ISOIL INDUSTRIA
Via F.lli Gracchi 27
20092 Cinisello Balsamo
Milano (MI) – ITALY

HEMINA
ACCREDIA - 01021LAT LIBRA Division.
Accredited Calibration Laboratory
Via Piemonte,2 - 35044 Montagnana
Padova (PD) – ITALY

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Riccardo Montafia
Luisfilippo Lanza

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THERMAL ENERGY METER

Proposal

THERMAL ENERGY IN ITALY

An Overview of Thermal Energy Demand in Italy: National Regulations for Cooling Meters, Subsequent Verification, and Influence of Commercial Glycol Mixtures on heat meters measurements

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Authors:

Riccardo Montafia
Product Manager at ISOIL Industria S.p.A. - Riccardo.MONTAFIA@isoil.it
Eng. Luisfilippo Lanza
In charge of LIBRA Accredited Calibration Laboratory - l.lanza@hemina.net -

Summary

Introduction:

Within the European Union, thermal energy meters fall under the scope of the MID, which regulates both type approval and initial verification, while the technical rules for subsequent (periodic) verification are defined at national level.
Type approval and initial verification are carried out under ideal laboratory conditions, which rarely reflect real operating environments.

This makes subsequent verification particularly significant, as it must consider the multi-component nature of thermal energy meters as well as real field conditions such as low flow rates, low temperature differences, and variations in heating fluid properties.

In Italy, DM 93/2017 specifies the requirements for periodic (subsequent) verification of meters used for legal purposes.
It is widely acknowledged that standards such as EN 1434 and OIML R75 do not provide detailed guidance for in-service verification.
At the national level, DM 93/2017 mandates that accredited inspection bodies (EN 17025, EN 17020 and EN 17065) perform periodic verification through visual and functional checks of the meter.

The functional verification can be conducted either in a fixed or mobile laboratory, or directly in the field without dismantling the thermal energy meter's sensor.
In-field verification does not require shutting down the plant and is generally more affordable than laboratory verification.
Laboratory verification benefits from controlled environmental conditions, whereas field verification relies on operational conditions that may differ significantly from standard laboratory tests. For instance, the widespread use of water–glycol mixtures as heat transfer fluids—intended to provide frost protection and reduce corrosion—can considerably alter their thermophysical properties depending on the glycol concentration.

The proposed EMATEM 2026 technical paper presents ISOIL Industria's experience across the entire lifecycle of thermal energy meters, including subsequent verification within the Italian framework.
Since heating and cooling demands are highly diversified across the country - from northern to southern regions - a concise overview of the main demand characteristics is provided.

Finally, regarding the thermophysical behaviour of heat transfer fluids, the proposal of technical paper reports the outcomes of a study investigating the metrological challenges associated with using fluids other than water (e.g., water–glycol mixtures at various concentrations).
The tests were conducted at the IEC/ISO 17025-accredited LAMI Laboratory of the University of Cassino and at the LIBRA Division of HEMINA – ISOIL Industria, located in Montagnana (PD), Italy.

ISOIL INDUSTRIA Company profile and experience

Probably we have never properly introduced our company to the association, so the opening slides are meant to give everyone a clear overview of who ISOIL Industria is and what value we can bring to the group.

ISOIL Industria is a global manufacturer and supplier of electromagnetic and ultrasonic flow meters for liquid applications, supported by HEMINA, our production centre, and LIBRA, our accredited calibration laboratory. Founded in 1959, the company has steadily grown over the years and today is able to provide the full lifecycle of a measurement instrument - from R&D activities through design and testing, up to conformity assessment and subsequent verification in line with international regulations.

ISOIL Industria's portfolio includes:

- ISOMAG – electromagnetic flow meters
- ISOFLUX – ultrasonic flow meters
- ISONRG – thermal energy meters
- ISOD@M – data loggers and software for data management and analysis

LIBRA, our calibration laboratory, has been IEC/ISO 17025 accredited since October 2013. It can calibrate instruments for volume, volume flow, mass flow and total mass - from DN3 up to DN3000 - both for ISOIL Industria products and for third-party meters, issuing the corresponding Accredia certificates.
By the end of 2025, LIBRA has also obtained accreditation for the calibration of thermal energy quantity.

ISOIL Industria has also recently established its new Italian Inspection Body: METRON.
METRON is a division of ISOIL Industria accredited under IEC/ISO 17020 and DM 93/2017 to perform on-site subsequent verification of water and thermal energy meters without removing the meter from the system, thereby avoiding shutdowns or disruptions.

Heating and cooling demand in Italy

Italy presents a unique situation, with highly diverse climatic conditions between the northern and southern regions. District Heating networks are concentrated in the central and northern areas of the country due to lower outdoor temperatures from October to April.

Conversely, the distribution of Cooling Systems is more uniform nationwide, driven by the high temperatures reached during the summer months and by the wide variety of applications - residential, service-sector (e.g., hotels, shopping centres, airports), and industrial.

This trend is increasing the demand for MID-approved cooling energy meters, ensuring accurate and secure measurement of thermal energy. To address this need, ISOIL aims to remain at the forefront of the sector by certifying its meters according to PTB TR 7.2K and by actively participating in international research programs with WELMEC and EURAMET.

These initiatives are focused on refining calculation methodologies and standardizing approaches to guarantee the highest European quality requirements, recognized worldwide.

Metrological issues of using fluids other than water

Introduction

The adoption of thermal energy meters (TEMs) in European residential buildings has increased significantly following the EU Energy Efficiency Directive, which mandates individual heat billing to promote energy savings. These instruments are further utilised in district heating networks to support demand management and transparent consumption reporting. Within the European Union, TEMs are regulated by the Measuring Instruments Directive (MID), which governs pattern approval and initial verification. However, technical rules for subsequent (periodic) verification are established at the national level, leading to varied procedures and verification intervals depending on the specific technology and flow rate.

A significant challenge arises because type approval and initial verification are conducted under ideal laboratory conditions, which often fail to reflect real-world operating environments. Standards like EN 1434 and OIML R75 do not currently specify detailed in-service verification methods. A common complexity in the field is the use of water (WT) and glycol mixtures to provide frost protection and stabilise the system. These additives alter the fluid's specific heat capacity, density, and viscosity, which can significantly influence measurement accuracy if the meter is only calibrated for pure water. This study investigates the metrological impact of these varied fluid properties on different meter technologies.

Three different heat meters (i.e., ultrasonic, impeller and magnetic) have been investigated under different plant conditions (heating/cooling, high/low flow and temperature difference) and with different heating fluids (i.e., WT and WT/PG mixtures).

Theory

The measuring principle of a thermal energy meter relies on determining the volumetric flow rate $\dot{V}(m^3 s^{-1})$ and the temperature difference between the flow $T_f\ (K)$ and return $T_r(K)$ pipes.

The heat output $\dot{Q}\ (W)$:

$$\dot{Q} = k(c_p, \rho)(T_f - T_r)\dot{V}$$

is calculated using the volumetric heat coefficient $k\ (J\, m^{-3} K^{-1})$, which is a function of the heat capacity $c_p\ \ (J\, kg^{-1} K^{-1})$ and the density $\rho\ \ (kg\, m^{-3})$ of the heating medium.

For standard applications, the calculation of follows formulas defined for water in Annex A of EN 1434-1. However, the introduction of propylene glycol (PG) significantly alters these thermophysical properties. Research shows that as PG concentration increases; density rises while specific heat capacity decreases. Consequently, the volumetric heat coefficient

$$k_f = \frac{\rho(T_f)}{\Delta T} \int_{T_r}^{T_f} c_p(T) dT$$

$$k_r = \frac{\rho(T_r)}{\Delta T} \int_{T_r}^{T_f} c_p(T) dT$$

deviates from that of pure water.

For a WT/PG mixture of 39.3%, relative deviations in compared to water can reach +6.8% at 5 °C and +3.4% at 50 °C. If a meter calibrated for water fails to compensate for these shifts, substantial errors in energy readings may occur.

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Method

The experimental campaign evaluated three commercial MID Class 2 thermal energy meters designed for water applications:

- impeller single-jet (compact)
- ultrasonic (compact)
- magnetic flow sensor (combined).

All tested meters had a diameter of DN25 and a permanent flow rate q_P of 1,5 m³/h.

Impeller single jet (compact), Ultrasonic (compact), Magnetic (combined)
DN25 (1”)
q_p=1,5m³/h; q_p/q_i=25
$\Delta\theta_{min}$=3K, θ_{min}=0°C, θ_{max}=100°C
Liquid: water

The test programme covered both heating mode (flow sensor liquid temperature at 50 °C) and cooling mode (flow sensor liquid temperature at 15 °C) and three fluid types: pure water, 25.4% PG, and 39.3% PG.
Concentrations were prepared using calibrated precision scales. Tests were performed at accredited laboratories using a gravimetric test bench as the reference system. To ensure reference accuracy, the reference thermal energy was corrected using experimental density and heat capacity values for the specific PG mixtures to calculate a corrected heat coefficient. The relative error was then calculated by comparing the meter's reading against this reference value. The scope is to evaluate the overall sensitivity of the meter designed for use with clean water when used with liquids other than water, such as the PG mixture in the case study under consideration.

Results

The results demonstrated that PG concentration affects meter accuracy differently based on technology and operating conditions.

Magnetic TEM

This meter was the most robust, with errors generally remaining within the MID Class 2 permissible limits, showing only isolated deviations in heating mode at specific flow and combinations.

Measured thermal energy relative errors of the
magnetic (combined) thermal energy meter at different PG concentrations and fluid temperatures.

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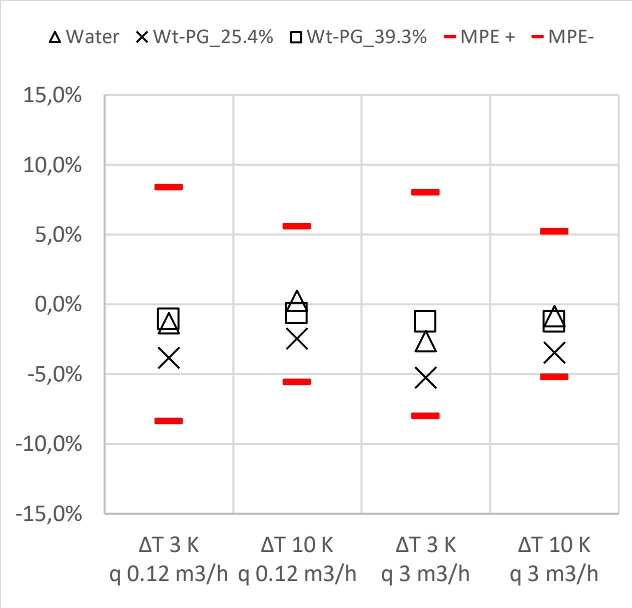
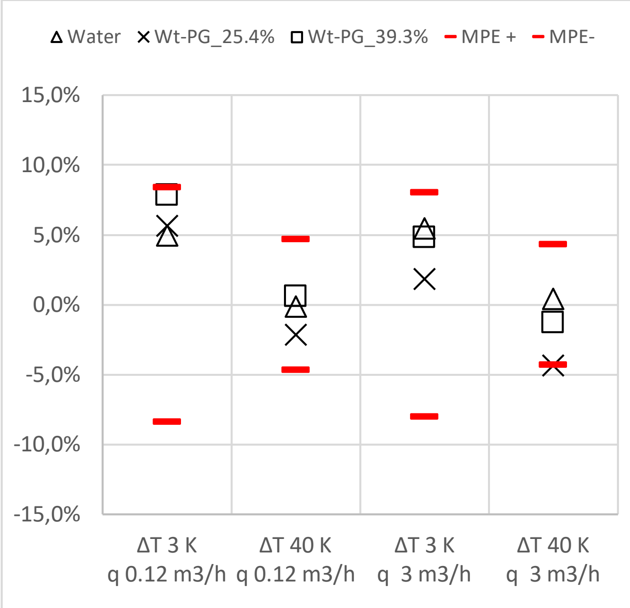


a) cooling (T=15 °C),

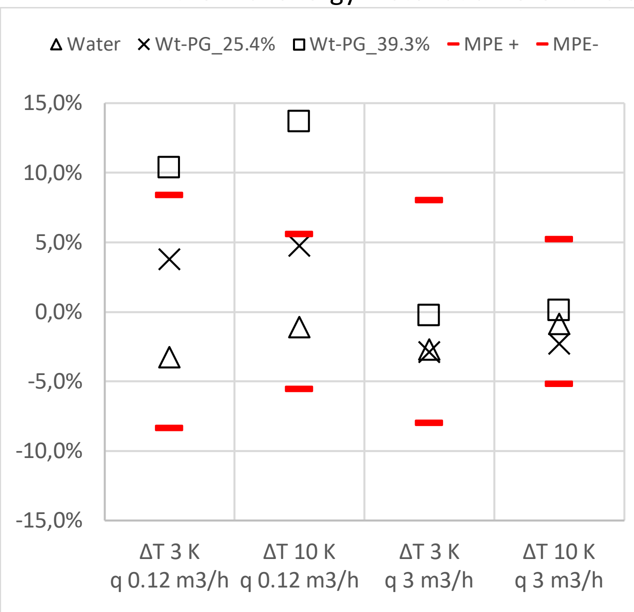


b) heating (T=50 °C).

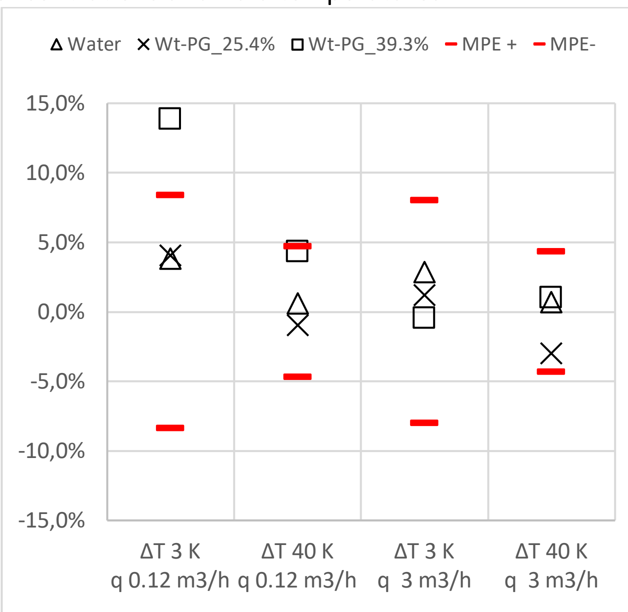
Ultrasonic TEM

A clear trend was observed where measurement error increased as PG concentration rise. At 39.3% PG, the permissible limits were significantly exceeded at low flow rates in both heating and cooling modes.

Measured relative errors of the Ultrasonic (compact)
thermal energy meter at different PG concentrations and fluid temperatures:



a) cooling (T=15 °C),



b) heating (T=50 °C).

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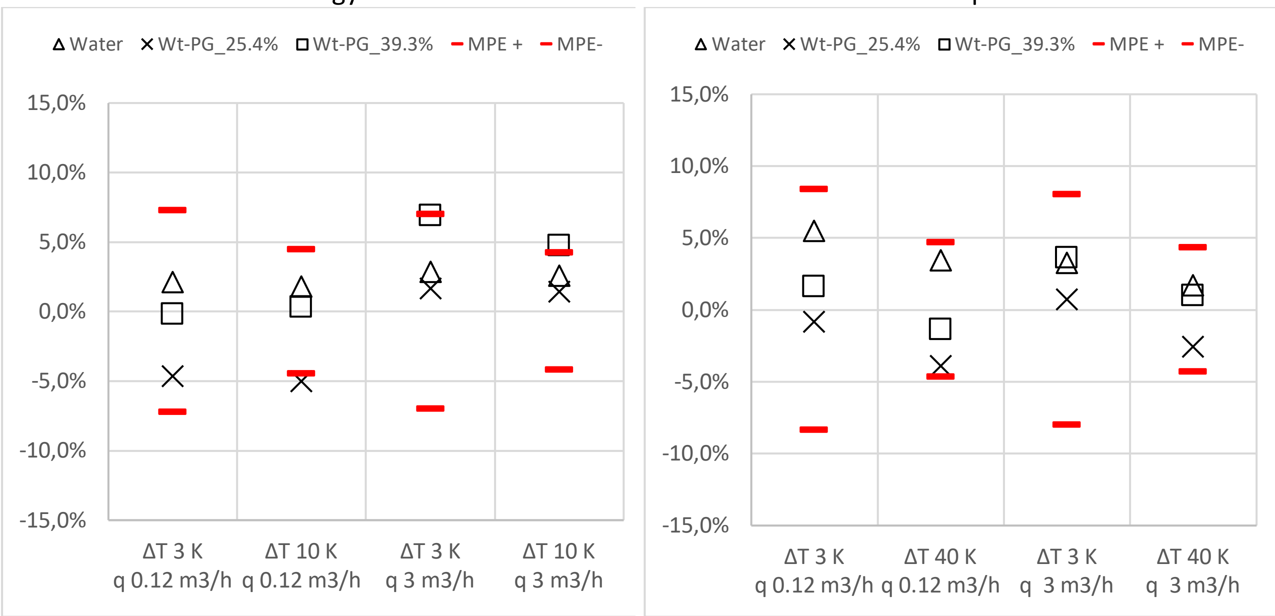
Impeller Single-jet TEM

This meter exceeded allowable limits during cooling and heating tests at low flow rates with 25.4% PG, and showed critical deviations at high flow rates with 39.3% PG.

Measured relative errors of the Impeller single jet (compact)
thermal energy meter at different PG concentrations and fluid temperatures:



a) cooling (T=15 °C), b) heating (T=50 °C).

Analysing the flow sensors as separate sub-assemblies revealed a non-negligible positive bias for ultrasonic and impeller technologies as glycol concentration and temperature increased. This bias is primarily attributed to viscosity changes associated with the glycol. In contrast, the electromagnetic flow sensor maintained a limited deviations within the accuracy class.

Conclusion

The study concludes that the accuracy of thermal energy meters is significantly challenged when using heat-conveying liquids other than water. While magnetic meters demonstrate higher metrological stability, ultrasonic and impeller meters are prone to significant positive biases as propylene glycol concentration increases, often exceeding the maximum permissible errors defined by the MID.

These findings highlight that fluid properties—specifically viscosity and heat capacity—are critical factors that must be addressed to ensure equitable energy billing and in-field subsequent verification procedures when the thermal vector liquid is not well known.

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