EMATEM

European Metrology Association
for Thermal Energy Measurement

Life time considerations of thermal energy measurement; expectations for more than 10 years.

Highlight: flow related

Humphrey L. Spoor

Lebensdauerbetrachtungen der thermische Energiemessung oberhalb von 10 Jahren.

Schwerpunkt: Durchfluss relatiert

Definitions durability and (expanded) life time.

1. Durability can be defined as the ability of a product to perform its required function over a long period under normal use conditions without excessive expenditure on maintenance or repair.

EN 1434-1: 3.24: Durability is the characteristic of a measuring instrument to ***keep the metrological characteristics over time (e.g. to fulfil the double of MPE***), provided that it is properly installed, maintained and used within the permissible environmental conditions.

EN 1434-4: 7.2 Durability test (7.8); the ***effect of abrasion and deposition*** is changing for liquids other than water because the viscosity and density of the liquid is an additional factor on the flow behaviour. Therefore, this test shall be carried out at the limits of the foreseen field of operation with regard to viscosity and density- so at the highest and lowest viscosity and density expected with the stated liquids, temperatures and concentrations.

EN 1434-4: 7.2.1 to 7.2.4 The ***durability period (5 years)*** is scalable by its number of hours ***up to 10 years***. After the test with ***liquids other than water*** the meters should be ***taken apart and examined for damages***.

Linear extrapolation is used to come from 5 to 10 years, however, the failure probability will increase exponentially in the long run.

2. A life time prognose, the lifespan, is the length of time for which material properties of a product have permanent strength to resist external influences, such as mechanical-, thermal-, chemical- or hydraulic stress.

EN 1434-1: 3.25, A ***long life flow sensor*** is a flow sensor designed to have a longer lifetime than a normal flow sensor, which (the latter one) typically has a durability of 5 years under the specified operating conditions. (What is longer? What is normal?)

There are clear overlaps between the two, but also distinctions. EN 1434 leaves the discussion open, especially the second interpretation… How is "End_of_Life" defined? Metrological? Leakage? Wear? Scaling? Any cause?

Complex costly testing should be avoided. Is it possible to get away from assumptions and do clever over-all measurement, which make a quantitative prediction?

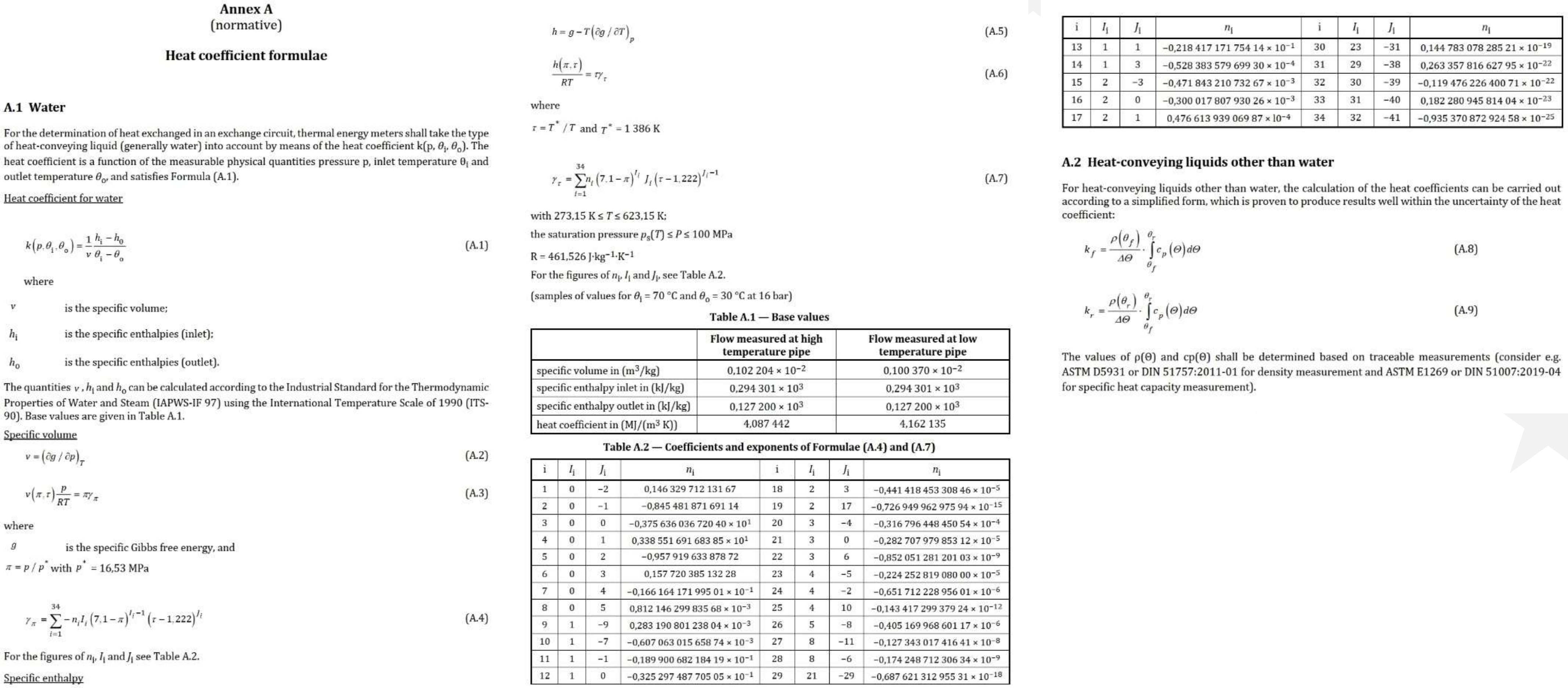
The priority here will start with regarding water-based conveying liquids.

EN 1434-1 Annex A (normative)

The IAPWS (*The International Association for the Properties of Water and Steam*) http://www.iapws.org/ has made polynomial fittings up to the 17th degree for various pure water quantities: e.g., density [kg/m^3], specific heat capacity [kJ/kg/K], and kinematic viscosity [m^2/s] in relation to temperature and pressure, which are reflected in the normative annex A of the norm EN 1434-1.

Unfortunately, no one in the world will use pure water as a heat conveyer in its thermal energy transport system, 😢 because of its aggressive chemical properties, high freezing point, and commercial availability.

EN 1434-1 Annex A (normative)



Annex A
(normative)

Heat coefficient formulae

A.1 Water

For the determination of heat exchanged in an exchange circuit, thermal energy meters shall take the type of heat-conveying liquid (generally water) into account by means of the heat coefficient k(p, θ_i, θ_o). The heat coefficient is a function of the measurable physical quantities pressure p, inlet temperature θ_i and outlet temperature θ_o, and satisfies Formula (A.1).

Heat coefficient for water

$$k(p,\theta_i,\theta_o) = \frac{1}{v}\frac{h_i - h_o}{\theta_i - \theta_o} \qquad \text{(A.1)}$$

where

v is the specific volume;

h_i is the specific enthalpies (inlet);

h_o is the specific enthalpies (outlet).

The quantities v, h_i and h_o can be calculated according to the Industrial Standard for the Thermodynamic Properties of Water and Steam (IAPWS-IF 97) using the International Temperature Scale of 1990 (ITS-90). Base values are given in Table A.1.

Specific volume

$$v = (\partial g / \partial p)_T \qquad \text{(A.2)}$$

$$v(\pi,\tau)\frac{p}{RT} = \pi\gamma_\pi \qquad \text{(A.3)}$$

where

g is the specific Gibbs free energy, and

$\pi = p / p^*$ with $p^* = 16{,}53$ MPa

$$\gamma_\pi = \sum_{i=1}^{34} -n_i I_i (7{,}1-\pi)^{I_i - 1}(\tau - 1{,}222)^{J_i} \qquad \text{(A.4)}$$

For the figures of n_i, I_i and J_i see Table A.2.

Specific enthalpy

$$h = g - T(\partial g / \partial T)_p \qquad \text{(A.5)}$$

$$\frac{h(\pi,\tau)}{RT} = \tau\gamma_\tau \qquad \text{(A.6)}$$

where

$\tau = T^* / T$ and $T^* = 1\,386$ K

$$\gamma_\tau = \sum_{i=1}^{34} n_i (7{,}1-\pi)^{I_i} J_i (\tau - 1{,}222)^{J_i - 1} \qquad \text{(A.7)}$$

with 273,15 K ≤ T ≤ 623,15 K;

the saturation pressure $p_s(T) \leq P \leq 100$ MPa

R = 461,526 J·kg^{-1}·K^{-1}

For the figures of n_i, I_i and J_i, see Table A.2.

(samples of values for θ_i = 70 °C and θ_o = 30 °C at 16 bar)

Table A.1 — Base values

	Flow measured at high temperature pipe	Flow measured at low temperature pipe
specific volume in (m^3/kg)	$0{,}102\,204 \times 10^{-2}$	$0{,}100\,370 \times 10^{-2}$
specific enthalpy inlet in (kJ/kg)	$0{,}294\,301 \times 10^{3}$	$0{,}294\,301 \times 10^{3}$
specific enthalpy outlet in (kJ/kg)	$0{,}127\,200 \times 10^{3}$	$0{,}127\,200 \times 10^{3}$
heat coefficient in (MJ/(m^3 K))	4,087 442	4,162 135

Table A.2 — Coefficients and exponents of Formulae (A.4) and (A.7)

i	I_i	J_i	n_i	i	I_i	J_i	n_i
1	0	−2	0,146 329 712 131 67	18	2	3	$-0{,}441\,418\,453\,308\,46 \times 10^{-5}$
2	0	−1	−0,845 481 871 691 14	19	2	17	$-0{,}726\,949\,962\,975\,94 \times 10^{-15}$
3	0	0	$-0{,}375\,636\,036\,720\,40 \times 10^{1}$	20	3	−4	$-0{,}316\,796\,448\,450\,54 \times 10^{-4}$
4	0	1	$0{,}338\,551\,691\,683\,85 \times 10^{1}$	21	3	0	$-0{,}282\,707\,979\,853\,12 \times 10^{-5}$
5	0	2	−0,957 919 633 878 72	22	3	6	$-0{,}852\,051\,281\,201\,03 \times 10^{-9}$
6	0	3	0,157 720 385 132 28	23	4	−5	$-0{,}224\,252\,819\,080\,00 \times 10^{-5}$
7	0	4	$-0{,}166\,164\,171\,995\,01 \times 10^{-1}$	24	4	−2	$-0{,}651\,712\,228\,956\,01 \times 10^{-6}$
8	0	5	$0{,}812\,146\,299\,835\,68 \times 10^{-3}$	25	4	10	$-0{,}143\,417\,299\,379\,24 \times 10^{-12}$
9	1	−9	$0{,}283\,190\,801\,238\,04 \times 10^{-3}$	26	5	−8	$-0{,}405\,169\,968\,601\,17 \times 10^{-6}$
10	1	−7	$-0{,}607\,063\,015\,658\,74 \times 10^{-3}$	27	8	−11	$-0{,}127\,343\,017\,416\,41 \times 10^{-8}$
11	1	−1	$-0{,}189\,900\,682\,184\,19 \times 10^{-1}$	28	8	−6	$-0{,}174\,248\,712\,306\,34 \times 10^{-9}$
12	1	0	$-0{,}325\,297\,487\,705\,05 \times 10^{-1}$	29	21	−29	$-0{,}687\,621\,312\,955\,31 \times 10^{-18}$
13	1	1	$-0{,}218\,417\,171\,754\,14 \times 10^{-1}$	30	23	−31	$0{,}144\,783\,078\,285\,21 \times 10^{-19}$
14	1	3	$-0{,}528\,383\,579\,699\,30 \times 10^{-4}$	31	29	−38	$0{,}263\,357\,816\,627\,95 \times 10^{-22}$
15	2	−3	$-0{,}471\,843\,210\,732\,67 \times 10^{-3}$	32	30	−39	$-0{,}119\,476\,226\,400\,71 \times 10^{-22}$
16	2	0	$-0{,}300\,017\,807\,930\,26 \times 10^{-3}$	33	31	−40	$0{,}182\,280\,945\,814\,04 \times 10^{-23}$
17	2	1	$0{,}476\,613\,939\,069\,87 \times 10^{-4}$	34	32	−41	$-0{,}935\,370\,872\,924\,58 \times 10^{-25}$

A.2 Heat-conveying liquids other than water

For heat-conveying liquids other than water, the calculation of the heat coefficients can be carried out according to a simplified form, which is proven to produce results well within the uncertainty of the heat coefficient:

$$k_f = \frac{\rho(\theta_f)}{\Delta\Theta} \cdot \int_{\theta_f}^{\theta_r} c_p(\Theta)\, d\Theta \qquad \text{(A.8)}$$

$$k_r = \frac{\rho(\theta_r)}{\Delta\Theta} \cdot \int_{\theta_f}^{\theta_r} c_p(\Theta)\, d\Theta \qquad \text{(A.9)}$$

The values of ρ(Θ) and cp(Θ) shall be determined based on traceable measurements (consider e.g. ASTM D5931 or DIN 51757:2011-01 for density measurement and ASTM E1269 or DIN 51007:2019-04 for specific heat capacity measurement).

Water quality

- Pure water [< 0.05 μS/cm] is hard to get in practice, dangerous, and highly aggressive. Minerals in water are indispensable also to prevent for tube wall damages. Pure water reacts chemically as a radical and in a matter of hours the water has distracted enough wall atoms to satisfy it's electro-chemical equilibrium; increasing its conductivity.
- Severe distillate water, resp. condensate [0.05 < μS/cm < 1] is undesirable too, for the same reason. Less severe distillation degrees will gradually be less harmful.
- The water conductivity should not become under say 100 μS/cm (and not on only because EMFM's might be present in the circuitry) to be and remain on the safe side.

The following table shows water qualities that all have been encountered in **real** situations and have been subjected to discussions and (field) testing. Many common meter materials do not cope with both extremities mentioned above.

Water quality

	less pure									more pure
quality	**Swimming pool water**	**Sea water / Brines**	**Sewage (waste) water**	**Drinking water (hard)**	**Drinking water (soft)**	**Tap water**	**Process water**	**Reverse osmosis water (*)**	**Distilled water / Condensate (*)**	**deionised / demineralized / H2O (*)**
		typical	typical	typical				**REOS**	**DIST / COND**	**DEION / DEMI**
toxicity :	-	-	-	-	-	-	-	-	**severe heath risk by intake**	
minimum acid degree :	pH 8.3	pH 8	pH 8	pH 8	pH 7.5	pH 7.5	pH 6	pH 6	pH 6	pH 5.5
maximum acid degree :	pH 8.4	pH 8	pH 8	pH 8	pH 8	pH 7.5	pH 7	pH 7	pH 7	pH 6.5
hardness [dH] :	20-25	>30	8-12	7-10	3-7	5-7	1	<1	<1	<1
minimum conductivity [µS/cm] :	2500	5'000	500	500	100	50	0.1	1	**0.1**	**< 0.055**
maximum conductivity [µS/cm] :	4000	50'000	10'000	5'000	500	5'000	50	5	**1**	**0.1**
maximum TDS (*) [ppm] :	500+	500+	400	330	170	400	0+++	0++	0+	0
(*) TDS = Total Dissolved Solids						**(*) it is important to know to which extent (concentration) it has been purified**				
TOC = Total Organic Carbon						**(*) agressive; acid behaviour due to CO_2 absorption**				

+ + = excellent
+ = good
0 = fair
- = not recommended / not sufficient
- - = bad

(*) High grade DEION water will errode brass and stainless steel. Lower concentrations DEION might lead to slow gradual depletion of less nobel elements from alloys

The use of high-degree DEION / DEMI water in installations is disputatble, as metal atoms from walls will be ripped out (pure water is very aggresive !). Consequently, the conductivity will soon rise again (reducing both degree and effect of DEION / DEMI water) and the walls will gradually be perforated (material degradation).

Stainless steel 304 (1.4301 - X 5 CrNi 18 10)	+ +	+ +	+ +	+ +	+ +	+ +	+	0	0	0
PPS (Polyphenylene Sulfide)	+	+ +	+ +	+ +	+ +	+ +	+	0	0	0
Brass CuZn40Pb2	0	+	+ +	+ +	+ +	+ +	+	0	0	0
PTFE coatings	+ +	+ +	+ +	+ +	+ +	+ +	+	0	0	0
cast iron GG40	0	-	0	0	0	0	+	+	+	0
cast iron GG40 & electrophoretic KTL layer (**)	+ +	+ +	+ +	+ +	+ +	+ +	+	+	+	0
CuZn40Pb2 & electrophoretic KTL layer (**)	+ +	+ +	+ +	+ +	+ +	+ +	+	+	+	0
Steel St. 52.0 (1.0421), coated (***)	+ +	+ +	+ +	+ +	+ +	+ +	+	+	+	0

Water and dissolved oxygen concentrations

Apart from this water quality the oxygen concentration may also become an issue.

As closed circuits does not really exist (e.g., exchanging parts, replenish water, pumps taking-in air through bearings, etc.) it is an illusion to assume that once purged and having overcome the bigger oxygen-part by means of scavengers it will stay that way.

So, here starts the endless story of additives in water.

First of all: overdose kills !!

Swiss Alchemist Paracelsus (1493-1541): „Alle Dinge sind Gift, und nichts ist ohne Gift; allein die dosis machts, daß ein Ding kein Gift sei.“

Second: not only the concentration counts, but also in combination with pH-Value, conductivity, solubility of ingredients, temperature, and so on.

Oxygen scavengers

The use of oxygen scavengers such as sulphite ions (SO_3^{2-}) may change the water composition and its physical quantities (ρ, c_p, ν), but will not chemically attack most materials. E.g., $4\ Na^+ + 2\ SO_3^{2-} + O^2 \Rightarrow 4\ Na^+ + 2\ SO_4^{2-}$ (sodium sulphite becomes sodium sulphate).

Sulphite chemistry is complex as there are many sulphur-valences possible (-2, -1, 0, +2, +4, +6).

Also the use of Hydrazine (N_2H_4) as scavenger has been used to reduce the rate of corrosion in boilers by removing the dissolved oxygen from the water, but this becomes more and more obsolete.

A few “ideal” water recommendations have been documented as references.
However, only what you see (water analysis, measured) is what you get.

AGFW FW 510: Requirements for circulation water

AGFW-REGELWERK

AGFW

AGFW-Arbeitsblatt FW 510

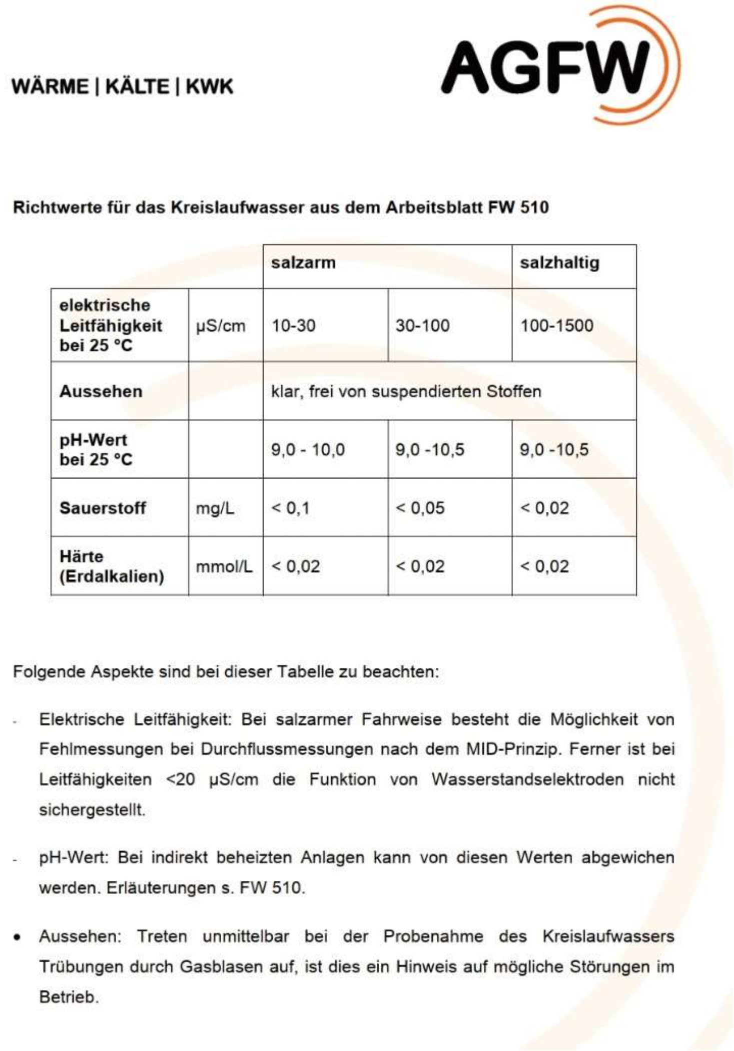
Anforderungen an das Kreislaufwasser von Industrie- und Fernwärmeheizanlagen sowie Hinweise für deren Betrieb

Requirements for circulation water in industrial and district heating systems and recommendations for their operation

Juni 2011

Ersatz für Ausgabe November 2003

AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK e. V.



WÄRME | KÄLTE | KWK

AGFW

Richtwerte für das Kreislaufwasser aus dem Arbeitsblatt FW 510

		salzarm		salzhaltig
elektrische Leitfähigkeit bei 25 °C	µS/cm	10-30	30-100	100-1500
Aussehen		klar, frei von suspendierten Stoffen		
pH-Wert bei 25 °C		9,0 - 10,0	9,0 -10,5	9,0 -10,5
Sauerstoff	mg/L	< 0,1	< 0,05	< 0,02
Härte (Erdalkalien)	mmol/L	< 0,02	< 0,02	< 0,02

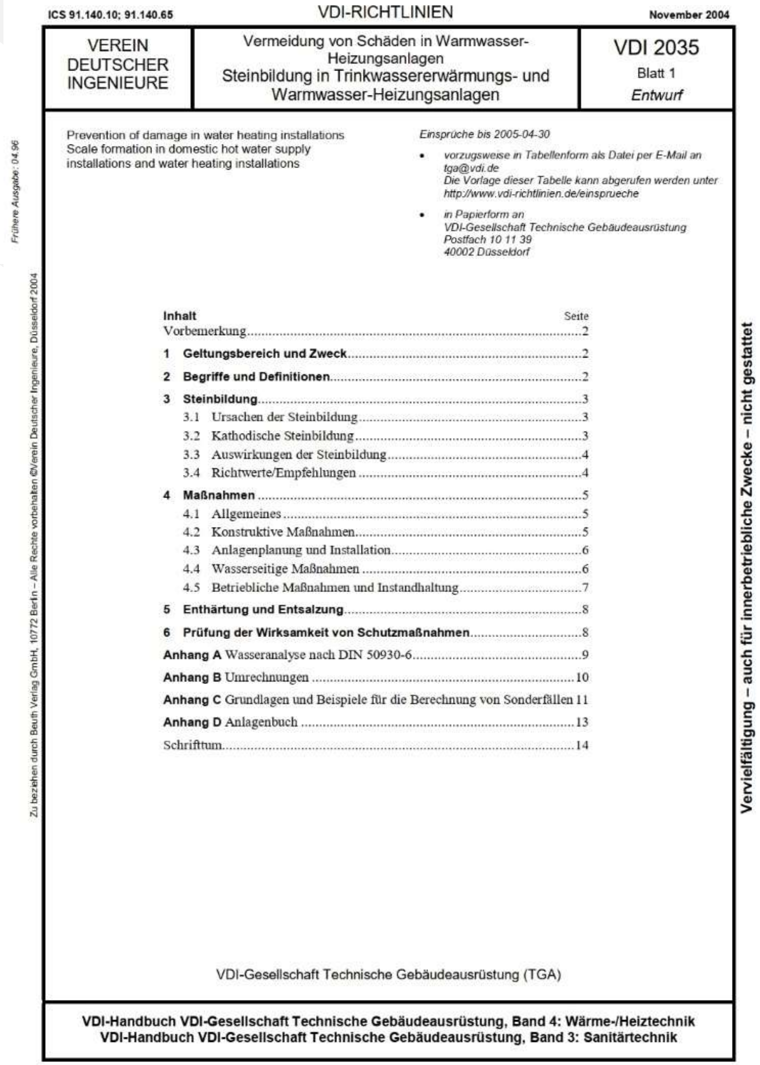
Folgende Aspekte sind bei dieser Tabelle zu beachten:

- Elektrische Leitfähigkeit: Bei salzarmer Fahrweise besteht die Möglichkeit von Fehlmessungen bei Durchflussmessungen nach dem MID-Prinzip. Ferner ist bei Leitfähigkeiten <20 µS/cm die Funktion von Wasserstandselektroden nicht sichergestellt.
- pH-Wert: Bei indirekt beheizten Anlagen kann von diesen Werten abgewichen werden. Erläuterungen s. FW 510.
- Aussehen: Treten unmittelbar bei der Probenahme des Kreislaufwassers Trübungen durch Gasblasen auf, ist dies ein Hinweis auf mögliche Störungen im Betrieb.

VDI-Richtlinie: VDI 2035

The VDI has issued a special bulletin on the topic of scaling:

Vermeidung von Schäden in Warmwasser Heizungsanlagen; Steinbildung in Trinkwasser Erwärmungs- und Warmwasser-Heizungsanlagen.



ICS 91.140.10; 91.140.65
VDI-RICHTLINIEN
November 2004

VEREIN
DEUTSCHER
INGENIEURE

Vermeidung von Schäden in Warmwasser-Heizungsanlagen
Steinbildung in Trinkwassererwärmungs- und Warmwasser-Heizungsanlagen

VDI 2035
Blatt 1
Entwurf

Prevention of damage in water heating installations
Scale formation in domestic hot water supply installations and water heating installations

Einsprüche bis 2005-04-30

- *vorzugsweise in Tabellenform als Datei per E-Mail an tga@vdi.de*
  Die Vorlage dieser Tabelle kann abgerufen werden unter http://www.vdi-richtlinien.de/einsprueche
- *in Papierform an*
  VDI-Gesellschaft Technische Gebäudeausrüstung
  Postfach 10 11 39
  40002 Düsseldorf

Frühere Ausgabe: 04.96

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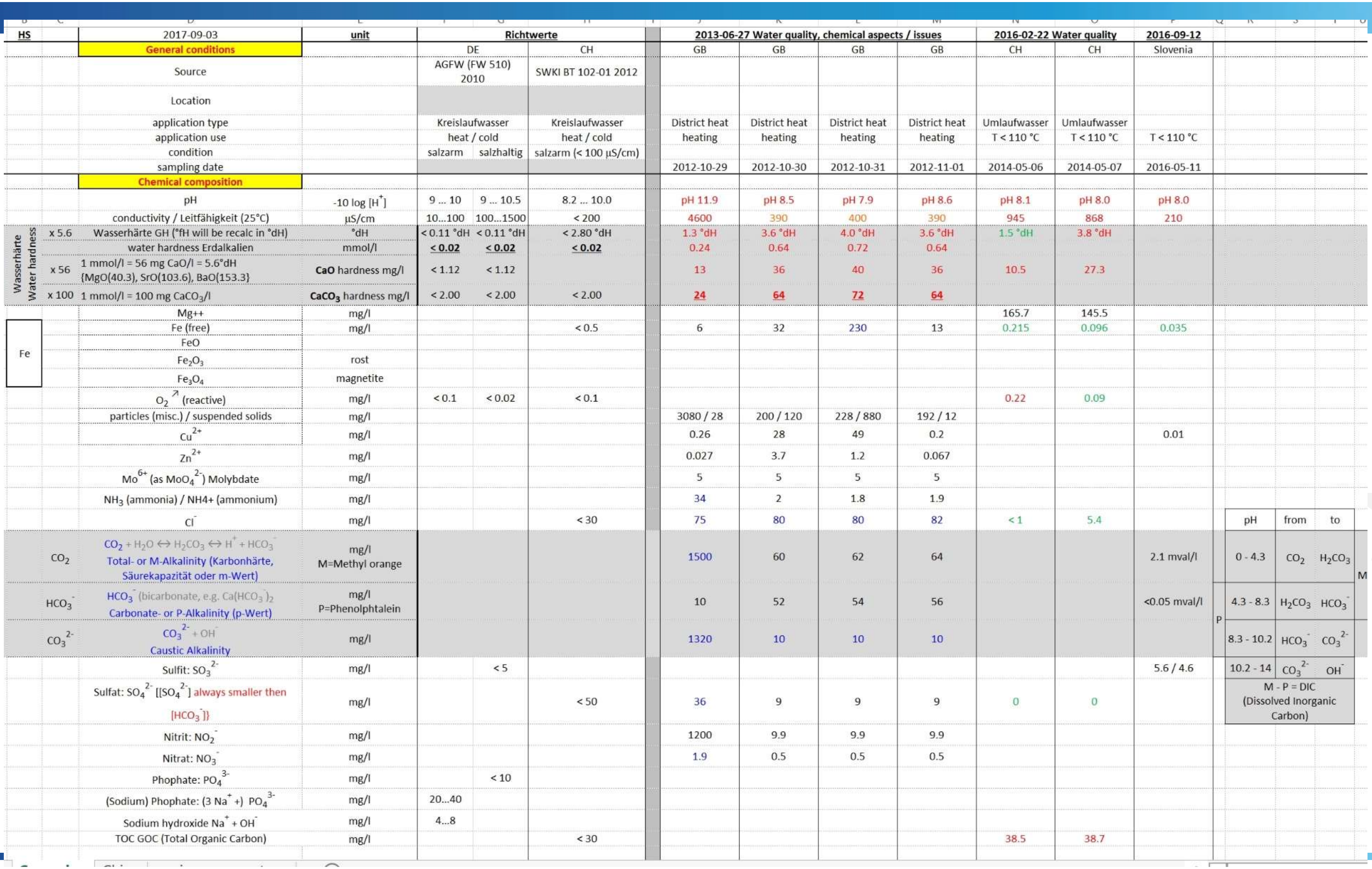
Vervielfältigung – auch für innerbetriebliche Zwecke – nicht gestattet

VDI-Gesellschaft Technische Gebäudeausrüstung (TGA)

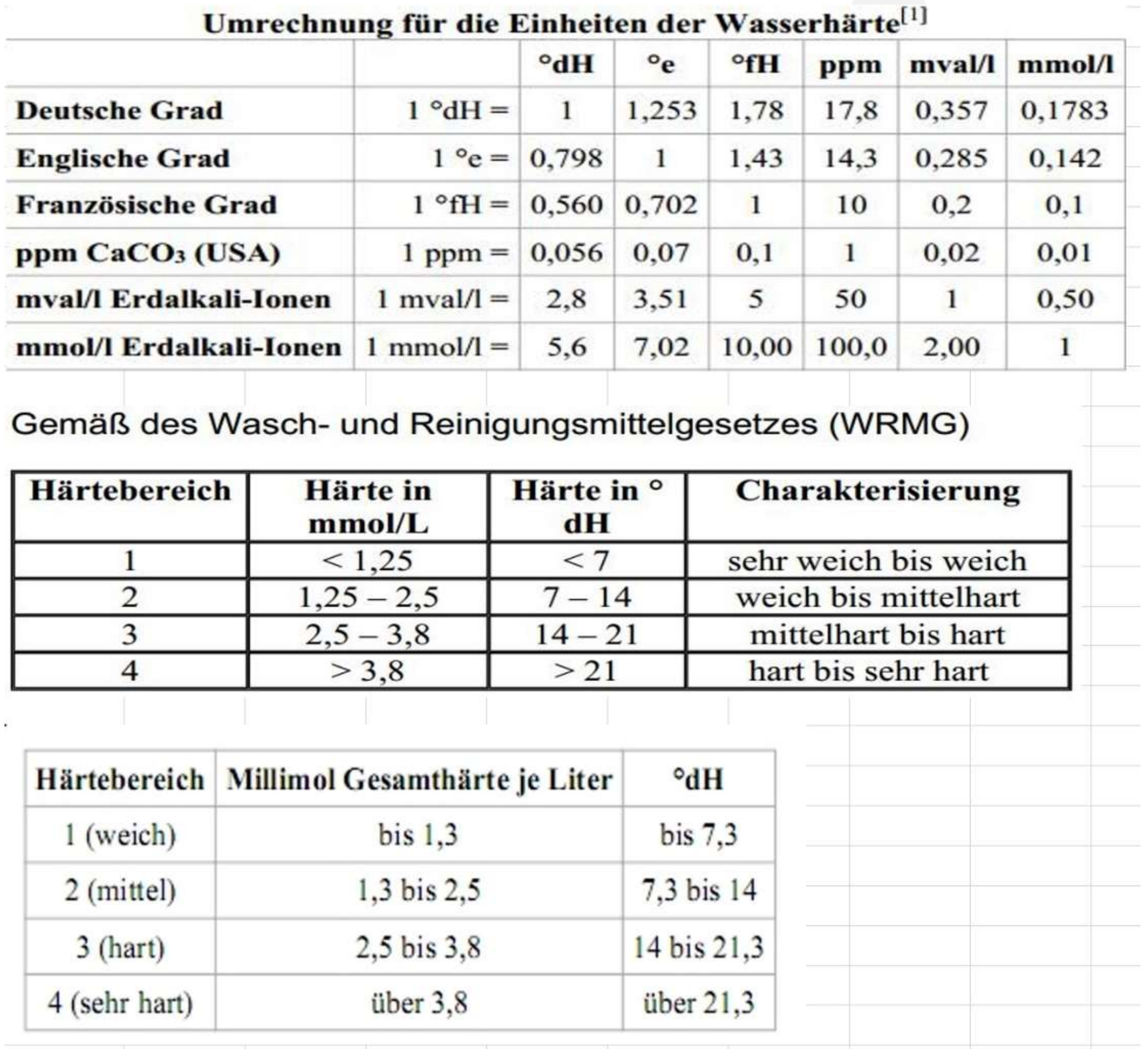
VDI-Handbuch VDI-Gesellschaft Technische Gebäudeausrüstung, Band 4: Wärme-/Heiztechnik
VDI-Handbuch VDI-Gesellschaft Technische Gebäudeausrüstung, Band 3: Sanitärtechnik



HS		2017-09-03	unit	Richtwerte			2013-06-27 Water quality, chemical aspects / issues				2016-02-22 Water quality		2016-09-12
		General conditions		DE		CH	GB	GB	GB	GB	CH	CH	Slovenia
		Source		AGFW (FW 510) 2010		SWKI BT 102-01 2012							
		Location											
		application type		Kreislaufwasser		Kreislaufwasser	District heat	District heat	District heat	District heat	Umlaufwasser	Umlaufwasser	
		application use		heat / cold		heat / cold	heating	heating	heating	heating	T < 110 °C	T < 110 °C	T < 110 °C
		condition		salzarm	salzhaltig	salzarm (< 100 µS/cm)							
		sampling date					2012-10-29	2012-10-30	2012-10-31	2012-11-01	2014-05-06	2014-05-07	2016-05-11
		Chemical composition											
		pH	-10 log [H^+]	9 ... 10	9 ... 10.5	8.2 ... 10.0	pH 11.9	pH 8.5	pH 7.9	pH 8.6	pH 8.1	pH 8.0	pH 8.0
		conductivity / Leitfähigkeit (25°C)	µS/cm	10...100	100...1500	< 200	4600	390	400	390	945	868	210
Wasserhärte Water hardness	x 5.6	Wasserhärte GH (°fH will be recalc in °dH)	°dH	< 0.11 °dH	< 0.11 °dH	< 2.80 °dH	1.3 °dH	3.6 °dH	4.0 °dH	3.6 °dH	1.5 °dH	3.8 °dH	
		water hardness Erdalkalien	mmol/l	**< 0.02**	**< 0.02**	**< 0.02**	0.24	0.64	0.72	0.64			
	x 56	1 mmol/l = 56 mg CaO/l = 5.6°dH {MgO(40.3), SrO(103.6), BaO(153.3)}	**CaO** hardness mg/l	< 1.12	< 1.12		13	36	40	36	10.5	27.3	
	x 100	1 mmol/l = 100 mg $CaCO_3$/l	**$CaCO_3$** hardness mg/l	< 2.00	< 2.00	< 2.00	**24**	**64**	**72**	**64**			
		Mg++	mg/l								165.7	145.5	
Fe		Fe (free)	mg/l			< 0.5	6	32	230	13	0.215	0.096	0.035
		FeO											
		Fe_2O_3	rost										
		Fe_3O_4	magnetite										
		$O_2^{\nearrow}$ (reactive)	mg/l	< 0.1	< 0.02	< 0.1					0.22	0.09	
		particles (misc.) / suspended solids	mg/l				3080 / 28	200 / 120	228 / 880	192 / 12			
		Cu^{2+}	mg/l				0.26	28	49	0.2			0.01
		Zn^{2+}	mg/l				0.027	3.7	1.2	0.067			
		Mo^{6+} (as MoO_4^{2-}) Molybdate	mg/l				5	5	5	5			
		NH_3 (ammonia) / NH4+ (ammonium)	mg/l				34	2	1.8	1.9			
		Cl^-	mg/l			< 30	75	80	80	82	< 1	5.4	
	CO_2	$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$ Total- or M-Alkalinity (Karbonhärte, Säurekapazität oder m-Wert)	mg/l M=Methyl orange				1500	60	62	64			2.1 mval/l
	HCO_3^-	HCO_3^- (bicarbonate, e.g. $Ca(HCO_3^-)_2$ Carbonate- or P-Alkalinity (p-Wert)	mg/l P=Phenolphtalein				10	52	54	56			<0.05 mval/l
	CO_3^{2-}	$CO_3^{2-} + OH^-$ Caustic Alkalinity	mg/l				1320	10	10	10			
		Sulfit: SO_3^{2-}	mg/l		< 5								5.6 / 4.6
		Sulfat: SO_4^{2-} [[SO_4^{2-}] always smaller then [HCO_3^-]}	mg/l			< 50	36	9	9	9	0	0	
		Nitrit: NO_2^-	mg/l				1200	9.9	9.9	9.9			
		Nitrat: NO_3^-	mg/l				1.9	0.5	0.5	0.5			
		Phophate: PO_4^{3-}	mg/l		< 10								
		(Sodium) Phophate: (3 Na^+ +) PO_4^{3-}	mg/l	20...40									
		Sodium hydroxide $Na^+ + OH^-$	mg/l	4...8									
		TOC GOC (Total Organic Carbon)	mg/l			< 30					38.5	38.7	

	pH	from	to	
	0 - 4.3	CO_2	H_2CO_3	M
P	4.3 - 8.3	H_2CO_3	HCO_3^-	
	8.3 - 10.2	HCO_3^-	CO_3^{2-}	
	10.2 - 14	CO_3^{2-}	OH^-	
	M - P = DIC (Dissolved Inorganic Carbon)			

The influence of water hardness



Umrechnung für die Einheiten der Wasserhärte[1]

		°dH	°e	°fH	ppm	mval/l	mmol/l
Deutsche Grad	1 °dH =	1	1,253	1,78	17,8	0,357	0,1783
Englische Grad	1 °e =	0,798	1	1,43	14,3	0,285	0,142
Französische Grad	1 °fH =	0,560	0,702	1	10	0,2	0,1
ppm $CaCO_3$ (USA)	1 ppm =	0,056	0,07	0,1	1	0,02	0,01
mval/l Erdalkali-Ionen	1 mval/l =	2,8	3,51	5	50	1	0,50
mmol/l Erdalkali-Ionen	1 mmol/l =	5,6	7,02	10,00	100,0	2,00	1

Gemäß des Wasch- und Reinigungsmittelgesetzes (WRMG)

Härtebereich	Härte in mmol/L	Härte in ° dH	Charakterisierung
1	< 1,25	< 7	sehr weich bis weich
2	1,25 – 2,5	7 – 14	weich bis mittelhart
3	2,5 – 3,8	14 – 21	mittelhart bis hart
4	> 3,8	> 21	hart bis sehr hart

Härtebereich	Millimol Gesamthärte je Liter	°dH
1 (weich)	bis 1,3	bis 7,3
2 (mittel)	1,3 bis 2,5	7,3 bis 14
3 (hart)	2,5 bis 3,8	14 bis 21,3
4 (sehr hart)	über 3,8	über 21,3

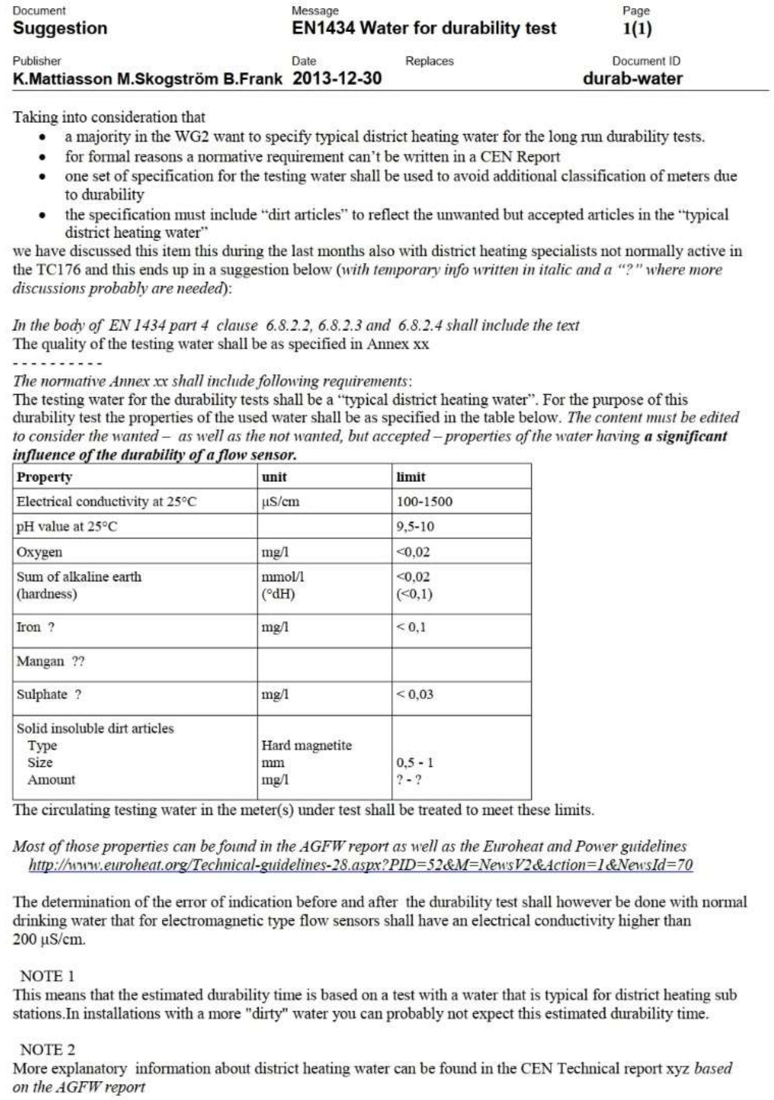
- The discussion about test water for durability tests started more than 10 years ago, and had not ended yet either.

Water composition is entangled with meter performance and life time. *The conveying liquid is part of the measurement system*!

- Studies of water with additives show that the conveying liquid composition interacts with the physical-metrological performance.
- The chemical-composition will influence other aspects, such as the strength of materials, the surface conditions, wear, fatigue of seals, scaling, magnetite building and particle structure.

Short history durability working groups TC 176 WG2

- 2013-12-30: An ad hoc group consitting of K.Mattiasson M.Skogström B.Frank had several meetings and communicated some of their findings.
- 2017-08-08: The ad hoc group changed composition: Marie Skogström, Tord Kjelling, Günter Leitgen, Edgar vom Schloß, Humphrey Spoor.
- 2018-11-07: the group made a final report about an operation modus with clear recommendations.



Document
Suggestion
Message
EN1434 Water for durability test
Page
1(1)
Publisher
K.Mattiasson M.Skogström B.Frank
Date
2013-12-30
Replaces
Document ID
durab-water

Taking into consideration that

- a majority in the WG2 want to specify typical district heating water for the long run durability tests.
- for formal reasons a normative requirement can't be written in a CEN Report
- one set of specification for the testing water shall be used to avoid additional classification of meters due to durability
- the specification must include "dirt articles" to reflect the unwanted but accepted articles in the "typical district heating water"

we have discussed this item this during the last months also with district heating specialists not normally active in the TC176 and this ends up in a suggestion below (*with temporary info written in italic and a "?" where more discussions probably are needed*):

In the body of EN 1434 part 4 clause 6.8.2.2, 6.8.2.3 and 6.8.2.4 shall include the text
The quality of the testing water shall be as specified in Annex xx
- - - - - - - - - - -
The normative Annex xx shall include following requirements:
The testing water for the durability tests shall be a "typical district heating water". For the purpose of this durability test the properties of the used water shall be as specified in the table below. *The content must be edited to consider the wanted – as well as the not wanted, but accepted – properties of the water having* ***a significant influence of the durability of a flow sensor.***

Property	**unit**	**limit**
Electrical conductivity at 25°C	µS/cm	100-1500
pH value at 25°C		9,5-10
Oxygen	mg/l	<0,02
Sum of alkaline earth (hardness)	mmol/l (°dH)	<0,02 (<0,1)
Iron ?	mg/l	< 0,1
Mangan ??		
Sulphate ?	mg/l	< 0,03
Solid insoluble dirt articles		
Type	Hard magnetite	
Size	mm	0,5 - 1
Amount	mg/l	? - ?

The circulating testing water in the meter(s) under test shall be treated to meet these limits.

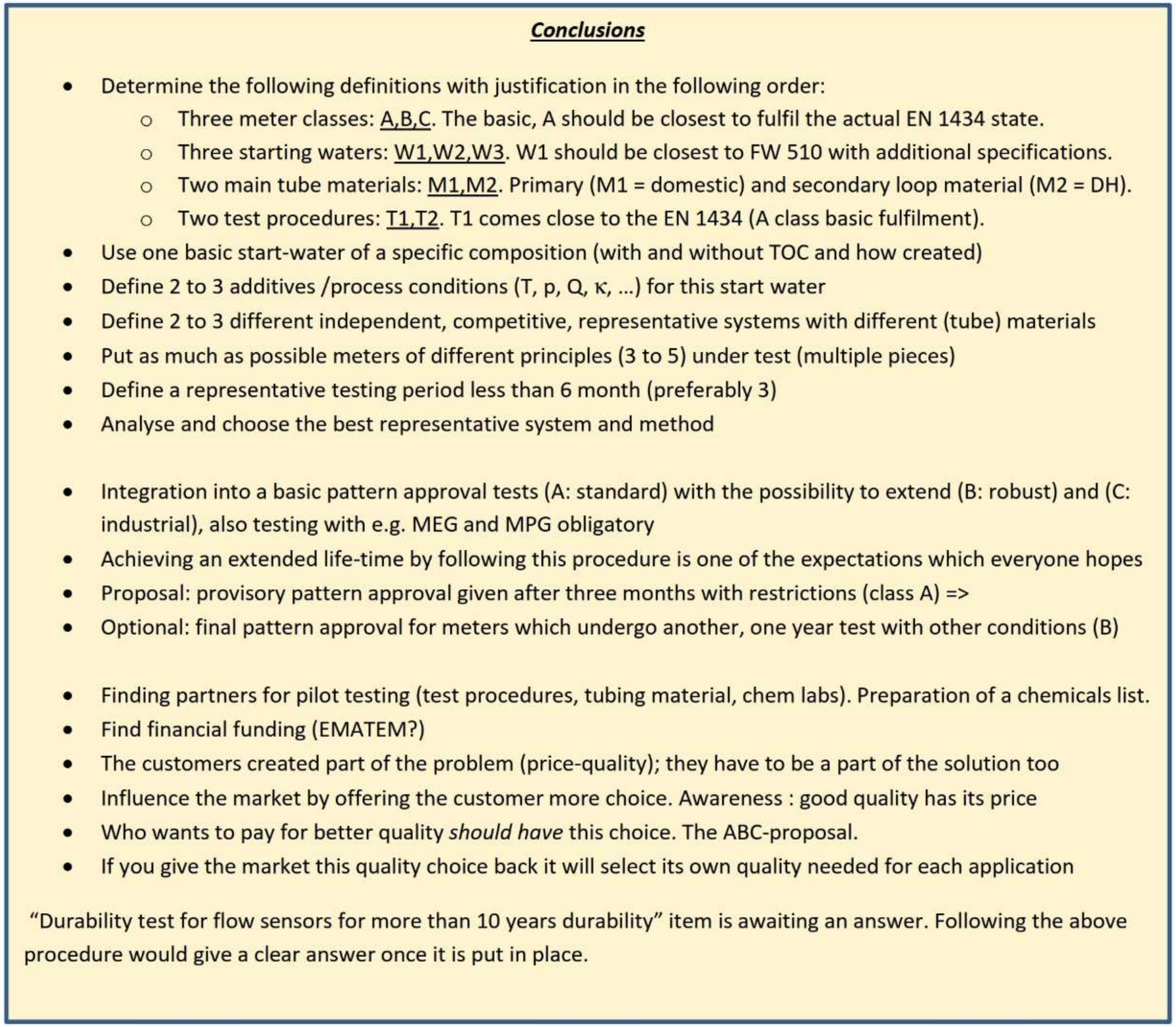
Most of those properties can be found in the AGFW report as well as the Euroheat and Power guidelines
http://www.euroheat.org/Technical-guidelines-28.aspx?PID=52&M=NewsV2&Action=1&NewsId=70

The determination of the error of indication before and after the durability test shall however be done with normal drinking water that for electromagnetic type flow sensors shall have an electrical conductivity higher than 200 µS/cm.

NOTE 1
This means that the estimated durability time is based on a test with a water that is typical for district heating sub stations.In installations with a more "dirty" water you can probably not expect this estimated durability time.

NOTE 2
More explanatory information about district heating water can be found in the CEN Technical report xyz *based on the AGFW report*

Findings 2018 ad hoc group TC 176 WG2



Conclusions

- Determine the following definitions with justification in the following order:
    - Three meter classes: A,B,C. The basic, A should be closest to fulfil the actual EN 1434 state.
    - Three starting waters: W1,W2,W3. W1 should be closest to FW 510 with additional specifications.
    - Two main tube materials: M1,M2. Primary (M1 = domestic) and secondary loop material (M2 = DH).
    - Two test procedures: T1,T2. T1 comes close to the EN 1434 (A class basic fulfilment).
- Use one basic start-water of a specific composition (with and without TOC and how created)
- Define 2 to 3 additives /process conditions (T, p, Q, κ, ...) for this start water
- Define 2 to 3 different independent, competitive, representative systems with different (tube) materials
- Put as much as possible meters of different principles (3 to 5) under test (multiple pieces)
- Define a representative testing period less than 6 month (preferably 3)
- Analyse and choose the best representative system and method

- Integration into a basic pattern approval tests (A: standard) with the possibility to extend (B: robust) and (C: industrial), also testing with e.g. MEG and MPG obligatory
- Achieving an extended life-time by following this procedure is one of the expectations which everyone hopes
- Proposal: provisory pattern approval given after three months with restrictions (class A) =>
- Optional: final pattern approval for meters which undergo another, one year test with other conditions (B)

- Finding partners for pilot testing (test procedures, tubing material, chem labs). Preparation of a chemicals list.
- Find financial funding (EMATEM?)
- The customers created part of the problem (price-quality); they have to be a part of the solution too
- Influence the market by offering the customer more choice. Awareness : good quality has its price
- Who wants to pay for better quality *should have* this choice. The ABC-proposal.
- If you give the market this quality choice back it will select its own quality needed for each application

"Durability test for flow sensors for more than 10 years durability" item is awaiting an answer. Following the above procedure would give a clear answer once it is put in place.

Conclusions ad-hoc group TC 176 WG2, 2018-011-07

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    - Three meter classes: A,B,C. The basic, A should be closest to fulfil the actual EN 1434 state.
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CEN TC 176 WG2 Ad-Hoc-Group „adapt the meter onto its application”.

Recommendation: make distinctions, offer choices, divide meter in classes: regular-robust-industrial. Give the consumer its free choice back.

- Spec. W1:
- Water according CEN/TR 16911

- Spec. W2:
- Water according CEN/TR XXX

- Spec. W3:
- water (particles, dirt, aggressive, desalted)

- Spec. O:
- Other liquids (has to be specified)

Other aspects (under construction)

In case of the use of applications with piezo-electric elements:

- Ultrasonic, thickness vibration mode, polarisation d33, typical 1 MHz
- Fluidic, flexion mode (cantilever), polarisation d31, typical 0.2 till 50 Hz

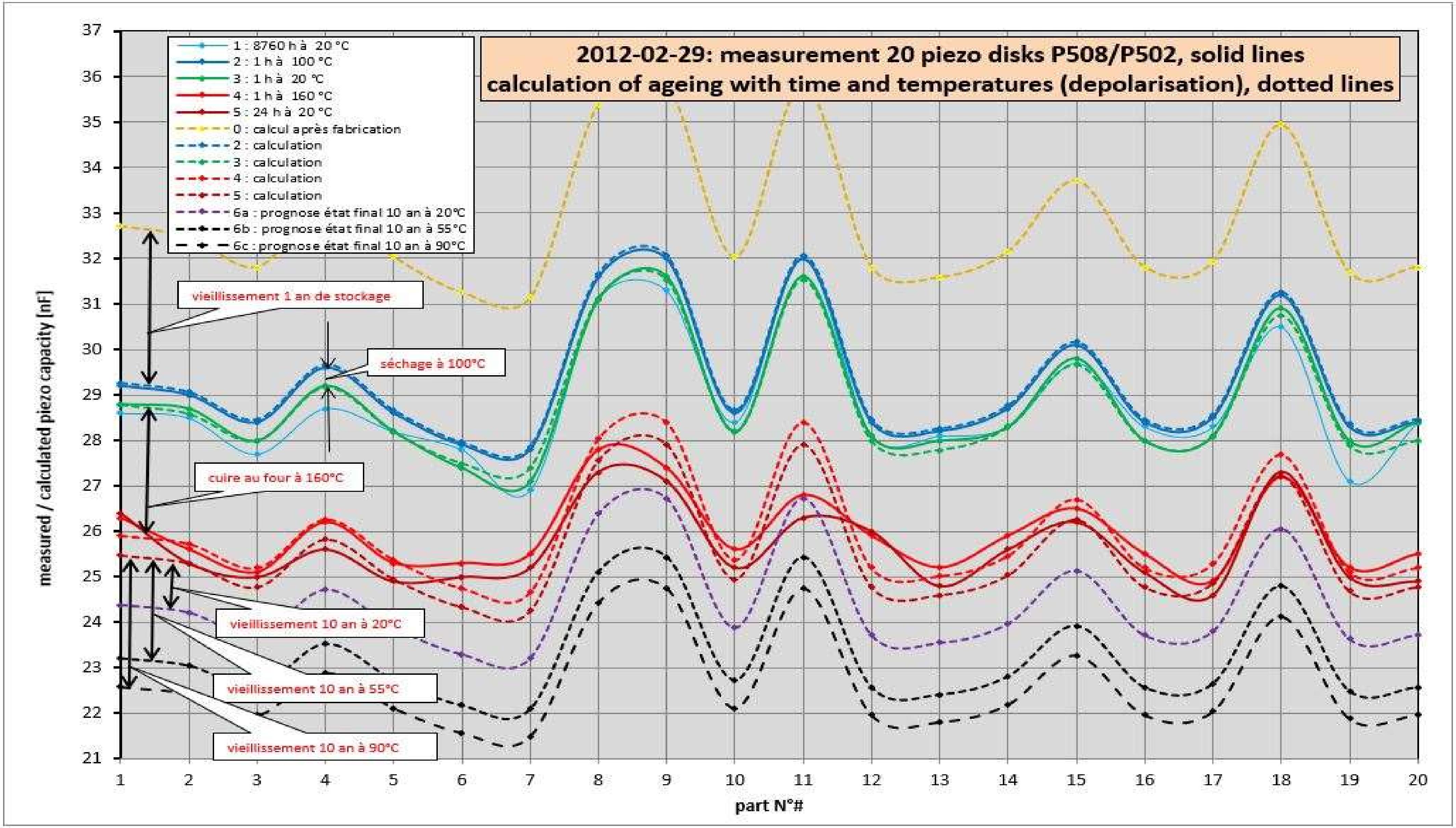
Ageing aspect influence on lifespan:

Ageing of poly-crystalline piezo material

Natural mono crystals as quartz have a weak natural piezo effect with a permanent polarization. The polarisation is “frozen”.

Industrial pressed poly-crystalline piezo disks have an artificial piezo effect, only up to their Curie-temperature. This is not some digital limit. PZT27 material for instance has a Curie temperature of 250°C, and can therefore only be used stable up to 150°C. Depolarisation of this material is a continuous degradation process, depending on both *time* and *temperature*. After a few hundred years they will have lost most of their piezo effect and become ordinary “stones”; however, one can polarize them again if one likes.

The following graph shows the ageing effect; on the shelf, or by use at elevated temperature. The initial state has been measured; the calculation has been done forwards- and backwards in time. The aging process described is easily practically verifiable.



2012-02-29: measurement 20 piezo disks P508/P502, solid lines
calculation of ageing with time and temperatures (depolarisation), dotted lines

To be continued: the creation of ad hoc group lifespan, besides the already existing ad hoc group durability.

Today's bonus: the "forgotten" contribution!

Partially related to life-time (the transport of conveying liquids under constant pressure stresses materials).

Thermodynamic Potential Functions

V (Volume) [m^3]
P (Pressure) [Pa]
T (Temperature) [K]
S (Entropy) [kJ/K]

Four basic thermodynamic potential functions [kJ] exist with each having their own applications / advantages:

U(S,V): Internal energy; isentropic (adiabatic), or isochoric apps

H(S,P): Enthalpy; heat transfer applications (H=U+pV)

F(T,V): Free energy (Helmholtz function); isothermal or isobaric processes; chemical reactions (F=U-TS)

G(T,P): Free enthalpy (Gibbs function); isothermal and isobaric processes; phase transitions (G=U+pV-TS)

For enthalpy difference ΔH this becomes:

$\Delta H = T\Delta S + V\Delta p$ = exchanged heat + transport energy (displacement work)

$$\Delta H = m \int c_p(T)\, dT + \int V(p)\, dp = \rho(T_{meter})\, V(T_{meter}) \int c_p(T)\, dT + \int V(p)\, dp = \text{TEM} + \text{WORK}$$

All terms consider **only** the part between T_{up} and T_{dwn}. And T_{meter} can be T_{up} or T_{dwn}.

The second term in the enthalpy equation **(red)** is the transportation energy, similar as for electric power transport. This part is **not** included in the TEM! V(p) becomes V for “incompressible” liquids. The eventual liquid volume change under declining pressure over the section between T_{up} and T_{dwn} may be present or not; but the component is there! A typical order of magnitude in practice is that 95% to 97% is thermal energy exchange, and, consequently, respectively 5% to 3% is transport energy loss in friction (pumping energy to bring the liquid from T_{up} to T_{dwn})!

It would only be fair to pay the postman! But then it takes two “integrated pressure/temperature” sensors; nothing magic today. *Besides*, **measuring both pressures also encloses a complete other world** 🤔, but that is another topic.

No two water compositions are the same!

So, what do you expect from a general statement about life-time?

Looking for the emergency exit?

Regularly spectral analysis with Q-Sweep!

Thank you for your attention !