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Metrology infrastructure for high-pressure gas and liquified hydrogen flows

Correction methodologies for temperature effects in Coriolis flow meters and their evaluation

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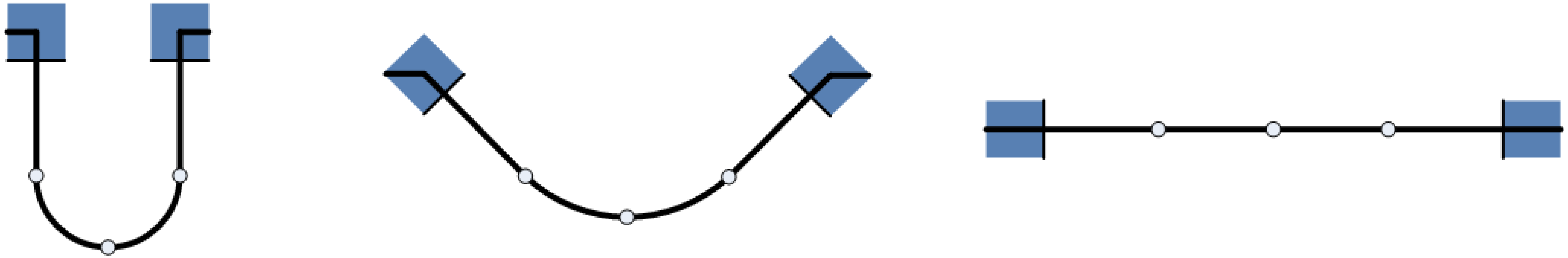
Introduction

- Three main temperature-related physical effects in CFMs:

  - temperature dependent elastic material properties
  - thermal strain
  - thermal stress

- In general magnitudes of these effects depend on the tube design

- Presentation deals with the evaluation of some available temperature-correction methods using the numerical modelling of three different meter designs



Correction of temperature effects

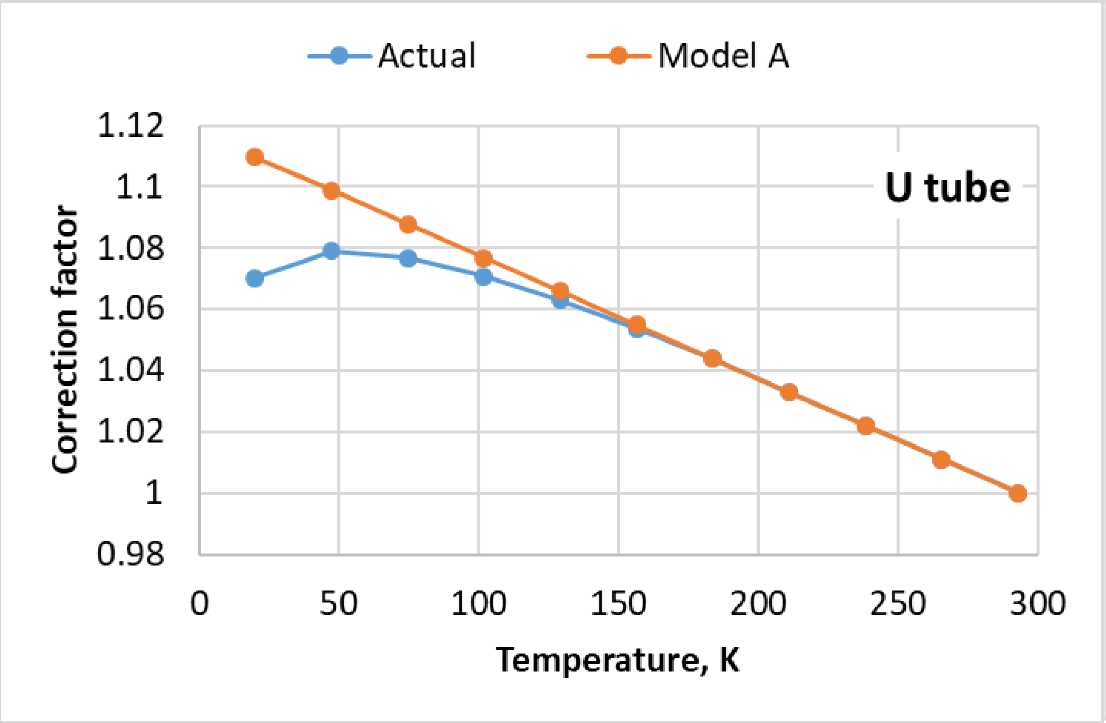
CFM's mass flow measurement: $q_m = F_{cal}(T)\Delta t = \xi(T) F_{cal}(T_{ref})\Delta t$ $\qquad \xi(T) = \dfrac{F_{cal}(T)}{F_{cal}(T_{ref})}$

- Correction model A: Correction based on flow calibration at higher temperatures, extrapolation to cryogenic temperatures

$$\xi^{(A)}(T) = 1 + K_\xi (T - T_{ref})$$

$$K_\xi = \frac{\Delta\xi}{\Delta T}$$

water, 283 K to 293 K



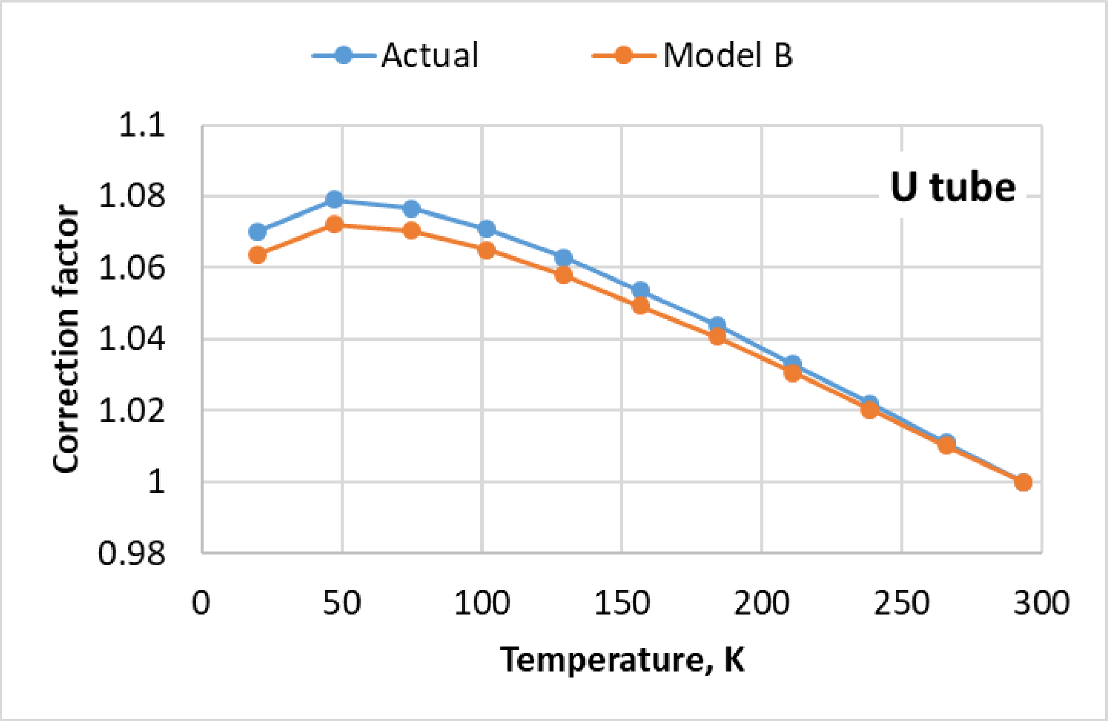
Correction of temperature effects

- Correction model B: Correction based on prediction of temperature effects related to elastic modulus, thermal expansion

$$\xi^{(B)}(T) = \xi_E(T)\,\xi_{\varepsilon_{th}}(T)$$

$$\xi_E(T) = \frac{E(T)}{E(T_{ref})}$$

$$\xi_{\varepsilon_{th}}(T) = 1 + \varepsilon_{th}(T)$$



Correction of temperature effects

- Correction model C: Correction based on prediction of temperature effects related to Poisson's ratio using 2-DOF model

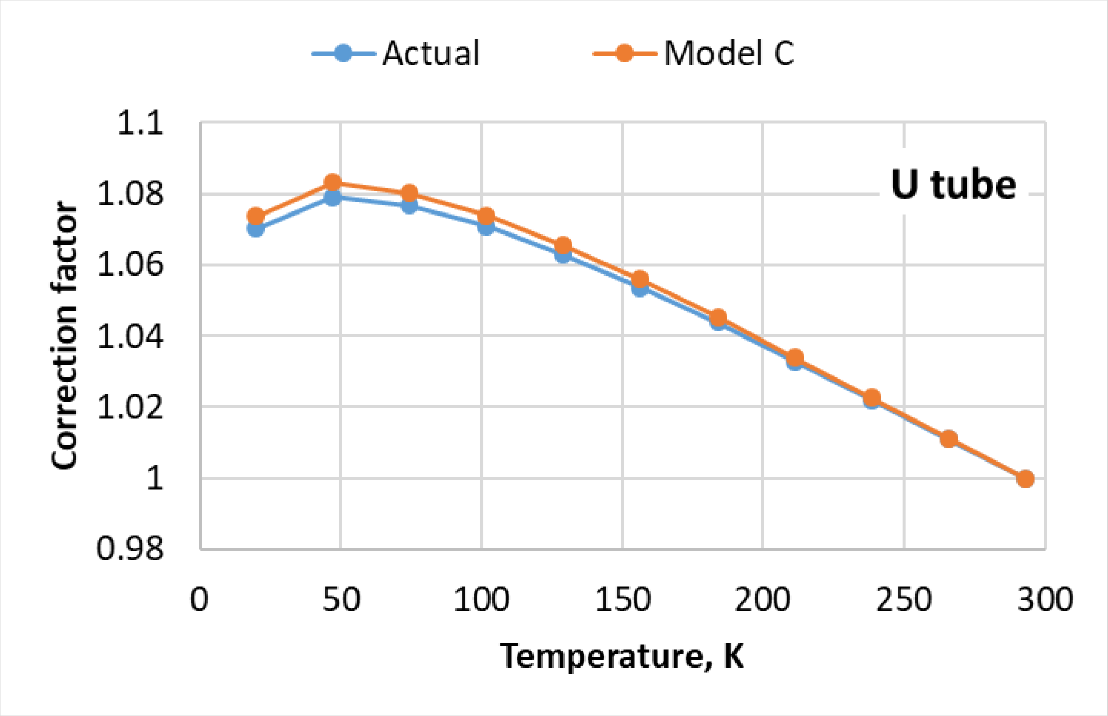
$$\xi^{(C)}(T) = \frac{E(T)}{E(T_{ref})}\left(1+\varepsilon_{th}(T)\right)\xi_{\mu}(T)$$

2-DOF model:

$$\xi_{\mu}(T) = \frac{1 - \frac{\pi\beta^4 W}{12L} + \frac{4L^2}{3W^2(\mu(T)+1)}}{1 - \frac{\pi\beta^4 W}{12L} + \frac{4L^2}{3W^2(\mu(T_{ref})+1)}}$$

Effective *W*/*L*

$$\begin{cases} \text{water, 293 K} \\ \omega_{nb}(L) = \omega_{n1} \\ \omega_{nt}(L,W) = \omega_{n2} \end{cases}$$



Correction of temperature effects

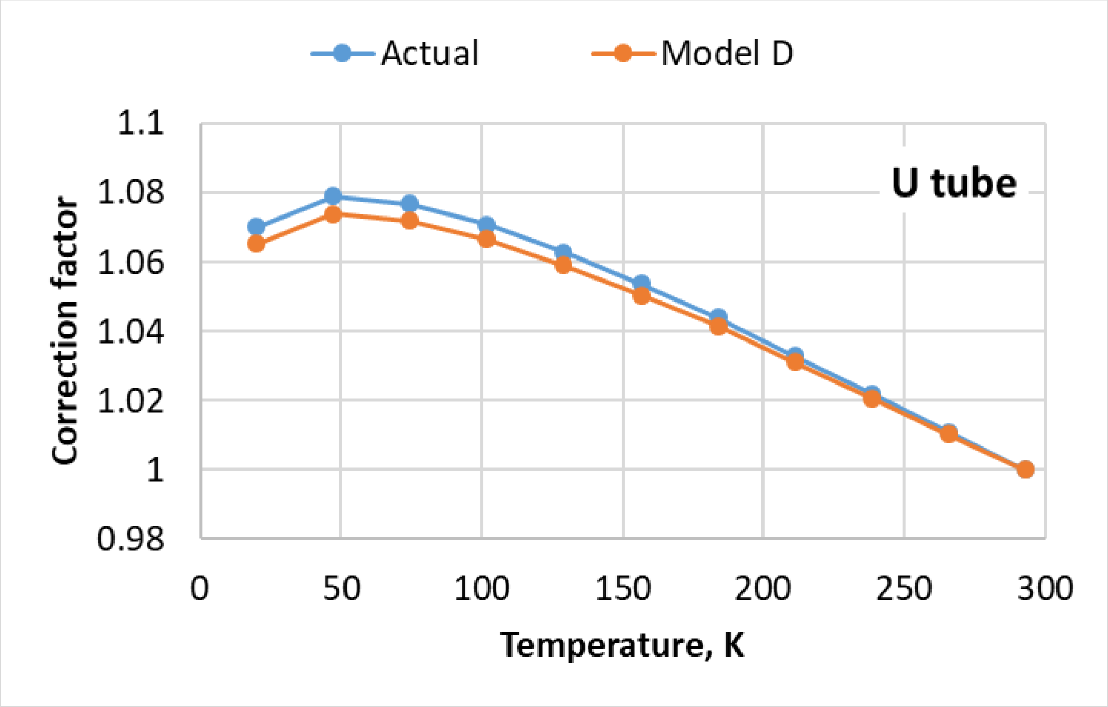
- Correction model D: Correction based on measurements of temperature effects on natural frequencies using known density

Fluid density vs. natural frequency model:

$$\rho_f = \frac{C_1 \xi_E(T)}{\left(1+\varepsilon_{th}(T)\right)^2} \frac{1}{f_1^2} - \frac{C_2}{\left(1+\varepsilon_{th}(T)\right)^3}$$

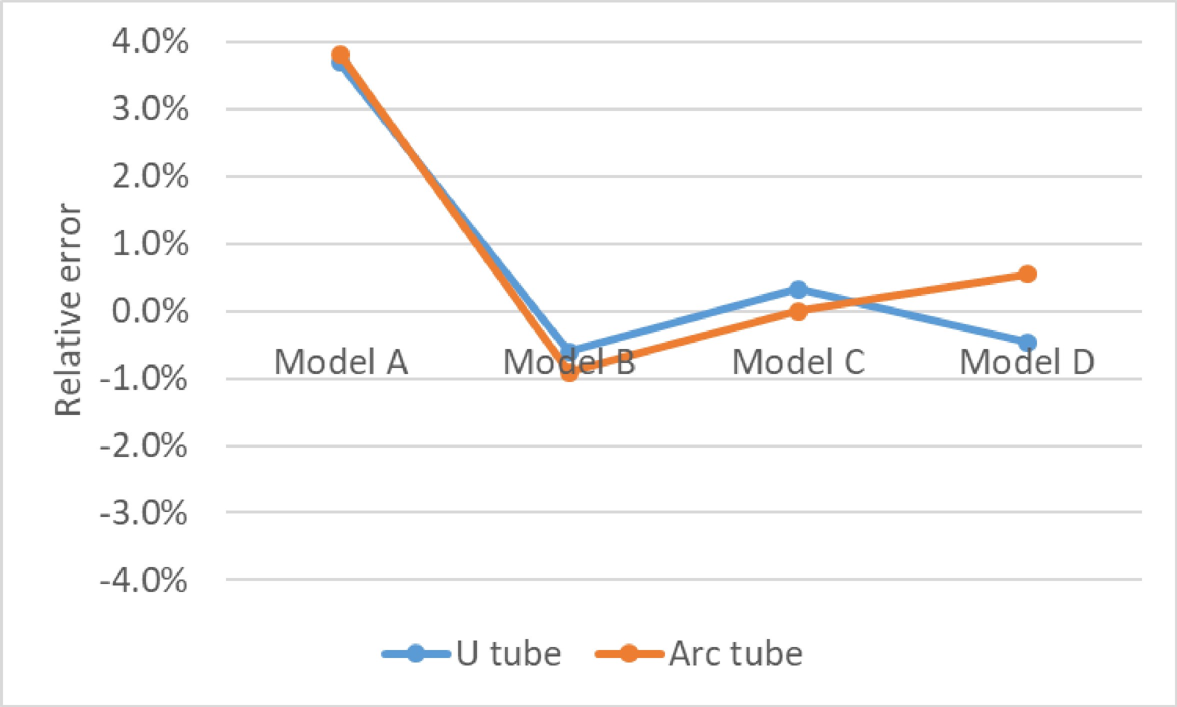
$$\xi^{(D)}(T) = \xi_E(T)\left(1+\varepsilon_{th}(T)\right) = \frac{\left[\rho_f \left(1+\varepsilon_{th}(T)\right)^3 + C_2\right] f_1^2}{C_1}$$

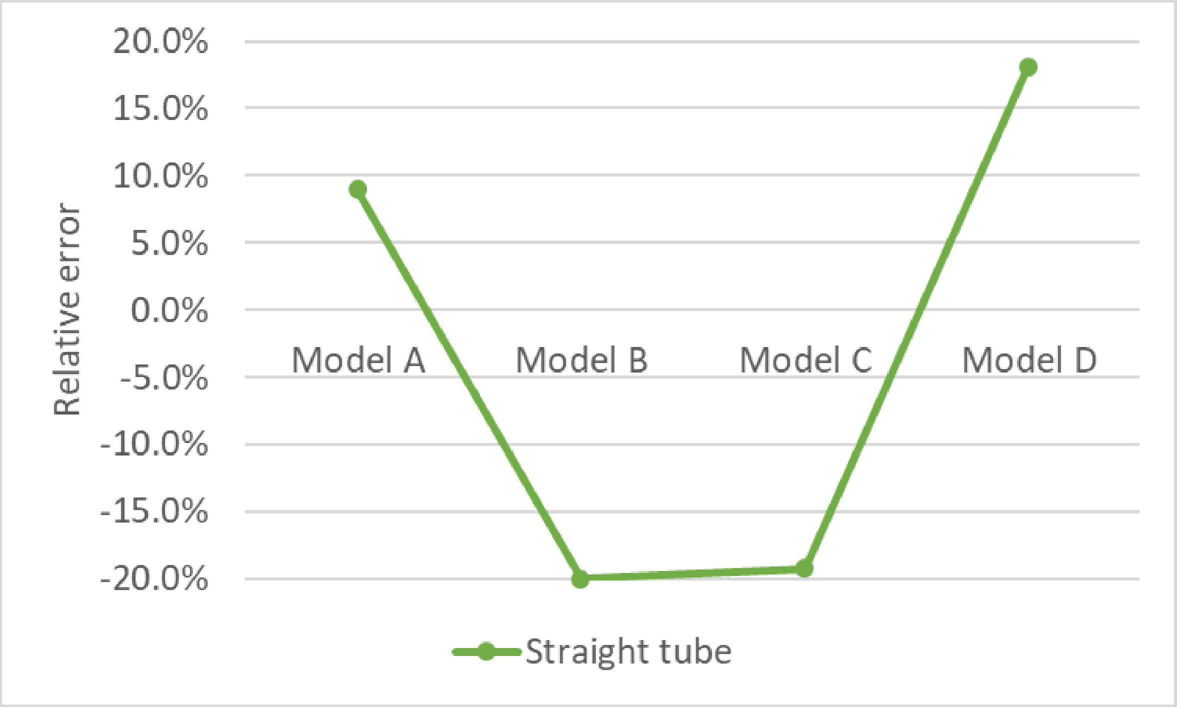
C_1 and C_2 determined by water and air density calibration at T_{ref}



Summary of evaluation results for liquified hydrogen (20 K)

- Relative error of the predicted temperature correction factor (with regard to the reference value determined by the numerical model)





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