



Durability of electronic parts and product life extension

CEN TC 176 / WG2 – Sub-group 6 – EMATEM 23. September 2026

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Outline

- CEN TC 176 / WG2 – Sub-group 6 – Group and mission.
- Identification of relevant stresses and failure mechanisms for Thermal Energy Meters.
- "Durability classes" and "Installation classes".
- Define reference environments for humidity (i.e. across Europe).
- Use acceleration models to determine duration of tests (humidity tests).
- Identify relevant test objects (if possible, with known field "durability") for pre-testing (all).
- Pre-testing with relevant exposures (all).
- Pre-testing with FORCE Technology's cyclic humidity test profile, starting in 2026 (week 20).
- Tests are carried out in parallel at FORCE (Hoersholm, DK) and Jumo (Fulda, DE).

CEN TC 176 / WG2 – SG6 – Group and mission

- 13 members of the group (all from WG2).
- 3 meetings per year.
- **Our job(s):**
Thorough definition of “Lifetime” (NOTE: “almost” the same meaning as Durability and Endurance).
- “To define a suitable Accelerated Life Test for the electronics included in all sub-assemblies of a thermal energy meter, with respect to use in the environments: A, B and C, already described in the standard”.
- Liaise with “Subgroup 1” (“Durability of flow sensors > 10 years”), (most of us are participating in both groups).
- **So far:**
“Lifetime” = Lifetime of batteries only, “Durability” = Lifetime of sub-assemblies.
- “Success run” strategy (all test objects shall “pass”!).

Identification of relevant stresses and failure mechanisms for Thermal Energy Meters

Failure mechanisms in TE meters - Electronics

Stress parameter	Wear out failure mechanisms (acc. models apply)	Effect (Wear out failures)	Overstress failure mechanisms (acc. models do not apply) (use outside of specified operation conditions)
Temperature	Diffusion, Evaporation, Thermal ageing (polymers), Relaxation	Bad contacts (+sticking reed contacts), component drift, Kirkendall voiding (bond lifting), dry out of electrolytic capacitors, “weak” displays (bad segments), “gate sinking” and “ohmic contact degradation”, Piezo ceramics (transducer), cable degradation/brittle (e.g. PVC, Silicone etc.), thermal contact paste degrades	Melting, Freezing, Boiling, Explosion, T_g transition (of polymers)
Humidity	Sorption (Adsorption/Absorption), Corrosion, Hydrolysis,	PCB tracks corrode, breaking vias, bad contact, component short circuit, plastic soaking with humidity and expanding, thermal contact paste degrades, cable degradation/brittle (e.g. PVC, Silicone etc.),	Condensation
Vibration	High Cycle Fatigue (HCF)	Broken vias, broken solder joints, broken components (e.g. capacitors),	M1, M2 and M3, “overstress” or specs.?
Thermal cycling	Low Cycle Fatigue (LCF)	Broken vias, broken solder joints, broken components, delamination withing transducer, bad contacts,	xxxx
Voltage	TDDDB (Time Dependent Dielectrical Breakdown)	Relevant?	EOS (Electrical Overstress), Electrostatic discharge
Current	Electromigration	Relevant?	EOS (Electrical Overstress),
Others	Creep, Wear, Ultra Low Cycle Fatigue, Rats, Water (flooding)	Buttons wear, bearing of mech. meter (covered in other group), self-cutting screws in housing (design related),	Impact,

Failure mechanisms in TE meter – Electronics

Result:

- Temperature (static)
- Temperature changes (=Thermal cycling)
- Humidity (static)
- Humidity (cyclic, i.e. "pump effect")
- Some durability tests are already covered in 2022 standard.

"Durability classes" and "Installation classes"

Durability classes – paintings (coatings)

Durability classes – paintings (coatings), an example - could it work for us?

TEST PROCEDURES FOR PAINT SYSTEMS*					
CORROSIVITY CATEGORY AS DEFINED IN ISO 12944-2	DURABILITY RANGES ACCORDING TO ISO 12944-1	TEST REGIME 1			TEST REGIME 2
		ISO 2812-2 (water immersion) in h	ISO 6270-1 (water condensation) in h	ISO 9277 (neutral salt spray) in h	ANNEX B (cyclic ageing test)
 C2	low	—	48	—	—
	medium	—	48	—	—
	high	—	120	—	—
	very high 	—	240	480	—
 C3	low	—	48	120	—
	medium 	—	120	240	—
	high 	—	240	480	—
	very high 	—	480	720	—
 C4	low 	—	120	240	—
	medium 	—	240	480	—
	high 	—	480	720	—
	very high 	—	720	1440	1680
 C5	low 	—	240	480	—
	medium	—	480	720	—
	high 	—	720	1440	1680
	very high	—	—	—	2688

*Applied to carbon steel, hot dip galvanized steel or steel with thermal-sprayed metallic coating

Equivalent durability:    

Status for WG2 - 11th March 2025

Durability classes for Thermal Energy Meters - Electronic parts						Exam Class
TC176 - WG2 - SG6						
Updated on: 13-01-2025 (ABK), 22-01-2024 (ABK)						
Environmental class / Installation class		Durability class	Tests and duration			
			Temperature - Static	Temperature - Cyclic	Humidity - Static	Humidity - Cyclic
Class A (Domestic, Indoor) / D1-Heat	Low (2 to 5 years)		100 hours	100 hours	100 hours	100 hours
	Medium (5 to 15 years)		200 hours (at ThetaQ)	200 hours	200 hours	200 hours
	High (15 to 25 years)		300 hours	300 hours	300 hours	300 hours
Class A (Domestic, Indoor) / D2-Heat	Low (2 to 5 years)					
	Medium (5 to 15 years)		MC 603, Calculator	MC 603, Calculator		
	High (15 to 25 years)					
Class A (Domestic, Indoor) / D3-Heat	Low (2 to 5 years)					
	Medium (5 to 15 years)					
	High (15 to 25 years)					
Class A (Domestic, Indoor) / D1-Cool	Low (2 to 5 years)					
	Medium (5 to 15 years)					
	High (15 to 25 years)					
Class A (Domestic, Indoor) / D2-Cool	Low (2 to 5 years)					
	Medium (5 to 15 years)				MC 603, Calculator	MC 603, Calculator
	High (15 to 25 years)					
Class A (Domestic, Indoor) / D3-Cool	Low (2 to 5 years)					
	Medium (5 to 15 years)					
	High (15 to 25 years)					
Class B (Domestic, Outdoor) / D1-Heat	Low (2 to 5 years)					
	Medium (5 to 15 years)					
	High (15 to 25 years)					

D1 – Parts in d
very close to th
Examples: Flow

D2 – Parts the
directly connec
expected.
Examples: Cabl
design) etc.

D3 – Parts comp
Example: Wall m

Indoor

10.2 Env
— Ambie
— Low le

Define reference environments for humidity (i.e. across Europe)

Define reference environments for humidity

- We need to define at least:
 - "Domestic indoor" = Env. class A (ABK suggests: 25 deg C / 50 %rh).
 - "Domestic outdoor" = Env. Class B (ABK suggests: Billund / DK on next page or other?)and choose:
 - Tests for "Cooling" (i.e. should they be different?) ABK-> Could be the same but with different liquid temp.
 - Tests for "Heating" (i.e. should they be different?) ABK-> Could be the same but with different liquid temp.
 - "Static" and/or "Cyclic" (for which environments)? ABK-> Could one test include both?
- Different types of "cycling" (condensation on cooled parts only or condensation on "all" parts)
NOTE: Liquid water might be "pumped" in/out in both types!
NOTE: Pumping (vapour!) is rarely dominating (i.e. diffusion through small holes or polymer is normally dominating)!
- **Maybe one (cyclic) type of test could be good enough (Kentved)!**

Define reference environments for humidity

“Classification” of use environment (indoor and outdoor sheltered) using Hallberg-Peck equation

Use environment	T _H	T _L	T _{AVG}	DP _H	DP _L	DP _{AVG}	%rh at T _H / DP _H (Day)	%rh at T _L / DP _L (Night)	%rh _{AVG}	AF (Hallberg-Peck) for 60 °C / 90 %rh with respect to use environment (Ea = 0.9 / n = 3.0)
IEC 60068-1 (2013) - Std. atmosphere - (20 °C / 65 %rh)			20,0						65	191
IEC 60068-1 (2013) - Std. atmosphere - (23 °C / 50 %rh)			23,0						50	293
IEC 60068-1 (2013) - Std. atmosphere - (25 °C / 50 %rh)			25,0						50	231
IEC 60068-1 (2013) - Std. atmosphere - (27 °C / 65 %rh)			27,0						65	83
Billund lufthavn, Denmark (Jan)	3	-1	1,0	N/A	N/A	2,0	N/A	N/A	91	824
Billund lufthavn, Denmark (Feb)	3	-2	0,5	N/A	N/A	1,0	N/A	N/A	89	944
Billund lufthavn, Denmark (Mar)	6	0	3,0	N/A	N/A	3,0	N/A	N/A	84	795
Billund lufthavn, Denmark (Apr)	11	3	7,0	N/A	N/A	4,5	N/A	N/A	77	601
Billund lufthavn, Denmark (May)	16	6	11,0	N/A	N/A	8,5	N/A	N/A	74	401
Billund lufthavn, Denmark (Jun)	18	9	13,5	N/A	N/A	10,5	N/A	N/A	77	258
Billund lufthavn, Denmark (Jul)	20	11	15,5	N/A	N/A	13,5	N/A	N/A	78	193
Billund lufthavn, Denmark (Aug)	20	11	15,5	N/A	N/A	13,5	N/A	N/A	79	186
Billund lufthavn, Denmark (Sep)	16	9	12,5	N/A	N/A	11,5	N/A	N/A	84	226
Billund lufthavn, Denmark (Oct)	12	6	9,0	N/A	N/A	8,5	N/A	N/A	88	309
Billund lufthavn, Denmark (Nov)	7	2	4,5	N/A	N/A	5,0	N/A	N/A	91	510
Billund lufthavn, Denmark (Dec)	4	-1	1,5	N/A	N/A	2,0	N/A	N/A	92	744
Billund lufthavn, Denmark (average over one year)	NOTE: The average AF is calculated from the average of the individual AF's of each month ->									499

Use acceleration models to determine duration of tests (humidity tests)

Humidity (static) – Hallberg-Peck

Acceleration factor (our model parameters are from IEC 62059-31-1 = “Electronics corrosion”)

A model widely used (e.g. in IEC 62059-31-1 and IEC 62506) for calculating the lifetime of an electronic product under humid conditions is the so-called Hallberg-Peck temperature-humidity acceleration model.

When used to calculate the correspondence between two different environments (i.e. the acceleration factor “AF”) the Hallberg-Peck model takes the form:

$$AF = \left(\frac{rh_{test}}{rh_{use}} \right)^n \cdot \exp \left[\frac{E_a}{k} \cdot \left(\frac{1}{T_{use}} - \frac{1}{T_{test}} \right) \right]$$

rh_{test} = Relative humidity of the test environment [%rh].

rh_{use} = Relative humidity of the use environment [%rh].

n = A constant, 3.0 is commonly used (e.g. in IEC 62059-31-1).

E_a = The so-called “activation energy”, 0.9 eV (electron volts) is commonly used (e.g. in IEC 62059-31-1).

k = Boltzmann constant = $8.6173 \cdot 10^{-5}$ [eV/K].

T_{test} = Temperature of the test environment [K].

T_{use} = Temperature of the use environment [K].

Humidity (static) – Lawson

The Lawson Model is used for the humidity enhanced corrosion failure mechanism, Lawson Model defines the acceleration factor due to the combined effects of high temperature and relative humidity. In situations, where the Lawson-Model can be applied e.g. High-Humidity-High-Temperature (HHHT-Tests), use the following equation:

$$A_{t/RH} = A_t \cdot A_{RH} = e^{[-(\frac{E_A}{k})(\frac{1}{T_1} - \frac{1}{T_2}) + b[(RH_1)^2 - (RH_2)^2]]} \quad (\text{Eq. 4})$$

where:

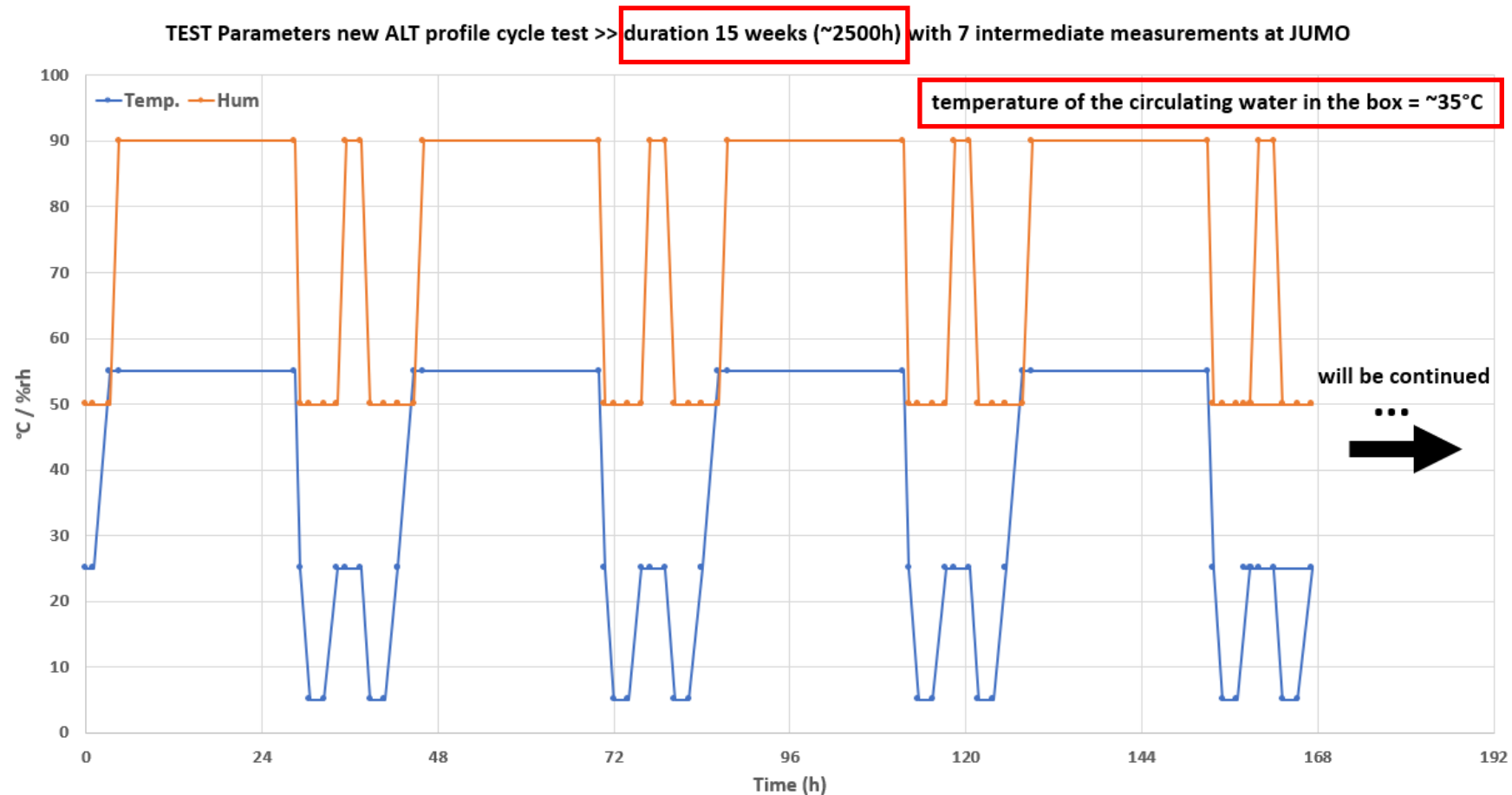
$A_{t/RH}$	Combined acceleration factor of the Lawson Model considering temperature (T) and relative humidity (RH)
A_t	Acceleration factor due to temperature
A_{RH}	Acceleration factor due to relative humidity
b	Constant ($b = 5.57 \times 10^{-4}$)
E_A	Activation energy ($E_A = 0.4 \text{ eV}$)
k	Boltzmann constant ($k = 8,617 \times 10^{-5} \text{ eV / K}$)
T_i	Absolute Kelvin temperature [K]: $i = 1$ for test condition, and $i = 2$ for field conditions
RH_i	Relative humidity [%]; $i = 1$ for test condition, and $i = 2$ for field condition

Note:

Generally, the values for the activation energies used in the Lawson Model and the Arrhenius Model are different, since both models describe completely different failure mechanisms.

Test profile

- Test profile “adapted” to EN 1434 levels (i.e. $T_{\text{high}} = 55 \text{ deg. C}$ and $T_{\text{low}} = 5 \text{ deg. C}$) for env. Class A/C.



Test profile – Acceleration factor

- Acceleration factor (87 times) based on equations for “Corrosion of electronics”.
- Test with 30 (or 35) deg. C water instead of 6/15 deg C to increase diffusion rate through polymer (4-8 times).

In SG6 we use Peck equation for test planning!

Approximately 4 days out of 7 contribute to acceleration.

AF reduced (effective) = $4/7 \times 143 = 87$

Test time [weeks]	Life at 25 deg C / 50 %rh [weeks]	Life at 25 deg C / 50 %rh [months]	Life at 25 deg C / 50 %rh [years]
1	87	21,75	1,7
2	174	43,5	3,3
5	435	108,75	8,4
6	522	130,5	10,0
7	609	152,25	11,7
10	870	217,5	16,7
15	1305	326,25	25,1
20	1740	435	33,5

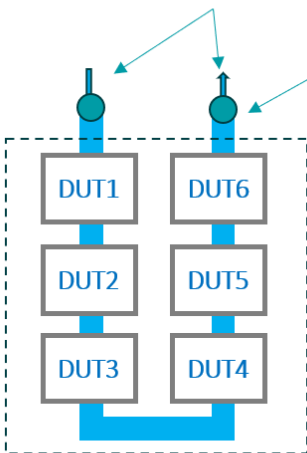
Pre-testing with relevant exposures

- Test objects from Kamstrup tested at FORCE (Hoersholm, DK).

Proposal for devices under test

ball valve with t-sensor

Inlet/outlet length flexible tube



	Calc. ¹⁾	Flow ²⁾	Temp. Sensor ³⁾
DUT1	MC603	&UF54	&TS63
DUT2	MC403	-T	&TS63
DUT3	MC403	-C ⁴⁾	&TS63

DUT4	MC603	&UF54	&TS63
DUT5	MC403	-T	&TS63
DUT6	MC403	-C ⁴⁾	&TS63

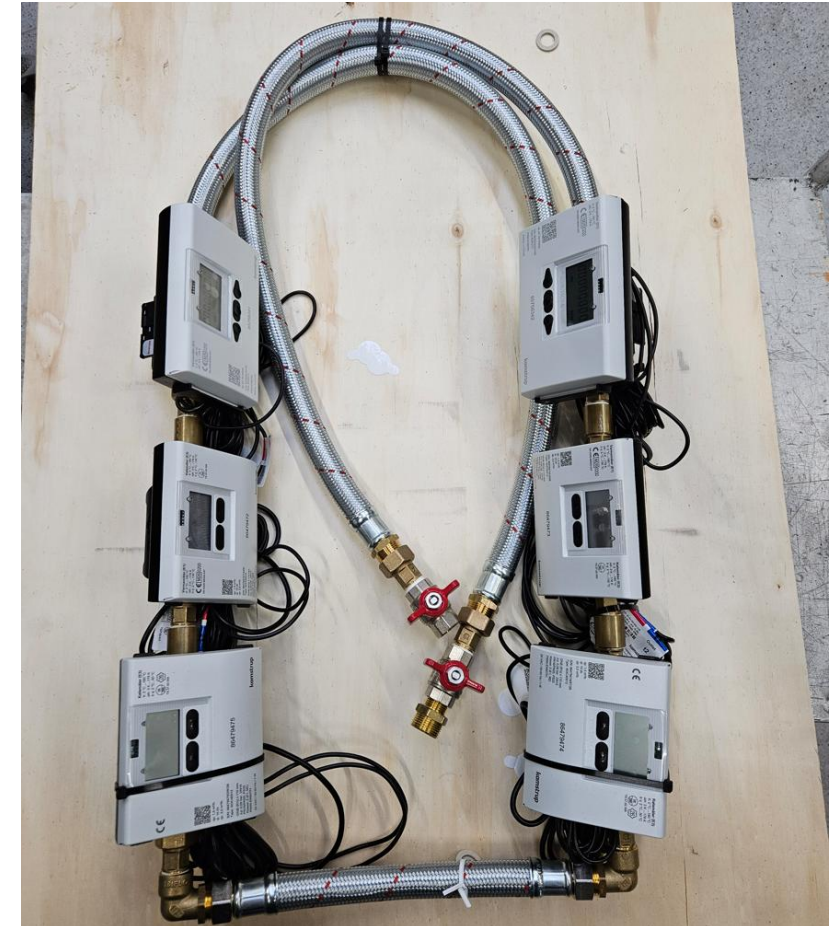
¹⁾ MC603 and MC403 is mounted on flow sensor, except from MC403-C, where this is not possible and prohibited (cooling meter)

²⁾ Flow sensors qp 1.5 m³/h; G3/4B x 110 mm with a permanent off-set (RVM conditions).

³⁾ One temp. sensor is mounted in flow sensor and part of the test, one temp. sensor cable is guided out of the climatic chamber, and the sensor is replaced by a resistor corresponding to a fixed temperature.

⁴⁾ with gel for additional condensation protection

kamstrup



Pre-testing with relevant exposures

- Test objects from Jumo test at Jumo (Fulda, DE).

From Jumo:

Temperature sensors (3 types):

10 pcs temperature probes with PVC Cable

10 pcs temperature probes with PUR (TPE-U)

10 pcs temperature probes with Silicone Cable

Temperature probes will be installed in a thermobox with circulating water (35°C).
Every 2 week there will be an intermediate measurement (check MPE) at 3 temperatures on our test bench (duration for measurement between the test not longer than 6 hours)

Idea for installation of the probes in the box inside the chamber for the new test

Use test plates / positioning plate for fixing the probes



5

JUMO

Pre-testing at FORCE Technology



Pre-testing at FORCE Technology

- 15 weeks of ALT corresponding to 25 years in DK, indoor and outdoor sheltered (i.e. milder than 25 deg C / 50 %rh).
- Functional test every week at 25 deg C / 50 %rh stable conditions, including:
 - Determination of volume error on flow sensors.
 - Determination of deltaT error on calculators (with fixed resistors placed outside climatic chamber).
 - Determination of energy measurement error on calculators.
 - Determination of temperature measurement error (absolute) on T-sensors mounted in flow sensors.
 - Measurement of insulation resistance on second T-sensors.
 - Visual inspection of calculator displays.

Pre-testing at FORCE Technology

AutoSave Off Functional test - 15 weeks ALT - 25-08-2026... Saved to this PC

File Home Templafy Developer Insert Draw Page Layout Formulas Data Review View Automate Help FORCE

Content Library New Spreadsheet Find Template Update Spreadsheet Templafy

Paste Clipboard

Calibri 11 A A

B I U Font

Alignment

General Number

A111 Week 7

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Measurements - DUT 1												
2													
3				MC603-D									
4	Week #	DUT #	Date / Time	Bath temp [°C]	Tin [°C]	Tout [°C]	Flow sensor temp [°C] MC603 A. B. C	Energi E1 [MWh]	Flow [l/h] - normal mode (with flow)	Close valves	Flow [l/h] - normal mode (zero flow)	ΔT (T₁₂) [°C]	Open valves
5	Initial	DUT1	08-05-2026 08:52	34.996	35.08	35.00	35.36	2.1581	1497		1172	29.96	
6	Initial	DUT1	13-05-2026 08:42	6.000	6.52	6.64	6.95	7.7642	1321		1022	29.96	
7	Initial	DUT1	13-05-2026 12:08	6.002	6.56	6.73	6.97	7.9202	1320		1025	29.95	
8	Week 1	DUT1	21-05-2026 10:53	6.126	6.82	7.11	7.39	16.5931	1320		1029	29.95	
9	Week 2	DUT1	28-05-2026 16:00	6.430	6.94	7.23	7.49	24.0205	1305		1029	29.96	
10	Week 3	DUT1	04-06-2026 12:47	6.235	6.74	7.05	7.32	25.3346	1311		1030	29.95	

Pre-testing at FORCE Technology – So far...

- The test seems to produce the right results in the expected environment.
- The calculated test acceleration and durability estimates are plausible.
- Final analysis of results is on-going.
- Test profile and set-up can be reproduced in different test labs.

Questions?

- **Title:**
CEN/TC 176_WG2 – Sub-group 6 - Durability of electronic parts and product life extension
- **Abstract:**
Information to the ongoing SG6's approach to developing estimates of measurement stability of electrical and electronic components and assemblies
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