BESA HIU Test Report

TI45 Ultra Lean

Carried out for

Rhico District Heating Products

Report 101924/1

Compiled by Colin Judd

7 September 2020




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BESA HIU Test Report

TI45 Ultra Lean

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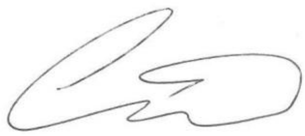
QUALITY ASSURANCE

Issue	Date	Compiled by:	Approved by:	Signature
Final	*07-Sep-2020*	*Colin Judd*	*Tom Garrigan*	
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1 INTRODUCTION

BSRIA carried out a series of tests on one heat interface unit (HIU), the TI45 Ultra Lean, manufactured by Rhico District Heating Products. Testing was carried out in accordance with the UK HIU Test Regime, October 2018. The test method covers testing one HIU at a primary inlet temperature of 70°C and 60°C. The HIU was a combined low temperature hot water (LTHW) and domestic hot water (DHW) unit.

This report is based on one sample of the above-mentioned product. Testing was carried out during July 2020. Charts of outputs obtained from this series of tests are shown in Appendix A of this report.

2 ITEM RECEIVED FOR TEST

The HIU received for testing was a Rhico District Heating Products TI45 Ultra Lean. This was a combined LTHW and DHW unit. The HIU was designed for both wet radiator systems and underfloor heating (UFH) systems. The test regime requires that the HIU is tested at two primary inlet temperatures, 70°C for wet radiator systems and 60°C for UFH systems. Table 1 gives details of the HIU tested.

Table 1 Manufacturer supplied data

Description	Data
Model	TI 45 Ultra Lean
Serial Number	428440300/Matr.: A202800460
Year of manufacture	2020
Firmware version	r.0.0
Height	750 mm
Width	560 mm
Depth	220 mm
Total unit weight	25 kg (including cover)
Maximum DHW output	92 kW at 85°C – DHW 10°C to 55°C (manufacturer supplied data) 69 kW at 60°C – DHW 10°C to 45°C (manufacturer supplied data)
Maximum central heating output	33 kW at 85°C – Htg 50°C to 70°C (manufacturer supplied data) 9.3 kW at 55°C – Htg 33°C to 38°C (manufacturer supplied data)
Maximum primary supply temperature	85°C
Recommended minimum DP	120 kPa
Maximum working pressure primary side	16 bar
Maximum working pressure DHW side	10 bar
Safety relief valve setting secondary heating side	3 bar
Expansion vessel capacity	7 Lt
Ball valve connections	1” male flat seal connection with adaptors down to ¾“ male BSP
Safety relief valve connection	¾” Female connection
Electrical power supply voltage	230 V AC±10%
Frequency	50/60 Hz

Table 2 gives a component list for the HIU as supplied by the Client.

Table 2 HIU Component list

Description	Manufacturer
Space heating heat exchanger	SWEP E8AS W-Nx10
DHW heat exchanger	SWEP E8AS W-Nx30
DHW flowmeter	Honeywell C7195 -0,7-30 l/m'
Check Valve on DCW inlet	Lovato code 20313113
Check Valve on filling circuit	Kramer
Temperature sensors	Brahama G 1/8"-ST06
Primary side strainer	M-M ¾" – VALBRASS
Controller for DHW and Space Heating	Brahama 1961 SAT
Control valve and actuator for space heating and DHW	Jonson control M30X1,5 VA 7481-0003
Heat Meter	Ista Ultego III smart
Differential pressure control valve	Frese Optima compact DN15
Circulation pump	WILO pump block PARA 15/7
Safety valve	Female 3/4"3 bar PINTOSSI +C SPA
Air vent valve	Manual 3/8" – MARVIT SPA
Digital pressure transducer	ELTEK 10.80.40.00.07
Expansion Vessel	Zilio Industries VRP204-7
Isolation valves	Arpro EPP 60 g/L
Pipes	Silmet / Feinrohren
o-ring	Teknofluor – EPDM 70
Joints and connections gasket	Flat seat and nuts-AFM34

Figure 1 shows the TI45 Ultra Lean installed in the test rig with the cover removed. A photograph of the name plate is also included.

Figure 1 TI45 Ultra Lean installed in the test rig

3 APPROACH

3.1 ABBREVIATIONS

The abbreviations given in Table 3 are used throughout this report.

Table 3 Abbreviations used

Abbreviation	Parameter	Units
DH	District Heating	-
SH	Space Heating	-
CWS	Cold Water Supply	-
P_1	Heat load – primary side	[kW]
P_2	Heat load – space heating system	[kW]
P_3	Heat load – domestic hot water	[kW]
t_{10}	Temperature at DH supply upstream of 9m HIU supply pipework	[°C]
t_{11}	Temperature – primary side flow connection	[°C]
t_{12}	Temperature – primary side return connection	[°C]
t_{21}	Temperature – space heating system return connection	[°C]
t_{22}	Temperature – space heating system flow connection	[°C]
t_{31}	Temperature – cold water supply	[°C]
t_{32}	Temperature – domestic hot water flow from HIU	[°C]
q_1	Volume flow – primary side	[$l.s^{-1}$]
q_2	Volume flow – space heating system	[$l.s^{-1}$]
q_3	Volume flow – domestic hot water	[$l.s^{-1}$]
Δp_1	Primary pressure drop across entire HIU unit	[bar]
Δp_2	Pressure drop – space heating system across HIU	[bar]
Δp_3	Pressure drop – domestic hot water across HIU	[bar]
$VWART_{DHW}$	DHW Volume Weighted Average Return Temperature	[°C]
$VWART_{SH}$	Space Heating Volume Weighted Average Return Temperature	[°C]
$VWART_{KWM}$	Keep-warm Volume Weighted Average Return Temperature	[°C]
$VWART_{HEAT}$	Annual Volume Weighted Average Return Temperature for Heating Period	[°C]
$VWART_{NONHEAT}$	Annual Volume Weighted Average Return Temperature for Non-Heating	[°C]
$VWART_{HIU}$	Total Annual Volume Weighted Return Temperature	[°C]
SH_{PROP}	Annual Heating Period	-
NSH_{PROP}	Annual Non-Space Heating Period	-
DH	District Heating (primary) circuit	-
SH	Space Heating circuit	-
CWS	Cold Water Supply	-
DHW	Domestic Hot Water	-
TMV	Thermostatic Mixing Valve	-
TRV	Temperature Regulating Valve	-
UFH	Under Floor Heating	-

3.2 INSTRUMENTATION USED

Table 4 shows details of the instrumentation used for the tests.

Table 4 Instrumentation used

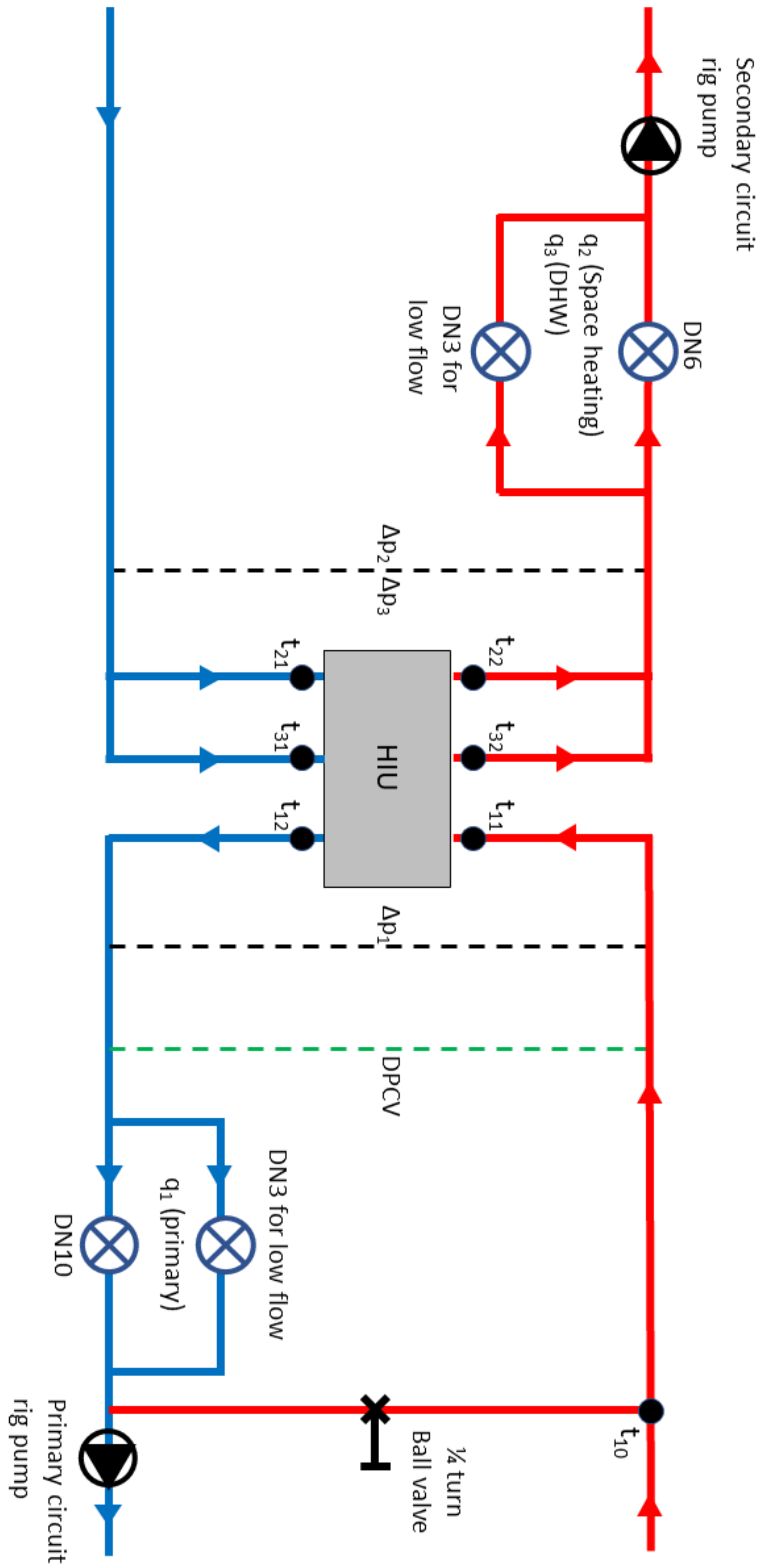
Instrument	Manufacturer	Range	Units	ID No.	Calibration Due
Keysight logging system	Keysight	N/A	N/A	1595	N/A
Static pressure transducer DHW circuit – Pressure test Primary circuit for all thermal tests	Fuji Electric	0 – 10	Bar	1592	29-04-21
Static pressure transducer SH circuit – Pressure test Secondary circuit for all thermal tests	Fuji Electric	0 – 10	Bar	1593	29-04-21
Platinum Resistance Thermometers (PRTs)* Used for measuring the inlet/outlet parameters during the testing	TC Ltd	1 – 90	°C	1685	05-11-20
Platinum Resistance Thermometer (PRT)	Anville Sensors Ltd	1 – 90	°C	1685	05-11-20
Flowmeter – DH circuit Space heating tests – (1a – 1f)	Siemens	0 – 0.07	$l.s^{-1}$	2961	21-01-21
Flowmeter – SH circuit Space heating tests – (1a – 1d)	Siemens	0 – 0.07	$l.s^{-1}$	1678	28-04-21
Flowmeter – SH circuit Space heating tests – (1f)	Danfoss	0 – 0.2	$l.s^{-1}$	94	27-04-21
Flowmeter – DH circuit Dynamic tests – (2a, 2b, 3c,3d)	Siemens	0 – 0.5	$l.s^{-1}$	1545	27-04-21
Flowmeter – DHW circuit Dynamic tests – (2a, 2b, 3c,3d)	Siemens	0 – 0.2	$l.s^{-1}$	94	27-04-21
Flowmeter – DH circuit Keep warm tests (4a & 4b) DHW response time tests (5a & 5b)	Siemens	0 – 0.07	$l.s^{-1}$	2961	21-01-21
Flowmeter – DHW circuit Keep warm tests (4a & 4b) DHW response time tests (5a & 5b)	Siemens	0 – 0.5	$l.s^{-1}$	94	27-04-21
Differential pressure transducer DH circuit for tests 1a – 1f ,2a, 2b, 3a, 3b, 4a, 4b, 5a,5b	Fuji Electric	0 – 200	kPa	2065	15-01-21
Differential pressure transducer SH and DHW circuit for tests 1a – 1f ,2a, 2b, 3a, 3b, 4a, 4b, 5a,5b	Fuji Electric	0 – 200	kPa	1591	29-04-21
Differential pressure transducer Secondary circuit tests 1a – 1f ,2a, 2b, 3a, 3b, 4a, 4b, 5a,5b	Fuji Electric	0 – 600	kPa	2958	28-04-21
Static pressure transducer Pressure test	Fuji Electric	0 – 30	barg	1582	03-06-21
Digital static pressure gauge – All thermal tests	Keller	0 – 10	Barg	1760	09-03-21
Stopwatch	Micronta	3,601.03	Secs	1119	04-02-21
Tape measure	Stanley	1,000	mm	683	28-02-22
Power meter	Yokogawa	0-300 0-25	V W	988	25-10-20

*The time constant for these temperature sensors is ≤ 1.5 s.

The calibration certificates for all the instrumentation used during this series of tests are available on request from BSRIA (test@BSRIA.co.uk)

Figure 2 shows a schematic of the test rig layout.

Figure 2 Schematic of the test rig layout



3.3 UNCERTAINTY BUDGET

The uncertainty of measurement given in the test regime is shown in Table 5.

Table 5 Uncertainty budget

Parameter	Required Uncertainty	BSRIA Uncertainty
Static pressure	±10 kPa	±0.72 kPa
Differential pressure, district heating	*Not supplied*	±0.08 kPa
Differential pressure, domestic hot water	±1 kPa	±0.06 kPa
Differential pressure, space heating	±1 kPa	±0.06 kPa
Temperature	±0.1°C	±0.023°C
Volume flow (≥ 0.06 l/s)	±1.5%	0.0003 l/s
Volume flow (< 0.06 l/s)	To be specified in conjunction with each measurement	0.0004 l/s
Voltage	*Not supplied*	±0.02 V
Power	*Not supplied*	±0.03 W
Current	*Not supplied*	±0.006 A

The uncertainty of the instrumentation used was calculated according to M3003 – The Expression of Uncertainty and Confidence in Measurement. All the instrumentation used in this series of tests was within the required uncertainty quoted above.

3.4 TESTS 1A TO 1F

Once the rig was running, the space heating tests were allowed to stabilise at the required power output for the particular test. Once stable conditions had been achieved, the test was logged at a rate of 1 Hz for a minimum period of 300 seconds.

3.5 TESTS 2A AND 2B

Prior to the test being carried out, the rig was running at the required stable conditions for a minimum of 120 seconds. After this period, the DHW draw off test was carried out as per the flow regime specified in the test method. The flow rates were controlled using a manifold of three control valves set to the correct flows. The data was logged at a rate of 1 Hz.

3.6 TESTS 3A AND 3B

Prior to the tests being carried out, the rig was running at the required stable conditions for a minimum of 120 seconds. After this period, the DHW flow was reduced to 0.02 l/s as required by the test regime and logged for 180 seconds at a rate of 1 Hz.

3.7 TESTS 4A AND 4B

Prior to the test being carried out, the rig was running at the required stable conditions for a minimum of 120 seconds. After this period, the DHW flow was turned off and left for a minimum of 8 hours to establish “keep warm” conditions. During this test, the primary flow was diverted through a DN3 flowmeter so that the trickle flow could be measured. The data was logged at a rate of 1 Hz throughout the duration of the 8-hour test period.

3.8 TESTS 5A AND 5B

These tests were carried out while the HIU was still in “keep warm” mode after the 8-hour keep warm test. With the data still being logged at a rate of 1 Hz, the DHW flow was immediately brought back to 0.13 l/s.

3.9 TEST SET UP

Table 6 shows the setup of the tests as given in the test regime.

Table 6 Test setup as given in the test regime

Test No.	Test	static pressure on return	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	bar	°C	°C	l/s	kW	kW	°C	°C
			dP_1	t_{11}	t_{32}	q_3	P_3	P_2	t_{22}	t_{21}
Static tests										
0a	Static pressure test (same static pressure on both flow and return connections)	1.43 times rated value		70	50	-	-	-	n/a	n/a
1a	Space Heating 1 kW	3.0	0.5	70	55	-	-	1	60	40
1b	Space Heating 2 kW	3.0	0.5	70	55	-	-	2	60	40
1c	Space Heating 4 kW	3.0	0.5	70	55	-	-	4	60	40
1d	Space Heating 1 kW	3.0	0.5	60	50	-	-	1	45	35
1e	Space Heating 2 kW	3.0	0.5	60	50	-	-	2	45	35
1f	Space Heating 4 kW	3.0	0.5	60	50	-	-	4	45	35
Dynamic tests										
2a	DHW only DH 70°C flow	3.0	0.5	70	55	see DHW test profile	see DHW test profile	-	60	-
2b	DHW only DH 60°C flow	3.0	0.5	60	50			-	45	-
3a	Low flow DHW, DH 70°C flow	3.0	0.5	70	55	0.02	Record value	-	60	-
3b	Low flow DHW, DH 60°C flow	3.0	0.5	60	50	0.02	Record value	-	45	-
4a	Keep-warm, DH 70°C flow	3.0	0.5	70	55	0	0	-	60	-
4b	Keep-warm, DH 60°C flow	3.0	0.5	60	50	0	0	-	45	-
5a	DHW response time	3.0	0.5	70	55	0.13	Record value	-	60	-
5b	DHW response time	3.0	0.5	60	50	0.13	Record value	-	45	-

Table 7 shows the reporting structure of the tests as given in the test regime. See section 4 for the full test results.

Table 7 Test reporting structure as given in the test regime

Test	Description	Reporting	Pass/Fail
Static Tests			
0	Pressure tests	Pass/Fail as to whether HIU manages pressure test without leaks or damage.	Pass
1a	Space Heating 1 kW, 60/40°C secondary	t_{11}-primary flow temperature t_{12}-primary return temperature. Plot of key metrics over duration of test. **Note:** Outputs used as input data to 'High Temperature' Space Heating Volume Weighted Average Return Temperature calculation.	N/A
1b	Space Heating 2 kW, 60/40°C secondary		N/A
1c	Space Heating 4 kW, 60/40°C secondary		N/A
1d	Space Heating 1 kW, 45/35°C secondary	t_{11}-primary flow temperature t_{12}-primary return temperature Plot of key metrics over duration of test. **Note:** Outputs used as input data to 'Low Temperature' Space Heating Volume Weighted Average Return Temperature calculation.	N/A
1e	Space Heating 2 kW, 45/35°C secondary		N/A
1f	Space Heating 4 kW, 45/35°C secondary		N/A
Dynamic Tests			
2a	DHW only, DH 70°C flow; 55°C DHW	Pass/Fail on DHW (at t_{32}) exceeding 65.0°C (to 1 decimal point) for more than 10 consecutive seconds. State the maximum and minimum DHW temperatures over the period of the test when there is a DHW flow. Assessment of scaling risk as per criteria detailed in 2.26. **Note:** Outputs used as input data to 'High Temperature' Domestic Hot Water Weighted Average Return Temperature calculation. Plot t_{32}, t_{31}, q_3, t_{12} q_1	Pass
2b	DHW only, DH 60°C flow; 50°C DHW	State the maximum and minimum DHW temperatures over the period of the test when there is a DHW flow. Plot t_{32}, t_{31}, q_3, t_{12} q_1 **Note:** Outputs used as input data to 'Low Temperature' Domestic Hot Water Weighted Average Return Temperature calculation.	N/A
3c	Low flow DHW, DH 70°C flow; 55°C DHW	Pass/Fail on DHW (at t_{32}) exceeding 65.0°C (1 decimal place) for more than 10 consecutive seconds. Comment on ability to deliver DHW at low flow based on DHW temperature reaching at least 45.0°C (1 decimal place) at the end of the 180 second period of low flow DHW. Comment on ability to deliver stable DHW flow temperature (at t_{32}), defined as ability to maintain 55.0 +/-3.0°C (1 decimal place) during the last 60 seconds of the test. Maximum temperature achieved and +/-°C variance around 55.0°C (1 decimal place) to be stated. Assessment of scaling risk as per criteria detailed in 2.26. Plot of key metrics for 60 seconds of 0.13 l/s flow and the subsequent 180 seconds of 0.02 l/s DHW flow.	Pass

Test	Description	Reporting	Pass/Fail
3d	Low flow DHW, DH 60°C flow; 50°C DHW	Comment on ability to deliver DHW at low flow rate based on DHW temperature reaching at least 45°C (one decimal place) at the end of the 180 second period of low flow DHW. Comment on ability to deliver stable DHW flow temperature (at t_{32}), defined as ability to maintain 50.0 +/-3°C (1 decimal place) during the last 60 seconds of the test. Maximum temperature achieved and +/-°C variance around 50.0°C (1 decimal place) to be stated. Plot of key metrics for 60 seconds of 0.13 l/s flow and the subsequent 180 seconds of 0.02 l/s DHW flow. Maximum temperature achieved and +/-°C variance around 50.0°C (1 decimal place) to be stated.	N/A
4a	Keep-warm, DH 70°C flow; 55°C DHW	Assessment of whether valid keep-warm operation, based on 5a response time criteria: Pass / Fail. Observation on the operation of the HIU during keep-warm. Assessment of scaling risk, based on duration of temperatures in excess of 55.0°C (one decimal place). Plot temperature t10. Comment on HIU keep-warm controls options. Plot of key metrics over duration of test. State average heat load for the duration of the test. State average primary flowrate for the duration of the test. **Note:** Outputs used as input data to 'High Temperature' Keep-warm Volume Weighted Average Return Temperature calculation.	Pass
4b	Keep-warm, DH 60°C flow; 50°C DHW	Assessment of whether valid keep-warm operation, based on 5b response time criteria: Pass / Fail. Observation on the operation of the HIU during keep-warm. Assessment of scaling risk, based on duration of temperatures in excess of 55.0°C (one decimal place). Plot temperature t10. Comment on HIU keep-warm controls options. Plot of key metrics over duration of test. State average heat load for the duration of the test. State average primary flowrate for the duration of the test. **Note:** Outputs used as input data to 'Low Temperature' Keep-warm Volume Weighted Average Return Temperature calculation.	Pass
5a	DHW response time, DH 70°C flow; 55°C DHW	Pass/Fail on DHW (at t_{32}) exceeding 65.0°C (1 decimal place) for more than 10 consecutive seconds. State time to achieve a DHW temperature 45.0°C (1 decimal place) and not subsequently drop below 42.0°C (1 decimal place).' Plot t_{32}, t_{31}, q_3, t_{12}, q_1 over duration of test.	Pass
5b	DHW response time, DH 60°C flow; 50°C DHW	Pass/Fail on DHW (at t_{32}). State time to achieve a DHW temperature 45.0°C (1 decimal place) and not subsequently drop below 42.0°C (1 decimal place). Plot t_{32}, t_{31}, q_3, t_{12}, q_1 over duration of test.	Pass

4 TEST RESULTS

During all the tests, the ambient temperature within the vicinity of the HIU being tested was within the tolerance of 20°C ±5°C as specified in the test regime. Charts of the key metrics for the thermal tests are given in Appendix A.

4.1 PRESSURE TEST – 0A

The DHW circuit and the space heating circuit were pressurised to 1.5 bar (±5%). The primary circuit was pressurised to 1.43 times the rated maximum static pressure of 16 bar (test pressure 22.88bar). This pressure was held for 30 minutes. After the 30-minute test period, the connections and fittings on the HIU were inspected for leaks and any signs of deformation. During the 30-minute period, there were no leaks or signs of deformation.

Result – Pass.

4.2 STATIC TESTING – 1A, 1B, 1C, 1D, 1E AND 1F

The following tests were carried out on the space heating circuit:

- 1a – DH inlet 70°C, heating return at 40°C and a flow set to achieve 1kW heating duty
- 1b – DH inlet 70°C, heating return at 40°C and a flow set to achieve 2kW heating duty
- 1c – DH inlet 70°C, heating return at 40°C and a flow set to achieve 4kW heating duty
- 1d – DH inlet 60°C, heating return at 35°C and a flow set to achieve 1kW heating duty
- 1e – DH inlet 60°C, heating return at 35°C and a flow set to achieve 2kW heating duty
- 1f – DH inlet 60°C, heating return at 35°C and a flow set to achieve 4kW heating duty

For tests 1a to 1c, the space heating outlet temperature was set to 59°C in the HIU control software to achieve 60°C (±0.5°C) during the 4kw test. The For tests 1d to 1f, the space heating outlet temperature was set to 45°C in the HIU control software to achieve 45°C (±0.5°C) during the 4kw test. Table 8 shows a summary of the results for the static tests.

Table 8 Results from the static tests

Test	District Heating Circuit					Space Heating Circuit			
	t_{11} (°C)	t_{12} (°C)	q_1 (l/s)	Δp_1 (kPa)	P_1 (kW)	T_{21} (°C)	T_{22} (°C)	q_2 (l/s)	P_2 (kW)
1a	69.99	42.49	0.010	50.60	1.14	39.73	61.66	0.011	0.99
1b	70.04	43.87	0.019	50.94	2.06	39.94	60.93	0.023	1.98
1c	70.10	45.28	0.039	50.70	4.01	39.99	59.77	0.048	3.90
Uncertainty	±0.018	±0.018	±0.0006	0.031	±0.06	±0.018	±0.018	±0.0006	±0.06
1d	59.93	36.26	0.012	50.67	1.18	35.10	48.33	0.020	1.09
1e	60.19	35.80	0.019	50.41	1.93	35.00	43.10	0.057	1.91
1f	60.24	37.44	0.043	51.25	4.07	35.20	45.01	0.098	3.98
Uncertainty	±0.018	±0.018	±0.0006	0.031	±0.06	±0.018	±0.018	±0.0007	±0.04

4.3 DYNAMIC TESTING OF THE HIU OPERATION – 2A AND 2B

4.3.1 Test 2a

Test 2a was carried out with the DH water temperature set to 70°C and the cold-water supply to the DHW circuit at 10°C. The DHW outlet temperature in the HIU control software was set to 56°C to achieve 55.0°C (±0.5°C) at a DHW flow rate of 0.130 l/s, prior to the test.

During test 2a:

- The DHW temperature did not exceed 65°C at any point during the test
- The maximum DHW temperature was 58.9°C
- The minimum DHW temperature was 50.0°C
- Details of the scaling risk are given in Table 9

Result – Pass

4.3.2 Test 2b

Test 2b was carried out with the DH water temperature set to 60°C and the cold-water supply to the DHW circuit at 10°C. The DHW outlet temperature in the HIU control software was set to 50°C to achieve 50.0°C (±0.5°C) at a DHW flow rate of 0.130 l/s, prior to the test.

During test 2b:

- The maximum DHW temperature was 52.9°C
- The minimum DHW temperature was 46.3°C

Result – There is no pass/fail criteria for this test.

4.4 LOW FLOW DHW TESTS – 3A AND 3B

4.4.1 Test 3a

Test 3a was carried out with the DH water temperature set to 70°C and the cold water supply to the DHW circuit at 10°C. The DHW outlet temperature setpoint remained at the same position, set to achieve 55.0 (±0.5°C) at a DHW flow rate of 0.130 l/s. The low DHW flow rate was set to 0.02 l/s as required by the test regime.

During test 3a:

- The DHW temperature did not exceed 65°C at any point during the test
- The HIU was able to deliver DHW above 45°C at the end of the 180 second test
- During the last 60 seconds of the test the DHW temperature averaged 54.5°C and ranged from 55.0°C to 54.0°C so the results were within the stated tolerance of 55.0°C ±3°C during this time period.
- The DHW maximum and minimum outlet temperatures were 59.2°C and 49.0°C respectively during the 180 second test.
- Details of the scaling risk are given in Table 9

Result – Pass

4.4.2 Test 3b

Test 3b was carried out with the DH water temperature set to 60°C and the cold water supply to the DHW circuit at 10°C. The DHW outlet temperature setpoint remained at the same position, set to achieve 50.0 (±0.5°C) at a DHW flow rate of 0.130 l/s. The low DHW flow rate was set to 0.02 l/s as required by the test regime.

During test 3b:

- The HIU was able to deliver DHW above 45°C at the end of the 180 second test
- During the last 60 seconds of the test the DHW temperature averaged 49.2°C and ranged from 49.7°C to 48.7°C so the results were within the stated tolerance of 50.0°C ±3°C during this time period.
- The DHW maximum and minimum outlet temperatures were 53.5°C and 42.9°C respectively during the 180 second test.

Result – There is no pass/fail criteria for this test.

4.5 KEEP WARM TESTS – 4A AND 4B

The keep warm function was a pulsed flow on the DH circuit as can be seen on the charts in Appendix A.

4.5.1 Test 4a

Test 4a was carried out with the DH water temperature set to 70°C and the cold water supply to the DHW circuit at 10°C. The DHW outlet temperature setpoint remained at the same position, set to achieve 55.0 (±0.5°C) at a DHW flow rate of 0.130 l/s.

The keep warm settings in the HIU control software were as follows:

Parameter P11 – 46°C

Based on the results for the DHW response time during test 5a, the HIU does perform a valid keep warm operation.

Once the keep warm function had stabilised (approximately 6,000 seconds into the test), the average t_{11} temperature for the remainder of the test (22,800 seconds) was 49.2°C varying between 51.2°C and 47.9°C.

During test 4a:

- The average heat load during the 8-hour keep warm period was 31 W
- The average primary flow rate during the 8-hour keep warm period was 4.1 l/h
- The average measured voltage was 230.0 V
- The average measured electrical power draw was 1.5W
- Details of the scaling risk are given in Table 9

4.5.2 Test 4b

Test 4b was carried out with the DH water temperature set to 60°C and the cold water supply to the DHW circuit at 10°C. The DHW outlet temperature setpoint remained at the same position, set to achieve 50.0 (±0.5°C) at a DHW flow rate of 0.130 l/s.

The keep warm setting in the HIU control software were as follows:

Parameter P11 – 46°C

Based on the results for the DHW response time during test 5b, the HIU does perform a valid keep warm operation.

Once the keep warm function had stabilised (approximately 4,000 seconds into the test), the average t_{11} temperature for the remainder of the test (24,800 seconds) was 48.5°C varying between 49.8°C and 47.5°C.

- The average heat load during the 8-hour keep warm period was 34 W
- The average primary flow rate during the 8-hour keep warm period was 6.9 l/h
- The average measured voltage was 229.9 V
- The average measured electrical power draw was 1.5 W
- Details of the scaling risk are given in Table 9

4.6 DHW RESPONSE TIME – 5A AND 5B

4.6.1 Test 5a

Test 5a was carried out immediately after test 4a with all the settings and conditions the same.

During test 5a:

- The DHW temperature did not exceed 65.0°C during the test
- The DHW achieved 45.0°C in 6 seconds from the first recorded non-zero DHW flow reading
- The DHW temperature did not subsequently drop below 42.0°C

Scaling risk factor – Pass
Achieving 45°C DHW within 15 seconds – Pass
DHW temperature not subsequently dropping below 42.0°C – Pass

Overall result – Pass

4.6.2 Test 5b

Test 5b was carried out immediately after test 4b with all the settings and conditions the same.

During test 5b:

- The DHW achieved 45.0°C in 7 seconds from the first recorded non-zero DHW flow reading
- The DHW temperature did not subsequently drop below 42.0°C

Achieving 45°C DHW within 15 seconds – Pass
DHW temperature not subsequently dropping below 42.0°C – Pass

Overall result – Pass

4.7 TOTAL SCALING RISK ASSESSMENT

The scaling risk criteria is given in section 2.26 of the test regime. Table 9 gives details of the scaling risk associated with this HIU. If any of the factors given in Table 9 occur, then there is an increased scaling risk of the DHW plate in hard water areas.

Table 9 Total scaling risk assessment

Has the HIU got a TMV or TRV on the output of the DHW plate heat exchanger?	**No**	
	Test	
	2a	3a
t_{32} above 60°C for more than 5 seconds	**No**	**No**
t_{12} exceeds 55°C at any point of the test	**No**	**No**
	4a	4b
t_{12} exceeds 50°C at any time	**No**	**No**

4.8 VOLUME WEIGHTED AVERAGE RETURN TEMPERATURE

The Volume Weighted Average Return Temperature (VWART) results are given in Appendix B.

APPENDIX A: DATA CHARTS

Figure 3 Results for test 1a: 1kW Space heating – DH 70°C supply

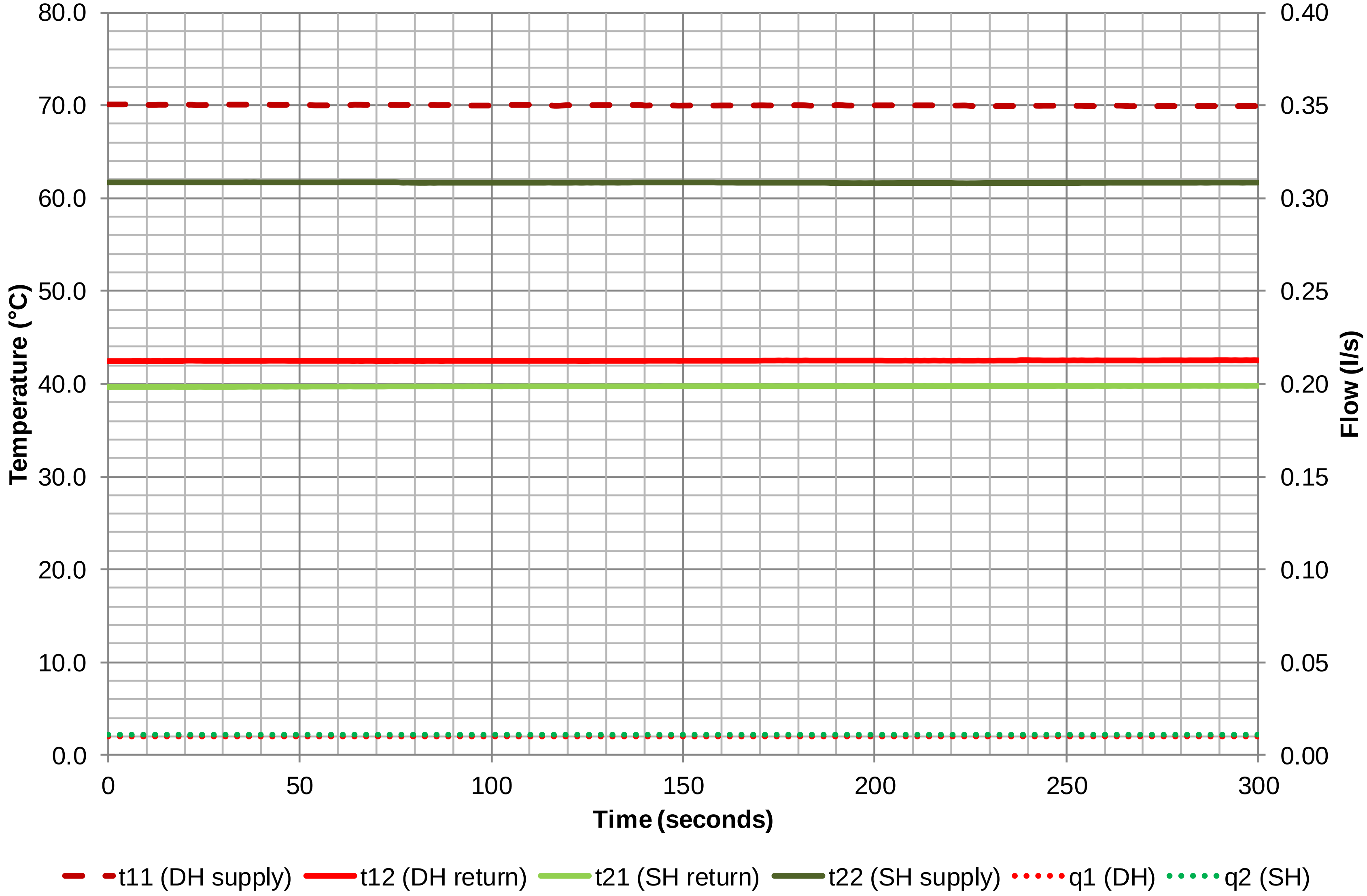


Figure 4 Results for test 1b: 2kW Space heating – DH 70°C supply

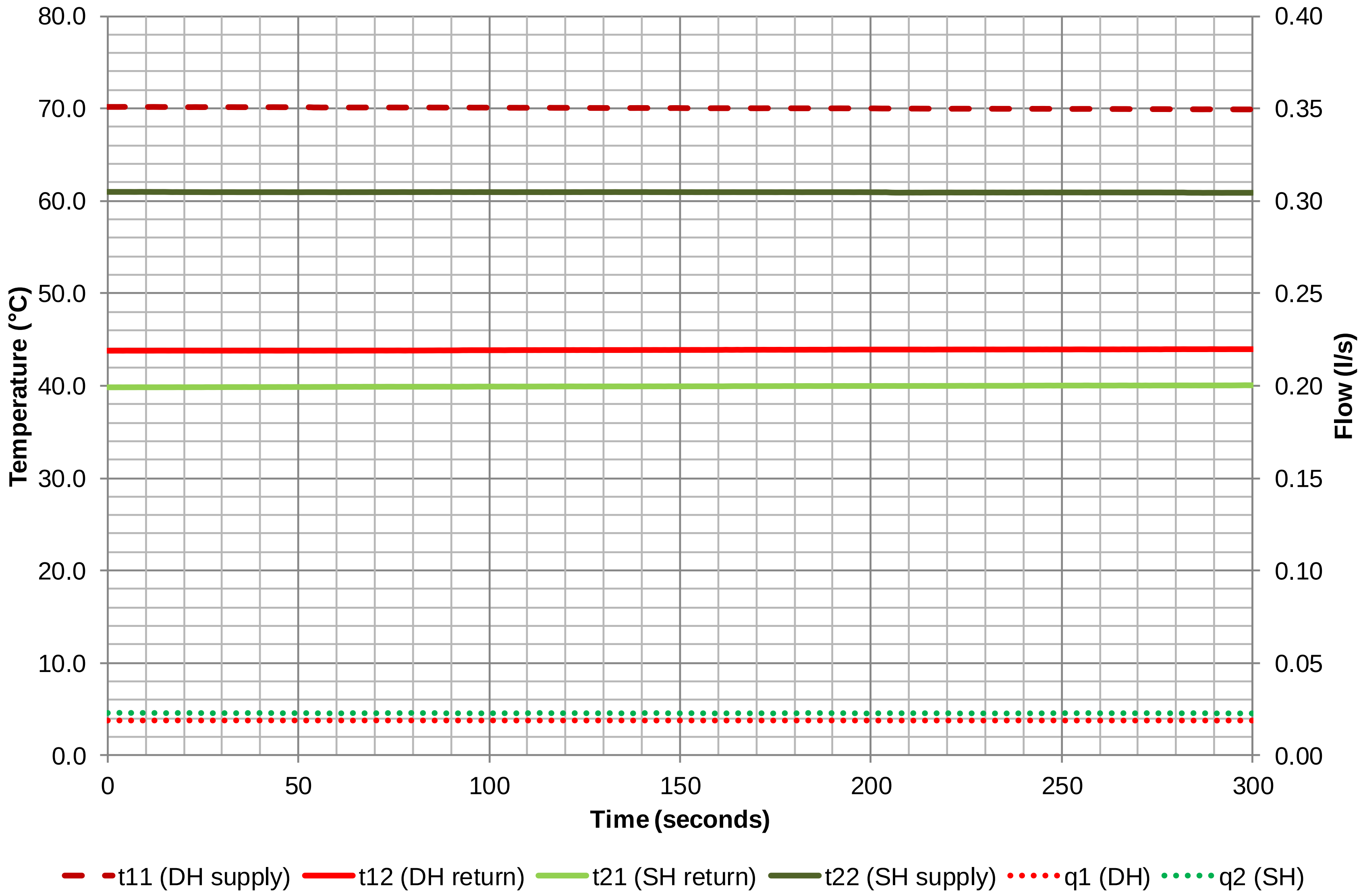


Figure 5 Results for test 1c: 4kW Space heating – DH 70°C supply

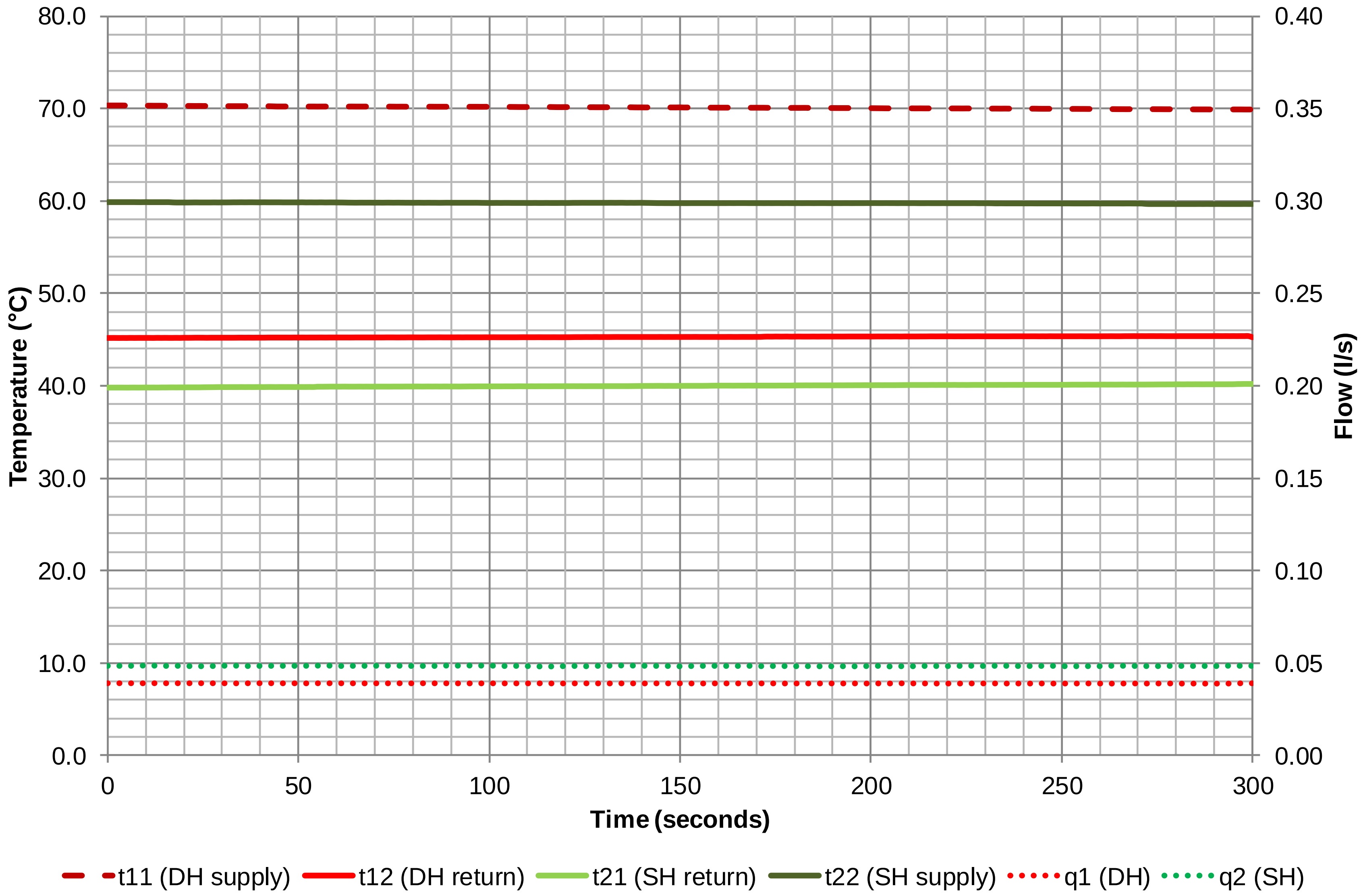


Figure 6 Results for test 1d: 1kW Space heating – DH 60°C supply

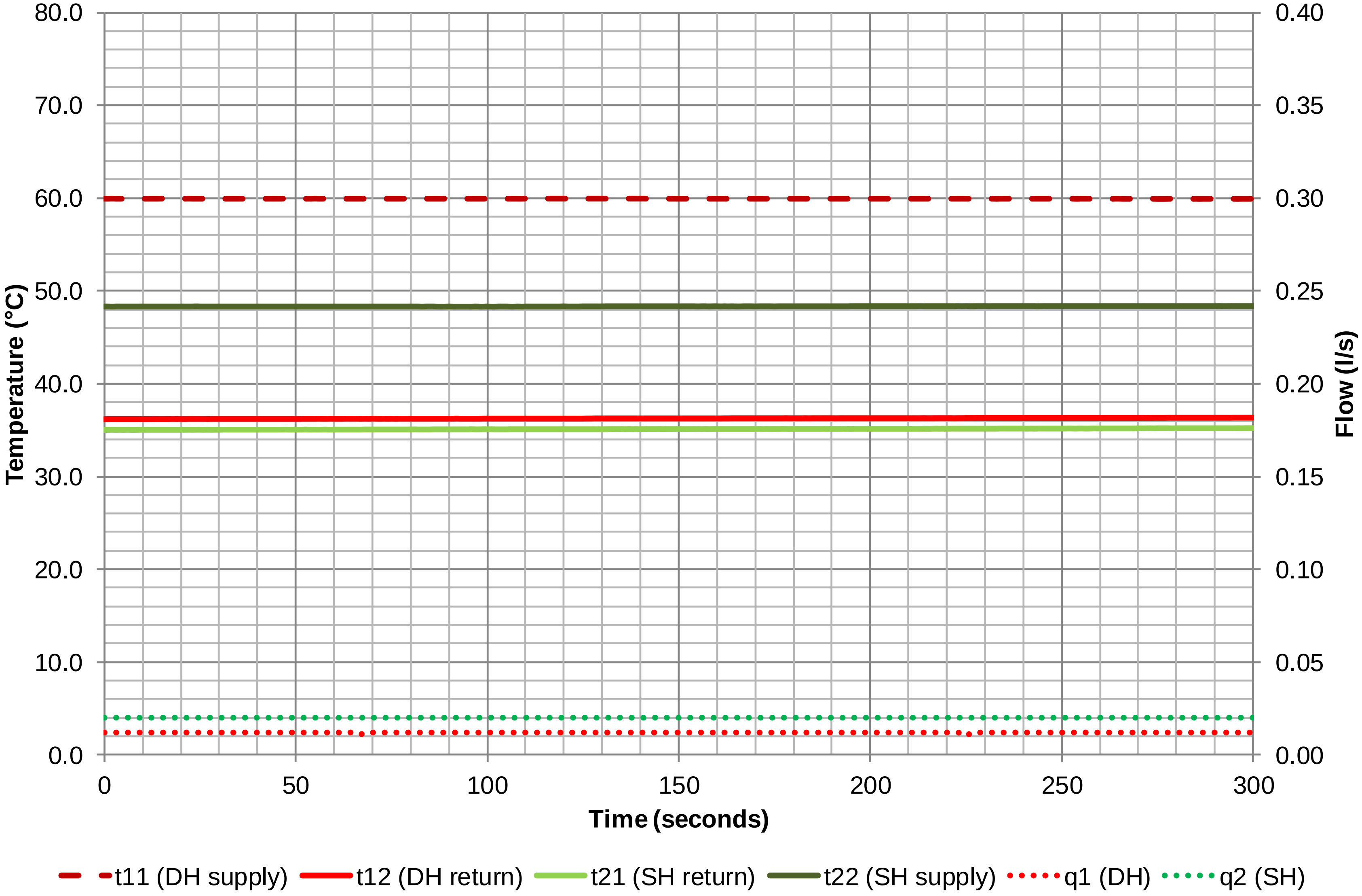


Figure 7 Results for test 1e: 2kW Space heating – DH 60°C supply

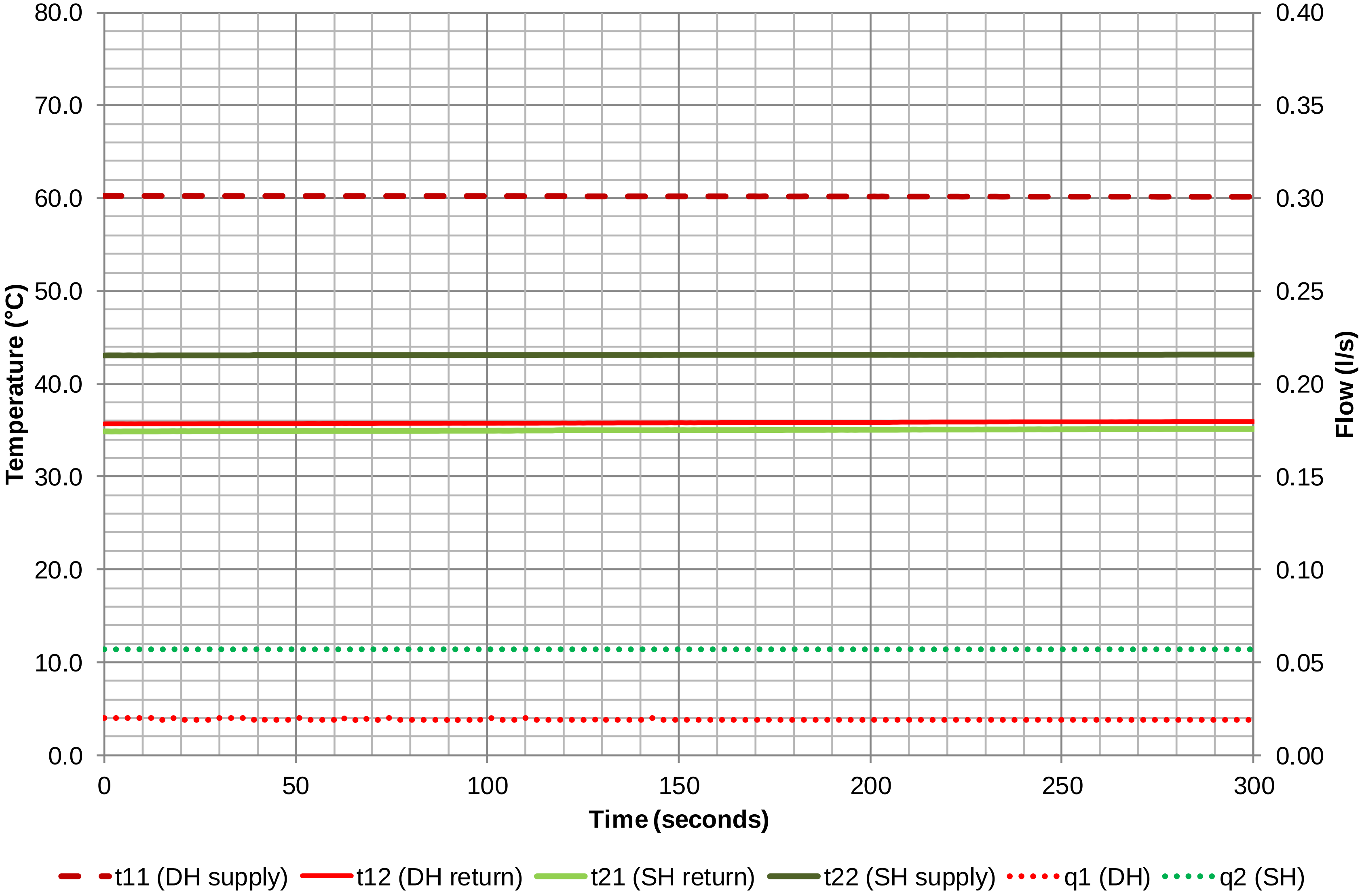


Figure 8 Results for test 1f: 4kW Space heating – DH 60°C supply

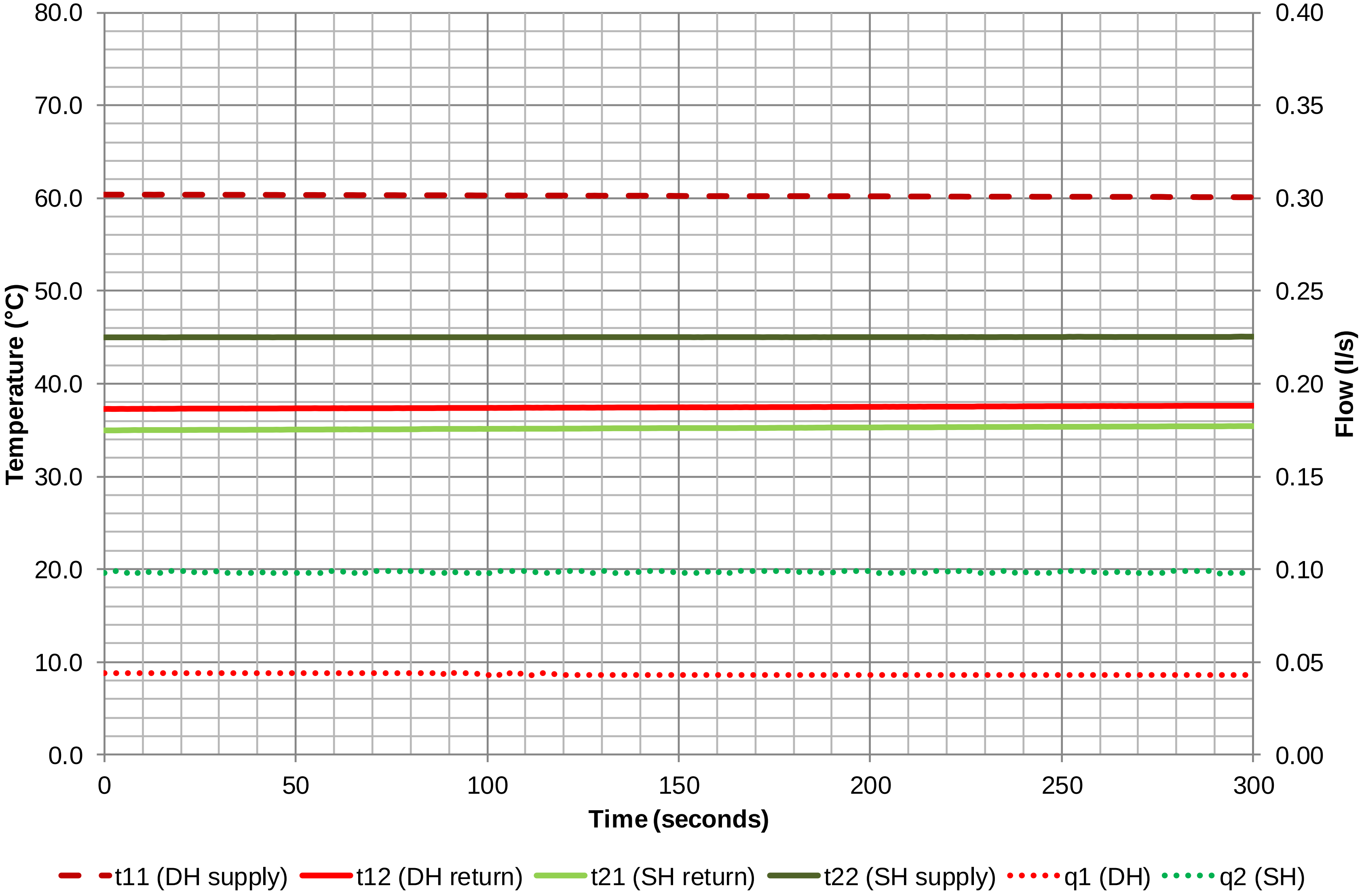


Figure 9 Results for test 2a: DHW dynamic test – DH 70°C supply

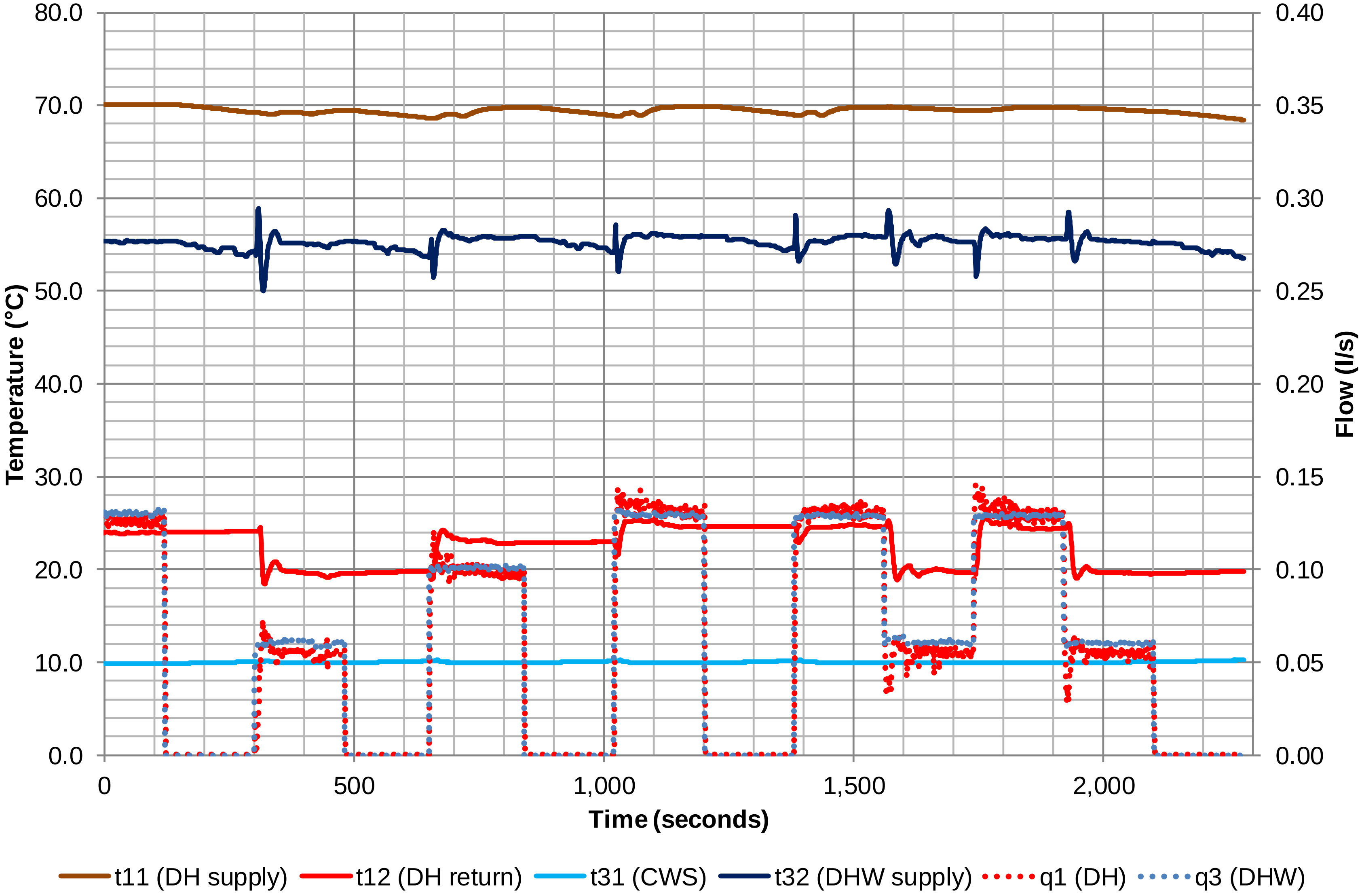


Figure 10 Results for test 2b: DHW dynamic test – DH 60°C supply

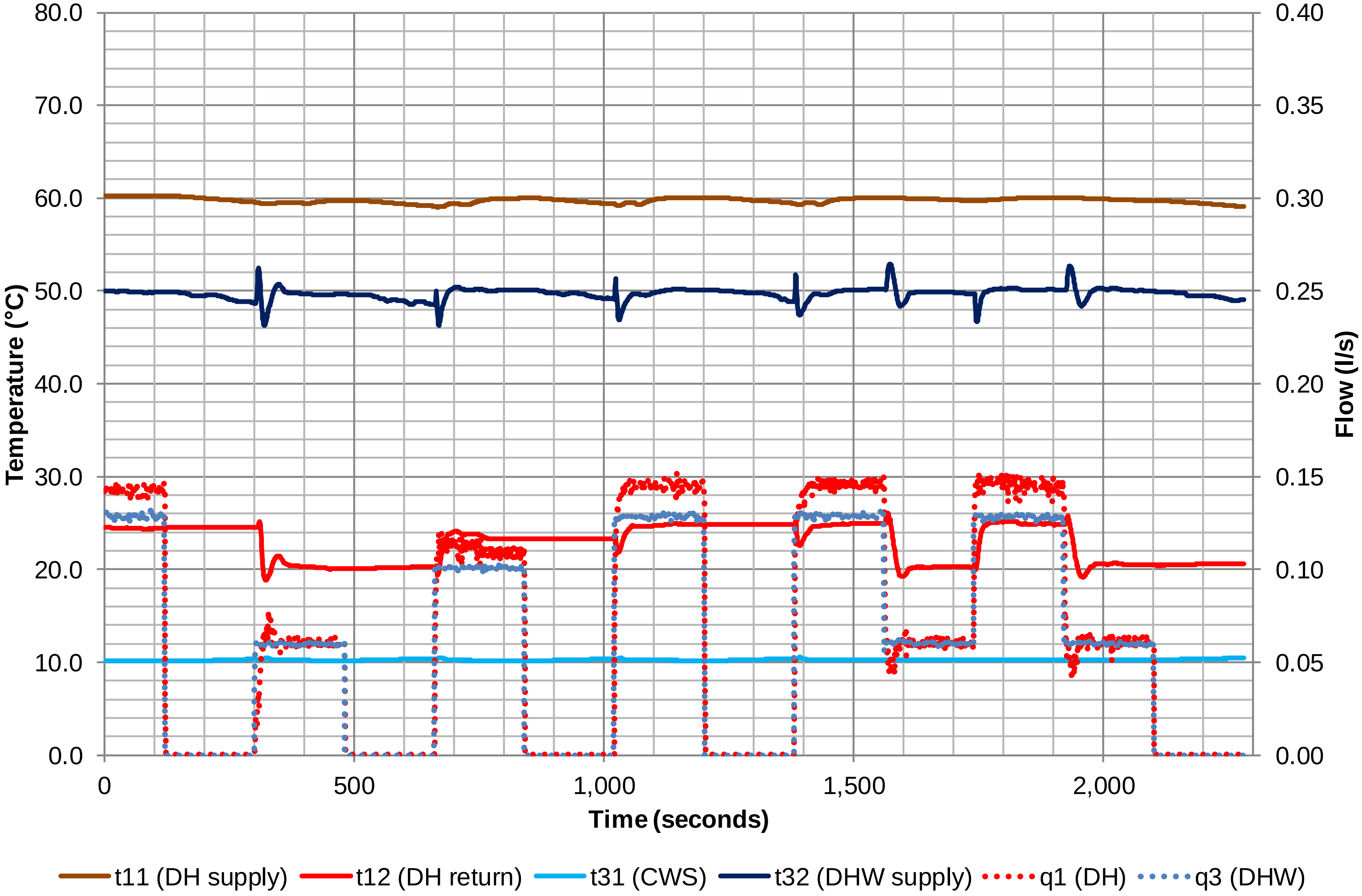


Figure 11 Results for test 3a: Low flow DHW test – DH 70°C supply

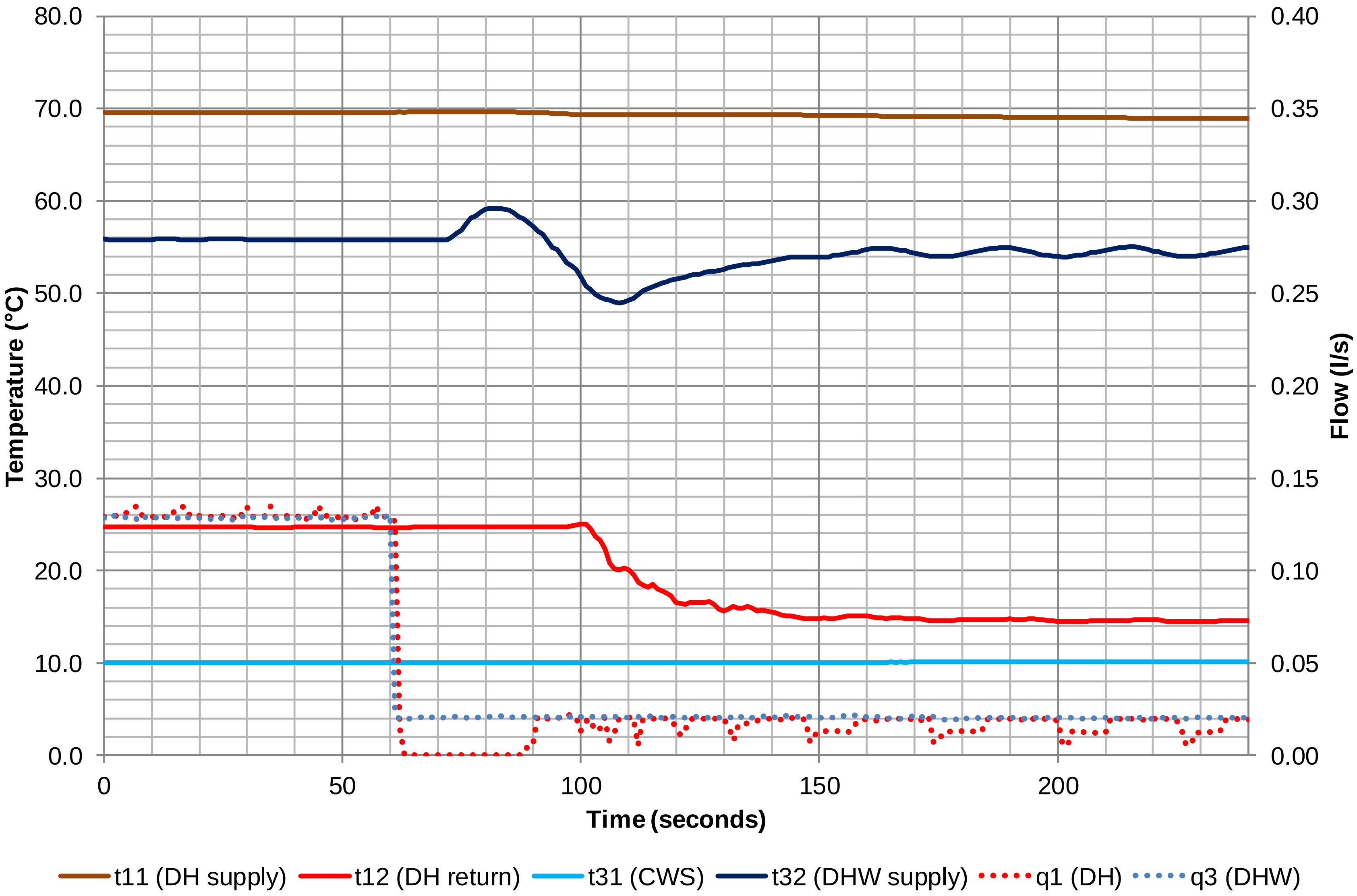


Figure 12 Results for test 3b: Low flow DHW test – DH 60°C supply

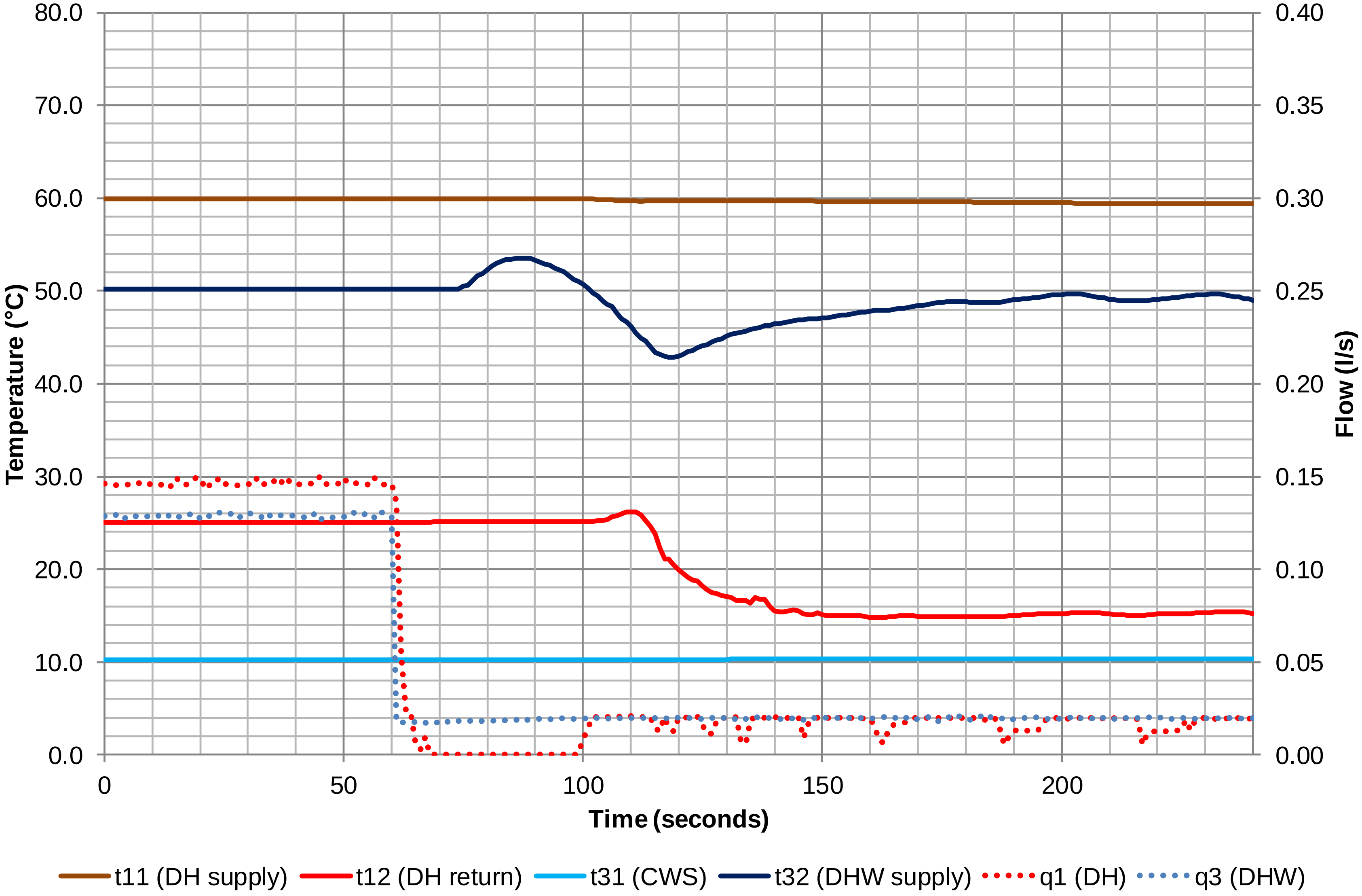


Figure 13 Results for test 4a: Keep warm test – DH 70°C supply

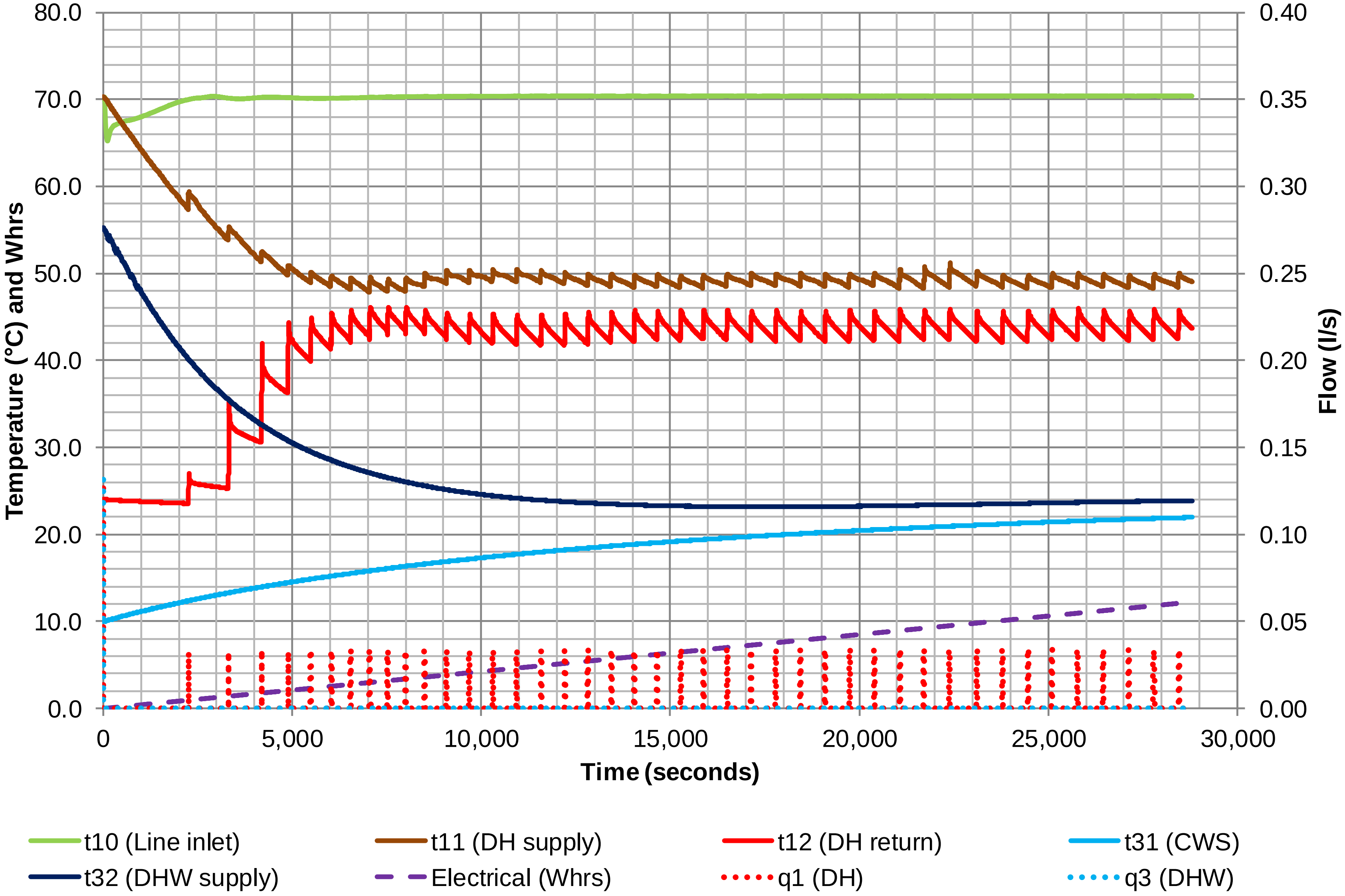


Figure 14 Results for test 4b: Keep warm test – DH 60°C supply

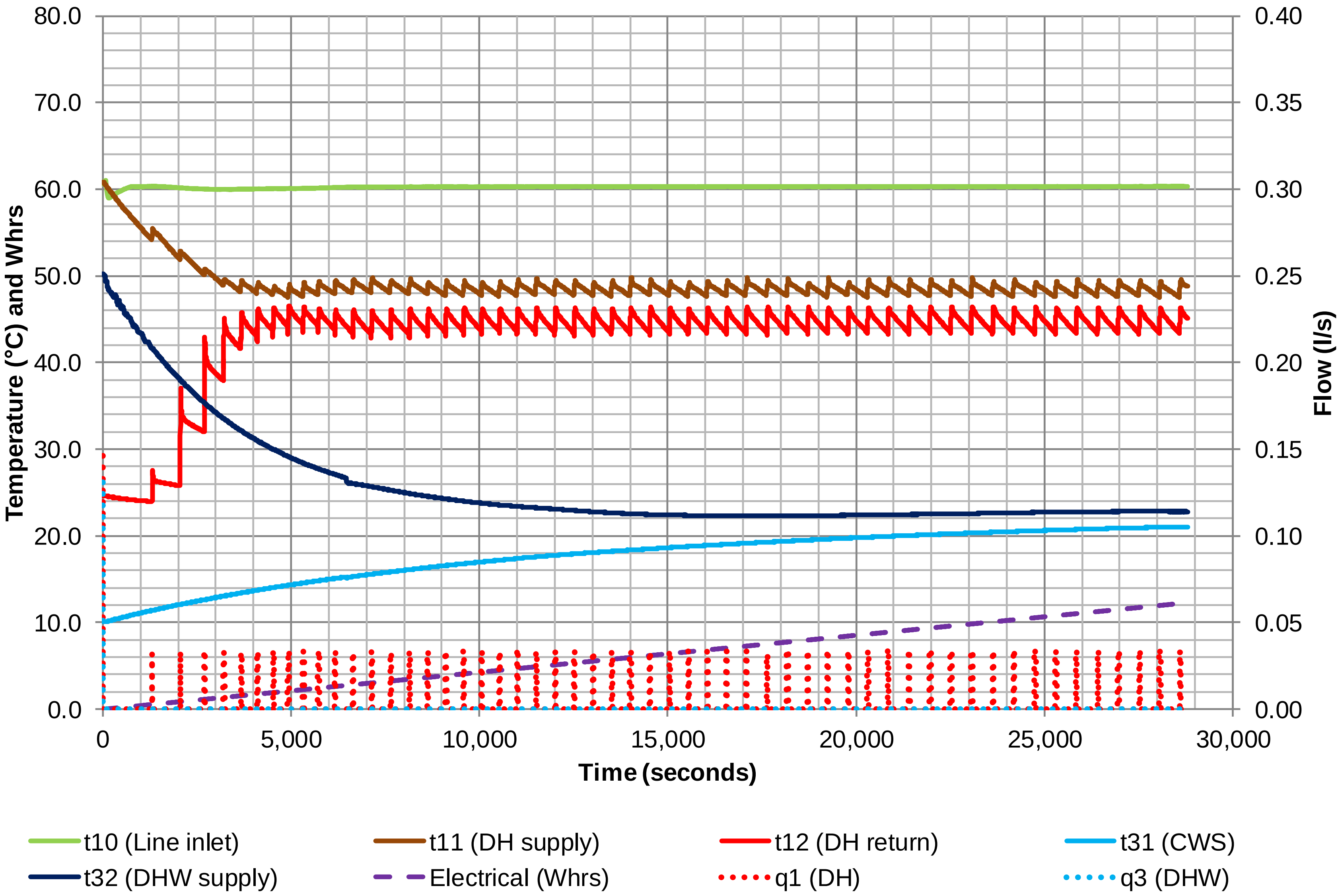


Figure 15 Results for test 5a: DHW response time – DH 70°C supply

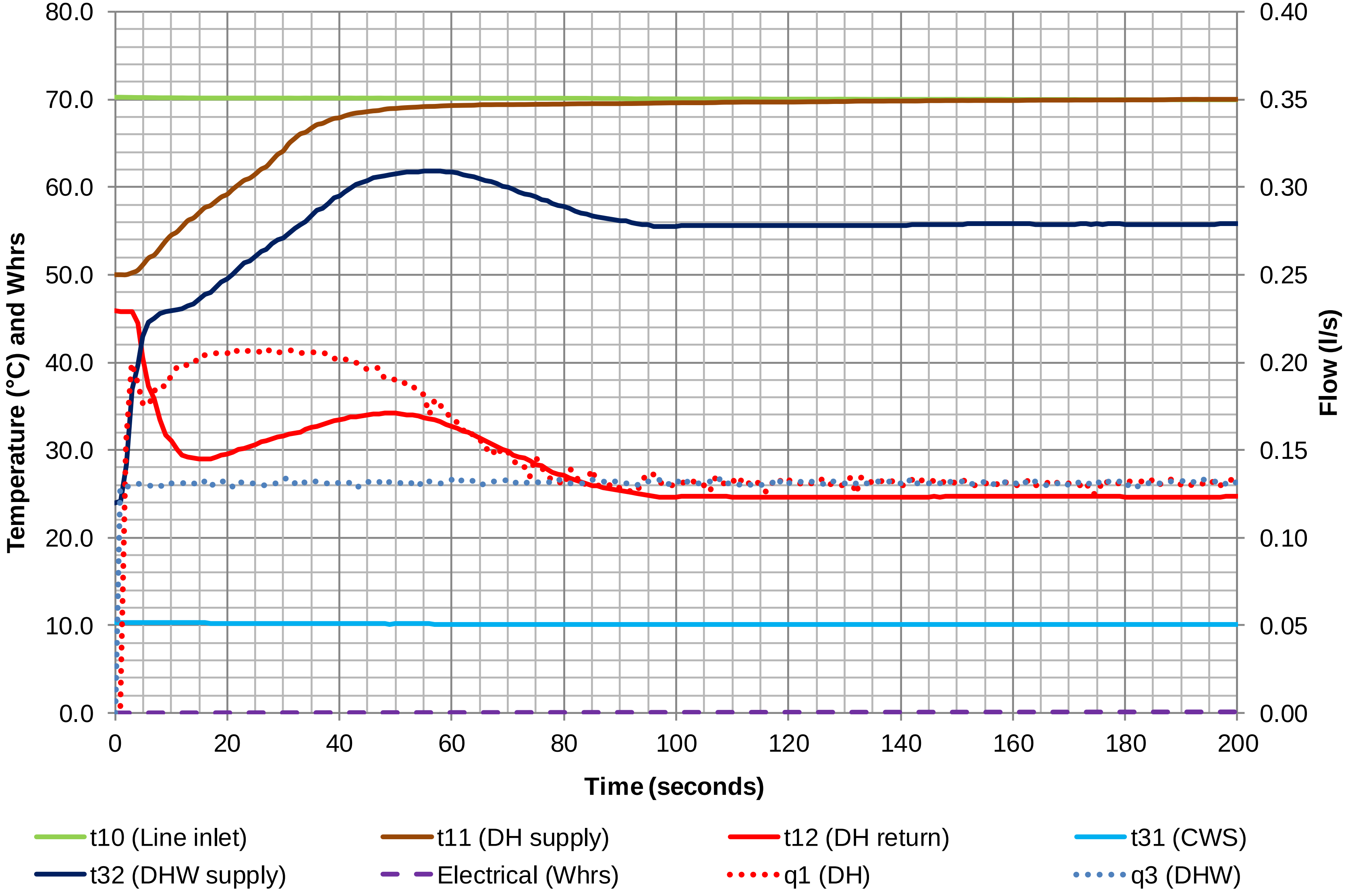
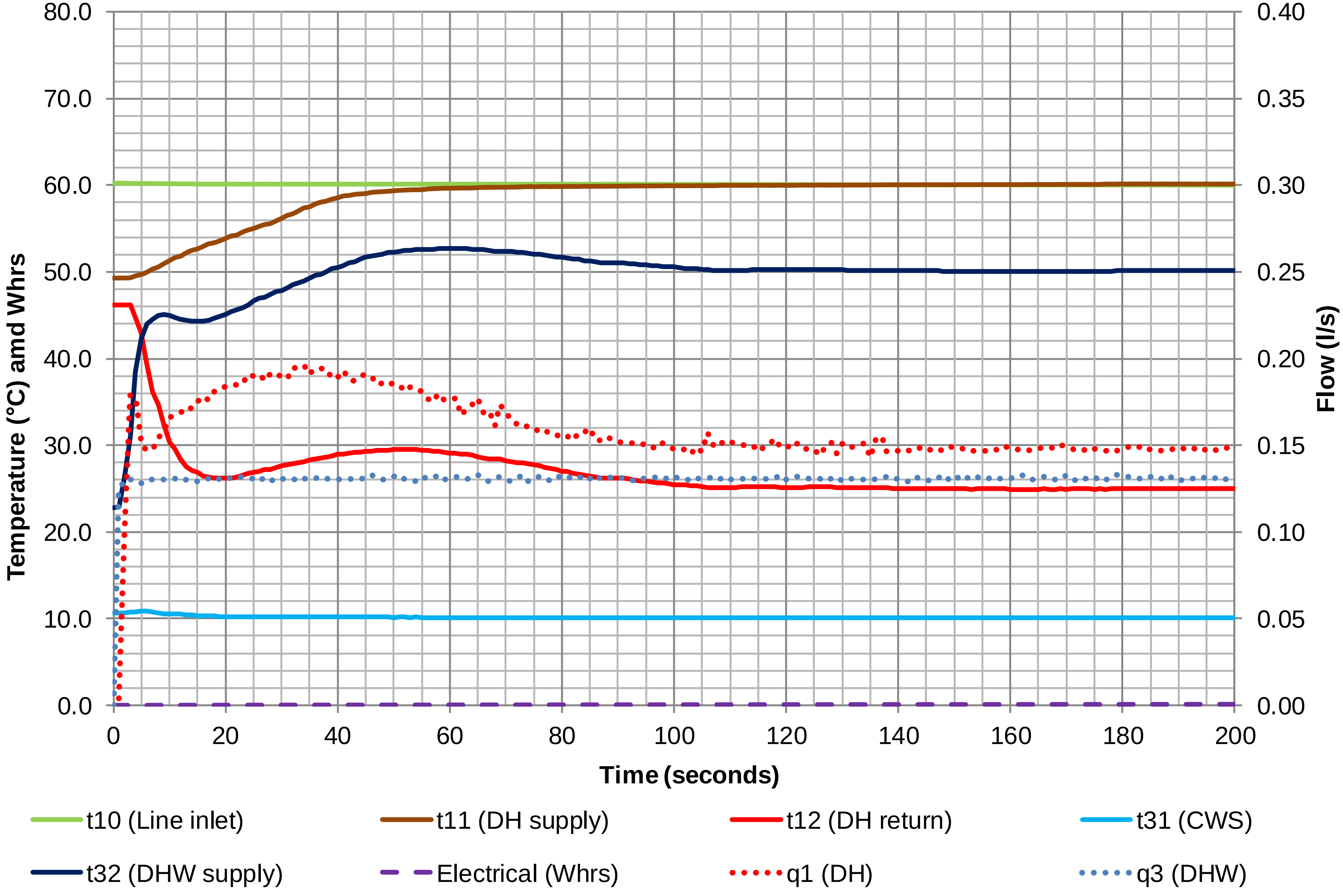


Figure 16 Results for test 5b: DHW response time – DH 60°C supply



APPENDIX B: VWART CALCULATIONS

High Temperature VWART Calculations

BSRIA

High Temperature VWART Calculation for Rhico Heating Solutions
Primary flow temperature = 70°C, DHW set point = 55°C, Space heating temperatures = 40°C/60°C
Test carried out by BSRIA Ltd. in July 2020, Test Reference 101924/1
Manufacturer: Rhico Heating Solutions; Model: TI45 Ultra Lean; Serial number: 428440300; Year of manufacture: 2020
VWART calculation prepared by Colin Judd of BSRIA Ltd. on 08 August 2020

	VWART (°C)	Volume (m^3)
DHW	22	26.7
Keep Warm	43	33.4
Space Heating	44	50.6

	VWART with keep warm active	
Period	VWART (°C)	% Time
No Heating	34	93%
Heating	44	7%
Overall	35	

	DHW draw test results			Post DHW draw (60 Seconds)	
	Power (W)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)
Low	11283	0.190	19.8	0.003	19.56
Medium	19262	0.359	22.9	0.005	22.90
High	24773	0.471	24.7	0.012	24.61

DHW draw volumes per annum		
Energy (kWh)	Time (Hours)	Volume (m^3)
729	64.61	12.273
297	15.42	5.533
444	17.92	8.442

Post DHW draw volumes per annum		
Events	Avg duration (Seconds)	Volume (m^3)
10000	30	0.270
660	75	0.074
300	145	0.143

Keep warm test results	
Primary Flow (m^3/hr)	Return Temp (VWART) (°C)
0.0042	43.5

Keep Warm volumes per annum	
Time (Hours)	Volume (m^3)
8026	33.437

	Space Heating Test Results		
	Power (W)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)
1kW	1009	0.036	42.5
2kW	1984	0.068	43.9
4kW	3974	0.140	45.3

Space Heating volumes per annum		
Energy (kWh)	Time (Hours)	Volume (m^3)
98	97.16	3.498
787	396.70	27.134
565	142.17	19.961

Low Temperature VWART Calculations

Low Temperature VWART Calculation for Rhico Heating Solutions

Primary flow temperature = 60°C, DHW set point = 50°C, Space heating temperatures = 35°C/45°C

Test carried out by BSRIA Ltd. in July 2020, Test Reference 101924/1

Manufacturer: Rhico Heating Solutions; Model: TI45 Ultra Lean; Serial number: 428440300; Year of manufacture:2020

VWART calculation prepared by Colin Judd of BSRIA Ltd. on 08 August 2020

	VWART (°C)	Volume (m^3)
DHW	22	33.8
Keep Warm	45	56.1
Space Heating	37	53.8

	VWART with keep warm active	
Period	VWART (°C)	% Time
No Heating	36	93%
Heating	36	7%
Overall	36	

	DHW draw test results			Post DHW draw (60 Seconds)		DHW draw volumes per annum			Post DHW draw volumes per annum		
	Power (W)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)	Energy (kWh)	Time (Hours)	Volume (m^3)	Events	Avg duration (Seconds)	Volume (m^3)
Low	9838	0.209	20.5	0.004	20.11	729	74.10	15.477	10000	30	0.315
Medium	16720	0.395	23.3	0.011	23.28	297	17.76	7.023	660	75	0.144
High	21099	0.512	24.5	0.004	24.82	444	21.04	10.768	300	145	0.044

Keep warm test results	
Primary Flow (m^3/hr)	Return Temp (VWART) (°C)
0.0070	44.6

Keep Warm volumes per annum	
Time (Hours)	Volume (m^3)
8011	56.051

	Space Heating Test Results			Space Heating volumes per annum		
	Power (W)	Primary Flow (m^3/hr)	Return Temp (VWART) (°C)	Energy (kWh)	Time (Hours)	Volume (m^3)
1kW	1106	0.043	36.3	98	88.64	3.825
2kW	1930	0.069	35.8	787	407.72	28.117
4kW	4038	0.156	37.4	565	139.93	21.839