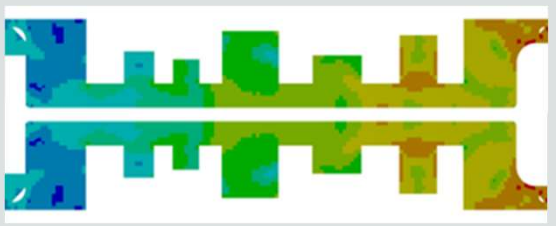
Transducers – key aspects of the subsea design

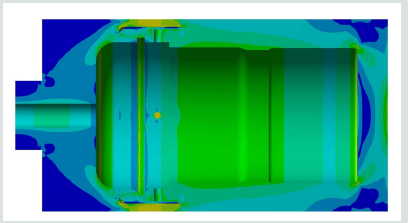
→ Gold plated c-ring seals
  - Qualified to 20 ksi and -50 to 400°F
  - Not susceptible to rapid gas decompression
  - Suitable for sour gas
  - Very low permeability
  - Long service life

→ Stem design optimized to impede noise transmission into meter body



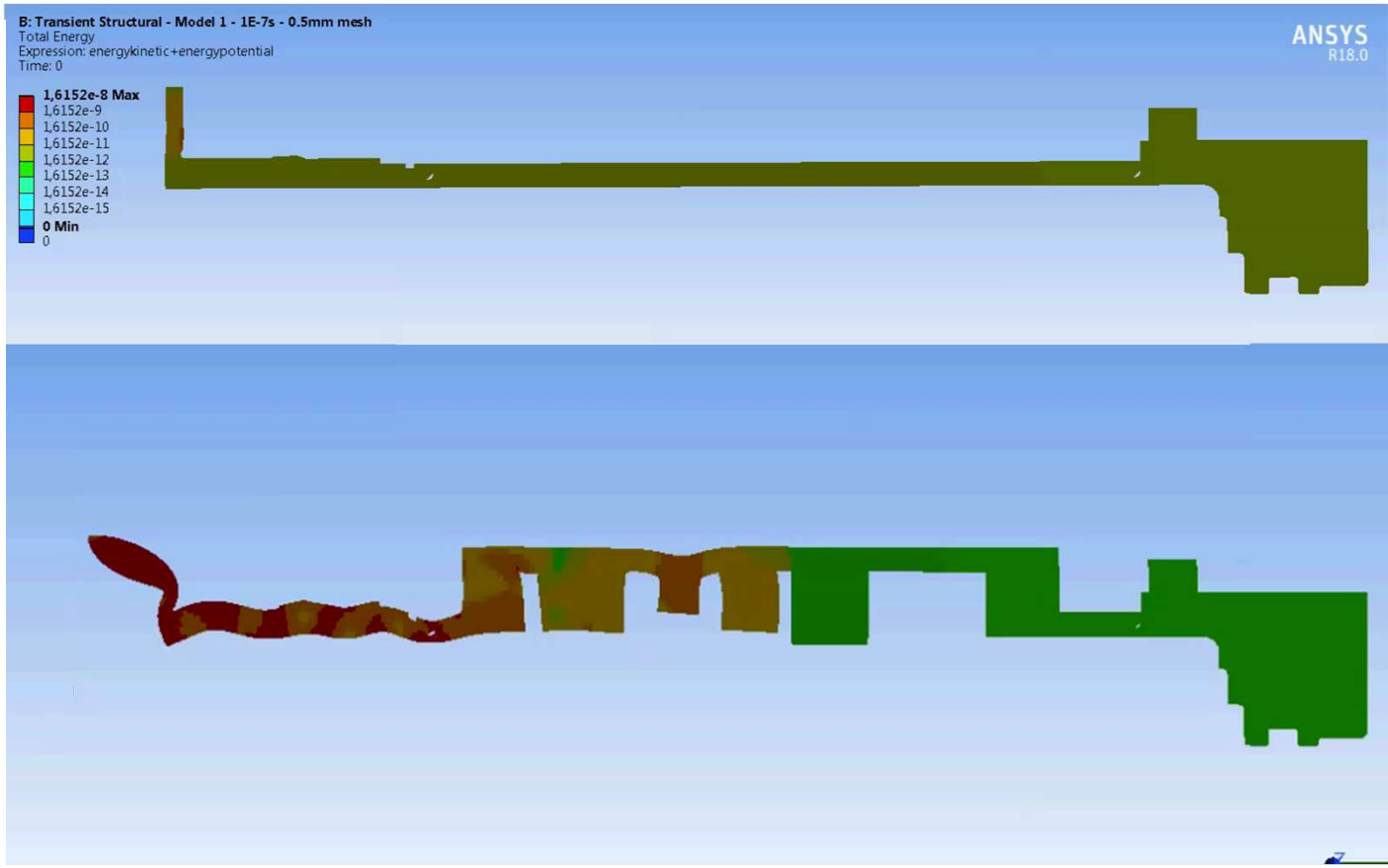






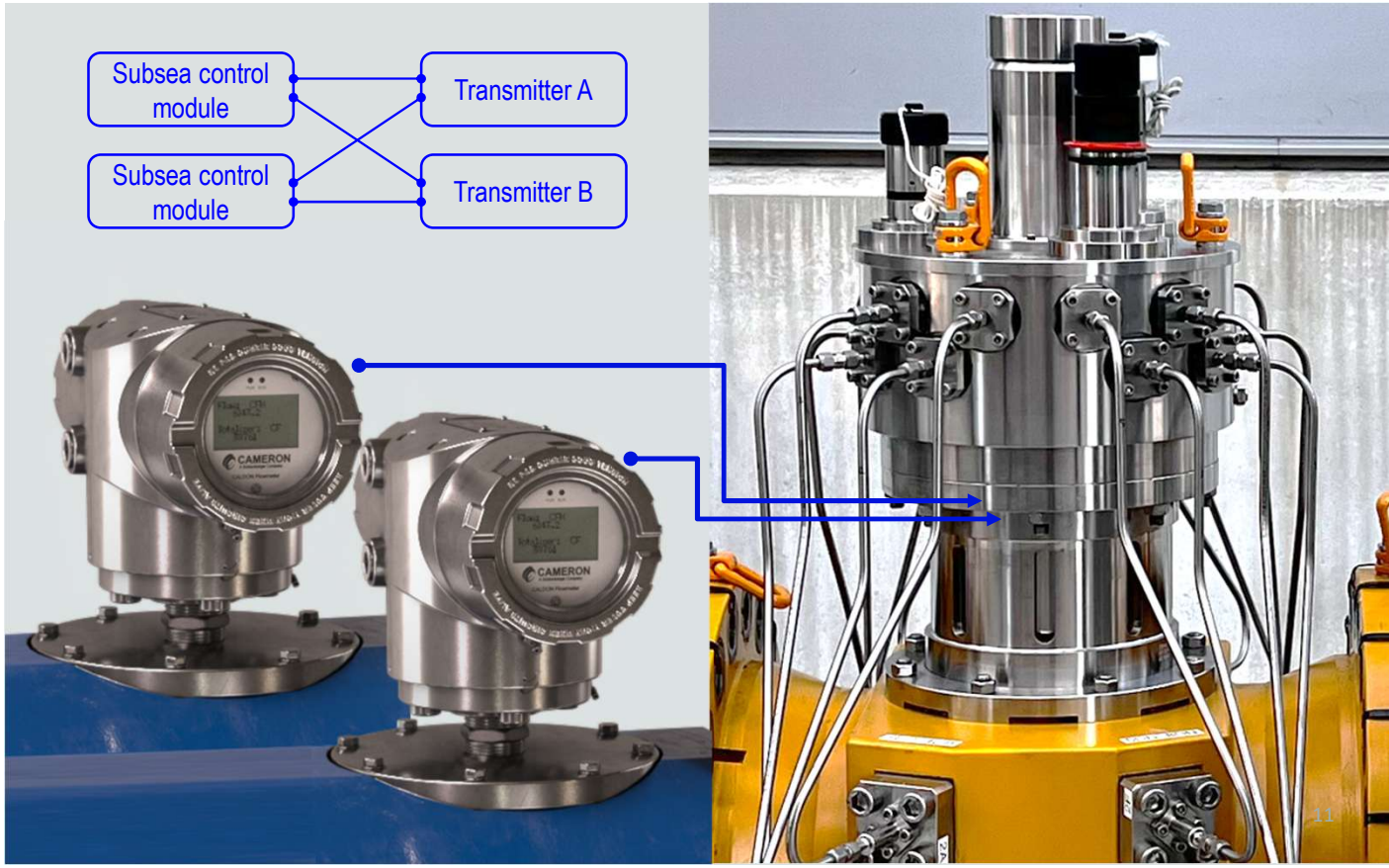
Transducer design optimisation

- → The primary source of noise is the ‘coherent noise’ generated at the same time as the signal and transmitted through the transducer housing
- → The ribbed stem acts as an acoustic filter, and has an optimised geometry designed to reduce the amplitude of the noise that reaches the sealing area of the housing



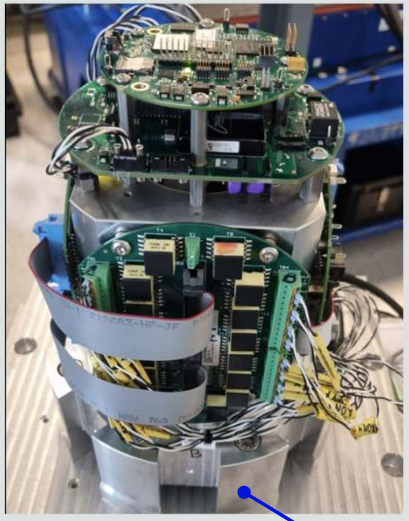
Electronics

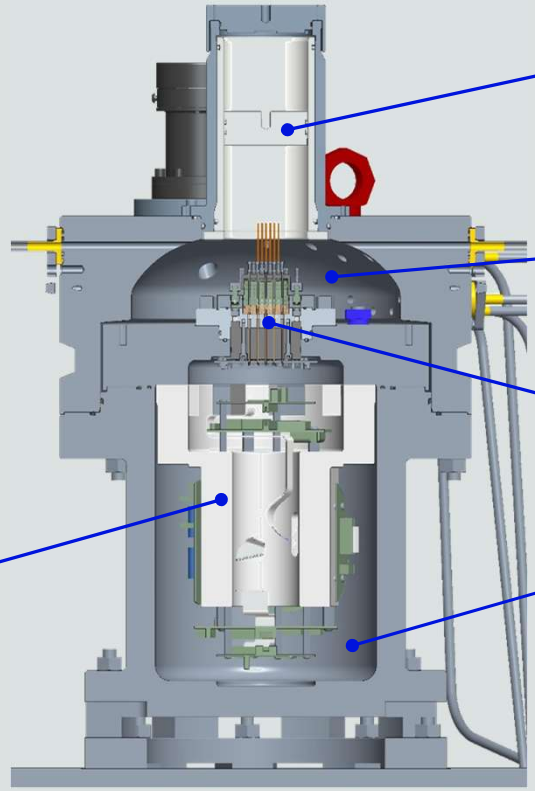
- → Based on the third generation (G3) electronics used Caldon custody transfer flow meters
- → Two complete transmitters in one enclosure for redundancy, each with redundant power and communications
- → Modified board layout to increase robustness against shock and vibration



Electronics

- → Electronics and enclosure designed to meet rigorous subsea standards
  - Including API 17F
- → Electronic boards are in atmospheric chamber, with glass-to-metal seals and a pressure-balanced oil filled cavity separating the electronics from the process connections





Static and flow testing

Static tests

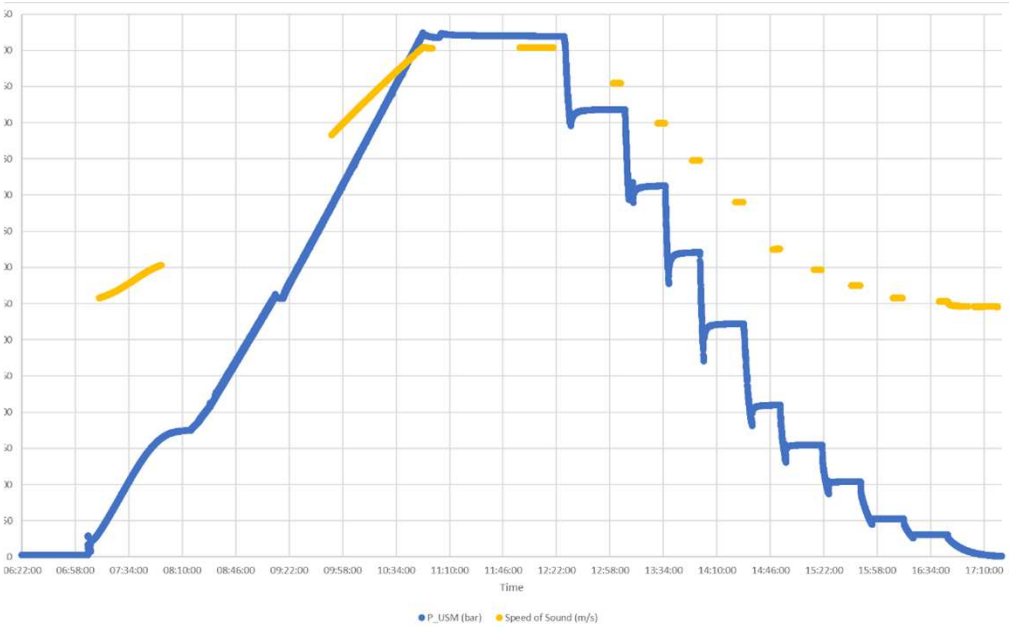
→ Hydro static tests up to 15 ksi (1035 bar)

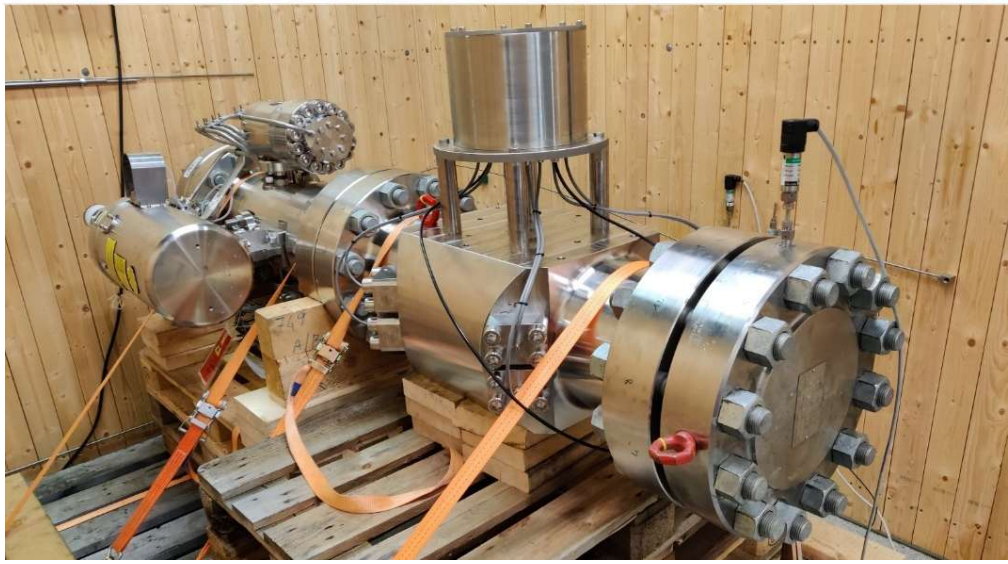
→ Nitrogen gas tests up to 10 ksi (690 bar)

- Example on the right, blue is pressure, yellow is the measured speed of sound

→ Signal evaluation tests

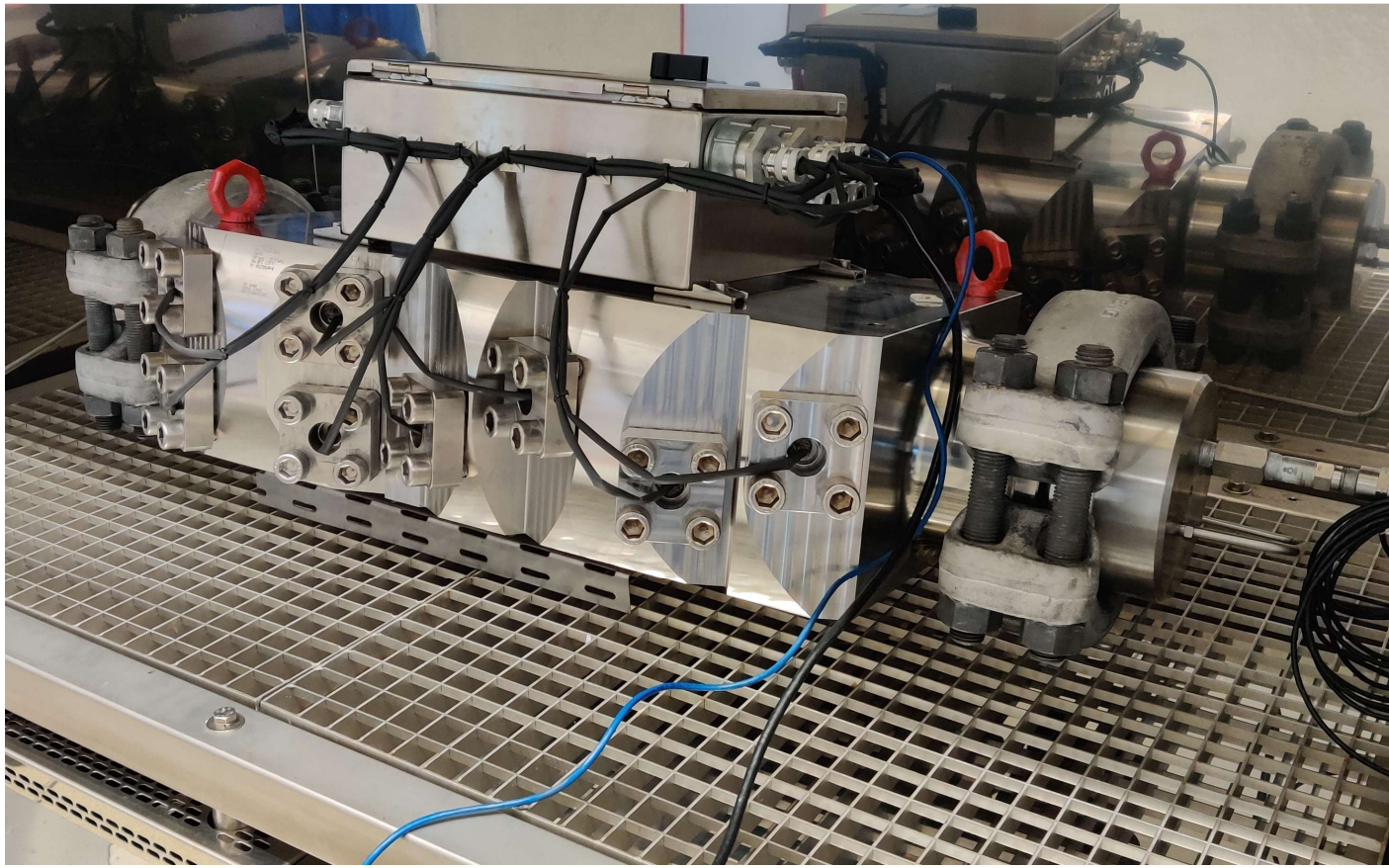
- Water
- Nitrogen
- CO_2
- CO_2 / nitrogen mixtures





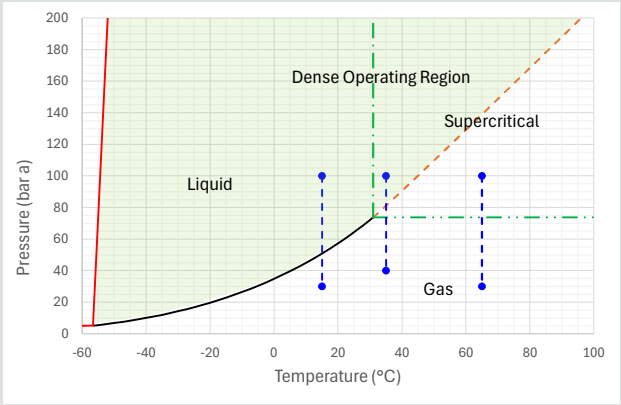
CO_2 static test on 6” meter

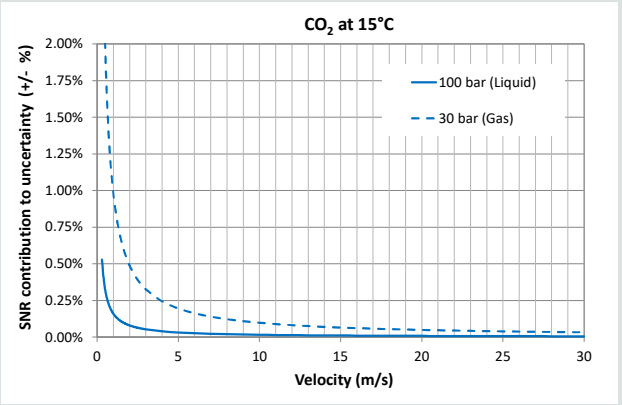
- → Tests starting at 100 bar and dropping to 30 or 40 bar in stages
- → Three temperatures of 15, 35 and 65° C
- → Conditions spanning liquid, supercritical and gas regions of the phase diagram

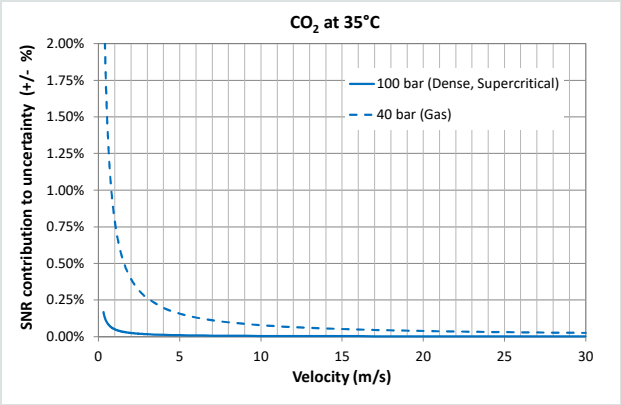


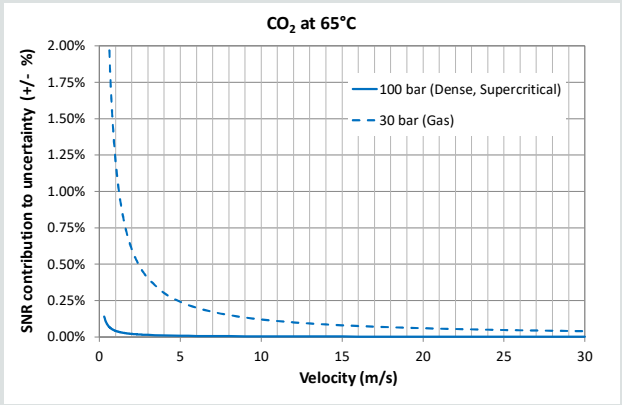
CO_2 static test on 6” meter

- → Very good signal-to-noise ratio (SNR) and resulting low uncertainty in transit time difference in liquid and dense supercritical CO_2
- → Acceptable SNR for measurement in the gaseous phase above 30 to 40 bar



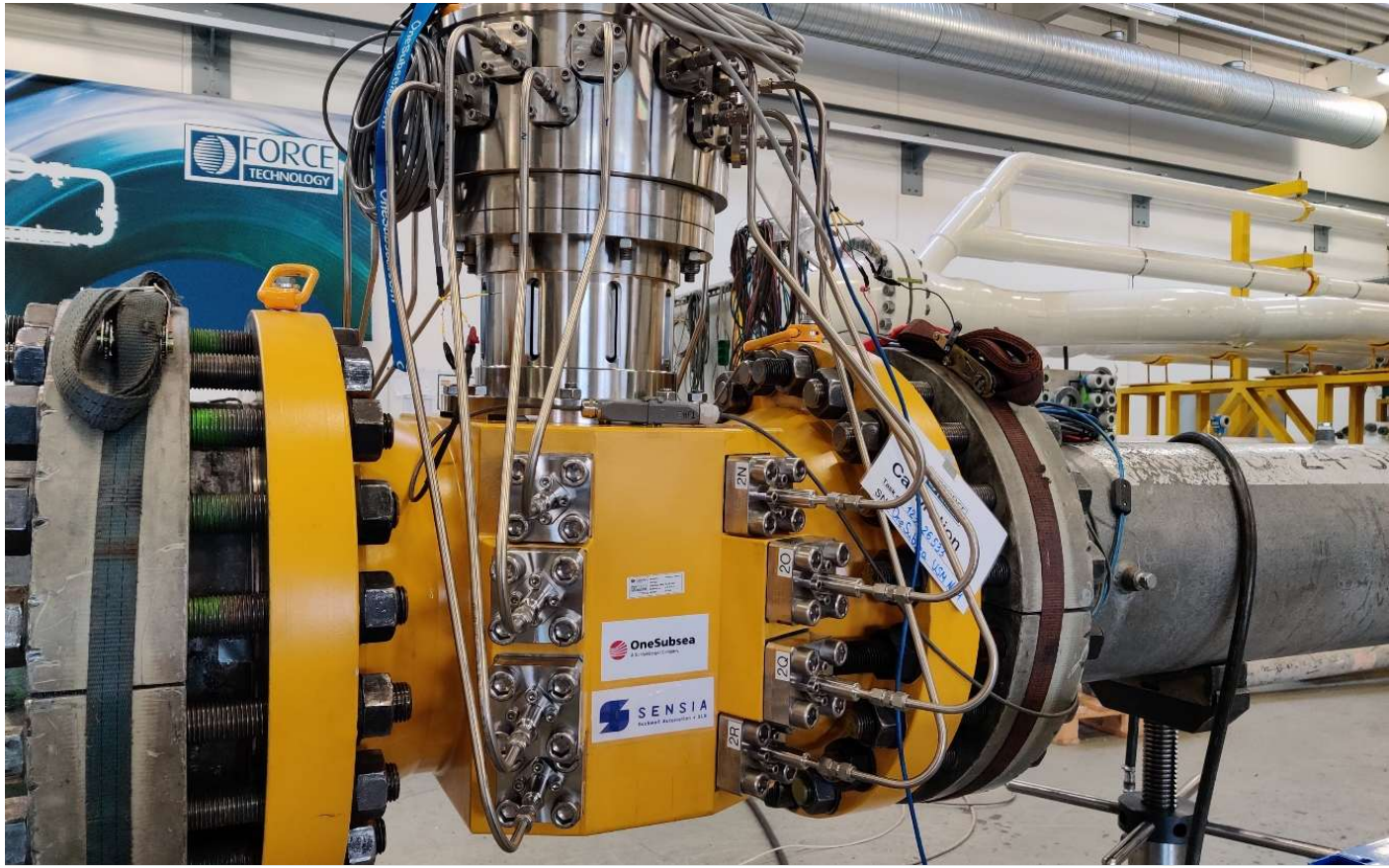






Custody transfer qualification testing at Force, Denmark

- → ISO 17025 Accredited Lab
- → Natural Gas
- → Pressure 60 bar(a)
- → Temperature 20 °C
- → Velocity 1 to 120 ft/s
  - 0.3 to 36 m/s

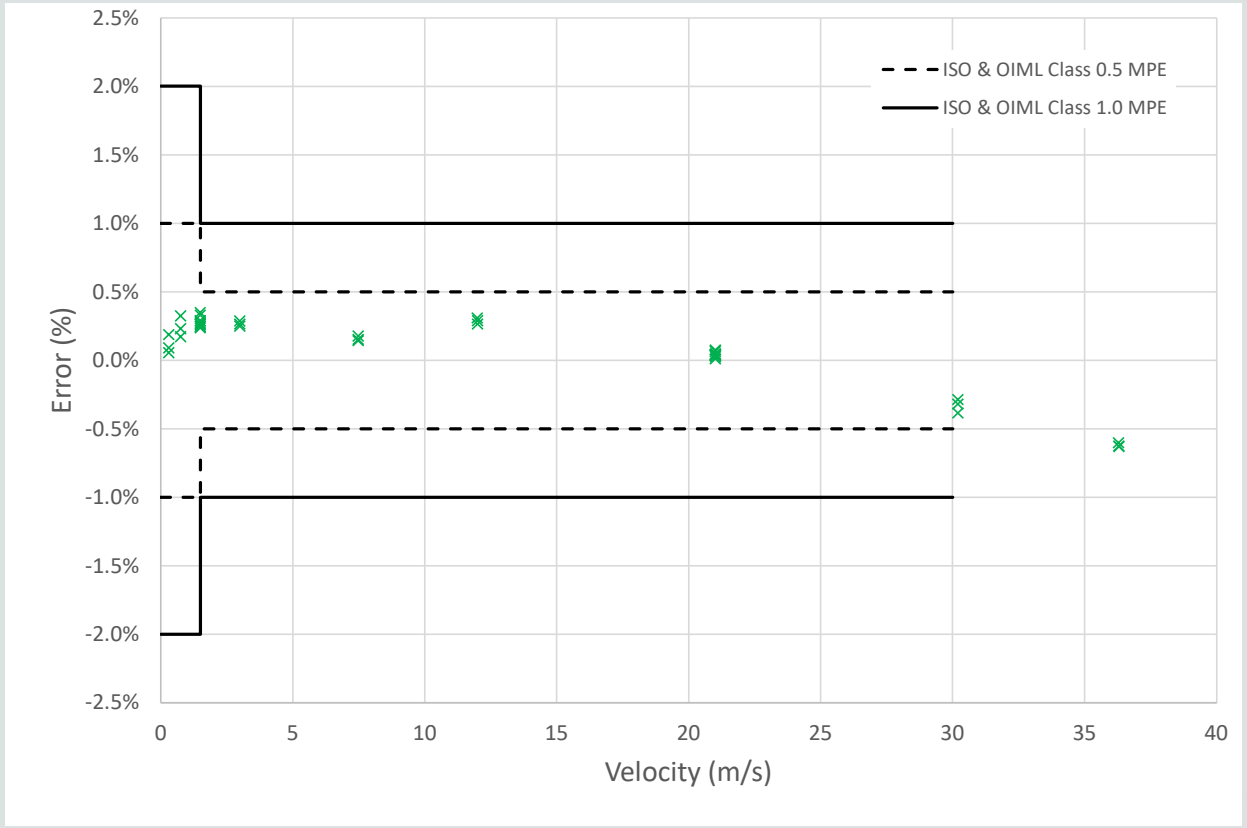


Custody transfer qualification testing at Force, Denmark

Maximum Permissible Error

→ Qualification criteria was to comply with ISO/OIML Maximum Permissible Error and Repeatability requirements for custody transfer over the operating range of 0.3 m/s to 30 m/s (1 to 100 ft/s)

→ Results comply with Accuracy class 0.5



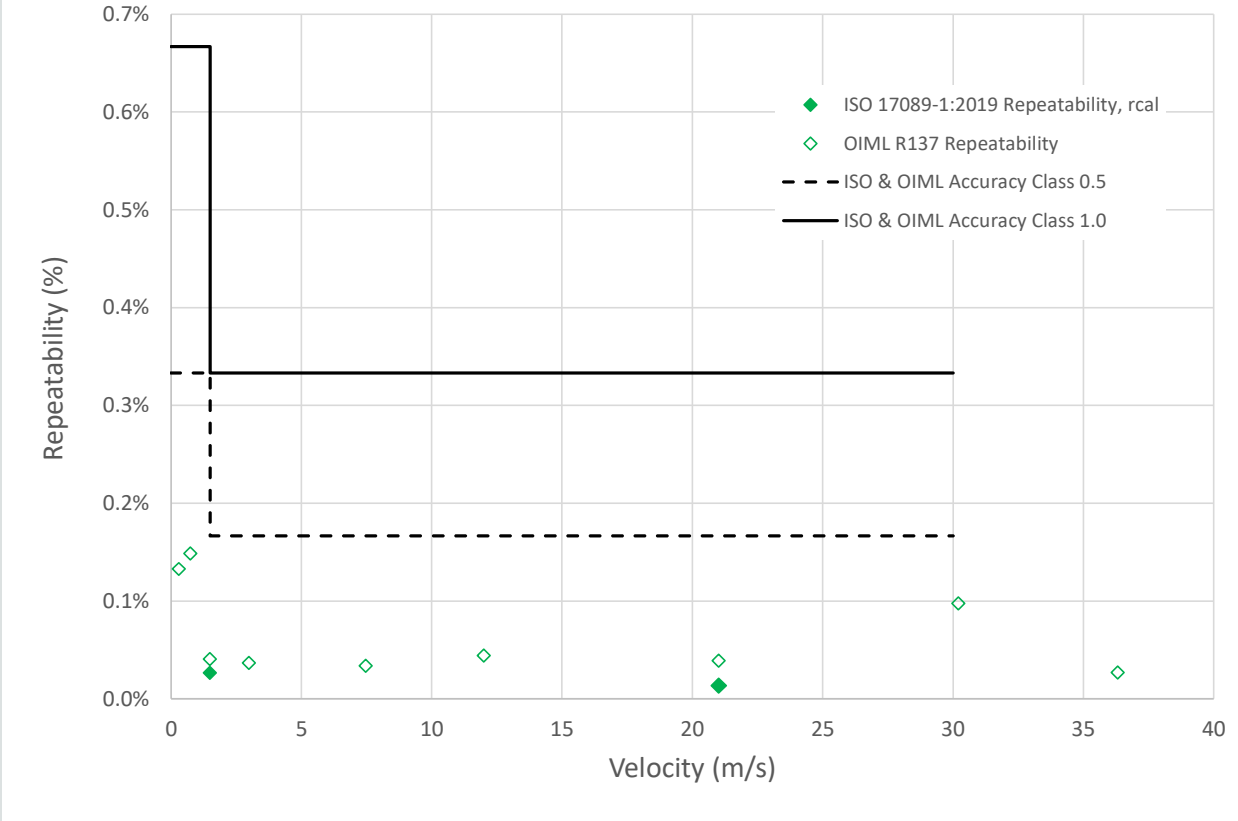
Custody transfer qualification testing at Force, Denmark

Repeatability

→ OIML 3-point repeatability evaluated at all flowrates

→ ISO 10-point repeatability evaluated at 21 m/s (63 ft/s) and marginally below 1.5 m/s (4.5 ft/s)

→ Compliant with Accuracy Class 0.5

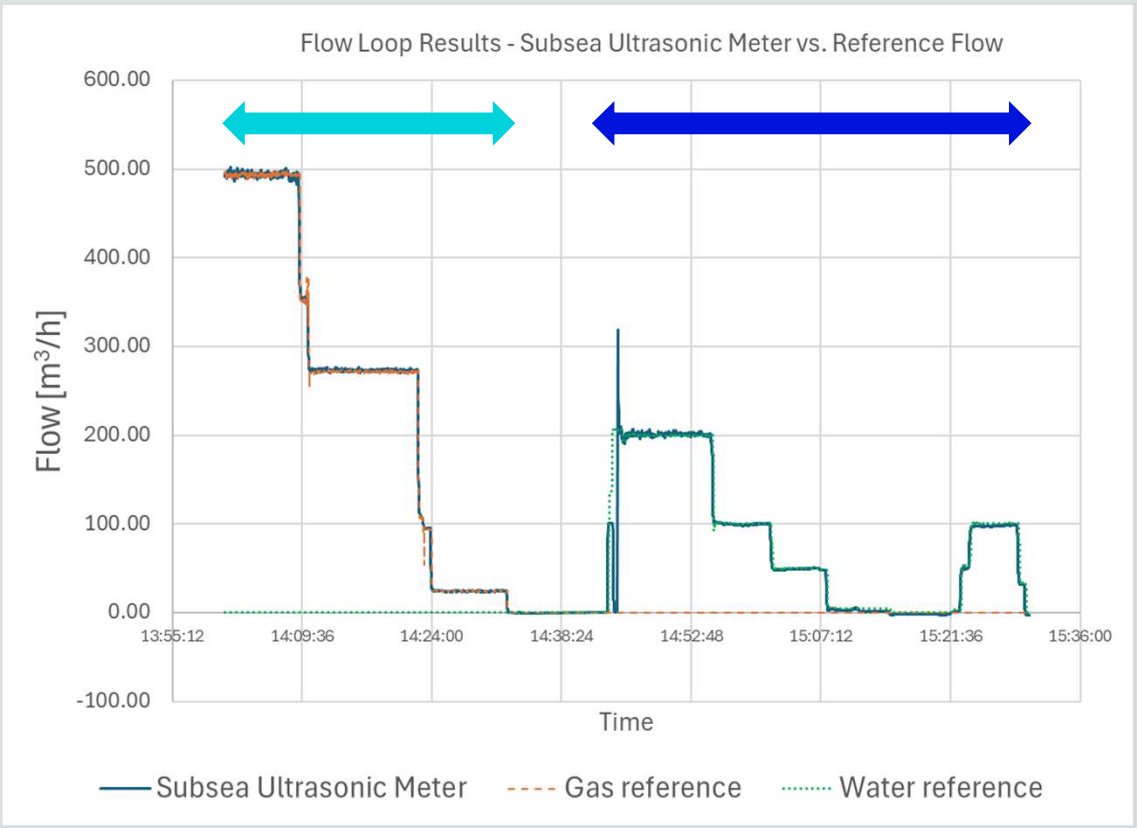


Water-alternating gas injection (WAG) trials

- → The subsea meter can handle a wide range of density and sound speed
- → In water-alternating-gas injection the meter can operate in both regimes without requiring configuration changes
- → This has been demonstrated in the OneSubsea multiphase flow testing facility in Horsoy, Norway
- → Various configurations have been tested – the one to the right shows a 7” 4-path meter installed with a blind-Tee upstream

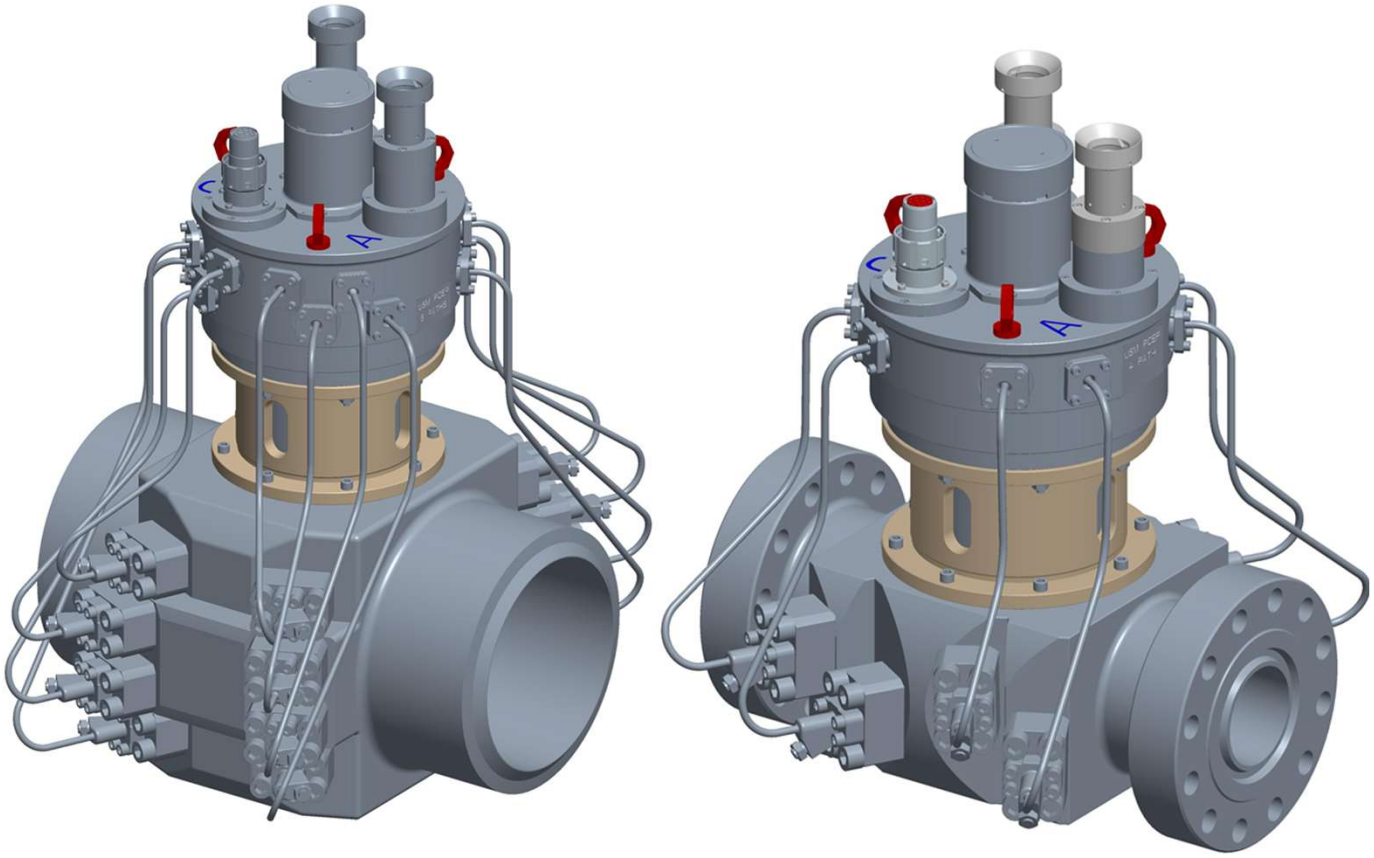
Water-alternating gas injection (WAG) trials

→ The results to the right show the time series data of meter operated first with nitrogen gas and then with water



Product range

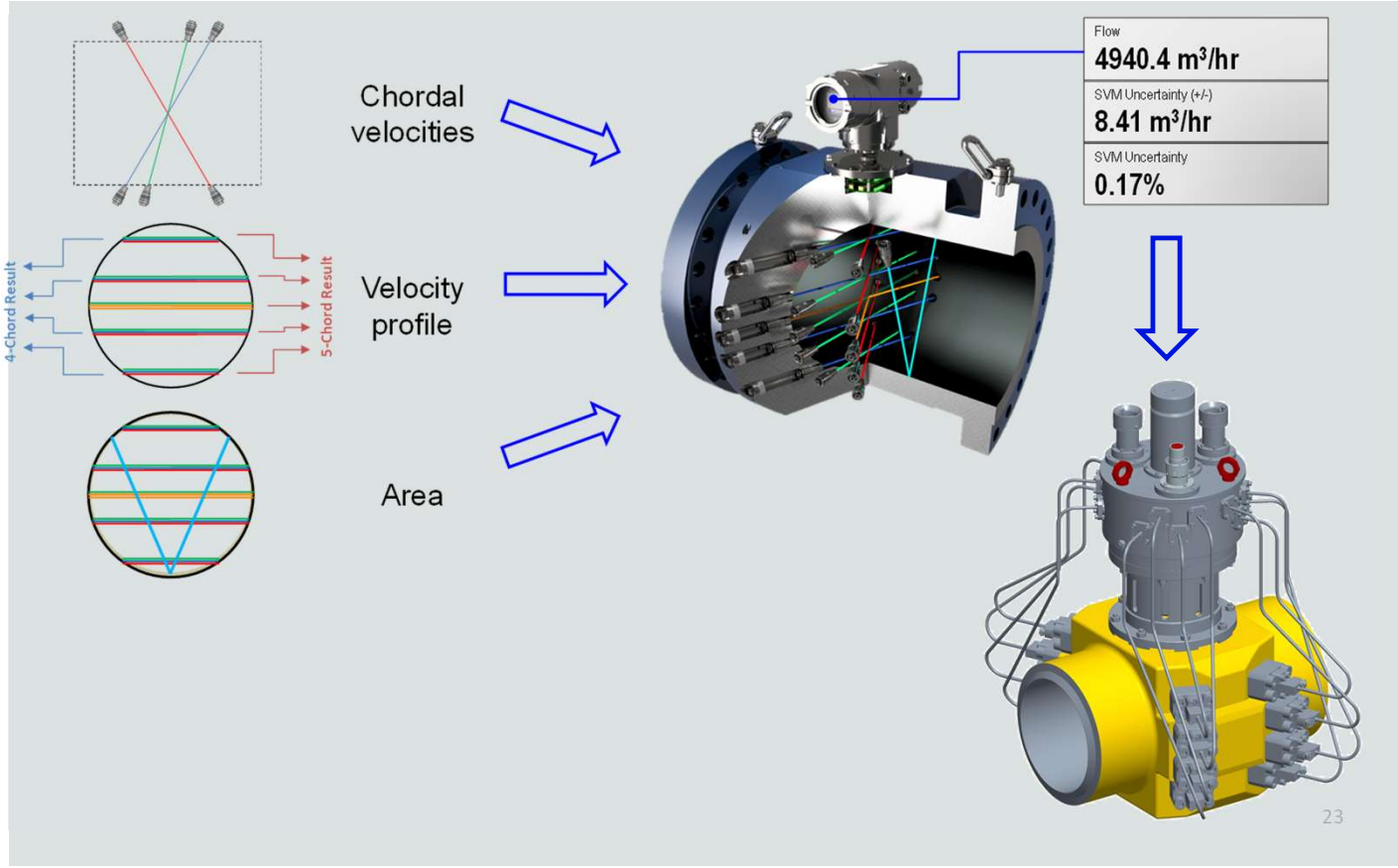
- → Custody transfer, 8-path
  - 6” and up
  - 5 ksi / 345 bar
  - Engineered to order
- → Gas production and CO_2
  - Standardised product
  - 5” and 7” to fit subsea trees
  - 10 ksi / 690 bar
  - 4-path



Future prospects – quantitative self-verification subsea

SVM Technology

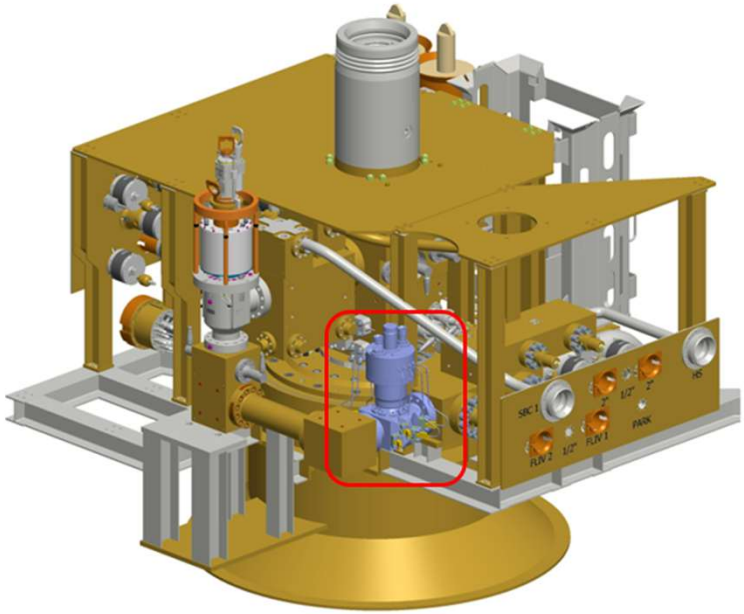
The dual redundant electronics of the subsea meter can handle 16 paths in total. With only software modifications required, this opens up the possibility of adding quantitative self-verification (measurement uncertainty output) to the subsea product line.

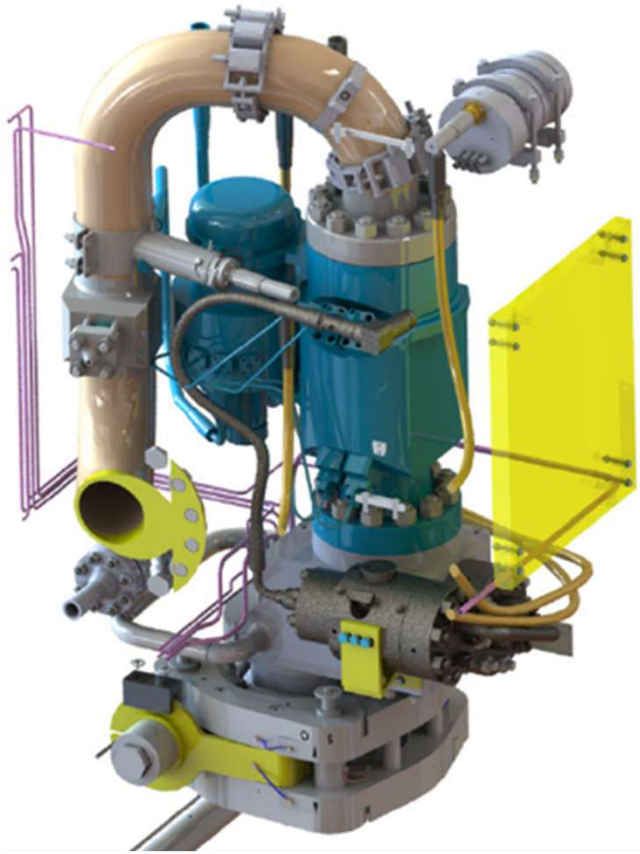


Application examples

→ Left hand image shows a 5” 4-path meter integrated into a subsea tree for carbon capture and storage

→ Right hand image show a 5” 4-path meter integrated into a subsea flow control module for natural gas production





Conclusions

- → Ultrasonic multipath metering technology has been developed based on a combination of SLB's CALDON and OneSubsea products and experience
- → The subsea meter benefits from the established custody transfer capabilities of the CALDON product line and compliments the 500 series ultrasonic meters for high-capacity CO_2 pipeline applications spanning onshore and subsea
- → The technology has undergone extensive qualification testing, offering customers a robust solution based on field-proven components