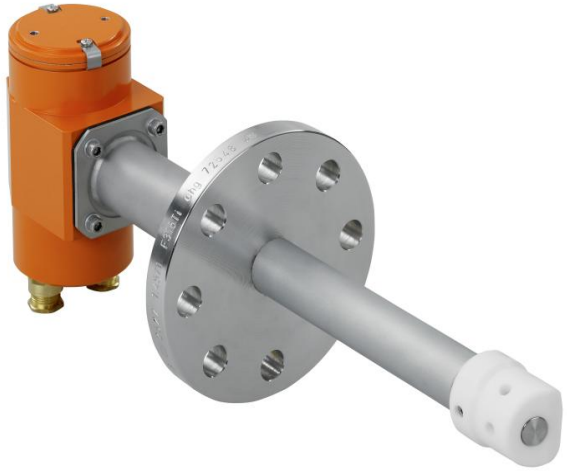

Improvements on ultrasonic flow meters for measuring flares with extended flow ranges

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Situation / Regulations

- Actual and new environmental regulations defines the requirements for flare gas metering:
  - Norwegian Petroleum Directorate (NPD)
  - NORSOK Standard I-104
  - EPA Flare Rule 40CFR part60
  - EU directive 2003/87/EC and its amending directive 2009/29/EC
  - Norwegian Climate and Pollution Agency (KLIF / Previously SFT)

Plants have to be equipped with adequate measuring devices.

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Application challenges

2. Wide range of flare gas velocity

- Standard operation of plant:
  - “Low flow” conditions – velocities close to zero

- Emergency case:
  - “High flow” conditions – velocities up to 120 m/s or more

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Ultrasonic flow meters

- Measurement of gas velocity, volumetric flow, mass flow and molecular weight in flare and vent stacks.

Molecular weight based on speed of sound

$$MW = \kappa \cdot \frac{R \cdot T}{c^2}$$

κ	= Adiabatic gas coefficient
R	= Universal Gas constant 8,3144 J/mol K
T	= Temperature
c	= Speed of sound

Mass flow based on speed of sound

$$MFlow = Q_{ac} \cdot \rho$$

$$\rho = \frac{p \cdot \kappa}{c^2}$$

Qac	= *Volumetric flow*
ρ	= Gas density
κ	= Adiabatic gas coefficient
c	= speed of sound
p	= Gas pressure

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Challenges in flare gas application

High Flow:

Limited Signal Noise Ratio (SNR) due to signal blow away and disturbing noise.

Low Flow:

Extreme stability requirements

Additional information:

Molecular weight to a appropriate uncertainty level

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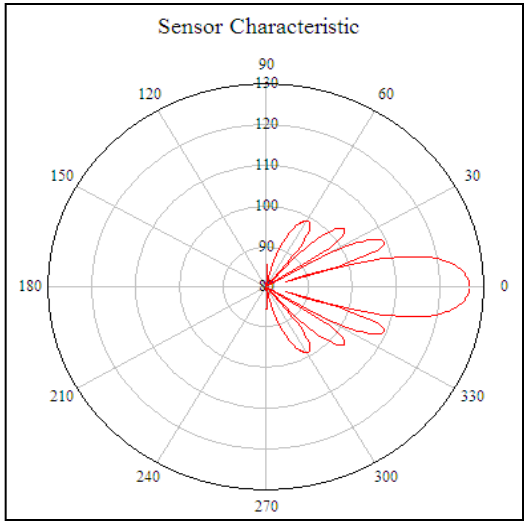
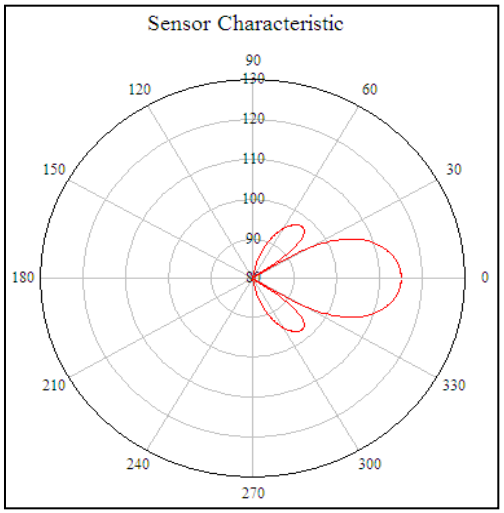
Signal beam challenge: Gas composition

- SNR reduced by changed transmission characteristics of transducer
  - *Smaller beam angles* for mixtures with low SOS
  - *Larger beam angles* for mixtures with higher SOS



Beam lobe in air (SOS 343 m/s)



Beam lobe in mixture of light gases (SOS ~700 m/s)

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Solution: Transducer for different operating frequencies

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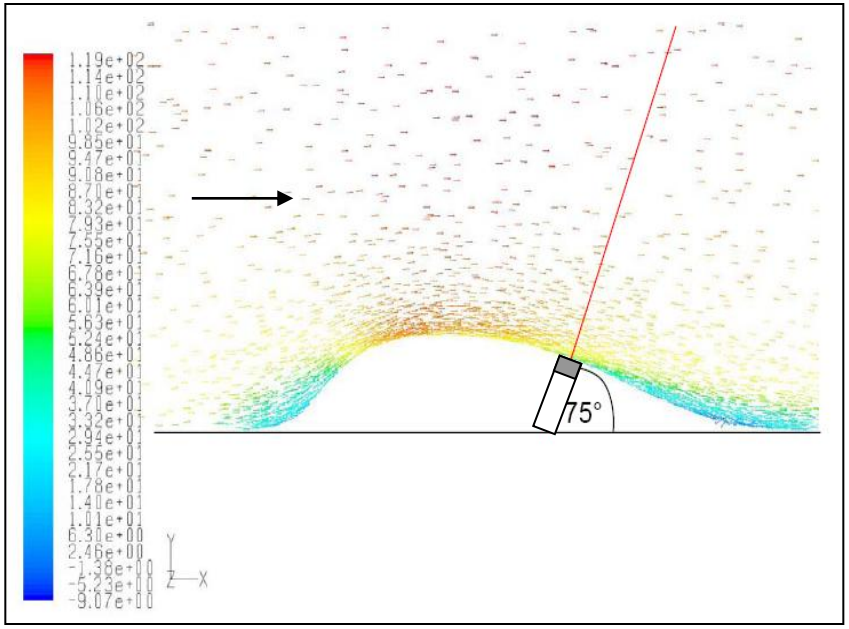
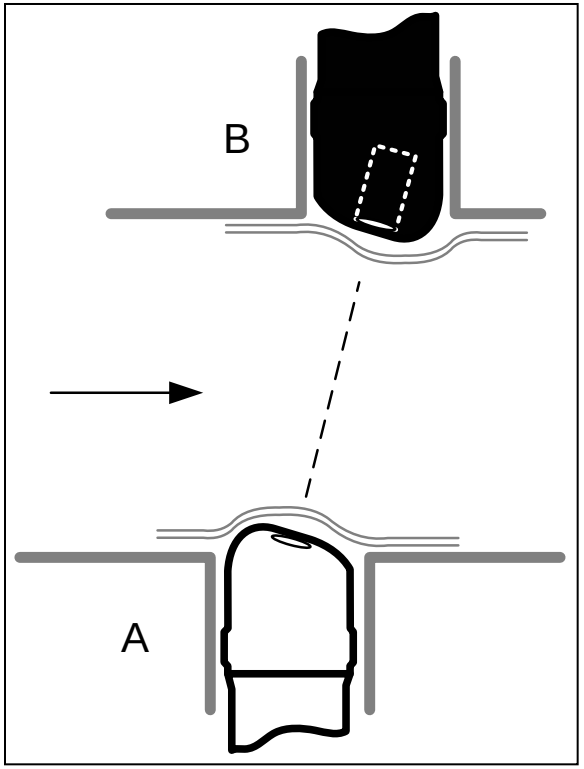
- Probe design with ultrasonic sensor embedded in an aerodynamic shape
- Noise reduction at sensor – Significant improvement of Signal Noise Ratio (SNR)



SNR is nearly doubled !



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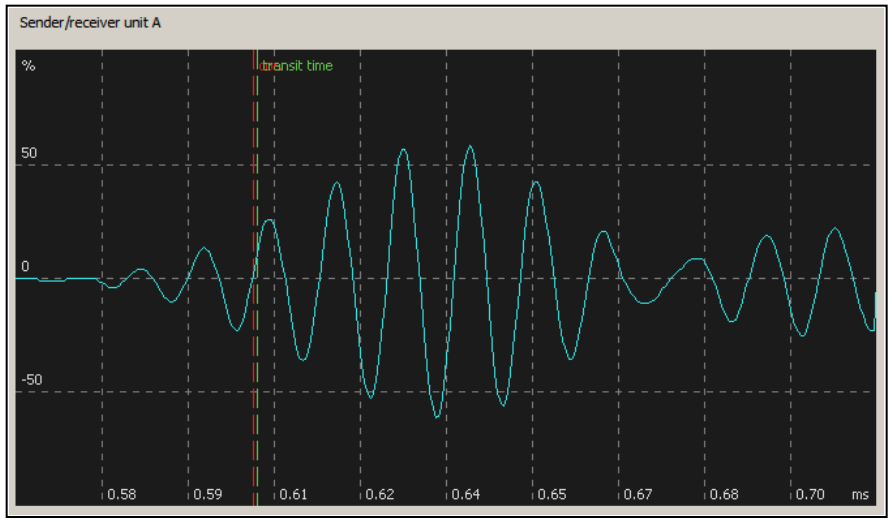
Challenge: “Low Flow” conditions < 1 m/s **- The SICK solution -**

: High accurate signal algorithm (taken from custody transfer meter)

- “Mathematical” timing resolution is in picosecond range !
- Practical resolution of gas velocity < 1 mm/s.



Marquard-Levenberg Algorithm

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Solution: different levels of molecular weight and density calculation

- Level 1 **basic**: fixed values for compressibility and adiabatic gas coefficient

- Level 2 **advanced**: molecular weight and adiabatic gas coefficient based on correlation to speed of sound

- Level 3 **extended**: molecular weight, density, adiabatic gas, compressibility based on gas composition and adequate equation of state (MR113 – associated gases)

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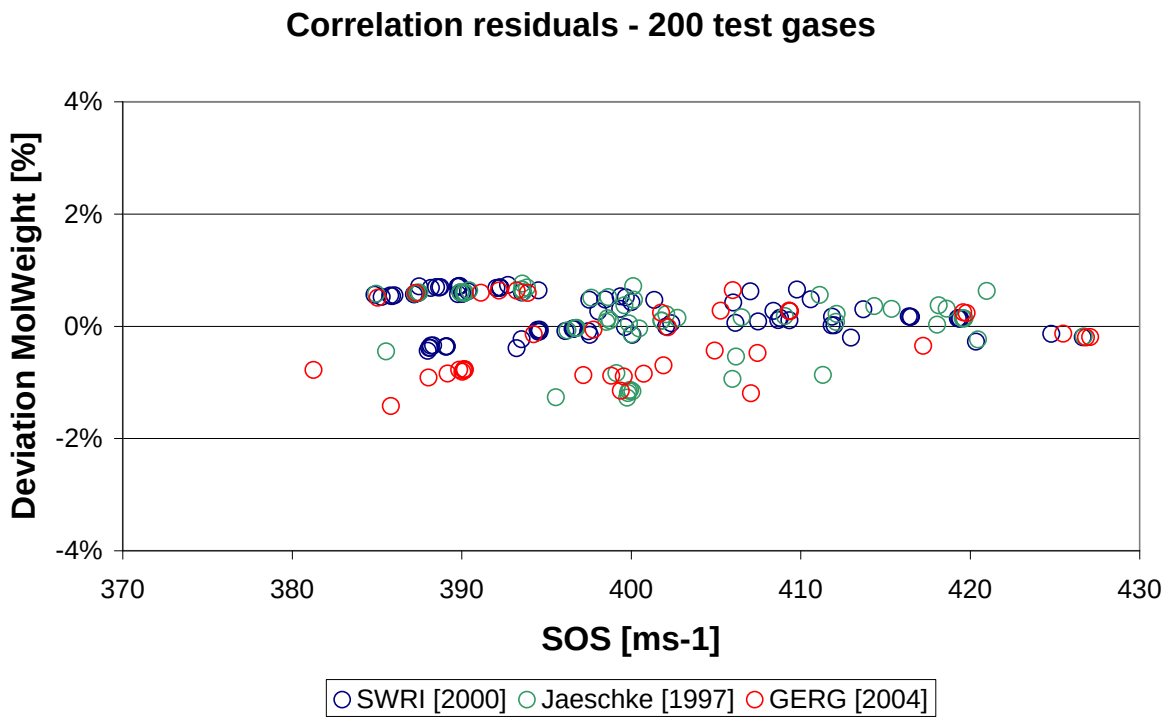
Solution: advanced level

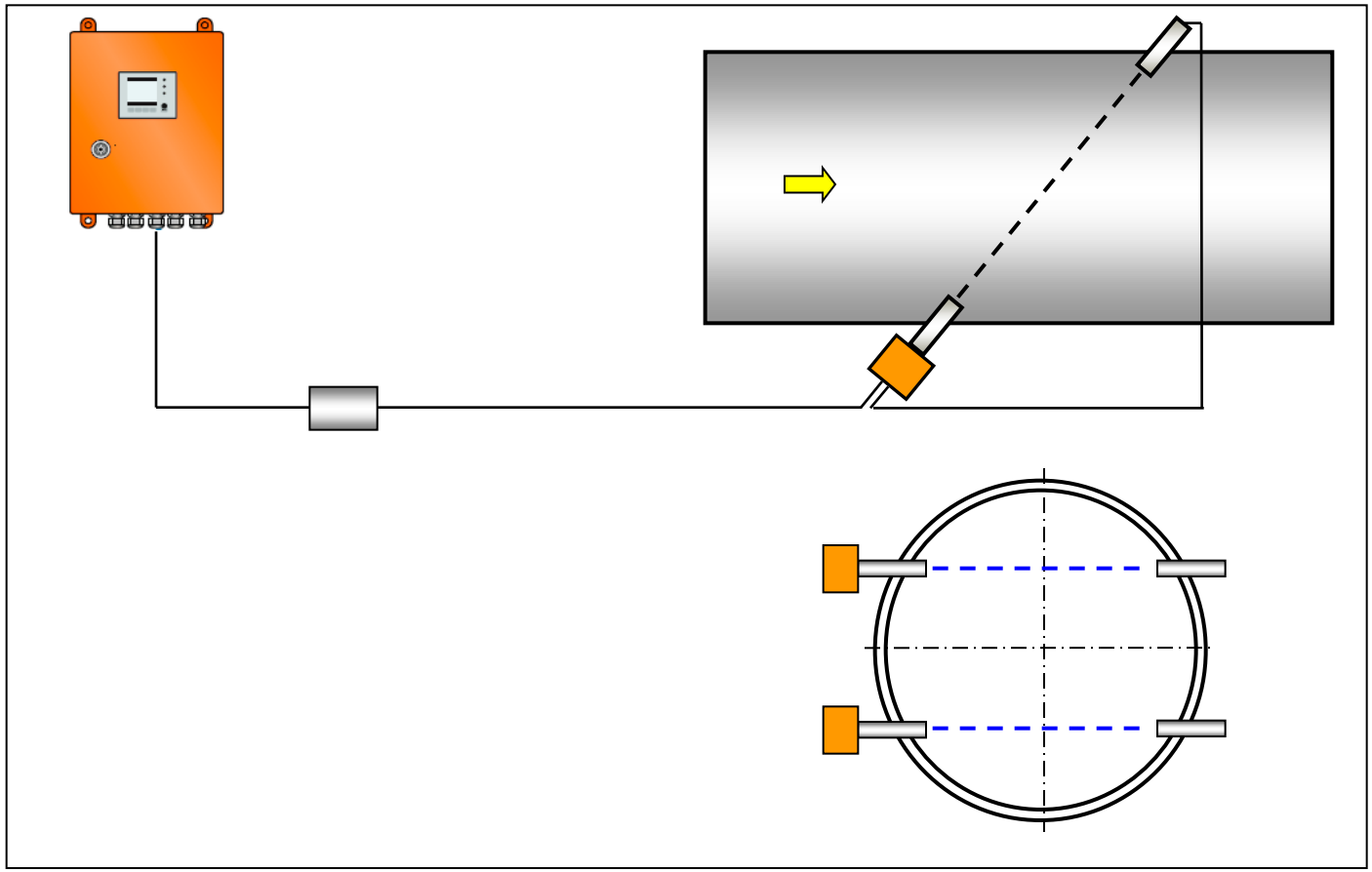
- Correlation algorithm established for a basic range of molecular weights (hydrocarbons and “natural gas like” fluids)



- Correlation algorithm expanded to low weight (e.g. Hydrogen) containing fluids

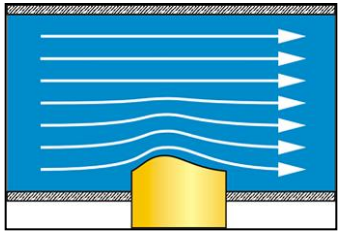
Some product features

FLOWSIC100 FLARE - 2 path configuration

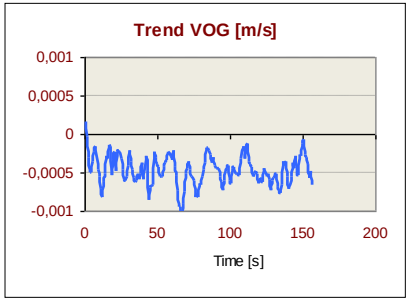


Conclusions

- Innovative sensor design improves Signal Noise Ratio in “High flow” conditions up to 120 m/s.



- Excellent performance for “Low flow” conditions close to zero – transducer stability further improved



Additional information from the ultrasonic meter like speed of sound offer additional benefits.