Technical Note			TN-001
Test: Domestic Hot Water, Paragraph 4.23			**Test no.:** 2a and 2b
Assumption: DHW Delivery Temperature			**Assumption no:** 17 & 18
Rev: 1_01	**Date:** 10/12/19	**Author:** Gareth Jones	**Checked:** Rob Clemson

1. Introduction

As a part of the move toward low carbon energy systems, there is a general movement toward reducing operating temperatures on heat networks. This is particularly relevant with respect to electrification of heat (i.e. a move toward using heat pumps), minimises the risk of overheating and will directly reduce the cost of heat.

This is referenced within the CP1: Heat Networks Code of Practice [1] and the move to low temperature networks is explicitly referenced within the London Plan (Policy S13) as a measure to minimise greenhouse gas emissions.

Government policy is also encouraging the move to low temperature heat networks. The Heat Networks Investment Project (HNIP) project, a £320 million capital investment program commissioned by the Department for Business, Energy & Industrial Strategy (BEIS), also requires applicants to prove that CIBSE CP1 is used in the design process, applying 4th generation design principles. Designs using 3rd generation design principles, including high network supply temperatures, are not eligible for funding [2].

The limiting factor on how low operating temperatures can be set on heat networks and thus, network losses, is the domestic hot water (DHW) delivery temperature.

Under Version 2 of the BESA HIU Test Standard, there are two temperature regimes:

- “High temperature” Regime, with 70 °C DH delivery temperatures; and
- “Low temperature” Regime, with 60 °C DH delivery temperatures.

For the High Temperature regime, the DHW setpoint is 55 °C, whereas for the Low Temperature regime, the DHW setpoint is 50 °C. These are the setpoints set out within Para 4.23 for test no 2a (High Temperature) and test no. 2b (Low Temperature) with Assumption No. 17 and 18 respectively.

The purpose of this technical note is to review the evidence for either retaining or adjusting these test points for a future version of the BESA HIU Test Standard.

There are four key issues to take into consideration when considering the DHW temperature set point on heat networks with instantaneous DHW generation via HIUs:

1. Technical Guidelines
2. Health & Safety (Legionella vs Scalding)
3. Dish washing
4. Resident comfort

The following sections review the considerations with regards to each of these elements.

2. Technical Guidelines

The NHBC Stardards 2019 (8.1.5 Hot Water Service) require 55°C to be delivered to the kitchen sink – see a reproduction of Table 3 below [3]. We understand that this figure is currently under review, but currently, all developments that have NHBC as the insurer have this requirement in order to be compliant.

Outlet	Design flow rate (1)		Minimum flow rate (2)		Supply temperature °C (3)
	L/sec	(L/min)	L/sec	(L/min)	
Bath (from storage)	0.30	(18)	0.15	(9)	48
Bath (from combi)	0.20	(12)	0.15	(9)	40
Shower (non-electric)	0.20	(12)	0.10	(6)	40
Wash basin	0.15	(9)	0.10	(6)	40
Sink	0.20	(12)	0.10	(6)	55

The latest version of CP1 put out for consultation (CP1.2) sets out a new requirement with regards to hot water delivery temperature, with temperatures to be set to 50-55°C:

"2.4.7b The hot water delivery temperature at the instantaneous HIU shall be set to 50-55°C. These temperatures are acceptable provided the volume of water is small and the Legionella risk can be controlled. HSG 274 (Part 2) and ACOP L8 state that instantaneous water heaters are low risk. The requirements of BS EN 8558 (2015)and BS EN 806 (2012) shall be followed."

However, it is understood that the 55°C upper bound was influenced by the NHBC technical standards, in order to not be in conflict with these – as such, there is some circularity.

BS 8558:2015, which provides guidance to the design, installation, testing and maintenance of services supplying water for domestic use within buildings, sets out in Para 4.3.5.1.1 that the water temperature delivered to a TMV or outlet should be an outlet should be at least 50 °C within 1 min of running the water, primarily for Legionella control. However, this document is specifically noted as being guidance and the preamble in 4.1 makes reference to the Health and Safety Executive's ACOP L8 and BS 8580.

BS 806-2:2005, which sets out the specification for installations inside buildings conveying water for human consumption, states that hot water installations shall be installed so that the risk of scalding is minimized. While it provides *maximum* temperatures for outlets in certain conditions (e.g. nursing homes) it has no requirements for minimum temperatures.

BS 8580-1:2019, Water quality – Risk assessments for Legionella control – Code of Practice, gives recommendations and guidance on Legionella risk assessment. The main body of the document provides no specific requirements with regards to control measures, other than to note that "*although Legionella actively grows between 20 °C and 45 °C, if the system contains water at a temperature greater than 20 °C* *and less than 50 °C, and an aerosol can be generated under any foreseeable circumstance (operation or maintenance), then it is a system at risk of causing legionellosis. The risk of proliferation is highest between 32 °C and 42 °C.*"

Annex B to BS 8580-1:2019, which is noted as being "informative", provides guidelines for specific systems. In this, it sets out that the commonly accepted method to control Legionella in hot water systems is by temperature, with non-circulating systems targeted to reach a minimum of 50 °C within one minute of turning on. However, this is in the context of a system with calorifiers and no consideration is made in the document of systems with instantaneous hot water generation.

In summary, there is a general consensus for industry specifications and guidance that hot water should be delivered to hot water outlets and/or TMVs at 50 °C, with specific requirements about maximum outlet temperatures to avoid scalding. However, this guidance generally defers to the HSE with respect to Legionella control.

The one outlier is NHBC, which has a requirement of 55 °C at the kitchen sink. NHBC do not provide any justification for this temperature requirement in their documentation. However, from conversations with NHBC it is understood that historically this was a legacy issue related to storage systems and, more recently, is related to concerns over adequate temperatures for manual dishwashing and concerns over resident complaints.

3. Health & Safety: Legionella vs Scalding

With regards to resident comfort and safety, there is a balance to be achieved between legionella control, comfort and the risk of scalding. As per HSG274 Part 2 (2.2), risk assessments should consider both the relative risks of Legionella and scalding [4].

As noted within HSG274 Part 2 (2.163), there is a risk of scalding where the water temperature at the outlet is above 44 °C. As set out in 2.83, "*at 50 °C, the risk of scalding is small for most people but the risk increases rapidly with higher temperatures*." Indeed, there is over a 10-fold increase in scalding with an increase in DHW temperature from 50 °C to 55 °C.

With respect to Legionella, as set out in DSG274 Part 2, there is a reasonably foreseeable risk of Legionella if:

a) water is stored and/or re-circulated;

b) the water temperature in all or some parts of the system may be between 20–45 °C;

c) there are deposits that can support bacterial growth; and

d) it is possible for water droplets to be produced and if so, they can be dispersed.

Traditional, hot water systems in the UK have had water storage, with calorifiers, and risk mitigation approaches have been set accordingly, with the use of higher temperatures to reduce the risk of Legionella growth in the system.

For these systems, the guidance within HSG274 Part 2 is to:

- Set control parameters to ensure water is stored at 60°C ;

- Ensure DHW delivered to outlet at a minimum of 50 °C within one minute; and
- Ensure return temperatures at least 50 °C on systems with recirculation.

However, HIUs with instantaneous DHW generation do not fall under this class of systems. While there are issues with the clarity with HSG274 Part 2, it does state that systems with low volumes of water storage (e.g. instantaneous DHW HIUs) are low risk systems:

"2.68 Low storage volume heaters (ie no greater than 15 litres) such as instantaneous units and POU heaters, may be generally regarded as lower risk"

The guidance within HSG274, Part 2 is that such systems:

- Should be able to achieve a peak temperature of 50 °C - 60 °C; and
- Recommend using temperatures <50 °C only where there is high turnover (or alternative control).

There is no recommendation with respect to 50 °C being achieved at the outlet and the "one minute" advice is absent.

As such, it can be taken that the guidance is that such systems are able to achieve 50 °C at peak temperature output. There is some indication that <50 °C is permissible where there is very high turnover, but no definition of "high turnover" is provided.

Looking to mature markets with heat networks, there is some evidence that would suggest that high DHW temperatures are not required (in that there have not been major outbreaks of Legionnaires disease in these countries). As example:

- The Danish standard (DS-439) [5] sets a 50 °C delivery temperature requirement for DHW, with the option of dropping to 45°C during peak period.
- The German standard (DVGW W 551) does not require *any* minimum temperature for systems which have a volume of less than 3 litres, based on evidence that these low volumes inhibit legionella growth [6].

We have further evidence in the UK with respect to instantaneous DHW production from combi boilers. A study by the Energy Savings Trust in 2008 [7] showed that >50% of the combi boilers in the study were generating hot water at or below 50 °C, with c.35% below 48 °C. Given that there were c.13m combi boilers in the country in 2011 [8] yet relatively limited numbers of Legionnaires' disease, this would suggest that operating DHW systems at these temperatures does not pose a significant Legionella risk.

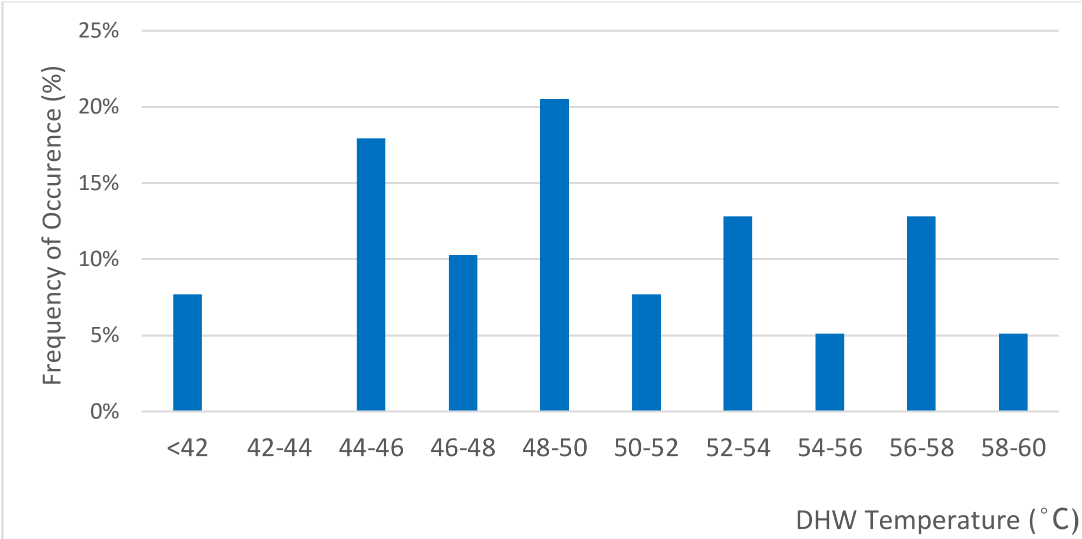

Figure 1 Energy Savings Trust: Frequency of DHW Delivery Temperatures for Combi Boilers.

To put it in context there were 532 confirmed cases of Legionnaires' disease in the UK in 2018 [9]. Of these, 35% of cases were from international travel. The domestic cases include Legionella from cooling towers, hot pools and other sources which have generally been the major drivers of outbreaks of Legionella in the UK.

This contrasts with c.2,500 cases of scalding per annum. According to NHS Hospital Episode Statistics for England, from 2017-2018, 755 people were treated in hospital for scalding from taps. Of these 178 incidents were for children under 4 and 111 were for older people between the ages of 85-89 [10].

In summary, the systems with HIUs of the type tested within the BESA HIU Test Standard may be considered to be "low risk systems", with the guidance being that such systems should achieve a minimum peak temperature of 50 °C.

Given that there is no good evidence that DHW temperatures need to be set above 50 °C for the control of Legionella with these systems, yet there is evidence of a significant increase in scalding risk, this would suggest that the DHW set point should not be set above 50 °C from a Health & Safety perspective, all other issues being equal.

While HSG274 Part 2 guidance does allow for temperatures lower than 50 °C, provided there is high turnover, and there is evidence from other countries and combi boilers in the UK that lower temperatures are not necessarily an issue. However, HSG274 Part 2 provides no definition of what would constitute "high turnover" and we have not uncovered any direct evidence or research showing that temperatures below 50 °C are an acceptably low Legionella risk.

As such, this would suggest that 50 °C should be seen as the floor for DHW temperature for these systems at this time.

4. Dish Washing

The requirement for high temperatures for dishwashing is sometimes cited as a reason for needing high DHW temperatures at the kitchen sink.

The following sub-sections provide evidence with regards to temperature requirements for manual dishwashing.

4.1. Testing of dishwashing detergents

Standards for performance testing of hand-dishwashing detergents have been published by the European Commission – under: “Revised Framework for testing performance for hand dishwashing detergents 2017” [11]. This framework serves as a proof to show compliance with the criterion "Fitness for use", for products that fall under the scope of product group “Hand Dishwashing Detergents”

One of the key details of the test is the temperature at which the washing tests are performed (as taken from the document):

“The water temperature shall be the same for all repetitions. At the start of the test the soak temperature in the basin shall be 45 ± 1°C and kept constant throughout the test. However, a decrease of the water temperature during the test is acceptable, if it is not more than 10°C and the same temperature decrease is documented for all repetitions”.

Since this is a test that is to be performed on all hand-dishwashing detergents, we can therefore assume that all the commercially available hand-washing detergents in Europe will be effective given DHW delivery temperatures of 45 °C and above.

4.2. Manufacturer Feedback

In the context of discussions with NHBC on DHW temperature requirements for a specific project, NHBC requested feedback from a manufacturer of dishwashing detergents that 50 °C was sufficient. As such the author’s company (FairHeat) contacted contacted Proctor & Gamble to enquire about the recommended usage for their Fairy brand dishwashing detergent.

The response from Proctor & Gamble’s R&D department was as follows:

"*We test Fairy across a range of temperatures. However, 38-41 °C is in the normal temperature range that a consumer would use for this product.*"

As such, it can be considered that any temperature in excess of 42 °C would be sufficient and certainly this is not the limiting factor with respect to temperature requirements.

4.3. Temperature decay

In the context of the same discussions with NHBC referred to in 4.2 above, NHBC raised some concerns about temperature decay within the sink when 50 °C water is used for hand dishwashing and whether an adequate temperature will be maintained for a sufficient period to enable dishes to be washed.

To measure this effect, FairHeat conducted a test by filling a standard stainless-steel kitchen sink with water at 50 °C and leaving it to rest in ambient conditions. This setup can be seen in Figure 2.

The instrumentation used to measure the water temperature was a Testo 115i smart probe; this allowed readings to be automatically recorded every 2 seconds for more than 2 hours. The probe had the following technical details:

- Measuring range: -40 °C to +150 °C
- Measurement accuracy: ±1.3 °C
- Measurement resolution: 0.1 °C

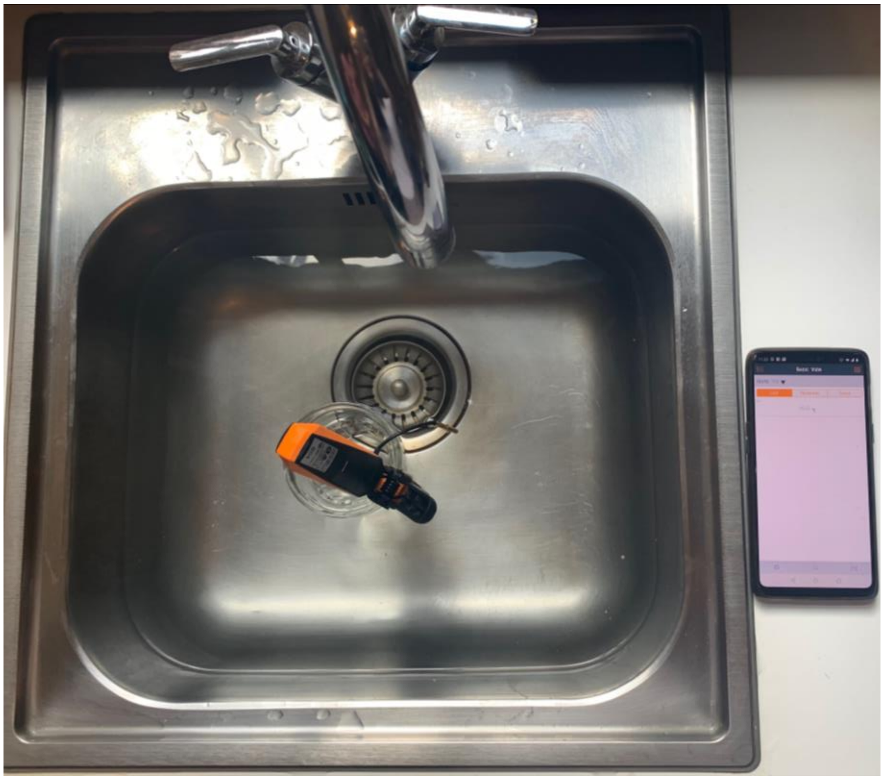

Figure 2: The testing setup used to measure the temperature decay of a bowl of 50 °C water.

The results of this process are displayed in Figure 3.

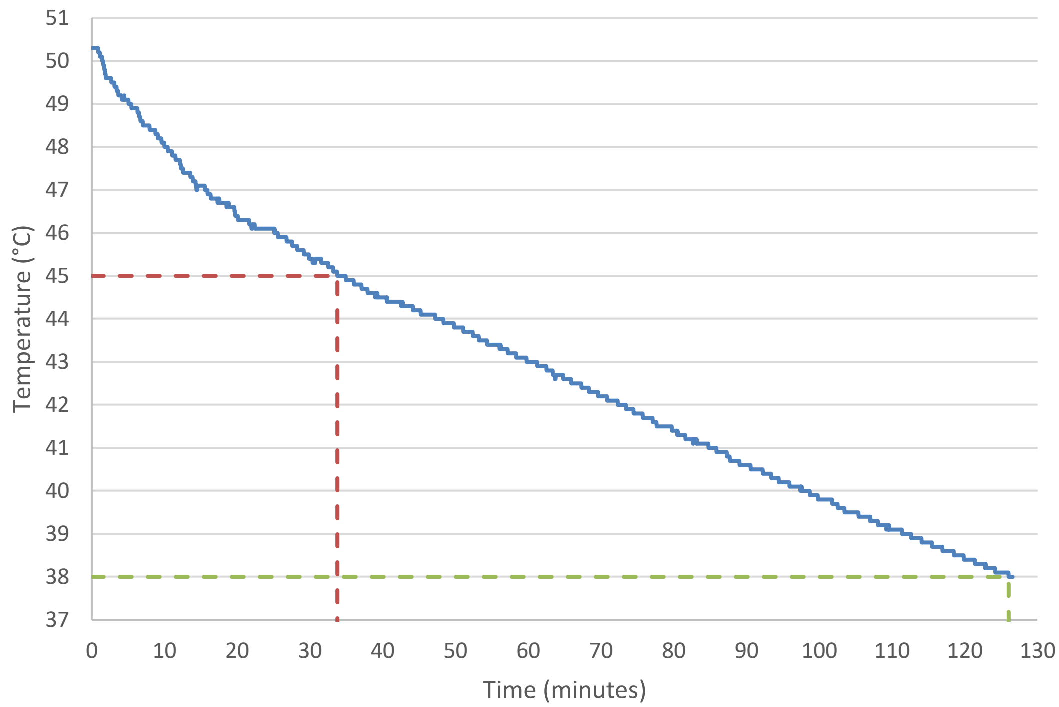

Figure 3: The decay in temperature of 50 °C water in ambient conditions. Lines are added to show the time to reach 45 °C and 38 °C respectively.

It can be seen that the decay in temperature of water within the kitchen sink provides ample time for hand dishwashing to be performed.

As shown, it took almost 35 minutes for a decay from 50 °C to 45 °C, which is the starting point for the testing of dishwashing detergents. Overall, over 2 hours of temperature decay was required for the water temperature to fall below that of Proctor & Gamble's expected use range.

Although it is accepted that performing hand dishwashing in the bowl of water would increase the rate of temperature decay, it is not believed that this decay would cause water temperatures to drop below usage temperature before dishwashing was completed.

4.4. Empirical feedback

The author's company (FairHeat) has worked on a total of 12 new-build developments making use of a DHW outlet temperature of 50 °C. In addition to these, FairHeat have also worked on 3 legacy developments where the DHW outlet temperature has been 50 °C.

These sites range between housing, shared ownership, private and commercial developments.

As part of the process for this current exercise (evaluating DHW temperatures) the author has contacted the client organisations and is not aware of any complaints by residents about the delivery temperature of the kitchen taps across these 15 developments.

Furthermore, during the legacy dwelling works performed engineers had chance to discuss issues with residents; there were no complaints about the final outlet temperature.

Finally, as part of a recent practical demonstration project in Denmark, a “real-life” operating district heating scheme was used to demonstrate how system temperatures could be lowered to improve energy efficiency while maintaining end-user satisfaction. System supply temperatures were around 50°C while DHW flow temperature averaged 40-45 °C over a two-year period with no complaints from any of the residents [12].

In summary, we have not managed to find any evidence that temperatures in excess of 50 °C DHW are required for dishwashing, with the great majority of evidence indicating that 45°C is an appropriate temperature for dish washing (particularly given that dishwashing liquids are optimised for this temperature).

5. Resident Comfort

As illustrated clearly in the table below from the Children’s Burns Trust campaign’s HotWaterBurns website, there is a risk of burns at temperatures of 45 °C and above. Indeed, HSG274 Part 2 states that the risk of burns increasing rapidly as temperatures increase above 44 °C.

As hot water is uncomfortably hot for human skin at above 44 ˚C, there is no evidence that hot water is required to be produced at temperatures above this point from a resident comfort perspective.

Type of Burn	Time of exposure in minutes and seconds							
Temp	45°C	50°C	55°C	60°C	65°C	70°C	75°C	80°C
Adult 3rd	>60 m (e)	300 s	28 s	5.4 s	2.0 s	1.0 s	0.7 s	0.6 s (e)
Adult 2nd	>60 m (e)	165 s	15 s	2.8 s	1.0 s	0.5 s	0.36 s	0.3 s (e)
Child 3rd	50 m (e)	105 s	8 s	1.5 s	0.52 s	0.27 s	0.18 s	0.1 s (e)
Child 2nd	30 m (e)	45 s	3.2 s	0.7 s	0.27 s	0.14 s	<0.1 s	<0.1 s (e)

(e) = estimated

6. Recommendations

<u>Test 2b: Low temperature regime</u>

There would be significant benefits to dropping the DHW temperature from 50 °C to 45 °C for low temperature heat networks.

While the evidence suggests that this temperature would be sufficient for manual dishwashing and resident comfort, HSG274 Part 2 guidance would suggest that a peak temperature of 50 °C should be achieved on these systems. While there is empirical evidence to suggest that lower temperatures are not a problem, further research would be required before a recommendation could be made to move away from this position.

As such, **the recommendation is to maintain the DHW temperature set-point at 50 °C for this test.**

<u>Test 2a: High temperature regime</u>

As with the considerations for Test 2b above, there is no evidence that temperatures above 45 °C are required for resident comfort and dish washing.

Furthermore, as per Section 3 above, the balance of evidence would suggest that the DHW set point should *not* be set above 50 °C from a Health & Safety perspective.

However, it needs to be appreciated that this position is in conflict with the NHBC technical standards, which require a minimum of 55 °C at the kitchen tap. Given that NHBC provides insurance to a significant proportion of new build developments in the UK, HIUs will need to output DHW at this temperature, unless NHBC's position can be changed.

As such, the recommended approach depends on the future position of the NHBC.

(a) If it is possible to convince the NHBC to change their technical standard, then the recommendation is that the DHW temperature for Test 2a should be changed to 50 °C, in line with Test 2b; alternatively
(b) If the NHBC position remains the same in future, then the DHW temperature for Test 2a should remain at 55 °C.

7. References

[1] CP1 – Heat Networks: Code of Practice for the UK, 2015; CP1.2 Heat Networks: Code of Practice for the UK, 2019 Update, Draft v7 (Public Comment), January 2019.

[2] Triple Point Heat Networks Investment Management. (2018). *Heat Networks Investment Project Application Guidance.* Department for Business, Energy & Industrial Strategy.

[3] National House Building Council. (2019). *NHBC Standards 2019*.

[4] Heath and Safety Executive, HSG274 Part 2: The control of legionella bacteria in hot and cold water systems, 2014.

[5] Dansk Standard, "DS 439 - Code of Practice for domestic water supply installations", 2009.

[6] DVGW, "W551 – Trinkwassererwärmungs- und Trinkwasserleitungsanlagen",1993, Bonn, (in German)

[7] Energy Savings Trust, Measurement of DHW Consumption in Dwellings, 2008.

[8] Department of Energy & Climate Change, United Kingdom Housing Energy Fact File, 2013.

[9] Public Health England, Monthly Legionella Report, December 2018.

[10] Chartered Institute of Plumbing and Heating Engineering press release: "Scalding and burn injuries on the rise this World Plumbing Day"

[11] "Fitness for use" of the Commission Decision (EU) 2017/1214 establishing EU Ecolabel criteria for "Hand Dishwashing Detergents"; Framework for testing performance for hand dishwashing detergents, 2017.

http://ec.europa.eu/environment/ecolabel/documents/performance%20test%20HDD.pdf

[12] Results and experiences from a 2 - year study with measurements on a low - temperature DH system for low energy buildings, Technical University of Denmark, Danish Technological Institute, Danfoss, COWI, 2012 – available at http://heating.danfoss.com/PCMPDF/VFHZC102_results-and-experiences_lores.pdf