



EMATEM

European Metrology Association
for Thermal Energy Measurement

THERMAL ENERGY METER

Experimental and numerical evaluation
of fast response test method

*Experimentelle und numerische Evaluierung
der Fast-Response-Testmethode*

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01

Introduction/ Einleitung

EN1434 - Flow sensor fast response test method

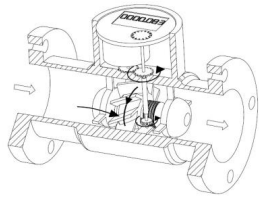
EN1434 - Fast-Response-Testmethode von Durchflusssensoren

// Thermal energy meter – Flow sensor

Wärmememzähler - Durchflusssensor

Continuous time domain/Kontinuierlicher Zeitbereich

Turbine flow meter/Turbinendurchflussmesser



Momentum law/Momentum-Gesetz:

$$\sum T = K_I \frac{d\omega_\varphi}{dt} \quad K_I \frac{d\omega_\varphi}{dt} + K_\mu \omega_\varphi = T_{idr}$$

$\sum T$ sum of all the torques acting on the turbine
Summe aller auf die Turbine wirkenden Momente

K_I turbine's axial moment of inertia
Axialträgheitsmoment der Turbine

ω_φ turbine's angular velocity
Winkeldrehzahl der Turbine

$$q = q(t)$$

Discrete time domain/Diskreter Zeitbereich

Electromagnetic and Ultrasonic flow meters
Elektromagnetische und Ultraschall-Durchflussmesser

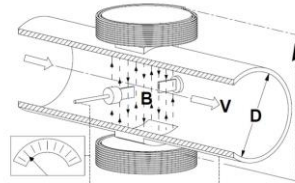


Figure 6 Magnetic-inductive flow sensor

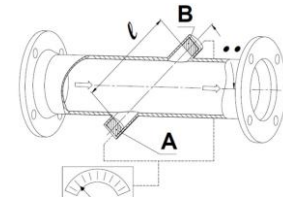
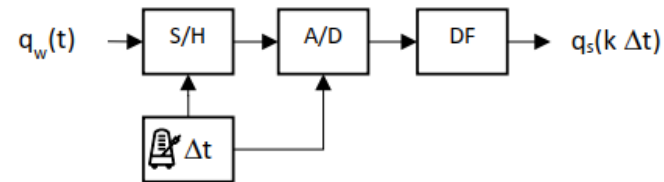


Figure 7 Ultrasonic flow sensor



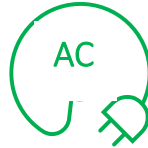
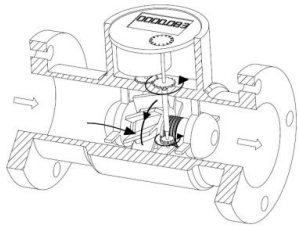
$$q = q_s(k\Delta t)$$



// Thermal energy meter – Flow sensor

Wärmemehrzähler - Durchflusssensor

Continuous time domain
Kontinuierlicher Zeitbereich

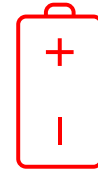
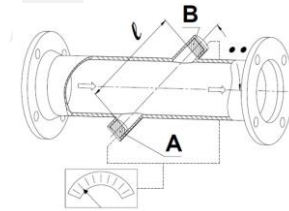
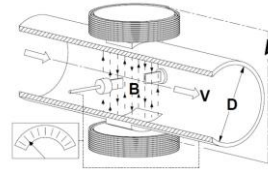


(AC power supply → no energy limitation)
HIGH Sampling Rate

Continuous behaviour
Kontinuierliches Verhalten

Almost Continuous behaviour
Nahezu kontinuierliches Verhalten

Discrete time domain
Diskreter Zeitbereich



(battery power supply → energy limitation)
LOW Sampling Rate

SAMPLING PROBLEM
Probenentnahmeproblem

Further details on the sampling problem can be found in the publications of Dr. Arne Kahler.

Weitere Einzelheiten zum Probenentnahmeproblem finden Sie in den Veröffentlichungen von Dr. Arne Kahler.

As example/ Zum Beispiel: EMATEM 2019, Fulda: Fast response thermal energy meters; Dr. Arne Kähler, Techem Energy Services GmbH

// Thermal energy meter – Flow sensor

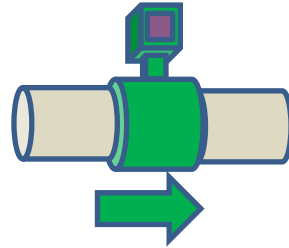
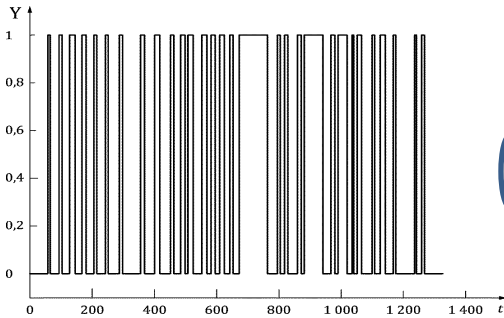
Wärmezähler - Durchflusssensor

Flow sensor test – actual approach EN 1434-4:2022

Annex C
(normative)

Decision rule: Pass/Fail

Fast response meters



A meter or sub-assembly defined as “Fast response meter” shall have at least the following additional specifications:

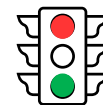
- response time ($\tau_{0,5}$): max. 6 s for direct long temperature sensors; max. 2,5 s for direct short temperature sensors;
- temperature sampling time/ temperature sampling time interval:
 - ≤ 4 Seconds (non-residential buildings, e.g. medical practice);
 - ≤ 8 Seconds (family houses, multi apartment / residential buildings);
- volume sampling time / volume sampling time interval:
 - ≤ 2 Seconds (non-residential buildings and family houses);
- integration time shall not be longer than the maximum of the sampling time for volume or temperature.

Flow sensor



$$V_{ref} = \int Y(t)dt \quad V = \Delta t \times \sum q(k\Delta t)$$

$$error = \frac{V - V_{ref}}{V_{ref}} \times 100 \leq MPE ?$$



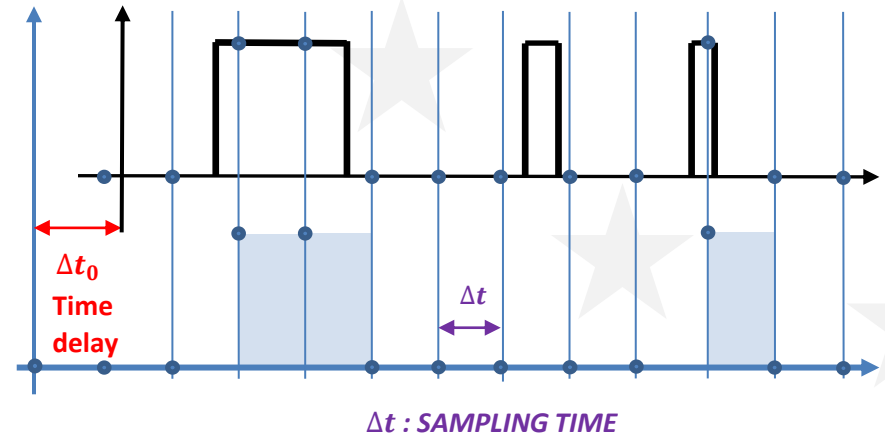
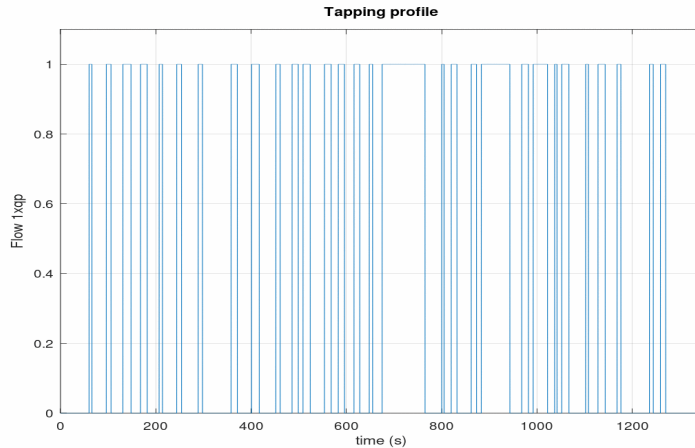
NO \Rightarrow *Not FAST*
YES \Rightarrow *FAST*

02
Measurement error and sampling rate,
numerical evaluation.

Messfehler und Abtastrate, numerische Auswertung.

// Flow sensor error and sampling rate, numerical evaluation

Messfehler und Abtastrate, numerische Auswertung.



$$V_{ref} = \int Y(t)dt = 475dm^3$$

$$q_p = 1 \frac{dm^3}{s}$$

$$V = \Delta t \times \sum q(k\Delta t)$$

$$error = \frac{V - V_{ref}}{V_{ref}} \times 100$$

// Flow sensor error and sampling rate, numerical evaluation

Messfehler und Abtastrate, numerische Auswertung.

Duration of simulation
Dauer der Simulation

$$T_{sim} = 1345s$$

Time discretisation
zeitliche Diskretisierung

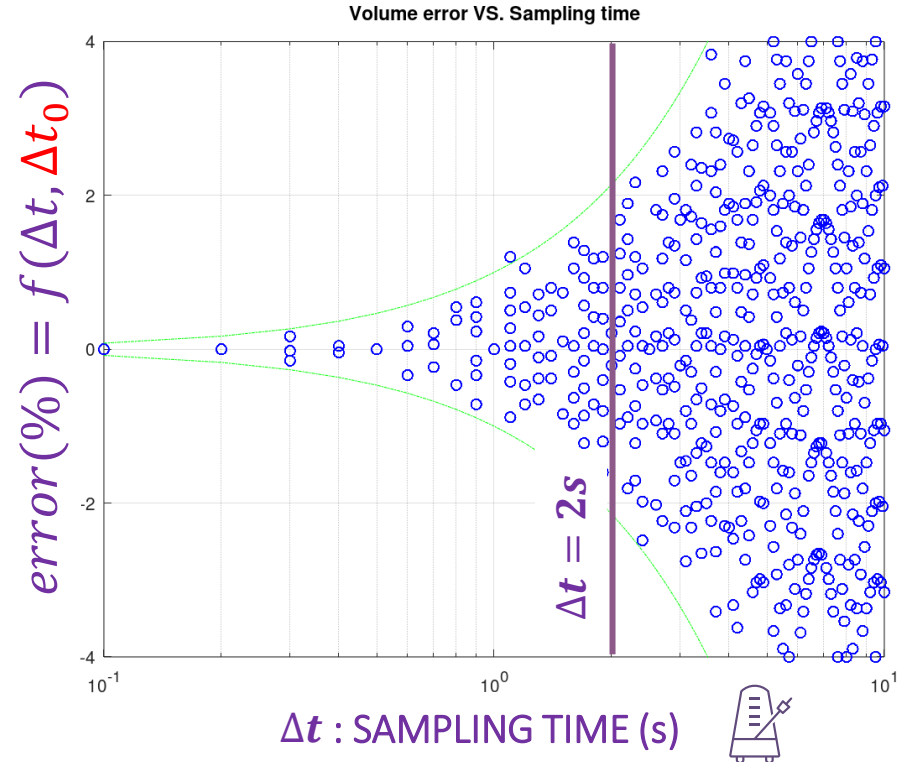
$$dt = 0,10s$$

Sampling time values
Abtastzeitwerte

$$\Delta t = [0,1: 0,1: 10]s$$

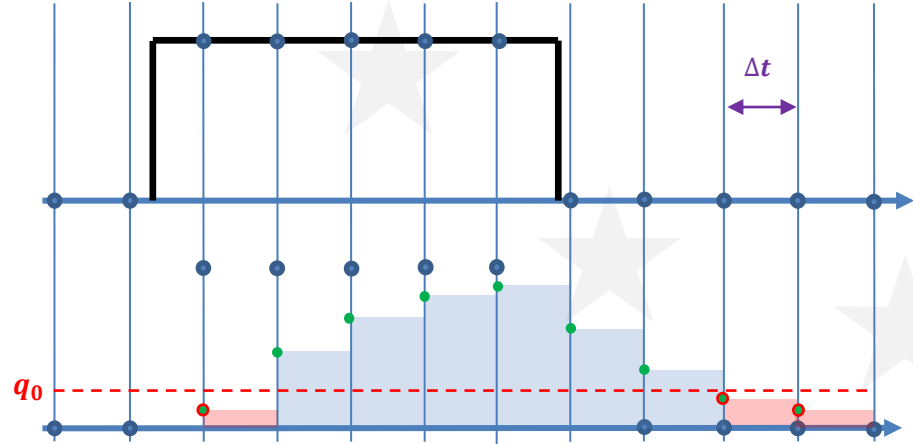
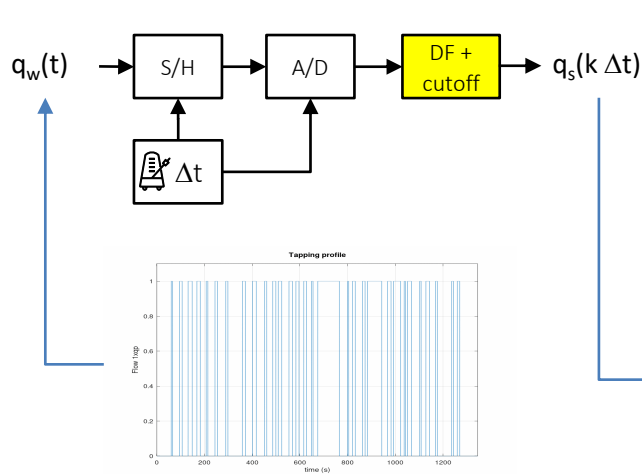
Time delay values
Verzögerungszeitwerte

$$\Delta t_0 = [0,1: 0,1: 60]s$$



// Flow sensor error and cutoff, numerical evaluation

Durchflusssensorfehler und cut-off-wert, numerische Auswertung.



Δt : SAMPLING TIME, q_0 : Flow cut off

$$V_{ref} = \int Y(t) dt = 475 dm^3$$

$$q_p = 1 \frac{dm^3}{s}$$

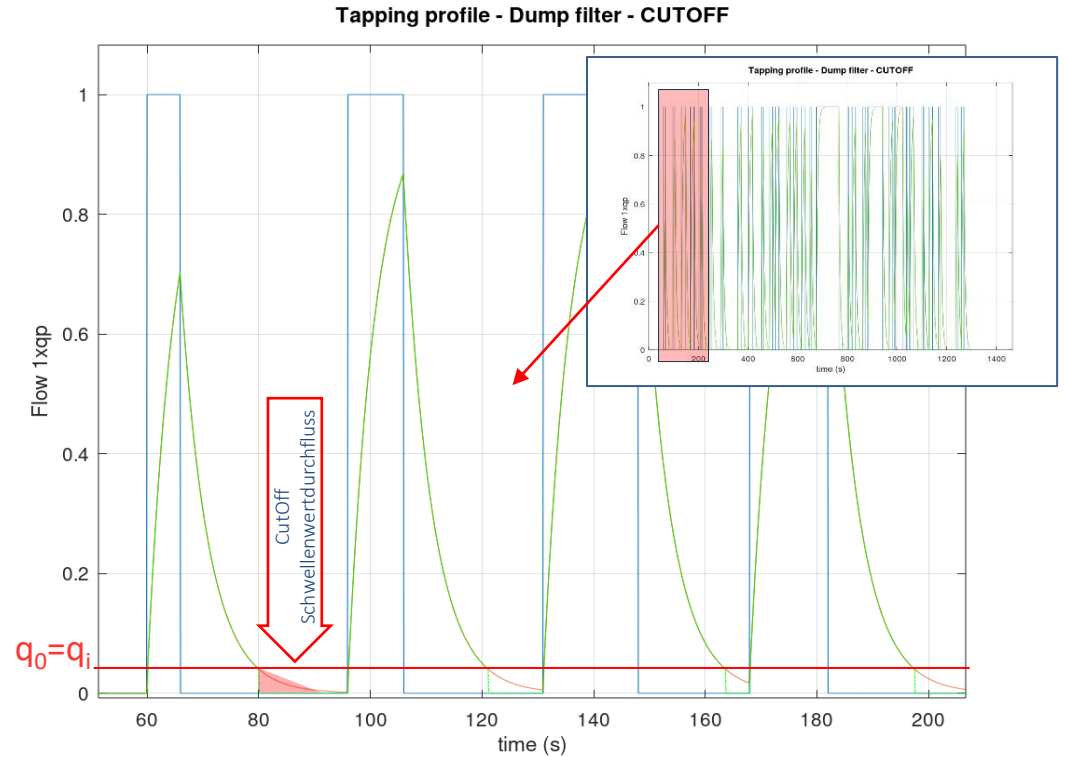
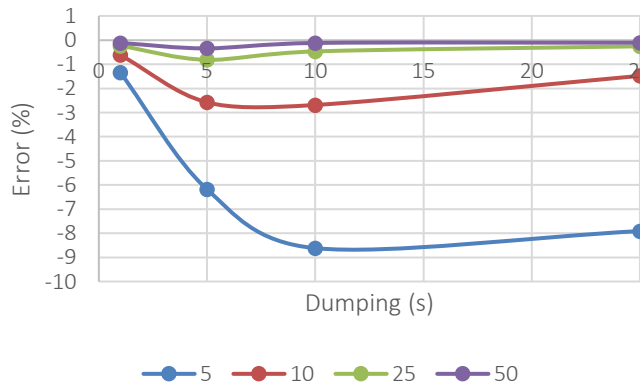
$$error = \frac{V - V_{ref}}{V_{ref}} \times 100$$

$$\left\{ \begin{array}{l} V = \Delta t \times \sum q(k\Delta t) \\ q(k\Delta t) > q_0 \end{array} \right.$$

// Flow sensor error and cutoff, numerical evaluation

Durchflusssensorfehler und cut-off-wert, numerische Auswertung.

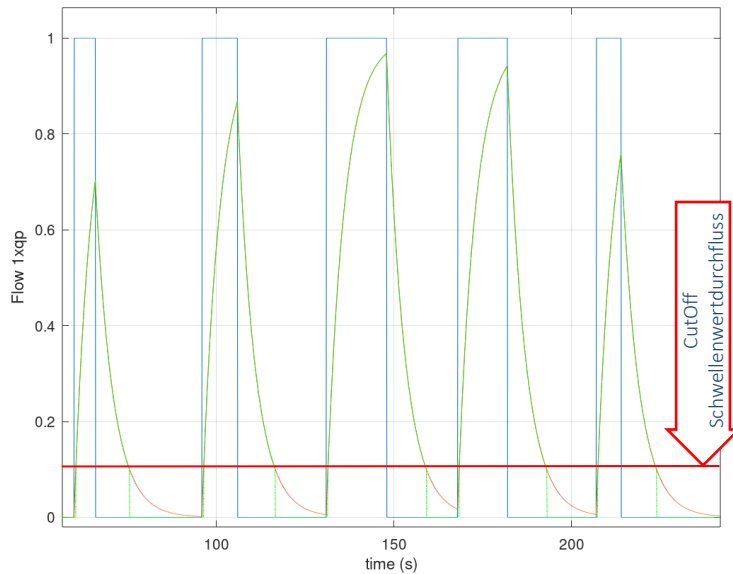
Error (%)				
qp/qi	Dumping τ (s)			
	1	5	10	25
5	-1,35	-6,18	-8,62	-7,91
10	-0,62	-2,58	-2,69	-1,48
25	-0,24	-0,82	-0,47	-0,26
50	-0,12	-0,34	-0,12	-0,11
fs=10Hz, CutOff: $q_0=q_i$				



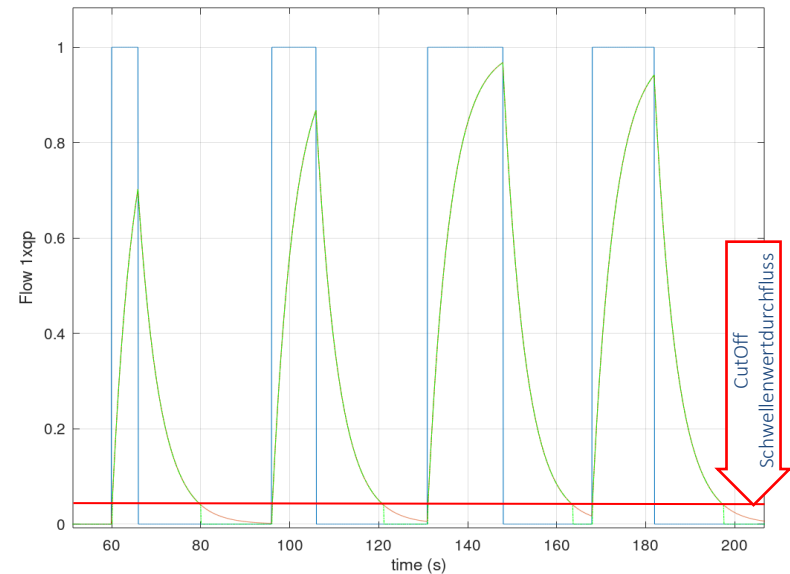
// Flow sensor error and cutoff, numerical evaluation

Durchflusssensorfehler und cut-off-wert, numerische Auswertung.

Dumping $\tau=5s$, $q_0=q_p/10$



Dumping $\tau=5s$, $q_0=q_p/25$



Measurement error and sampling rate, experimental evaluation.

Messfehler und Abtastrate, experimentelle Auswertung.

// Flow sensor error and sampling rate, experimental evaluation

Messfehler und Abtastrate, experimentelle Auswertung.



EN ISO 17025 CALIBRATION LABORATORY



LAT N° 237

Scope of Accreditation:

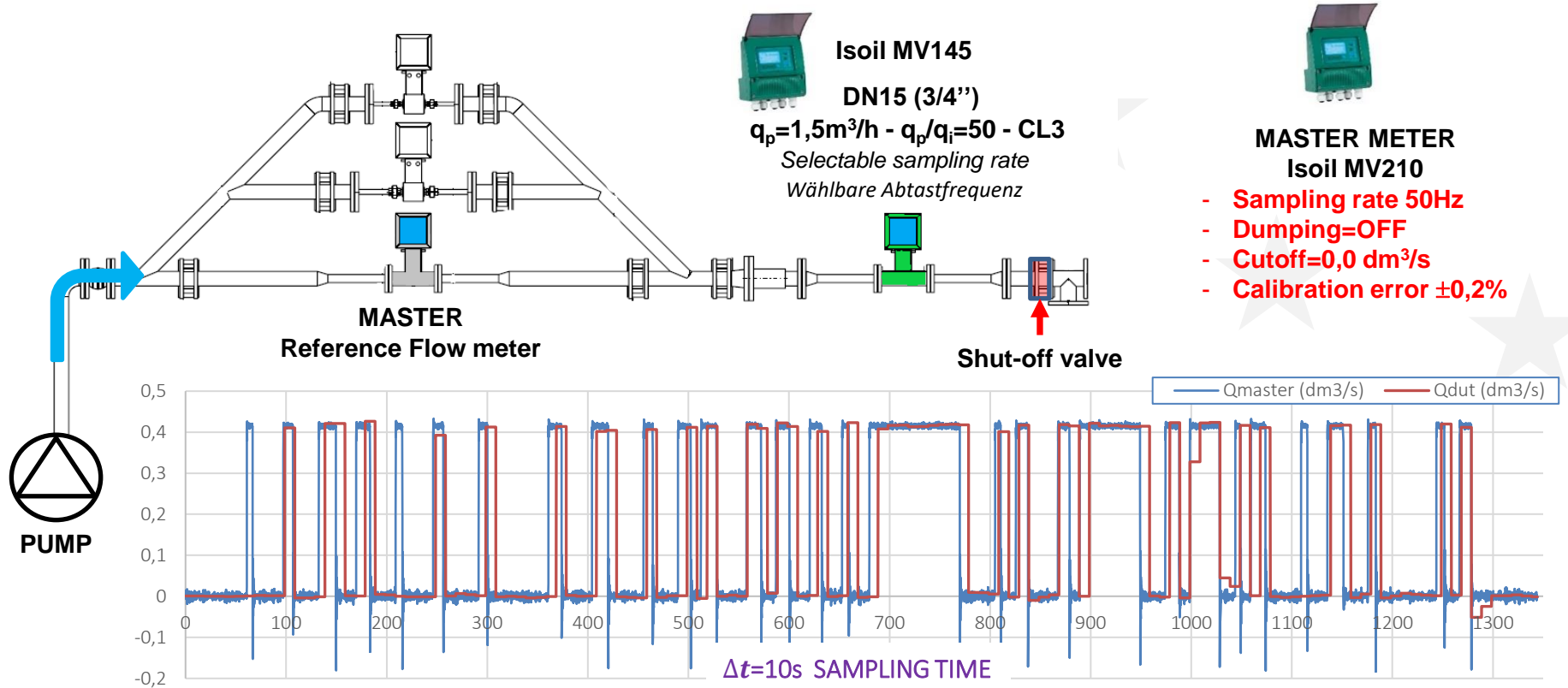
Calibration: Flow meter, water meter

Quantity: Mass and volume flowrate,
Totalized mass and volume.

Capability: from 0,015m³/h up to 14400m³/h,
Calibration Uncertainty from 0,15% up to 0,35%
according method applied.

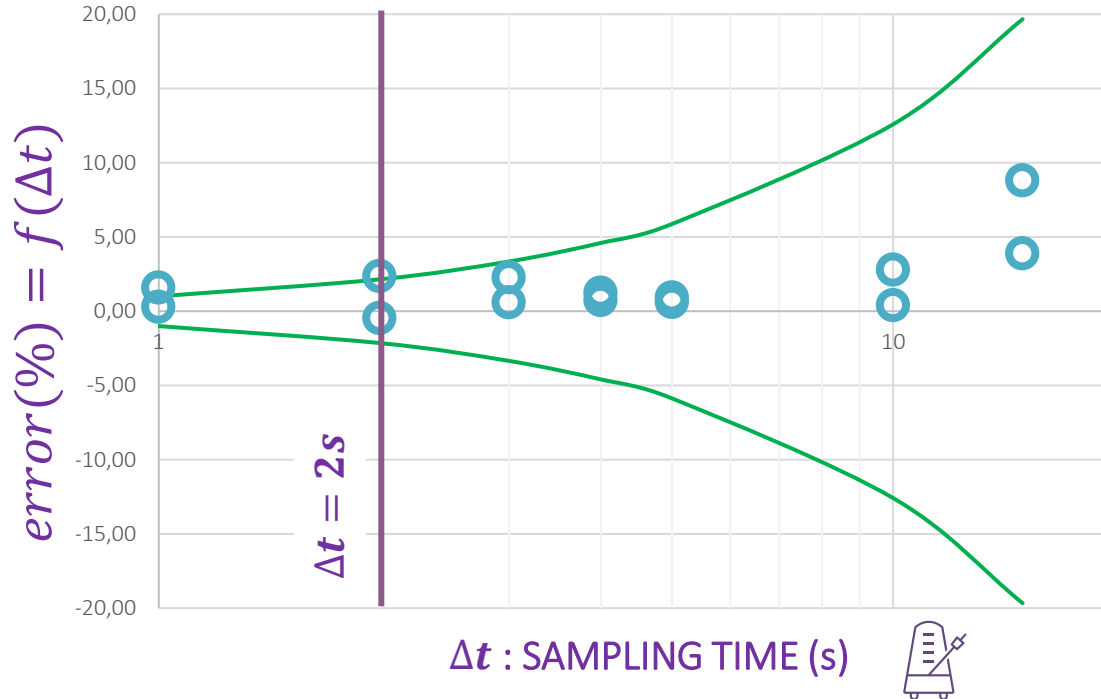
// Flow sensor error and sampling rate, experimental evaluation

Messfehler und Abtastrate, experimentelle Auswertung.



// Flow sensor error and sampling rate, experimental evaluation

Messfehler und Abtastrate, experimentelle Auswertung.



Sampling Time (s)	Error (%)	
	(%)	(%)
1	0,29	1,59
2	-0,46	2,36
3	2,27	0,58
4	1,24	0,74
5	0,92	0,61
10	2,79	0,40
15	8,80	3,90

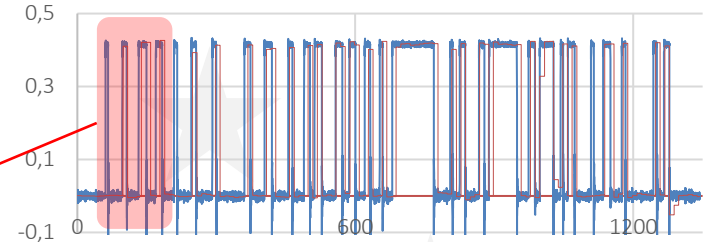
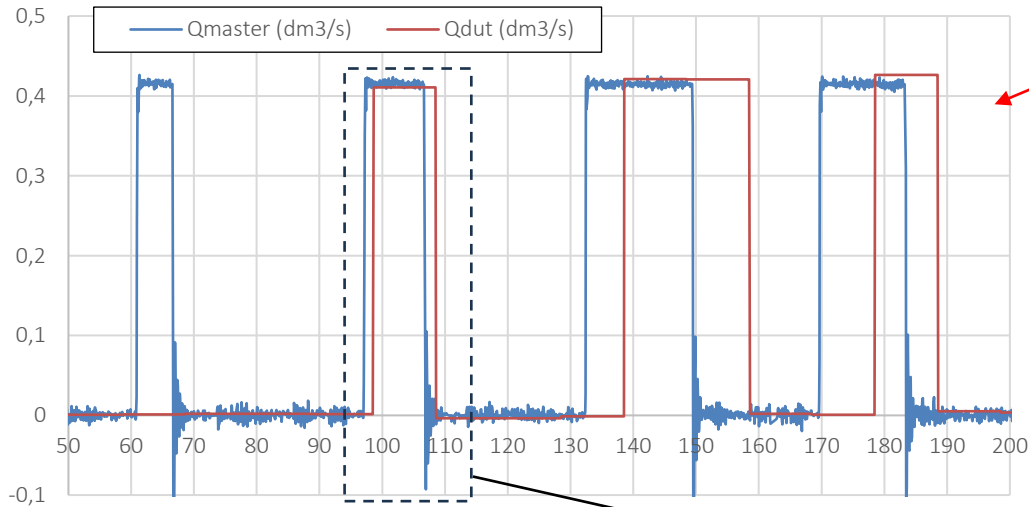
MASTER METER Isoil MV210: $\pm 0,2\%$

DUT Isoil MV145 (CL3): $\pm 3,0\%$

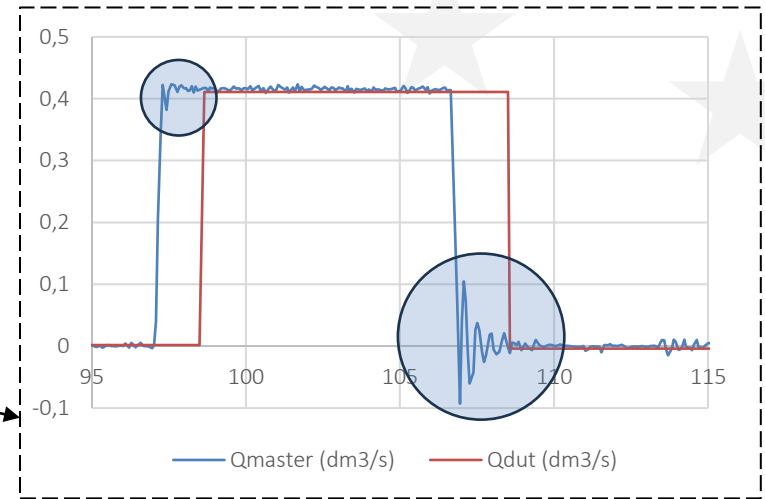
// Flow sensor error and sampling rate, experimental evaluation

Messfehler und Abtastrate, experimentelle Auswertung.

Sampling Time 10s



Mechanical shocks and vibrations
Mechanische Schwingungen



04

Conclusion
Schlussfolgerung

// EN1434 - Flow sensor fast response test method

EN1434 - Fast-Response-Testmethode von Durchflusssensoren

- ✓ Experimental results confirm numerical simulation for fast response test method of flow sensor.
Experimentelle Ergebnisse bestätigen die numerischen Simulationen zur Fast-Response-Testmethode von Durchflusssensoren.
- ✓ Test method can be implemented on calibration laboratory test facility.
Die Testmethode kann in einem Kalibrierlaboratorium durchgeführt werden.
- ✓ Test method accuracy is affected by:
Die Genauigkeit der Prüfmethode wird beeinflusst durch:
 - Reference meter and Flow sensor accuracy (permanent conditions)
die Genauigkeit des Referenzmessgeräts und des Durchflusssensors (stationäre Bedingungen)
 - Flow sensor's Digital filter and flow cutoff threshold
Digitaler Filter und cut-off-wert des Durchflusssensors
 - Mechanical shocks and vibrations due to fast shutoff valve
Mechanische Erschütterungen und Vibrationen aufgrund des Schnellschlussventils

THANK YOU FOR YOUR ATTENTION

Eng. Luisfilippo Lanza
l.lanza@hemina.net
www.hemina.eu