PTB

3rd international EMATEM-Workshop

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Experimental study for accelerated durability tests

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Kinds of failures in the practice of thermal energy measurement with heat meters

Primary failure: inner defects of *one or more devices* caused by bad production quality managements, total failure in *short time after putting into use*

↓

Secundary failure of whole units: by consequence of primary failures <u>and</u> caused by: fatigue of materials and settlement

- <u>drifting</u>, measurement stability: in this sense a „total failure“ → exceeding of MPE in service

<u>conclusion:</u> safeguarding of influences on stability by normal wear to meet the MPE in trade during validity of verification, increase the *<u>M</u>ean <u>T</u>ime <u>B</u>efore <u>F</u>ailure* (rate < $1 \cdot 10^{-5}$),

→ **stretch the „bathtub“ curve**

In the scope of durability

What means „failure“ in connection with durability after putting into use?

- The meter has to maintain an adequate stability of its metrological characteristics over a period of time *estimated by the manufacturer*. (acc. to Annex I, Ess.Requir., no. 5)

that means: measurement stability,
meet the MPE in service = 2 · MPE over period of time

[normel situation: validity of verification, 5 years in Germany]

→ Consequently *adapted tests* must be created.

Requirements for an alternative durability test for flow sensor units

- The currently durability test according to EN 1434-4 (2002) / OIML R 75-2, no.6.8 ff. with a measurement time of about ¼ year is too long and too expensive

- The MID annex 1, no.5 allows a declaration of durability over a period estimated by the manufacturer. Thats why adequate stabilities of the metrological characteristics have to bee sured by measurements

- An alternative durability test has to mirror the reality of heat-exchanging cycles in district heatings. The currently research is charged to the PTB by an industrial association.

- An alternative durability test should be terminated in a short time, about 14 days

- The new test must allow - preferably simple - adaptations on different durability periods of use, simply the best: under linear approximation

- Criterion for recognition or refusal: in accordance with EN 1434-4 / R 75-2, no significant fault shall occur, durability error with faults > MPE is not permissible

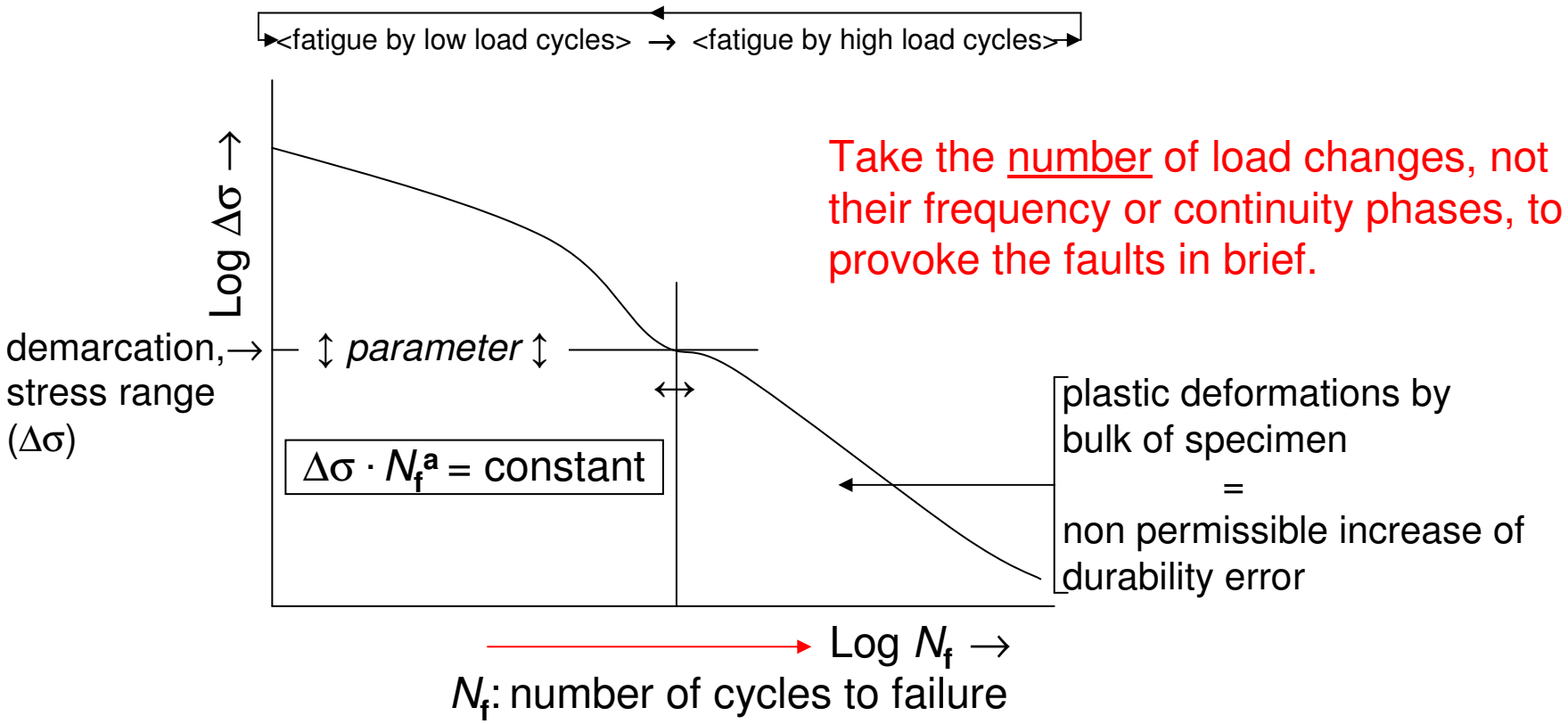
- To obtain further criterions: It is to expect that the standard deviation of the durability error will increase after stress, in relation to the initial intrinsic error.

- Comparability between test result and reality: Measurement results according to PTB‘s „Technischer Richtlinie K 20“ (guidline, flow meters measured after periods of verification validities), estimation of the *MTBF*-rates under results of field

Short journey into test philosophies in technical use, material research

Models of fatigue, according to Basquin's Law

- came from crack initiation and grow under cyclic loading, air- and spacecraft as well as car research industry, bef. 1980
- in transcription: fatigue provokes the increase of error of indication with time, durability error before total failure, nearly to testings of water meters



Take the <u>number</u> of load changes, not their frequency or continuity phases, to provoke the faults in brief.

Transcription into the practice of heating systems

The average spreading situation in heating systems over the years

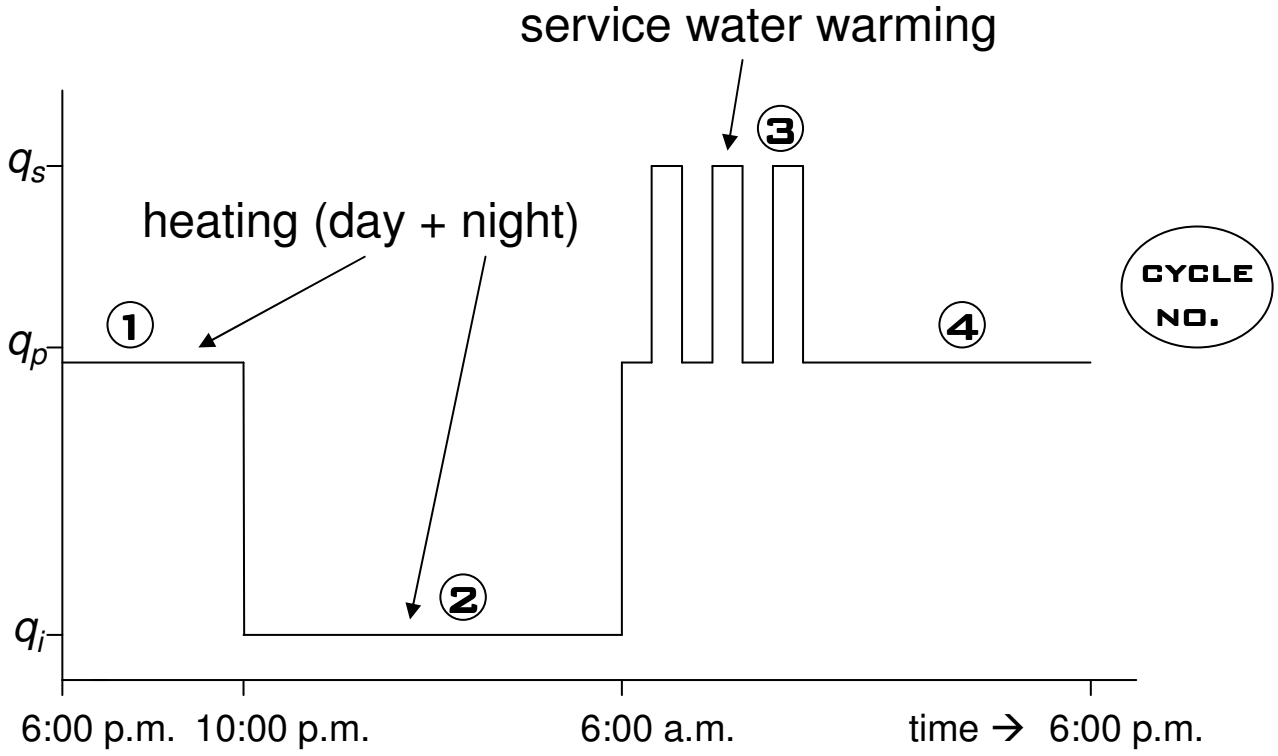


figure: typical profile in residential use over one day, load changes flow (low/high)

- crucial influence on wear mainly caused by differential flow rates on *mechanical flow sensors (e.g. Turbine Type, performing of axis)* -

estimate: 4 load changes over day x 200 heating days over year x 5 years validity of verification (example for Germany) = 4000 load changes

The average spreading situation in heating systems over the years

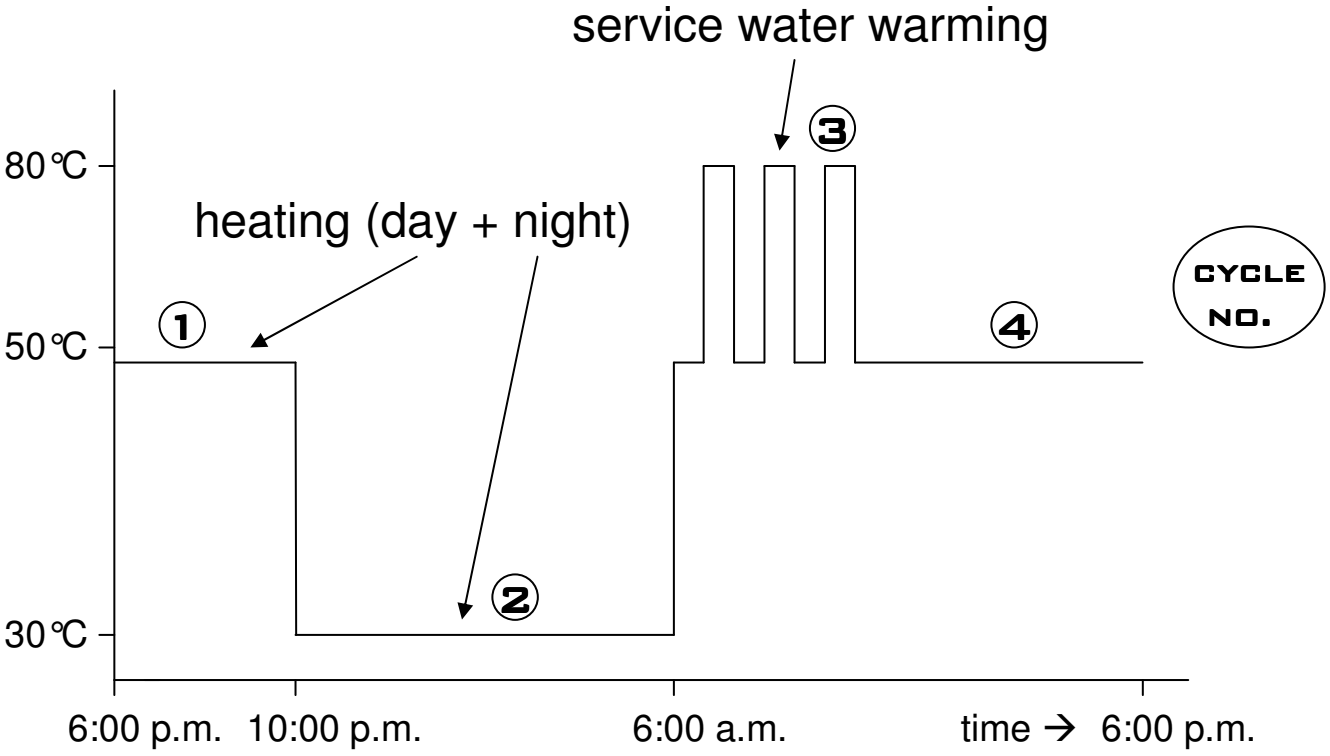


figure: typical profile in residential use over one day, load changes temperature (low/high)

- crucial influence on wear mainly caused by temperature shocks on *electronic flow sensors (e.g. Ultra Sonic Type, unthickness of US-transducer)* -

estimate: 4 load changes over day x 200 heating days over year x 5 years validity of verification (example for Germany) = 4000 load changes

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Development of alternative *accelerated endurance tests* for the sensor units of heat and water meters

The basic philosophy of test regimes for sensory units in contact with the medium flowing water:

Take the *number* of load changes from the reality, not their frequency or continuity phases (see: Basquin's Law)

under

equal absorptions of energy, in relation between reality and test. *)

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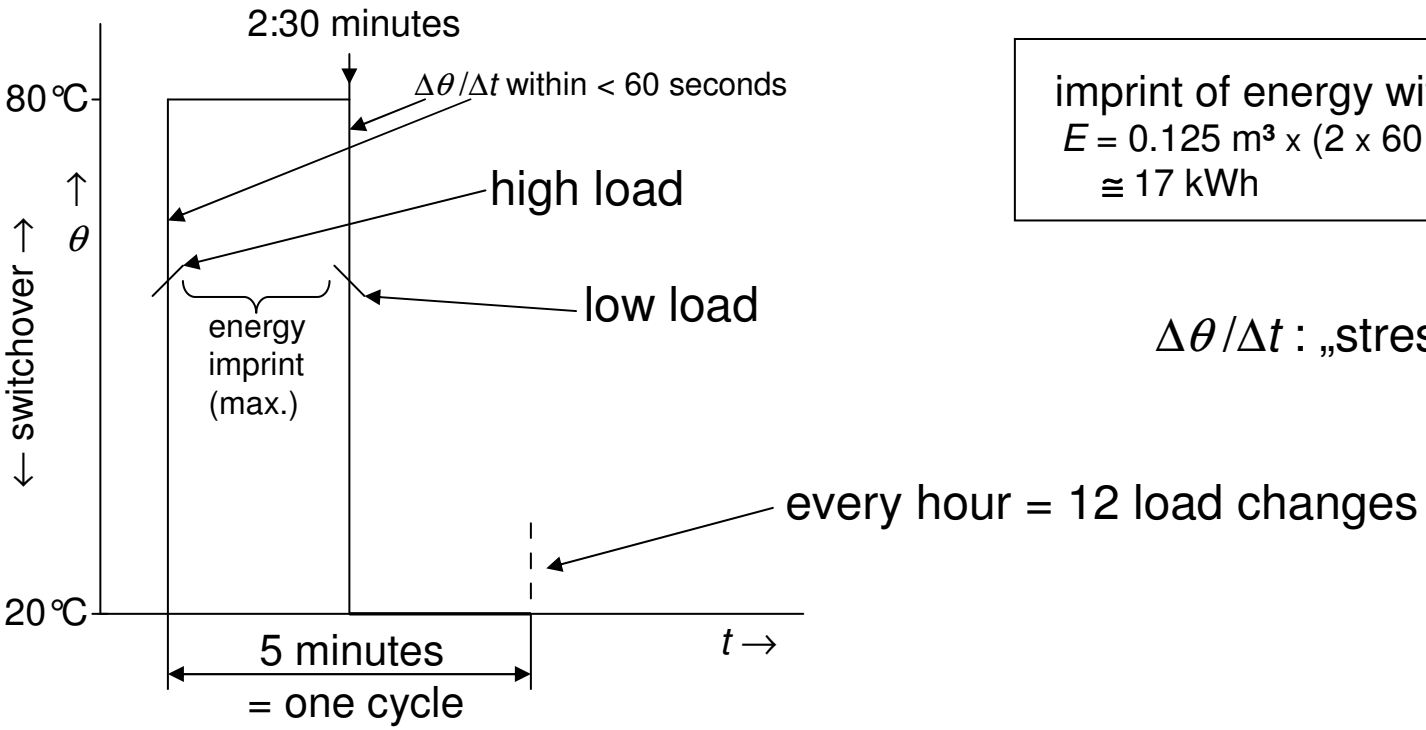
*) Imprint of Energy according to the „Equivalent of heat and mechanical energy“ by Robert Mayer,1842

Timesaving testings: scheme of double-load changes (for *electronic flow sensors)*



imprint of energy within of one cycle:
E = 0.125 m³ x (2 x 60 K) x 1.13 kWh m^{-3} K^{-1}
≅ 17 kWh

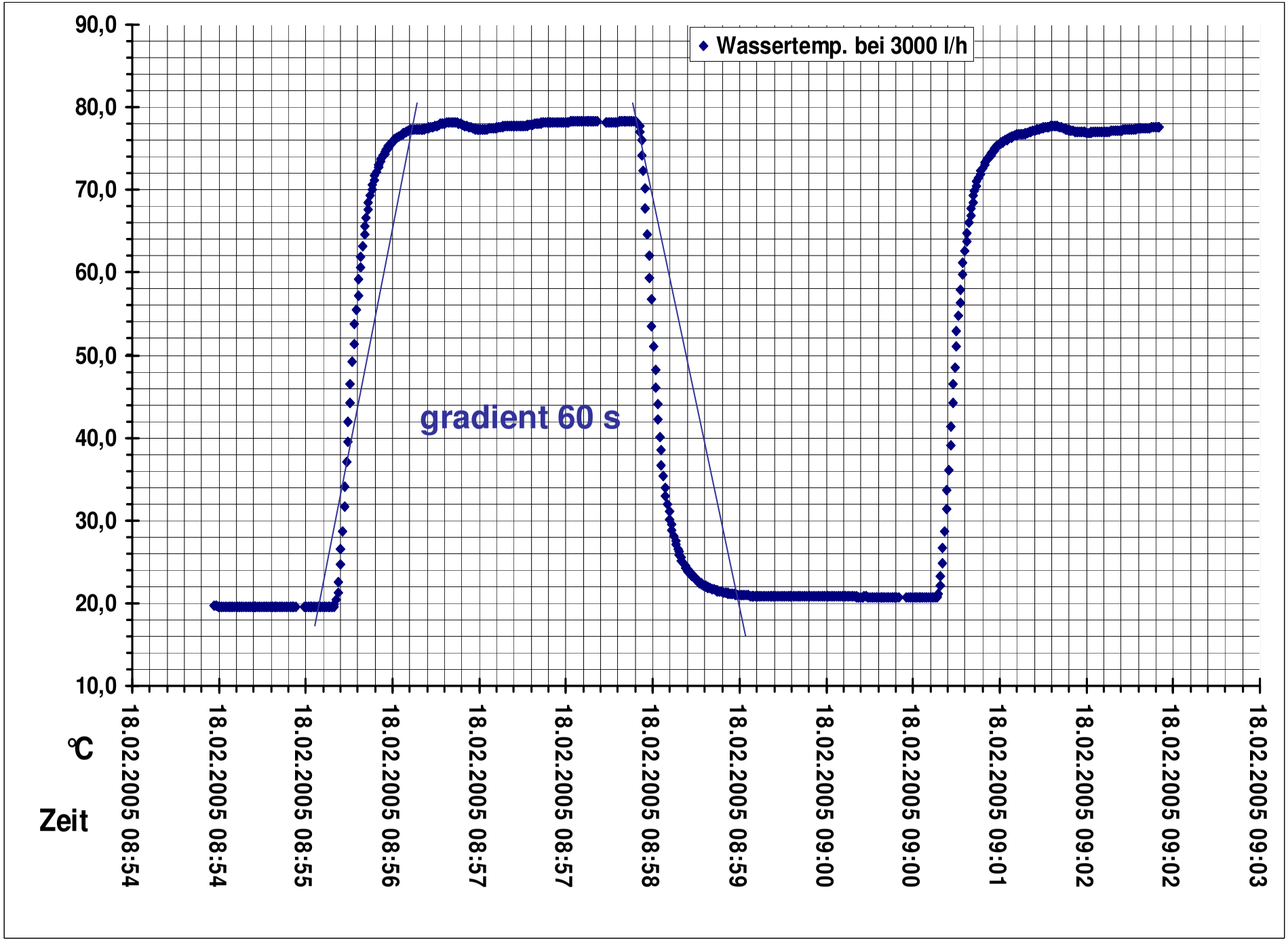
$\Delta\theta/\Delta t$: „stress intensity factor“

test parameters: q_P = constant = 1.5 m³/h, θ_{max} = 80 °C, $\Delta\theta$ over sensor caused by switching = 60 K, under pressure ≥ 1.2 bar (avoidance of cavitation)

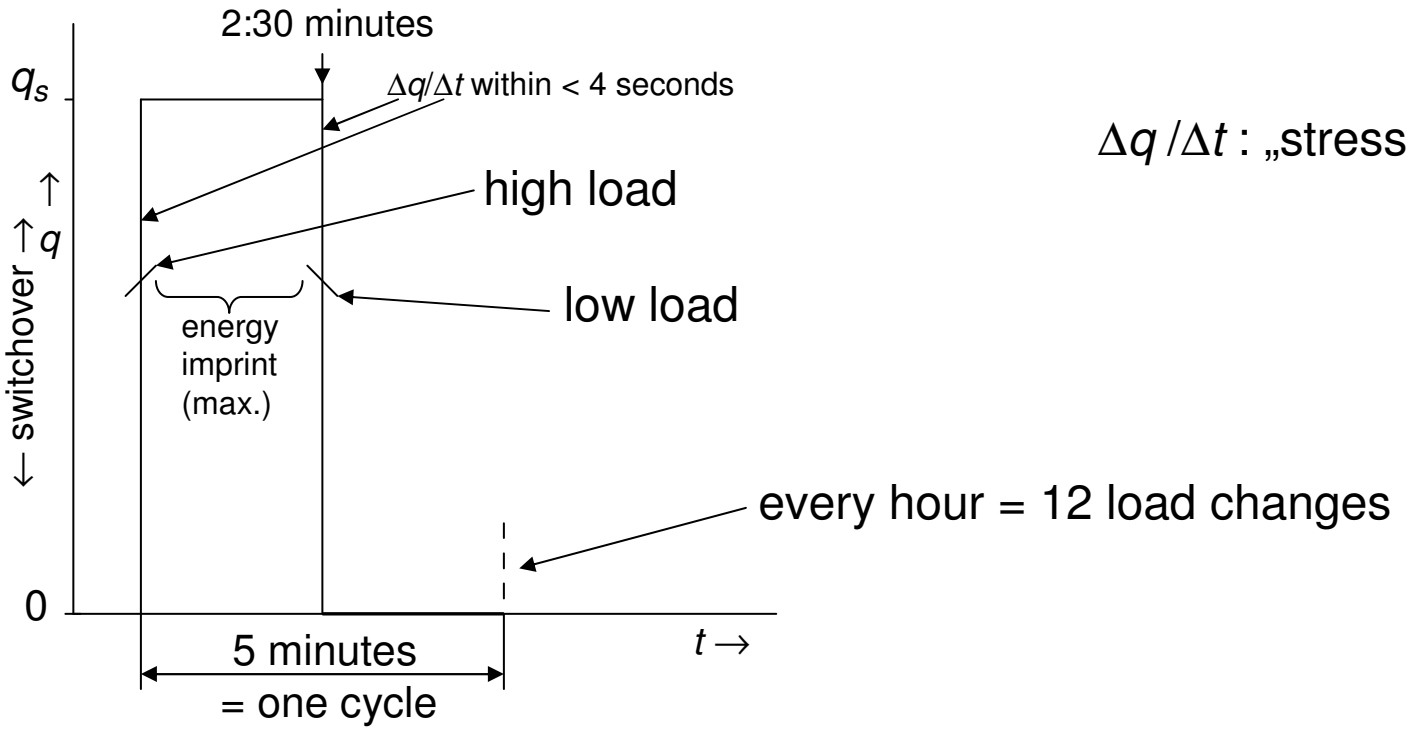
estimate: 288 load changes over day, enlarged up to 4000 load changes (≅ 14 days)
→ E ≅ 68 MWh for all load changes

PTB stress rig for electronic flow sensors, f.e. Ultra Sonic meter)

(temperatures switched between 20 °C and 80 °C with q_P = constant)


Wassertemp. bei 3000 l/h
gradient 60 s
90,0
80,0
70,0
60,0
50,0
40,0
30,0
20,0
10,0
°C
Zeit
18.02.2005 08:54
18.02.2005 08:54
18.02.2005 08:55
18.02.2005 08:56
18.02.2005 08:57
18.02.2005 08:57
18.02.2005 08:58
18.02.2005 08:59
18.02.2005 09:00
18.02.2005 09:00
18.02.2005 09:01
18.02.2005 09:02
18.02.2005 09:02
18.02.2005 09:03

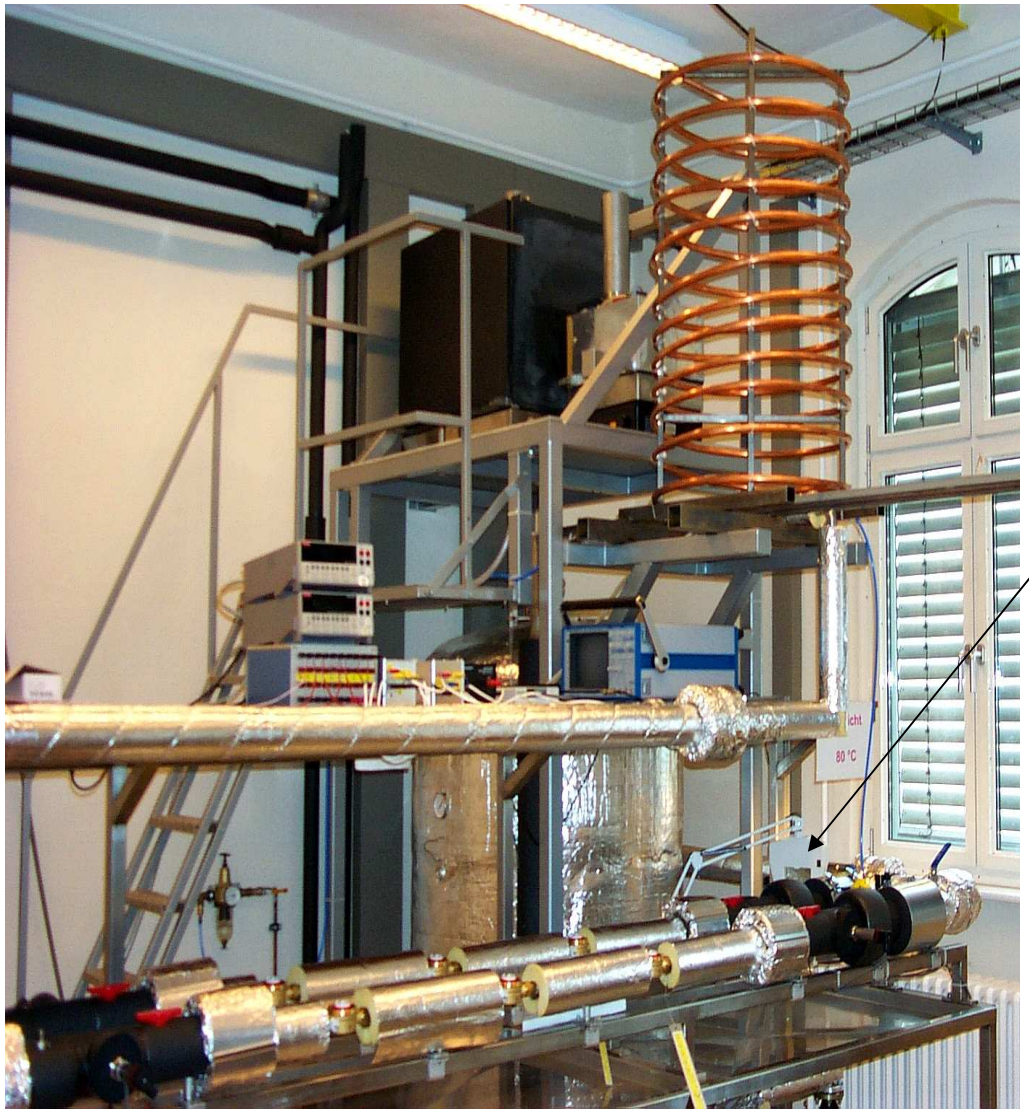
Timesaving testings: scheme of double-load changes
(for *mechanical flow sensors)*

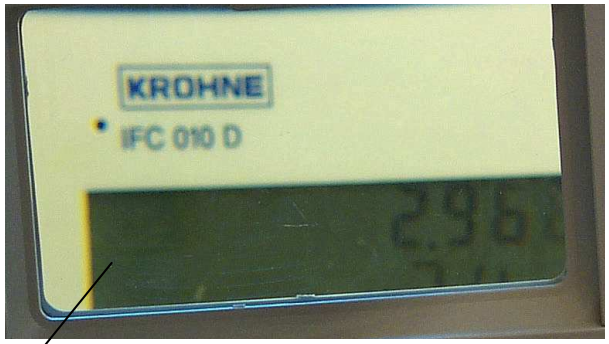


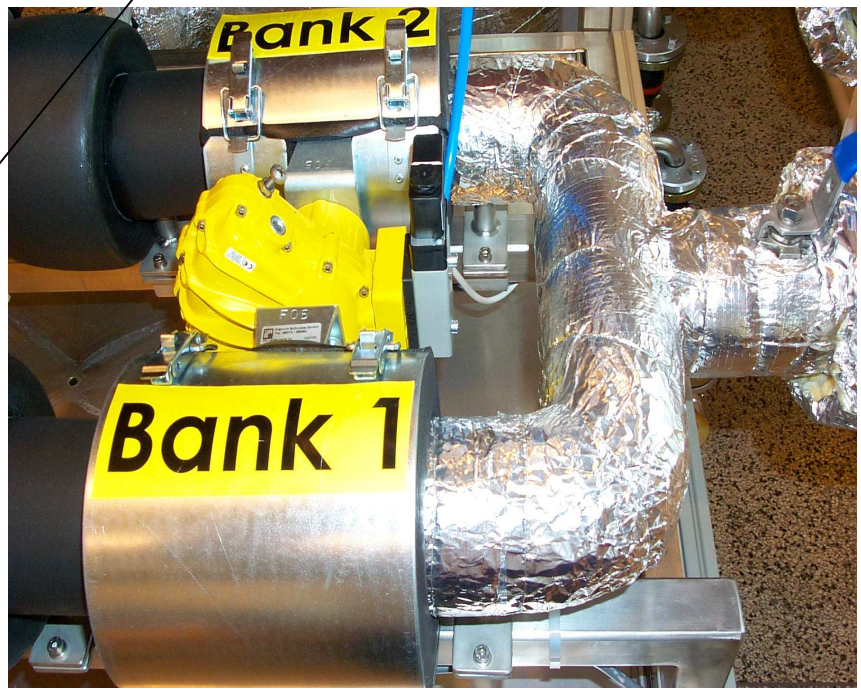
$\Delta q / \Delta t$: „stress intensity factor“

test parameters: θ = 80 °C = constant (middle fluctuation over sensor‘s surface caused by switching < 5 K),
q_S = 3 m³/h, under pressure ≥ 3 bar (avoidance of cavitation)

estimate: 288 load changes over day, enlarged up to 4000 load changes (≅ 14 days)







PTB stress rig for mechanical flow sensors, f.e. turbine type meter)
(flow switched between two tubes)

Safety factors between situations of the new accelerated durability tests and reality in field

- stress cycles are harder than reality: switchover between flow-rate 0 and q_{max} respectively lowest and highest temperatur

- gradients / differential changes $\Delta q / \Delta t$ respectively $\Delta \theta / \Delta t$ (stress intensity factors) are stronger than situations in field

- possibilities of combinations: combinations of changes $\Delta q / \Delta t$ <u>with</u> $\Delta \theta / \Delta t$ and use of water which is defined polluted (e.g. magnetized particles)

Hersteller
M1-(1-6)

Zusammenfassung der Ergebnisse aller Prüflinge nach Durchflüssen sortiert

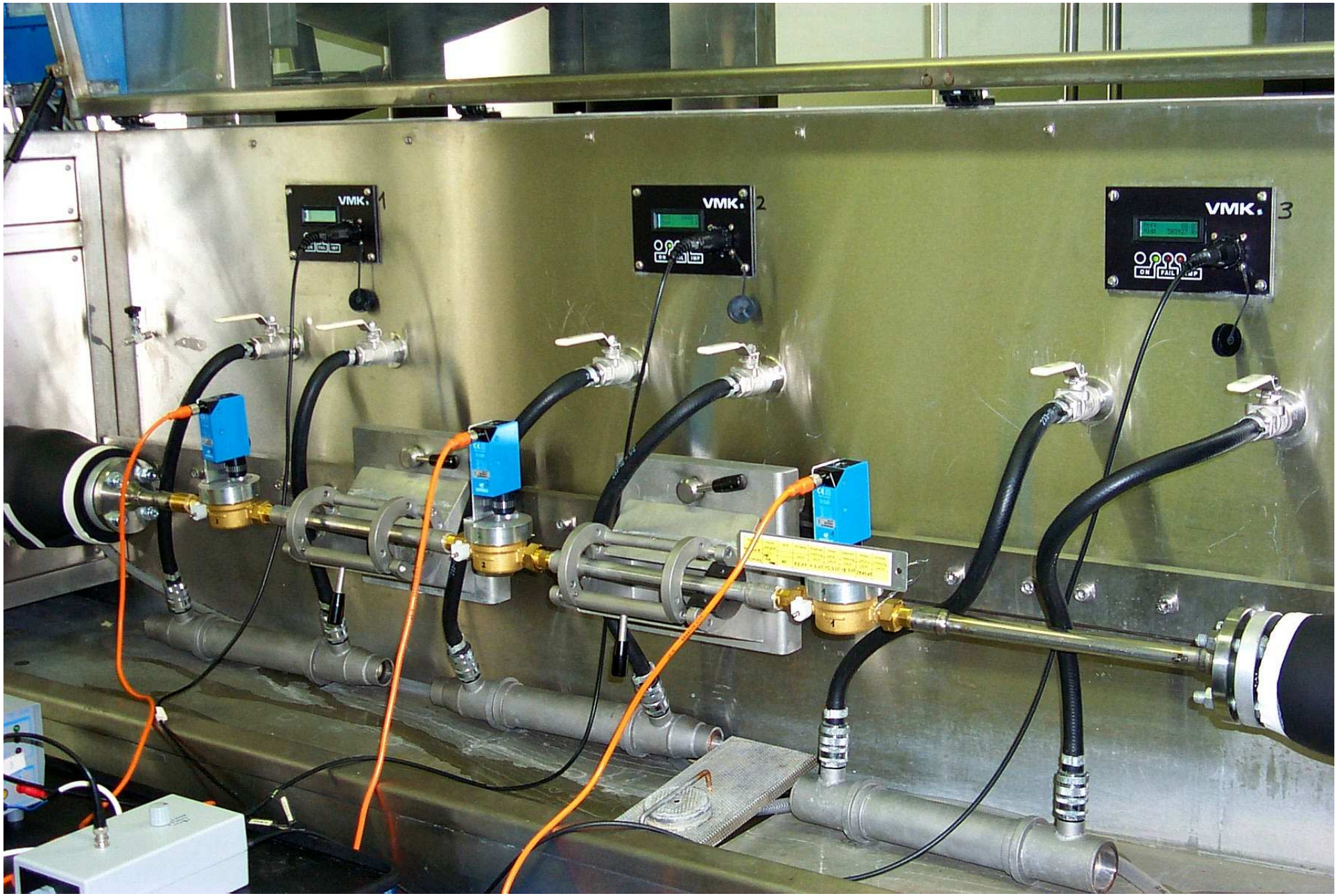
Prüftemperatur 50°C

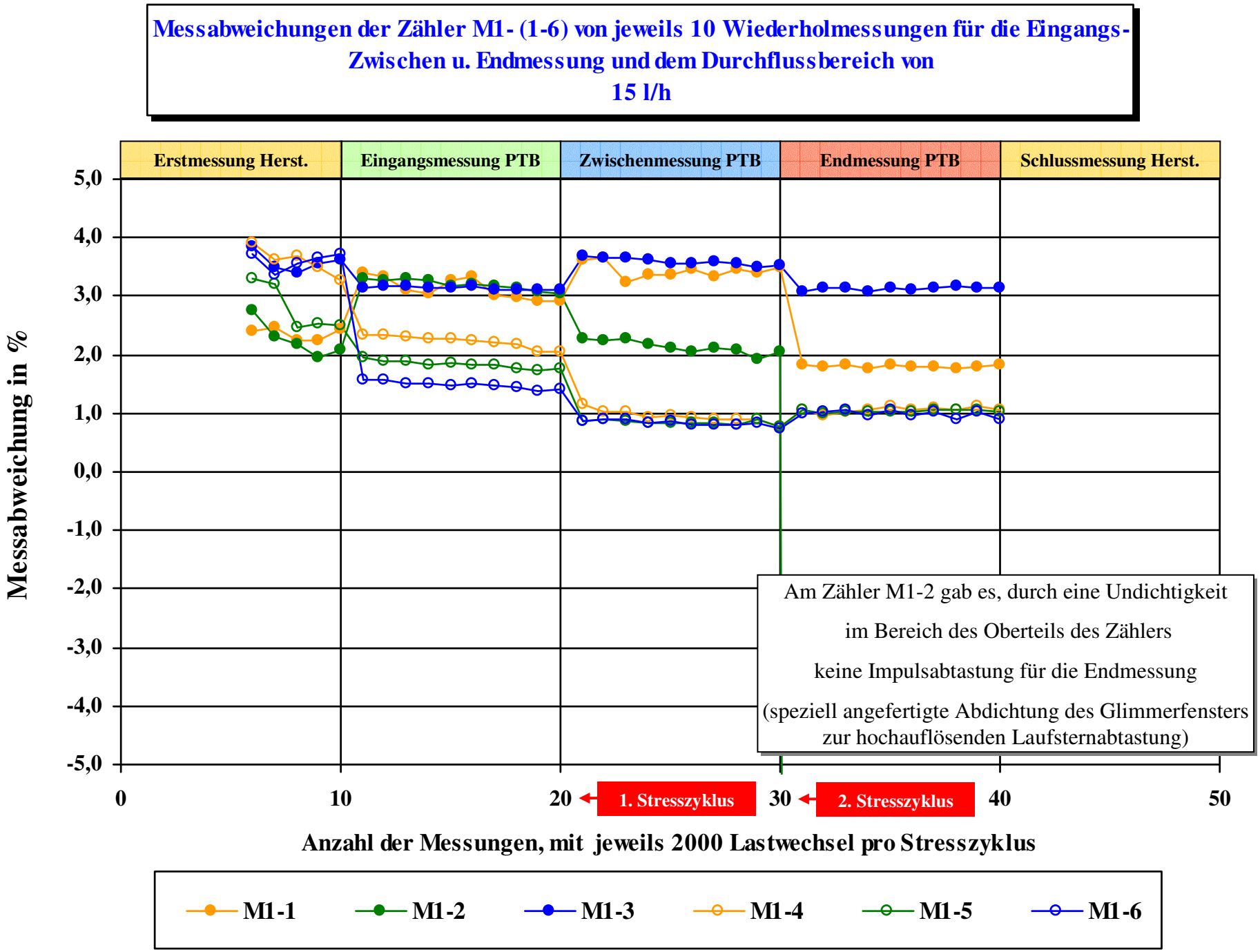
Tests are still running in the PTB, will be finished before the end of year 2005.

→ some currently measurement results

(about 6 identical mechanical flow sensors)

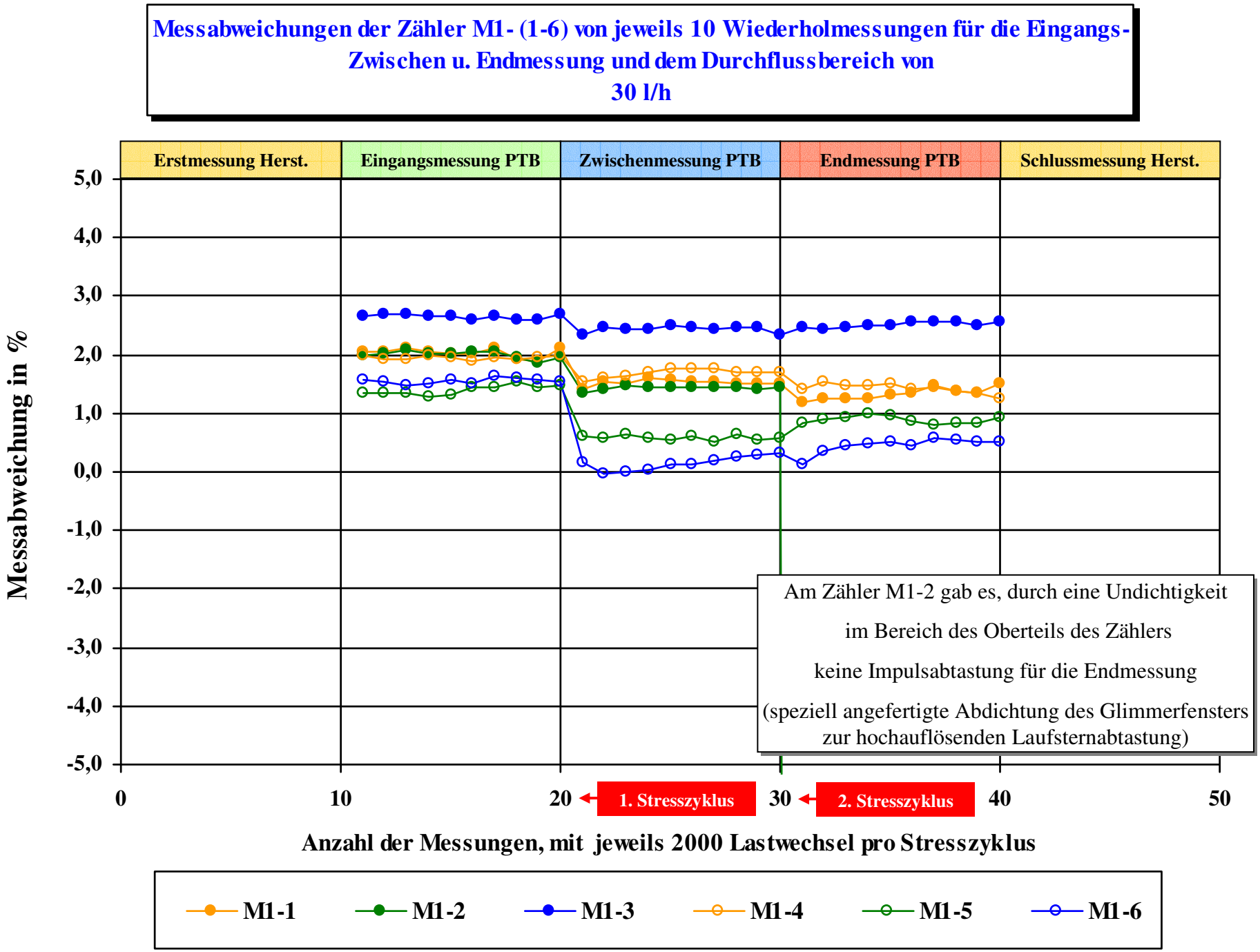
PTB test rig for the respectively measurement phases (durability error)




Messabweichungen der Zähler M1- (1-6) von jeweils 10 Wiederholmessungen für die Eingangs-
Zwischen u. Endmessung und dem Durchflussbereich von
15 l/h
Erstmessung Herst.
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
Schlussmessung Herst.
Messabweichung in %
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
0
10
20
30
40
50
1. Stresszyklus
2. Stresszyklus
Am Zähler M1-2 gab es, durch eine Undichtigkeit
im Bereich des Oberteils des Zählers
keine Impulsabtastung für die Endmessung
(speziell angefertigte Abdichtung des Glimmerfensters
zur hochauflösenden Laufsternabtastung)
Anzahl der Messungen, mit jeweils 2000 Lastwechsel pro Stresszyklus
M1-1
M1-2
M1-3
M1-4
M1-5
M1-6

currently result

q = 15 l/h → durability error 1 ... 1.5 %


Messabweichungen der Zähler M1- (1-6) von jeweils 10 Wiederholmessungen für die Eingangs-
Zwischen u. Endmessung und dem Durchflussbereich von
30 l/h
Erstmessung Herst.
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
Schlussmessung Herst.
Messabweichung in %
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
0
10
20
30
40
50
1. Stresszyklus
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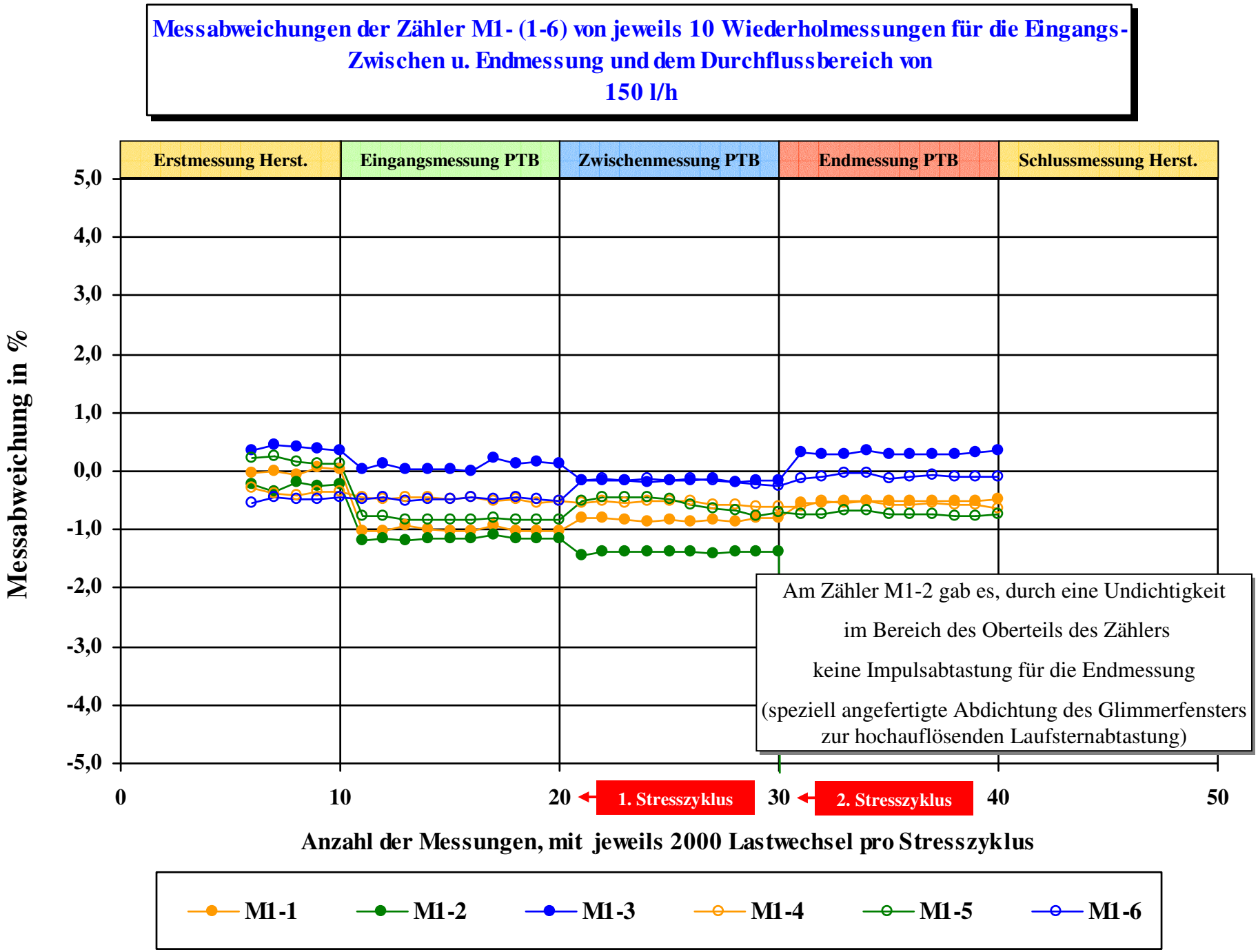
Anzahl der Messungen, mit jeweils 2000 Lastwechsel pro Stresszyklus
M1-1
M1-2
M1-3
M1-4
M1-5
M1-6

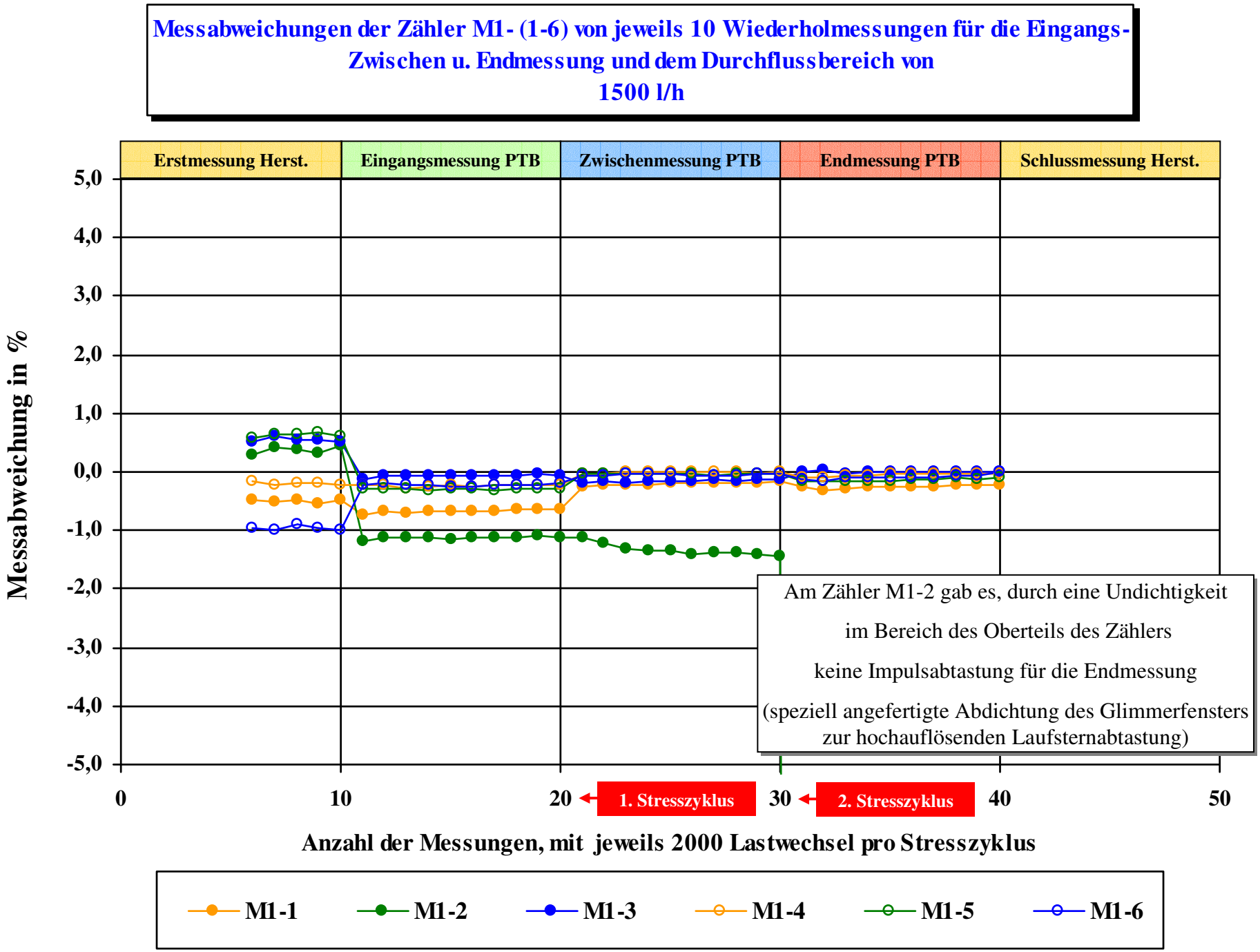
currently result

q = 30 l/h → durability error 1 ... 1.5 %


Messabweichungen der Zähler M1- (1-6) von jeweils 10 Wiederholmessungen für die Eingangs-
Zwischen u. Endmessung und dem Durchflussbereich von
150 l/h
Erstmessung Herst.
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
Schlussmessung Herst.
Messabweichung in %
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
0
10
20
30
40
50
1. Stresszyklus
2. Stresszyklus
Am Zähler M1-2 gab es, durch eine Undichtigkeit
im Bereich des Oberteils des Zählers
keine Impulsabtastung für die Endmessung
(speziell angefertigte Abdichtung des Glimmerfensters
zur hochauflösenden Laufsternabtastung)
Anzahl der Messungen, mit jeweils 2000 Lastwechsel pro Stresszyklus
M1-1
M1-2
M1-3
M1-4
M1-5
M1-6

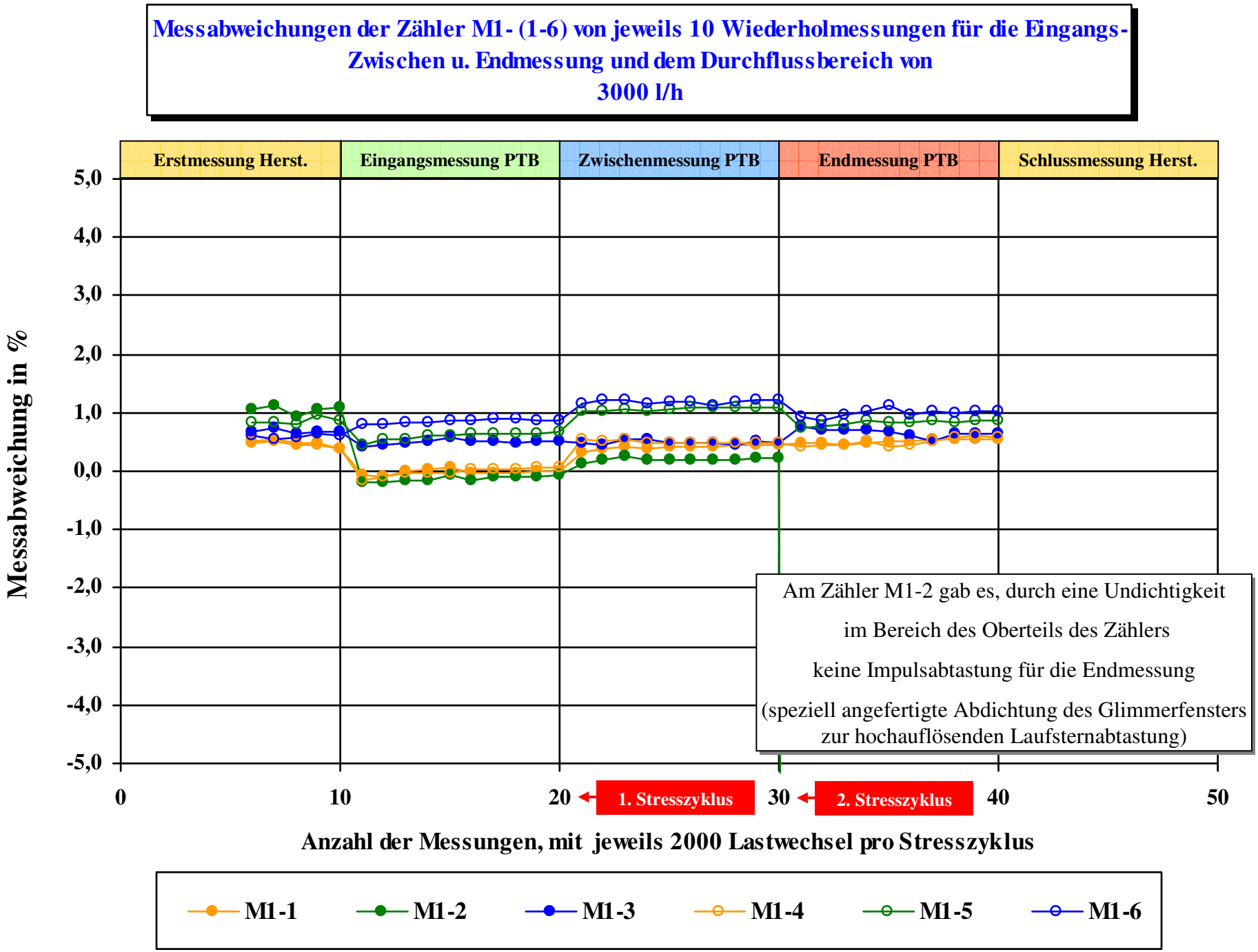
currently result

q = 150 l/h → durability error 0.5 ... 0.6 %


Messabweichungen der Zähler M1- (1-6) von jeweils 10 Wiederholmessungen für die Eingangs-
Zwischen u. Endmessung und dem Durchflussbereich von
1500 l/h
Erstmessung Herst.
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
Schlussmessung Herst.
Messabweichung in %
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
0
10
20
30
40
50
1. Stresszyklus
2. Stresszyklus
Am Zähler M1-2 gab es, durch eine Undichtigkeit
im Bereich des Oberteils des Zählers
keine Impulsabtastung für die Endmessung
(speziell angefertigte Abdichtung des Glimmerfensters
zur hochauflösenden Laufsternabtastung)
Anzahl der Messungen, mit jeweils 2000 Lastwechsel pro Stresszyklus
M1-1
M1-2
M1-3
M1-4
M1-5
M1-6

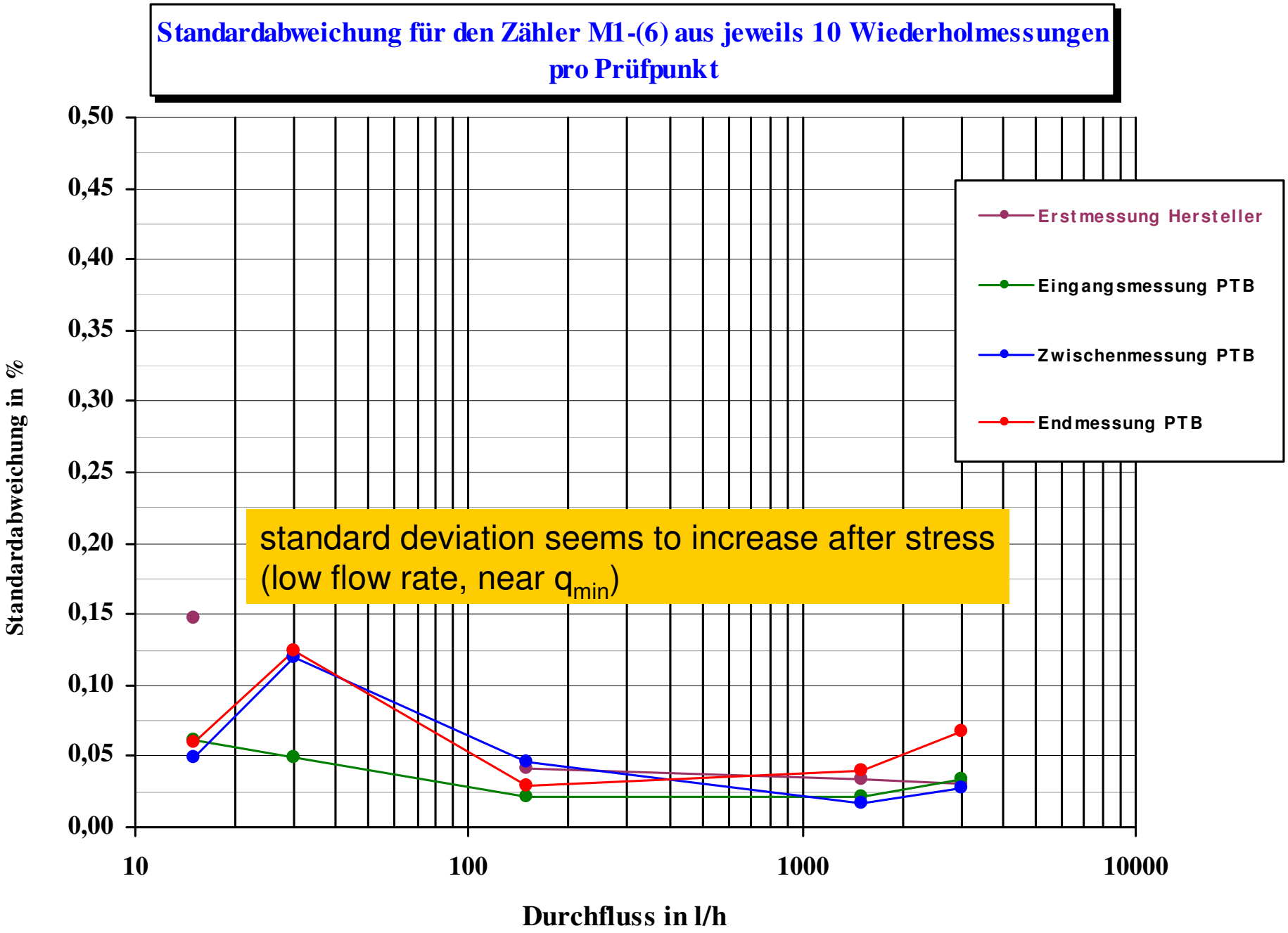
currently result

q = 1500 l/h $\rightarrow$ durability error 0.2 %


Messabweichungen der Zähler M1- (1-6) von jeweils 10 Wiederholmessungen für die Eingangs-
Zwischen u. Endmessung und dem Durchflussbereich von
3000 l/h
Erstmessung Herst.
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
Schlussmessung Herst.
Messabweichung in %
5,0
4,0
3,0
2,0
1,0
0,0
-1,0
-2,0
-3,0
-4,0
-5,0
0
10
20
30
40
50
1. Stresszyklus
2. Stresszyklus
Am Zähler M1-2 gab es, durch eine Undichtigkeit
im Bereich des Oberteils des Zählers
keine Impulsabtastung für die Endmessung
(speziell angefertigte Abdichtung des Glimmerfensters
zur hochauflösenden Laufsternabtastung)
Anzahl der Messungen, mit jeweils 2000 Lastwechsel pro Stresszyklus
M1-1
M1-2
M1-3
M1-4
M1-5
M1-6

currently result

q = 3000 l/h $\rightarrow$ durability error 0.2 ... 0.3 %


Standardabweichung für den Zähler M1-(6) aus jeweils 10 Wiederholmessungen pro Prüfpunkt
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0,05
0,00
Standardabweichung in %
10
100
1000
10000
Durchfluss in l/h
Erstmessung Hersteller
Eingangsmessung PTB
Zwischenmessung PTB
Endmessung PTB
standard deviation seems to increase after stress
(low flow rate, near q_{min})

PTB

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Experimental study for accelerated durability tests

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→ *Thank you for your attention.*