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SOGIN

Design Of An Anisokinetic Probe For Sampling Radioactive Particles From Ducts Of Nuclear Facilities

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Presentation outline

- Introduction
- Sampling scheme
- ISO 2889 requirements
- Simulations performed
- Equations and computational domain
- Numerical – Experimental comparison results
- Commercial vs. New Concept probe
- Conclusions

Introduction

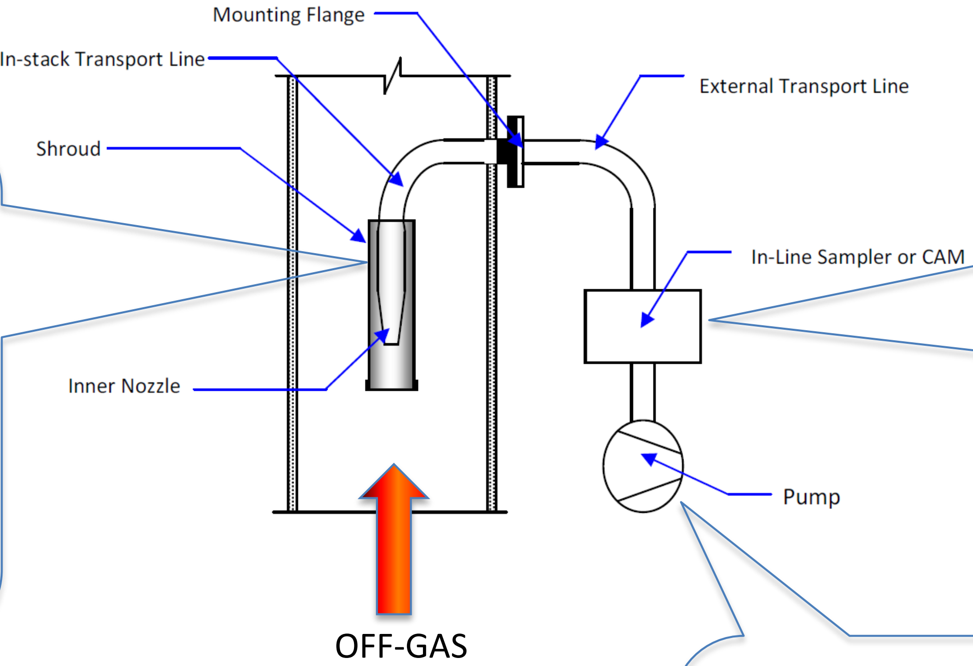
Nuclear facilities discharge the **off-gas** into the atmosphere and suitable monitoring and recording systems are required to protect the environment, workers and surrounding public.

The amount of **radioactive substances** (activity concentration) released from the stack has to be measured. A known sample amount (mass flow) is withdrawn from the stack and analyzed by Continuous Air Monitoring system. The **ISO 2889** provides performance-based criteria for the design and use of air-sampling equipment (including probes).

The aim of this study is to design a new concept of shrouded probe that:

- meets the ISO 2889 requirements;
- is suitable for small-ducts installation (up to 300 mm equivalent diameter);
- is constructed with standard stainless steel welding fittings manufactured (according to ASME/ANSI specifications) in order to reduce the manufacturing costs.

Sampling scheme

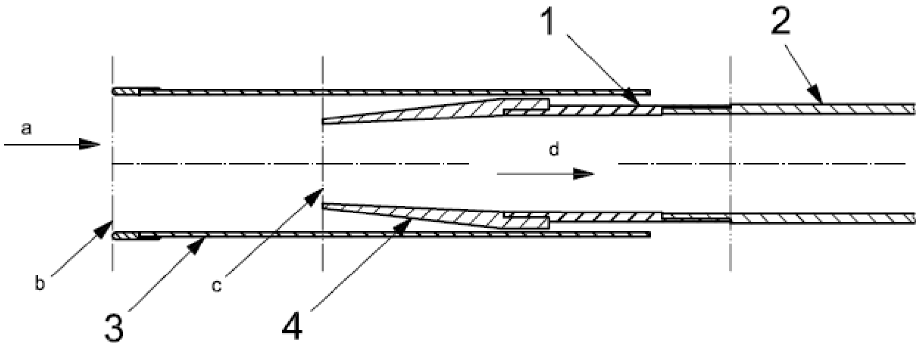


Definitions of “Isokinetic” and “Anisokinetic” (ISO 2889):

❖**Isokinetic** is the condition that prevails when the velocity of air at the inlet plane of a nozzle is equal to the velocity of undisturbed air in a stack or duct at the point where the nozzle inlet is located

❖**Anisokinetic** is the antonym of isokinetic. Sub-isokinetic refers to the condition where the nozzle inlet velocity is less than the free-stream velocity. Super-isokinetic refers to the condition where the nozzle inlet velocity is greater than the free-stream velocity.

ISO 2889 requirements



Key

1	nozzle
2	transport line
3	shroud
4	inner nozzle
a	Stack gas flow.
b	Shroud entrance plane.
c	Nozzle entrance plane.
d	Sample flow to collector or monitor.

Nozzle design and operation for extracting aerosol particles:

✓ A sampling nozzle should have a transmission ratio τ within the range of 0,80 to 1,30 during normal and accidental conditions for an aerosol with a particle aerodynamic diameter size *AED* of 10 µm;

✓ The presence of a nozzle should not disturb the aerosol particle concentration in the stack or duct. Accordingly, the frontal area of a nozzle should not be excessive (e.g. not greater than 15 % of the stack or duct cross-sectional area) and the inlet diameter should not be too small;

✓ The leading edge of the nozzle inlet should have a sharp edge and the external cone angle should not exceed 30°;

✓ …

$$\tau = \frac{C_{pout}}{C_0} = \left(\frac{N_{prout}}{N_0}\right)\left(\frac{U_0}{U_{pr}}\right)\left(\frac{A_0}{A_{pr}}\right)$$

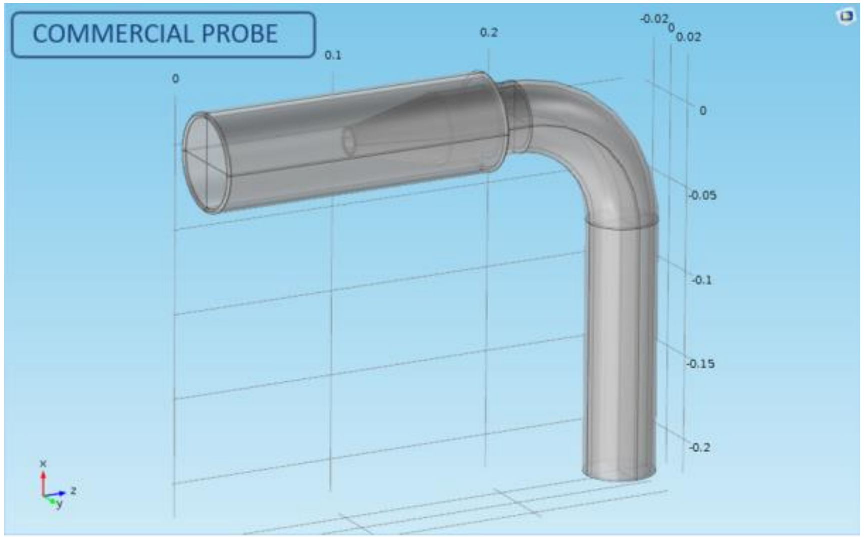
C_{pout} particle concentration at the nozzle outlet
C_0 particle free stream concentration
N_{prout} particle that reached the sampling section
N_0 uniformly distributed in area A_0
U_0 free stream velocity
U_{pr} mean velocity at the probe inlet
A_{pr} cross sectional area of the probe inlet
A_0 particle section inlet

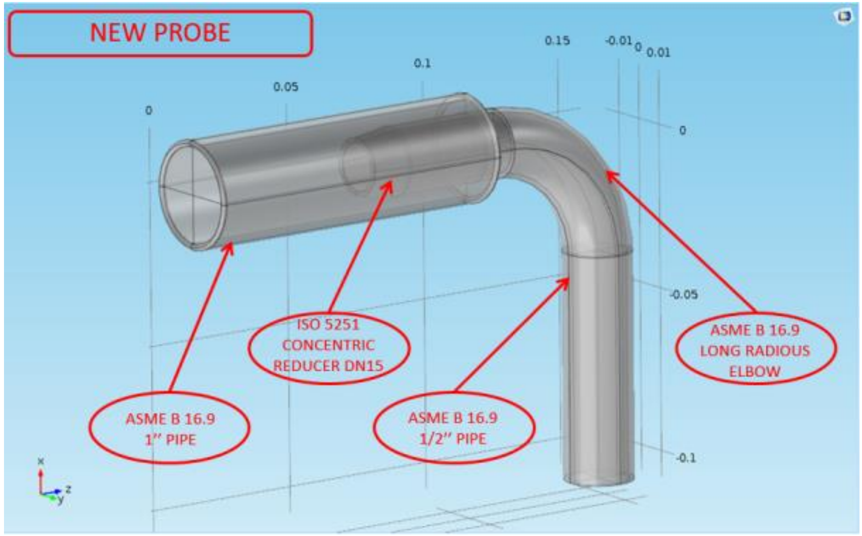
Simulations performed

The simulation study is divided into two phase:

- firstly they have been evaluated the capabilities of the numerical model to reproduce the available experimental data for a **commercial shrouded probe**;
- secondly they have been investigated the performances of the **new concept design**.

Computations are carried out for free stream velocities in the range of 2 to 25 m/s and for particle size of 5, 10 and 15 µm aerodynamic equivalent diameter (for the second phase).





Equations and computational domain

Governing equations:

$$\nabla \cdot \boldsymbol{u} = 0$$

$$\rho \frac{\partial \boldsymbol{u}}{\partial t} + \rho(\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = \nabla \cdot [-p\boldsymbol{I} + \boldsymbol{\tau}]$$

$$\frac{d}{dt}(m_p \boldsymbol{v}) = \left(\frac{1}{\tau_p}\right) m_p(\boldsymbol{u}' - \boldsymbol{v}) + m_p \boldsymbol{g} \frac{(\rho_p - \rho)}{\rho_p} + \boldsymbol{F}_{\boldsymbol{brow}}$$

SEGREGATED APPROACH

FLUIDYNAMICAL SIMULATION

COMSOL MODULE: HEAT TRANSFER

TYPE: STATIONARY

MODEL: TURBULENT FLOW K-EPS (WALL FUNCTION)

SOLVER: DIRECT, SEGREGATED, MUMPS

PARTICLE TRACING SIMULATION

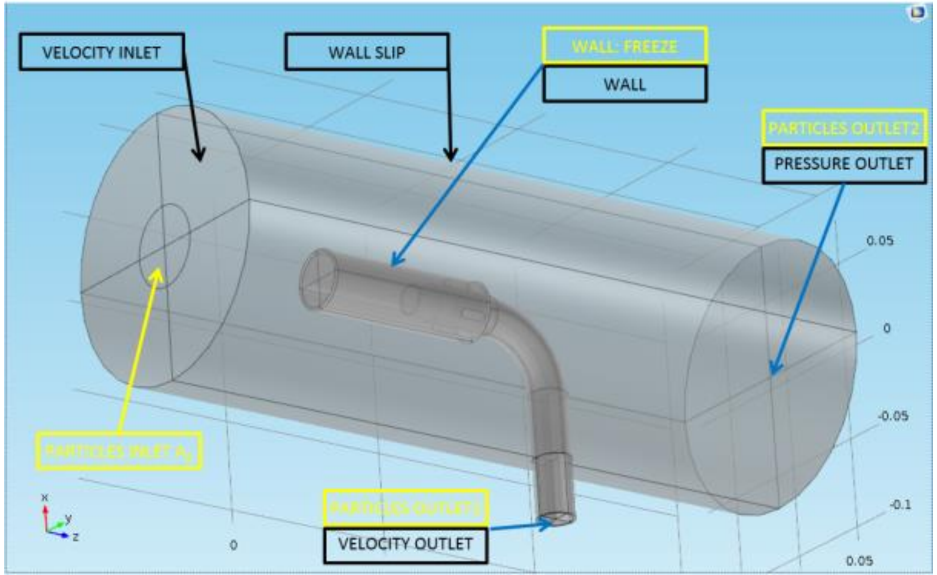
COMSOL MODULE: PARTICLE TRACING

TYPE: TRANSIENT

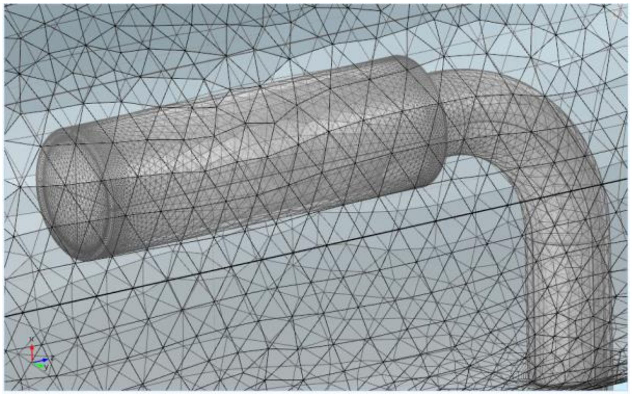
MODEL: STANDARD DRAG CORRELATION + GRAVITY + BROWIAN

SOLVER: DIRECT, MUMPS, FULLY-COUPLED SOLVER

Boundary conditions:

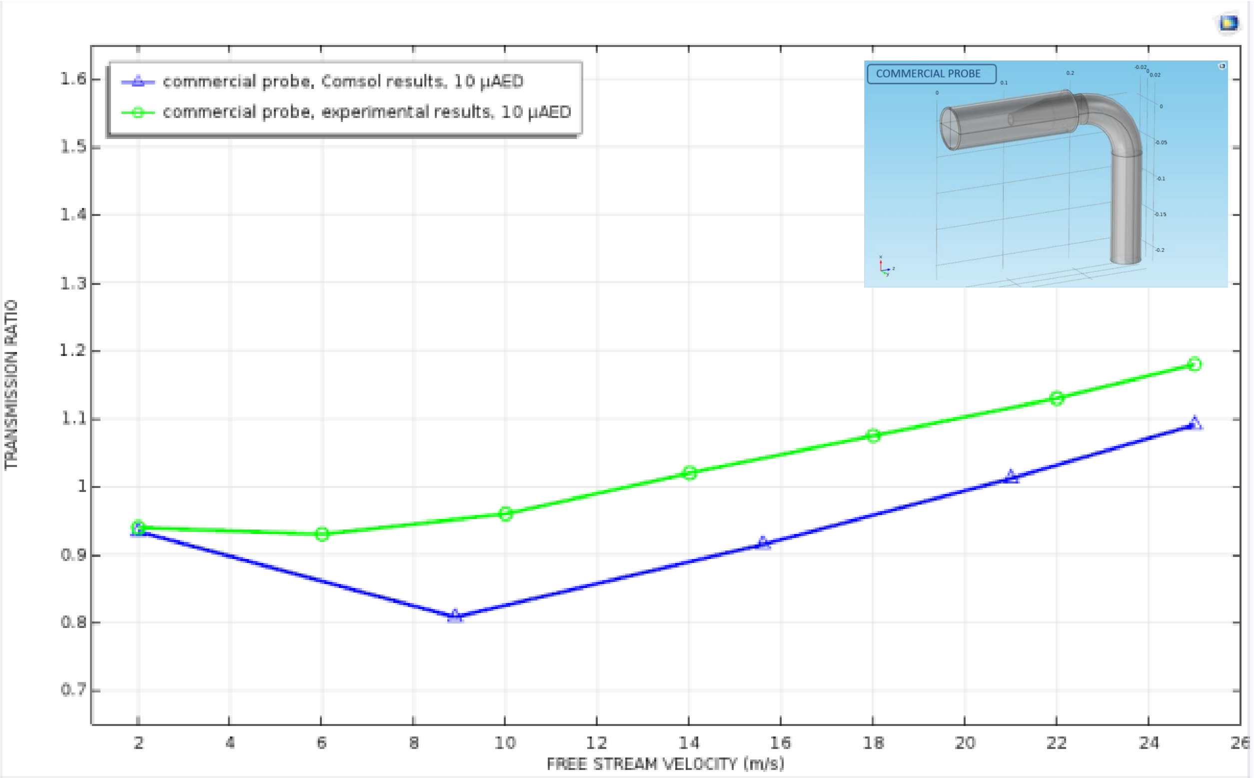


Mesh:



Numerical – Experimental comparison results

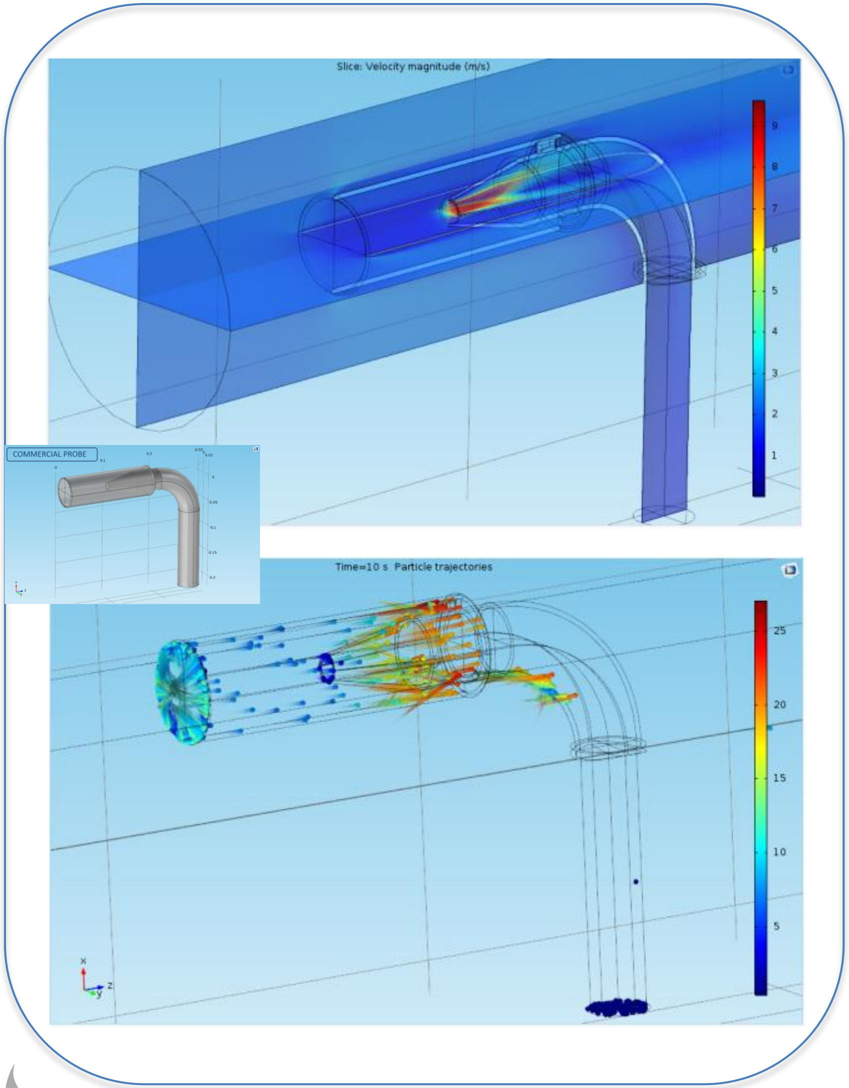
Capabilities of the numerical model to reproduce the available experimental data for a **commercial shrouded probe**:

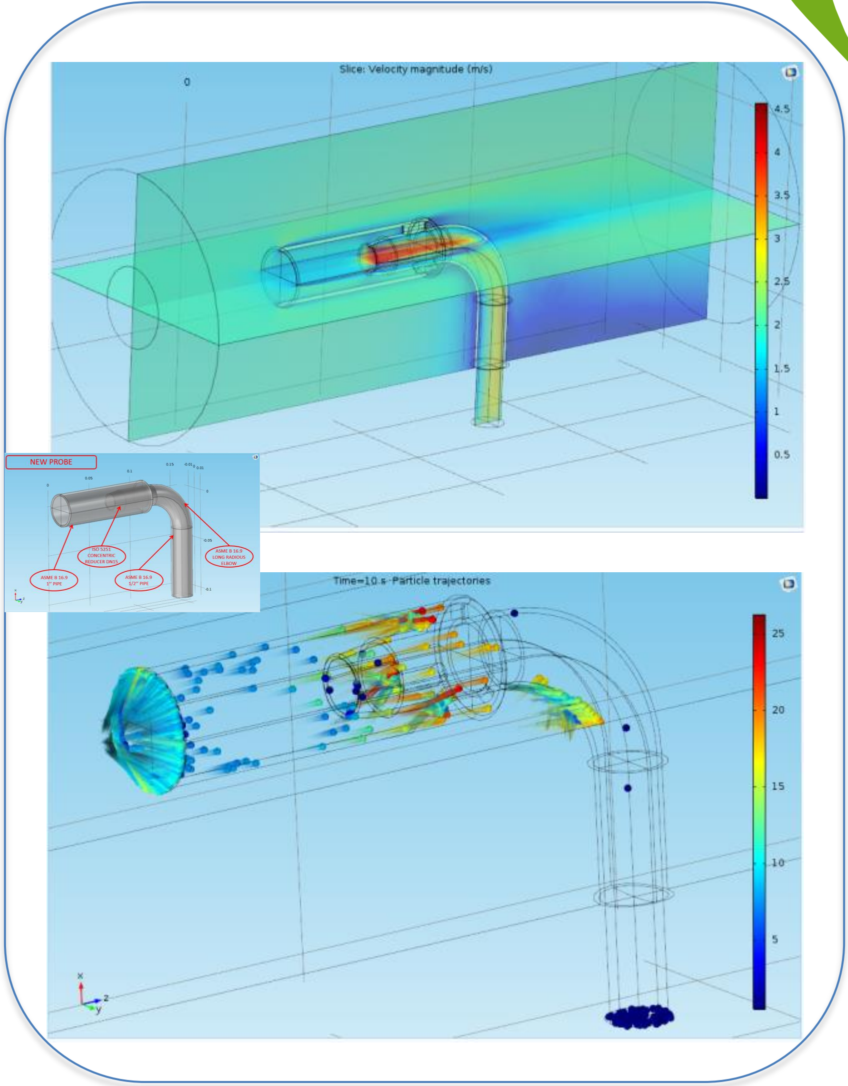


It is evident that the numerically predicted transmission ratios compare well with the experimentally determined values. The maximum difference is less than 10%, probably due to conservative hypothesis of stick walls.

Commercial vs. New Concept probe (1/2)

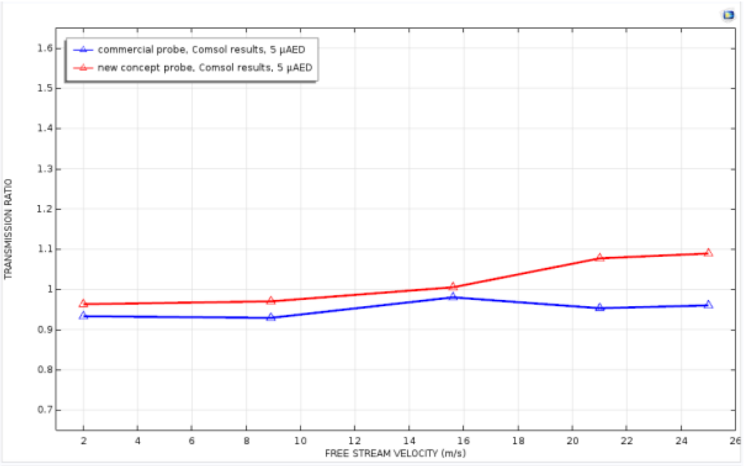
Velocity field (2 m/s external flow) and comet tail diagram (25 m/s external flow, 10 µm AED)

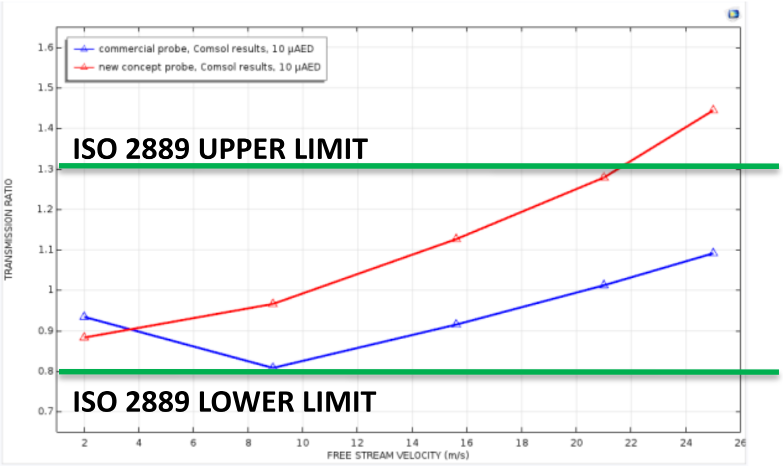




Commercial probe vs. New Concept (2/2)

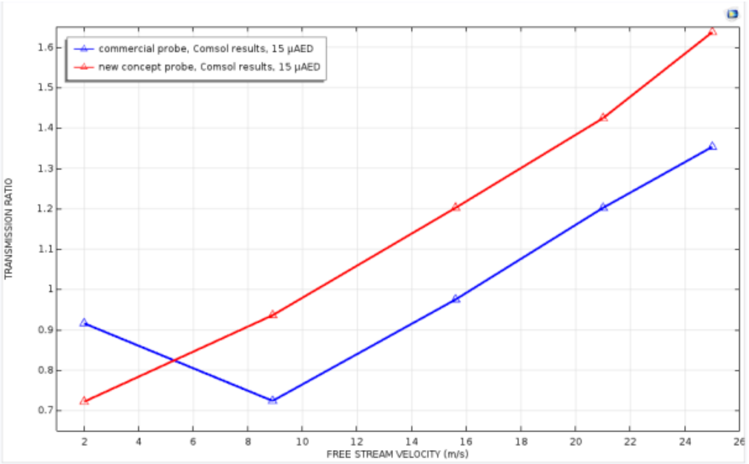
Comparison of transmission ratio for commercial probe and new concept probe for 5 – 10 - 15 µm aerodynamic diameter:





ISO 2889 UPPER LIMIT

ISO 2889 LOWER LIMIT



Conclusions

- the ISO requirements for the new concept probe are met except for external velocity flow greater than 20 m/s;
- the transmission ratio of the shrouded probes increases with both free stream velocity and particle size;
- the transmission ratio of new concept probe is slightly higher than the commercial except for low external velocity flow;
- the new concept probe seems to be less flexible than the other one and the variation of transmission ratio with the velocity is more evident;
- a sampling flow rate optimization study can be performed in order to modify the behavior of the new probe with a velocity.

Thank you for your attention!