Glycol Compensation Algorithm for Ultrasonic Thermal Energy Meters

Philip Holoch

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CONTENT

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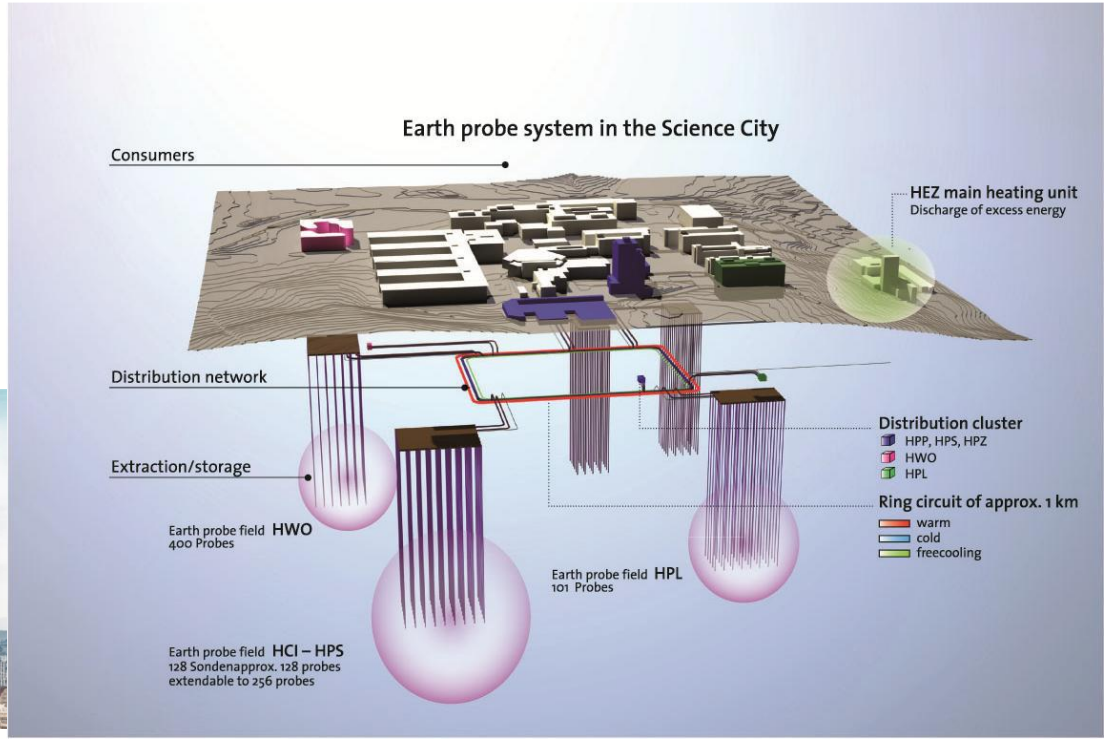
Motivation – what for?

Where are Thermal Energy Meters used with Glycol?

usually no accounting

- Solar appli
- Co thin the building
- District Cooling
- Anergy Networks

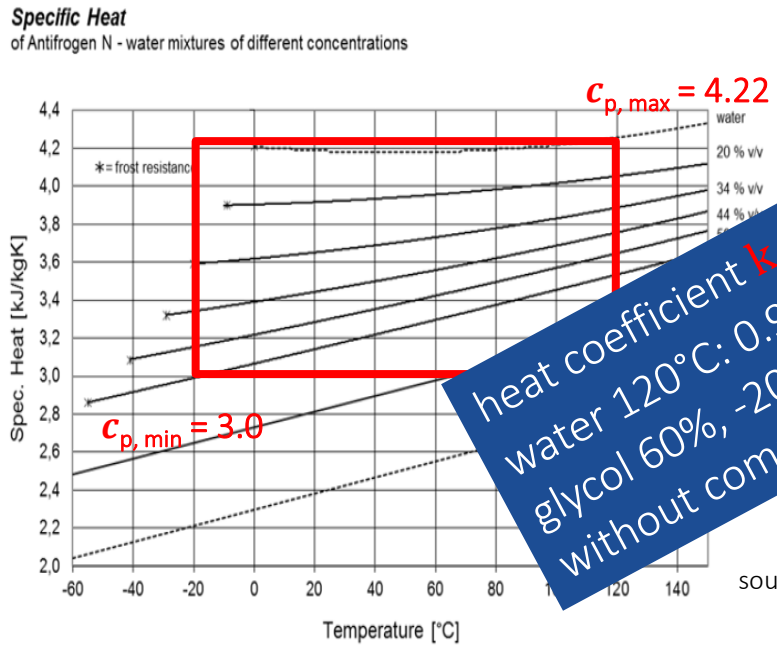


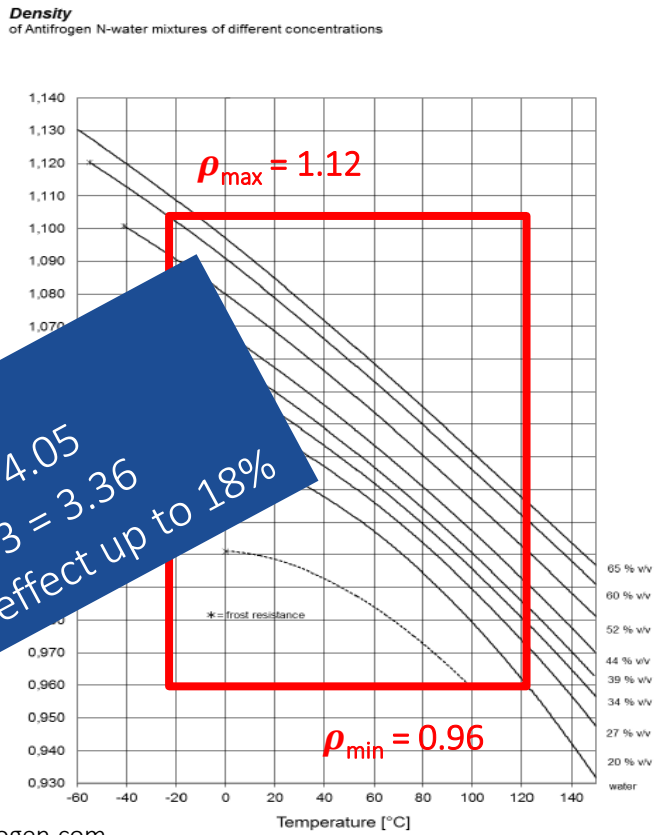
https://www.international-sustainable-campus-network.org/downloads/conference-and-symposia/iscn-conference-2012/255-2012-iscn-award-building-ethz/file

Why do we need compensation for glycol?

Thermal Energy $\boldsymbol{Q} = \int_{V_0}^{V_1} \boldsymbol{k} \cdot \Delta \boldsymbol{T} \cdot \boldsymbol{dV} = \int \dot{\boldsymbol{V}} \cdot \boldsymbol{\rho} \cdot \boldsymbol{c_p} \cdot \Delta \boldsymbol{T} \cdot \boldsymbol{dt}$

operating range -20…+120°C, 0…60% glycol

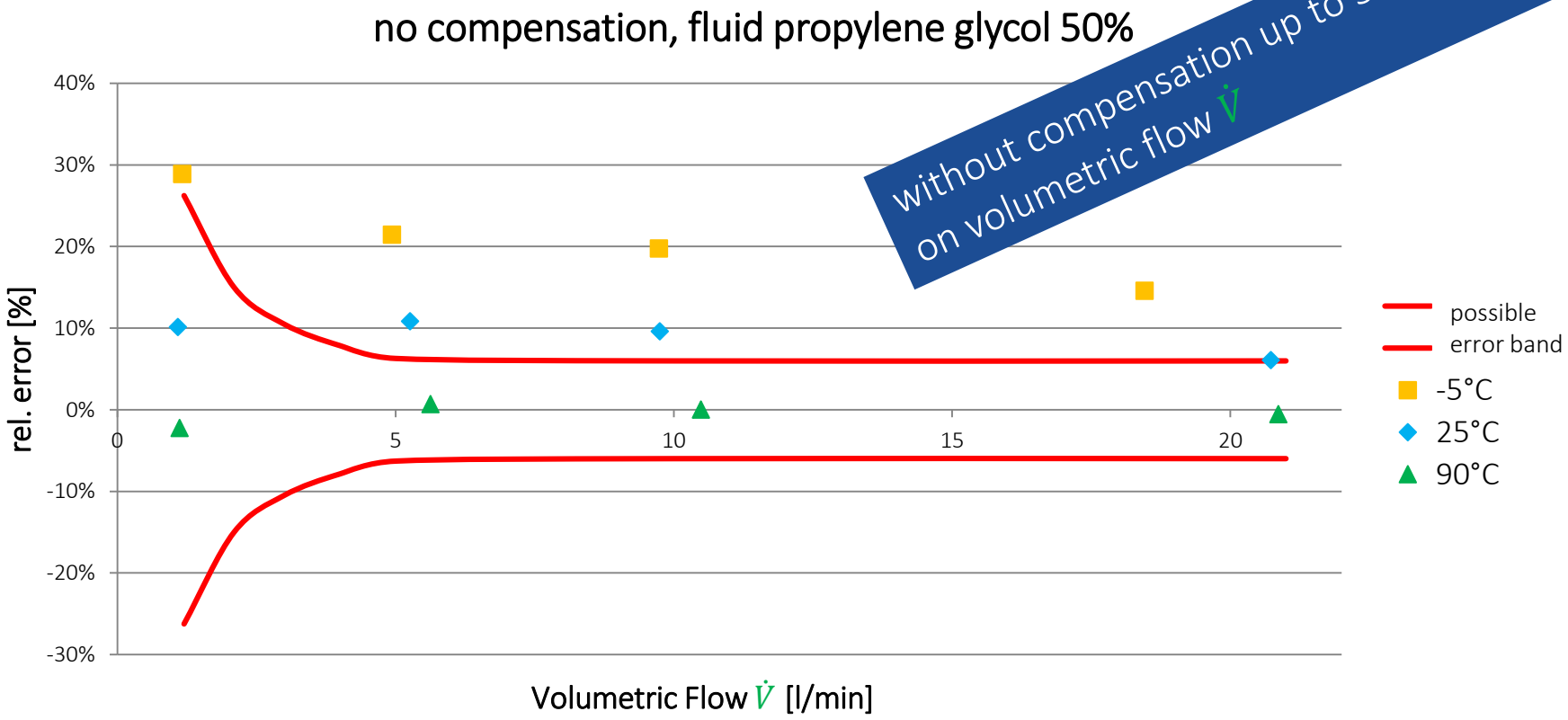




heat coefficient $\boldsymbol{k} = \boldsymbol{\rho} \cdot \boldsymbol{c_p}$
water 120°C: 0.96 x 4.22 = 4.05
glycol 60%, -20°C: 1.12 x 3 = 3.36
without compensation effect up to 18%

source: www.antifrogen.com

Influence on Volumetric Flow $\dot{V}$



Current Approach for Accreditation (in discussion)

- Accreditation only for specific fluid (brand name) and concentration
  i.e. Antifrogen L (propylene glycol, 34%)
  - measurement of MPE at various temperatures

→ Almost impossible to get accreditation for a universal meter for various fluid brands and concentrations

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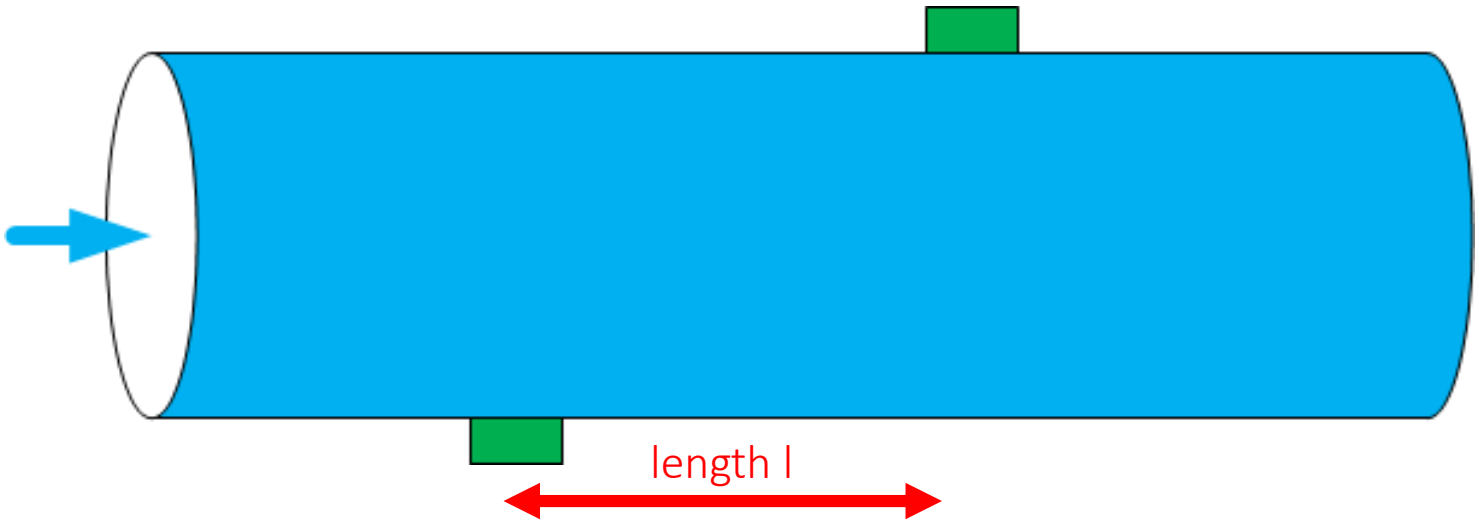
Glycol Compensation for Volumetric Flow

Measuring Volumetric Flow with Ultrasound



Flow velocity

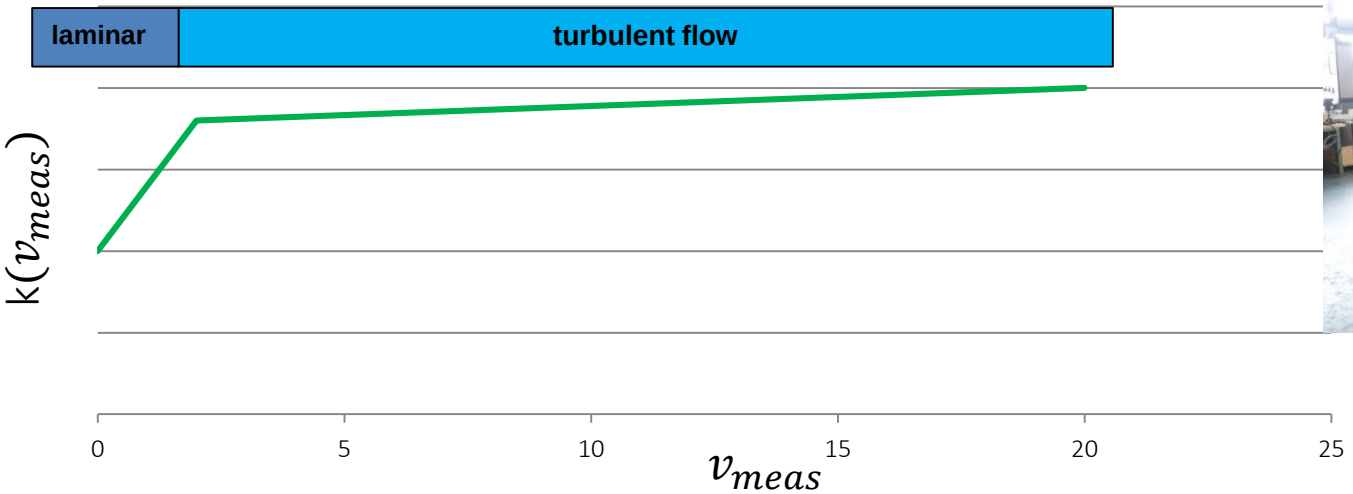
$$v_{meas} = c \cdot \frac{l}{2} \cdot \left(\frac{1}{tt_{down}} - \frac{1}{tt_{up}} \right)$$

Volumetric Flow

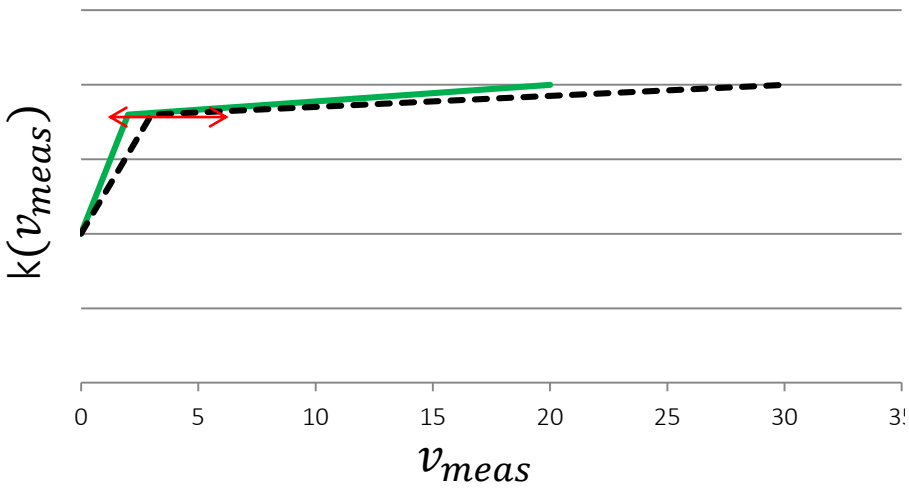
$$\dot{V} = \int v \cdot dA = A \cdot \bar{v}$$

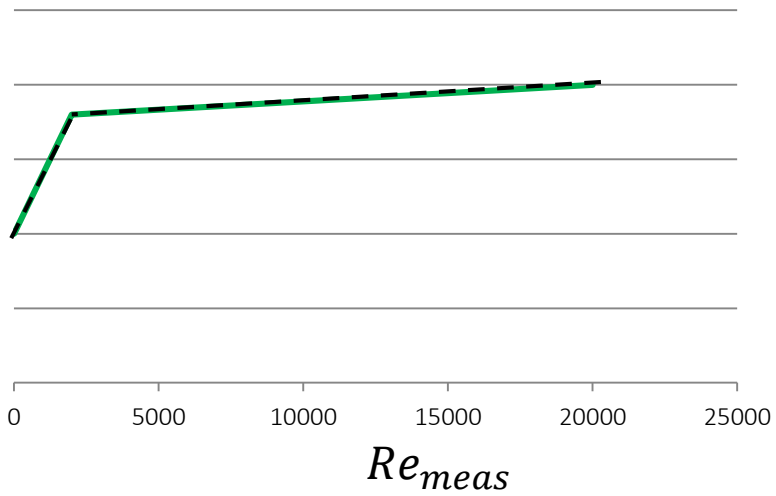
Calculation of Average Velocity

- $\bar{v} \neq v_{meas} \rightarrow \bar{v} = k(v_{meas}) \cdot v_{meas}$
- influence of flow profile (laminar, transient, turbulent)
- usually empirically determined on calibration rig



Influence of Viscosity





- Viscosity has an influence on the flow profile. It «moves» the transition between laminar and turbulent flow on the flow axis

- Use of Reynoldsnumber as reference makes curve independent from viscosity

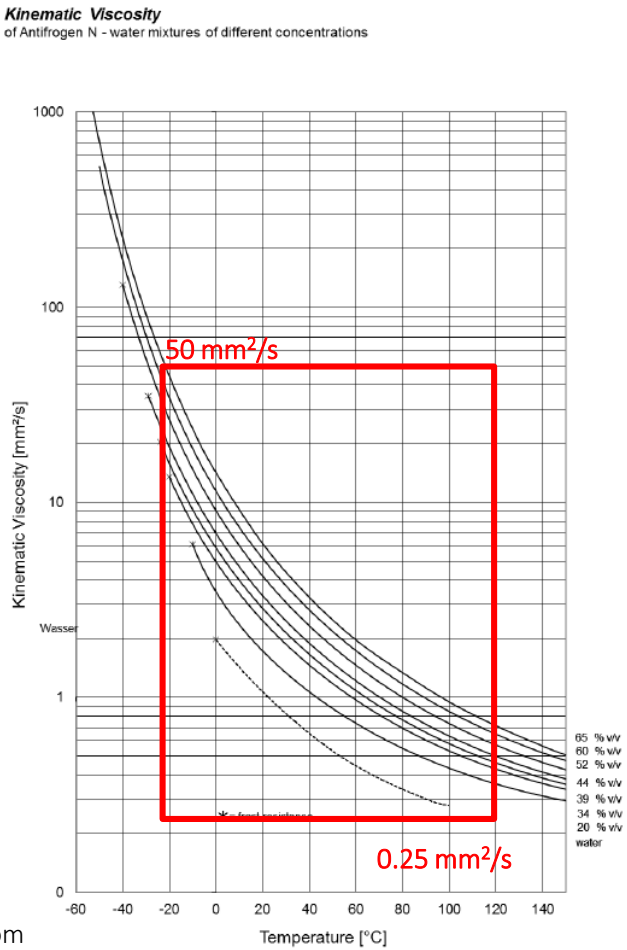
$$Re = \frac{r \cdot v}{\eta}$$

η = kinematic viscosity

Kinematic Viscosity

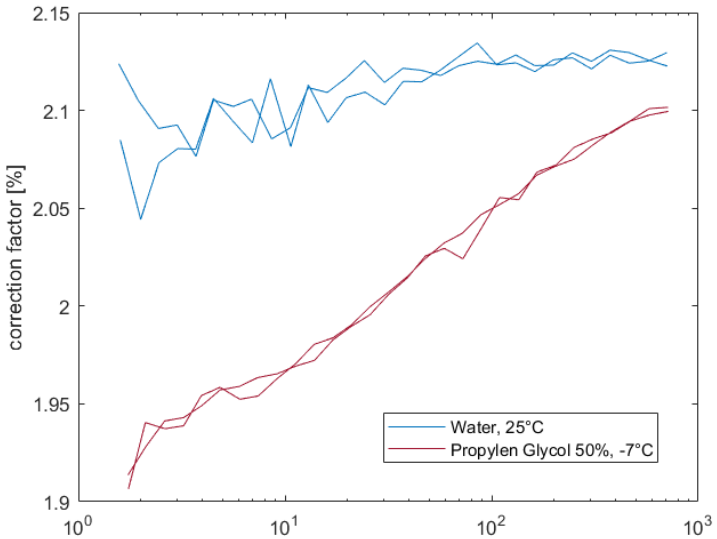
- the kinematic viscosity depends on
  - temperature
  - glycol concentration
  - type of glycol (ethylene- or propylene based)

- temperature range -20…+120°C, 0…60% glycol
  ~1:200



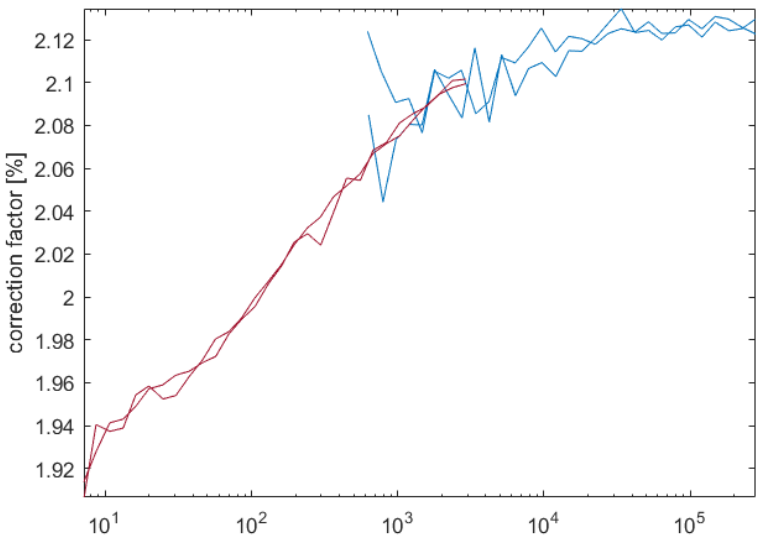
source: www.antifrogen.com

Real Calibration Curves of DN100 Meter



flow

$$Re = \frac{r \cdot v}{\eta}$$

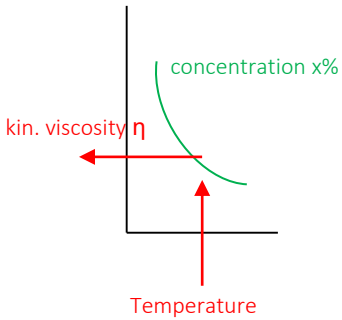


Reynoldsnumber

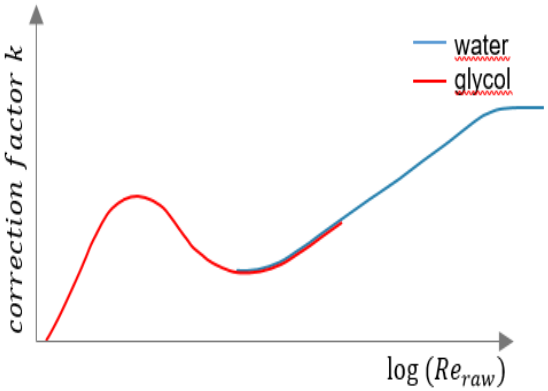
$\Rightarrow$ it is the same calibration curve for glycol and water!

Compensation Algorithm

- kin. viscosity calculated from fluid data and temperature
- raw Reynolds number calculated from measured velocity and kin. viscosity
- correction factor k calculated from raw Reynolds number
- average velocity calculated from correction factor k and measured velocity
- volumetric flow calculated from average velocity and cross section



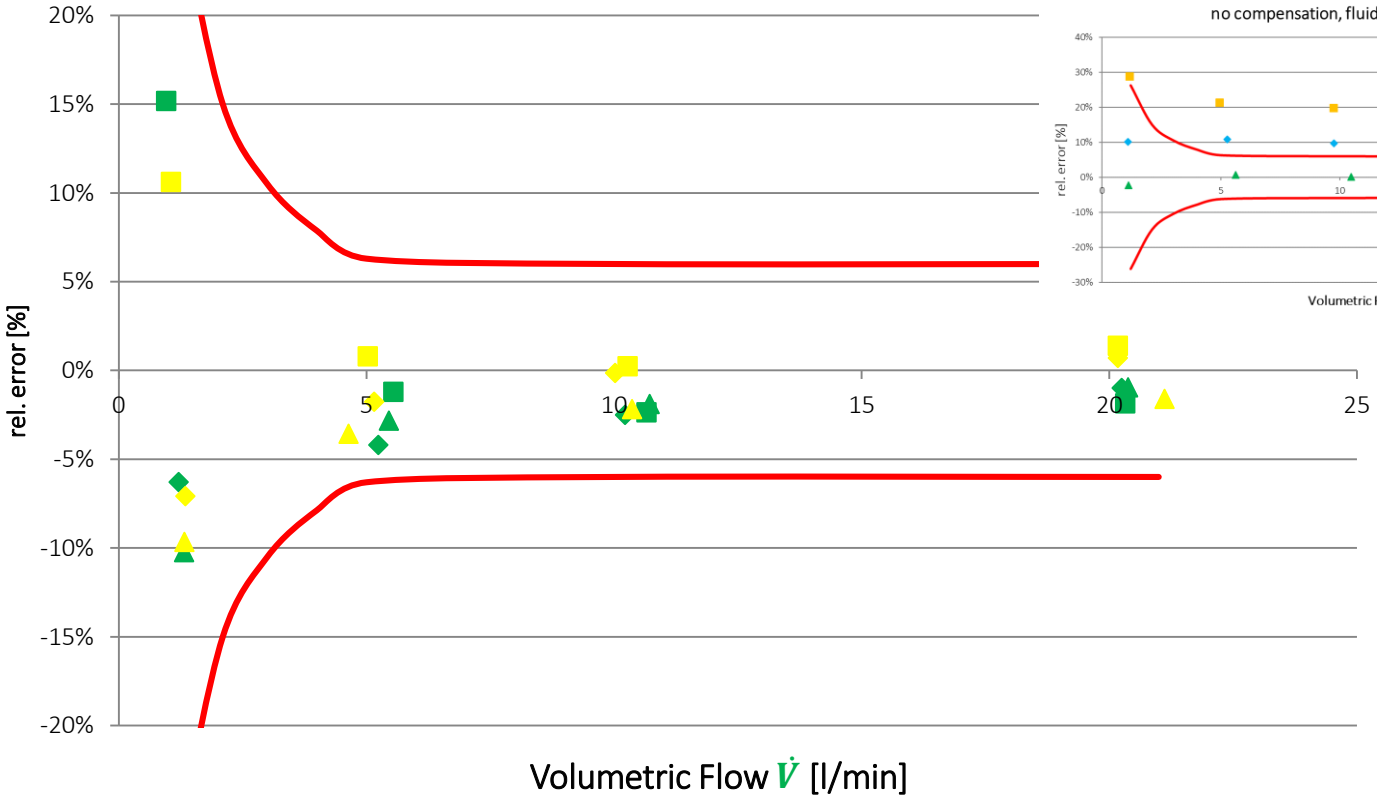
$$Re_{raw} = \frac{r \cdot v_{meas}}{\eta}$$

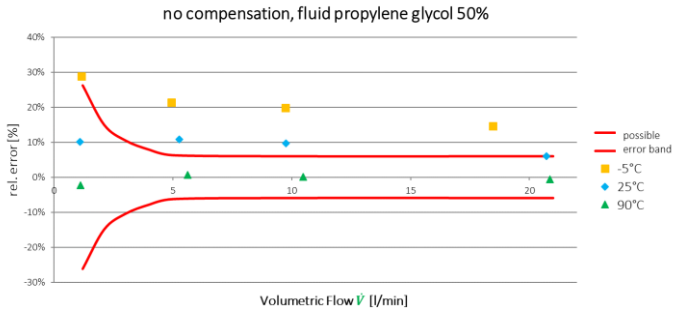


$$\bar{v} = k \cdot v_{meas}$$

$$\dot{V} = \bar{v} \cdot A$$

Effect of Compensation

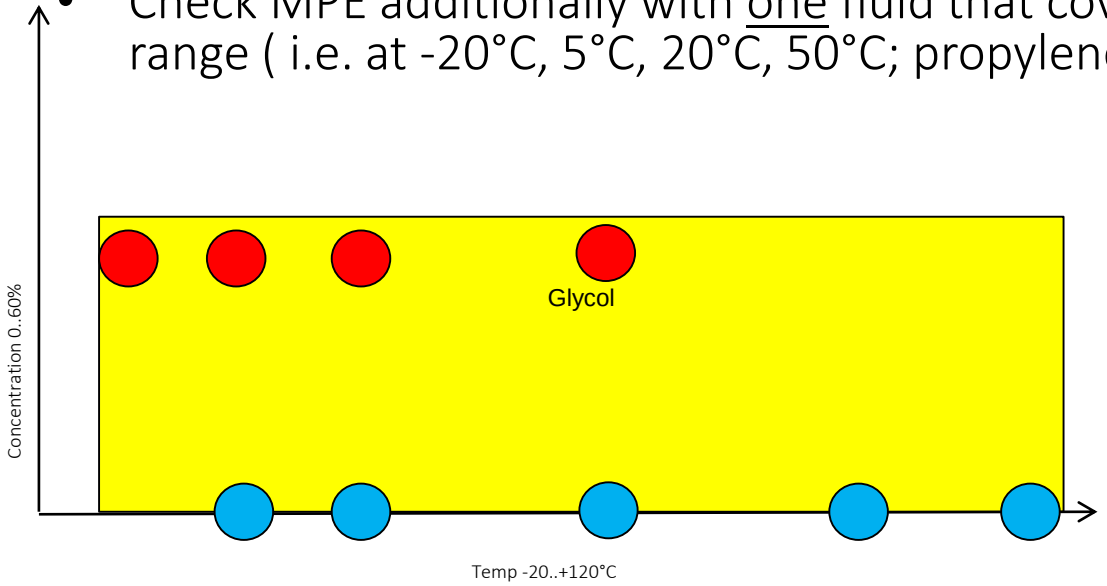


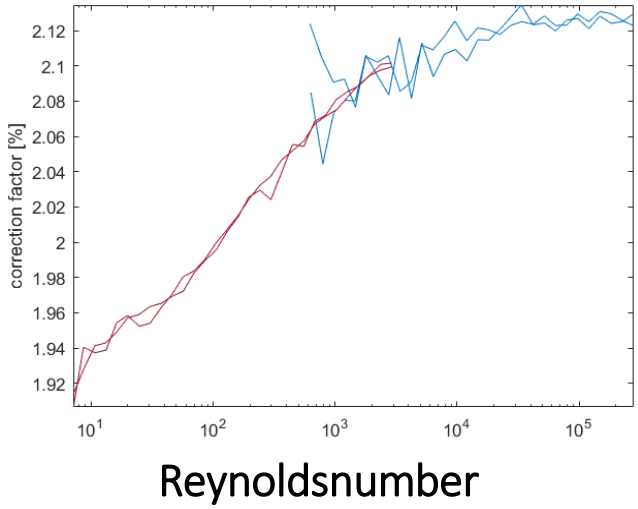


- prop. glycol 51%, 25°C
- prop. glycol 51%, -5°C
- prop. glycol 51%, 90°C
- eth. glycol 47%, 25°C
- eth. glycol 47%, -5°C
- eth. glycol 47%, 90°C

Proposal for a Verification Procedure during Type Approval

- Check MPE with water (5°C, 20°C, 50°C, 80°C, max temperature)
- The meter needs to be adjusted to the fluid
- Check MPE additionally with <u>one</u> fluid that covers the specified viscosity range (i.e. at -20°C, 5°C, 20°C, 50°C; propylene glycol)





Summary

- Compensation of thermal energy meters for the influence of glycol is possible
- Necessary to know:

  fluid density $\rho(T, conc)$,
  specific heat capacity $c_p(T, conc)$
  and kinematic viscosity $\eta(T, conc)$

but

- The fluid properties add uncertainties to the measurement
- The fluid properties must not change

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Use of Glycol in real Life

Uncertainties in Fluid Parameters

- Current high-end lab equipment has the capability to measure the fluid properties with these uncertainties

	uncertainty
Density	0.001% [1]
Heat Capacity	1 – 3 % + uncertainty of reference [2]
Viscosity	0.5% + uncertainty of reference [3]

[1] Refering to Anton Paar DSA5000M
[2] Refering to Hitachi Application Note
[3] Refering to Anton Paar Lovis 2000

Compensation in real Life

The physical parameters density $\rho(T)$, specific heat capacity $c_p(T)$, and kinematic viscosity $\eta(T)$ do change

degradation of the fluid due to thermal overexposure	Operator
refilling of the system (with water or other fluids) due to pressure loss	Operator
mixing the fluids on site	Installer / Operator
additional additives on site to improve corrosion or bacterial behavior of the system or water softening	Installer / Operator
storage and transport of the fluid	
recipe changes (i.e.due to environmental regulations, technical findings or economic optimizations)	Fluid Manufacturer
batch-to-batch variations	Fluid Manufacturer

When high reliability of the measurement is needed

- We have to ensure that the fluid parameters are measured on a regular basis at the customer site
- We should improve the methods to determine the fluid properties
- We should encourage the fluid manufacturers for cooperation, so that
  - they state the fluid parameters including tolerances
  - they agree, not to change the fluid composition without notice
  - possibly some fluids could be certified

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Conclusion

Conclusion - Achievements

- A correct measurement of the **volumetric flow** is possible even with glycol
  - the viscosity curve of the fluid must be known
- A correct measurement of the **thermal energy** is possible even with glycol
  - the density and heat capacity curve of the fluid must be known

- It is possible to make a universal meter for various fluids and concentrations that can compensate the fluid effect if above parameters are known to the meter
- It is possible to type approve such a meter with little extra effort for various fluids and concentrations

Conclusion - Challenges

- To have a good measurement stability over the lifetime it is essential that the fluid parameters are measured on a regular basis and are available to the meter

- High uncertainties in the methods to determine fluid parameters directly affect the accuracy of the energy measurement

→ Focus on the Fluid!

Questions?

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