INTERNATIONAL RECOMMENDATION

OIML R 75-1

Edition 2002 (E)

Heat meters
Part 1: General requirements

Compteurs d'énergie thermique
Partie 1: Exigences générales

OIML R 75-1 Edition 2002 (E)

ORGANISATION INTERNATIONALE DE MÉTROLOGIE LÉGALE

INTERNATIONAL ORGANIZATION OF LEGAL METROLOGY

Contents

Foreword

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The two main categories of OIML publications are:

- **International Recommendations (OIML R)**, which are model regulations that establish the metrological characteristics required of certain measuring instruments and which specify methods and equipment for checking their conformity; the OIML Member States shall implement these Recommendations to the greatest possible extent;

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International Recommendations and International Documents are published in French (F) and English (E) and are subject to periodic revision.

This publication - reference OIML R 75-1 edition 2002 - was developed by the OIML Technical Committee TC 11 *Instruments for measuring temperature and associated quantities* on the basis of Part 1 of the European Standard EN 1434 (1997), the relevant paragraphs of which have been reproduced with the agreement of the European Committee for Standardization (CEN). This publication was approved for final publication by the International Committee of Legal Metrology in 2001 and will be submitted to the International Conference of Legal Metrology in 2004 for final sanction.

OIML Recommendation R 75 includes three parts: Part 1 *(General requirements)* and Part 2 *(Type approval tests and initial verification tests)* which have been issued in 2002 as separate publications, and Part 3 *(Test report format)* which is expected to be approved and issued at a later stage. It supercedes the former edition dated 1988.

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Heat meters

Part 1: General requirements

1 Scope

This Recommendation applies to heat meters, that is to instruments intended for measuring the heat which, in a heat-exchange circuit, is given up by a liquid called the heat-conveying liquid.

Heat meters which are submitted for control by legal metrology services shall comply with the requirements formulated in this Recommendation.

2 References

International Vocabulary of Terms in Legal Metrology (VIML, 2000)

International Vocabulary of Basic and General Terms in Metrology (VIM, 1993)

IEC 61010-1 (2001-02). *Safety requirements for electrical equipment for measurement, control and laboratory use. Part 1: General requirements*. International Electrotechnical Commission, Geneva

ISO 7268 (1983-05). Amendment ISO 7268-am1(1984-07). *Pipe components - Definition of nominal pressure*. International Organization for Standardization, Geneva

IAPWS-IF97. *The Industrial Standard for the Thermodynamic Properties and Supplementary Equations for other Properties of Water and Steam*. Ed. by Wagner, W. and Kruse, A. Springer Verlag, Berlin-Heidelberg, 1998 ISBN 3-540-64339-7

IEC 60751 (1983-01). Amendments IEC 60751-am1(1986-01) and IEC 60751-am2(1995-07) *Industrial platinum resistance thermometer sensors*. International Electrotechnical Commission, Geneva

3 Types of instrument

For the purpose of this Recommendation, heat meters are defined either as complete instruments or as combined instruments.

3.1 Complete instrument

A heat meter which does not have separable sub-assemblies as defined in 3.4.

3.2 Combined instrument

A heat meter which has separable sub-assemblies as defined in 3.4.

3.3 Hybrid instrument

A heat meter - often called a “compact” instrument - which for the purpose of type approval and verification, can be treated as a combined instrument as defined in 3.2. However, after verification, its sub-assemblies shall be treated as inseparable.

3.4 Sub-assemblies of a heat meter, which is a combined instrument

The flow sensor, the temperature sensor pair and the calculator or a combination of these.

3.4.1 Flow sensor

A sub-assembly through which the heat-conveying liquid flows, at either the flow or return of a heat-exchange circuit, and which emits a signal, which is a function of the volume or the mass or the volumetric or mass flow rate.

3.4.2 Temperature sensor pair

A sub-assembly (for mounting with or without pockets), which senses the temperatures of the heat-conveying liquid at the flow and return of a heat-exchange circuit.

3.4.3 Calculator

A sub-assembly which receives signals from the flow sensor and the temperature sensors and calculates and indicates the quantity of heat exchanged.

3.5 Equipment under test (EUT)

A sub-assembly, a combination of subassemblies or a complete meter subject to a test.

4 Terminology and symbols

For the purposes of this Recommendation, the following terms, definitions and symbols apply.

Note: The terminology used in this Recommendation complies with the *International Vocabulary of Terms in Legal Metrology* (VIML) and the *International Vocabulary of Basic and General Terms in Metrology* (VIM) of which certain definitions are reproduced below.

4.1 Response time, $\tau_{0,5}$

Time interval between the instant when the flow, the temperature or the temperature difference is subjected to a specified abrupt change, and the instant when the response reaches 50 % of its final steady value.

4.2 Fast response meter

Meter suitable for heat-exchange circuits with rapid dynamic variations in the exchanged heat.

4.3 Rated voltage, U_n

Voltage of the external power supply required to operate the heat meter, conventionally the voltage of the AC mains supply.

4.4 Rated operating conditions

Conditions of use for which specified metrological characteristics of a measuring instrument are intended to lie within the specified maximum permissible errors [adapted from VIM 5.5].

4.5 Reference conditions

Conditions of use prescribed for testing the performance of a measuring instrument or for intercomparison of results of measurements [VIM 5.7].

4.6 Influence quantity

Quantity that is not the measurand but that affects the result of the measurement [VIM 2.7].

4.7 Influence factor

Influence quantity having a value within the rated operating conditions.

4.8 Disturbance

Influence quantity having a value outside the rated operating conditions.

4.9 Types of error

4.9.1 Error (of indication) of a measuring instrument

Indication of the measuring instrument minus the conventional true value of the corresponding input quantity [adapted from VIM 5.20].

4.9.2 Intrinsic error (of a measuring instrument)

Error of a measuring instrument, determined under reference conditions [VIM 5.24].

4.9.3 Initial intrinsic error

Intrinsic error of a measuring instrument as determined prior to performance tests and durability tests.

4.9.4 Durability error

Difference between the intrinsic error after a period of use and the initial intrinsic error.

4.9.5 Maximum permissible error, MPE

Extreme values of the error (positive or negative) permitted by this Recommendation [adapted from VIM 5.21].

4.10 Types of fault

4.10.1 Fault

Difference between the error of indication and the intrinsic error of the instrument.

4.10.2 Transitory fault

Momentary variations in the indication which cannot be interpreted, memorized or transmitted as measurements.

4.10.3 Significant fault

Fault greater than the absolute value of the MPE which is not a transitory fault.

Example: If the MPE is ± 2 %, then the significant fault is a fault larger than 2 %.

4.11 Reference values of the measurand, RVM

Specified set of values of the flow rate, the return temperature and the temperature difference, fixed to ensure valid intercomparison of the results of measurements.

4.12 Conventional true value

Value of a quantity which, for the purpose of this Recommendation, is considered as a true value.

Note: A conventional true value is, in general, regarded as sufficiently close to the true value for the difference to be insignificant for the given purpose.

4.13 Meter model

Different sizes of heat meters or sub-assemblies having a family similarity in the principles of operation, construction and materials.

4.14 Electronic device

Device employing electronic components and performing a specific function.

4.15 Electronic component

Smallest physical entity in an electronic device which uses electron or hole conduction in semi-conductors or electron conduction in gases or in a vacuum.

4.16 Minimum immersion depth of a temperature sensor

Depth of immersion in a thermostatic bath with a temperature of (80 ± 5) °C at an ambient temperature of (25 ± 5) °C, beyond which deeper immersion changes the output value by an amount corresponding to less than 0.1 K.

4.17 Self-heating effect

Increase in temperature signal that is obtained by subjecting each temperature sensor of a pair to a continuous power dissipation of 5 mW when immersed to the minimum immersion depth in a water bath, having a mean water velocity of 0.1 m/s.

5 Rated operating conditions

5.1 Limits of temperature range

5.1.1 The upper limit of the temperature range, Θ_{max}, (expressed in °C) is the highest temperature of the heat-conveying liquid, at which the heat meter shall function without the maximum permissible errors being exceeded.

5.1.2 The lower limit of the temperature range, Θ_{min}, (expressed in °C) is the lowest temperature of the heat-conveying liquid, at which the heat meter shall function without the maximum permissible errors being exceeded.

5.2 Limits of temperature differences

5.2.1 The temperature difference, $\Delta\Theta$, (expressed in K) is the absolute value of the difference between the temperatures of the heat-conveying liquid at the flow and return of the heat-exchange circuit.

5.2.2 The upper limit of the temperature difference, $\Delta\Theta_{max}$, is the highest temperature difference, at which the heat meter shall function within the upper limit of thermal power without the maximum permissible errors being exceeded.

5.2.3 The lower limit of the temperature difference, $\Delta\Theta_{min}$, is the lowest temperature difference, at which the heat meter shall function without the maximum permissible errors being exceeded.

5.3 Limits of flow rate

5.3.1 The upper limit of the flow rate, q_s, is the highest flow rate, at which the heat meter shall function for short periods (less than 1 h/day and less than 200 h/year) without the maximum permissible errors being exceeded.

5.3.2 The permanent flow rate, q_p, is the highest flow rate at which the heat meter shall function continuously without the maximum permissible errors being exceeded.

5.3.3 The lower limit of the flow rate, q_i, is the lowest flow rate, above which the heat meter shall function without the maximum permissible errors being exceeded.

5.4 Limits of thermal power

The upper limit of the thermal power, P_s, is the highest power at which the heat meter shall function without the maximum permissible errors being exceeded.

5.5 Maximum admissible working pressure, MAP

The maximum positive internal pressure that the heat meter can withstand permanently at the upper limit of the temperature range, expressed as a PN-series as defined in ISO 7268.

5.6 Maximum pressure loss

The loss of pressure in the heat-conveying liquid passing through the flow sensor when the flow sensor is operating at the permanent flow rate, q_p.

6 Technical characteristics

The materials used and the construction of heat meters shall ensure sufficient stability to enable the instrument to comply with the maximum permissible errors stated when the device is set up in accordance with the supplier's instruction manual.

6.1 Materials and construction

All the constituent elements of heat meters shall be solidly constructed of materials having appropriate qualities to resist the various forms of corrosion and wear which occur under rated operating conditions, especially those due to impurities in the heat-conveying liquid. Correctly installed meters shall also be able to withstand normal external influences. Meters shall, in all circumstances, withstand the maximum admissible pressure and the temperatures for which they are designed, without malfunction.

6.1.1 Suppliers of heat meters shall declare any limitations with regard to installation of the heat meter and its orientation with respect to the vertical.

6.1.2 Casings of heat meters shall protect the parts inside against water and dust ingress. The minimum forms of enclosure protection shall be IP54 for enclosures that are to be installed into pipework and IP52 for other enclosures, all in accordance with IEC 61010-1.

6.1.3 Heat meters may be fitted with interfaces allowing the connection of supplementary devices. Such connections shall not modify the metrological qualities of the heat meter.

6.1.4 The maximum pressure loss at q_p shall not exceed 0.25 bar, except where the heat meter includes a flow controller or also acts as a pressure-reducing device.

6.2 Requirements outside the limiting values of the flow rate

When the flow rate is less than a threshold value declared by the supplier, no registration is allowed.

Note: The flow rate through a "nominally" closed valve or the movement of liquid in the pipe behind a closed valve caused by thermal expansion and contraction should not be recorded.

For flow rates greater than q_s, the behavior of the meter, e.g. the production of spurious or zero signals, shall be declared by the manufacturer. Flow rates greater than q_s shall not result in a positive error greater than 10 %.

6.3 Display (indicating device)

6.3.1 The quantity of heat shall be indicated in joules, watt-hours or in decimal multiples of those units. The name or symbol of the unit in which the quantity of heat is given shall be indicated adjacent to the display.

6.3.2 The display shall include a numerical or semi-numerical scale. Heat meters shall be so designed that, in the event of an external power supply failure (mains or external DC), the meter indication of energy at the time of failure is not lost, and remains accessible for a minimum of one year.

Note: Compliance with 6.3.2 will not necessarily ensure that the heat meter will continue to register the heat consumed in the event of a power supply failure.

6.3.3 The indicating device shall provide an easily read, reliable and unambiguous indication.

6.3.4 The real or apparent height of the figures on the display for energy shall not be less than 4 mm.

6.3.5 The figures indicating decimal fractions of a unit shall be separated from the others by the decimal divider. In addition, the figures indicating decimal fractions of energy shall be clearly distinguishable from the others.

6.3.6 Where the display is of the roller-type, the advance of a figure of a particular significance shall be completed during the time when the figure of next lower significance changes from 9 to 0. The roller carrying the figures of lowest significance may have a continuous movement, of which the visible displacement shall then be from bottom to top.

6.3.7 The display indicating the quantity of heat shall be able to register, without overflow, a quantity of heat at least equal to the transfer of energy which corresponds to a continuous operation for 3000 h at the upper limit of the thermal power, P_s, of the heat meter.

The quantity of heat, measured by a heat meter operating at the upper limit of the thermal power for 1 h, shall correspond to at least one digit of lowest significance of the display.

6.4 Protection against fraud

Heat meters shall have protective devices which can be sealed in such a way that, after sealing, both before and after the heat meter has been correctly installed, there is no possibility of dismantling, removing, or altering the heat meter or its adjustment devices without evident damage to the device(s) or seal(s).

Means shall also be provided for meters with external power supply, either to give protection against the meter being disconnected from the power supply or to make it evident that this has taken place.

Sites shall be provided for marks (e.g. legal status marks) to be sited on that part of the heat meter indicating the quantity of heat for a complete meter or on each sub-assembly for combined meters. All parts of the heat meter that might be separated after calibration and testing shall have sites for placing an identity mark. The sites for these marks shall be situated so that the marks are clearly visible when attached.

Note: The incorporation in the meter casing of a counter indicating the hours run will make it evident if the power supply has been disconnected.

6.5 Supply voltage

The instrument shall be fully operational and shall not exceed the maximum permissible errors if the electric power supply is influenced as described in 6.5.1 to 6.5.4.

6.5.1 Instruments supplied by AC mains supply

- Variations in AC mains voltage of – 15 % to + 10 % related to the instrument's rated nominal voltage.
- Variations in AC mains frequency of – 2 % to + 2 % related to the instrument's rated nominal frequency.

6.5.2 Instruments supplied by external AC or DC low voltage (< 50 V)

- Variations in AC remote voltage of ± 50 % related to the instrument's rated nominal voltage.
- Variations in DC remote voltage of – 50 % to + 75 % related to the instrument's rated nominal voltage.

6.5.3 Instruments supplied by internal non-rechargeable batteries or rechargeable batteries that cannot be (re)charged during the operation of the measuring instrument

When the battery voltage has dropped to a critical value, this shall be clearly indicated by the instrument at a time safely before the instrument starts functioning improperly (resulting in for instance poor display, unstable memory function, errors exceeding MPE, etc.), or the instrument shall automatically switch off, storing actual data and time at the moment of switching off for a period of at least 1 year. The moment of switching off may be preprogrammed.

The minimum period of time during which the instrument shall function properly without renewing or recharging batteries shall be specified by the manufacturer, and shall be at least 2 years.

6.5.4 Instruments supplied by internal rechargeable batteries that are intended to be (re)charged during the operation of the measuring instrument

These instruments shall:

- *either* comply with the requirements for battery supplied instruments (6.5.3) with the external supply switched off (manually or by accident),
- *or* comply with the requirements for instruments supplied by external AC or DC low voltage (6.5.2) with the external supply switched off (manually or by accident),

and shall additionally:

- comply with the requirements for AC-powered instruments (6.5.1) with the mains supply switched on.

7 Specified working range

The working parameters of the heat meter are bounded by the limiting values of the temperature range, the temperature difference, the thermal power and the flow rates (q_s and q_i).

If the measurement of heat is affected by the pressure of the heat-conveying liquid, pressure shall be regarded as a parameter.

7.1 Temperature difference

The ratio of the upper and lower limits of the temperature difference shall not be less than 10. The lower limit shall be stated by the supplier to be either 1, 2, 3, 5 or 10 K. The preferred value is 3 K.

7.2 Flow rate

The ratio of the permanent flow rate to the lower limit of the flow rate (q_p/q_i) shall be 10, 25, 50, 100 or 250.

8 Heat transmission formula

Heat transmitted to or from a body of liquid can be determined from knowledge of its mass, specific heat capacity and change in temperature.

In a heat meter, the rate of change of enthalpy between the flow and return through a heat exchanger is integrated with respect to time. The equation for its operation is as follows:

$$Q = \int_{t_0}^{t_1} q_m \, \Delta h \; dt$$

where:

Q is the quantity of heat given up;

q_m is the mass flow rate of the heat-conveying liquid passing through the heat meter;

Δh is the difference between the specific enthalpies of the heat-conveying liquid at the flow and return temperatures of the heat-exchange circuit;

t is time.

If the instrument determines the volume instead of the mass, its equation becomes:

$$Q = \int_{V_0}^{V_1} k \, \Delta\Theta \, dV$$

where:

Q is the quantity of heat given up;

V is the volume of liquid passed;

k called the heat coefficient, is a function of the properties of the heat-conveying liquid at the relevant temperatures and pressure;

$\Delta\Theta$ is the temperature difference between the flow and return of the heat exchange circuit.

The conventional true value of the heat coefficient k for water, if it is used as the system heat-conveying liquid, shall be obtained from the formulas (A.1.) to (A.5.) in Annex A, where the pressure shall be set to 16 bar.

For meters intended for use with heat-conveying liquids other than water, the supplier shall declare the heat coefficient used as a function of temperature and pressure.

Note: Tables with values for the heat coefficient for liquids other than water can be found in the book *Handbuch der Wärmeverbrauchsmessung*, by Dr. F. Adunka, Vulkan-Verlag, Essen, ISBN 3-8027-2373-2

9 Metrological characteristics (maximum permissible errors, MPEs)

Heat meters shall meet the tolerances stated which are considered as being the maximum permissible errors in type approval tests, initial and subsequent verification.

9.1 General

9.1.1 Flow sensors of heat meters and complete instruments belong to one of the following three accuracy classes:

class 1, class 2 and class 3.

The class of the complete instrument is determined by the class of the flow sensor.

9.1.2 The maximum permissible errors of heat meters, positive or negative, in relation to the conventional true value of the heat, are defined as relative errors varying as a function of the temperature difference and flow rate.

9.1.3 The maximum permissible errors of sub-assemblies, positive or negative, are calculated from the temperature difference in the case of the calculator and the temperature sensor pair and from the flow rate in the case of the flow sensor.

9.1.4 The relative error, E, is expressed as:

$$E = \frac{X_d - X_c}{X_c} 100\ \%$$

where:

X_d is the indicated value;

X_c is the conventional true value.

9.2 Values of maximum permissible errors

9.2.1 Maximum permissible relative errors of a complete instrument

The MPEs of a complete instrument are calculated as a function of the temperature difference ratio ($\Delta\Theta_{min}/\Delta\Theta$) and the flow rate ratio (q_p/q). The MPEs of the complete instrument of accuracy classes 2 and 3 are the arithmetic sums of E_c (in 9.2.2.1), E_t (in 9.2.2.2) and E_f (in 9.2.2.3). The classes of heat meters are defined by the class of the flow sensor.

Class 1: see note in 9.2.2.3

Class 2 and Class 3: $E = E_c + E_t + E_f$

9.2.2 Maximum permissible relative errors of sub-assemblies

9.2.2.1 Calculator

$E_c = \pm (0.5 + \Delta\Theta_{min} / \Delta\Theta)$

where the error, E_c, relates the value of the heat indicated to the conventional true value of the heat.

9.2.2.2 Temperature sensor pair

$E_t = \pm (0.5 + 3\ \Delta\Theta_{min} / \Delta\Theta)$

where the error, E_t, relates the indicated value to the conventional true value of the relationship between temperature sensor pair output and temperature difference.

The relationship between temperature and resistance of each single sensor of a pair shall not differ from the values of the formula given in IEC 60751 (using the standard values of the constants A, B and C) by more than an amount equivalent to 2 K.

9.2.2.3 Flow sensor

Class 1: E_f = See note

Class 2: $E_f = \pm (2 + 0.02\ q_p/q)$, but not more than ± 5 %

Class 3: $E_f = \pm (3 + 0.05\ q_p/q)$, but not more than ± 5 %

where the error, E_f, relates the indicated value to the conventional true value of the relationship between flow sensor output signal and mass or volume.

Note: E and E_f for class 1 will be defined when improvements in testing procedures and flow sensors make it possible.

The definitions for class 1 flow sensors could be presumed to be:

For complete meters:

$E = \pm (2 + 4\ \Delta\Theta_{min} / \Delta\Theta + 0.01\ q_p/q)$.

For flow sensors:

$E_f = \pm (1 + 0.01\ q_p/q)$, but not more than ± 3.5 %.

It is presumed that these maximum permissible errors could be applied to heat meters with flow sensors of $q_p \geq 100\ m^3/h$.

9.3 Application of maximum permissible errors

9.3.1 For a combination of sub-assemblies as defined in 3.4, the maximum permissible error for the combination is the arithmetic sum of the maximum permissible errors of all sub-assemblies.

9.3.2 The errors of combined instruments shall not exceed the arithmetic sum of the maximum permissible errors of the sub-assemblies indicated in 9.2.2.1 to 9.2.2.3.

9.3.3 Suppliers of combined instruments can stipulate that they shall be considered as complete instruments for the application of the maximum permissible errors.

9.4 Maximum permissible errors in service

Where different values for maximum permissible errors in service and at verification are prescribed by national regulations, the values of the maximum permissible errors in service shall be equal to 2 times the maximum permissible errors fixed for verification.

10 Environmental classification

Heat meters shall conform to one or more of the following environmental classifications according to the application.

10.1 Environmental class A (domestic use, indoor installations)

- Ambient temperature: + 5 °C to + 55 °C
- Low level humidity conditions
- Normal electrical and electromagnetic conditions
- Low level mechanical conditions

10.2 Environmental class B (domestic use, outdoor installation)

- Ambient temperature: – 25 °C to + 55 °C
- Normal level humidity conditions
- Normal electrical and electromechanical conditions
- Low level mechanical conditions

10.3 Environmental class C (industrial installations)

- Ambient temperature: + 5 °C to + 55 °C
- Normal level humidity conditions
- High electrical and electromagnetic conditions
- Low level mechanical conditions

11 Heat meter specifications, inscriptions and instruction manual

Each heat meter shall be accompanied by an instruction manual and data sheets, which shall include all the information listed in 11.1 to 11.4.

A heat meter and/or its sub-assemblies shall be marked clearly and indelibly with the information listed in *italics* in 11.1, 11.2, 11.3 and 11.4.

11.1 Flow sensor

- *Supplier (name or trade mark)*
- *Type identification, year of manufacture, serial number*
- *Accuracy class*
- *Limits of flow rate (q_i, q_p and q_s)*
- *Limits of temperature (Θ_{min} and Θ_{max})*
- *Maximum admissible working pressure (PN-class)*
- *One or more arrows to indicate the direction of flow*

- *Environmental class*
- *Heat conveying liquid if other than water*
- *Nominal meter factor (litres/pulse or corresponding factor for normal output)*
- *Orientation limitations for installing the meter*

- Maximum pressure loss (pressure loss at q_p)
- Installation requirements, including installation pipe lengths
- Physical dimensions (length, height, width, weight, thread/flange specification)
- Output signal for rated operation (type/levels)
- Output signal for testing (type/levels)
- Performance at flow rates greater than q_s
- Low flow threshold value
- Response time - for fast response meters
- Mains power supply requirements - voltage, frequency
- Battery power supply requirements - battery voltage, type, life-time

11.2 Temperature sensor pair

- *Supplier (name or trade mark)*
- *Type identification, e.g. Pt 100, year of manufacture, serial number*
- *Limits of temperature (Θ_{min} and Θ_{max})*
- *Limits of temperature difference ($\Delta\Theta_{min}$ and $\Delta\Theta_{max}$)*
- *Maximum admissible working pressure for direct mounted sensors (PN-class)*
- *Identification of flow and return temperature sensors, if needed*

- Wiring of sensors (e.g. 4- or 2-wire)
- Total resistance of a 2-cable wire
- Principle of operation
- Maximum RMS value of sensor current
- Physical dimensions
- Installation requirements (e.g. for pocket mounting)
- Maximum liquid velocity for sensor over 200 mm length
- Minimum immersion depth
- Output signal for rated operation (type/levels)
- $\tau_{0.5}$ response time

11.3 Calculator

- *Supplier (name or trade mark)*
- *Type identification, year of manufacture, serial number*
- *Type of temperature sensors (e.g. Pt 100 or Pt 500, etc.)*
- *Environmental class*
- *Installation requirements, including wiring of temperature sensors, indication if shielding is necessary or not*
- *Limits of temperature (Θ_{min} and Θ_{max})*
- *Limits of temperature difference ($\Delta\Theta_{min}$ and $\Delta\Theta_{max}$)*
- *Required input signal from the flow sensor*
- *Heat conveying liquid if other than water*
- *Flow sensor to be operated at the flow or return temperature*

- Display unit options (MJ, kWh)
- Dynamic behavior (circumstances of temperature measurement and integration)
- Maximum value of thermal power (P_s)
- Other functions in addition to heat indication
- Physical dimensions
- Mains power supply (voltage, frequency)
- Battery power supply requirements (battery voltage, type, lifetime)
- RMS value of temperature sensor current
- Maximum permissible flow sensor signal (pulse rate)
- Output signal for normal operation (type/levels)
- Output signal for testing (type/levels)

11.4 Complete instrument

- *Supplier (name or trade mark)*
- *Type identification, year of manufacture, serial number*
- *Limits of flow rate (q_i, q_p and q_s)*
- *Limits of temperature (Θ_{min} and Θ_{max}) of the flow sensor/temperature sensor pair*
- *Limits of temperature difference ($\Delta\Theta_{min}$ and $\Delta\Theta_{max}$)*
- *Accuracy class*
- *Maximum admissible working pressure (PN-class)*
- *Environmental class*
- *Maximum admissible working pressure for the flow sensor, MAP*

- *Heat conveying liquid if other than water*
- *Meter to be installed in flow or return*
- *One or more arrows to indicate the direction of flow*
- *Orientation limitations for installing the meter*

- Display unit option (MJ, kWh)
- Other functions in addition to heat indication
- Maximum value of thermal power (P_s)
- Low flow threshold value
- Maximum pressure loss of flow sensor (pressure loss at q_p)
- Installation requirements, including installation pipe lengths
- Physical dimensions (length, height, width, weight, thread/flange specification)
- Mains power supply requirements (voltage, frequency)
- Battery power supply requirements (battery voltage, type, lifetime)
- Output signal for normal operation (type/levels)
- Output signal for testing (type/levels)
- Performance at flow rates greater than q_s
- Response time for the temperature sensor pair
- Response time, for fast response meters

12 Information to be delivered with the heat meter or sub-assemblies

Installation instructions under the following heading shall include at least the following information.

a) Flow sensor:

- flushing the system before installation;
- installation in flow or return as stated on calculator;
- minimum straight installation pipe length upstream and downstream;
- orientation limitations;
- need for flow straightener;
- requirement for protection from risk of damage by shock and vibration;
- requirement to avoid installation stresses from pipes and fittings.

b) Temperature sensor pair:

- possible need for symmetrical installation in the same pipe size;
- use of pockets or fittings for temperature sensor;
- use of thermal insulation for pipe and sensor heads.

c) Calculator (and flow meter electronics):

- free distance around the meter;
- distance between meter and other equipment;
- need for adapter plate to fit standardized holes.

d) Wiring:

- need for earth connection;
- maximum cable lengths;
- required separation between signal and power cables;
- requirement for mechanical support;
- requirements for electrical screening.

e) Other:

- initial function check and operation instructions;
- installation security sealing.

Annex A - Heat coefficient equations

(Mandatory)

For the determination of heat exchanged in an exchange circuit, heat meters shall take the type of heat-conveying liquid (generally water) into account by means of the heat coefficient $k(p, \Theta_f, \Theta_r)$. The heat coefficient is a function of the measurable physical quantities pressure p, flow temperature Θ_f and return temperature Θ_r, and satisfies equation A.1.

Heat coefficient for water $$k(p, \Theta_f, \Theta_r) = \frac{1}{v} \frac{h_f - h_r}{\Theta_f - \Theta_r} \qquad \text{(A.1)}$$

where v is the specific volume, h_f, h_r are the specific enthalpies (f-flow; r-return). The quantities v, h_f and h_r can be calculated according to *The Industrial Standard for the Thermodynamic Properties of Water and Steam* (IAPWS-IF 97) using the International Temperature Scale of 1990 (ITS-90).

Specific volume $$v = (\partial g / \partial p)_T \qquad v(\pi, \tau) = \frac{p}{RT} = \pi\gamma_\pi \qquad \text{(A.2)}$$

where g is the specific Gibbs free energy and

$\pi = p / p^*$ with $p^* = 16.53$ MPa

$$\gamma_\pi = \sum_{i=1}^{34} - n_i I_i (7.1 - \pi)^{I_i - 1} (\tau - 1.222)^{J_i} \qquad \text{(A.3)}$$

For the figures of n_i, I_i and J_i see Table 1.

Specific enthalpy $$h = g - T(\partial g / \partial T)_p \; ; \quad \frac{h(\pi,\tau)}{RT} = \tau\gamma_\tau \qquad \text{(A.4)}$$

where $\tau = T^* / T$ and $T^* = 1386$ K

$$\gamma_\tau = \sum_{i=1}^{34} n_i (7.1 - \pi)^{I_i} \; J_i (\tau - 1.222)^{J_i - 1} \qquad \text{(A.5)}$$

with $273.15 \text{ K} \le T \le 623.15$ K; $p_s(T) \le p \le 100$ MPa and $R = 461.526 \text{ J·kg}^{-1}\text{·K}^{-1}$

with $p_s(T)$: saturation pressure

For the figures of n_i, I_i and J_i see Table 1.

Samples of values for Θ_f = 70 °C and Θ_r = 30 °C at 16 bar; flow sensor in:

	Flow position	Return position
Specific volume in (m^3/kg)	$0.102204 \cdot 10^{-2}$	$0.100370 \cdot 10^{-2}$
Specific enthalpy$_{flow}$ in (kJ/kg)	$0.294301 \cdot 10^{3}$	$0.294301 \cdot 10^{3}$
Specific enthalpy$_{return}$ in (kJ/kg)	$0.127200 \cdot 10^{3}$	$0.127200 \cdot 10^{3}$
Heat coefficient in (MJ/(m^3 K))	4.0874	4.1621

Table 1 Coefficients and exponents of equations (A.3) and (A.5)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	–2	0.146 329 712 131 67	18	2	3	–0.441 418 453 308 46 × 10^{-5}
2	0	–1	–0.845 481 871 691 14	19	2	17	–0.726 949 962 975 94 × 10^{-15}
3	0	0	–0.375 636 036 720 40 × 10^{1}	20	3	–4	–0.316 796 448 450 54 × 10^{-4}
4	0	1	0.338 551 691 683 85 × 10^{1}	21	3	0	–0.282 707 979 853 12 × 10^{-5}
5	0	2	–0.957 919 633 878 72	22	3	6	–0.852 051 281 201 03 × 10^{-9}
6	0	3	0.157 720 385 132 28	23	4	–5	–0.224 252 819 080 00 × 10^{-5}
7	0	4	–0.166 164 171 995 01 × 10^{-1}	24	4	–2	–0.651 712 228 956 01 × 10^{-6}
8	0	5	0.812 146 299 835 68 × 10^{-3}	25	4	10	–0.143 417 299 379 24 × 10^{-12}
9	1	–9	0.283 190 801 238 04 × 10^{-3}	26	5	–8	–0.405 169 968 601 17 × 10^{-6}
10	1	–7	–0.607 063 015 658 74 × 10^{-3}	27	8	–11	–0.127 343 017 416 41 × 10^{-8}
11	1	–1	–0.189 900 682 184 19 × 10^{-1}	28	8	–6	–0.174 248 712 306 34 × 10^{-9}
12	1	0	–0.325 297 487 705 05 × 10^{-1}	29	21	–29	–0.687 621 312 955 31 × 10^{-18}
13	1	1	–0.218 417 171 754 14 × 10^{-1}	30	23	–31	0.144 783 078 285 21 × 10^{-19}
14	1	3	–0.528 383 579 699 30 × 10^{-4}	31	29	–38	0.263 357 816 627 95 × 10^{-22}
15	2	–3	–0.471 843 210 732 67 × 10^{-3}	32	30	–39	–0.119 476 226 400 71 × 10^{-22}
16	2	0	–0.300 017 807 930 26 × 10^{-3}	33	31	–40	0.182 280 945 814 04 × 10^{-23}
17	2	1	0.476 613 939 069 87 × 10^{-4}	34	32	–41	–0.935 370 872 924 58 × 10^{-25}

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