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TNO-report

R 2003/141

Test Directive for Hot Water Heat Pumps

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1. Introduction / Considerations

Commissioned by Novem and in consultation with NUON and several manufacturers and suppliers of hot water heat pumps (HWHP), TNO Environment, Energy and Process Innovation drew up a test directive for hot water heat pumps (R 98/463) in November 1998. The aim of this directive was to positively affect the implementation of hot water heat pumps by means of a realistic assessment in the NEN 5128;1998. We chose an approach that presents the performance of hot water heat pumps in a clear and standardized manner, complying as much as possible with existing rules (NEN5128), tests (quality mark for heat pumps) and guarantees (GIW). In this way, also a method was established that could be used as a tool for subsidy schemes.
As a result of the tests, TNO deemed it necessary to adapt the test directive. Compared to the directive published in 1998 (R 98/463), these adaptations do not affect the final results, but should be regarded as a clarification of the directive.

To classify hot water heat pumps, we will comply with the classification according to the tapping patterns described in NEN 5128;2001 (see also Appendix 1) [1]. In order to determine the energy efficiency of hot water heat pumps, the appliances are tested using one or more tapping patterns from the NEN standard referred to above. In this way, we will obtain a clear picture of the efficiency of hot water heat pumps for a specific application within the NEN5128;2001. The method described can be used for the heat pump quality mark, subsidy schemes and the GIW requirements. In determining the appliance's efficiency, the pipe length falls outside the system limits (pipe length 0 metre). This means that the maximally required temperature at the appliance's outlet is 55 °C [1].

In testing hot water heat pumps that can be used for both hot water production and space heating, the coefficient of performance for space heating is determined in conformity with the NEN-EN 255 part 2 [3].

2. Test Directive

2.1 Definitions and Symbols

Hot water heat pumps
Hot water heat pumps include heat pump boilers and integrated heat pumps.

Heat pump boilers
Heat pump boilers are appliances that, by way of an electric heat pump, produce a quantity of hot water which is stored in a boiler tank. In addition to the heat pump, this appliance can also be equipped with an electric auxiliary heating source.

Integrated heat pumps
Integrated heat pumps are electric appliances that combine two functions: space heating and hot water production, possibly stored in a boiler tank. Both functions use the same cooling agent cycle, but not necessarily simultaneously.

Tapping curve
The tapping curve of a hot water heat pump is a graphical representation of the hot water temperature when the initially thermally completely filled boiler is thermally emptied with a constant volume flow.

Stage 0. Tapping curve at maximum temperature setting (optional)
In this test stage, the heating-up time, the energy consumption during heating-up and the tapping curve of the hot water heat pump are determined. This is done for the settings at which the hot water heat pump reaches its maximum temperatures. This stage is passed through if these settings differ from those at normal operation.

Stage 1. Heating-up period
In this test stage, the heating-up time of the hot water heat pump is determined.

Stage 2. Determination of standby losses
In this test stage, the net standby loss of the hot water heat pump is determined.

Stage 3. Determination of the COP
In this test stage, the COP of the hot water heat pump is determined for a tapping pattern as defined in the NEN 5128 [1]. For heat pumps that use returned ventilation air as a heat source, the COP should be determined both including and excluding the fan's energy consumption for the returned ventilation air. These units should be stated with the indices $_{\text{incl.vent.}}$ and $_{\text{excl.vent.}}$.

Stage 4. Determination of the tapping curve
In this test stage, the tapping curve of the hot water heat pump will be determined for the settings with which stages 1 through 3 have been passed through.

Nominal hot water flow rate, F_n
This is the volume flow in litres per minute with which draw-offs are carried out according to one of the tapping patterns in conformity with the NEN 5128 [1].

Energy consumption, E
The energy consumption of a hot water heat pump is the total quantity of electric energy in MJ that is needed to produce hot tap water (compressor, control, safety devices, pumps, fans and any auxiliary heating sources). For heat pumps that use returned ventilation air as a heat source, the electricity consumption (E) should be determined – both including and excluding the fan's energy consumption for the returned ventilation air. These units should be stated with the indices $_{\text{incl.vent.}}$ and $_{\text{excl.vent.}}$.

Energy consumption during the heating-up period, E_h
The quantity of electric energy in MJ that is needed to heat up a completely cold boiler (10 °C) until the control turns off the heat pump, and possibly the auxiliary heater.

Energy consumption during the period of standby loss, E_{s2}
The quantity of electric energy in MJ that is needed to keep a heated-up boiler at operating temperature during a minimum period of 24 hours, in which a number (at least three) of complete on/off cycles have been passed through.

Energy consumption during the draw-off period, E_{t2}
The quantity of electric energy in MJ that is needed during the third stage of the tests, the tapping period of minimally 24 hours.

Corrected energy consumption during the draw-off period, E_t
The quantity of electric energy in MJ, corrected for standby loss, that is needed during the third stage of the tests, the draw-off period of minimally 24 hours.

Energy contents of draw-offs, Q_{t2}
The heat content of the hot water tapped in the third stage in MJ.

Energy contents of the tapping curve, Q_{tk}
The heat content of the hot water tapped in the fourth stage in MJ.

Cold water temperature at entry, θ_{wk}
The temperature of the cold water entering the boiler in °C (default: 10 ^{o}C).

Hot water temperature at outlet, θ_{ww}
The temperature of the hot water withdrawn from the boiler in °C.

Heat source temperature at entry, θ_{bi}
The temperature of the heat source when entering the hot water heat pump in °C.

Relative humidity of incoming air, RV_{bi}
The relative humidity of the air when returned ventilation air is used as a heat source, on entering the hot water heat pump in %.

Quantity of tapped hot water, V_t
The quantity of hot water tapped in the third stage of the tests in litres.

Quantity of tapped hot water with temperatures above 40 °C, V_{40}
The quantity of hot water tapped in the fourth stage of the tests in litres, of which the temperature is 40°C or higher.

Heating-up period, t_h
The time in minutes needed to heat up a completely cold boiler (10 °C) until the thermostat has turned off the heat pump and the auxiliary heating source.

Minimum standby loss period, t_s
A 24-hour period.

Standby loss period, t_{s2}
The period of minimally 24 hours in which several (at least three) complete on/off cycles have been passed through.

Minimum tapping period, t_t
A 24-hour period.

Tapping period, t_{t2}
The period in which, during the third test phase, draw-offs have been carried out. This period ends the moment the thermostat has turned off the heat pump and the auxiliary heating source after a maximum 24h period.

Net standby loss, P_{s2}
The hot water heat pump's average power consumption in Watt that is needed to keep the boiler at operational temperature, without draw-offs taking place. In the case of heat pumps that use returned ventilation air as a heat source, this unit should be determined both including and excluding the fan's energy consumption for the returned ventilation air, and be indicated with the indices $_{\text{incl.vent.}}$ and $_{\text{excl.vent.}}$.

Coefficient of performance for tapping pattern X (COP_x)
The quotient of the energy content of the draw-offs, Q_{t2}, and the corrected energy consumption during the tapping period, E_t. In the case of heat pumps that use returned ventilation air as a heat source, this quantity should be determined both including and excluding the fan's energy consumption for the returned ventilation air, and be indicated with the indices $_{incl.vent.}$ and $_{excl.vent.}$.

2.2 General Procedure

The tests can be divided in five stages.
- Stage 0. Tapping curve at maximum temperature setting (optional)
- Stage 1. Heating-up period
- Stage 2. Determination of standby loss
- Stage 3. Determination of COP_x
- Stage 4. Tapping curve

Before being able to start with the tests (stages 1 through 4), the commissioning party can decide to set the hot water heat pump in such a way that the maximum hot water temperature can be reached in the boiler. With these settings, the hot water heat pump is heated up from a cold condition (boiler tank 10 °C) and subsequently completely thermally emptied in order to determine the tapping curve at the maximum temperature setting (stage 0).

In the first stage of the tests, the cold boiler tank is heated up from a cold condition (boiler 10 °C), followed by stage 2 in which the standby losses of the hot water heat pump are determined. The third stage of the tests consists of performing the tapping pattern in which the COP is determined. In order to determine the tapping curve of the hot water heat pump, the boiler tank is completely emptied thermally in stage 4. Figure 1 gives a clear picture of the various stages of the test directive for hot water heat pumps.

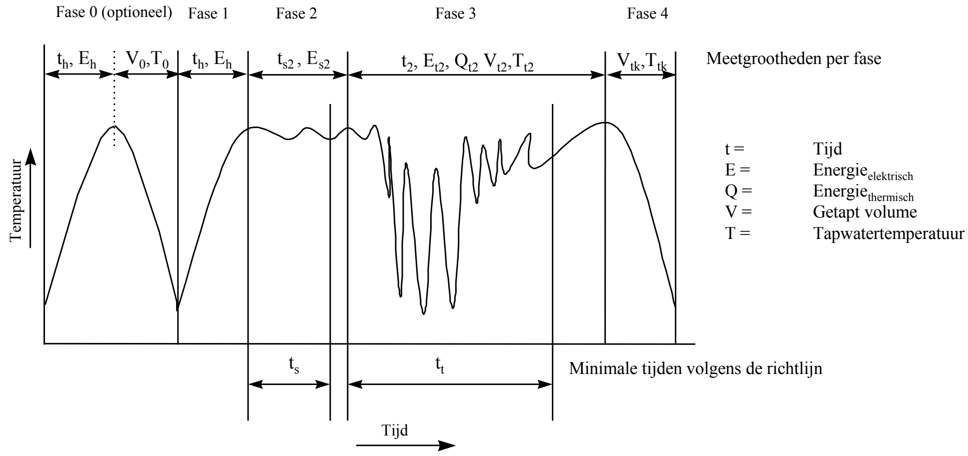

Figure 1 Different stages in the test directive.

2.3 Settings

In stage 0, the settings of the hot water heat pump should be such that the temperature of the hot water supplied (θ_{ww}) is maximal.

If the appliance is equipped with a circulation pump with several operating levels, it is set at the minimum level or the lowest level required for practical use.

The appliance is set in conformity with the manual or according to specifications given by the commissioning party. Prior to the test, the appliance should be set in such a way that the compressor and/or any auxiliary heater can become operational at any moment, if this is required on the basis of temperature levels in the appliance.

During stages 1 through 4, the appliance settings should be such that the desired temperature stated in the tapping pattern is realized at each draw-off ($\theta_{desired}$).

Table 1 shows the conditions of the various heat sources for the heat pump.

Table 1 Test conditions for hot water heat pumps.

Type of heat source	Temperature of heat source	Relative humidity	Temperature of set-up area
Outside air	7 °C	87%	20 °C
Ambient air at indoor set-up	15 °C	71%	20 °C
Ventilation air	20 °C	57%	20 °C
Water (groundwater)	10 °C	n.a.	20 °C
Brine (ground source heat exchanger)	5 °C	n.a.	20 °C

The volume flows of the heat source are set as indicated in the manual or by the commissioning party. If returned ventilation air is used as a heat source, this means that for this volume flow at least the total external pressure difference across the heat pump boiler and the pressure at discharge, calculated using formula 1 below, should be realized.

$$\Delta p_{external\ HP} = \left(\frac{F_{air\ actual}}{150}\right)^2 * 60 \quad [Pa]$$
$$p_{discharge} = \left(\frac{F_{air\ actual}}{150}\right)^2 * 15 \quad [Pa] \qquad (1)$$

$\Delta p_{external\ HP}$ = Minimal external pressure difference across the heat pump boiler [Pa]
$F_{air\ actual}$ = Air flow stated by the commissioning party [m^3/h]
$p_{discharge}$ = Minimal overpressure at discharge of the HP boiler [Pa]

The ventilation quantity stated by the commissioning party is the quantity of air that is measured at the entrance side of the hot water heat pump. For hot water heat pumps that use ventilation air as a heat source, the external leakage losses of the ventilation system are also monitored.

2.3.1 Stage 0. Tapping curve at maximum temperature setting

Objective
To show whether the appliance is able to supply a hot water temperature of 60 °C. This temperature is required by the GIW and in the VEWIN worksheets.

Method
Stage 0 comprises the heating up of the boiler, followed by a draw-off. During tapping, the maximum hot water temperature of the appliance is determined. To this end, the boiler is heated up from a cold condition (10 °C) to the maximum temperature; subsequently, the boiler tank is completely emptied by way of a volume flow of 6 l/min. During this tapping, it is determined how much hot water can be tapped with a temperature above 60 °C and how much with a temperature between 40 and 60 °C.

The tapping stops after the boiler volume has been tapped, provided the hot water temperature has dropped below 40 °C. If not, further water will be tapped until this temperature has been reached. During the withdrawal, the heat pump and the electric auxiliary heater can be turned on because of the hot water heat pump control (depending on the settings stated by the commissioning party). Figure 2 shows the result of such a tapping test (the tapping curve).

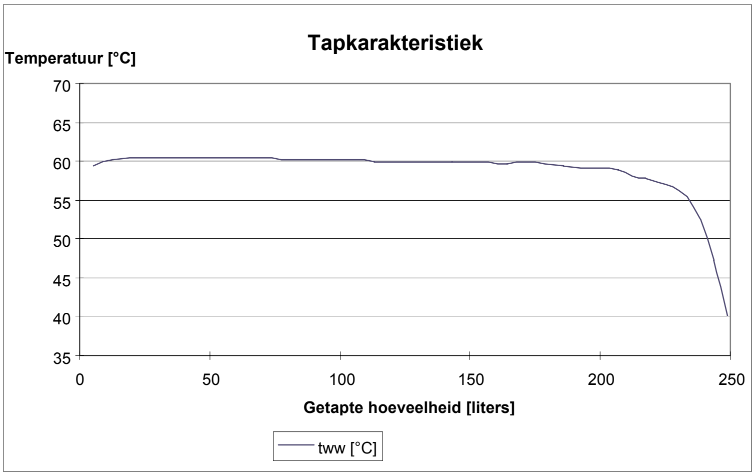

Figure 2 Tapping curve.

2.3.2 Stage 1. Heating-up period

Objective
To determine the heating-up time of the appliance.

Method
At the start of the tests, the heat pump is set according to the manual or to specifications by the commissioning party; the boiler tank is flushed with 10 °C water, until the temperature difference between inlet and outlet water is less than 2 K. During flushing, the heat pump is not operative. If the above criteria are met, the flushing stops and the test can start.
The heat pump is turned on; every five minutes it is determined how much energy the hot water pump has used, including the fan energy or the pump energy. Heating-up lasts until the control turns off the heat pump, and possibly the auxiliary heater. During this heating-up stage, the time (t_h) and the used energy (E_h) are determined that are required to heat up the boiler from a cold condition.

2.3.3 Stage 2. Determination of the standby loss

Objective
To determine the appliance's net standby losses.

Method
After the control has turned off the heat pump – and possibly the electric auxiliary heater – for the first time, we begin to determine the standby loss. The standby loss is determined over a minimum period of 24 hours (t_s), and ends the first time the control turns off the heat pump – and possibly the auxiliary heater – after this maximum 24 h period (t_{s2}). In this maximum period of 24 hours, at least three complete on/off cycles should be passed through. If not, the measurement period is extended until this condition has been met.
During this test stage, it is determined every 15 minutes how much energy has been used by the hot water heat pump, including the fan (E_{s2}). The net standby loss is determined using formula 2. For heat pumps that use returned ventilation air as a heat source, this unit should be determined both including and excluding the fan's energy consumption for the returned ventilation air. These units should be stated with the indices $_{incl.vent.}$ and $_{excl.vent}$.

$$P_{s2} = \frac{E_{s2}}{t_{s2}} \; [Watt] \qquad (2)$$

2.3.4 Stage 3. Determination of the COP

Objective
To determine the COP during hot water production.

Method
As soon as the control turns off the heat pump – and possibly the auxiliary heater – for the first time after the 24-hour period required for determining the standby losses, stage 3 of the tests starts. In this stage, hot water is withdrawn from the hot water heat pump according to a pre-determined tapping pattern [1] (see also Appendix 1). In this process, the required energy content ($Q_{desired}$) is realized for each tapping with water whose outlet temperature is at least above the useful temperature θ_{useful} stated in the tapping pattern. Also, the temperature $\theta_{desired}$ in the tapping pattern must at least be reached during each tapping. If this is not the case, the determined COP may not be applied in the NEN 5128, which fact must explicitly be stated upon presentation of the measurement data (Chapter 3). The actual volumes of water withdrawn are determined on the basis of the quantity of useful energy transmitted to the tapping water. At each draw-off, the desired quantity of energy is derived as follows from the tapping pattern:

$$Q_{desired} = m \times 4.18 \times \Delta\theta$$

where:

$Q_{desired}$	is the desired quantity of energy that must be tapped each time, kJ;
m	is the quantity of tapped water with the desired temperature, in kg; this figure is identical to that used to indicate the tapping volume in dm^3 per draw-off [1];
$\Delta\theta$	is the difference between $\theta_{desired}$ and θ_{cold} in K.

The measurement for each draw-off starts when the tap water has reached the temperature of θ_{useful}. Hot water with a lower temperature is considered loss and thus not taken into account in $Q_{desired}$.
The measurement is stopped as soon as $Q_{supplied} \geq Q_{desired}$. $Q_{supplied}$ is the measured energy content of the tapping. θ_{cold} is used as a reference here.
It should be seen to that the heat volume of the appliance is the same at the beginning and at the end of the measurement. For storage appliances, the start of the measurement is defined as the moment at which the appliance switches off on its thermostat during the heating-up period. After measuring the tapping pattern for a 24-hour period, the appliance is heated up once more. The storage appliance is expected to have reached the same point as soon as it is switched off again by the thermostat. As this may take a long time for low-capacity appliances (for example, heat pump boilers), the energy consumption during this additional period (after 24 h) is determined *excluding* the standby losses.
During tapping, measuring must take place at least as frequently as every 2 seconds Hz. The moment tapping stops, this frequency may be reduced to every 60 seconds. This stage will last for a minimum of 24 hours; the moment the control thermostat

turns off the hot water heat pump for the first time after the 24-hour period, marks the end of this stage. The COP of the hot water heat pump is determined using formula 3 below.

$$COP = \frac{Q_{t2}}{E_{t2} - (t_{t2} - t_t) * P_{s2}} \, [--] \qquad (3)$$

Note:
For heat pumps that use returned ventilation air as a heat source, this unit should be determined both including and excluding the fan's energy consumption for the returned ventilation air. These units should be indicated with the indices $_{\text{incl.vent.}}$ and $_{\text{excl.vent}}$.

The unit excluding the fan's energy consumption for the returned ventilation air may be used in the NEN 1528;2001 as heating efficiency for hot water. As for the unit including the fan's energy consumption for the returned ventilation air, three situations can be distinguished that cannot possibly be compared with each other:

a) The fan for the returned ventilation air is continuously operating at the same level;
b) The fan for the returned ventilation air is turned on and turned off at the same time as the compressor;
c) The fan for the returned ventilation air is switched from the basic level to a higher level every time the compressor starts.

Therefore, it is imperative that the regulation of the fan should be stated.

Tapping pattern
The commissioning party determines the tapping pattern as used within the scope of the test directive. A selection can be made from one or several tapping patterns (class 1 through 4), as described in NEN 5128 [1].

2.3.5 Stage 4. Determination of the tapping curve under normal operating conditions

Objective
To determine the temperature curve at complete emptying of the boiler under normal operating conditions.

Method
After completing stage 3, the tapping curve is determined in the final stage of the tests. To this end, the boiler tank is completely emptied thermally, by way of a 6 l/min flow. The draw-off stops after tapping the boiler volume, provided the hot water temperature has dropped below 40 °C. If this is not the case, draw-offs continue until this temperature has been reached. During the draw-off, the heat pump

and the electric heater can be turned on by the hot water heat pump control. Figure 2 presents the results of such a tapping test.

2.4 Measurement Accuracy

Table 2 shows the required measurement accuracy.

Table 2 Measurement accuracy.

Measured value	Unit	Accuracy
Temperature	°C	± 0.1
Temperature difference	K	± 0.2
Volume flow water	m^3/s	± 2%
Volume flow air	m^3/s	± 5%
Electric energy used	kWh	± 1%
Resolution of the energy measurement	Wh	1
Time	Seconds	± 0.1
Relative humidity	%	± 5%
Time constant (τ) temperature detector	< 1 second	

3. Results / Report

The test report should include at least the following data:
- Brief description of the measurement method
- Brief description of the hot water heat pump
- Test centre
- Test date
- Project manager
- Type of hot water heat pump
- Manufacture, type number, serial number
- Tapping pattern or tapping patterns used to perform the test
- Settings
- Heating-up time
- Standby loss
- COP_x
- Desired and realized temperature during stage 3 (performance of tapping pattern)
- Tapping curve for stages 0 and 4 (figures)
- Conclusions

The conclusions are summarized in a table; table 3 offers an example.

Table 3 Conclusions of test results.

Date:	xx xxxxxx xxxx	
Test institute:	TNO Environment, Energy and Process Innovation 501 Laan van Westenenk P.O.Box 342 7300 AH Apeldoorn, The Netherlands	
Report:	TNO-MEP-R xx/xxx	
Test in conformity with:	Test Directive for hot water heat pumps (HWHP)	
Manufacturer:	“the heat pump manufacturer”	
Type:	“Air/water heat pump boiler”	
Serial number:	xxxx-xxxx	
Boiler contents:	xxx litres	
Equipped with integrated fan and/or pumps:	Yes/no	
Tapping pattern:	pattern x	pattern x
Coefficient of performance for hot water production including fan:	x,xx [-]	x,xx [-]
Coefficient of performance for hot water production excluding fan:	x,xx [-]	x,xx [-]
Heating-up time (only with heat pump)	x:xx:xx [h:m:s]	
Net standby loss, including fan	xxx [W]	
Net standby loss, excluding fan	xxx [W]	
Average volume flow heat source inlet	Xxx [m^3/h]	
Average volume flow heat source outlet	Xxx [m^3/h]	
Maximum number of tapped litres of water with temperatures above 40 °C	xxx [°C]	
Maximum realized temperature in stage 0 (optional)	xxx [°C]	
Maximum number of tapped litres of water with temperatures above 60 °C (optional)	xxx [°C]	

* In the case of heat pumps with returned ventilation air as a heat source, this figure is used to determine over-ventilation)

4. Literature

[1] NEN 5128 Energieprestatie van woningen en woongebouwen - Bepalingsmethode. ICS 91.120.10, December 2001

[2] NEN1006 Algemene voorschriften voor leidingwaterinstallaties (AVWI-2002). ICS 91.140.60, January 2002

[3] EN 255-2
Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors- Heating mode - Part 2: Testing and requirements for marking for space heating units

5. Authentication

Name and address of the principal:

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J. van Wolferen, MSc.

Names and establishments to which part of the research was put out to contract:

Date upon which, or period in which, the research took place:

Signature:	Approved by:
A.A.L. Traversari, MBA, BSc Project Manager	S.M. van der Sluis, MSc Head of Department

Appendix 1 Classification according to NEN 5128

The classification is based on tapping patterns varying around a basic tapping pattern; see Table B.1.

Table B.1 Basic tapping patterns.

No.	Time h/min	Tapping volume dm^3 at θdesired	Tapping flow rate Dm^3/min	θdesired °C	θuseful °C	Use
1	7	4	3.5	40	25	Washbasin
2	7.15	Depending on class	Depending on class	40	40	Shower
3	7.3	4	3.5	40	25	Washbasin
4	8	1	3.5	55	40	Rinsng
5	9	1	3.5	40	25	Washing hands
6	9.05	1	3.5	40	25	Washing hands
7	10	1	3.5	55	40	Rinsing before washing
8	10.3	1	3.5	40	25	Washing hands
9	10.35	0,5	3.5	40	25	Short tap
10	10.45	1	3.5	40	25	Washing hands
11	11	1	3.5	55	40	Rinsing before washing
12	11.3	1	3.5	40	25	Washing hands
13	11.32	1	3.5	40	25	Washing hands
14	11.34	1	3.5	40	25	Washing hands
15	13	5	3.5	55	40	Rinsing before washing
16	13.05	5	3.5	55	40	Dishwashing
17	13.25	2	3.5	55	40	Rinsing before washing
18	13.27	2	3.5	55	40	Rinsing before washing
19	13.29	2	3.5	55	40	Rinsing before washing
20	14	1	3.5	40	25	Washing hands
21	14.3	1	3.5	40	25	Washing hands
22	14.35	0.5	3.5	40	25	Short tap
23	14.45	1	3.5	40	25	Washing hands
24	14.48	1	3.5	40	25	Washing hands
25	14.51	0.5	3.5	40	25	Short tap
26	15	2	3.5	40	25	Washing hands
27	16	1	3.5	40	25	Washing hands
28	16.1	0.5	3.5	40	25	Short tap
29	16.2	0.5	3.5	40	25	Short tap
30	16.3	1	3.5	55	40	Rinsing before washing
31	18	5	3.5	55	40	Rinsing before washing
32	18.05	5	3.5	55	40	Dishwashing
33	18.25	2	3.5	55	40	Rinsing before washing
34	18.27	2	3.5	55	40	Rinsing before washing
35	18.29	2	3.5	55	40	Rinsing before washing
36	19.3	1	3.5	40	25	Washing hands
37	19.35	1	3.5	40	25	Washing hands
38	19.4	0.5	3.5	40	25	Short tap
39	19.45	1	3.5	40	25	Washing hands
40	19.5	1	3.5	40	25	Washing hands
41	20	1	3.5	55	40	Rinsing before washing
42	20.1	2	3.5	55	40	Rinsing after washing
43	21	1	3.5	40	25	Washing hands
44	22	1	3.5	55	40	Rinsing before washing
45	22.3	1	3.5	40	25	Washing hands
46	23	2	3.5	55	40	Rinsing before washing
47	23.15	4	3.5	40	25	Washbasin
48	23.3	Depending on class	Depending on class	40	40	Shower
49	23.45	4	3.5	40	25	Washbasin

Without shower: total volume 60 °C = 61.2 dm^3

Class 'counter': exclusively for use without shower (counter):
— Basic tapping pattern, but with tapping flow rate 2.5 dm^3/min.

Total volume 60 °C = 61.2 dm^3

Class 1: tapping pattern with small tapping volumes, including 1 shower draw-off:
— Basic tapping pattern, but with the addition of shower at time 23.3. See Table B.2:

Table B.2 Class 1: tapping pattern with small tapping volumes, including 1 shower draw-off: basic tapping pattern, but with the addition of shower at time 23.3.

no.	Time h/min	Tapping volume dm^3 at $\theta_{desired}$	Tapping flow rate dm^3/min	$\theta_{desired}$ °C	$\theta_{efficient}$ °C	Use
48	23.3	47	3.5	40	40	shower

Total volume 60 °C = 89.2 dm^3

Class 2: tapping pattern with moderate tapping volumes, including 2 shower draw-offs:
— Basic tapping pattern, but with the addition of shower at times 7.15 en 23.3. See table B.3:

Table B.3 Class 2: tapping pattern with moderate tapping volumes, including 2 shower draw-offs: basic tapping pattern, but with the addition of shower at times 7.15 and 23.3.

no.	Time H/min	Tapping volume dm^3 at $\theta_{desired}$	Gap flow rate dm^3/min	$\theta_{desired}$ °C	θ_{useful} °C	Use
2	7.15	47	3.5	40	40	shower
48	23.3	47	3.5	40	40	shower

Total volume 60 °C = 117.2 dm^3

Class 3: tapping pattern with large tapping volumes:
— Basic tapping pattern, but with the addition of shower at times 7.15 and 23.3. See Table B.4:

Table B.4 Class 3: tapping pattern with large tapping volumes: basic tapping pattern, but with the addition of shower at times 7.15 and 23.3.

no.	Time H/min	Tapping volume dm^3 at $\theta_{desired}$	Tapping flow rate dm^3/min	$\theta_{desired}$ °C	θ_{useful} °C	Use
2	7.15	73	5.5	40	40	shower
48	23.3	73	5.5	40	40	shower

Total volume 60 °C = 149.2 dm^3

Class 4: tapping pattern with very large tapping volumes:
— Basic tapping pattern, but with the addition of shower at times 7.15 and 23.3. See Table B.5:

Table B.5 Class 4: tapping pattern with very large tapping volumes: basic tapping pattern, but with the addition of shower at times 7.15 and 23.3.

no.	Time h/min	Tapping volume dm^3 at $\theta_{desired}$	Tapping flow rate dm^3/min	$\theta_{desired}$ °C	θ_{useful} °C	Use
2	7.15	100	7.5	40	40	shower
48	23.3	100	7.5	40	40	shower

Total volume 60 °C = 181.2 dm^3