Heat Metering

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The centralised production of heat and the distribution of heat as a utility (for example district and communal heating systems) necessitates the measurement of the heat supplied for monitoring and billing purposes. Financial incentives to encourage the generation of heat from renewable sources also depend on the measurement of the heat generated to quantify the amount of renewable heat. Heat metering is essentially another form of utility metering, with the principal difference being that heat energy is more complex to measure than electricity or gas.

1. Introduction

Heating accounts for nearly half of final energy consumption in the UK (48% in 2013) and 78% of non-transport energy use (DECC, 2013).

2. Definition of heat metering

Heat meters are devices used to measure heat or thermal energy. In a heating system the thermal energy is directly proportional to the product of the fluid flow rate and the fluid temperature difference. A heat meter consists of a flow measurement device, a pair of temperature sensors to measure the temperature difference, and a calculator to determine the thermal energy on the basis of the inputs from the flow and temperature difference (see Figure 1).

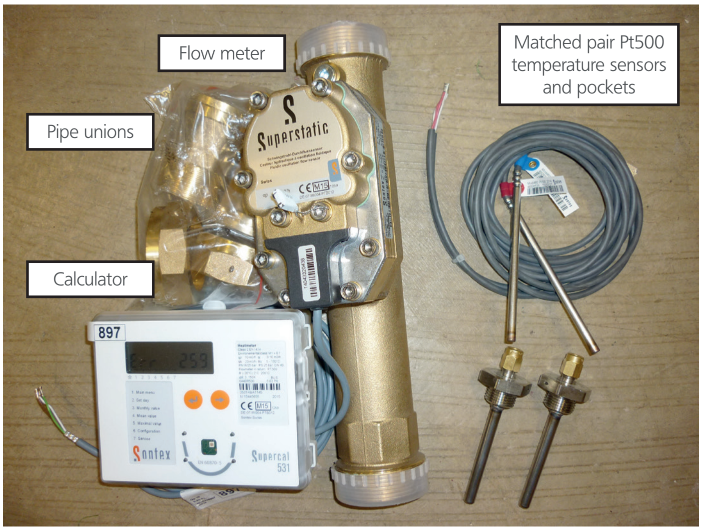

Figure 1. Components of a heat meter

3. Heat metering applications

The principal application of heat metering is for the billing of heat supplied to consumers through district or communal heating systems. This is another form of utility metering (similar to gas, electricity, or water). In the UK, heat metering is also used for the measurement of renewable heat, in connection with the Renewable Heat Incentive (RHI) scheme.

4. Relevant standards and legislation

The Measuring Instruments Directive (2004/22/EC) (MID) is a directive by the European Union, which seeks to harmonize many aspects of metrology across member states of the EU. Its most prominent tenet is that all kinds of meters which receive MID approval may be used in all countries across the EU where legal metrological control is prescribed.

BS EN 1434:2007 Parts 1 to 6 is the UK implementation of EN 1434:2007 Parts 1 to 6. EN 1434 is harmonised to the MID and defines general requirements, constructional requirements, data exchange and interfaces, pattern approval tests, initial verification tests, and installation, commissioning, operational monitoring and maintenance of heat meters.

The International Organisation of Legal Metrology (OIML) has also published international recommendations on heat meters, consisting of documents OIML-R75 Parts 1 and 2 covering general requirements, type approval tests and initial verification tests. The requirements of OIML-R75 are similar to the specifications of EN 1434.

Annex MI-004 of the MID defines a heat meter as an instrument designed to measure the heat which, in a heat exchange circuit, is given up by a liquid called the heat-conveying liquid. The directive further specifies that a heat meter can be either a complete instrument, or a combined instrument consisting of the sub-assemblies comprising of the flow sensor, the temperature sensor pair, and the calculator.

Heat meter accuracy is specified by the MID class notation. The directive defines accuracy of instruments in terms of Class 1, 2 or 3, with Class 1 being the most accurate. The pair of temperature sensors does not have an accuracy class, and neither does the calculator, so it is only the flow sensor which has the associated accuracy. The allowable Maximum Permissible Error (MPE) for temperature sensors is the same no matter what the accuracy class of the complete assembly is.

Although heat meters are not presently regulated in the UK, in certain circumstances the installation of meters is a mandatory requirement (The Heat Network (Metering and Billing) Regulations 2014). These are where a new district heating or district cooling connection is made in a new building, where a building undergoes a major renovation or at the point at which a multi-apartment/multi-purpose building is supplied from a district heating or district cooling network. However, in all other circumstances and for all buildings, individual meters must be installed where it is cost effective and technically feasible to do so.

The RHI regulations define the minimum standards that heat meters must meet in order for measurement of the amount of renewable heat that is eligible for RHI payments. The non-domestic RHI scheme regulations stipulate that heat metering must comply with the specific requirements listed in Annex MI-004 to the MID and fall within accuracy class 2 as defined in the Directive whilst the domestic RHI scheme regulations stipulate that metering should meet the requirements for accuracy class 3.

5. Different technologies for heat metering

Heat meters are made up of three components: the flow meter, the temperature sensors, and the calculator.

Temperature measurement is generally carried out using platinum resistance thermometers (PRTs) which offer excellent accuracy over a wide temperature range (from –200 to +850 °C). Alternative sensors for temperature measurement include digital temperature sensors.

The main variances between different types of heat meters relate to the flow meter.

A velocity-type meter measures the velocity of flow through a meter of a known internal capacity. The speed of the flow can then be converted into volume of flow to determine the usage. There are several types of meters that measure water flow velocity, including jet meters (single-jet and multi-jet), turbine meters and electromagnetic meters.

5.1 Multi-jet meters

Multi-jet meters are very accurate in small sizes and are commonly used as water meters for residential and small commercial users. Multi-jet meters use multiple ports surrounding an internal chamber to create multiple jets of water against an impeller, whose rotation speed depends on the velocity of water flow. Multi-jets are very accurate at low flow rates. They generally have an internal strainer element that can protect the jet ports from getting clogged.

5.2 Turbine meters

Turbine meters are less accurate than jet meters at low flow rates, but the measuring element does not occupy or severely restrict the entire path of flow. The flow direction is generally straight through the meter, allowing for higher flow rates and less pressure loss than displacement-type meters. They are the meter of choice for large commercial users, fire protection and as master meters for the water distribution system. Strainers are generally required to be installed in front of the meter to protect the measuring element from gravel or other debris that could enter the water distribution system.

5.3 Electromagnetic meters

Electromagnetic meters use electromagnetic Induction to determine the flow of liquid in a pipe. In a magnetic flow meter, a magnetic field is generated and channeled into the liquid flowing through the pipe. Following Faraday's Law, flow of a conductive liquid through the magnetic field will cause a voltage signal to be sensed by electrodes located on the flow tube walls. The voltage generated is proportional to the movement of the flowing liquid. The electronic transmitter processes the voltage signal to determine liquid flow.

This flow meter does not obstruct flow, so it can be applied to clean, sanitary, dirty, corrosive and abrasive liquids. Electromagnetic flow meters can only be applied to the flow of conductive liquids, so hydrocarbons and gases cannot be measured with this technology due to their non-conductive nature and gaseous state respectively.

Electromagnetic flow meters do not require much upstream and downstream straight run so they can be installed in relatively short meter runs.

5.4 Ultrasonic meters

Ultrasonic flow measurement using the transit-time differential method is now one of the most universally applied flow metering processes. Flow is generally measured using the bidirectional ultrasonic technique based on the transit time method, with proven long-term stability and accuracy. Two ultrasonic transducers are used to send the sound signal both against and with the flow direction. The ultrasonic signal travelling with the flow direction reaches the opposite transducer first. The time difference between the two signals can be converted to a flow velocity and thus a volume. Ultrasonic meters are non-invasive and have no moving parts. Long unimpeded inlet runs are needed for accurate measurement.

5.5 Vortex meters

Vortex flow meters, also known as vortex shedding flow meters or oscillatory flow meters, measure the vibrations of the downstream vortexes caused by a barrier placed in a moving stream. The vibrating frequency of vortex shedding can then be related to the velocity of flow.

Heat Meter Installation and Factors Affecting Accuracy

Correct installation

The installation requirements differ between meter types. The following is a set of general principles. Reference should always be made to the manufacturer's installation manual.

- Install the meter in a horizontal run of straight pump. The preferred meter orientation is at +/- 45° to the horizontal.
- Take the necessary precautions to avoid air entrapment in the meter circuit. Ensure that the system can be vented at all high points. Do not install meters at high points in pipework.
- Verify that the static pressure at the meter is above the minimum pressure recommended by the manufacturer.
- Install a fine mesh strainer immediately before the flow meter.
- Check manufacturer's guidance, but in general ensure that the meter is installed in a straight length of pipework as far as practically possibly from bends, valves, or other fittings.
- Do not install meters downstream of pumps or fast acting valves that could set up pulsating flow.
- Ensure the meter has the same diameter as the piping. If a reducer or expander is required these not be installed directly adjacent to the meter.
- Ensure temperature sensors are installed in the correctly sized pocket so that the sensor is in the main flow
- Use a suitable thermal grease to pack temperature sensor pockets.
- Avoid exposed lengths of temperature probe or uninsulated areas of pipe around the probe.
- Ensure power cables are not routed near meter components or communication cables other than the necessary power connection for the meters.

7. Installation Errors

The definition of maximum permissible heat meter measurement error in the MID is related to the actual operating flow rate and the actual operating temperature difference. This has the effect that the expected accuracy is dependent on the operating conditions, and this effect is particularly pronounced when operating at low flow rates, or low temperature differences.

However, the meter accuracy is defined by the manufacturer in connection with a fully compliant installation, generally in laboratory or workshop conditions. Site installations of heat meters face a different range of constraints which can also have a bearing on meter accuracy. Figure 2 represents the different measurement errors recorded from a series of laboratory tests on various new heat meters carried out at different flow rates with a fixed temperature difference of 5K. These were the errors recorded when the meters were installed in accordance with the manufacturers' recommendations.

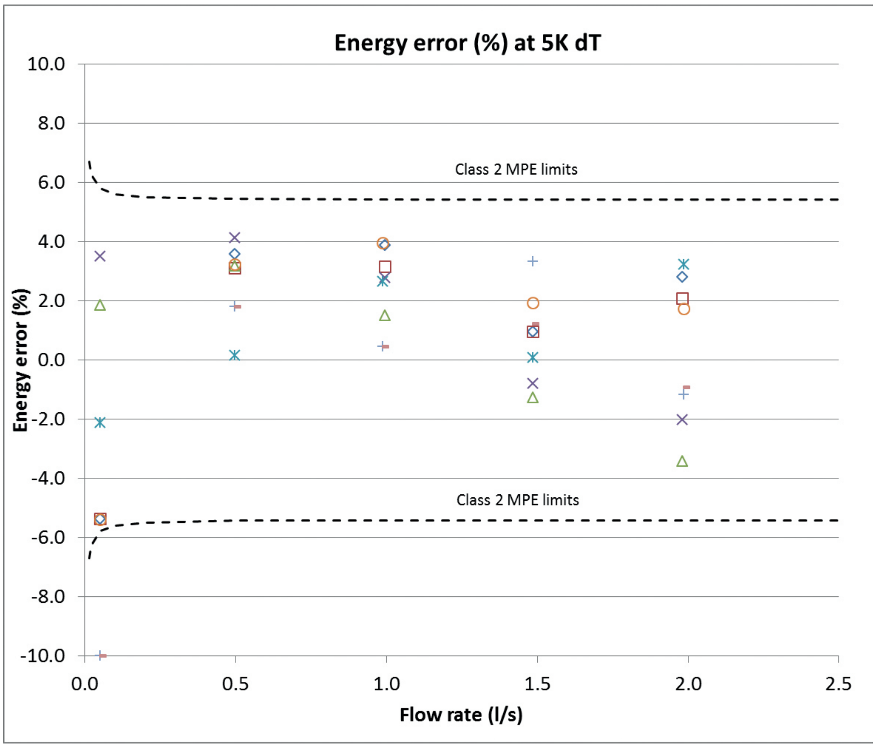

Figure 2. Heat meter energy measurement error for different meter types from BRE laboratory testing of new heat meters

Whilst the data presented in Figure 2 does not demonstrate any significant differences between the different meter types when new and installed correctly, the susceptibility to measurement errors caused by incorrect installation, system setup, and/or aging, could be expected to differ.

7.1 Temperature Measurement

The accurate measurement of heat energy is dependent on the accuracy of measurement of the temperature difference between the flow and return circuits. The requirements of EN 1434 are based on temperature sensors designed for direct immersion into the fluid and these sensors should have a qualifying immersion depth specified over which the temperature measurement is stable. The standard also allows for the temperature sensors to be inserted into pockets but specifies that the difference in measuring result with and without specified pockets shall be within 1/3rd of the MPE. Surface mounted temperature sensors are not covered by this standard.

Heat meter manufacturers supply temperature sensors as matched pairs, calibrated to minimise the error in measurement of temperature difference to values of the order of 0.05K. In order to maintain this level of precision it is essential that the sensors be installed in direct contact with the fluid, and in an identical fashion.

Figure 3 shows a 'binder' type pocket for the insertion of a temperature sensor directly in the fluid flow. Figure 4 shows a typical temperature installation in a pocket in the flow whilst Figure 5 shows a surface mounted temperature sensor.

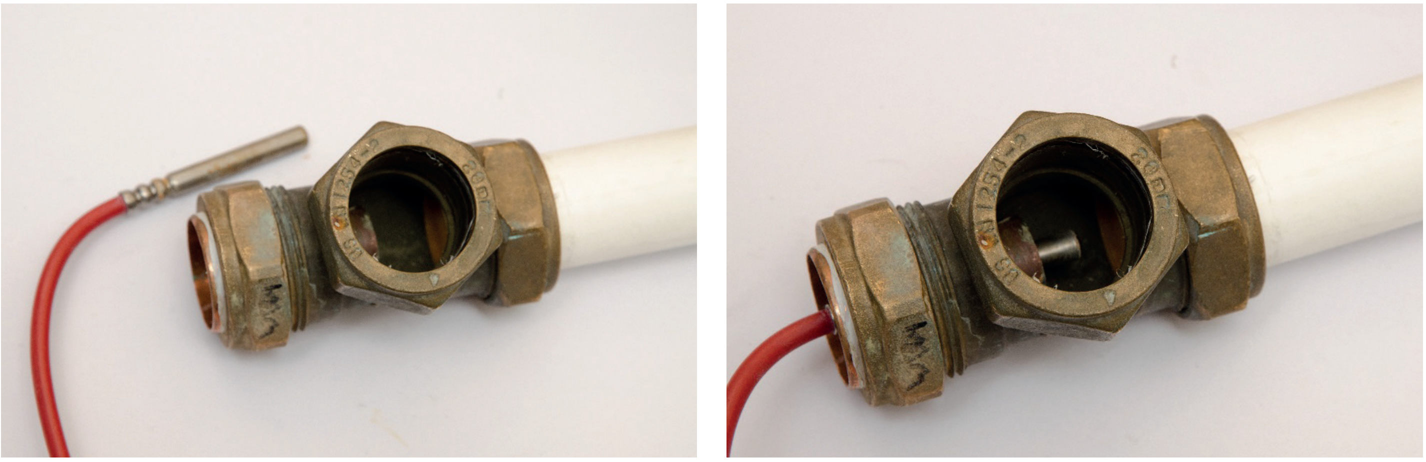

Figure 3. 'Binder' type temperature sensor for direct insertion in fluid flow

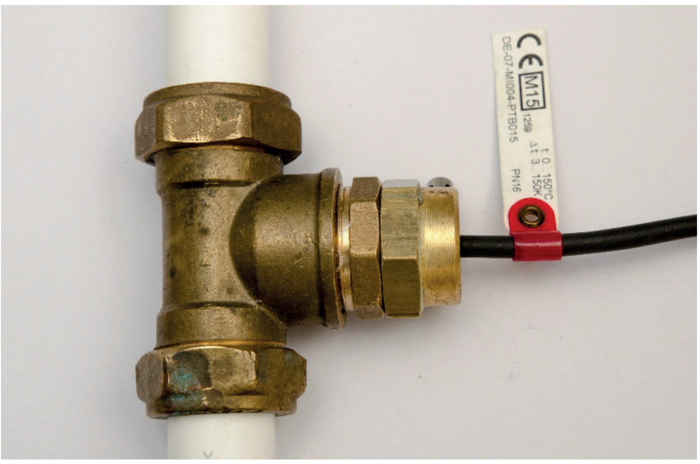

Figure 4. Temperature sensor inserted in pocket

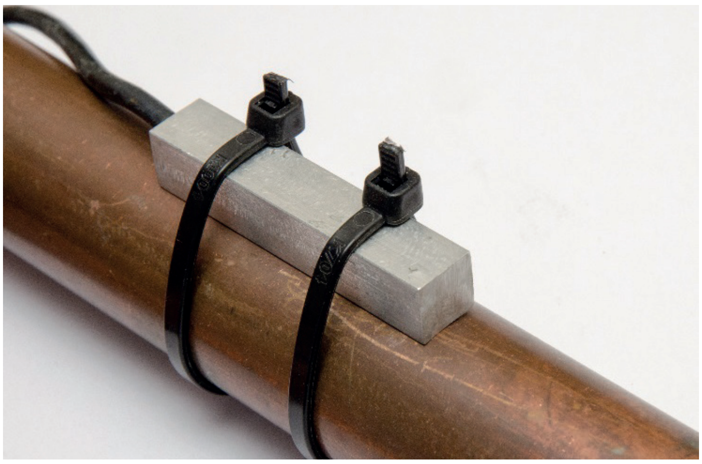

Figure 5. Surface mounted temperature sensor

Experimental data for a series of tests on heating systems with both constant and cyclical operation demonstrated that the error in energy measurement for temperature sensors directly immersed in the fluid flow or mounted in pockets averaged 2%, with a maximum error <6%.

Similar data for strap-on temperature sensors mounted externally to the pipe, whether insulated or not, resulted in an average error in energy measurement of 6%, with maximum error values exceeding 12%,

Installation of the temperature sensors is facilitated when provision for their location is made at the design stage. When a heat meter is fitted to an existing system, the temperature sensor location can be defined by questions of accessibility and the possibility of 'cutting in' to the system.

7.2 Flow measurement

Measurement of the fluid flow can be achieved by a number of different technologies, amongst which are electromagnetic, ultrasonic, vortex, and mechanical flow meters. Conformity to the MID implies that the meter meets the specific class requirements, irrespective of the means of flow measurement. However, the accuracy of measurement is dependent on the correct installation of the flow meter, and different technologies have varying sensitivities to incorrect installation conditions.

The overriding principle for correct installation is to ensure that the meter is installed at a position within the system where the fluid flow is stable. In other words, it is necessary to avoid locations close to transitions, bends or pumps, which can cause flow disturbances, and to avoid positioning which could encourage the entrapment of air and/or dirt in the meter.

It is also important to note that the flow meter element of the heat meter needs to be sized or selected to match the design flow of the system. The MPE is larger at low flow rates and hence it is recommended to avoid operation at the lower end of the flow meter range.

Experimental data for a series of tests on a variety of new heat meters installed incorrectly showed that in most cases the effect on flow meter accuracy was limited to approximately 2%. More significant measurement errors were noted for vortex meters when installed in close proximity to flow disturbances (between 5 and 10% error) and for ultrasonic meters with air entrainment in the fluid flow (no accurate reading possible).

The effects of incorrect installation could be expected to increase over time, particularly the effects of dirt build-up on moving parts. Long term testing over six months indicated that the ultrasonic and electromagnetic meters were not affected by dirt, probably due to the smooth bore of the flow meter. The accuracy of mechanical and vortex meters was affected by dirt build-up over time, with the tendency being to over-read.

7.3 Energy calculation and data collection

The energy calculator uses the data from the temperature sensors and the flow meter to establish the amount of heat energy passing through the measurement point. Calculators generally display instantaneous and cumulative values and the readings can be read from the meter display or transmitted to a data collection system, either as pulses, or using the M-Bus communication protocol.

The calculator must be configured to match the system where the heat meter is installed, specifically in relation to the properties of the system fluid. The thermal properties of glycol mixtures vary with glycol concentration and differ from the properties of water. The use of a meter configured for water on a system with a 30% glycol concentration would introduce an error of the order of 4%.

It is also possible for measurement errors to arise in relation to the frequency of measurement (the sampling rate), the resolution of measurement, and the method of data collection. Different models of heat meter have different limits on the level of resolution available and the pulse resolution (number of pulses per Wh, kWh, or MWh) can be an important consideration when selecting a heat meter to be monitored remotely by pulse output. The M-Bus communication protocol is more complex to set up, but allows many meters to be connected to one bus by using an addressing protocol and provides a larger range of data.

8. Accuracy over time and recalibration

There is little data available defining the long term accuracy of heat metering, and the available data is generally restricted to specific meter types and makes. A number of EU states have defined periods of validity for heat meter calibration ranging from two to ten years.

Heat meter accuracy is dependent on the accuracy of the three components required for thermal energy measurement: the flow meter, the temperature sensor pair, and the calculator. Laboratory and field data show that it is difficult for the installed flow meter to meet the MID accuracy levels, but this component is relatively resilient to incorrect installation. On the other hand, accurate measurement of temperature difference is straightforward, but the proper installation of the temperature sensors in the fluid flow is essential. The calculator can output precise results if the meter is configured correctly for the actual system fluid and sized appropriately.

The technology and materials used for the temperature measurement and the calculator are unlikely to demonstrate deterioration over time. The meter component which is most liable to manifest a decrease in accuracy over time is the flow meter, since this may contain moving parts subject to wear and tear, could experience corrosion or erosion by the system fluid, and possibly collect dirt or limescale over time.

9. Conclusions and Recommendations

Heat metering is more complex than traditional utility metering. Building services engineers may have little or no previous experience of heat metering installation and operation. With an ever increasing variety of environment friendly means of generating and distributing heat, the metering of heat is assuming the same importance as utility metering, with both economic and fiscal implications. The over-riding consideration for heat meter installation is to ensure the accurate measurement of flow and temperature difference in the system being metered.

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The Heat Network (Metering and Billing) (Amendment) Regulations 2015

The Heat Network (Metering and Billing) Regulations 2014

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