REPORT

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Testing of heat interface unit – SAV Systems (Danfoss Termix VVX-I-FI-1-5 RAD STD.)

(1 appendix)

1 Assignment

SP has tested a heat interface unit (HIU) (also known as a district heating substation) from SAV Systems on behalf of FairHeat Ltd.

This report, 5P07886A-rev2, replaces report 5P07886A-rev1 from 2016-03-31. The current version includes changes to section 7.9 (Test 7a: Standby), section 7.10 (Test 7b: DHW response time) and editorial changes.

2 Test method

The test method is described in the UK HIU Test Regime Technical Specification (based on Swedish District Heating Association F:103-7), V1-Rev-009, issued by FairHeat. This will be referred to as the Test Regime throughout this document.

3 Test object

Manufacturer: Danfoss
Model: VVX-I-FI-1-5 RAD STD.
Serial number: L5826460
Year of manufacture: 2015
Domestic hot water priority: no

3.1 Design pressures

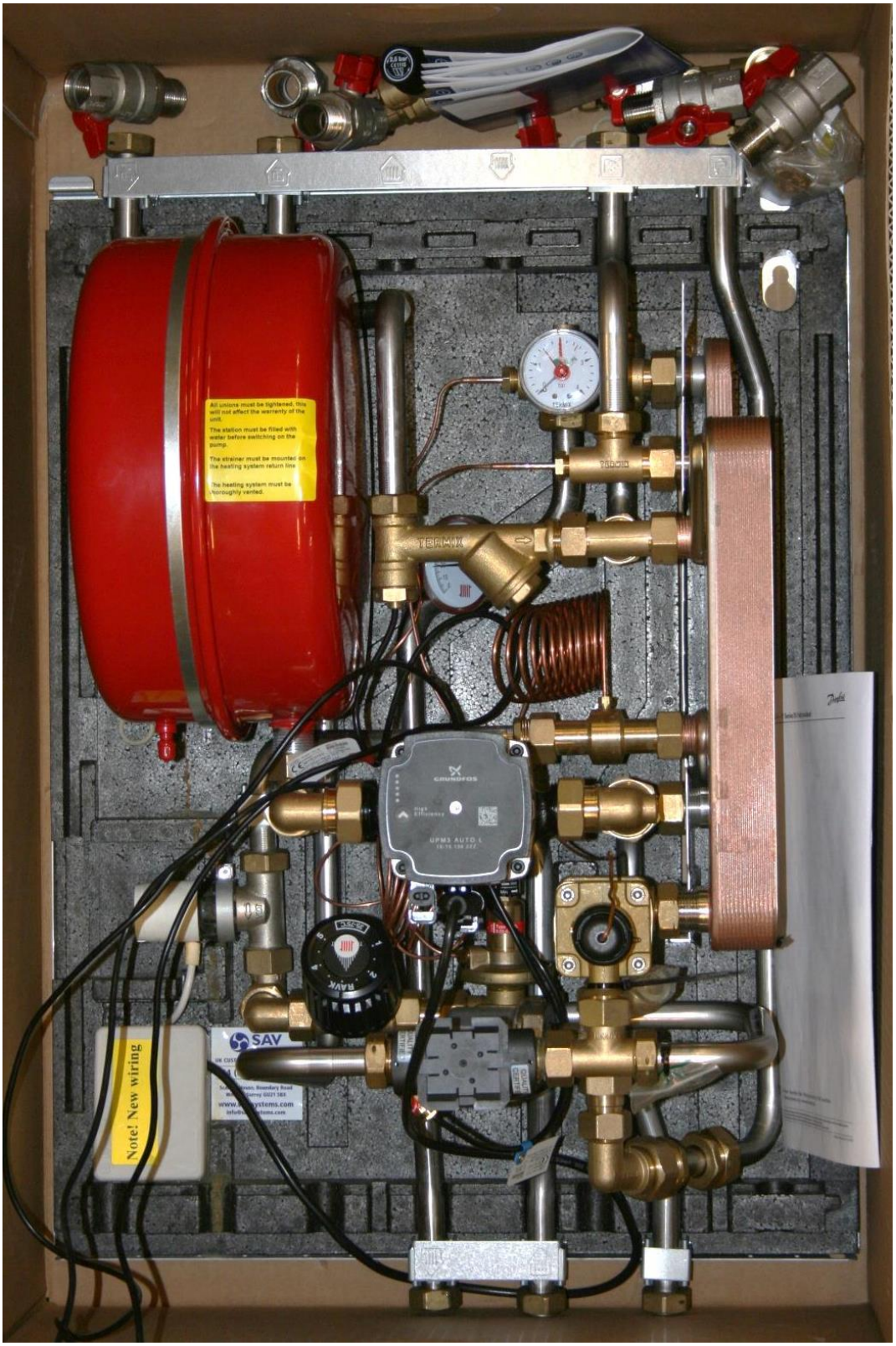
Primary side: 10 bar
Secondary side, radiator: 4.5 bar
Secondary side, DHW: 6 bar

3.2 Design temperatures

Primary side: 120 °C
Secondary side, radiator: 75 °C
Secondary side, DHW: 65 °C

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Figure 1. The test object after testing. Insulation removed.



3.3 Components

Heat exchanger for space heating Danfoss micro heat plate exchanger XB 06H-1 08HP, 3/4", 8 plates **Control system for space heating** *Thermostatic actuator* Danfoss thermostatic actuator RAVK (003L3531), 35 – 75 °C *Control valve* Differential pressure controller AVPL (003L5030), DN 15, k_{vs} 1.0 m^3/h **Heat exchanger for DHW** Danfoss micro heat plate exchanger XB 06H-1 26HP, 3/4", 26 plates **Control system for DHW** Self-acting controller integrated to heat exchanger IHPT-90 (003L3815), DN 15, k_{vs} 3.0 m^3/h	**Other components** *Pump for space heating* Grundfoss UPM3 Auto L 15-70 130 *Expansion vessel* CIMM 12 L 3/4” 0.5 bar *Safety valve* Safety valve Watts MSL 1/2”, 2.5 bar *Manometer* Termix 0-4 bar *Water hammer arrester* FAR Water hammer arrester 2895

3.4 Documents pertaining to the test object

The following document has been supplied with the unit:

- *Installation Guide - Termix VVX-I – 7 Series DS fully insulated* (November 2015)

4 Test location and time

The testing was performed at SP, section of Energy and bioeconomy, in November-December 2015.

The test object arrived to SP in November 2015 with no visible damage.

5 Abbreviations

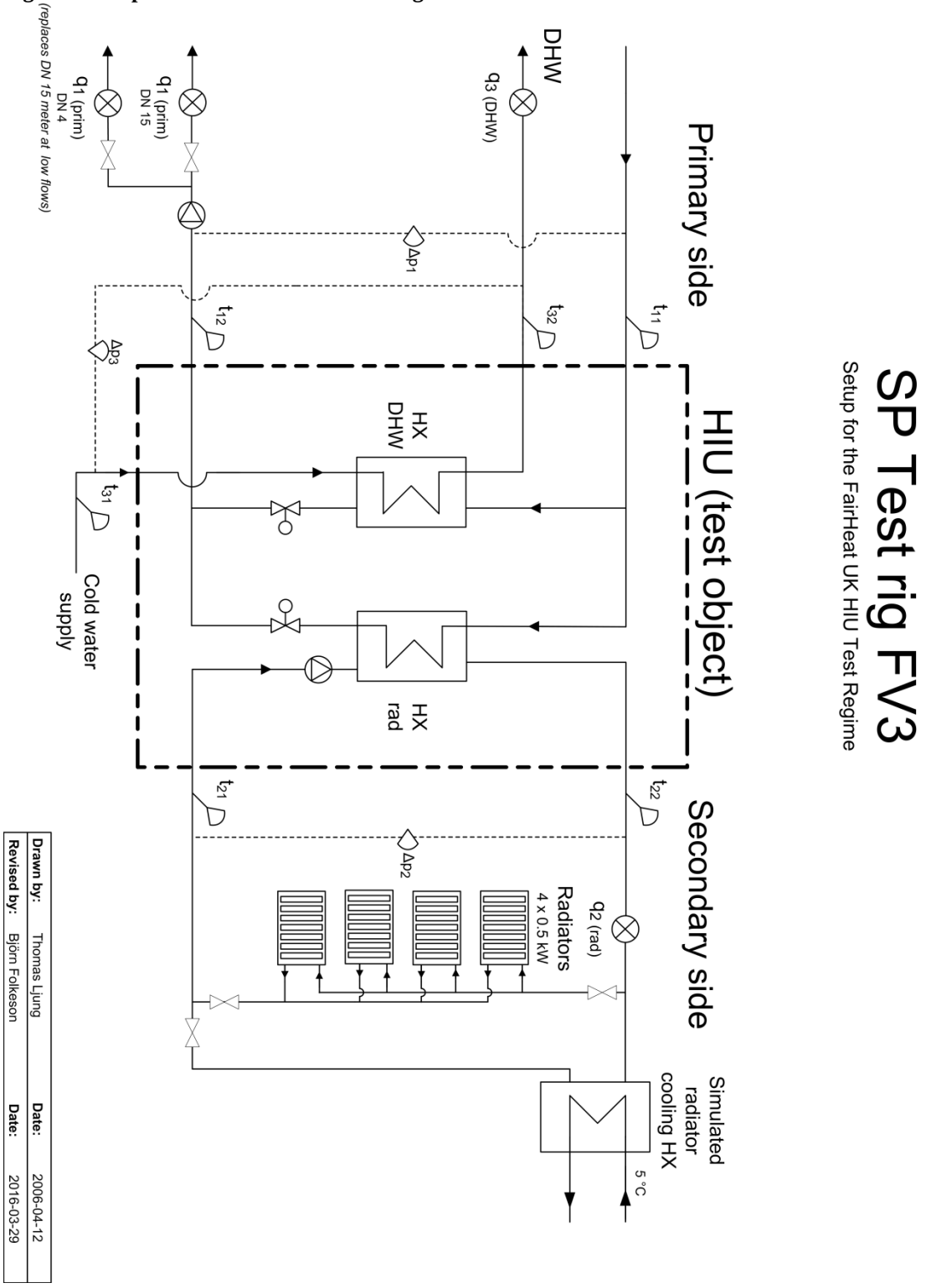
Term	Meaning (*diagram legend entry*)	
DHW	Domestic hot water	-
HIU	Heat Interface Unit	-
SH	Space heating	-
TMV	Thermostatic mixing valve	-
$\mathbf{P_1}$	Power, primary side	[kW]
$\mathbf{P_2}$	Power, space heating system	[kW]
$\mathbf{P_3}$	Power, domestic hot water	[kW]
$\mathbf{t_{11}}$	Temperature, primary side supply connection (*DH supply*)	[^{o}C]
$\mathbf{t_{12}}$	Temperature, primary side return connection (*DH return*)	[^{o}C]
$\mathbf{t_{21}}$	(Temperature, space heating system return connection (*SH return*)	[^{o}C]
$\mathbf{t_{22}}$	Temperature, space heating system supply connection (*SH supply*)	[^{o}C]
$\mathbf{t_{31}}$	Temperature, cold water (*CWS*)	[^{o}C]
$\mathbf{t_{32}}$	Temperature, domestic hot water supply connection (*DHW supply*)	[^{o}C]
$\mathbf{q_1}$	Volume flow, primary side (*DH*)	[l/s]
$\mathbf{q_2}$	Volume flow, space heating system (*SH*)	[l/s]
$\mathbf{q_3}$	Volume flow, domestic hot water (*DHW*)	[l/s]
$\Delta\mathbf{p_1}$	Primary pressure drop across entire HIU unit	[bar]
$\Delta\mathbf{p_2}$	Pressure drop, space heating system across HIU	[kPa]
$\Delta\mathbf{p_3}$	Pressure drop, domestic hot water across HIU	[kPa]

6 Test equipment

The following equipment has been used during the tests:

District heating test rig FV3	ETu-QD CB:11
Differential pressure meter	Inv. no. 202 111
Differential pressure meter	Inv. no. 202 112
Differential pressure meter	Inv. no. 202 680
Flow meter, inductive, DN 15	Inv. no. 901 997
Flow meter, inductive, DN 15	Inv. no. 202 688
Flow meter, inductive, DN 15	Inv. no. 202 686
Flow meter, inductive, DN 4	Inv. no. BX60131
Logger for measured data	Inv. no. 202 879
Pressure meter for pressure test	Inv. no. 900 050

Figure 2. Simplified schematic of the test rig used for the tests.



6.1 Collection of measurement data, static measurements

When conditions were as stable as possible measurement results were registered for at least 60 seconds. Registered static measurement test values are averages of 60 data points. Sampling rate was 1 Hz for static tests.

6.2 Collection of measurement data, dynamic measurements

Sampling rate was 1 Hz for dynamic measurements.

The time constant for the temperature sensors in the measuring point t_{32} is ≤ 1.5 s and represents 63% of the final value of a momentary change of temperature from 10 to 90°C.

The time constant for the flow meter to measure the DHW flow is ≤ 0.2 s.

The pressure for the incoming cold water was 1.5 bar for the production of DHW in direct heat exchanging, except for test point 3 where the pressure was 2.5 bar.

For the control of DHW flow the test rig has two parallel coupled solenoid valves. Each solenoid valve controls a set flow.

Results are presented in chart form and are verified with numerical values.

6.3 Control systems for DHW

The tested HIU is intended for direct exchange of DHW. This means that the incoming cold water (10 ± 0.5 ºC), is heated directly in the heat exchanger to DHW temperature. The temperature of DHW in the measuring point t_{32} was measured in connection to the HIU DHW tap.

6.4 Measurement uncertainty

The measurement uncertainty has been estimated to be better than following values:

Differential pressure, primary	± 10 kPa
Differential pressure, radiator	± 1 kPa
Differential pressure, tap water	± 1 kPa
Temperature 0-100 °C	± 0.1 °C
Flow, primary (0.05-0.5 l/s)	± 1.5 %
Flow, primary (< 0.05 l/s)	± 4.0 %
Flow, radiator (0.07-0.5 l/s)	± 1.5 %
Flow, tap water (0.04-0.4 l/s)	± 1.5 %
Power (Δt=10.0 ºC)	± 2.1 %
Power (Δt=20.0 ºC)	± 1.7 %
Pressure 0-7 MPa	± 10 kPa

The measurement uncertainty has been calculated according to EA-4/16 with a coverage factor k=2.

7 Test results

The results of each test are presented as specified in the Test Regime. Refer to Table 1 for details on the reporting and to Table 2 regarding the test setup.

The test results apply only to the tested unit.

Table 1. Reporting of test results. Extract from the Test Regime.

Test	Description	Reporting
Static Tests		
0	Pressure tests	Pass/Fail as to whether HIU manages pressure test without leaks or damage
1a	Space Heating 1 kW	t_{12}- primary return temperature. **Note:** t_{12} readings to be used as inputs to Space Heating Weighted Average Return Temperature
1b	Space Heating 2 kW	
1c	Space Heating 4 kW	
1d	Space Heating 4kW, at lower operating temperatures	t_{12}- primary return temperature Observations on impact of lower operating temperatures on performance.
2a	DHW performance DHW 50°C	t_{12} – primary return temperature Note where the set point needs to be adjusted to achieve the target DHW temperature. Note any variances to 40kW DHW load.
2b	DHW performance DHW 55°C	
2c	DHW performance DHW 60°C	
3	Max DHW output	t_{11} – primary flow temperature t_{12} – primary return temperature t_{32} – Temperature, DHW leaving heat exchanger P_3 – DHW load q_1 – Volume flow, primary side q_3 – Volume flow, domestic hot water

Dynamic Tests		
4a	DHW only, DH 75°C flow	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Comment on stability of DHW temperature. Assessment of scaling risk, based on extent and duration of temperatures in excess of 55°C. Plot of key metrics over duration of test. **Note:** Outputs used as base input data to DHW Volume Weighted Return Temperature calculation
4b	DHW only, DH 65°C flow	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Assessment of whether return temperatures remain under control at the lower flow temperature. Assessment of scaling risk, based on extent and duration of temperatures in excess of 55°C. Plot of key metrics over duration of test.
5a	DHW and space heat, 0.5 dP	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Observation of the impact of simultaneous space heating and DHW draw upon performance. Assessment of scaling risk, based on extent and duration of temperatures in excess of 55°C. Plot of key metrics over duration of test.
5b	DHW and space heat higher dP	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Observation of the impact of higher dP on performance. Plot of key metrics over duration of test.
6	Low flow DHW	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Assessment of scaling risk, based on extent and duration of temperatures in excess of 55°C. Commentary if DHW supply not stable. Plot of key metrics over duration of test.
7a	Standby	Observation on the operation of the HIU during standby. Assessment of scaling risk, based on extent and duration of temperatures in excess of 55°C. Plot of key metrics over duration of test. If cycling is observed, plot of the key metrics over the duration of a typical standby cycle. **Note:** Outputs used as base input data to Standby Volume Weighted Return Temperature calculation
7b	DHW response time	Pass/Fail on DHW exceeding 65°C (at t_{32}) for more than 10 seconds. Comment on stability of DHW temperature. Plot of key metrics over duration of test.

Table 2. Test setup. Extract from the Test Regime.

Test No	Test	static pressure	dP across HIU	Primary flow temp	Hot water setpoint	DHW flow rate	DHW power	space heat output	space heat flow temp	space heat return temp
		[bar]	Δp_1 [bar]	t_{11} [°C]	t_{32} [°C]	q_3 [l/s]	P_3 [kW]	P_2 [kW]	t_{22} [°C]	t_{21} [°C]
Static tests										
0a	Static pressure test (same static pressure on both flow and return connections)	1.43 times rated value		75	55	0	0	0	n/a	n/a
0b	Differential pressure test (DH flow at higher pressure than DH return)		1.43 times rated value	75	55	0	0	0	n/a	n/a
1a	Space Heating 1 kW	3	0.5	75	55	0	0	n/a	70	40
1b	Space Heating 2 kW	3	0.5	75	55	0	0	n/a	70	40
1c	Space Heating 4 kW	3	0.5	75	55	0	0	n/a	70	40
1d	Space Heating 4kW, at lower operating temperatures	3	0.5	70	55	0	0	4	60	35
2a	DHW performance DHW 50°C	3	0.5	75	50	Record value	40	0	n/a	n/a
2b	DHW performance DHW 55°C	3	0.5	75	55	Record value	40	0	n/a	n/a
2c	DHW performance DHW 60°C	3	0.5	75	60	Record value	40	0	n/a	n/a
3	Max DHW output	3	HIU max dP	75	55	Record values achieved		0	allow DHW to drop to 10°C below setpoint	
Dynamic tests										
4a	DHW only DH 75°C flow	3	0.5	75	55	see DHW test profile	see DHW test profile	0		
4b	DHW only DH 65°C flow	3	0.5	65	55					
5a	DHW and space heat, 0.5 dP	3	0.5	75	55	see DHW test profile	see DHW test profile	4	70	40
5b	DHW and space heat higher dP	6	HIU max dP	75	55			4	70	40
6	Low flow DHW	3	0.5	75	55	0.02	Record value	0	n/a	n/a
7a	Standby	3	0.5	75	55	0	0	0	n/a	n/a
7b	DHW response time	3	0.5	75	55	0.13	Record value	0	n/a	n/a

7.1 Test 0: Pressure tests

During the static pressure test 0a, the tightness of the components on the primary side of the HIU has been checked. This has been performed by closing the primary return and pressurizing the primary flow with 14.3 bar (1.43 times the construction pressure) for 30 minutes.

During the differential pressure test 0b, the tightness of the radiator control valve and the DHW control valve has been checked. This has been performed by pressurizing the primary flow to 6.4 bar (1.43 times the maximum differential pressure) for 30 minutes with the primary return open and the radiator control valve and the DHW control valve closed.

Test requirement: The HIU is to manage the pressure tests without leaks or damage.
Result: Pass.

7.2 Test 1a-1d: Space Heating 1-4 kW

For test points 1a-1d, a space heating load of 1-4 kW was simulated using a heat exchanger on the test rig. The space heating flow and return temperatures t_{22} and t_{21} were set to 70/40 °C for test points 1a-1c and to 60/35 °C for test point 1d. The primary flow temperature t_{11} was 75 °C for test points1a-1c and 70 °C for test point 1d. The pressure in the radiator circuit was set to 1.5 bar. For further details regarding the test setup, see Table 2.

The results of the test points 1a-1d are presented in Table 3. Results are averages of 60 data points. Data for a longer period is presented in Figure 3 to Figure 6.

Table 3. Test results for test points 1a-1d.

Test point	Primary				Secondary				
	t_{11} [°C]	t_{12} [°C]	q_1 [l/s]	P_1 [kW]	t_{21} [°C]	t_{22} [°C]	q_2 [l/s]	Δp_2 [kPa]	P_2 [kW]
1a	74.7	49.4	0.011	1.2	40.3	70.3	0.008	2.0	1.0
1b	74.7	48.9	0.020	2.1	39.9	70.3	0.015	3.3	1.9
1c	75.4	49.6	0.039	4.2	40.1	69.9	0.033	5.0	4.0
1d	70.0	41.1	0.035	4.2	35.1	60.2	0.040	5.3	4.1

7.3 Test 2a-2c: DHW performance DHW 50-60°C

For test points 2a, 2b and 2c, the DHW temperature setpoint on the HIU was adjusted to reach 50, 55 and 60 °C respectively. The primary flow temperature t_{11} was 75 °C. For further details regarding the test setup, see Table 2.

The results of the test points 2a-2c are presented in Table 4. Results are averages of 60 data points. Data for a longer period is presented in Figure 7 to Figure 9.

Table 4. Test results for test point 2a-2c.

Test point	Primary				Secondary				
	t_{11} [°C]	t_{12} [°C]	q_1 [l/s]	P_1 [kW]	t_{31} [°C]	t_{32} [°C]	q_3 [l/s]	Δp_3 [kPa]	P_3 [kW]
2a	75.0	17.2	0.166	40.2	9.9	50.0	0.243	70.0	40.2
2b	75.3	19.3	0.170	39.9	9.8	54.8	0.216	63.2	39.9
2c	75.4	22.5	0.183	40.3	9.8	60.0	0.196	58.2	40.2

The HIU was able to produce 40 kW of DHW for all three temperatures tested.

7.4 Test 3: Max DHW output

In test point 3, the maximum DHW output was tested. The primary flow temperature t_{11} was 75 °C and the hot water setpoint was 55 °C. The DHW temperature t_{32} was allowed to drop to 10 °C below the setpoint. For further details regarding the test setup, see Table 2.

The results of the test point 3 are presented in Table 5 and in Figure 10.

Table 5. Test results for test point 3.

Test point	Primary				Secondary				
	t_{11} [°C]	t_{12} [°C]	q_1 [l/s]	P_1 [kW]	t_{31} [°C]	t_{32} [°C]	q_3 [l/s]	Δp_3 [kPa]	P_3 [kW]
3	74.8	21.0	0.314	70.5	9.9	50.9	0.415	67.5	70.7

The HIU was able to produce 70.7 kW of DHW while maintaining a tap water temperature of 50.9 °C. This deviation from the DHW setpoint of 55 °C was within the allowed range of 10 °C specified in the test program. Due to limitations of the test rig, no higher DHW flow could be achieved.

7.5 Test 4a: DHW only, DH 75°C flow

In test point 4a, a dynamic test of DHW was performed according to DHW flow rates specified in the Test Regime. The primary flow temperature t_{11} was 75 °C and the hot water setpoint was 55 °C. For further details regarding the test setup, see Table 2.

The DHW temperature (t_{32}) did not exceed 65 °C during the test. The highest measured temperature in point t_{32} was 58.7. Between 200 and 2160 seconds, the lowest measured temperature was 50.4 °C.

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The test results for test point 4a are presented in Figure 11, appendix 1.

7.6 Test 4b: DHW only, DH 65°C flow

In test point 4b, a dynamic test of DHW was performed according to DHW flow rates specified in the Test Regime. The primary flow temperature t_{11} was 65 °C and the hot water setpoint was 55 °C. For further details regarding the test setup, see Table 2.

The DHW temperature (t_{32}) did not exceed 65 °C during the test. The highest measured temperature in point t_{32} was 57.0 °C. Between 200 and 2160 seconds, the the lowest measured temperature was 51.6 °C.

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The results of the test point 4b are presented in Figure 12, appendix 1.

7.7 Test 5a-5b: DHW and space heating

In test points 5a-5b, a dynamic test of DHW and a simultaneous static space heating load was performed according to DHW flow rates specified in the Test Regime. The primary flow temperature t_{11} was 75 °C and the hot water setpoint was 55 °C. The space heating flow and return temperatures t_{22} and t_{21} were set to 70/40 °C. Test point 5a was performed at a dP of 0.5 bar, while test point 5b was performed at the maximum dP of the HIU. For further details regarding the test setup, see Table 2.

7.7.1 5a: DHW and space heating, 0.5 bar dP

The DHW temperature (t_{32}) did not exceed 65 °C during the test. The highest measured temperature in point t_{32} was 59.1 °C. Between 200 and 2160 seconds, the lowest measured temperature was 51.7 °C.

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The results of the test point 5a are presented in Figure 13, appendix 1.

7.7.2 5b: DHW and space heating, max dP

The maximum differential pressure of the HIU was 4.5 bar. This differential pressure was used for the test point 5b.

The DHW temperature (t_{32}) did not exceed 65 °C during the test. The highest measured temperature in point t_{32} was 59.5 °C. Between 200 and 2160 seconds, the lowest measured temperature was 52.0°C.

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The results of the test point 5b are presented in Figure 14, appendix 1.

7.8 Test 6: Low flow DHW

In test point 6, a low DHW flow of 0.02 l/s was tested. The primary flow temperature t_{11} was 75 °C and the hot water setpoint was 55 °C. For further details regarding the test setup, see Table 2.

The DHW temperature (t_{32}) did not exceed 65 °C during the test. During the test, all relevant temperatures and flows were stable, but t_{32} was consistently above 55 °C (around 59.3 °C).

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The results of the test point 6 are presented in Figure 15, appendix 1.

7.9 Test 7a: Standby

In test point 7, the standby characteristics of the HIU were tested. A DHW flow of 0.13 l/s was drawn until stable conditions were reached, and was then turned off. Data was then collected until stable conditions had been reached. For further details regarding the test setup, see Table 2.

The standby performance of the HIU is dependent on the standby control method used. For instance, in cases a higher DHW heat exchanger keep hot temperature setpoint is used DHW delivery is quicker while standby losses increase.

HIU standby settings: the HIU had no specific setting for the standby function, but performance might be affected by the DHW temperature setpoint.

The primary return temperature t_{12} was maintained at 43 ± 3 °C from 8600 seconds until the end of the test. The primary flow was generated at appr. 75 °C. At the HIU connection, primary flow temperature t_{11} was stable at 52 ± 3 °C from 20200 seconds until the end of the test. From 20200 seconds until the end of the test, the average primary flow q_1 was 6.2 l/h. For the first 14400 seconds (4 hours) of the test after turning off the domestic hot water flow, the average power P_1 was 52.7 W.

The results of the test point 7a are presented in Figure 16, appendix 1.

7.10 Test 7b: DHW response time

Immediately after test point 7a, test point 7b was carried out. A DHW flow of 0.13 l/s was drawn until conditions were stable. For further details regarding the test setup, see Table 2.

The DHW response time might be dependent on the HIU standby settings. See Test 7a: Standby.

The DHW temperature (t_{32}) did not exceed 65 °C during the test. The DHW temperature (t_{32}) reached 55 °C appr. 85 seconds after the DHW flow was started and did not drop below 52 °C thereafter.

Test requirement: The DHW flow temperature t_{32} is not to exceed 65 °C for more than 10 seconds.
Result: Pass.

The results of the test point 7b are presented in Figure 17, appendix 1.

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Energy and bioeconomy - Urban Supply Systems

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Björn Folkeson	Markus Alsbjer	Thomas Ljung

Appendix

1. Diagrams

Appendix 1. Diagrams

Figure 3. Results for test point 1a: space heating 1 kw, DH 75°C flow.

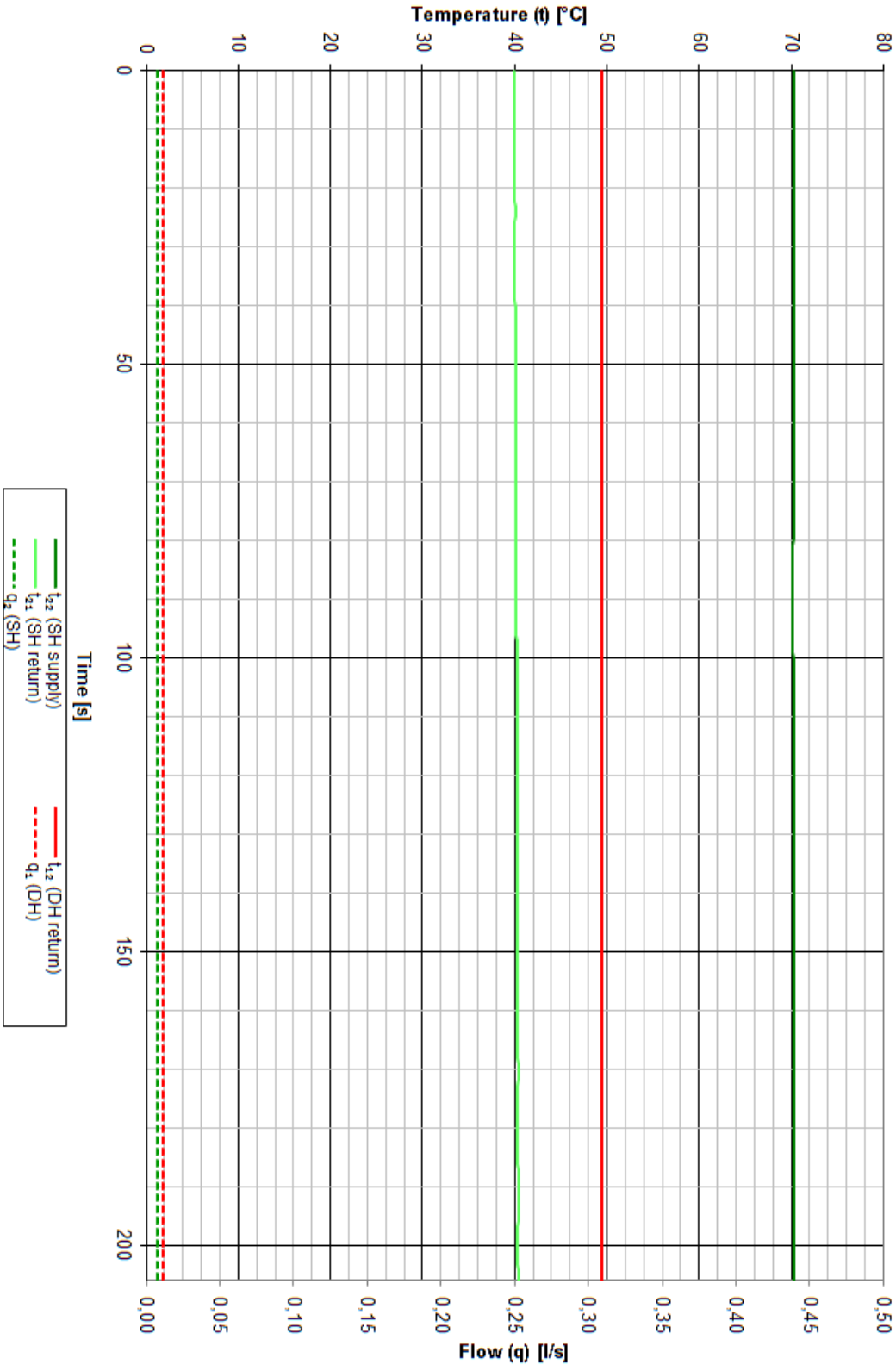


Figure 4. Results for test point 1b: space heating 2 kw, DH 75°C flow.

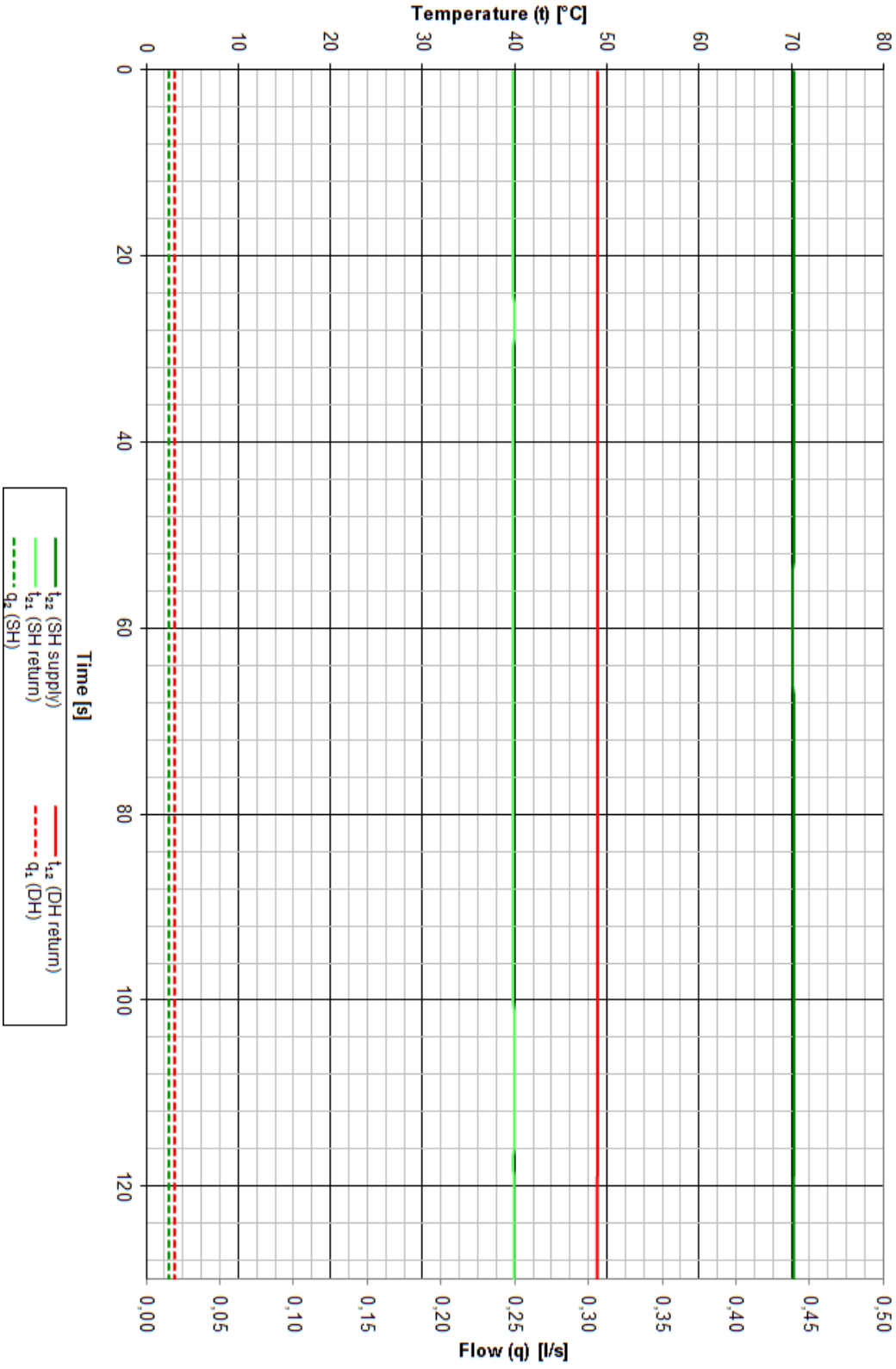


Figure 5. Results for test point 1c: space heating 4 kw, DH 75°C flow.

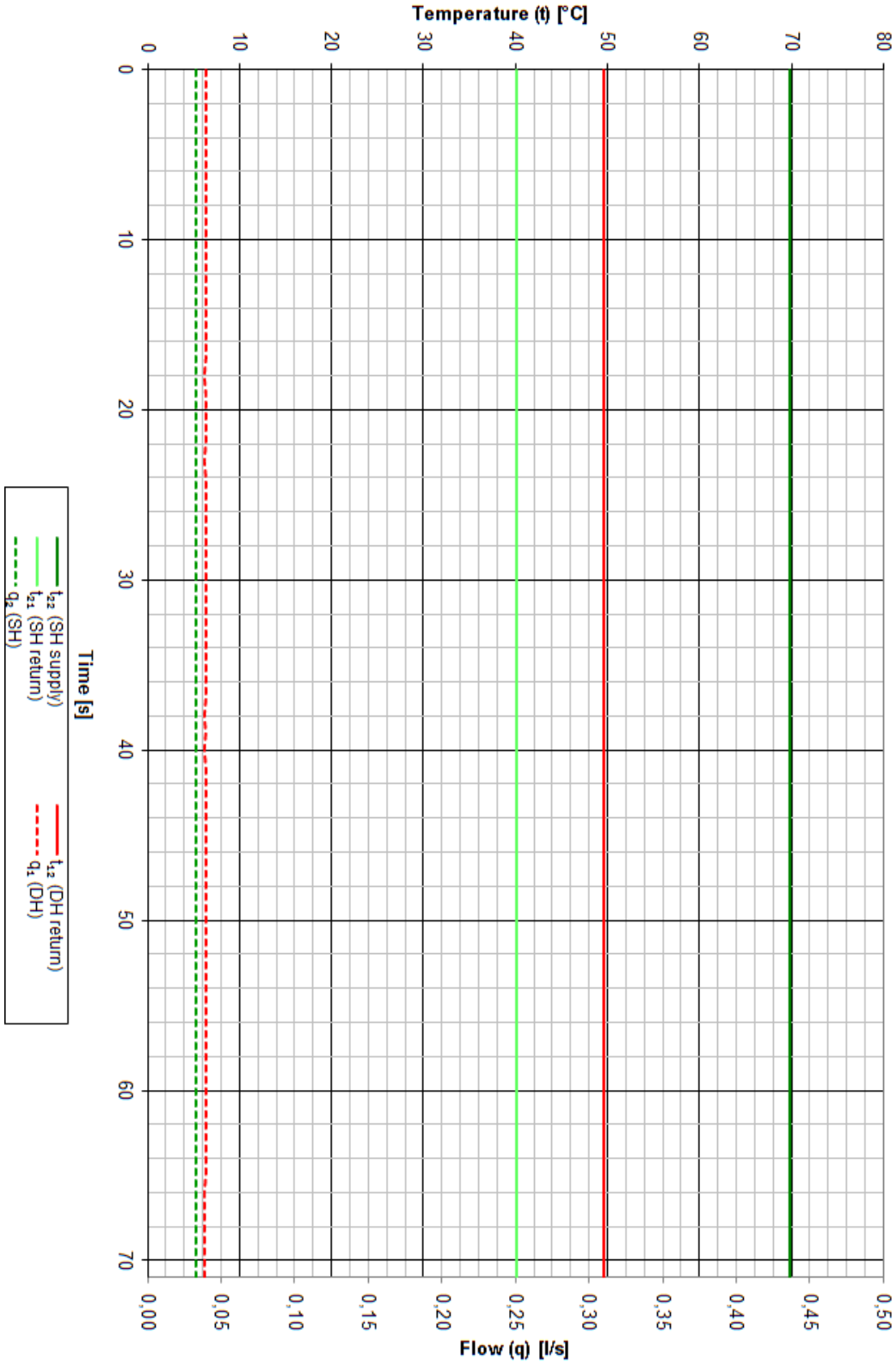


Figure 6. Results for test point 1d: space heating 4 kw, DH 70°C flow.

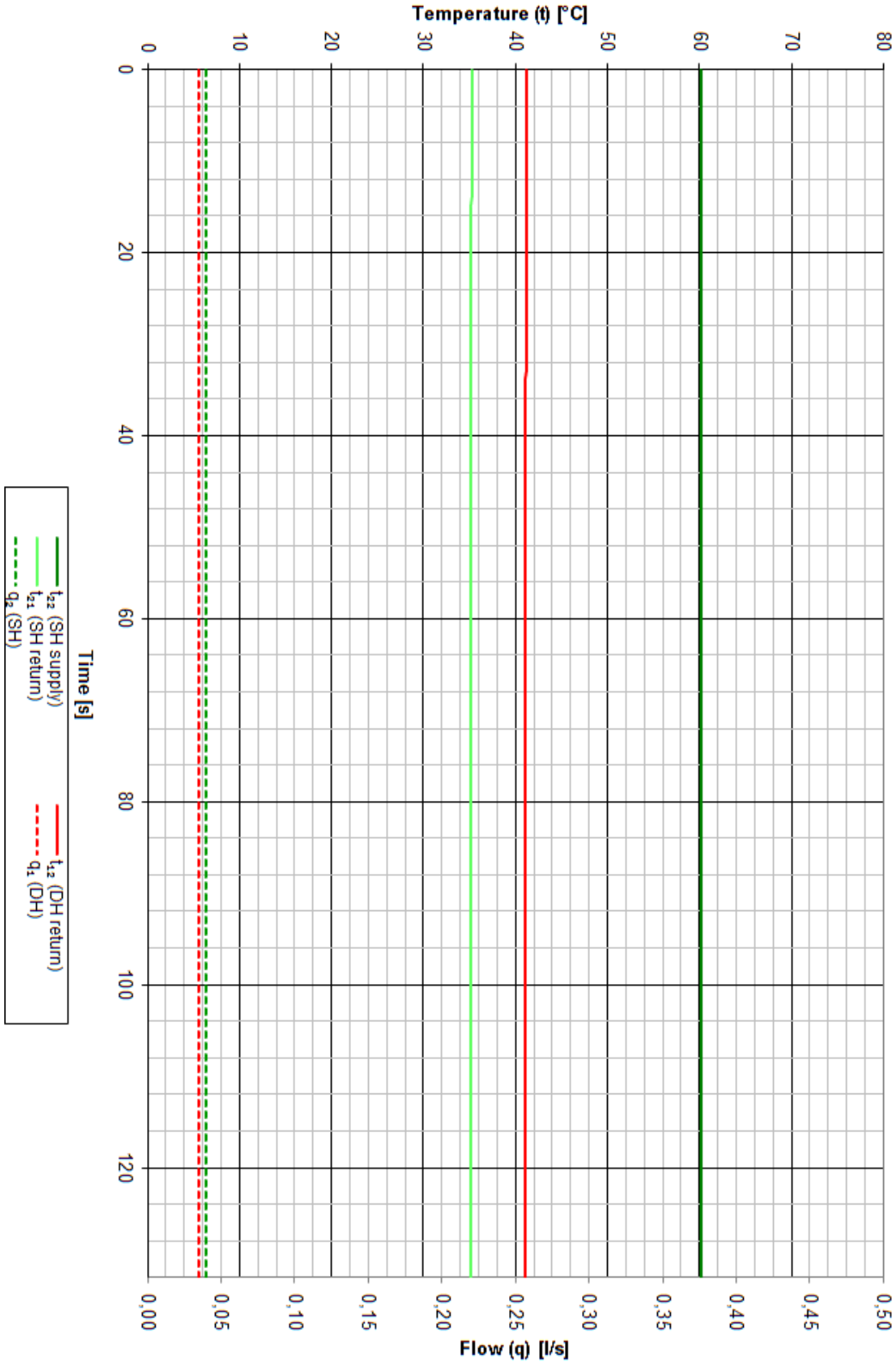


Figure 7. Results for test point 2a: DHW performance DHW 50°C.

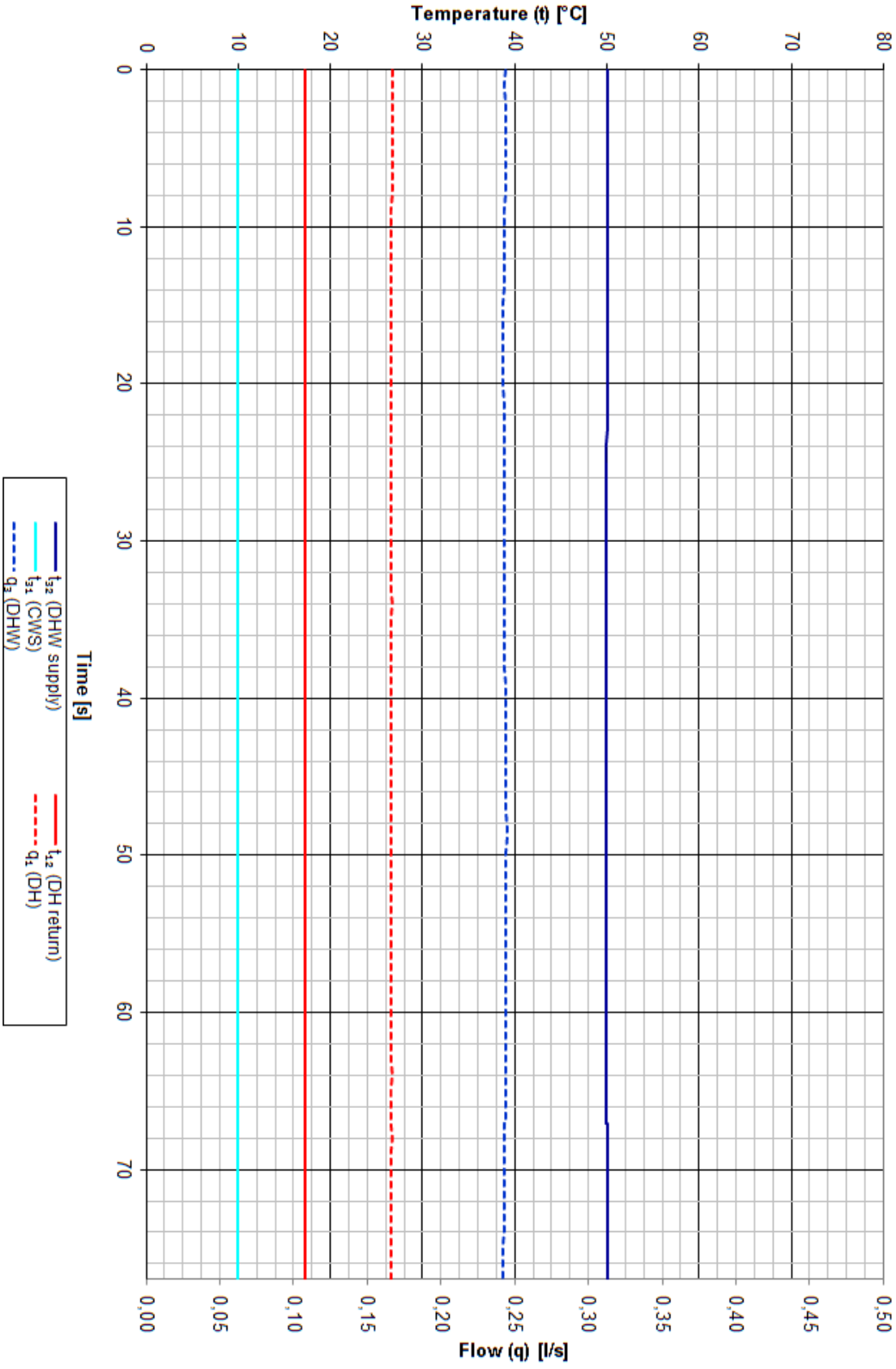


Figure 8. Results for test point 2b: DHW performance DHW 55°C.

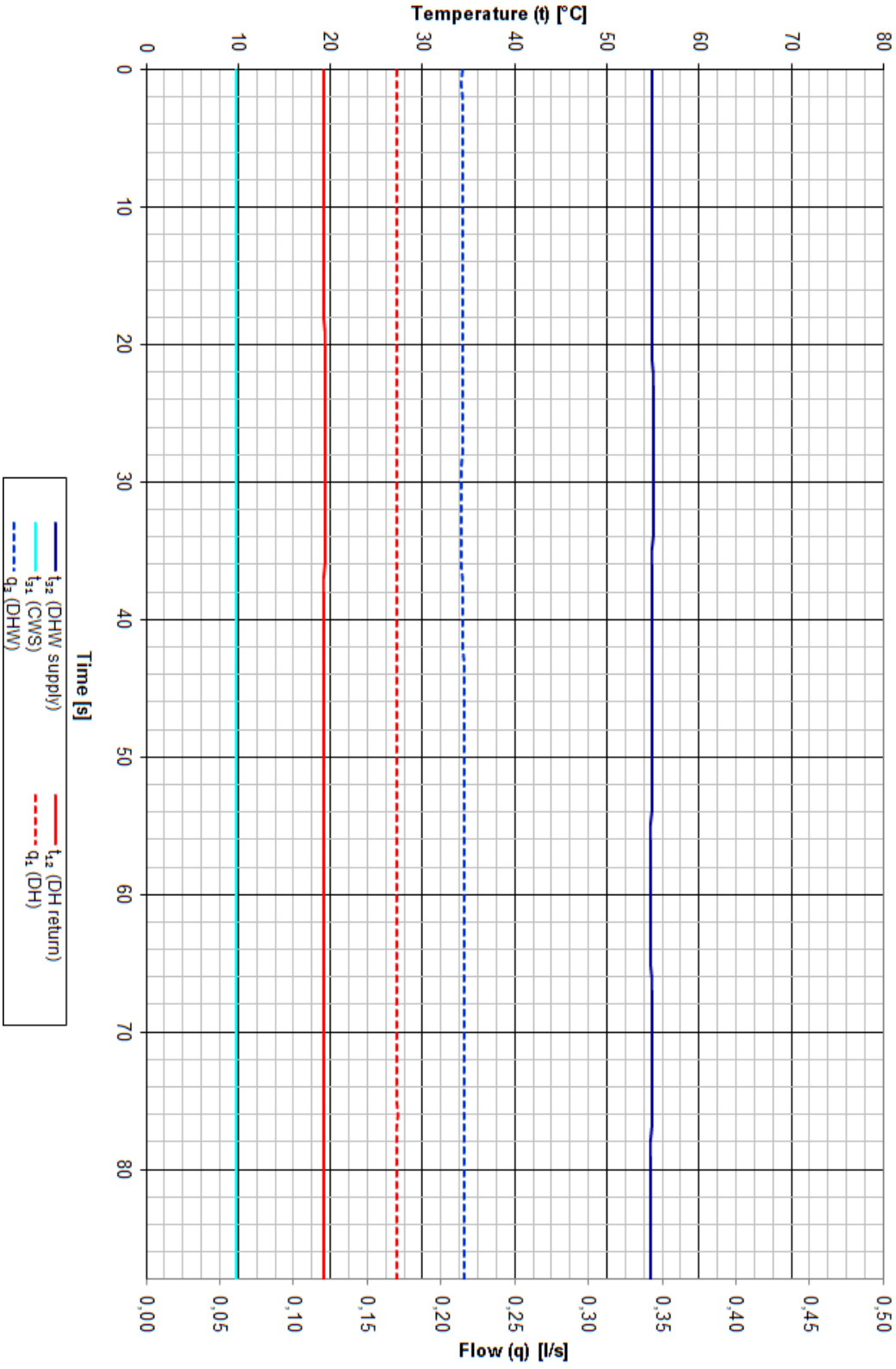


Figure 9. Results for test point 2c: DHW performance DHW 60°C.

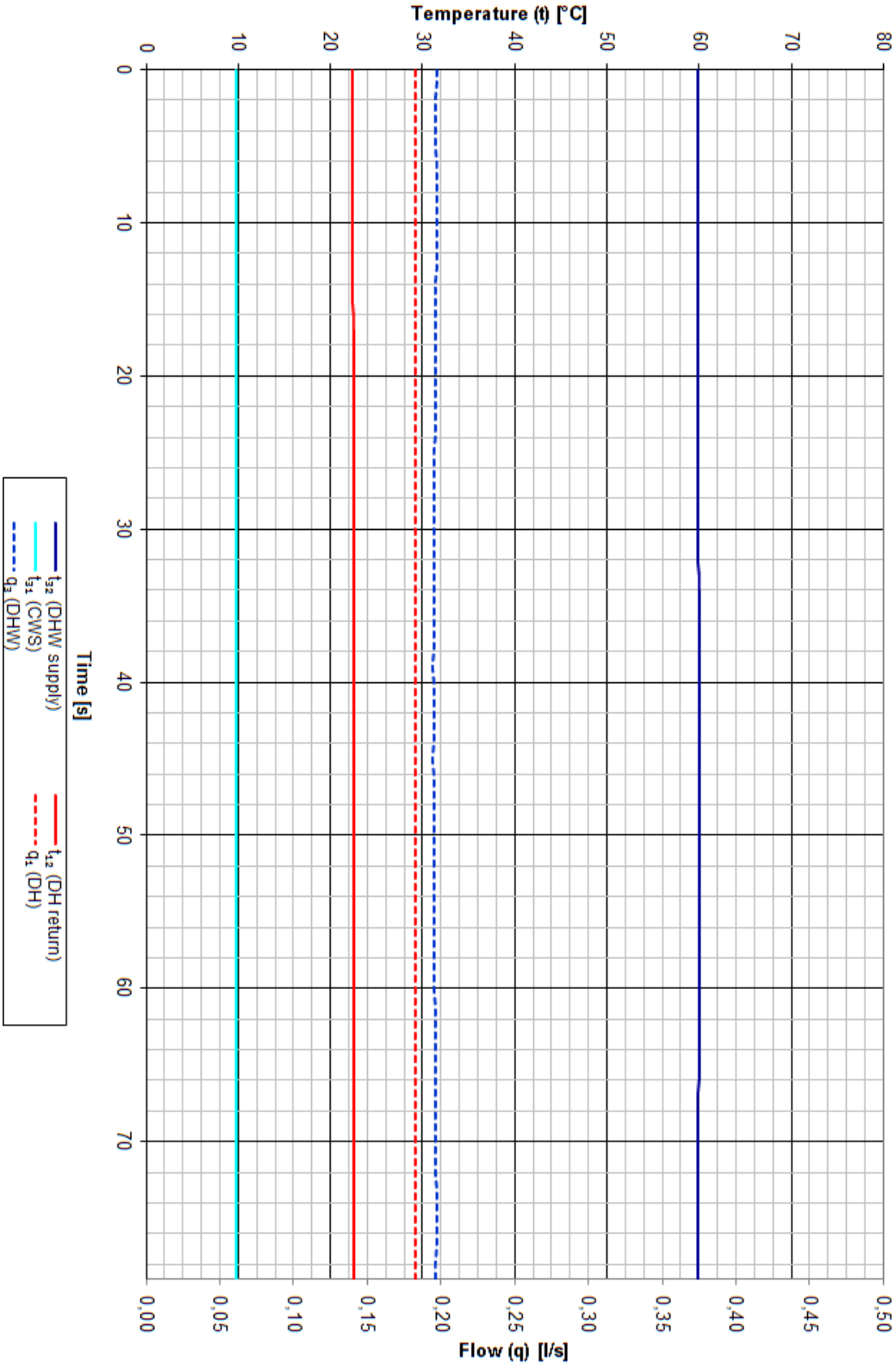


Figure 10. Results for test point 3: Max DHW output.

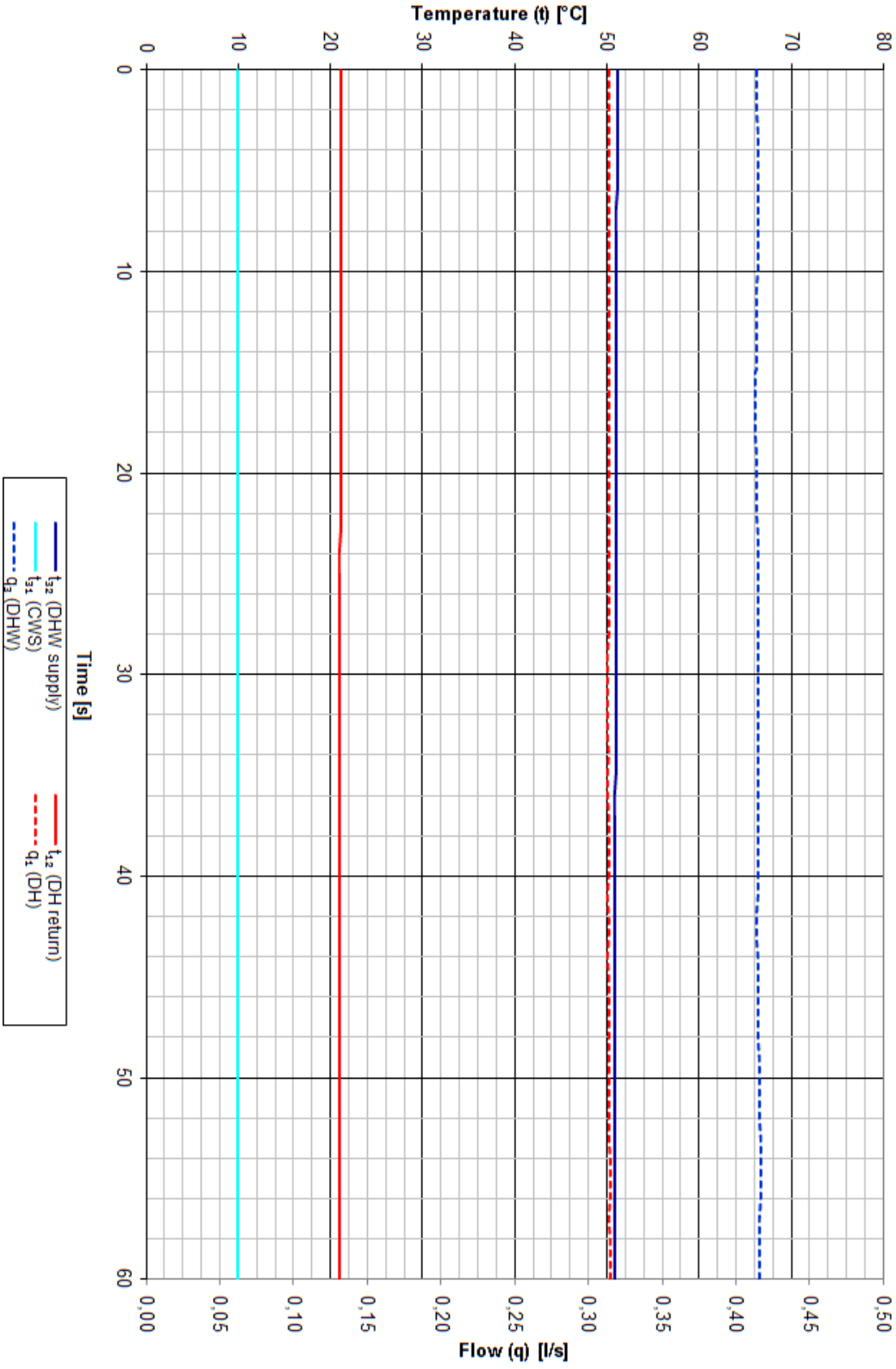


Figure 11. Results for test point 4a: DHW only, DH 75°C flow.

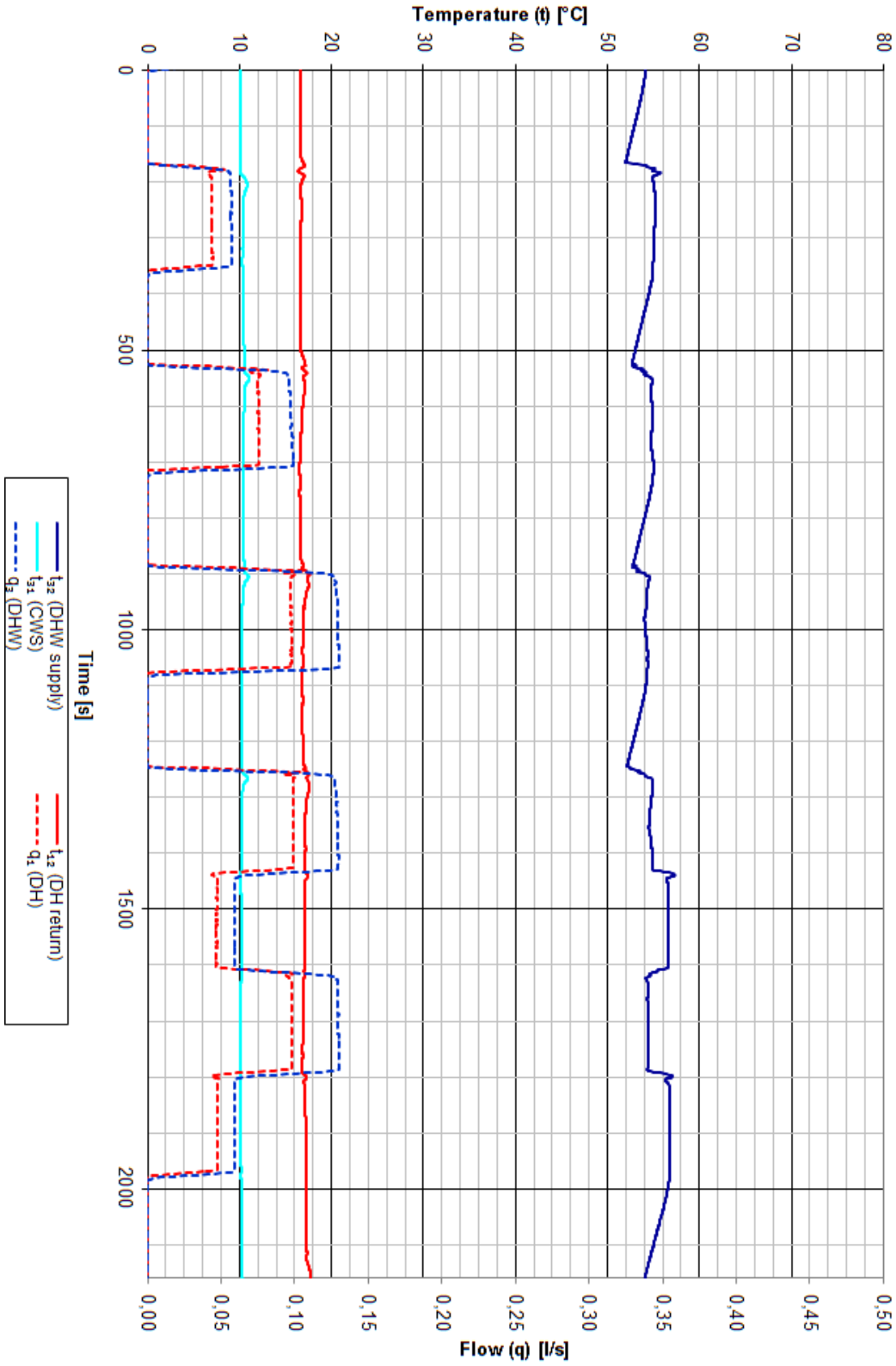


Figure 12. Results for test point 4b: DHW only, DH 65°C flow.

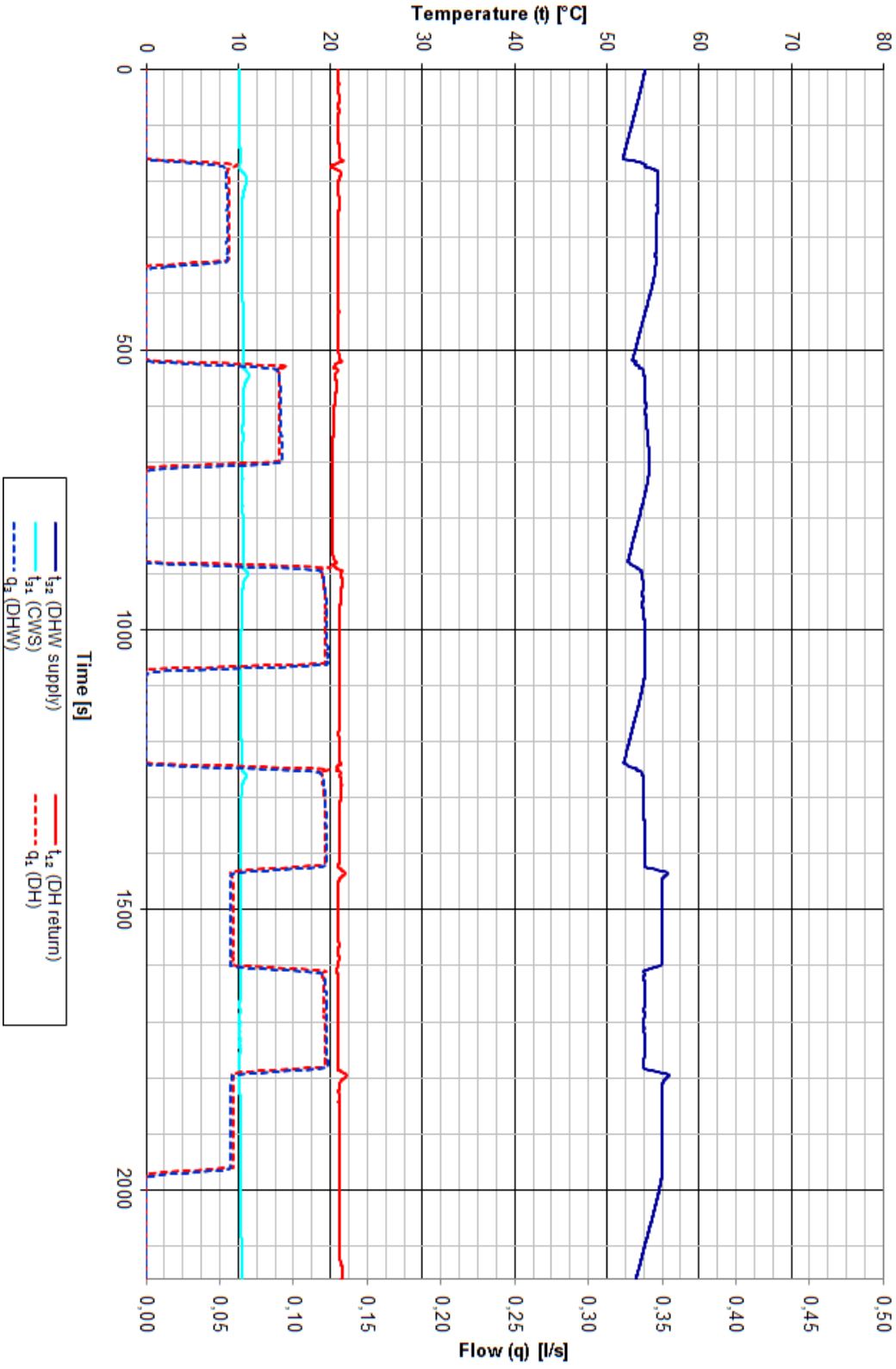


Figure 13. Results for test point 5a: DHW and space heating, 0.5 bar dP

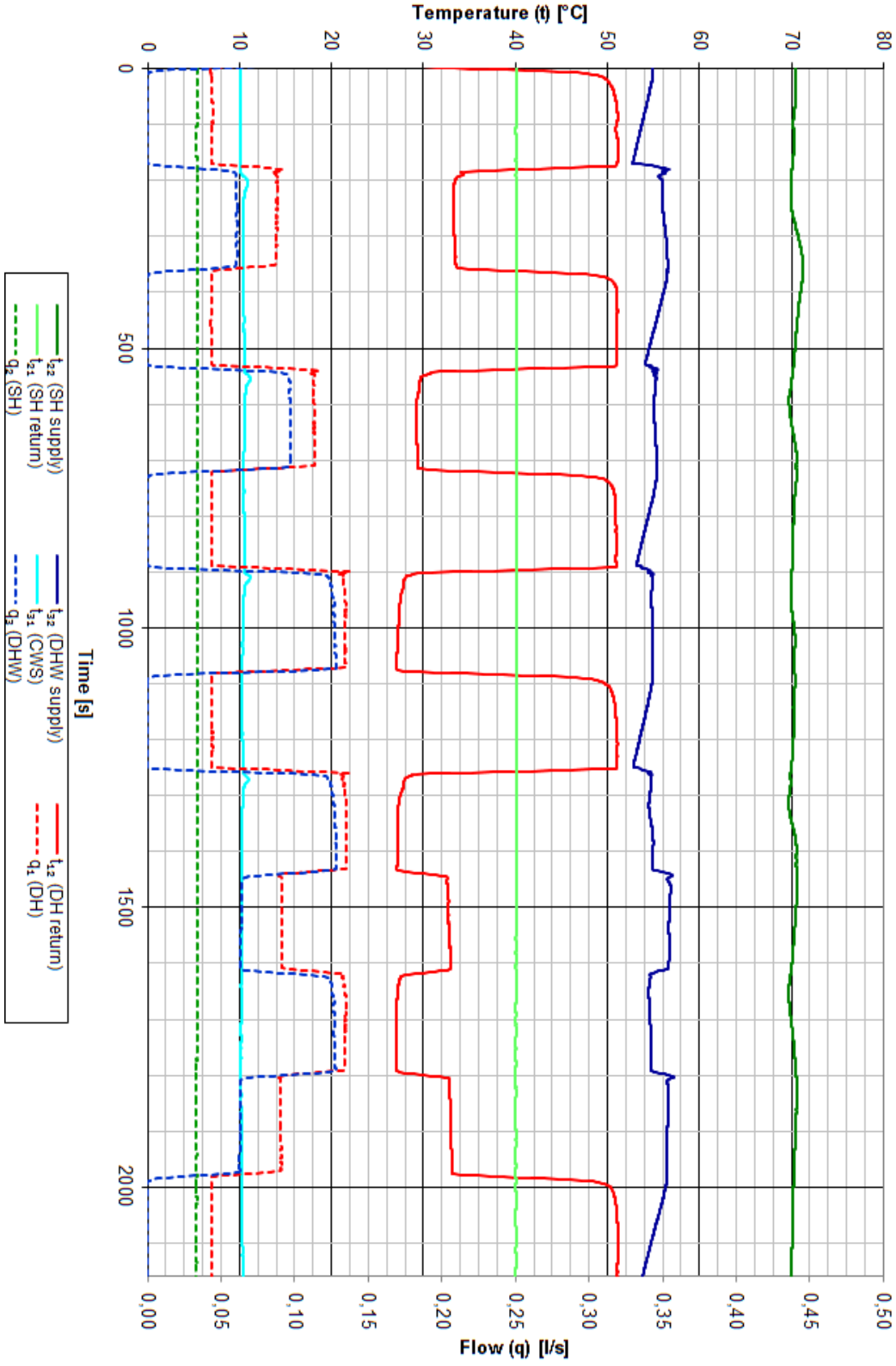


Figure 14. Results for test point 5b: DHW and space heating, max dP.

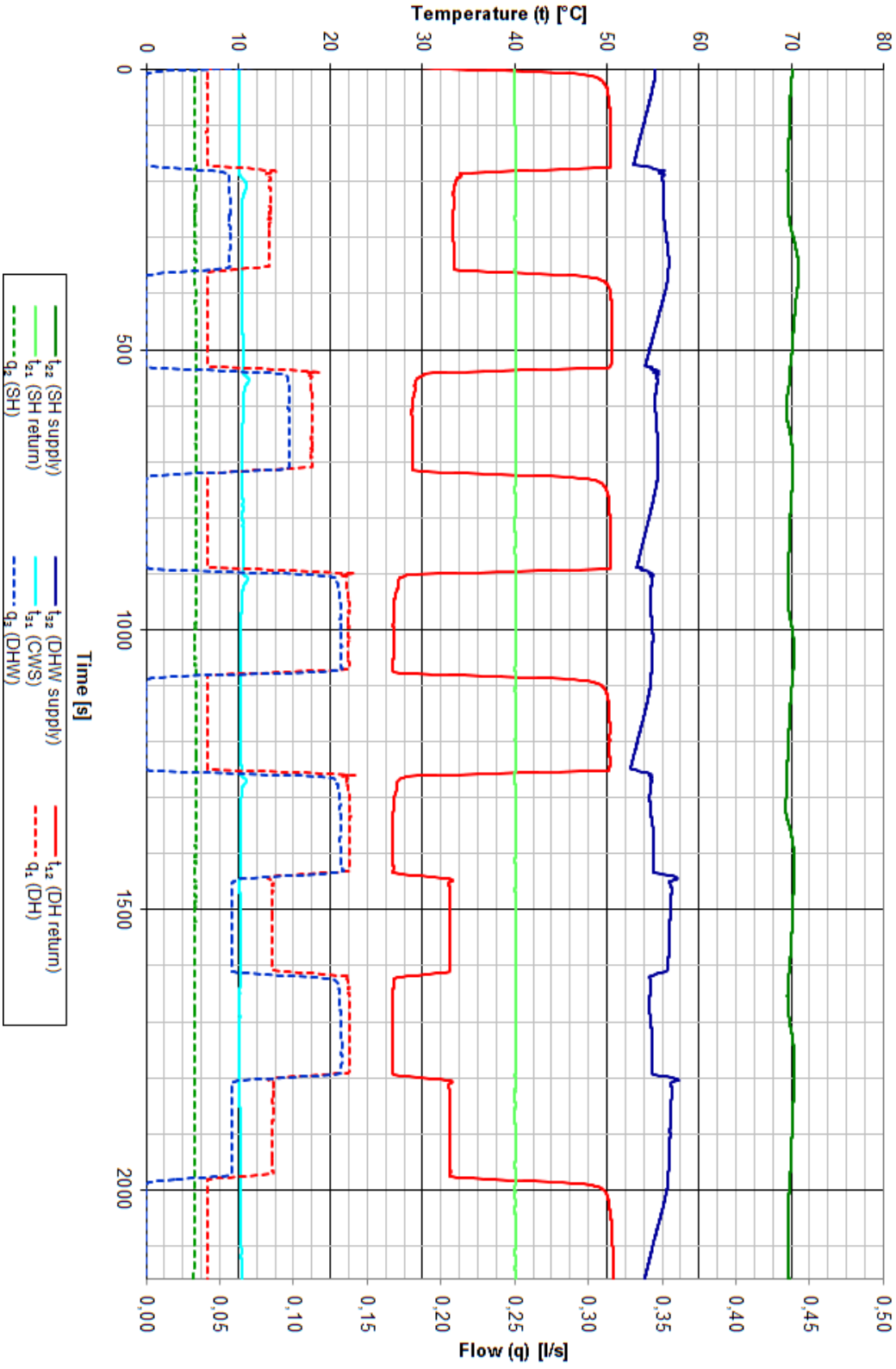


Figure 15. Results for test point 6: Low flow DHW.

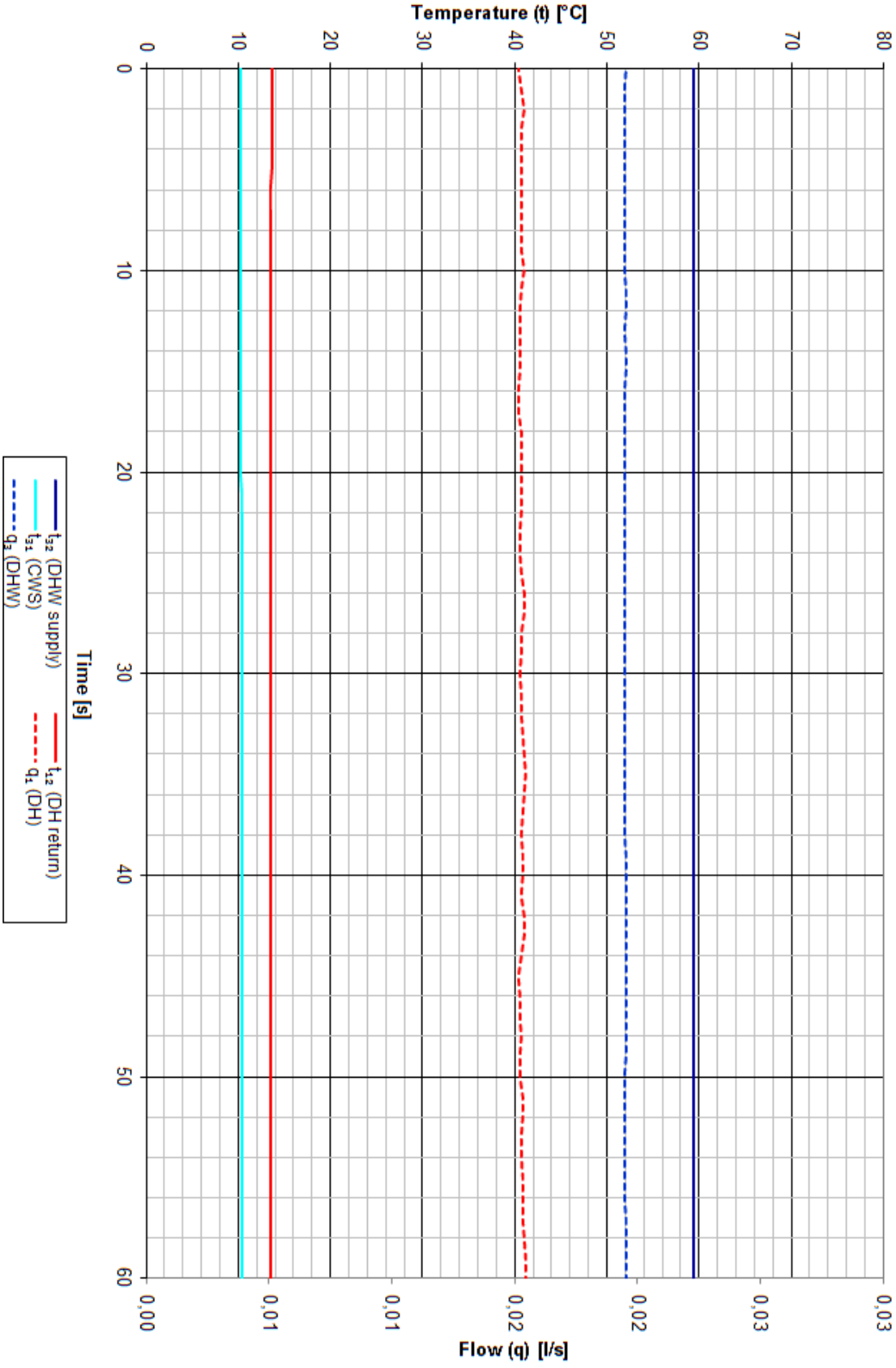


Figure 16. Results for test point 7a: Standby.

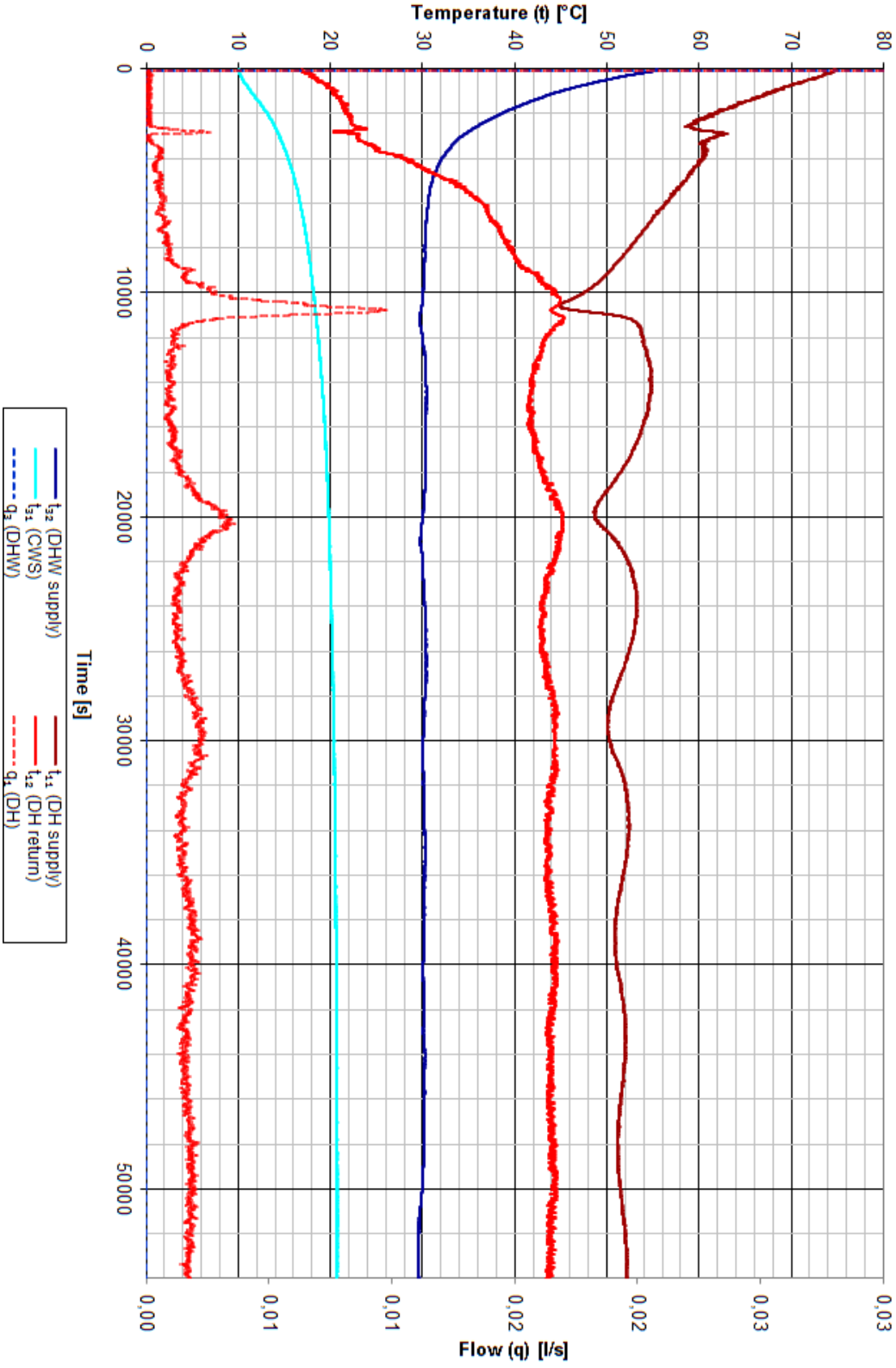


Figure 17. Results for test point 7b: DHW response time.

