Twinning Project "Strengthening the capacities of the Bureau of Metrology for internal market integration"
Twinning ref. MK 12 IPA EC 01 16 TWL

A Project funded by the European Union and Implemented and led by CMI

Water meters (in next WM), Heat meters (in next HM) Legislation, introduction on the market, labeling, documentation, principles, data transmission, parameters, errors, testing, applications

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TWINNING

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Content:

1. WM, HM, legislation, introduction on the market, main documents, labeling
2. WM, flowmeters, terminology, principles
3. HM, terminology, equations, pictures, HAM
4. Data transmission, smart metering
5. Permissible errors (MPE)
6. Testing
7. Application

Point 1

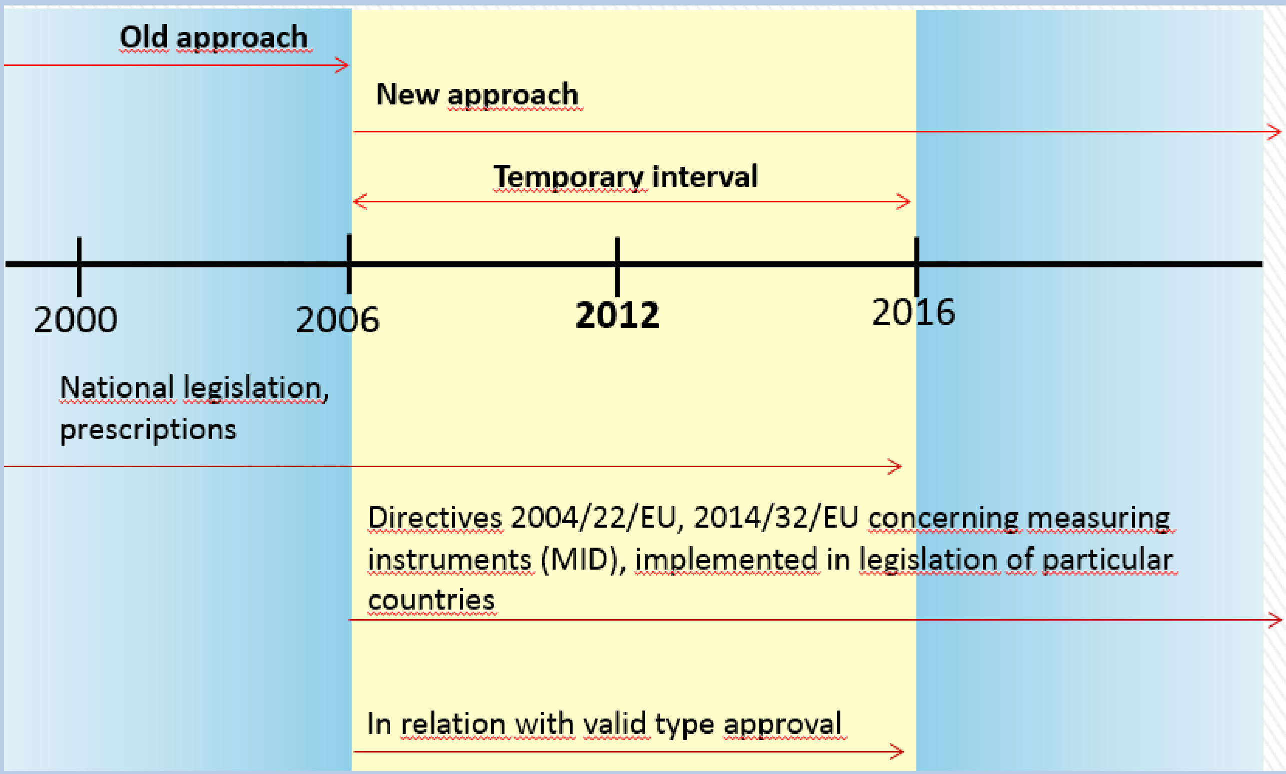
WM (for cold and hot water), HM (water, other liquids, steam)

Classification concerning legislation

- meters determined for application in commerce and residental districts and in light industry for measurement of volume of clear cold, resp. hot water
  certification and introduction on the marked in accordance with new approach (Directives MID, 2004/22/EU, 2014/32/EU)
- meters determined for other application as in commerce and residental districts and in light industry
  approvals and introduction on the market concerning old approach in accordance with national legislation of the countries

- Meters, WM, HM labeled by EU marks
  approvals and introduction on the market concerning old approach (Directives 71/316/EU, 75/033/EU, 79/830/EU, etc.)

Introduction of new meters on the market:



Determination about utilization of the meters in commerce, residental districts, resp. in light industry. Specification of WM, HM. Who decide ?

- General kind of purpose of the meter is determined by manufacturer
- Technical demarcation of the meter is not precisely clarified from this point of view (f. inst. nominal diameter, maximal flow, temperature difference, etc.)
- Subject which buy and distribute water and thermal energy for consumption in commercial spaces and in light industry. Regular introduction on the market must be in accordance with MID directive
- Subject which buy and distribute water and thermal energy for consumption in other as in commercial spaces and in light industry. Regular introduction on the market must be in accordance with national prescriptions of the particular countries

a) Introduction on the marked concerning new approach (Directives 2004/22/EU, 2014/32/EU)

- Certification is proceeding by notified body in accordance with particular modules of MID directive on the basis of manufacturer´s selection
- Manufacturer takes a responsibility for complete process of certification
- Certification is performed concerning Annexes of MID directive for WM, HM, resp. concerning harmonized standards (documents)
- Manufacturer has a full responsibility to place on each meter a determined labeling
- Manufacturer issues a Conformity certificate either for each or for batch of meters

Introduction on the market cocerning new approach (Directives 2004/22/EU, 2014/32/EU) – modules for certification

WM
HM

B+F or **B+D** or **H1**

Type approval

EU conformity of type on the basis of meter´s verification

EU conformity of type on the basis of assurance of production process

EU conformity of type on the basis of full quality assurance and design examination

Introduction on the market concerning new approach – WM, documents

MID directives, Annex III (MI-001)
EN 14154 – WM
Part 1 – General requirements
Part 2 – Installation, applications
Part 3 – Test methods, equipments
Now, EN ISO 4064:2014, parts 1 – 5, mostly part 2, Test methods
OIML R 49:2013 – WM for measurement of potage cold water and for measurement of hot water **(useable also for OIML certification)**
Part 1 – Metrological and technical requirements
Part 2 – Test methods
Part 3 – Form of test report

Examples of required tests:
Intrinic error estimation
Temperature of water
Test by temperature oveloading
Durability test
Climatic tests
Flow disturbance test
Test by static pressure
Test by water pressure
Pressure loss
Reverse flow test
Test of flow absence
Statické magnetic field influences
Tests for electronic WM, EMC tests
Vibration tests, etc.

Introduction on the market concerning new approach – HM, documents

MID directives, Annexes VI (MI-004)
EN 1434: 2015 – HM
Part 1 – General requirements
Part 2 – Constructional requirements
Part 3 – Interfaces, data transmission
Part 4 – Pattern approval tests
Part 5 – Tests for verification
Part 6 - Installation, application, maintaice
OIML R 75 – HM **(usable also for OIML certification)**
Part 1 – Metrological and technical requirements
Část 2 – Pattern approval tests
Část 3 – Form of test report

Examples of tests
Performance tests of all HM components, intrincis errors evaluation
Climatic tests
Durability tests
Power supply deviation, interruption
Static magnetic field influences
EMC tests (f. inst. elmag. field, transients, burst, etc.)
Internal pressure
Pressure loss
Flow disturbance test
Shock/vibration tests), etc.

New, important, SW validation of WM (electronic), resp. of HM

Basic document: WELMEC 7.2 Software Guide

Main requirements:

- Legally relevant software (LRSW) of WM, resp of HM (where all basic metrological parameters are stored) must be validated
- Version of LRSW must be declared on display of meter by CRC - checksum (at least 16 bit)

Types of meters concerning application of LRSW:

- Type P. WM, HM displays by help of LRSW values of measured quantity
- Type L. LRSW of WM, HM disposes by possibility of long tem stored data – datalogging
- Type T. It is possible a transmission of measured data via communication networks
- Extention D. Download of LRSW is possible.

This guide is aimed in particular chapters on WM, resp. on HM also. It defines „risk classes“ for over used types of meters.

Introduction on the market concerning new approach, MID directives, labeling of meters

Number of EU certificate - f. inst.: **TCM 142/12-4947**

Conformity labeling:

CE $\boxed{\text{M17}}$ XXXX

CE conformity mark

supplementary metrological mark M+year

Identification code of notified body

f. inst. ČMI - 1383

Assurance mark, f. inst. mark of ČMI:

ČMI

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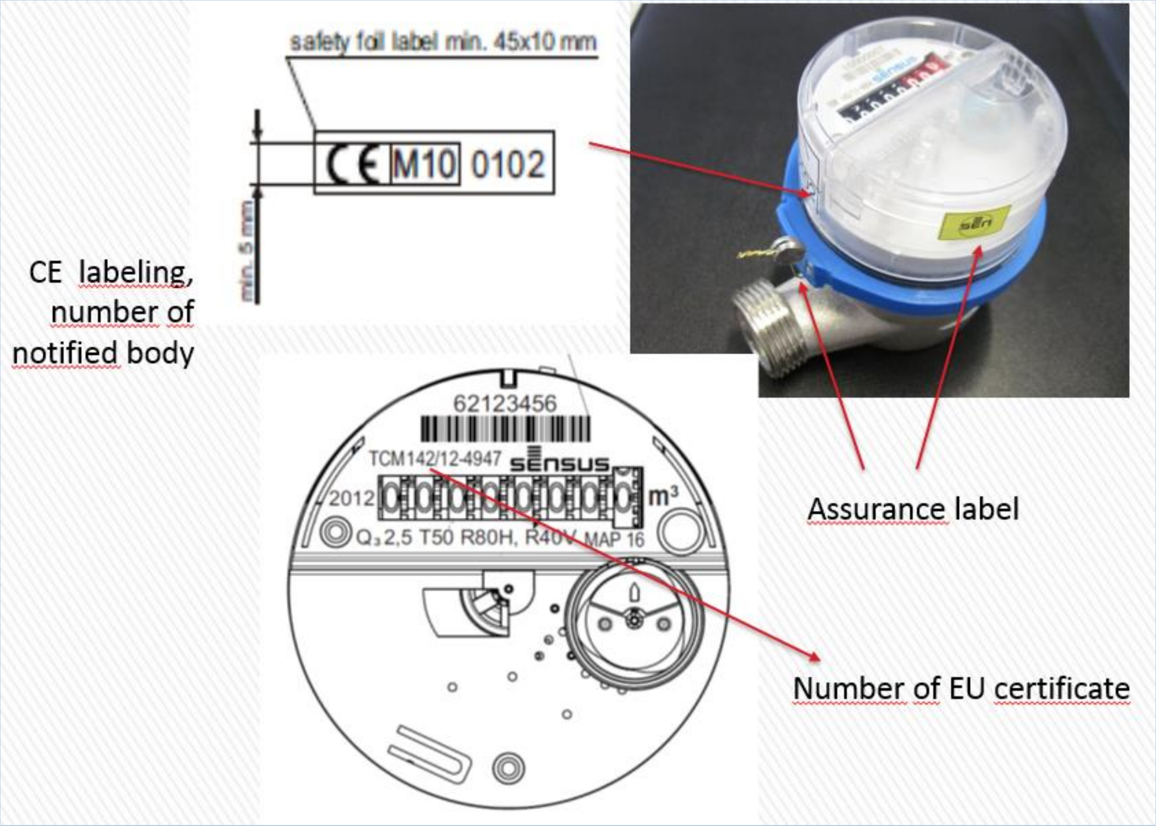
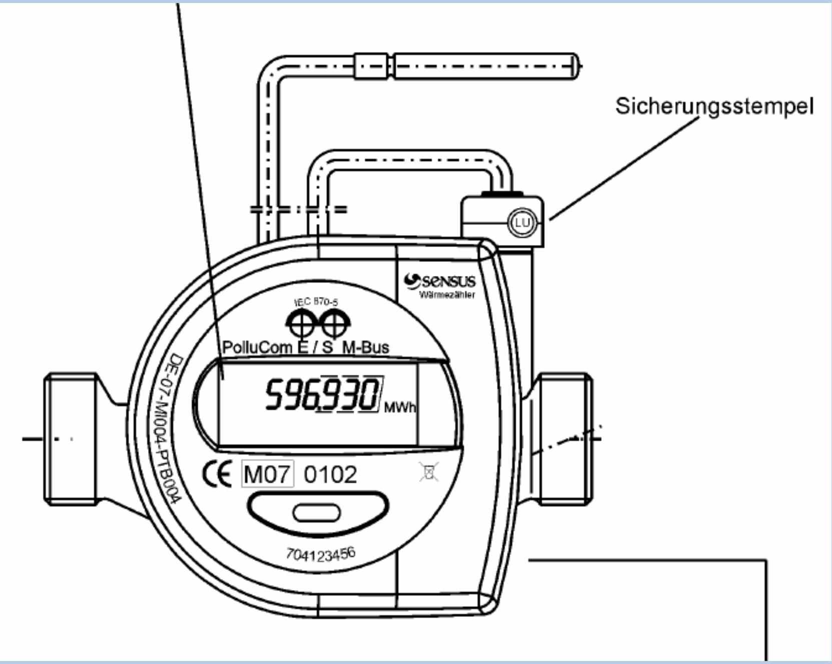
Labeling and placing of the marks on the meter (WM)



Labeling and placing of the marks on the meter (HM)

Same labeling (as for WM) is used for HM also, see you a picture here. Some differences, resp. rules may be here (connected with point 2 of this presentation also):

- HM can be produced as complete, resp. as compact meter. That means: calculator, temperature sensors and flow meter together. Labeling is identical as for WM on previous snap, also here on the picture.
- Or, HM as combined meter, e.g. calculator, temperature sensors and flow meter separately. At that case, if combination of particular parts is possible (on basis of EU certification, each part must be labeled separately.



b) Introduction on the market concerning old approach

- Type approval and first verification are proceeding on the basis of national prescriptions where the metrological and technical conditions (requirements) including tests methods are determined
- Metrological requirements are taken from harmonized documents (standards) if relevant
- Manufacturer asks a National Metrology Institute (NMI) of the country for type approval. This institution performes all proceeding
- Each meter is labeled by mark of type approval by the manufacturer
- First verification is performed either by NMI or by state authorised organisation (it can be a manufacturer also)

Introduction on the market concerning old approach – labeling of meters (WM, HM). Examples from CZ, CMI

Type approval mark: **TCM 311/06-4435**

Serial number
Year of issuing of certificate
Field of measurements

Mark of first verification
Verified by:

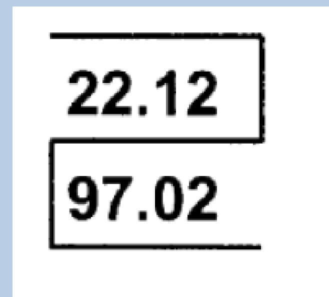
CMI — CM X 00 — CM 6 01

State authorized organisation — K001 01

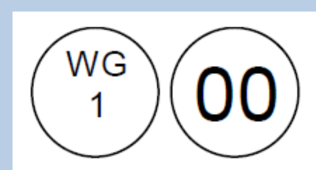
Year of verification

Introduction on the market, old approach, examples of labeling in Germany

Mark of national type approval:



Mark of first verification:



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Old approach, examples of labeled meters (WM, HM)

c) Introduction on the market concerning a Directives of old approach

- Type approval is proceeding in accordance with directives of old approach
- Meters are labeled by marks of EU type approval, resp. of first verification

Next directives were used in this field:

- 71/316/EU aimed on metrological control of measuring instruments under a state legislation of EU member coutries
- 75/033/EU aimed on metrological control of WM for cold water under a state legislation of EU member coutries
- 79/830/EU aimed on metrological control of WM for hot water under a state legislation of EU member coutries
- It is not generally EU old approach directive for HM. Closed documents: Directive 2012/27EU (energy efficiency) and other ones

Introduction on the market concerning EU directives of old approach – labeling of meters

Type approval label:

CZ 04

y

Symbol of the country (here CZ) and year of issuing of EU type approval

Code of EU type approval – determined by state metrological authority

Mark of EU first verification – label or seal:

CZ

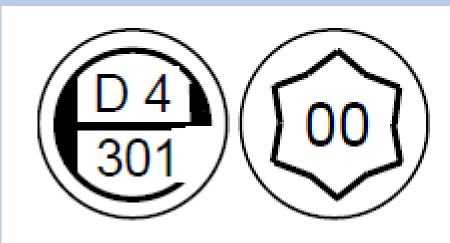
X

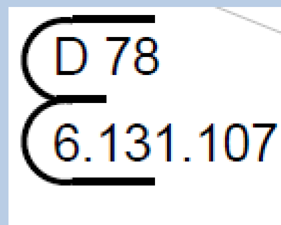
05

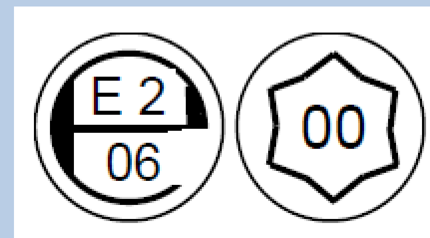
1. part of mark
CZ – country, here CZ
X – number, determined by state metrological authority

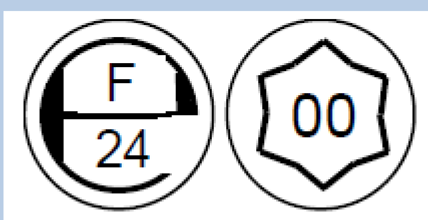
2. part of mark
05 – last two digits of year when an EU first verification was proceeded, resp. finished

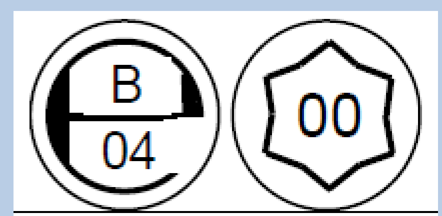
EU directives, old approach, examples of labeling in other EU countries (Germany, Spain, France, Belgium)











End of point 1

Point 2

WM (generally flowmeters also), terminology, principles, pictures

WM (generally flowmeters also), terminology, principles, pictures
Basic terminology for all types of WM, flovmeters

direct meter – installed in closed pipeline by help of end connections (screw or flange)

compact meter: meter without separable sensor (transducer) and totalizer (including indication device)

combined meter: meter wit separable sensor (transducer) and totalizer (including indication device)

Following: Mechanical WM, electronic WM, mechanical totalizer, electronic totalizer.

As for the new approach testing (MID) there is a difference between mechanical and electronic meters

a) WM, flowmeters, velocity meters

Basic terminology:

- Velocity meters, measurements of flow, volume on the basis of velocity (speed) of flow. Velocity of flow is identified by moving part of meter
- Single jet meters, multijet meters, turbine meters
- Single jet, water acts on moving part (propeller) only from one direction – tangential
- Multijet, water acts from more direction
- Turbine – turbine as moving part - perpendicularly or paralel with flow direction
- Dry totalizer, wet totalizer
- Dry meter, totalizer without wasser, liquid – using of magnetic clutch
- Wet meter, water in totalizer, mechanical connection

WM, flowmeters, velocity meters, continue

Basic equations:

$Q = \mathrm{d}V/\mathrm{d}t$ where V is actual volume and t is time taken for this volume to pass through the meter

Volume flow $$Q_v = \frac{V}{\tau}$$ (unit)

Mass flow $$Q_m = \frac{M}{\tau}$$ (unit)

WM, flowmeters, velocity meters, continue

Basic equations:

Flow, velocity, cross section, density

Density $$\rho = \frac{M}{V}$$ (unit)

Flow $$Q_v = S \,.\, w$$ (unit)

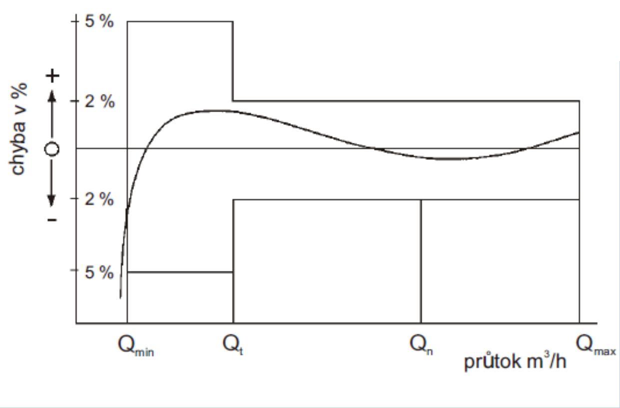
Crosssection area

speed

WM, flowmeters, velocity meters, continue

Examples, pictures

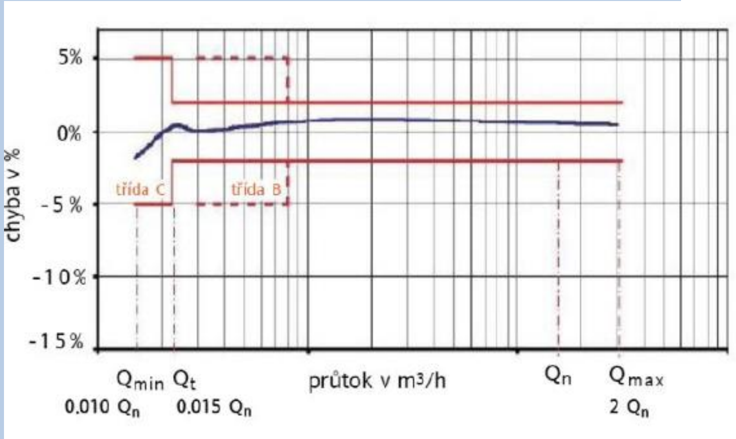
- **Typical single jet, dry meter**
- **Using as apartment meters for cold and hot water**
- **Typical curved line of errors in measuring range**



WM, flowmeters, velocity meters, continue

Examples, pictures

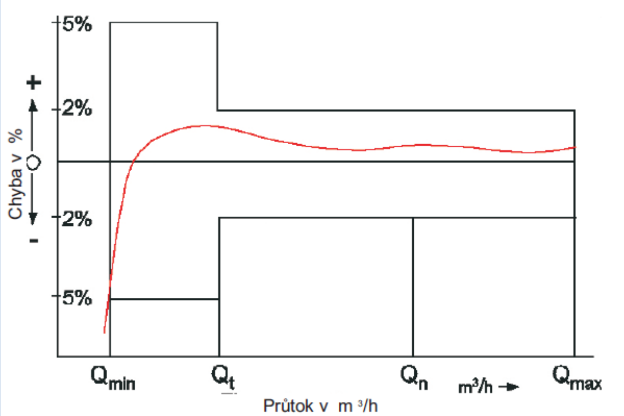
- Typical multijet, wet meter
- Using as domestic meters mostly for cold water
- Typical curved line of errors in measuring range



WM, flowmeters, velocity meters, continue

Examples, pictures

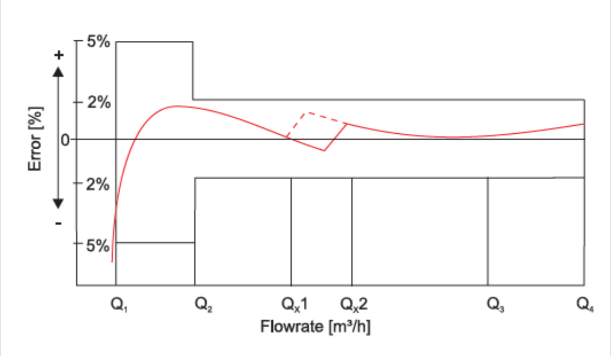
- Turbine, dry meter
- Using as domestic and industrial meters for cold and hot water
- Typical curved line of errors in measuring range



WM, flowmeters, velocity meters, continue

Examples, pictures

- Combined meter, 2 meters inside, turbine and multijet
- Large measuring range (combination of small and large meter)
- Using as domestic, resp. as industrial meters for cold water. If used as domestic meter, it allows also a measurements of high flow (f. inst. in case of fire)
- Typical curved line of errors in measuring range



b) WM, flowmeters, volumetric meters

Basic terminology:

- Volumetric meter, meter which identifies a flow (volume) of water (liquid) by moving part – ring, inside o chamber
- Volume between a ring and chambre is precisely defined
- Moving (rotation) of the ring is transferred by kinematic equipment on the totalizer
- Number of ring rotation defines a flow, resp. volume
- Volumetric meters work on dry principles, mostly for cold water

WM, flowmeters, volumetric meters, continue

Basic equation:

- **It is similary as by velocity meters**
- **Volume V is defined by number of ring rotation with precise definition of particular volume Vi/rotation**

After: V = Vi x n

n is number of ring rotation

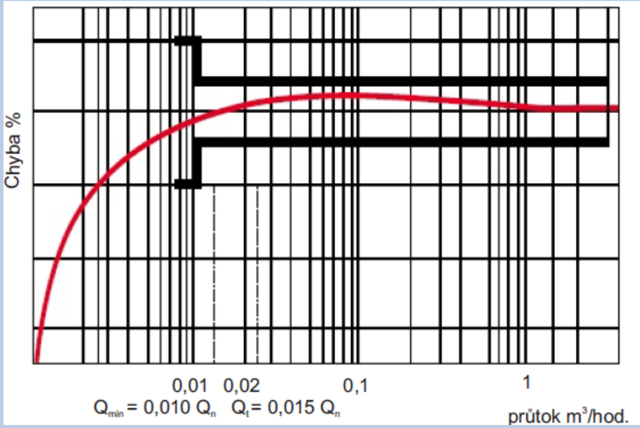
and:

Volume flow $$Q_v = \frac{V}{\tau}$$ (unit)

WM, flowmeters, vvolumetric meters, continue

Examples, pictures

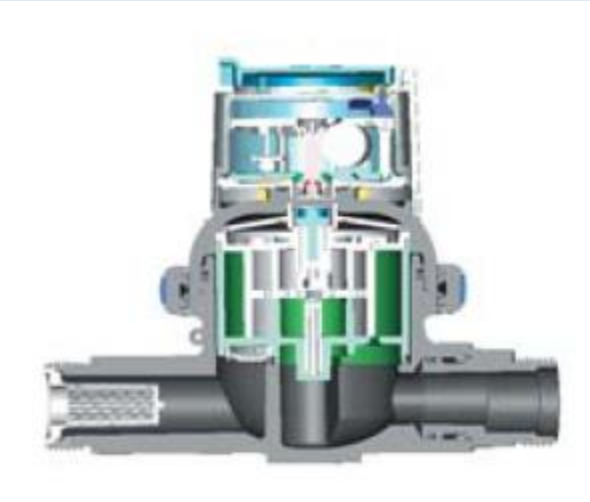
- **Volumetric, dry meter, all construction, composite materials**
- **Using as domestic meter for cold water**
- **Typical curved line of errors in measuring range (different as by velocity meters – more flat**

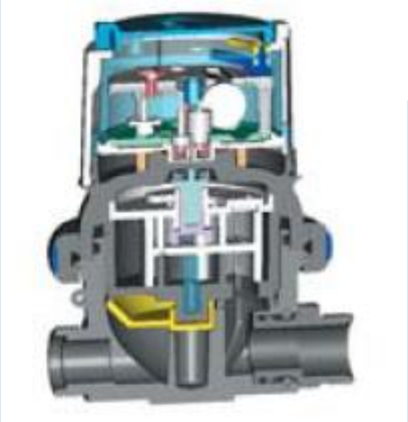


WM, flowmeters, vvolumetric meters, continue

Examples, pictures

- Volumetric, dry meter
- Illustration of principle – ring inside a chamber





c) WM, flowmeters, ultrasonic meters

Basic terminology:

- Ultrasonic meter, meter which identifies a flow (volume) concerning measured ultrasonic signals between at least 2 sensors
- Frequency of ultrasonic signal (in water, liquid) in units of MHz
- It is measured a time difference between a trajectory of signal in direction of flow and in direction against a flow
- From time difference a speed of flow of medium is determined
- Concerning dimension, resp. cross-section of the pipe, a quantity flow or volume of water is estimated

WM, flowmeters, ultrasonic meters, continue

Principle, equations:

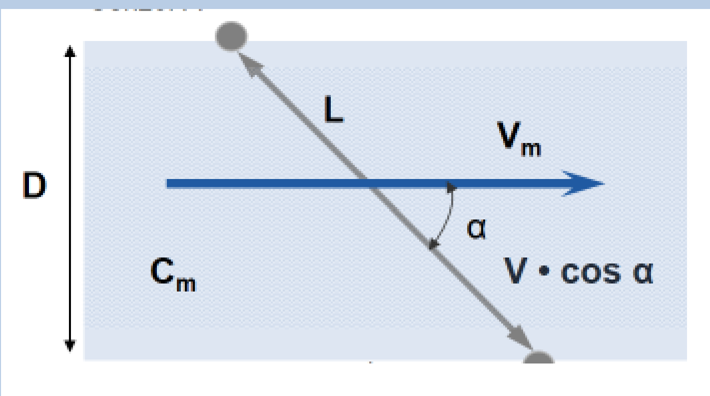
T – time, C – ultrasonic speed, v – speed of medium, L – trajectory of signal, D – dimension of pipe

$$T_{A\to B} = \frac{L}{C + V \cdot \cos\alpha}$$

$$T_{B\to A} = \frac{L}{C - V \cdot \cos\alpha}$$

$$V = \frac{L}{2 \cdot \cos\alpha} \cdot \frac{T_{B\to A} - T_{A\to B}}{T_{B\to A} \cdot T_{A\to B}}$$

Sensor A



Sensor B

WM, flowmeters, ultrasonic meters, continue

Picture, example

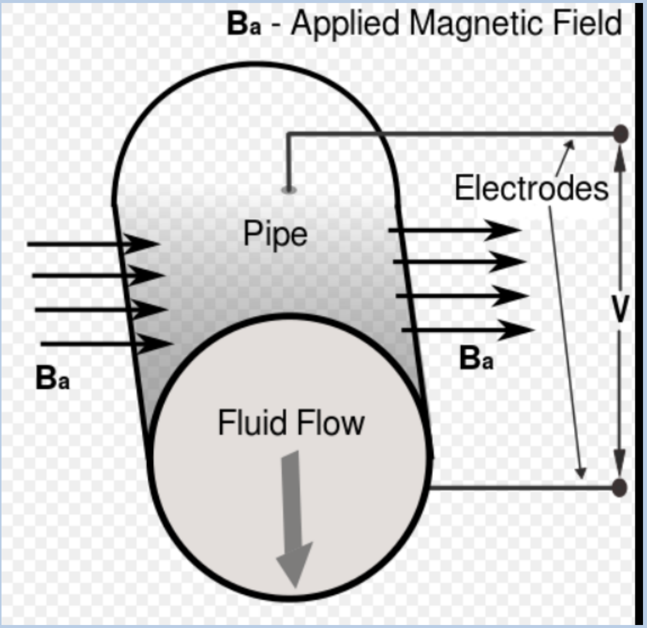
- **Accuracy, repeatability in range (0,2 – 0,5) %**
- **Wide range of dimensions DN**
- **Not moving parts – resistance against pollution**

d) WM, flowmeters, electromagnetic (EMD) meters

Basic terminology:

- EMD meter, meter based on acting of electromagnetic field (induction) on the liquid
- On basis of speed of liquid flow (by suitable conductivity of liquid in µS), electrical voltage is generated on electrodes of the meter
- On the basis of voltage a speed of medium is determined
- Very high accuracy of these EMD meters. In measuring range appr. (from 10 up to 100) %, in units 0,1 %
- Mostly used for measurements of cold water

WM, flowmeters, EMD meters, continue



Principle:

- Ba, applicated magnetic field, induction
- V – generated voltage on electrodes

WM, flowmeters, EMD meters, continue

Basic equation for EMD meters, whe are:

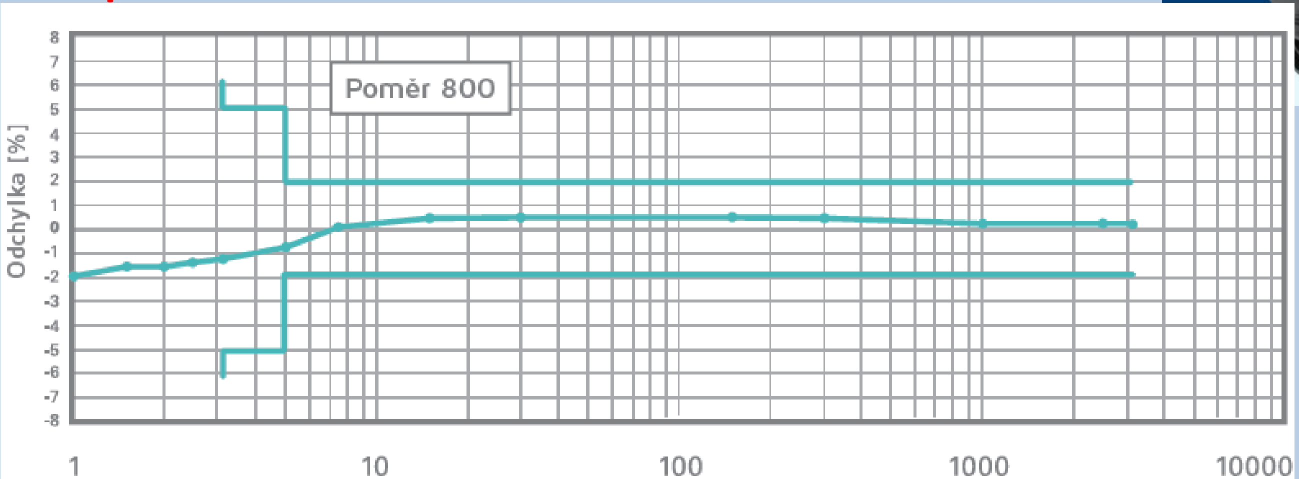
Ui – generated voltage on electrodes
B - electromagnetic induction
l – characteristic dimension, mostly diameter D of pipe
v - speed (velocity) of liquid
Qv – liquid flow

$$U_i = B \cdot l \cdot v = B \cdot D \cdot \frac{4 \cdot Q_v}{\pi \cdot D^2}$$

WM, flowmeters, EMD meters, continue

Picture, curved errors line, example

- **EMD domestic meter for cold water**
- **Curved line of errors very flat**
- **Wide range of measurements, ratio R = 800**
- **Not moving parts – resistance against pollution**



e) WM, flowmeters, mass (Coriolis) meters

Basic terminology:

- Mass, Coriolis meter, meter which identifies a mass or volumetric flow of liquid on basis of Coriolis acceleration, resp. of Coriolis force
- Suitable for water or other liquids
- Suitable for cold and hot water
- Very high accuracy – in units 0,1 %
- Probably, meters on highest level from metrology point of view, mostly used for interlaboratory comparison of National metrology institutes (NMI)

WM, flowmeters, mass (Coriolis) meters, continue

Principle:

- Liquid moves by defined speed v in the pipe (pipes) in bow form (or other form) which generate angle speed
- Angle speed ω origines in pipe
- On basis of liquid speed v, angle speed ω and mass of liquid m, vector of Coriolis acceleration ac, resp. of force Fc arises

WM, flowmeters, mass (Coriolis) meters, continue

Equations, explication:

- Vector of Coriolis accelaration, resp. force causes vibration of the pipe on given frequency and amplitude (snap before). This is identified by electronic of meter
- On basis of defined parameters of the meter (radius of bow, diameter DN) and by defined density of liquid ρ which must be put in into SW of meter, it can be estimated speed of liquid v and consequently mass, resp. volumetric flow

$$a_C = -2\omega \times v$$

$$\mathbf{F}_c = -2m\omega \times \mathbf{v}$$

WM, flowmeters, mass (Coriolis) meters, continue

Picture, example:

- **Mass flowmeter installed on test bench**
- **Wide range of diameters – (from 10 up to 100 or more) mm**
- **Not moving parts – resistance against pollutio**

f) WM, flowmeters, working on principle of pressure difference Δdp, resp. dp measurements

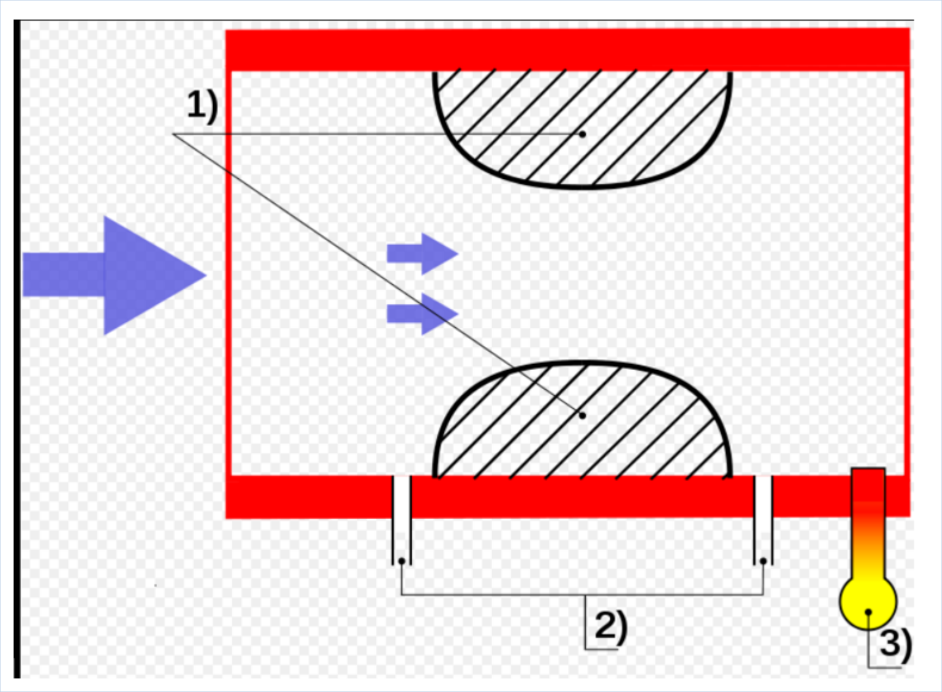
Available for liquids, gases, possible application for measurement of steam flow (next point 3, HM)

Basic terminology:

- Orifice plates
- Nozzles, Venturi nozzles
- Venturi pipes
- Coefficient of flow
- Expansion coefficient
- Reynold´s number Re (without dimension), etc.

WM, flowmeters, working on principle of pressure difference Δdp, resp. dp measurements, continue

- Flow of medium (blue), coming into strangling equipment 1 on basis of flow acceleration generates pressure difference **Δdp**, 2
- Temperature sensor 3, necessary for determination of flow medium parameters



WM, flowmeters, working on principle of pressure difference Δdp, resp. dp measurements, continue

$$q_m = \frac{C}{\sqrt{1-\beta^4}} \varepsilon \frac{\pi}{4} d^2 \sqrt{2 \Delta p \rho_1}$$

Examples of possible used equations, main symbols:

qm, Qm - mass flow
C - flow coefficient, function of Re
ε - expansion coefficient
d - dimension
β - relation of dimensions (d, D)
ρ - density of medium, etc.

$$Qm = Qmv * \sqrt{\left(\frac{dp}{dpv} * \frac{\rho}{\rho v}\right)}$$

WM, flowmeters, working on principle of pressure difference Δdp, resp. dp measurements, continue

Basic standard here: EN ISO 5167

Necessity to take in attention by flow estimation, most important points:

- Pressure difference Δp is measured by manometer
- Manometer – having mostly unified electric output, f. ex. (4 – 20) mA, linear
- But, Δp for flow calculation (equations before) is under a root – not linear
- Also, full combination of the meter including manometer can be calibrated by other liquid (mostly by water) as in real application. This one can has an other parameters as water (mostly density ρ). This fact must be also include by estimation (calculation) of real flow.

Picture, example: in next point 3, HM

g) WM, flowmeters, Vortex meters

Available for liquids, gases, possible application for measurement of steam flow

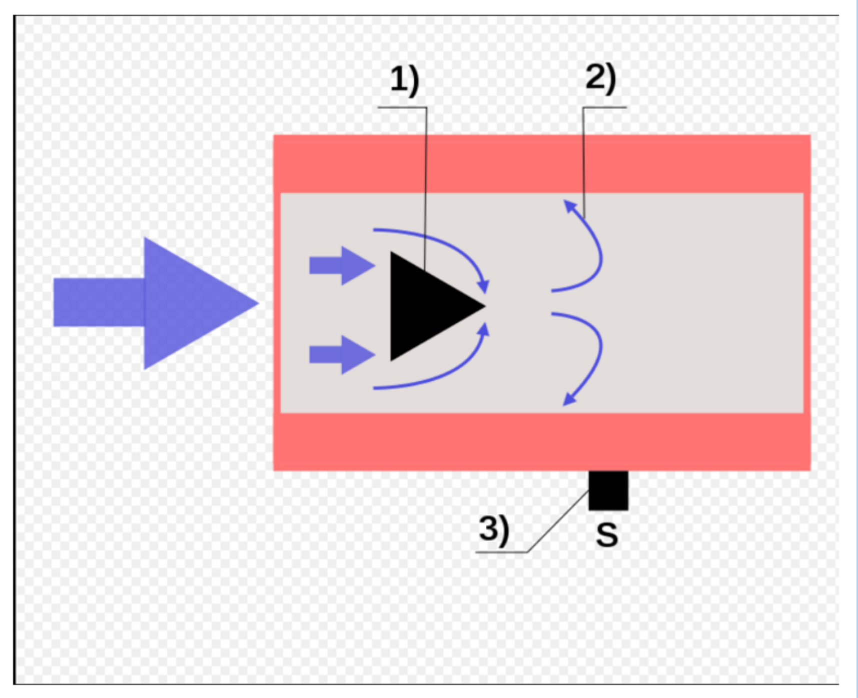
Basic terminology:

- Von Karman effect
- Strouhal number Sr (without dimension)
- Reynold´s number Re
- Obstacle in flow
- Generated frequency (impulses) reasoned by vortex

WM, flowmeters, Vortex meters

Principle:

- Flow of medium (blue) is passing an obstacle 1 istalled in flow trajectory
- Concerning von Karman effect a vortex 2 are generated by defined frequency
- Sensor S identifies a frequency, resp. number of pulses reasoned by vortex.



WM, flowmeters, Vortex meters

Main equations, symbols:

Qv, qv - volume, volumetric flow

St - Strouhal number

Re - Reynold´s number, characterizes measuring range of meter

v - kinematic viscosity

D - diameter of meter

d - width of the obstacle

U - velocity of flow

f - generated frequency

N - number of output impulses

K - factor of meter

$$St = \frac{fd}{U}$$

$$Re = \frac{DU}{v}$$

$$K = \frac{N}{Q_v} = \frac{f}{q_v}$$

Vortex meters disposes by linear outputs

End of point 2

Point 3

HM, terminology, equations, pictures – examples, HAM

a) HM, basic terminology

Heat meter – meter determined for measurement of thermal energy (capacity) which is given or taken by heat conveying liquid in exchanger. Heat conveying liquid can be water, mixture of water with other substances (for cooling applications) or steam.
Remark: cooling application and steam are not subject of MID directive.

Electric heat meter – HM which elaborates a measured values by help of electrical components and circuits

Complete HM – meter which does not have a separate sub-assemblies (see you next)

Combined HM – meter which has a separate sub-assemblies

Hybrid, compact HM – meter which can be approved or verified as combined meter (by separable sub-assemblies). However, by utilization a sub-assemblies are inseparable

Sub-assemblies – generally: calculator, temperature sensors, flowmeter (flow sensor)

Calculator – sub-assembly which receives a signals from temperature sensors and flowmeter and calculates and indicates heat energy.
Remark: By HM for steam application an identification of pressure of steam is included

Flow sensor – sub-assembly which measures a flow, resp. volume of heat conveying liquid and sends a signal into calculator

Temperature sensors (pair) – a sub-assembly which senses a temperature of heat conveying liquid in inlet and outlet part of heat exchange circuit
Remark: by steam application a temperature of steam is measured only by one sensor

Pressure sensor – sensor which measures an absolute or gauge pressure (by steam application), resp. pressure difference (applicated on flow sensors of steam based on nozzle, Venturi pipe principles, etc.)

Limit range of temperature measurement – minimum and maximum values of temperature of heat conveying liquid (symbol θ) which can be measured by temperature sensors of HM and evaluated by calculator

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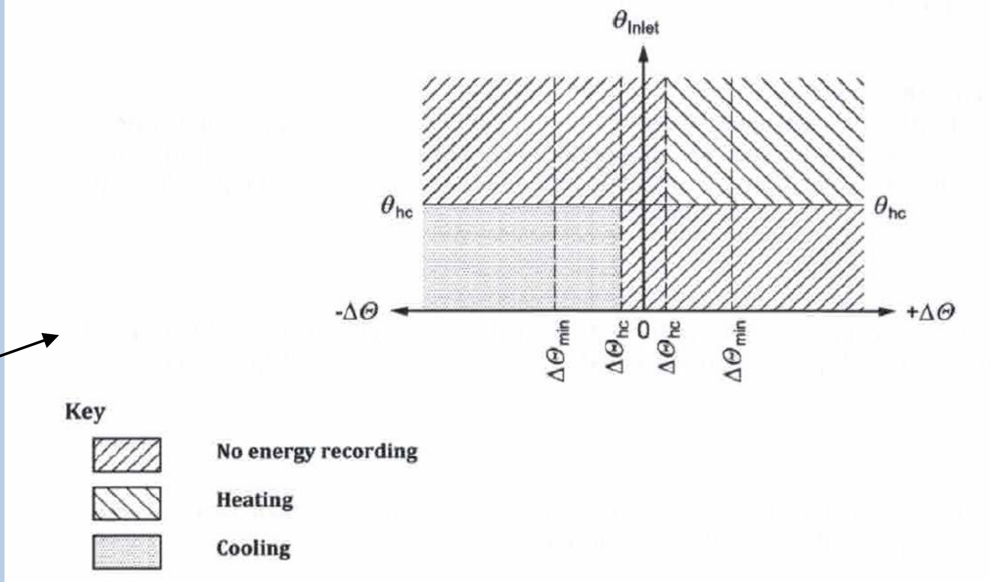
Limit range of temperature difference – minimum and maximum temperature difference of heat conveying liquid (symbol Δθ) in inlet and outlet parts of heat exchange circuit which can be measured by temperature sensors of HM and evaluated by calculator

New (EN 1434:2015):

Switching temperature Θhc for bifunctional HM (calculators) – automatic change over either for heating or for cooling application



Maximum permissible error (MPE) of HM, see you more in detail next point 5 of this presentation - maximum values of errors of: calculator, temperature sensors and flow sensors determined by technical documentation

Direct method of heat energy measurement of steam (see you also next point 7 of this presentation) – method using a mass of passed overheated steam and its enthalpy

Indirect method of heat energy measurement of steam (see you also next point 7 of this presentation) – method using a mass of returned condensate and enthalpy of overheated steam

b) Basic equations for heat energy estimation, consequences

HM – heat conveying liquid water

Generally, heat energy Q [MJ, GJ, kWh, MWh], is measured by HM on the basis of equation:

$$Q = \int qm \,.\, \Delta h .\, d\tau$$

Where are:

qm - [kg/h, t/h, atd.], mass flow of water

Δh – [MJ/kg], difference of enthalpy of water depending on temperature difference $\Delta\Theta$ [°C] of inlet and outlet parts of heat exchanging circuit (temperature Θ_p [°C] for inlet, temperature Θ_v [°C] for outlet)

τ – [s, h], time

HM – heat conveying liquid water, continue

It can be written then:

$$Q = m.\ \Delta h$$

and by enthalpy explication next equation is valid:

$$Q = m.\ c.\ \Delta\Theta$$

where are:

c – [MJ/kg. °C] specific heat of water, function of pressure p [MPa] and temperatures Θ_p, resp. Θ_v

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HM – heat conveying liquid water, continue

If passed mass of water m [kg] is explicated by multiplication of volume V [m^3] and density ρ [kg/m^3] (in part of heat exchange circuit where volume V is measured – dependance of density on temperature), it may be written:

$$Q = V.\, \rho.\, c.\, \Delta\Theta$$

When multiplication ρ x c is marked as K, [MJ, kWh/m^3.°C] - function of pressure p, temperatures Θ_p, Θ_v, and installation place (inlet, outlet) of flow sensor (volume V measurement by correction of density ρ depending on temperature), next equation is valid:

$$Q = K(\Theta_p,\, \Theta_v,\, p,\, \rho).\, V.\, \Delta\Theta$$

Symbol K is named as thermocoefficient

HM – heat conveying liquid water, continue

In next there are examples of values *K* for water, for typical testing, resp. application conditions (pressure, temperature differences, installation of flow sensor in outlet part of heat exchanger):

$K(53,50,1bar)$ = 4,1315 MJ/m³ . °C, eg. 1,1476 kWh/m³ . °C
$K(70,50,1bar)$ = 4,1350 MJ/m³ . °C, eg. 1,1486 kWh/m³ . °C
$K(150,50,16bar)$ = 4,1746 MJ/m³ . °C, eg. 1,1596 kWh/m³ . °C.

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HM – heat conveying liquid water, continue

Tables IAPWS (IF) 97, water, steam, thermodynamic parameters, example

Properties given pressure and temperature		
Pressure	**1,00**	bar a
Temperature	**20,00**	°C
Enthalpy	84,0	kJ/kg
Density	998,21	kg/m3
Entropy	0,30	kJ/kgK
Vapour fraction	0	%
IF97 Region	1	
Phase	**Liquid**	
Isobaric heat capacity	4,184798	kJ/kg
Speed of sound	1483,417	m/s

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HM – heat conveying liquid water, continue

Final presented equation gives a basic information concerning measurement of heat energy in water by help of combined or completed (hybrid, compact) HM.

- Thermocoefficient *K* is estimated by SW of HM of the basis of temperature values measurements
- Volume *V* of water is identified by flow sensor. Output signals are transferred into calculator mostly by help of impulses (on defined impuls values and frequences). It can not be excluded also an unified electrical signals, f. ex. (0, resp. 4 up to 20) mA, (0 up to 10 V), etc.
- Temperature difference is measured by help of platinum temperature sensors pair (mostly Pt 100 or Pt 500). These sensors (either particular sensor or a complete pair) must fulfill metrological requirements. Sensors are paired for all temperature measuring range of HM, also for all measuring range of temperature difference. Minimum value of difference $\Delta\Theta$ is mostly given by value (2, resp. 3) °C.

HM – other liquids, not subject of MID directive

Important theme

- HM allow an energy measurements either for heat or for cooling application (typical: combination of heating, solar systems, aircondition, etc., possible using of the same liquids and HM without necessty of exchange)
- HM can automaticaly switch over its function for heat or cooling measurements (see you also temperature Θhc in snap before)
- Heat conveying liquids (solutions) using in these cases are others as pure water. Mostly mixtures of water and glycol
- Thermodynamic parameters of these solutions are really different as parameters of water
- Parameters must be programmed into HM, other way a large errors can arise (it is not enough to give „some“ correction factor, f. inst. 0,95 againt a pure water)
- Actual problems of HM which are subordinated to metrological legislation

HM – other liquids, continue
Possible polynomical estimation of thermodynamic parameters (sources, Conde Engineering, Swiss, PTB, Germany):

Freezing temperature of liquid T_F :

$$\frac{T_F}{273.15} = A_0 + A_1\xi + A_2\xi^2$$

Density ρ, heat capacity C_p of heat conveying liquid:
Units marked by symbol Px

$$P_x = A_1 + A_2\xi + A_3\frac{273.15}{T} + A_4\xi\frac{273.15}{T} + A_5\left(\frac{273.15}{T}\right)^2$$

Where are:

- ξ mass ration of not freezing substance in water solution
- T absolute temperature in K
- A_n coefficients of polynoms given in tables (for particular estimated quantities.

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HM – other liquids, continue

Example of polynom coefficients for particular quantities, ethylenglycol:

Koef. A	ϱ [kg/m3]	Cp [kJ/kg K]	T_F [K]
0			1.0
1	658.498 25	5.364 49	-0.069 82
2	-54.815 01	0.788 63	-0.357 80
3	664.716 43	-2.590 01	
4	232.726 05	-2.731 87	
5	-322.616 61	1.437 59	

HM – other liquids, continue

Other possibility of quantities specification in tables (presented by manufacturer of solution). Here, solution marked as „Pekasol", possible application up to – 40 °C:

Temperature [°C]	Density [g/cm3]	Specific heat [kJ/kg K]
-40	1,259	2,67
-30	1,255	2,72
-20	1,252	2,76
-10	1,248	2,79
0	1,243	2,82
10	1,239	2,85
20	1,234	2,87
30	1,229	2,89
40	1,224	2,91
50	1,218	2,92

HM – other liquids, continue, example

Solution, ethylenglycol, 50 % in water, meter programmed on this solution, reference value for water only, large errors

[°C] T-inlet	[°C] T-outlet	P [GJ/h] Ref. val.	P [GJ/h] Measured	Error [%]
6,00	3,00	0,126086	0,1068	-18,071
8,00	3,00	0,210015	0,1782	-17,845
23,00	3,00	0,836042	0,7206	-16,014
43,00	3,00	1,658797	1,4597	-13,64
53,00	50,00	0,123695	0,1161	-6,546
55,00	50,00	0,205978	0,1936	-6,405
70,00	50,00	0,817932	0,7795	-4,926
90,00	50,00	1,617552	1,5706	-2,992
200,00	50,00	5,549088	6,0294	7,966
200,00	180,00	0,769086	0,8716	11,76
200,00	160,00	1,524373	1,7258	11,67
200,00	3,00	7,2482	7,6115	4,773

HM – steam, not subject of MID directive

Similary as by HM for water, also here are valid basic equations for heat energy of steam Q:

$$Q = \int qm\,.\,h.\,d\tau$$

resp.:

$$Q = m.\,h$$

Comparing with equations for HM and conveying liquid water, **here is not important a difference of enthalpy Δh** which depends on temperature difference of medium $\Delta\Theta$ in inlet and outlet parts of of heat exchange circuit.

HM – steam, continue

For measured heat energy of steam there is a basic information actual temperature *Θ*, and pressure *p* (mostly absolute). Same dependance on quantities *Θ*, resp. *p* is valid for density *ρ* and consequently for passed mass *m* of overheated steam. So, it is possible to write:

$$Q = m.\ h(\Theta, p)$$

resp. in relation between volume of steam *V* and mass of steam *m* depending on density *ρ*:

$$Q = V.\ \rho(\Theta, p).\ h(\Theta, p)$$

HM – steam, continue

Heat energy of steam - estimation:

Calculator of HM on the basis of measured values temperature *Θ*, resp. pressure *p* determines by help of its SW, where a thermodynamic parameters of steam are implements (mostly values from IAPWS97) actual enthalpy *h*(*Θ*, *p*), resp. density *ρ*(*Θ*, *p*). Simultaneously, it estimates parameters of steam (overheated, saturated, below saturation). Mostly, by case below the saturation, measurement is interrupted and values are transferred in other register of HM.

Actual temperature of steam is identified by temperature sensors with suitable range (up to 400 °C) and unified output into calculator. Mostly, there are Pt sensors, but also current (4 - 20) mA, frequency outputs, etc. may be used.

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HM – steam, continue

Actual pressure (pressure difference) of steam is identified by sensors of suitable construction and resistance against temperature of steam. Absolute or gauge pressure (by precise definition of barometric pressure) is measured. Upper limit of measurement is in units of MPa (concerning parameters of steam). Unified current output signal is mostly used (0, resp. 4 - 20) mA. Difference manometers on flow sensors of steam (nozzles, etc.) have a same unified outputs, its range of measurement are in tens of kPa.

Identification of passed volume *V* or mass *m* of steam:

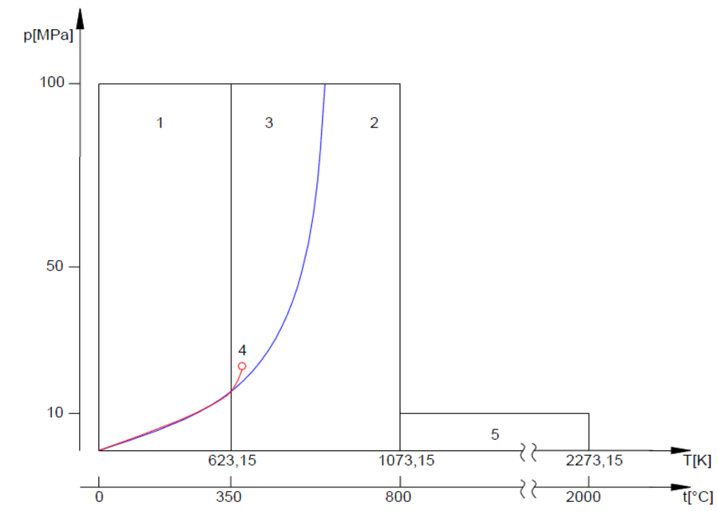
- calculator could be programmed on volumetric method. F. ex. Vortex flowmeters of steam (direct method, see you point 7 of presentation) are using frequently here, with linear characteristic and unified current outputs. Also volumetric velocity flowmeters (for indirect method, see you point 7 again) for measurement of return condensate volume with unified output are applicated here often.

HM – steam, continue

- calculator programmed on mass method. Here can be used a different types of flow sensors (orrifice plates, nozzles, Venturi pipes, annubars, etc. **Standard EN ISO 5167**), mostly using dependance of measured pressure difference on the flow of steam. Here must be guaranted that output signal (some times not linear) coming into calculator from the sensor (from difference manometer) must include all behaviors (mathematical, constructional, metrological – f. inst calbration by water, installation, etc.) of the sensor for correct estimation of mass flow by calculator

HM – steam, continue

Explication of terms: water, saturated, overheated (superheated) steam depending on temperature and pressure



IAPWS-IF97 Regions

1. Water
2. Superheated Steam
3. Water
4. Saturation Line
5. Superheated Steam

HM – steam, continue

Example of steam thermodynamic parameters, IAPWS (IF) 97:

- Pressure 10 bars, abs
- Temperature 250 oC
- Enthalpy of steam more hogher as for water (snap before)

Properties given pressure and temperature		
Pressure	**10,00**	bar a
Temperature	**250,00**	°C
Enthalpy	2943,2	kJ/kg
Density	4,30	kg/m3
Entropy	6,93	kJ/kgK
Vapour fraction	100	%
IF97 Region	2	
Phase	**Steam**	
Isobaric heat capacity	2,21162	kJ/kg
Speed of sound	550,1075	m/s

c) Pictures of HM, examples

Hybrid (compact) HM, medium water, ultrasonic flow sensor

Complete (compact) HM, medium water, mechanical flow sensor

Pictures of HM, examples, continue

Combined HM – calculator, temperature sensor pair, mechanical (turbine) flowmeter with pulse output, medium water

Mechanical (velocity) flowmeter with pulse output, medium water

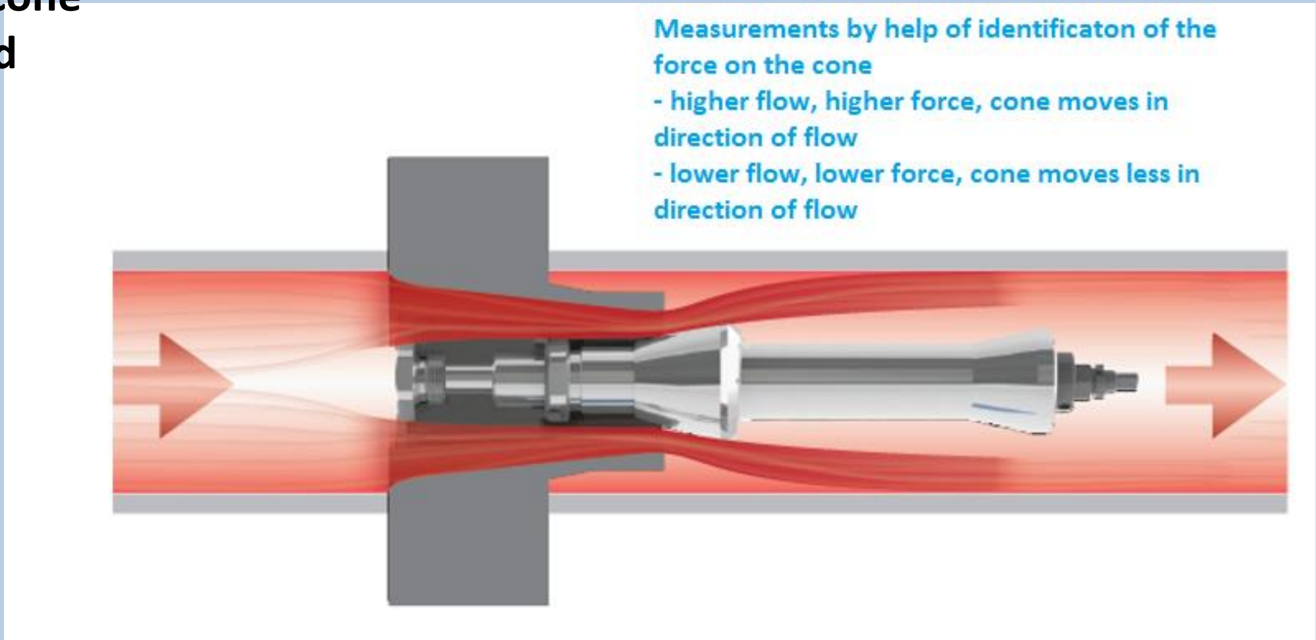
Pictures of HM, examples, continue

Sophisticated HM – calculator with lot of SW versions

- measurement of heat energy of water
- measurements of heat energy of other liquids (f. inst. cooling application)
- measurements of heat energy of steam

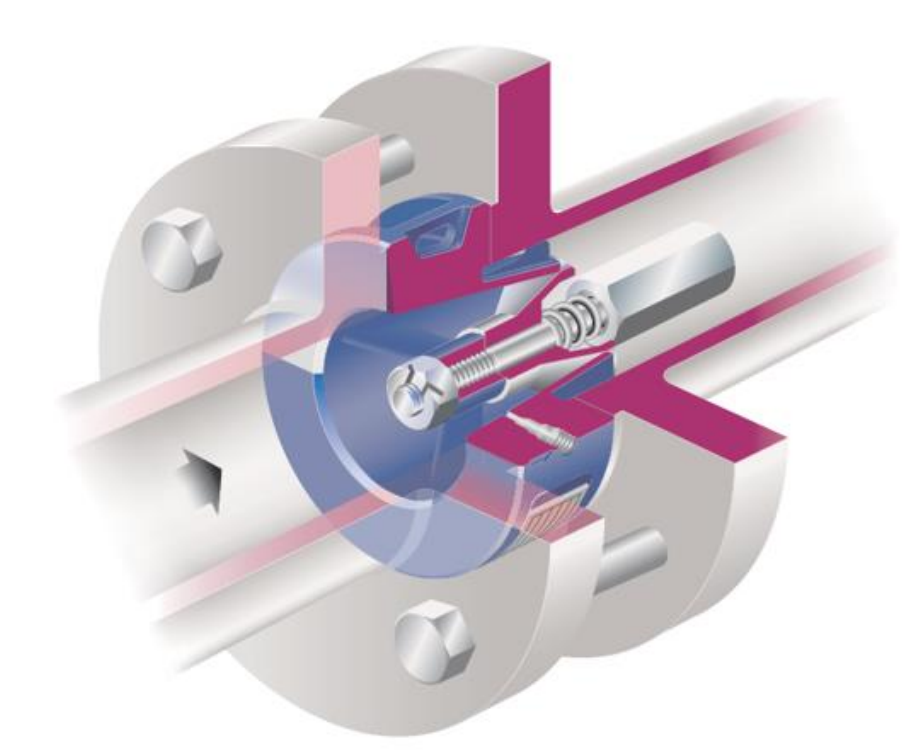
Pictures of HM, examples, continue

- flow sensor for steam,
- force on the cone
- direct method



Pictures of HM, examples, continue

- moving cone
- pressure difference generation, measurement
- direct method
- full configuration of HM, next snap

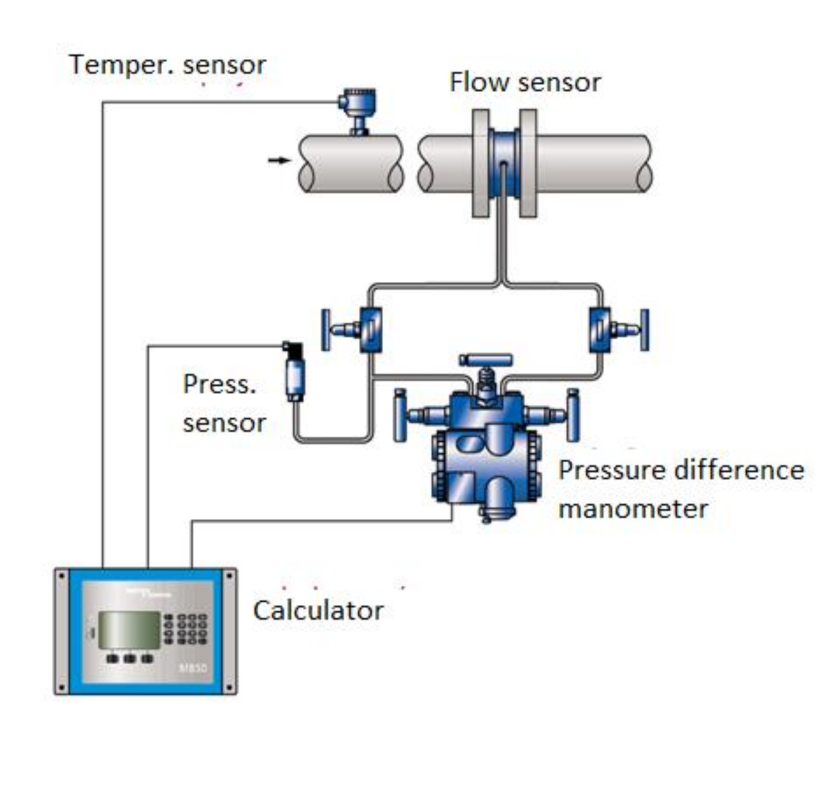


Pictures of HM, examples, continue

- Pressure sensor
- HM for steam

Pictures of HM, examples, continue

- full configuration of HM, steam
- direct method



d) Heat allocation meters (HAM)

Only remark in this presentation:

- not under legal metrological control
- HAM – not HM, HAM only identify a ratio of heat energy consumption, in rooms, appartements, etc.

Requirements:

- Qualified installation of HAM in apartments on heating radiators
- Correctly programmed SW in HAM in accordance with installation parameters (position of apartment, kind of heating radiator, etc.)
- Remote, smart reading of HAM, etc.

Documents:

- EN 834, EN 835 (electronic HAM)

End of point 3

Point 4

Data transmission, smart metering

All modern electronic WM and HM are equipped with possibilities of data transmission (see you f. ex. T-type of instruments in point 1, SW validation). Even an older mechanical WM which handle by input outputs are available here.

Remark: This field covers not only WM and HM but also electricity, resp. gas meters at least.

Development on this field is going on by „rocket speed“ as all new technologies. It is not possible to go through more in detail in this presentation. It is only for infomation.

Document CEN/CENELEC marked as **CEN/CLC/ETSI/TR 50572 (Functional reference architecture for communications in smart metering systems)** issued already in year 2011 assumed lot of possibilities and presented high number of connected technical documentation

Interfaces, protocols

Typical possible interfaces:

- RS 232, serial
- RS 485, serial
- Radio (free frequences, f. ex. 433 MHz, 870 MHz, low pover up to 10 mW)
- Internet
- (Power line)

Typical protocols for AMR - automatic meter reading (determined in particular documents, standards)

- M-BUS, wire
- M-BUS wireless
- IP, GPRS protocols
- PCL, power line protocol, etc.

OSI, open systems interconnection, defined by ISO

- Framework for communication processes, divided in defined layers.
- Unification of particular protocols (icluding f. inst. PROFIBUS, HART, etc.)

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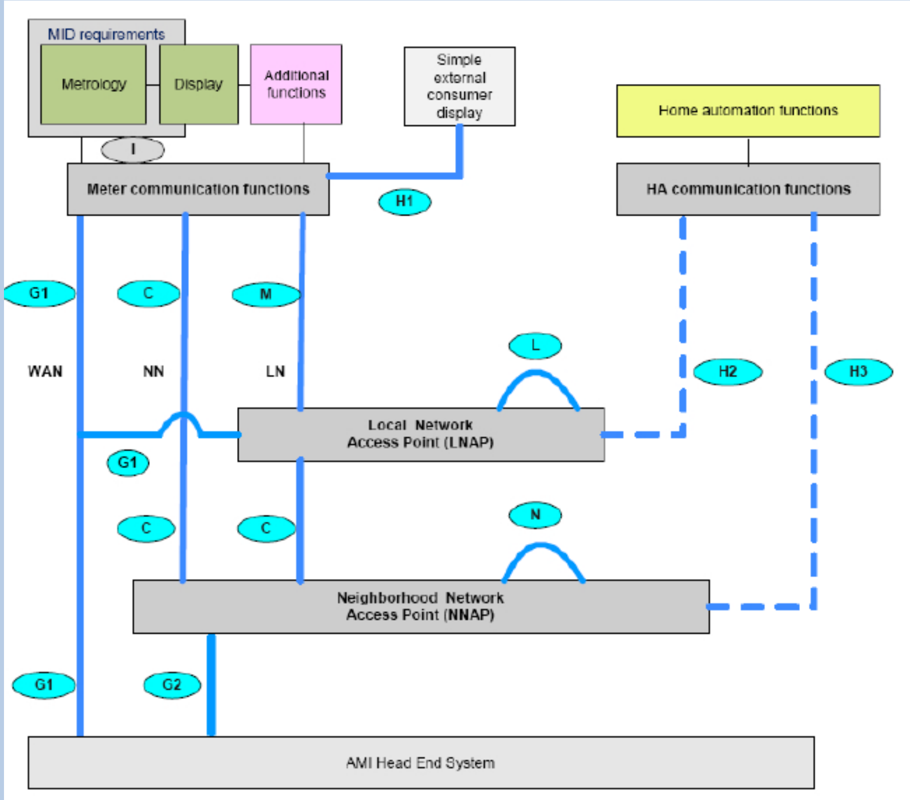
AMI, advanced metering infrastructure, reliability, security, invoicing etc., basic scheme



Typical actually applicated AMR (automatic meter reading)

- Long distance reading (LDR)
- Mobile reading (MR)
- Datalogging (DL)

LDR, main principles:

- Meters, WM, HM are provide with suitable features – at least suitable output modules (transmitters for particular interfaces and protocols), SW for communications
- Meters are installed in defined communication network
- Gateway of network exports measured data to the final user
- Data can be used farther away for AMI

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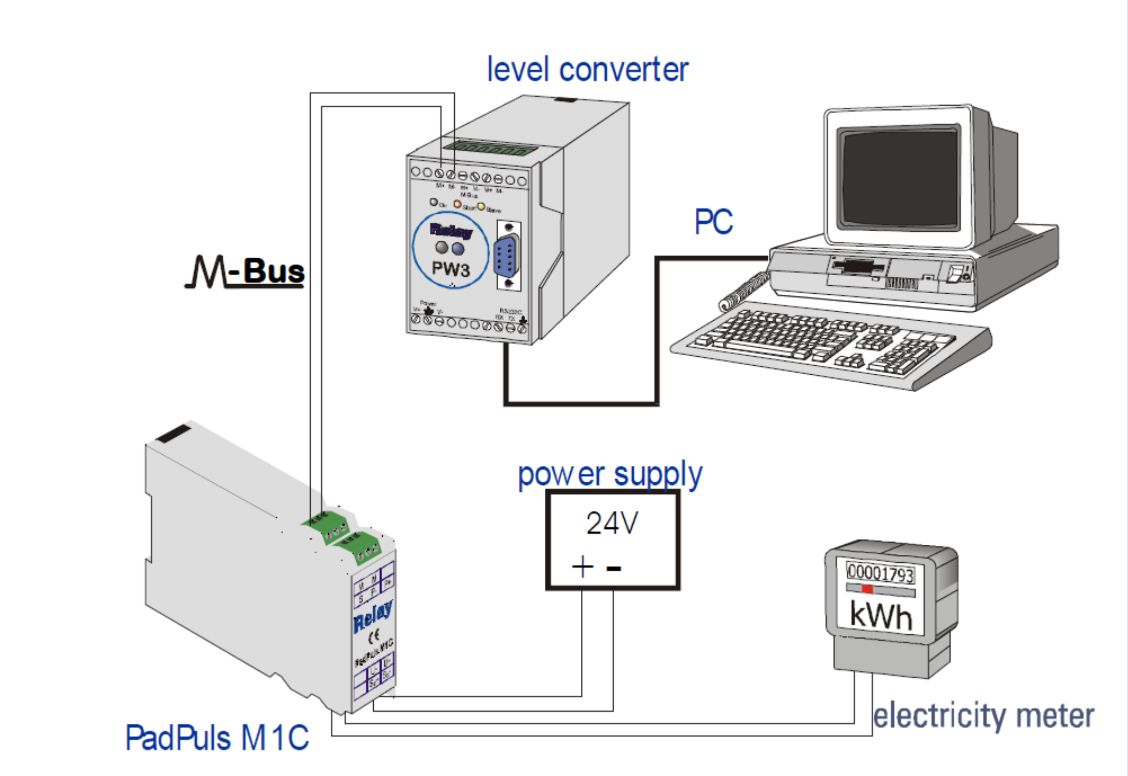
Example of configuration of LDR (M-BUS, elektricity meter here , may be WM, HM of course):



Other example of LDR configuration, communication by RF from WM, gateway, data-transmission, via GPRS, Internet:

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Typical table, AMR, LDR, HM

Quantities: Heat, Volume

Historie kontrolních odečtů

11152

Datum	Název1	Název2	Název3	Sériové číslo	Počít..	Hodnota 1	J...	Počít...	Hodnota 2	Je...	Počít.
2001-10-02	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	128,9	GJ	Objem	2418,1	m3	P
2001-10-03	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	130,6	GJ	Objem	2472,4	m3	P
2001-10-04	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	132,3	GJ	Objem	2527,3	m3	P
2001-10-05	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	133,9	GJ	Objem	2581,7	m3	P
2001-10-06	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	135,6	GJ	Objem	2636	m3	P
2001-10-07	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	136,9	GJ	Objem	2677	m3	P
2001-10-08	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	138,8	GJ	Objem	2731,9	m3	P
2001-10-09	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	140,5	GJ	Objem	2786,8	m3	P
2001-10-10	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	142,3	GJ	Objem	2841,1	m3	P
2001-10-11	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	143,7	GJ	Objem	2882,2	m3	P
2001-10-12	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	145,8	GJ	Objem	2952,3	m3	P
2001-10-13	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	147,4	GJ	Objem	3004,8	m3	P
2001-10-14	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	149	GJ	Objem	3059,7	m3	P
2001-10-15	0803-018\000\111	Tesaříkova 1021	K1;1021;WS50	00015332	Teplo	150	GJ	Objem	3088,1	m3	P
2001-09-24	0803-017\002\511	Tesaříkova 1022-3	K1 1023 WS50	00012568	Teplo	3647	GJ	Objem	60039,1	m3	P
2001-09-28	0803-017\002\511	Tesaříkova 1022-3	K1 1023 WS50	00012568	Teplo	3658,2	GJ	Objem	60535,1	m3	P
2001-09-29	0803-017\002\511	Tesaříkova 1022-3	K1 1023 WS50	00012568	Teplo	3661,4	GJ	Objem	60701,3	m3	P
2001-09-30	0803-017\002\511	Tesaříkova 1022-3	K1 1023 WS50	00012568	Teplo	3663,6	GJ	Objem	60833,6	m3	P

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MR, main principles:

- Meters, WM, HM are provide with suitable features – at least suitable output modules (transmitters for particular interfaces and protocols), SW for communications
- Selected terminal (f. inst. PSION, Motorola, etc.) must be to disposition. Terminal must be equipped with interface which communicates with each meter
- Mostly radio-communication (f. int. wireless M-BUS) is applicated
- Also other interfaces (f. inst. IR, optical) can be used
- SW of terminals transferred a collected data on PC of user
- Data can be eventually used farther away for AMI

MR, example of WM with RF module, terminal with PC:

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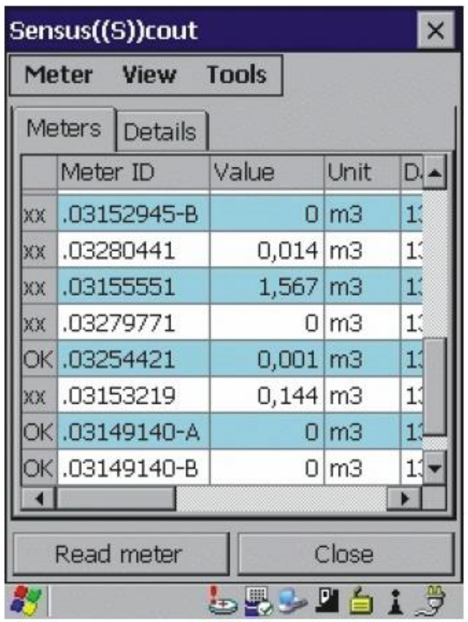
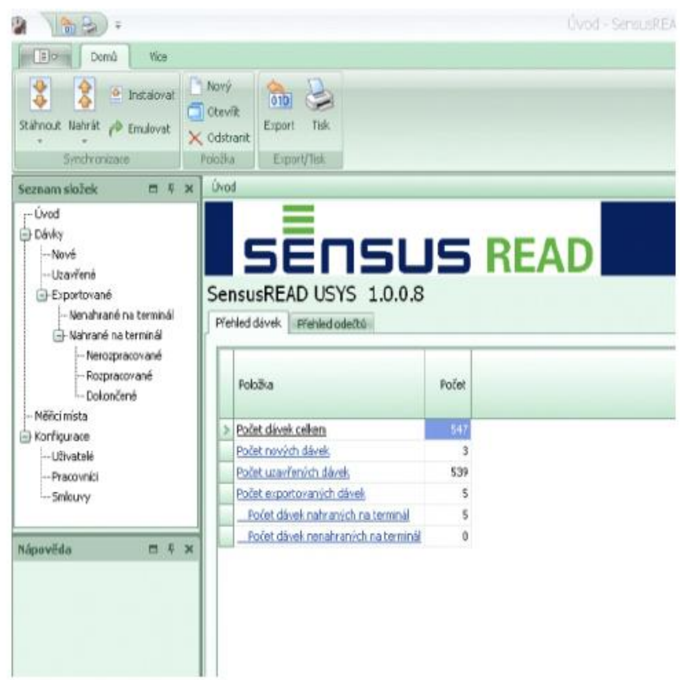
MR, read value from WM on terminal, display of SW on PC, example





DL, dataloggers of measured values

- Dataloggers with suitable interfaces and SW are still in utilization
- Advantage – to install a programmed datalogger on the meter (WM, HM) and after a longer time period (f. inst. several weeks) to put a collected data into PC
- Collected data can be analysed in graphical, resp. in digital form (in selected interested time interval, f. inst. hours with resolution in seconds). It is important for water and heat utilities for analyse of operating water and heat networks
- Of course, application of AMI, AMR, LDR, even features of measured values logging in particular meters, can restrict utilization of specialized dataloggers. But still in given cases, this solution can be very helpfull (f. inst. only from the point of view of price – not necessity of all system building)

Datalogger, combination with WM, connections

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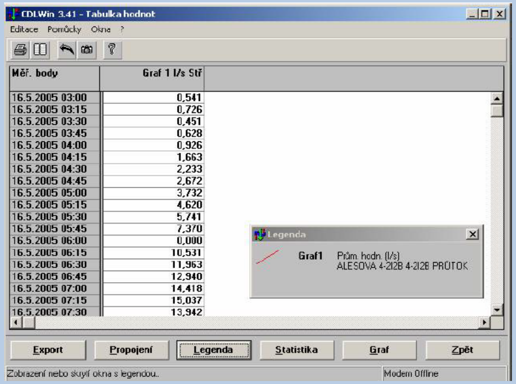
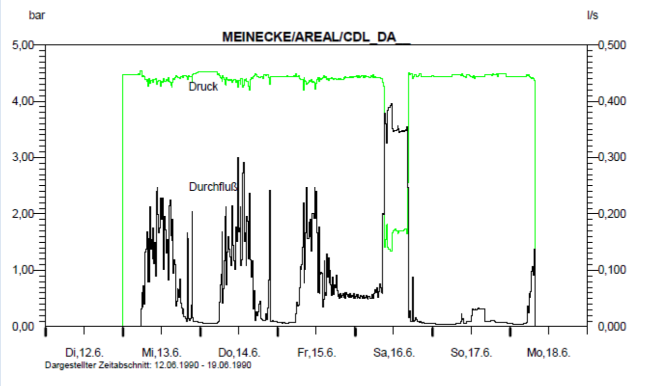
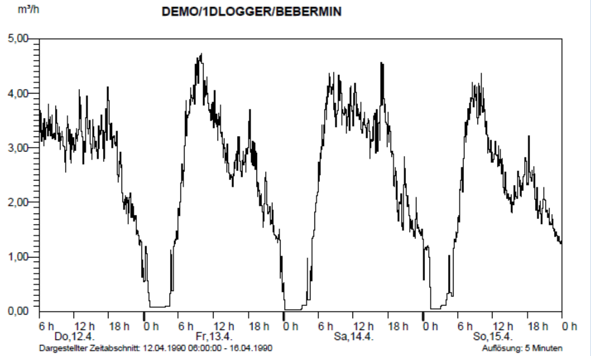
Examples of datalogger results, digital, graphical. WM, quantities: flow, pressure



Měř. body	Graf 1 l/s Stř
16.5.2005 03:00	0,541
16.5.2005 03:15	0,726
16.5.2005 03:30	0,451
16.5.2005 03:45	0,628
16.5.2005 04:00	0,926
16.5.2005 04:15	1,663
16.5.2005 04:30	2,233
16.5.2005 04:45	2,672
16.5.2005 05:00	3,732
16.5.2005 05:15	4,620
16.5.2005 05:30	5,741
16.5.2005 05:45	7,370
16.5.2005 06:00	0,000
16.5.2005 06:15	10,531
16.5.2005 06:30	11,963
16.5.2005 06:45	12,940
16.5.2005 07:00	14,418
16.5.2005 07:15	15,037
16.5.2005 07:30	13,942





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End of point 4

Point 5

WM, HM, parameters, MPE, old and new approach

WM, old and new approach

Old approach

WM for:

cold water (0- 30)°C
hot water (30 - 90)°C

Range of flow:
metrological classes A, B, C

Verification on the flows:

Qmin, Qt, Qn or Qmax

New approach

Temperature classes (f. inst.):

T30 (0,1 - 30)°C
T90 (0,1 – 90)°C
T30/90 (30 - 90)°C

Range of flow:
selection of ratio R = Q3/Q1, from 40

Verification by the flows:

Q1, Q2, Q3

Optional possibility of upstream, downstream lenghs: from U0, D0

Pressure loss: from ΔP 10 (0,1 bar) up to ΔP 63 (6,3 bar)

Pressure class MAP from 6 up to MAP 40

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Maximum permissible errors (MPE) of WM – cold water up to 30°C

old approach			new approach			MPE	
						by verif.	in appl.
DN	15		DN	15			
A, class			**R 40**	40			
Qmin/Qn	0,04		Q2/Q1=1,6	1,6			
Qt/Qn	0,1		Q4/Q3=1,25	1,25			
Qmin	**0,06**	m3/h	Q1	**0,063**	m3/h	5%	10%
Qt	**0,15**	m3/h	Q2	**0,100**	m3/h	2%	4%
Qn	**1,5**	m3/h	Q3	**2,5**	m3/h	2%	4%
Qmax	**3**	m3/h	Q4	**3,125**	m3/h	2%	4%
B, class			**R 80**	80			
Qmin/Qn	0,02		Q2/Q1=1,6	1,6			
Qt/Qn	0,08		Q4/Q3=1,25	1,25			
Qmin	**0,03**	m3/h	Q1	**0,031**	m3/h	5%	10%
Qt	**0,12**	m3/h	Q2	**0,050**	m3/h	2%	4%
Qn	**1,5**	m3/h	Q3	**2,5**	m3/h	2%	4%
Qmax	**3**	m3/h	Q4	**3,125**	m3/h	2%	4%

This Project is funded by the European Union

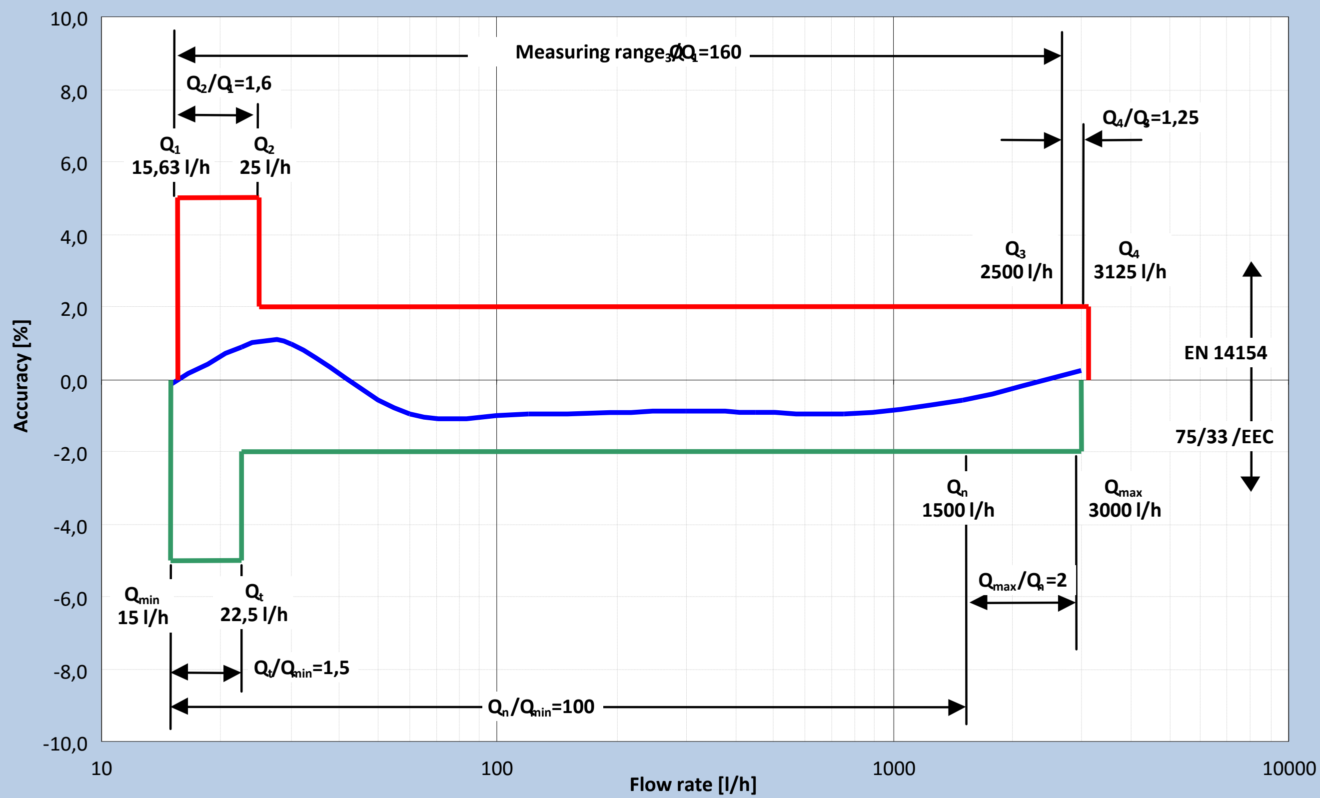
Project Implemented by the CMI

WM, MPE – hot water (30-90)°C

old approach			new approach			MPE	
						by verif.	in appl.
DN	50		DN	50			
A, class			**R 40**	40			
Qmin/Qn	0,08		Q2/Q1=1,6	1,6			
Qt/Qn	0,2		Q4/Q3=1,25	1,25			
Qmin	**1,2**	m3/h	Q1	**0,625**	m3/h	5%	10%
Qt	**3**	m3/h	Q2	**1,000**	m3/h	3%	6%
Qn	**15**	m3/h	Q3	**25**	m3/h	3%	6%
Qmax	**30**	m3/h	Q4	**31,25**	m3/h	3%	6%
B, class			**R 80**	80			
Qmin/Qn	0,04		Q2/Q1=1,6	1,6			
Qt/Qn	0,15		Q4/Q3=1,25	1,25			
Qmin	**0,6**	m3/h	Q1	**0,313**	m3/h	5%	10%
Qt	**2,25**	m3/h	Q2	**0,500**	m3/h	3%	6%
Qn	**15**	m3/h	Q3	**25**	m3/h	3%	6%
Qmax	**30**	m3/h	Q4	**31,25**	m3/h	3%	6%

Graphical example, WM
- old approach, class C
- new approach, R = 160

Remark: flow rate, logaritmic



New approach, more in detail, possible selections of flow values and ratio R

The value of Q_3 , expressed in m^3/h, shall be chosen from the following list:

1	1,6	2,5	4	6,3
10	16	25	40	63
100	160	250	400	630
1 000	1 600	2 500	4 000	6 300

The value of the ratio Q_3/Q_1 shall be chosen from the following list:

40	50	63	80	100
125	160	200	250	315
400	500	630	800	1 000

The ratio Q_2/Q_1 shall be 1,6.

The ratio Q_4/Q_3 shall be 1,25.

Old approach, more in detail, classes of WM for cold water, based on value Qn

Classes A,B,C

for Qn less as 15 m3/h	for Qn equal or more as 15 m3/h
Třída A	Třída A
Qmin = 0,04 x Qn	Qmin = 0,08 x Qn
Qt = 0,10 x Qn	Qt = 0,30 x Qn
Třída B	Třída B
Qmin = 0,02 x Qn	Qmin = 0,03 x Qn
Qt = 0,08 x Qn	Qt = 0,20 x Qn
Třída C	Třída C
Qmin = 0,01 x Qn	Qmin = 0,006 x Qn
Qt = 0.015 x Qn	Qt = 0.015 x Qn

Old approach, more in detail, classes of WM for hot water, based on value Qn

Classes A,B,C

for Qn less as 15 m3/h	for Qn equal or more as 15 m3/h
Třída A Qmin = 0,04 x Qn Qt = 0,10 x Qn	Třída A Qmin = 0,08 x Qn Qt = 0,20 x Qn
Třída B Qmin = 0,02 x Qn Qt = 0,08 x Qn	Třída B Qmin = 0,04 x Qn Qt = 0,15 x Qn
Třída C Qmin = 0,01 x Qn Qt = 0,06 x Qn	Třída C Qmin = 0,02 x Qn Qt = 0,10 x Qn

Old approach, HM, MPE

Calculators

HM in metrological classes 4 or 5. MPE are given for calculators (without temperature sensors) on dependance on temperature difference mostly from 3 °C up to 150 °C as follows:

ΔΘ (from 3 up to 20) °C:	+/- 1% (class 4)	+/- 1,5% (class 5)
ΔΘ equal or more as 20 °C	+/- 0,5% (class 4)	+/- 1% (class 5)

Old approach, HM, MPE

Pt 100, Pt 500 temperature resistance sensors

It must be fulfilled requirements on accuracy for classes A, resp. B concerning standard EN IEC 60751. Stability of ssensors is given by value 0,025 ^{o}C. In all temperature range a pair of sensors must keep next conformity:

+/- 0,05 ^{o}C (for HM class 4)   +/- 0,10 ^{o}C (class 5)

Next requirements are valid for classes of temperature sensors, classes A, resp. B concerning EN IEC 60751 in all measuring range:

± (0.15+0.002*/t/) ^{o}C, class A

± (0.30+0.005*/t/) ^{o}C, class B. (f. inst. for characteristic temperature 150 ^{o}C there is an error appr. 0,7 %).

Flowmeters for HM

Flowmeters are tested on flow values: Qt, 0,25 Qmax a Qn (Qmax) with permissible error +/- 3%

Old approach, HM, MPE

Compact, combined meters

These HM are completing of calculator, temperature sensors and flow sensors.

For class 5 of HM (mostly used), by testing of all parts together, next MPE are given in dependance on ΔΘ.

ΔΘ up to 10 °C: +/- 8%
ΔΘ from 10 °C up to 20 °C: +/- 7%
ΔΘ over 20 °C: +/- 5%.

New approach, HM, MPE

For compact, resp. combined HM (classes 1, 2 or 3) an aditional formula for MPE estimation is given (indexes: f for flowmeters, t for temperature sensors, c for calculators):

$$E = E_f + E_t + E_c,$$

This formula for mostly used HM in classes 2 and 3 can be written then:
For class 2:
$E = (3 + 4\ \Delta\Theta_{min}/\Delta\Theta + 0{,}02\ q_p/q)$,
For class 3:
$E = (4 + 4\ \Delta\Theta_{min}/\Delta\Theta + 0{,}05\ q_p/q)$.
This is coming out from MPE of particular components of HM, in next.

New approach, MPE for particular parts of HM

MPE of flowmeters, classes 1, 2, 3. Value 5% can not be exceeded here. qp is a permenent, q is an actual flow value.

Temperature sensors, calculator. $\Delta\theta_{min}$, resp. $\Delta\theta$ are minimum, resp. actual temperature differences

$$E_f = (1 + 0{,}01\ q_p/q),$$
$$E_f = (2 + 0{,}02\ q_p/q),$$
$$E_f = (3 + 0{,}05\ q_p/q),$$

Temperature sensors:

$$E_t = (0{,}5 + 3\ \Delta\theta_{min}/\Delta\theta),$$

Calculators:

$$E_c = (0{,}5 + \Delta\theta_{min}/\Delta\theta).$$

Remark, MPE for HM for other liquids, resp. for steam

- Same values of MPE are generally valid here
- By HM for steam measurements, aditionally, MPE for measurements of pressure, resp. of pressure differences have a values 0,2 %

End of point 5

Point 6

WM, HM, metrological testing, equipments

Metrological tests (certification, type approval, first verification) of WM and HM are proceeding in accordance with documents (standards, RI OIML) presented in point 1 of this presentation.

Basic rules can be explained shortly:

- WM are tested by prescribed values of flow in all measuring range by water with suitable temperature in determined meter position. Measured volume of water is compared by reference volume of standard equipment. Erros can not exceed a values of MPE
- HM are tested by prescribed values of flow, temperature and temperature difference in all measuring range. Measured heat (cooling) energy is compared by reference volume of standard equipment. Erros can not exceed a values of MPE
- Selected standard test equipments must have a traceabilty on international standards. **Accuracy must be in ratio (1/3 – 1/5) of MPE of tested meters**
- Examples of main standard test equipments - in next snaps

Typical examples of parameters by verification of WM, resp. of HM (see you also point 5 before)

For WM:

Q_1 to $1{,}1Q_1$;

Q_2 to $1{,}1Q_2$;

$0{,}9Q_3$ to Q_3;

For compact HM:

For heating applications:

a)	$\Delta\theta_{min}$	$\leq \Delta\theta \leq$	$1{,}2\ \Delta\theta_{min}$	and	$0{,}9\ q_p$	$\leq q \leq$	$1{,}1\ q_p$
b)	10 K	$\leq \Delta\theta \leq$	20 K	and	$0{,}1\ q_p$	$\leq q \leq$	$0{,}11\ q_p$
c)	$\Delta\theta_{max}$- 5 K	$\leq \Delta\theta \leq$	$\Delta\theta_{max}$	and	q_i	$\leq q \leq$	$1{,}2\ q_i$

For cooling applications:

a)	$\Delta\theta_{min}$	$\leq \Delta\theta \leq$	$1{,}2\ \Delta\theta_{min}$	and	$0{,}9\ q_p$	$\leq q \leq$	$1{,}1\ q_p$
b)	$0{,}8\Delta\theta_{max}$	$\leq \Delta\theta \leq$	$\Delta\theta_{max}$	and	$0{,}1\ q_p$	$\leq q \leq$	$0{,}11\ q_p$
c)	$0{,}8\Delta\theta_{max}$	$\leq \Delta\theta \leq$	$\Delta\theta_{max}$	and	q_i	$\leq q \leq$	$1{,}2\ q_i$

Example of tests equipment for WM (CMI)

Equipment allows (at least):

- Fully automatic regime of tests controlled by PC (selection of either particular or cycle of tests)
- Testing of WM (also flowmeters for HM) up to dimension DN 40 for cold and hot water in different positions
- Utilization of either gravimetric (by installed balances) or volumetric (by installed EMD, resp. mass flowmeters) methods
- Start-Stop method or flying start method possible
- Testing of water pressure
- Disturbance tests, pressure loss tests, etc.

Example of tests equipment for WM (supplementary, CMI)

Equipment allows :

- In connection with reference test bench to test a WM by short-time loading (in seconds) by selection of different values of flow
- PC controlled, simullation assured by set of electromagnetic valves

Example of tests equipment for HM (CMI)

Precise equipment for temperature and temperature difference simulation MEATEST 612:

- It is allowed to simulate a resistance for temperature sensors Pt100, Pt500, Pt1000 in accordance with standard EN 60751 (ITS 90)
- Accuracy in mΩ
- 2-wire, resp. 4-wire application is possiblen flow
- Possibility of PC control (GPIB interface)

Example of tests equipment for HM (CMI)

Precise temperature bathes TECHNE used for temperature and temperature difference simulation by testing of compact HM:

- Temperature range from 0°C up to 180°C
- Immersion possibility up to 300 mm
- Using liquid, water, oil
- Full homogenity (stability) of temperature field in all spaces used for testing (in order 0,01°C)

Example of tests equipment for HM (CMI)

Precise digital thermometer F500 (ASL) with 2 reference temperature sensors ISOTECH, Pt 100 (utilization for temperature bathes TECHNE):

- Temperature range suitable for all tested HM
- Stability of PT100 reference temperature sensors better as 10 mΩ /year
- Accuracy of measurement in order 0,01°C, resp. better

Example of tests equipment for HM (CMI)

Unit for simulation of flow for practical all types of tested HM:

- Based on calibrated cards of National Instruments, controlled by PC, SW LabView
- Pulses simulation, reed, OC, etc. in frequency range in order from Hz up to kHz (or more)
- Voltage simulation in standard range, mostly 12, 24, 36 V DC
- Circuit loop, active, passive (0-20) mA, resp. (4-20) mA

End of point 6

Point 7

Main rules by application of WM, HM

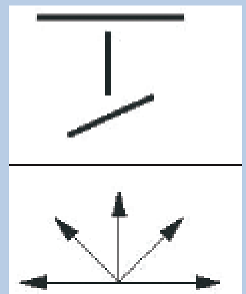
WM

- Necessity of keeping upstream (U(X)) and downstream (D(Y)) lenght, given in certificate or in manual of manufacturer
- Necessity of keeping of installation position of the meter´s body, resp. of totalizer (horizontal, vertical, optional, upwards, sideway). Again, given in certificate or in manual. Not fulfilling of this conditions may influnce correctness of WM´s measurement, esp. by velocity sigle jet meters
- Assurance of full flooding of the meter´s body by the water (with absence of air). Very important condition for correct measurement
- If inlet strainer is installed, high attention must be devoted to installation without deformation, resp. attention must be aimed on quality of water. Plugging of strainer can be a reason of „jet effect“, esp. by mechanical WM

WM

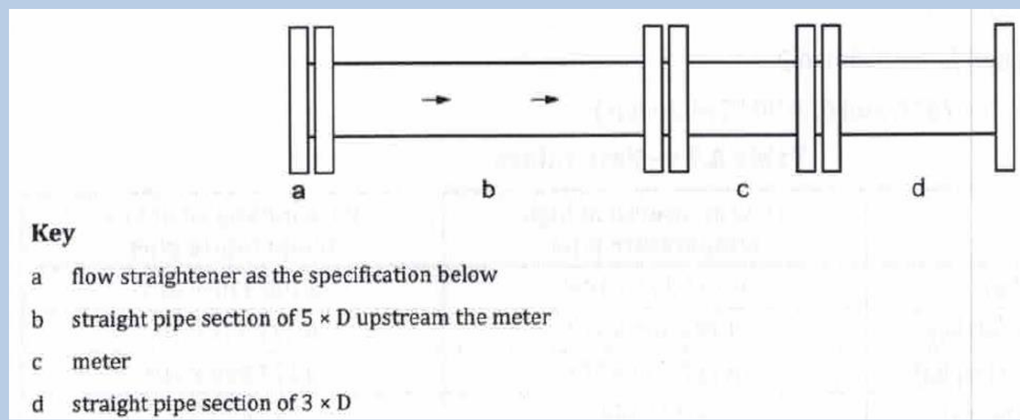
Installation marking, example:

- Pipeline: horizontal, vertical, optional
- Totalizer (dial) of the meter: upwards, sideway



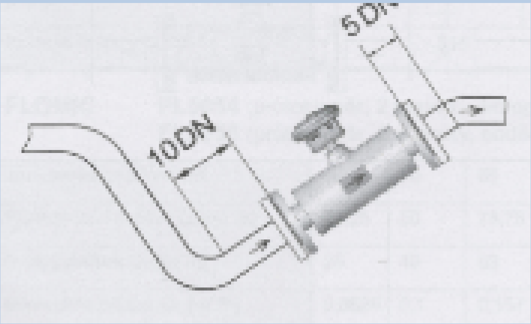
Upstream, downstream installation

- U5, D3

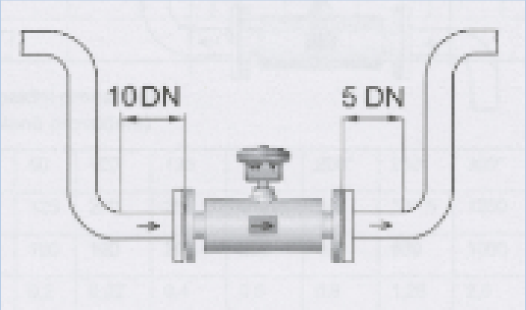


WM
Installation, example:

- Assurance of fully flooding of the body, optional position, U10, D5, totalizer upwards



- Assurance of fully flooding of the body, horizontal position, U10, D5, totalizer upwards

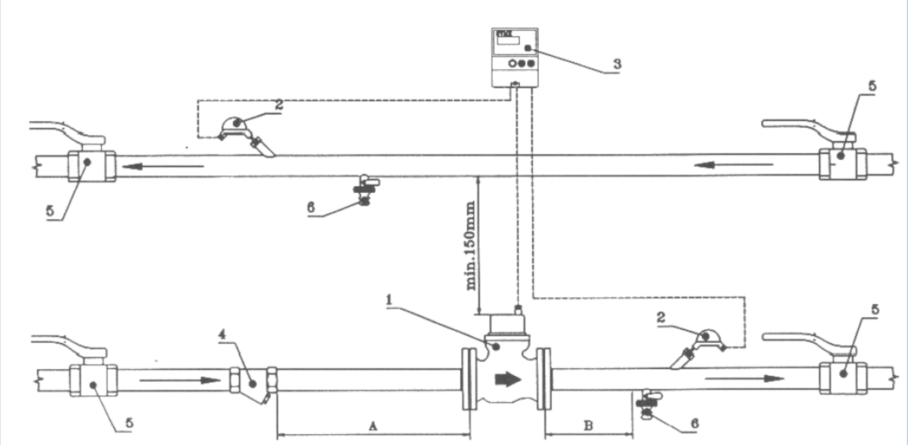


HM, main rules:

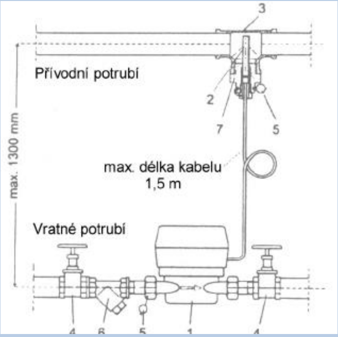
- Correct selection of installation of all parts of HM as for the character of heat exchange circuit
- Correct installation of flowmeters (similary as for WM). Flow meter must be installed in brach of the circuit as calculator is programmed.
- Outputs parameters from flowmeters into calculators must must be in accordance with programmed values in calculators
- Correct installation of Pt temperature sensors. By different lenght of cable connection of Pt sensors, 4-wire connection must be used
- Temperature sensors must be installed in the pipes in position for precise measurement of temperature of liquid
- By using of other thermal conveing liquid as water, thermodynamical parameters of liquid must be programmed in calculator
- By measurement of steam energy a correct measurement of steam temperature and pressure must be assured (possible influence of water in expansion pipe)

HM installation, examples

- Typical installation of combined HM:



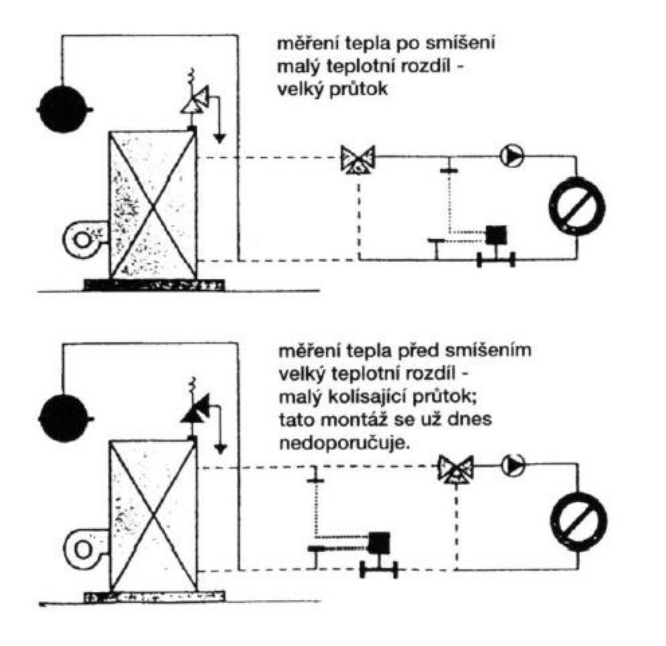
- Typical installation of compact HM:



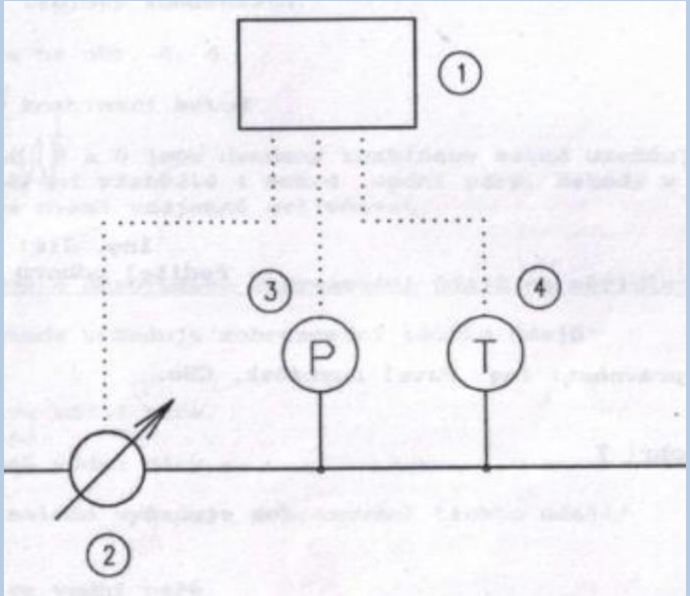
Thermal circuit with mixing valve. Attention on correct installation, either before or after mixture

- After (lower temperature difference, higher flow):

- Before (higher temperature difference, lower flow):



Steam (overheated) energy measurement, direct method, example

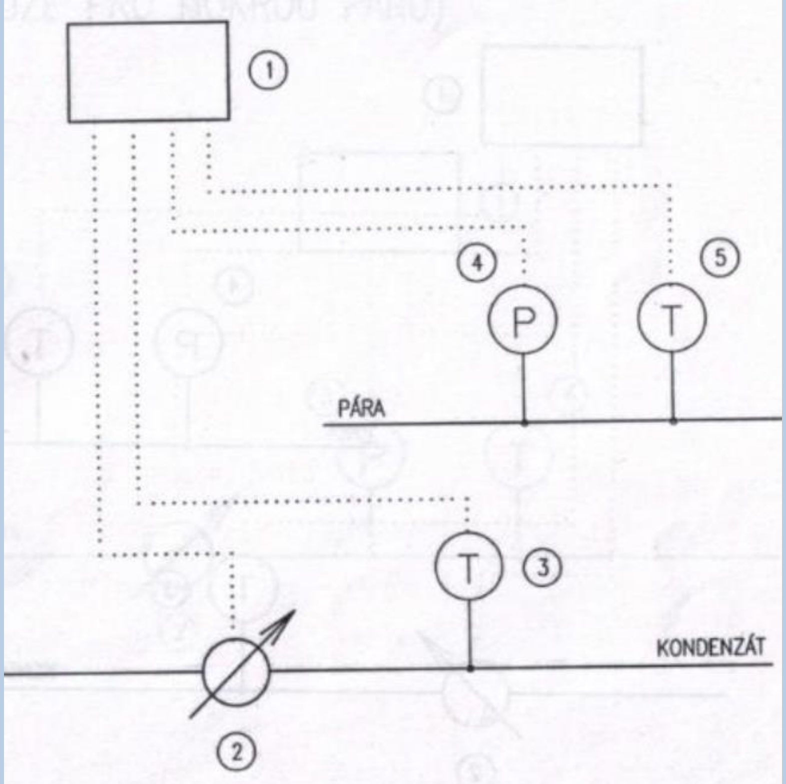


1, calculator
2 flowmeter (nozzle, Wortex, f. inst.)
3 pressure sensor
4 temperature sensor

Attention on correct measurement of steam pressure (gauge, absolute). May be influenced by place of pressure measurement. If condensation pipe is used here, influence of column of condensed water must be corrected

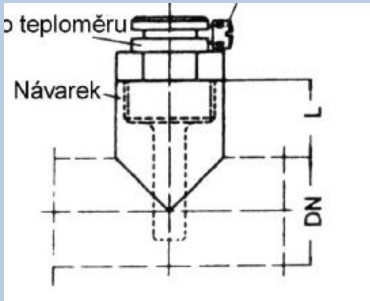
Steam (overheated) energy measurement, indirect method, example

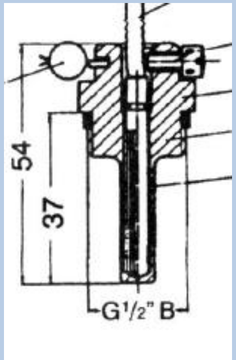
1, calculator
2 flowmeter (in return pipe of condensate, mostly WM for hot water)
3 temperature sensor for condensate(returned energy of condensate can be measured by calculator by this method also)
4 pressure sensor for steam
5 temperature sensor for steam

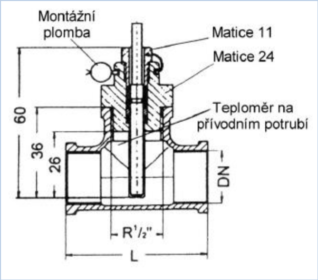


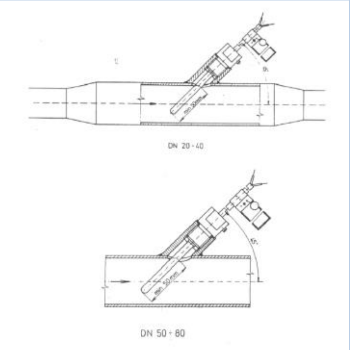
Correct installation of temperature sensors in the pipes, examples

- welding connection on the pipe for screwing of sensor´s pocket (casing)
- sensor´s pocket with thread
- sensor installed directly in pipe without pocket



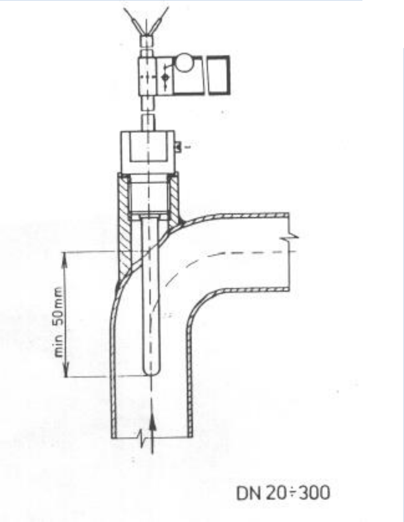






Correct installation of temperature sensors in the pipes, examples

Assurance of full immersion of the sensor into a liquid (also in bow) by different dimension DN of the pipes for correct identification of temperature

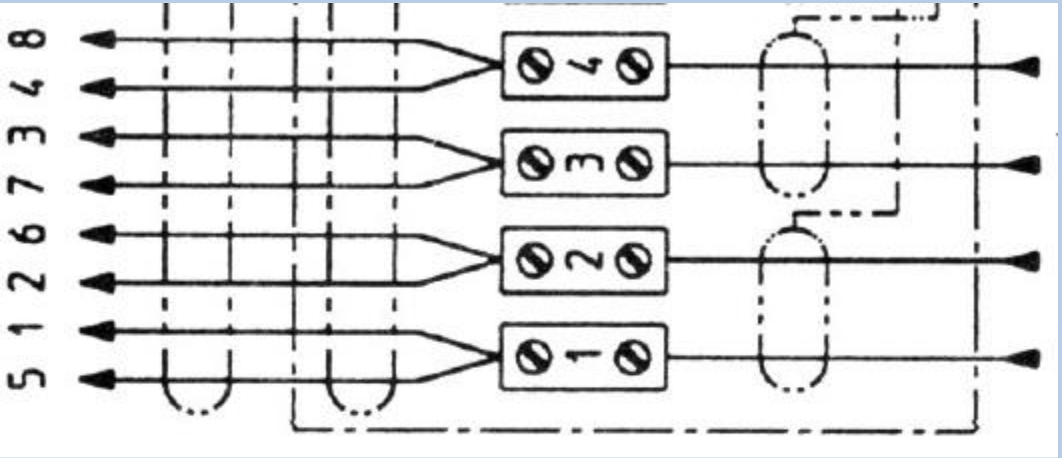


Elimination of different lenghts of the cables of Pt temperature sensors (elimination of resistance of the cables), 4-wires connection

Connection box:

4-wires connection to calculator

2-wires connection of PT sensors installation places by different lengh of the cables



End of point 7 and of all presentation

Thank you for your attention!

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