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Overcoming the Glycol Measurement Challenge

Glycol is commonly used to prevent heat transfer fluids freezing in heating, cooling and air conditioning systems. It is typically found in systems where pipework is exposed to the exterior environment – rooftop units, free cooling, cooling towers – and also in green energy applications, such as solar thermal collectors. Glycol may also be used in district cooling systems – for example, in high rise properties – and low temperature energy networks serving a number of customers. However, the addition of glycol into any system can result in large errors in thermal energy measurement when using a meter intended for water alone. Now, an innovative inline flow sensor has come to market that can automatically detect and compensate for changes in the fluid composition, providing accurate volumetric flow and thermal energy measurement in both water and glycol applications. This article shares some of the technical insights and concepts behind this unique product.

The Pros and Cons

Modern heat transfer fluids are complex mixtures of around 60 to 75 percent deionized water, 25 to 40 percent mono-ethylene or propylene glycol and, typically, additives such as stabilizers, corrosion inhibitors, oxygen scavengers and anti-fouling components. The big advantage of using glycol-water mixtures as heat transfer fluids, rather than only water, is that they allow systems to operate at temperatures below zero. However, there are a number of issues associated with using these mixtures. They are considerably more expensive than water and have a lower heat capacity, requiring up to 30 percent higher flow to achieve the same energy transport. At low temperatures, glycol-water mixtures also become quite viscous, needing between 50 and 100 percent additional pump energy to match the heat transfer of water alone. A further complication is that ethylene glycols are toxic, and propylene glycols – ralong with many additives – are not environmentally friendly, meaning that professional disposal is required once the fluid reaches the end of its service life.

The Right Recipe

There are significant variations between the compositions of pre-mixed glycols from the myriad of manufacturers on the market, with each provider offering a range of different formulations for specified applications. The precise composition of these pre-mixed glycols can also change periodically for cost optimization or due to new legislation regarding the ingredients, often without manufacturers informing customers. And, while it is common practice in Europe to buy pre-mixed glycols, in North America mixing of heat transfer fluids can also be performed on site. The whole issue is further complicated by the fact that the fluid composition, and therefore its physical properties, can change unpredictably over time, due to:

- degradation causing the fluid to become flocculent, particularly due to thermal overexposure in solar applications;
- addition of water to adjust for pressure losses in the system, diluting the glycol concentration (reducing or potentially removing the freeze protection);
- variations in concentration of additives due to imprecise on-site mixing.

The Glycol Measurement Challenge

Any changes in the composition of the heat transfer fluid, such as those outlined above, will have an impact on its density, heat capacity and viscosity which, in turn, will affect the measured thermal energy (Q, see equation below) and the measured volumetric flow.

A change in viscosity will have an effect on the flow profile, or velocity distribution, within the pipe. Consequently, if a thermal energy meter intended for use with water is employed with a glycol-water mixture, changes in any of these fluid properties can result in a cumulative heat measurement error of as much as 40 percent. However, if the correct fluid parameters are known, it is possible to compensate for this.

Thermal energy, Q, is defined by the formula:

$$\boldsymbol{Q = \int \dot{V} \cdot \rho \cdot c_p \cdot \Delta T \cdot dt}$$

$\dot{V}$ = volumetric flow

ρ = density

c_p = heat capacity

ΔT = differential temperature (supply – return)

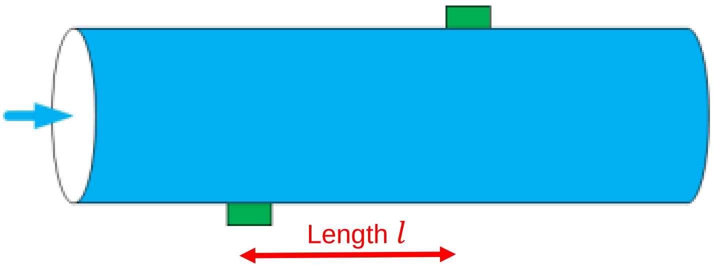
Trusted Flow Measurement

Despite this issue having been widely recognized and understood for many years, the only options until recently were to accept this potential for measurement error, avoid the use of glycol in systems where the heat transfer needs to be measured – in Europe, its use is very restricted in district heating networks, where accurate measurements are essential to ensure correct consumer billing – or invest in expensive measurement equipment to allow manual compensation for changes in the fluid properties. However, a novel inline flow sensor (Belimo) has been developed that offers automatic, continuous glycol measurement and compensation, ensuring optimal HVAC system performance. Using ultrasonic transit-time technology, this approach offers a method for thermal energy measurement that is insensitive to magnetite problems – unlike electromagnetic flow sensors –, has a longer lifetime than impeller technology and is suitable for use with a wide range of heat transfer fluids of varying glycol concentrations.

How it Works

This novel ultrasonic flow meter uses two offset transducers (Figure 1) to determine the flow velocity by measuring the speed of sound in the heat transfer fluid. The downstream transit time is measured by passing an ultrasonic pulse from the lower transducer to the upper transducer, then the process is reversed to obtain the upstream transit time. These transit times will differ based on the flow of fluid through the sensor tube: the downstream pulse is accelerated by the flow, while the upstream pulse is impeded and slowed by it. The transit times of these ultrasound pulses can be used to determine the measured velocity (v_{meas}).

Flow Velocity



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

v_{meas} = measured flow velocity

c = constant

l = length

tt = transit time

Figure 1: Measuring volumetric flow with ultrasound.

This data, together with the fluid temperature, can then be used to calculate the kinematic viscosity (η) and determine the volumetric flow. However, as volumetric flow requires an average of the flow velocities across the diameter of the pipe – not just a single pathway – this is affected by differing flow profiles (Figure 2). In laminar flow (grey), the velocity is greatest in the center and slower at the pipe wall. In contrast, in turbulent flow (blue) the flow velocity is virtually identical across the pipe diameter. This effect is usually compensated for during production by using correction curves to calibrate the flow sensor. However, as the flow profile is influenced by fluid viscosity, the presence of glycol in the system can lead to significant measurement error.

Volumetric Flow

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

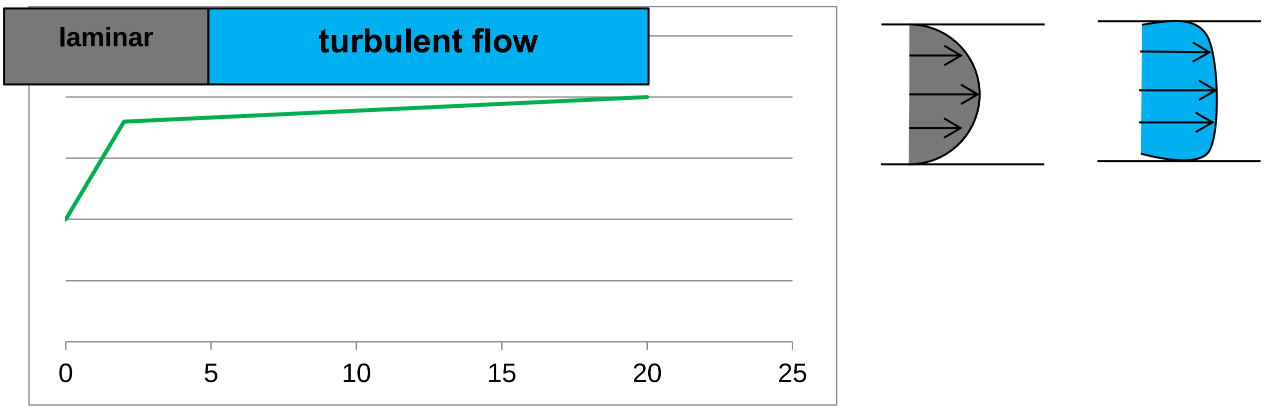


Figure 2: Calculation of average flow velocity.

An alternative approach is to use the Reynolds number (Re) rather than the flow velocity.

$$Re = \frac{v.D}{\eta}$$

v = flow velocity

D = diameter

η = kinematic viscosity

The practical significance of this ratio is that the flow velocity distribution is similar for a given Reynolds number and geometry. Consequently, the correction factor (k) – used to relate the volumetric flow to the average velocity across the cross-sectional area of the pipe – plotted as a function of Reynolds number is independent of the fluid viscosity, and the resulting water and glycol-water calibration curves superimpose. This means that the sensor can be calibrated with water and still measure any other fluid of known viscosity. The process is summarized in Figure 3.

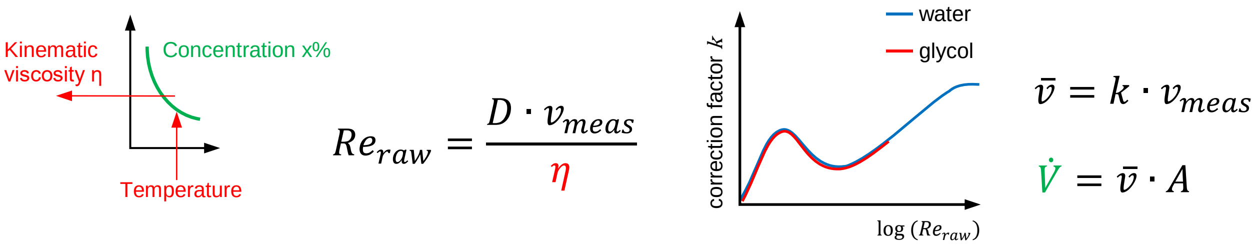


Figure 3: Summary of the automatic glycol compensation algorithm.

This Reynolds number approach has been used to develop a patented automatic glycol compensation algorithm that is able to select the correct fluid properties to use for the flow and energy calculation, and can be applied to a wide range of heat transfer fluids, ensuring accurate, repeatable measurements in any HVAC application.

Accurate Results Without Drift

The benefit of glycol compensation is clearly demonstrated in Figures 4 and 5. Without compensation (Figure 4), volumetric flow measurements can show errors of as much as 30 percent; the application of automatic glycol concentration (Figure 5) minimizes drift and significantly reduces the degree of measurement error.

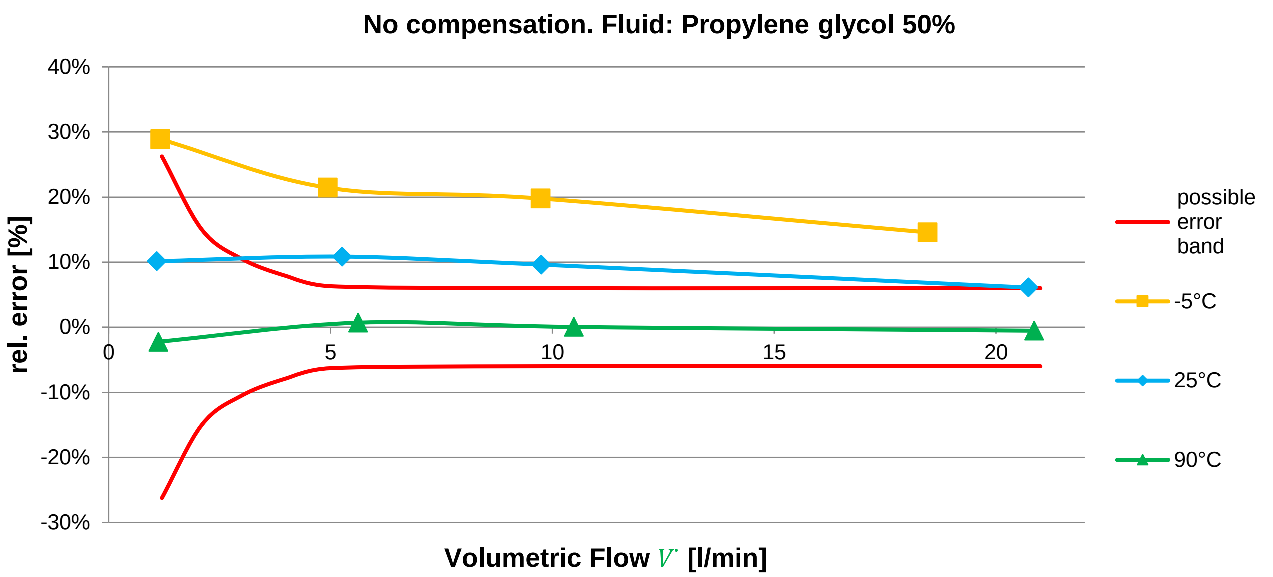


Figure 4: The influence on glycol on volumetric flow measurement without viscosity compensation.

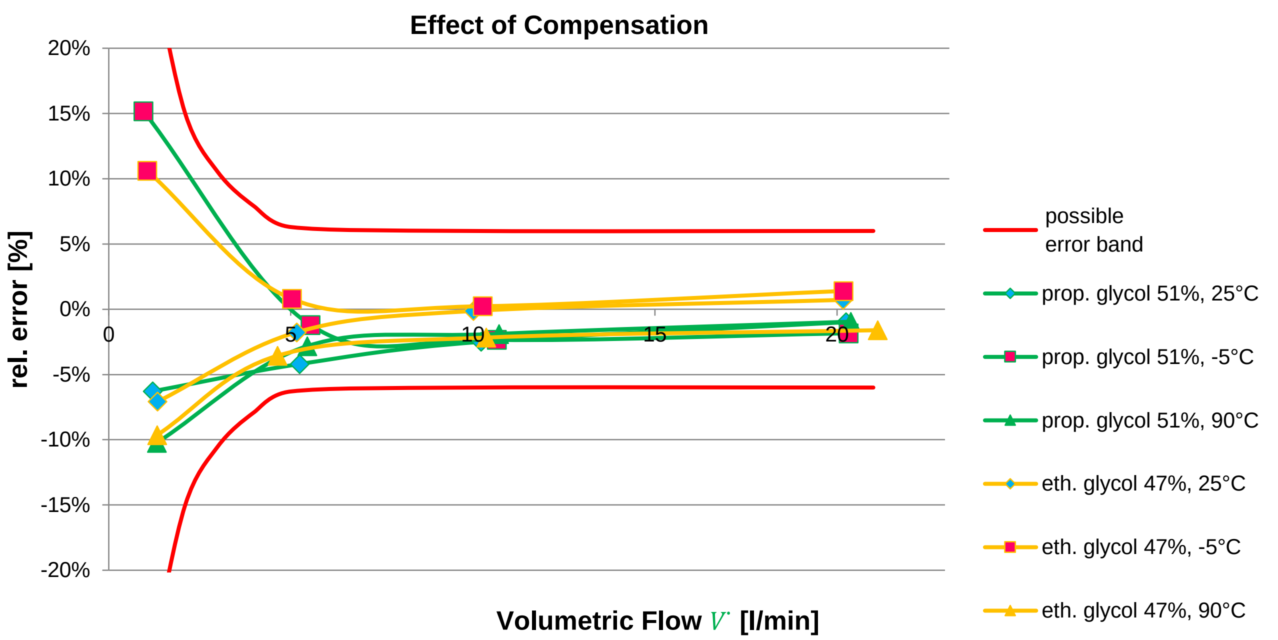


Figure 5: The effect of glycol compensation on volumetric flow measurement.

Conclusion

The development of an inline flow sensor that uses ultrasonic transit-time technology to automatically measure and compensate for glycol concentration is a huge advance in thermal energy measurement. A single ‘fit and forget’ flow sensor is all that is necessary to compensate for the variable and changing viscosities and heat capacities of heat transfer fluids. With no moving parts, the sensor is extremely robust and requires no calibration, providing certainty that the measured flow is correct. This makes it ideal for accurate, repeatable measurements, improving the control and efficiency of HVAC systems.