



Guidance for Interpreting BESA HIU Test Results

Modules 1, 2, 7 & 8 –
Indirect Space Heating
and Domestic Hot Water
with Keep Warm

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In the rapidly evolving landscape of building services, Heat Interface Units (HIUs) play a critical role in ensuring the efficient distribution of heat within residential heat network developments. With over 50,000 HIUs being installed each year in the UK, it is crucial to set performance standards in order to improve HIU performance across the sector.

The BESA HIU Test Regime provides a detailed and rigorous evaluation of HIU performance in UK residential heat networks (refer to the BESA Technical Standard for UK HIU Test Regime). As part of the regime, HIUs are tested across several usage scenarios, for space heating or domestic hot water (DHW). However, the output results presented in the test reports are often complex to interpret, leading to a lack of understanding in how to evaluate HIU performance from test data. This can result in an overreliance on simplified metrics, such as volume-weighted average return temperatures (VWARTs).

This document serves as a guide to those interpreting the results from test reports of the BESA HIU Testing Regime. Users should consult this document to supplement any test reports, under the newest version of the BESA Test Standard (V3-Rev001).

Section 3 details guidance for interpreting the results of each test under Modules 7 and 8 of the BESA HIU Testing Regime for domestic hot water (DHW) with Keep Warm. Section 4 provides the corresponding guidance for Modules 1 and 2 of the BESA HIU Testing Regime for indirect Space Heating.

For each test, a discussion of the purpose and context behind the test is given, followed by its pass/fail criteria and best practice benchmarks (if any). Following this, graphical examples of the test output figures are illustrated, labelled with features to compare HIU performance against the pass/fail and best practice criteria. These are accompanied by technical explanation of the HIU operation and how performance issues manifest in the results graphs.

Please note that the discussion in this document is objective and does not constitute any commercial stance or preference. Also, the graphs in this guidance document are not from specific test reports but rather have been generated to highlight technical points and features relevant to individual tests. As such, these figures have been constructed only for technical discussion purposes, without any intended commercial bias.

Whilst the Test Standard has been updated recently and has imposed stricter standards on HIU performance, there are several limitations of the regime worth mentioning. The points below should be considered before referring to Sections 3 and 4 of this document or looking at test results.

2.1 HIU Caveats

The purpose of the BESA HIU Test Regime is for performance testing only. The tests measure a significant number of variables, some of which may be of a higher importance than others to specific end users. However, it is recommended that all aspects of the BESA test results are assessed to objectively determine a HIU's tested performance.

For HIU procurement, there are several other important factors that are not relevant to the Test Standard and so are not covered within the scope of the test regime. A more detailed overview of these is provided in [Appendix D: HIU Procurement Considerations](#). This includes, but is not limited to, the following attributes:

- Installed performance
- Metering solutions
- Reliability/maintenance
- Price
- Remote access to dwelling/HIU data
- Strength of manufacturers' UK support team
- Financial standing of manufacturer

It is also important to note that this document does not cover certain types of HIU. At present, the Test Standard does not cover HIUs with cooling, storage or calorifiers, however this may be included in further iterations of the standard. The regime does also not explore high performance functionality that may be built into certain HIUs.

Furthermore, this guidance document only applies to Modules 1, 2, 7 & 8 of the Test Standard, which applies to HIUs with indirect space heating and/or a valid Keep Warm facility. Therefore, the results from the tests in Modules 3-6 and 9-10 are not covered in this document, which are relevant to HIUs with direct space heating or Non-Keep Warm functionality. For more information about HIU types and which modules are applicable to each type, please consult the Test Standard.

Currently, the only results from the newest version of the Test Standard are for Modules 1, 2, 7 & 8. This is due to the fact that indirect HIUs with Keep Warm functions dominate the HIU market today and are the most commonly manufactured type of HIU in the UK. When further results become available for direct or Non-Keep Warm HIUs, future versions of this guidance for Modules 3-6 and 9-10 will be produced.

2.2 Test Regime Limitations

The test rig has been automated, and extensive work has been undertaken by BESA to standardise the test rig set up. However, there are practical limitations with the test rig which mean that replicability of test set up is difficult to establish with a high degree of accuracy. As such, parameters are given with relatively wide margins of error, particularly the VWARD figures, which are published with uncertainties of ± 2 °C.

The test rig for a twin-plate HIU has been shown schematically in [Figure 1](#), however all details and abbreviations are provided more comprehensively in the Test Standard.

The Test Standard is constantly evolving, and further test reports will continue to be released. Therefore, it is important to note which version of the Test Standard a particular HIU has been BESA tested under.

Please note that all publicly available BESA test reports are from HIUs that have passed all tests and so have met the baseline performance thresholds set out in the testing regime. There have been HIUs that have been tested and failed under the new test criteria; however, these reports have only been made available to the relevant HIU manufacturers.

2.3 Real Heat Networks

The test regime is designed to assess HIU performance and allow comparison between different HIUs under the test conditions. One of the key considerations to make is that these chosen conditions are only a representation of the expected conditions on a real heat network. The decisions around these parameters were based on real life observations and calculations using the Reference Buildings (see [Appendix C: Keep Warm](#)). Therefore, anyone investigating test results should be aware that test conditions and results will not necessarily reflect operational performance on a live heat network. This is specifically the case if operating parameters at the network are different from the tested parameters.

For example, this is true for DHW tests I3a-b (see [Section 3.3](#)), where typical maximum DHW demands in real networks are much lower than the tested maximum DHW capacities. This can have implications during design – designers must specify hot water and space heating demands properly to ensure that the HIU plate heat exchangers (PHEs) are sized correctly.

The focus of the testing regime is on the individual HIU, not the network. The performance of the heat network itself depends on several factors, beyond the HIU. As a result, features such as network size, pipework arrangement, temperature and pressure requirements, etc. will influence how well the HIU performs.

2.4 Network Nomenclature

To maintain consistency with the Test Standard, the “network side” and the “dwelling side” of the HIU are referred to as the “primary” side and “tertiary” side of the HIU respectively. Please note that these definitions are different from those in CPI (2020) and the upcoming Department for Energy Security and Net Zero: Heat Network Technical Assurance Scheme. These differences in nomenclature are summarised in Table 1.

Document	Nomenclature for:	
	Network side of HIU	Dwelling side of HIU
BESA HIU Test Standard	Primary side	Tertiary side
CPI (2020)	Secondary network	Tertiary network
Heat Network Technical Assurance Scheme	District/Communal Distribution Network	Consumer Heat System

Table 1: Nomenclature of the Test Standard in reference to other industry documents.

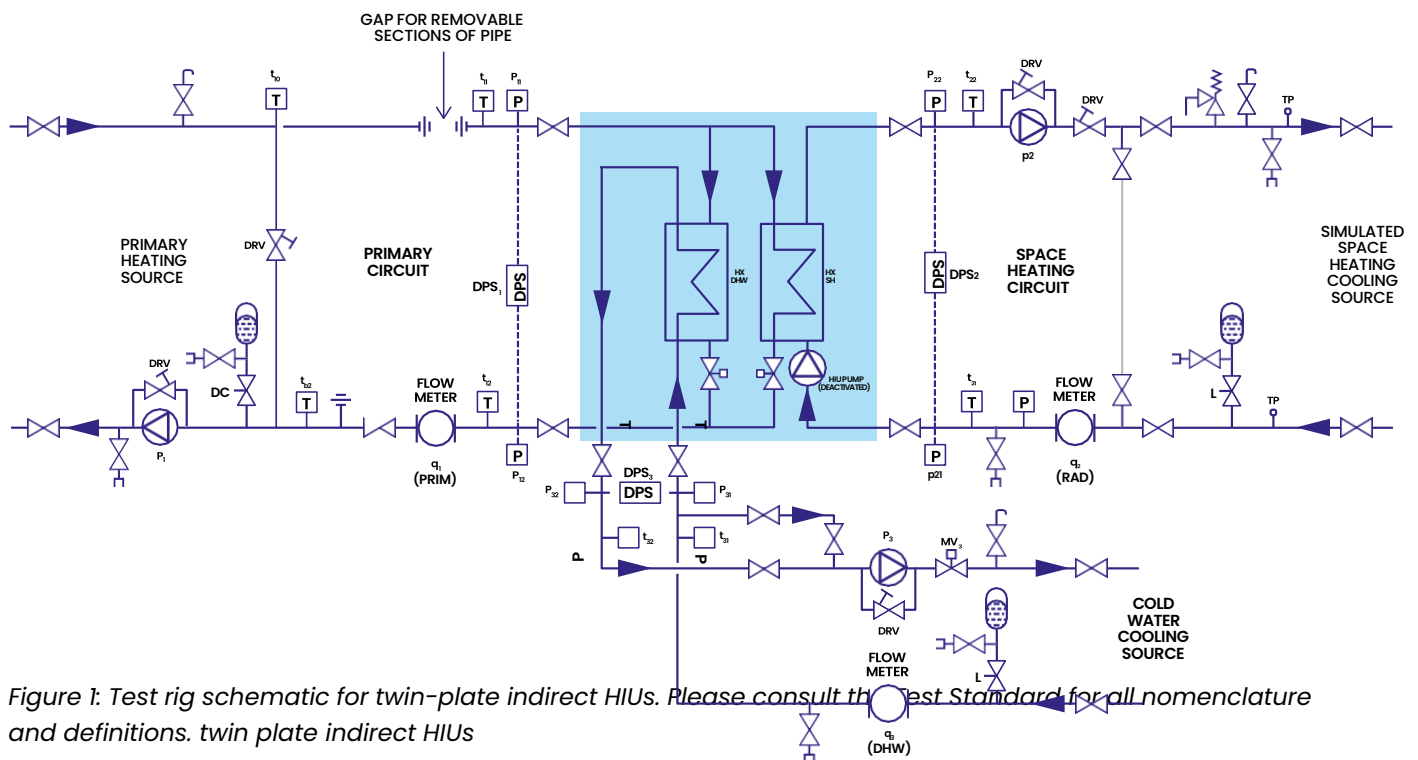


Figure 1: Test rig schematic for twin-plate indirect HIUs. Please consult the Test Standard for all nomenclature and definitions. twin plate indirect HIUs

3. Domestic Hot Water:

Modules 7 & 8 (with Keep Warm)

The BESA Test Standard for the UK HIU Testing Regime defines Modules 7-10 as the modules which test the HIU's performance under domestic hot water operation. As mentioned in Section 2, this guidance only covers HIUs with Keep Warm functionality, which relates to Modules 7 and 8. Module 7 refers to the high temperature regime, where the primary flow temperature (t_{11}) is 70 °C, whilst Module 8 relates to the low temperature regime, where this is 55 °C. All further information for each module is available within the individual BESA HIU Test Module documents.

The objective of these modules is to explore the performance of the HIU under changing loads, as would be the case in practical operation. As discussed in the sections below, the key performance criteria are speed and consistency of DHW delivery, DHW staying at a safe temperature at all times and the volume weighted average return temperature when supplying DHW.

Within the following sections for each test, the outputs of both temperature regimes have been described equally. Where the outputs of a test are likely to be significantly influenced by the choice of temperature regime, this has been explicitly mentioned for the particular test.

3.1 Tests 11a-b: DHW performance testing at variable flow rates and differential pressures

3.1.1 Purpose

Tests 11a-b examine hot water performance for HIUs in response to changes in DHW flow rate (q_3) and differential pressure on the primary network (dP_1).

Test 11a is done under the high temperature regime (Module 7) with a primary flow temperature (t_{11}) of 70 °C, whilst Test 11b is carried out under the low temperature regime (Module 8) with $t_{11} = 55$ °C.

The tests are performed at three different DHW draw-off rates to simulate typical usage scenarios: 0.06 l/s (low), 0.10 l/s (medium) & 0.13 l/s (high).

Due to the sudden demand of neighbouring HIUs, a HIU experiences sudden fluctuations in dP_1 . Based on the expected range of operating conditions within the Reference Building (indicated in Section 2.3), these changes in dP_1 are approximately 25 kPa.

These changes are simulated at both high and low differential pressure ranges: 50–75 kPa and 175–200 kPa. This is done to represent HIUs located at different points in a network (HIUs located closer to the network distribution pumps receive a higher dP_1).

It is also expected that high dP_1 challenges the hot water control system at low flows, therefore these tests determine the consistency of DHW delivery across the network for different typical usage scenarios.

The outputs of these tests also indicate the accuracy and stability of DHW delivery at the target DHW temperature (50 °C), as well as the response of the primary flow rate (q_1) and return temperature (t_{12}).

3.1.2 Pass/fail and best practice criteria

Fail if:
VWART > 22 °C
VWART > 27 °C
DHW temperature (t_{32}) > 60 °C for more than 1 second (due to scalding risk)
Primary return temperature (t_{12}) > 55 °C at any point (due to scaling risk)
Average DHW temperature (t_{32}) > 51.0 °C or < 49.0 °C for final 150 seconds of each 180 second draw off period
DHW temperature (t_{32}) is not being maintained at 50.0 °C ± 3.0 °C for over 150 seconds of each 180 second draw off period
DHW temperature (t_{32}) < 45 °C for more than 5 consecutive seconds (due to resident comfort)

Table 2: Test 11 pass/fail criteria. Any criteria specific for the high temperature regime (Test 11a) and low temperature regime (Test 11b) are highlighted in red and blue respectively.

Best practice if:
VWART < 17 °C
VWART < 17 °C
DHW temperature (t_{32}) is being maintained at 50.0 °C ± 2.0 °C throughout periods of DHW flow)
DHW temperature (t_{32}) doesn't drop below 45.0 °C for more than 2 consecutive seconds

Table 3: Test 11 best practice criteria. Any criteria specific for the high temperature regime (Test 11a) and low temperature regime (Test 11b) are highlighted in red and blue respectively.

3.1.3 Comparative performance assessment

The outputs of these tests are reported with a single figure of the key metrics over the course of the tests. There are several features of this graph, however the following parameters are the most important to assess:

- DHW flow temperature (t_{32})
- Primary return temperature (t_{12})
- Primary flow rate (q_i)

The following sections provide technical description about how each parameter affects test performance. [Figure 2](#) displays a typical output graph for Tests 11a-b, depicting best practice performance. However, [Figure 3](#) shows the corresponding output for a HIU with less responsive control, which would have narrowly met the pass/criteria for this test.

Note that the graphs produced here are not from specific test reports, but have been generated with exaggerated features to display certain performance characteristics. The figures given in the following sections use the same dataset as that used for [Figure 2](#) and [Figure 3](#), but with certain parameters emboldened for clarity.

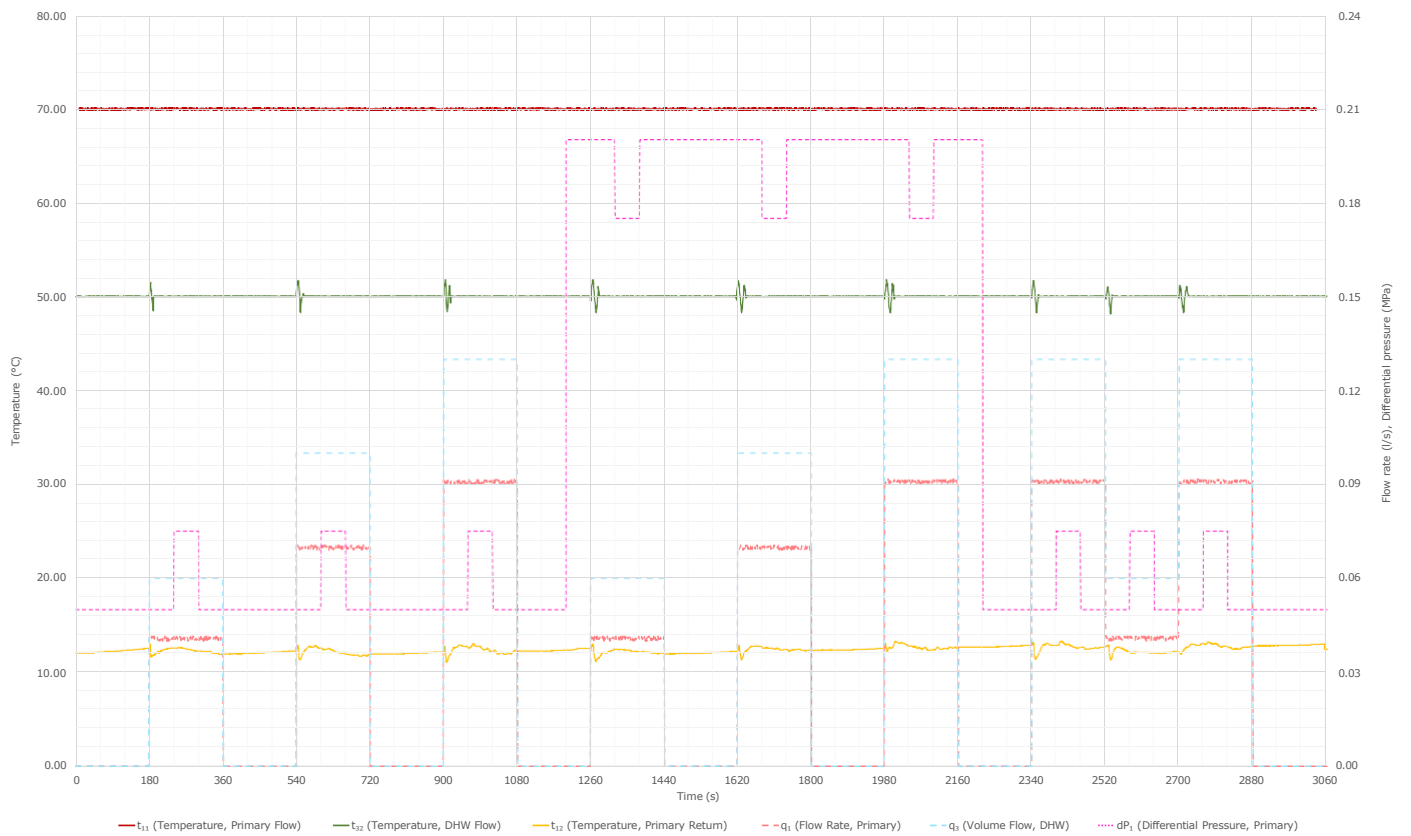


Figure 2 : Example of best practice overall performance for Tests 11a-b.

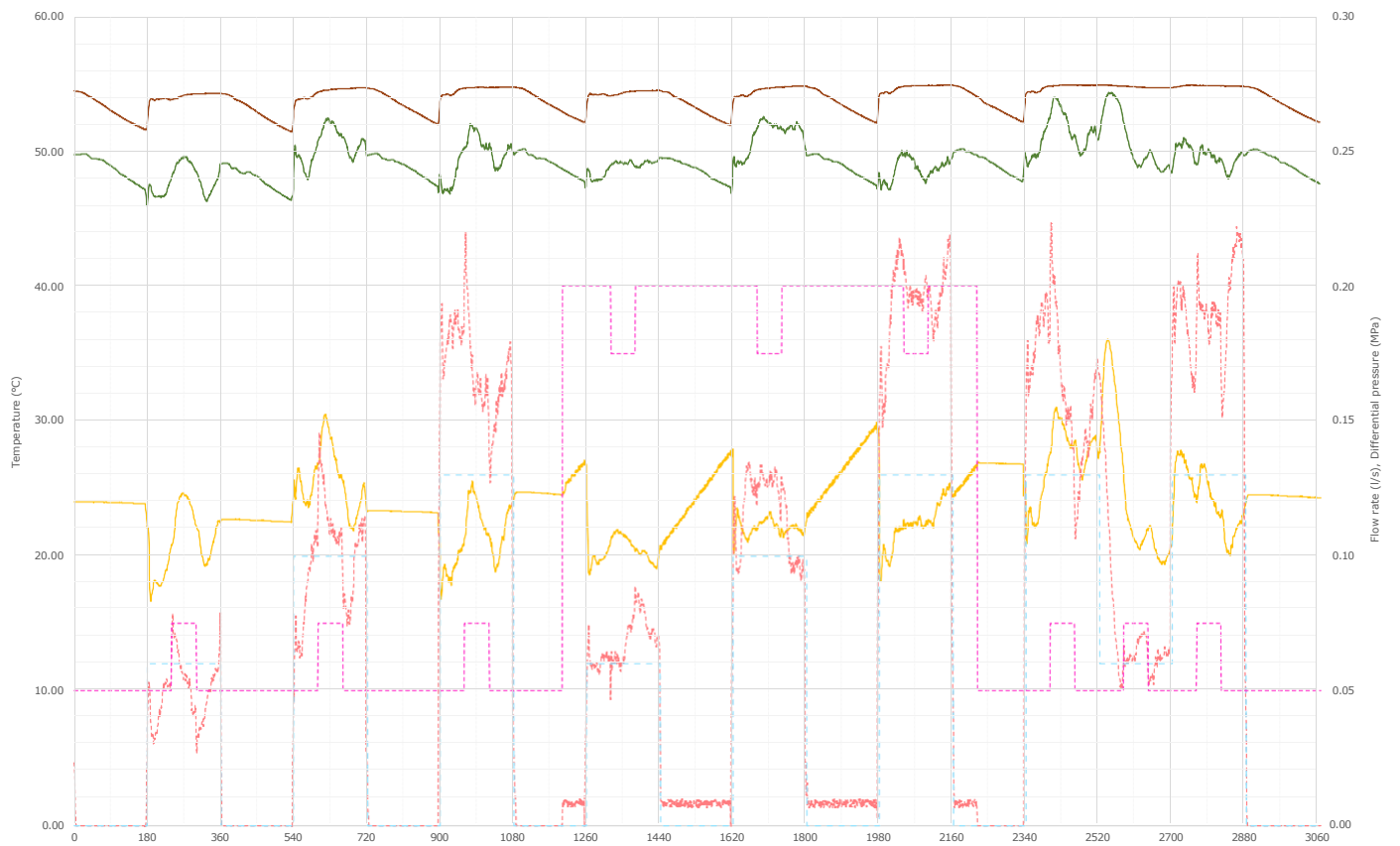


Figure 3 : Example of overall performance for Tests 11a-b for a HIU with less responsive control.

3.1.3.1. DHW flow temperature (t_{32})

The DHW flow temperature is a crucial parameter in Tests 11a-b, which should be examined closely, especially with how quickly it responds at the start of the DHW flow periods. The speed of response of t_{32} at these points will be dictated by the speed of response of the DHW control system.

When DHW draw-off begins, the DHW control system must quickly recognise hot water demand. As such, the HIU must respond promptly to allow primary flow through the DHW plate and generate instantaneous hot water to be delivered to the dwelling outlets, as displayed in [Figure 4](#). [Figure 5](#) shows an example where slower HIU control means this is not achieved.

Note that whilst the outputs from Tests 11a-b are useful to determine how quickly the DHW control system can respond to DHW demand after a period of no load, DHW response time is covered more comprehensively in Tests 22a-b (see [Section 3.5](#)).

It is also important to note how t_{32} changes in response to changes in dP1 during DHW flow, i.e. 60 and 120 seconds into each 180 second draw-off period.

Especially within the higher dP1 range (175-200 kPa), best practice performance for this test is indicated with stable profiles for t_{32} . It is expected that there will be moderate variation in the DHW flow temperature around the start of the flow period, however [Figure 4](#) demonstrates that this should soon stabilise and target a final temperature of 50 °C. Less responsive DHW control will result in sudden changes in t_{32} throughout the flow period, which is shown in [Figure 5](#).

The final draw-off period, when q_3 falls and rises again, is the most important portion of these tests. Stable values of t_{32} during this period are indicative of best practice DHW performance for these tests.



Figure 4 : Example of best practice DHW flow temperature response during Tests 11a-b.



Figure 5 : Example of DHW flow temperature response during Tests 11a-b for a HIU with less responsive control.

3.1.3.2 Primary return temperature (t_{12})

The speed of response of t_{12} is another feature worth noting, particularly at the start and end of the DHW flow periods. This will also be influenced by how quickly the DHW control system can respond to changes in DHW demand.

As mentioned above, the DHW control system must rapidly recognise and respond to the hot water demand at the start of the flow period. However, towards the end of the flow period, once DHW demand has stopped, the control system must act quickly again to shut off primary flow to the DHW plate. This is to prevent a primary side bypass and keep primary return temperatures stable, which is presented in [Figure 6](#).

If this is not the case, primary return temperatures will increase, as indicated in [Figure 7](#). As LTHW circulates through the primary side of the DHW plate whilst cold water flow has ceased on the tertiary side, considerably less heat is extracted from the primary side flow, and a bypass is created. This is also important during periods of no demand, where any unwanted primary flow (e.g. due to less responsive control at the high dP1 range) can lead to undesirable increases in return temperatures and a detrimental impact on the VWARTs reported for Tests 11a-b.

As before, the stability of t_{12} in response to changes in dP1 is important throughout the DHW flow periods, as well as during the final draw-off period with steps up and down in q_3 . In both cases, best practice DHW performance typically shows slight variation in t_{12} , without extreme fluctuations, such that the VWART falls below the required thresholds.

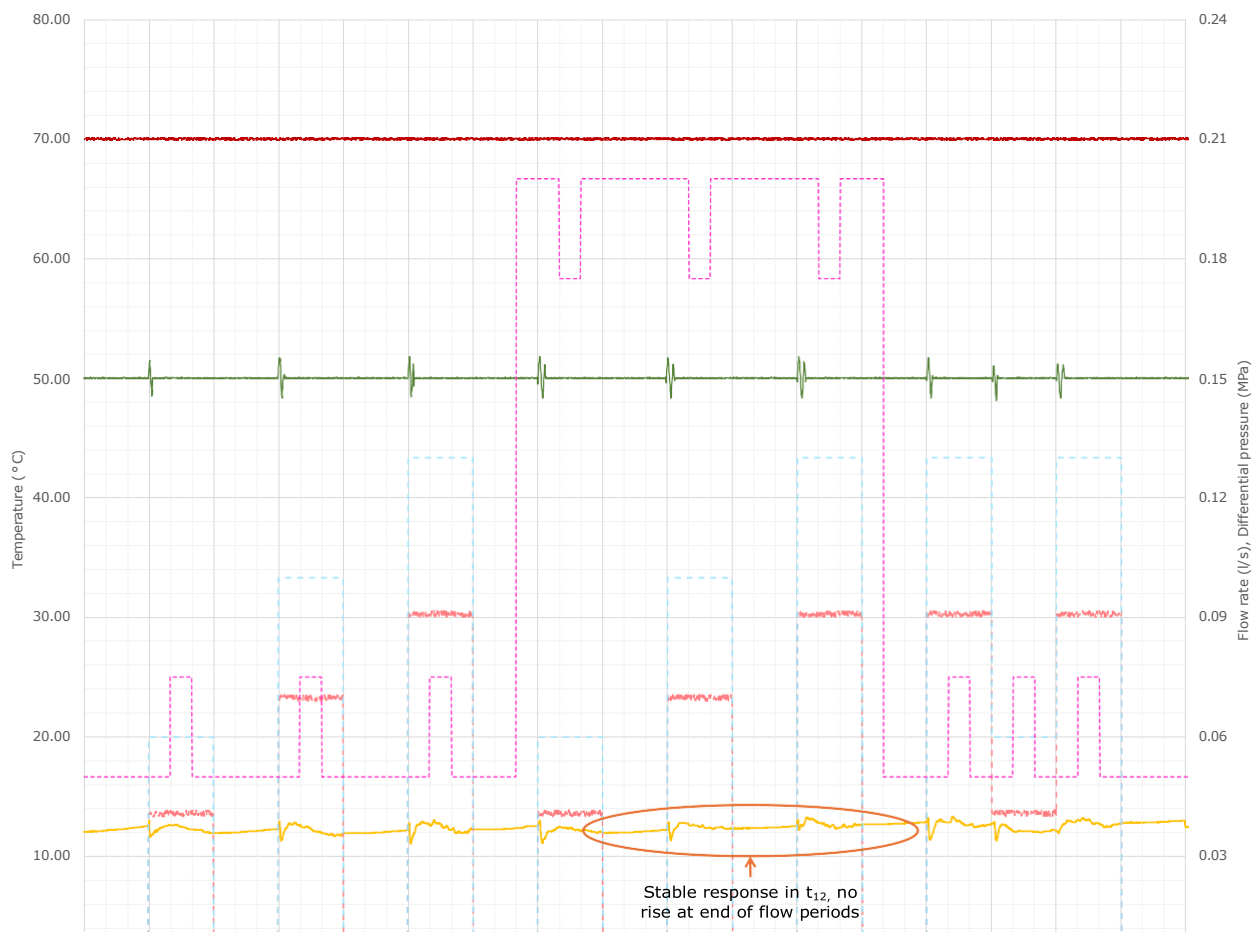


Figure 6 : Example of best practice primary return temperature response during Tests 11a-b.

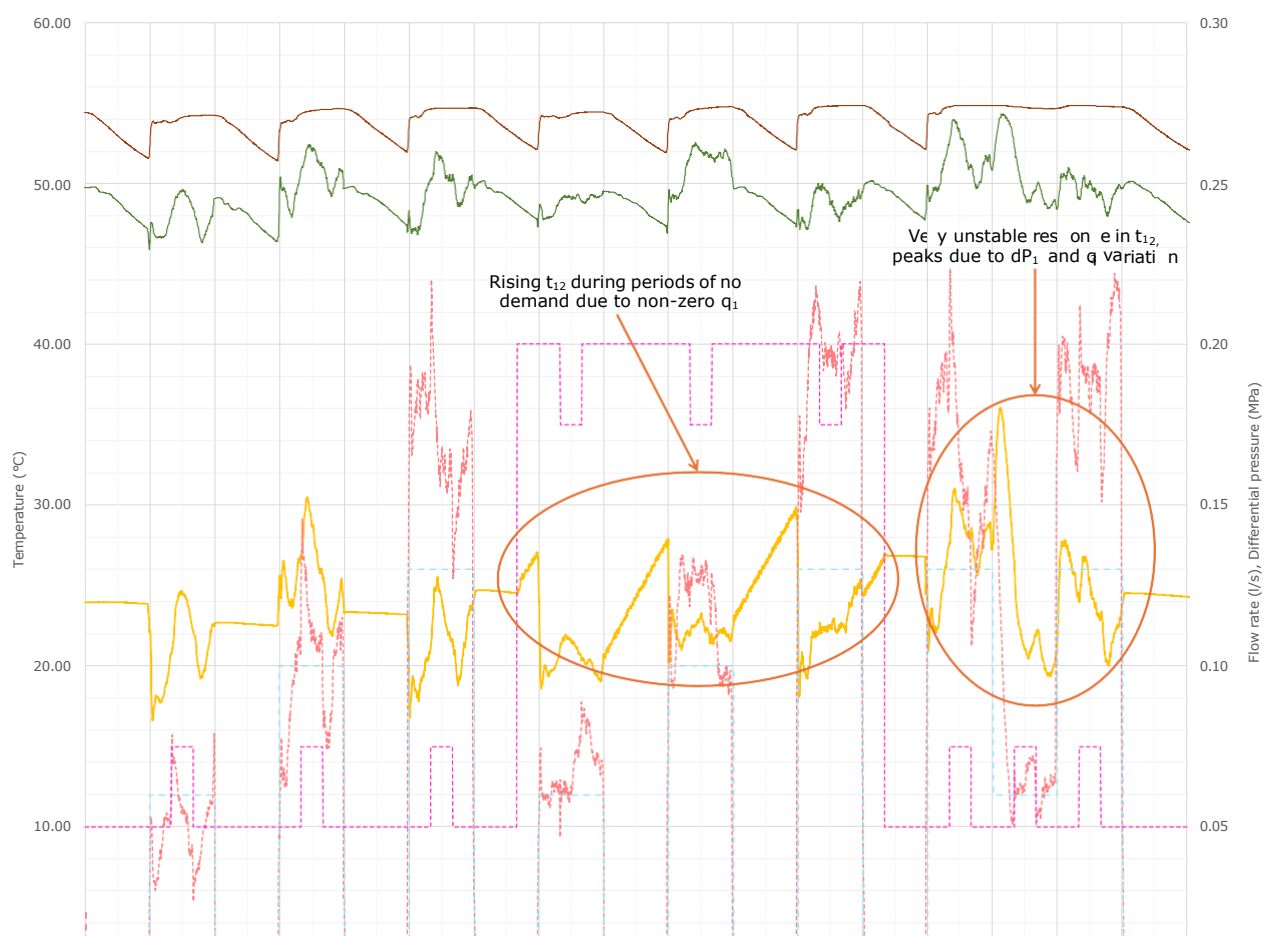


Figure 7: Example of primary return temperature response during Tests 11a-b for a HIU with less responsive control.

3.1.3.3. Primary flow rate (q_1)

The stability of the primary flow rate is essential for best practice HIU performance, as this significantly influences the response of DHW flow temperature.

This applies during changes in dP_1 , especially at the higher dP_1 range. Less responsive DHW control will result in sudden changes in q_1 throughout the flow period, which is depicted in [Figure 9](#). This also extends to the final draw-off period (when the DHW flow rate is varied from 0.13 l/s to 0.06 l/s and back up to 0.13 l/s), where primary flow rate is expected to shift in a well controlled manner for best practice performance.

Also, at the high dP_1 range, it is important to check the response of q_1 during periods of no demand (where there is no DHW draw-off). A DHW system with more responsive control will ensure no primary flow is permitted during periods of no demand, as shown in [Figure 8](#). If the HIU allows unwanted primary flow during no-flow as a result of high dP_1 , as displayed in [Figure 9](#), this can have a significant effect on return temperatures and risk elevating the VWART for these tests.

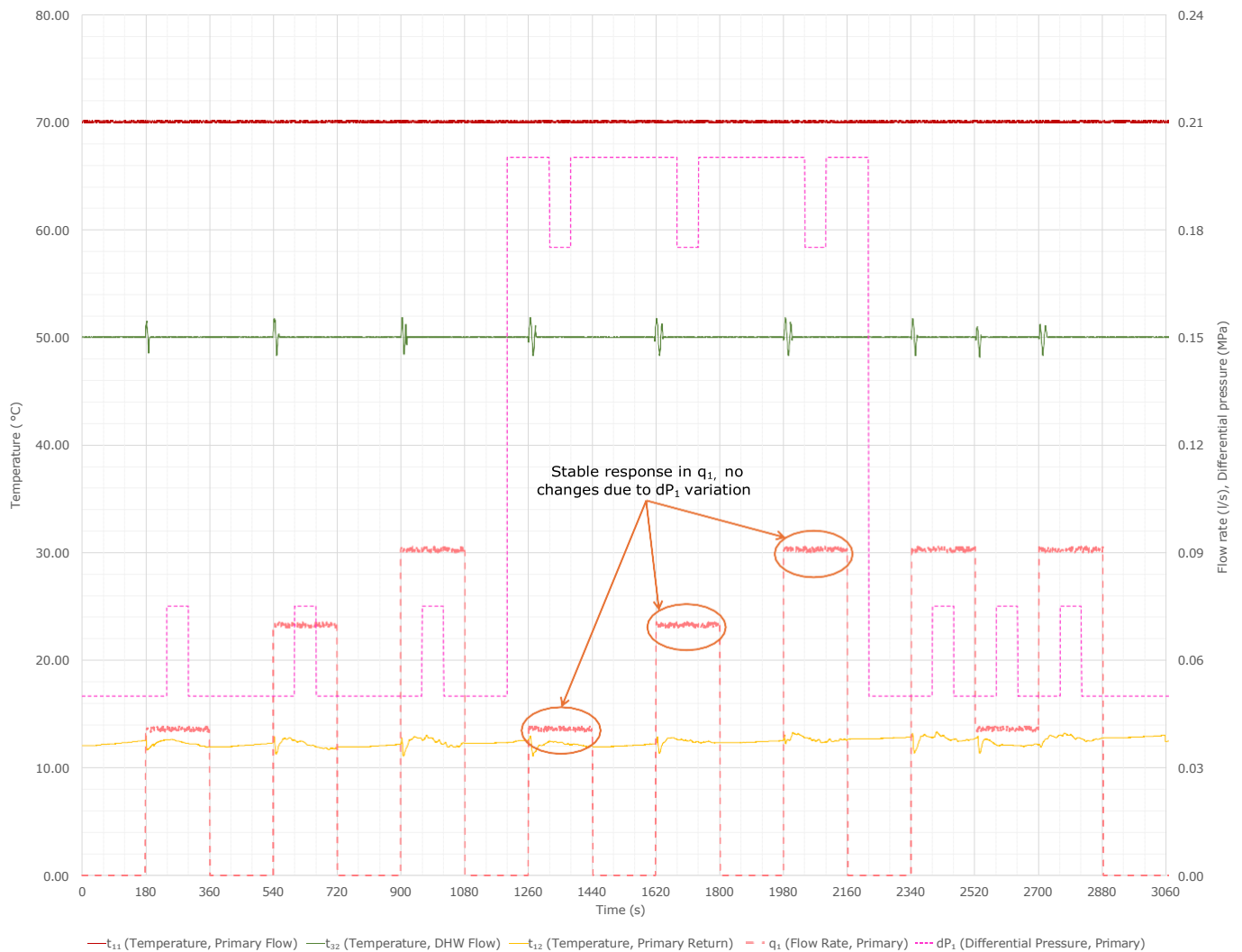


Figure 8 : Example of best practice primary flow rate response during Tests 11a-b.



Figure 9 : Example of primary flow rate response during Tests 11a-b for a HIU with less responsive control.

3.2 Tests 12a–d: DHW low flow rate stability test

3.2.1 Purpose

Tests 12a–d assess DHW performance at very low flow rates (0.02 l/s), which is sometimes experienced during typical hot water operation. These tests ensure that, when stepping down DHW flow rates, the same accuracy and stability can be achieved as that seen for Tests 11a–b at more typical flow rates.

Tests 12a and 12c are done under the high temperature regime (Module 7) with a primary flow temperature (t_{11}) of 70 °C, whilst Tests 12b and 12d are carried out under the low temperature regime (Module 8) with $t_{11} = 55$ °C.

For each temperature regime/test module, there are two different tests to display pressure independence and confirm whether DHW low flow delivery is consistent across the network.

Based on calculations using the Reference Building, HIUs at different points in a typical heat network experience primary differential pressures (dP_1) between approximately 50 kPa and 200 kPa. Tests 12a and 12b are performed at $dP_1 = 50$ kPa, to reflect HIUs located at the index point of a typical heat network, whilst Tests 12c and 12d are done at $dP_1 = 200$ kPa, to simulate HIUs near the energy centre.

The outputs of these tests also demonstrate the response of the primary flow rate (q_1) and return temperature (t_{12}) during low flow.

3.2.2 Pass/fail and best practice criteria

Fail if:

DHW temperature (t_{32}) > 60 °C for more than 1 second (due to scalding risk)

Primary return temperature (t_{12}) > 55 °C at any point (due to scaling risk)

DHW temperature (t_{32}) is not maintained at $50.0\text{ °C} \pm 3.0\text{ °C}$ for more than 60 seconds

Table 4 : Test 12 pass/fail criteria. These criteria are the same for both temperature regimes/test modules.

Best practice if:

DHW temperature (t_{32}) is maintained at $50.0\text{ °C} \pm 2.0\text{ °C}$ throughout both tests 12a and 12c (for high temperature regime) or tests 12b and 12d (for low temperature regime)

Table 5 : Test 12 pass/fail criterion. This criterion is the same for both temperature regimes/test modules.

3.2.3 Comparative performance assessment

The outputs of these tests are reported with two figures of the key metrics over the course of the tests, one for each primary differential pressure scenario. There are several features of this graph, however the following parameters are the most important to assess:

- DHW flow temperature (t_{32})
- Primary flow rate (q_1)

The following sections provide technical description about how each parameter affects test performance. [Figure 10](#) displays a typical output graph for Tests 12a-d, depicting best practice performance. However, [Figure 11](#) shows the corresponding output for a HIU with less responsive control, which would have narrowly met the pass/criteria for this test.

Note that the graphs produced here are not from specific test reports, but have been generated with exaggerated features to display certain performance characteristics. The figures given in the following sections use the same dataset as that used for [Figure 10](#) and [Figure 11](#), but with certain parameters emboldened for clarity.

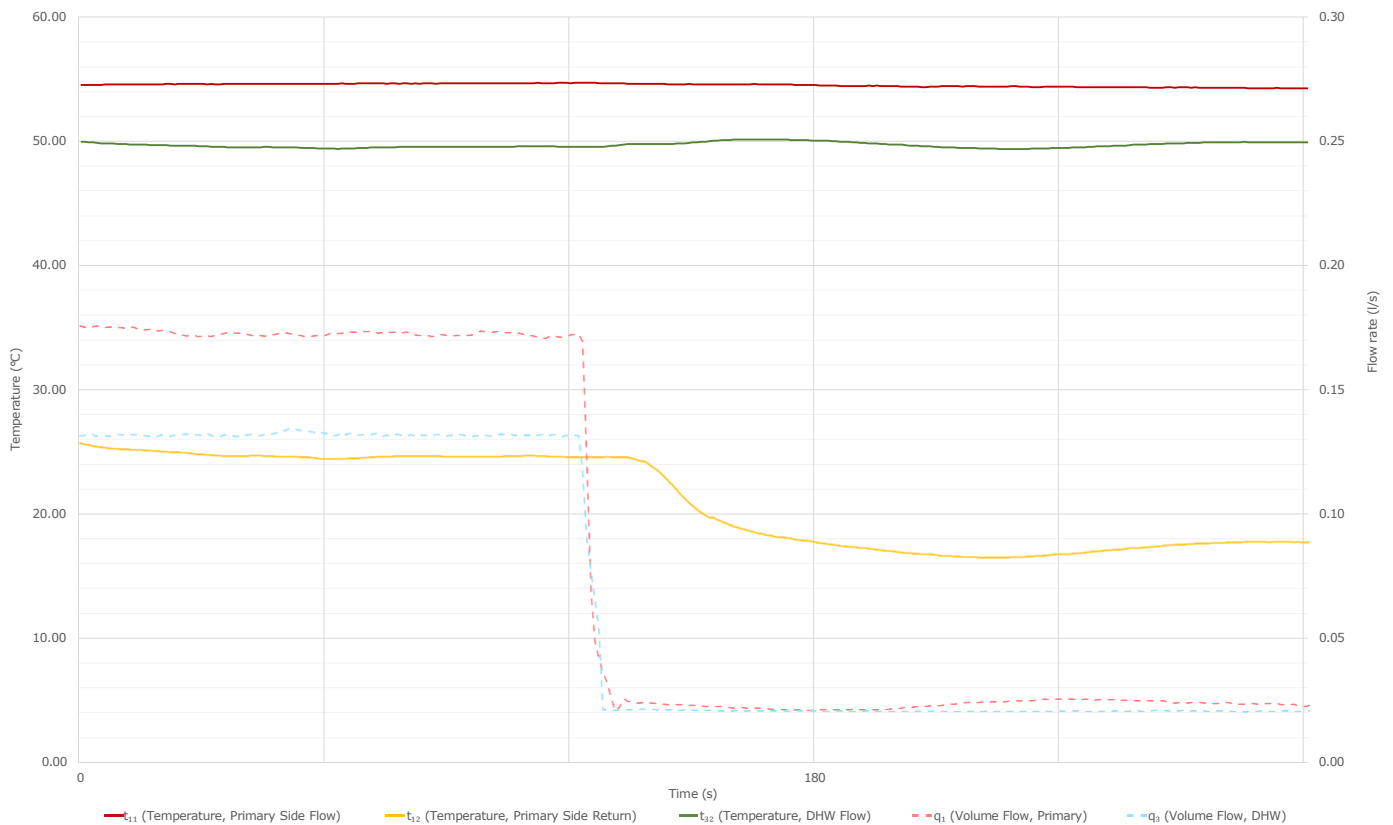


Figure 10 : Example of best practice overall performance for Tests 12a-d.

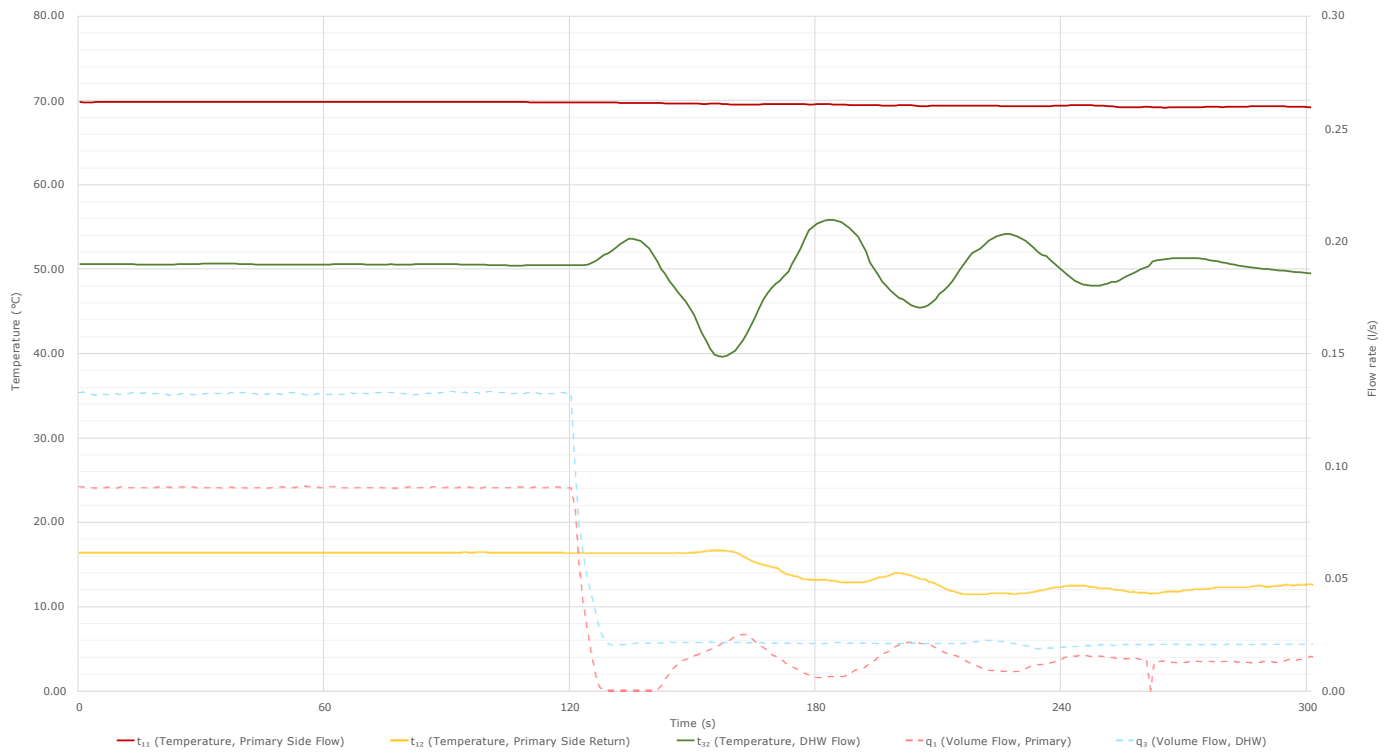


Figure 11 : Example of overall performance for Tests 12a-d for a HIU with less responsive control.

3.2.3.1 DHW flow temperature (t_{32})

To achieve best practice, it is expected that the DHW flow temperature will be well-controlled at the onset of low flow, without significant rises or troughs over the course of the tests. If the DHW control system does not maintain the primary flow rate with sufficient accuracy, this can manifest in output graphs similar to [Figure 13](#), where there are large peaks in t_{32} (and t_{12}) or t_{32} plateaus towards the end of the test at temperatures higher than the target 50 °C.

The absence of any major peaks or fluctuations in t_{32} following the onset of low flow and the final DHW temperature targeting 50°C are indicators of best practice low flow performance, as illustrated in [Figure 12](#).

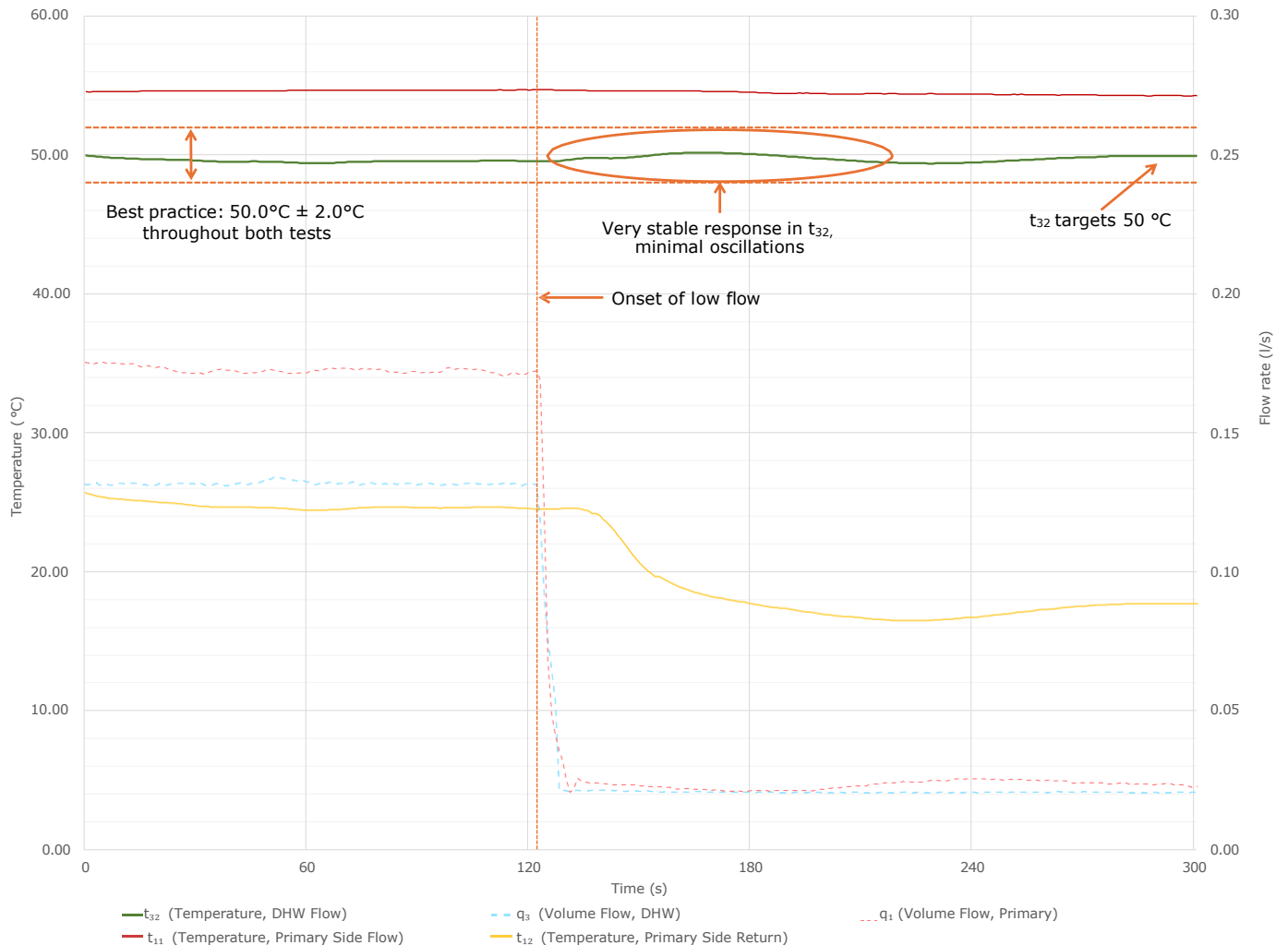


Figure 12: Example of best practice DHW flow temperature response during Tests 12a-d.

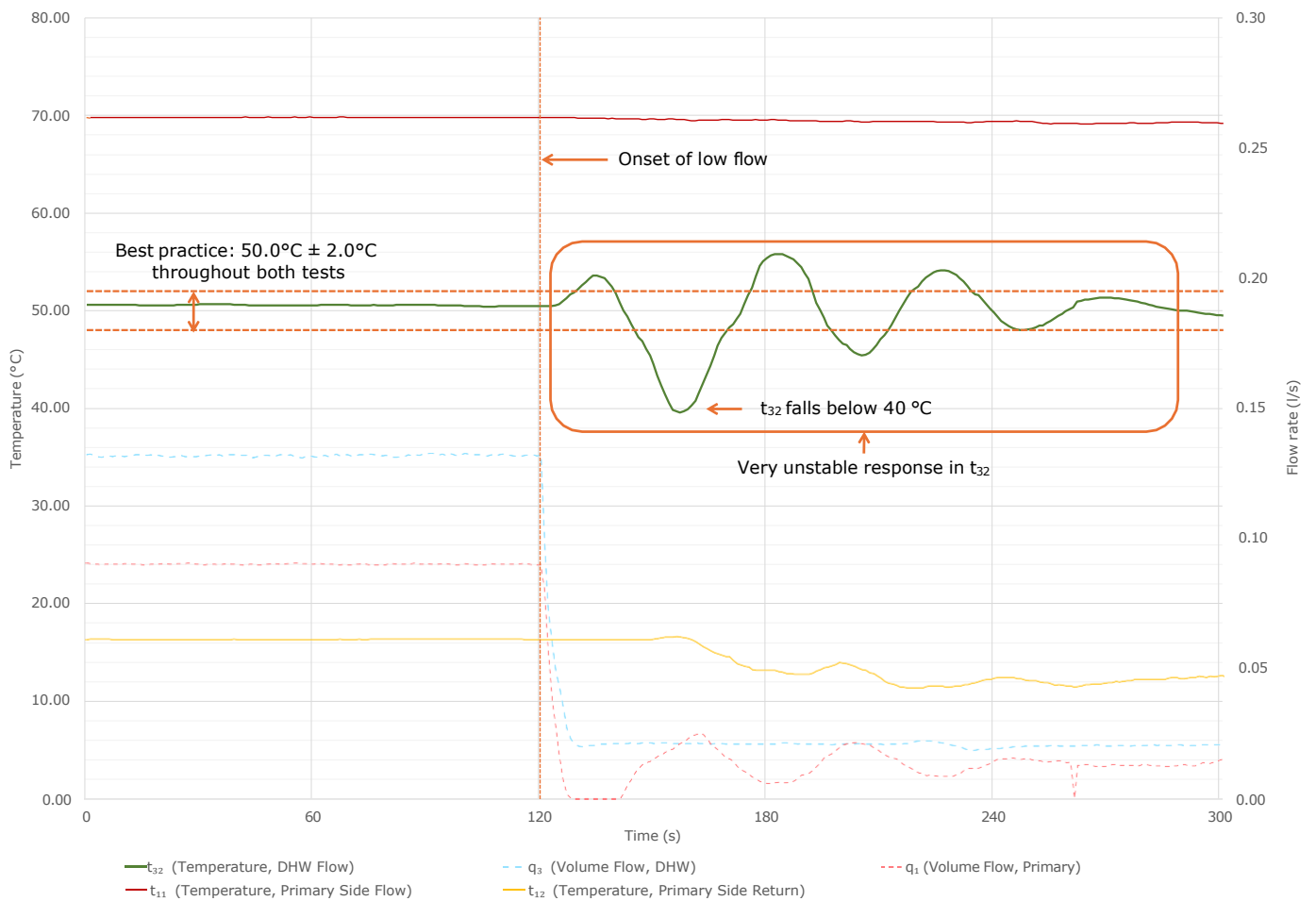


Figure 13 : Example of DHW flow temperature response during Tests 12a-d for a HIU with less responsive control.

3.2.3.2 Primary flow rate (q_1)

As mentioned above, the DHW control system must rapidly react to the reduction in DHW flow rate, otherwise excessive primary flow rates may be seen during low flow. This will result in the undesirable increases in DHW flow and primary return temperatures mentioned in [Section 3.2.3.1](#).

If the HIU's DHW control system does not recognise the low DHW flow after reducing from the previously higher DHW draw-off, primary flow may be ceased altogether, leading to a lack of sufficient heat transfer to meet the low demand. In the results figures, this may appear as a considerable decline in t_{32} below 50 °C (after any peaks), since there is no primary flow to supply heat to the low DHW flow, severely impacting DHW delivery. This behaviour is displayed in [Figure 15](#). A stable response in q_1 with minimal overshoot, as in [Figure 14](#), is expected for best practice low flow performance.

For Module 7 (high temperature regime with primary flow temperature of 70 °C), the higher primary flow temperatures require lower primary flow rates to meet the low flow DHW demand. This means that control becomes more difficult, especially during the high dPI test (test 12c), and may lead to the DHW control system restricting primary flow rate further by stopping primary flow for a period of time. This leads to the same problems mentioned above. If operating conditions change slightly within real heat networks, these features may become exaggerated (e.g. in summer periods where the cold water temperature may rise above 10 °C).

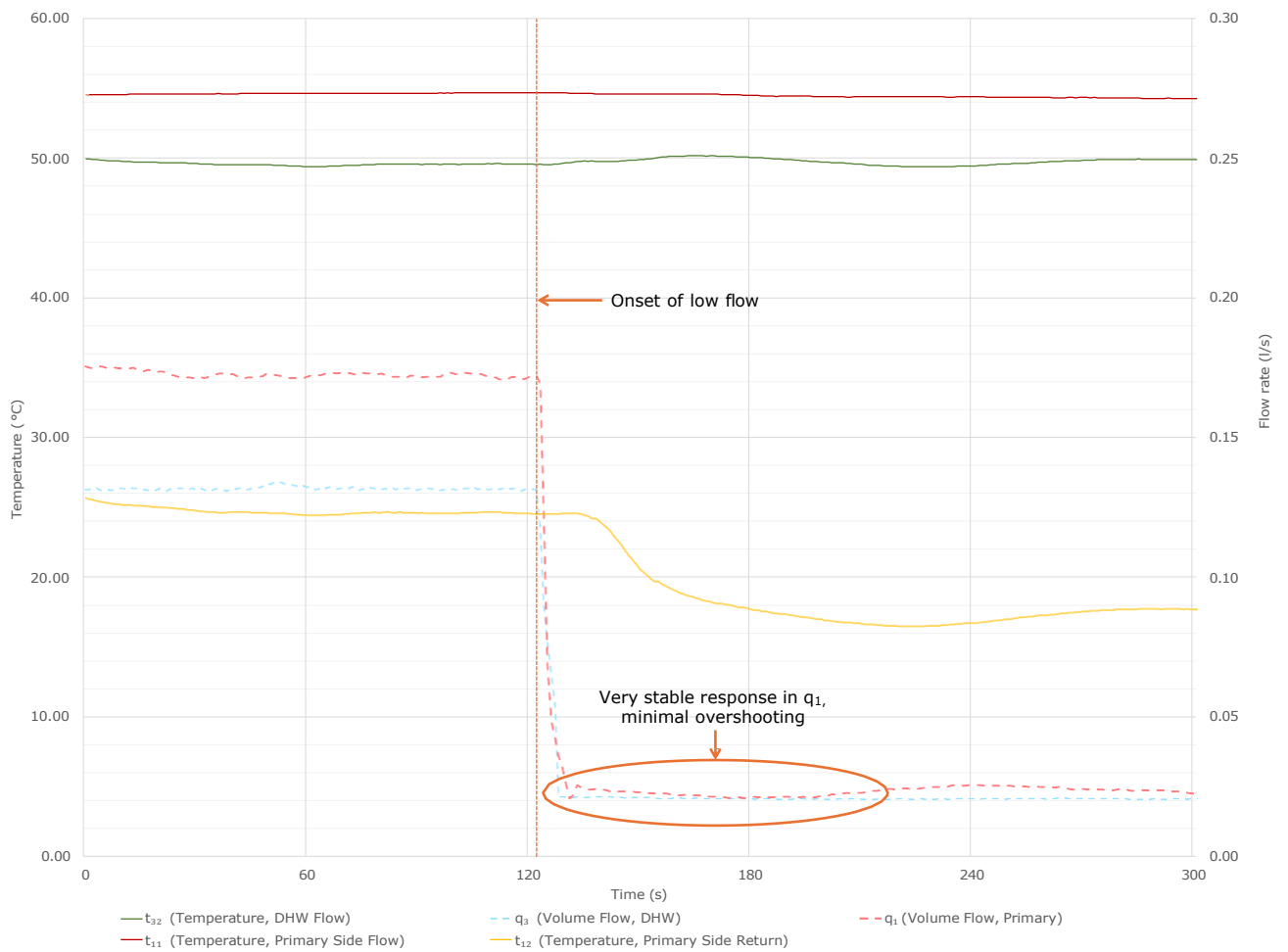


Figure 14 : Example of best practice primary flow rate response during Tests 12a-d.

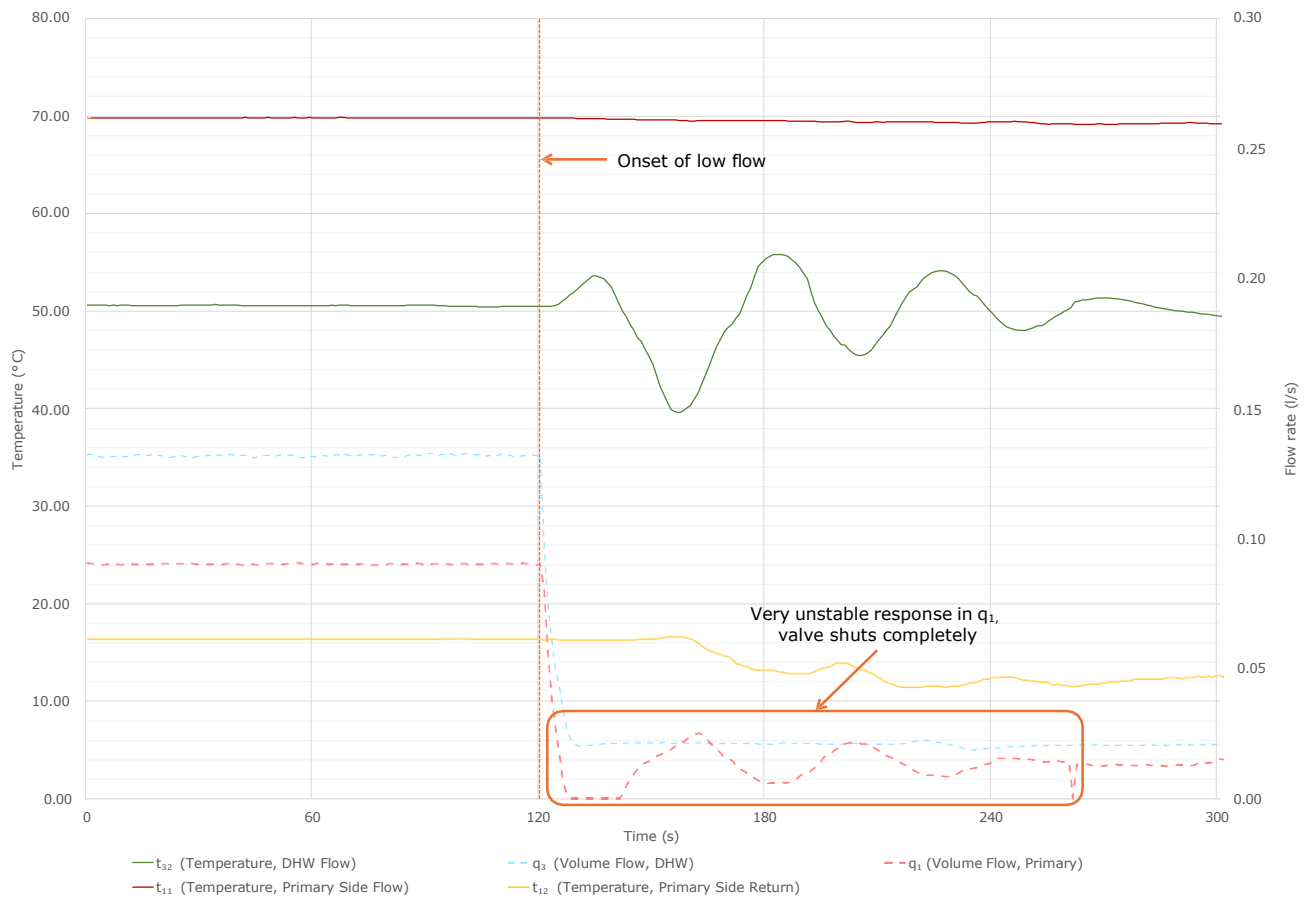


Figure 15 : Example of flow rate response during Tests 12a-d for a HIU with less responsive control.

3.3 Tests 13a–b: DHW maximum heat output and flow rate load test

3.3.1 Purpose

Tests 13a–b determine the maximum capacity of the DHW PHE, and the resulting DHW flow rate and pressure drop, when delivering DHW at 45 °C or above, up to 70 kW. Effectively, these tests indicate the limit of DHW control, to identify the upper bound of DHW demand before outlet temperatures cannot be sustained at 45 °C or above.

Test 13a is done under the high temperature regime (Module 7) with a primary flow temperature (t_{11}) of 70 °C, whilst Test 13b is carried out under the low temperature regime (Module 8) with $t_{11} = 55$ °C.

As per HSE guidance in HSG274 Part 2 (which states that water becomes painful and can cause burns at or above 44 °C), DHW at temperatures of 45 °C or above is considered “hot” and therefore acceptable for the purpose of these tests.

These tests are particularly useful for DHW PHE sizing. The outputs of these tests allow heat network designers to specify PHEs that appropriately meet hot water demands, given the potential draw-off rates and occupancy of the dwellings on a particular network. For instance, these results enable designers to determine how many outlets can simultaneously demand DHW before outlet flow temperatures drop below acceptable limits for a particular DHW plate (e.g. for large dwellings at maximum occupancy with several DHW outlets). However, it is important to remember that typical loads during normal DHW operation rarely meet the maximum PHE capacities specified by HIU manufacturers, as mentioned in [Section 2](#). It is also worth noting that a higher PHE capacity does not necessarily represent a better performing HIU. As shown below, there is no pass/fail criteria for the capacity, rather the test is providing the designer with maximum capacity information to ensure a suitable unit is selected.

In addition, these tests assess the stability of DHW temperature control throughout the full capacity of the DHW PHE.

3.3.2 Pass/fail criteria

Fail if:

DHW temperature (t_{32}) is not maintained at 50.0 °C $\pm$ 1.0 °C at 0.13 l/s DHW flow rate (the HIU must be able to provide DHW to the target temperature at a moderate load)

DHW temperature (t_{32}) > 60 °C for more than 1 second (due to scalding risk)

Primary return temperature (t_{12}) > 55 °C at any point (due to scaling risk)

Table 6 : Test 13 pass/fail criteria. These criteria are the same for both temperature regimes/test modules.

3.3.3 Comparative performance assessment

The outputs of these tests are presented with a single figure of the key metrics over the course of the tests, with additional parameters given in written form. There are several features of this graph, however the following parameters are the most important to assess at the end of the test:

- DHW power (H_3)
- DHW flow rate (q_3)
- DHW pressure drop (dP_3)

Performance is expected to be highly varied for Tests 13a-b, with the parameters above dependent on the HIU sizing and manufacturer's recommended application. Also, note that there are no best practice criteria for these tests.

As such, it is not appropriate to define and compare performance for this test, in the same way as the other tests within this module. The performance aspect of Tests 13a-b is only associated with meeting the specified DHW PHE demand.

Figure 16 and Figure 17 are examples of the graphical outputs expected from two different sized HIUs tested under Test 13a (Module 7 – high temperature regime), one with a high final value of H3 and the other with a low final value respectively.

Figure 18 and Figure 19 display the corresponding graphs for two differently sized HIUs tested under Test 13b (Module 8 – low temperature regime).

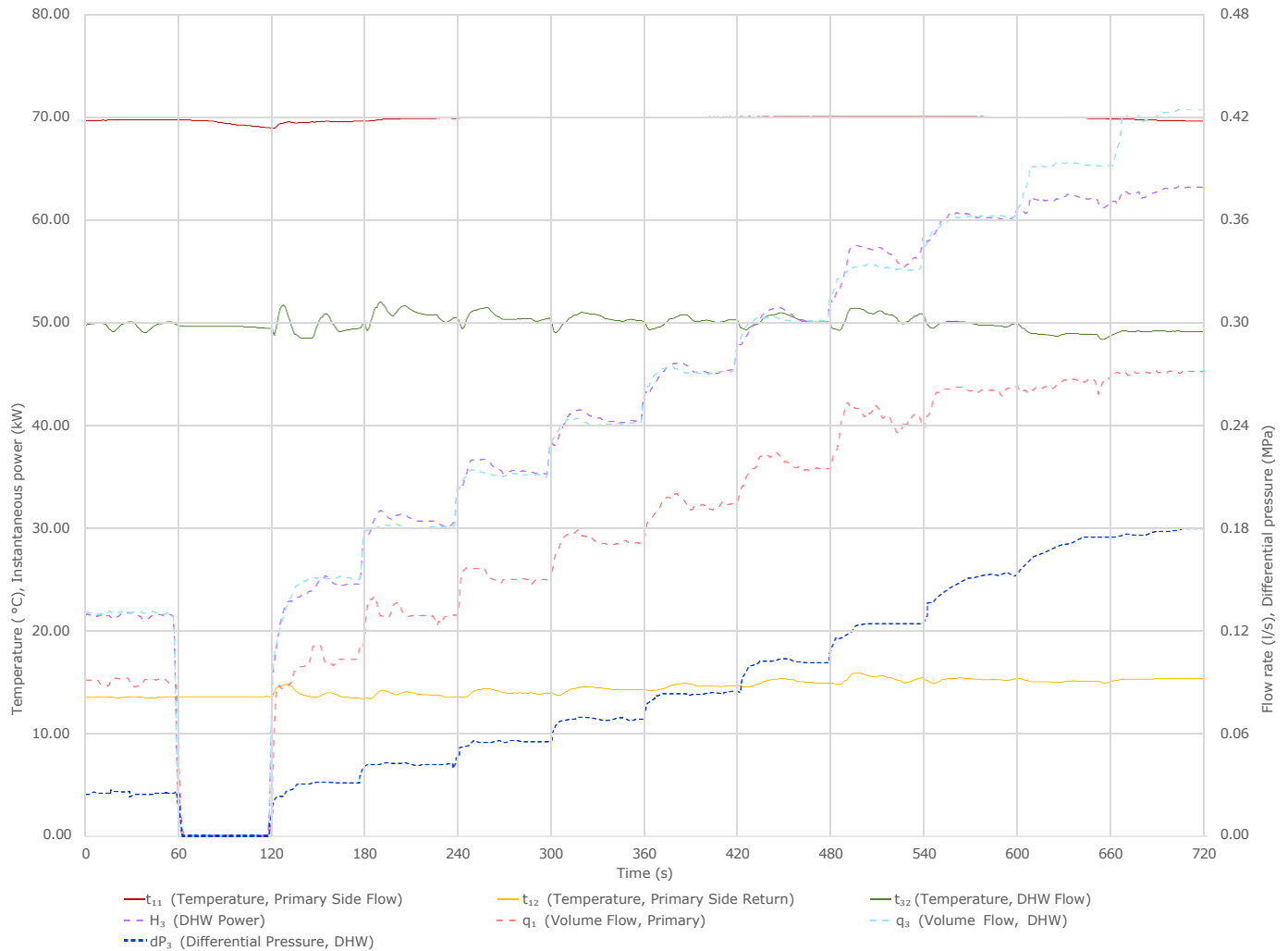


Figure 16 : Example of performance for a HIU with a high maximum DHW capacity for Test 13a (Module 7 – high temperature regime).

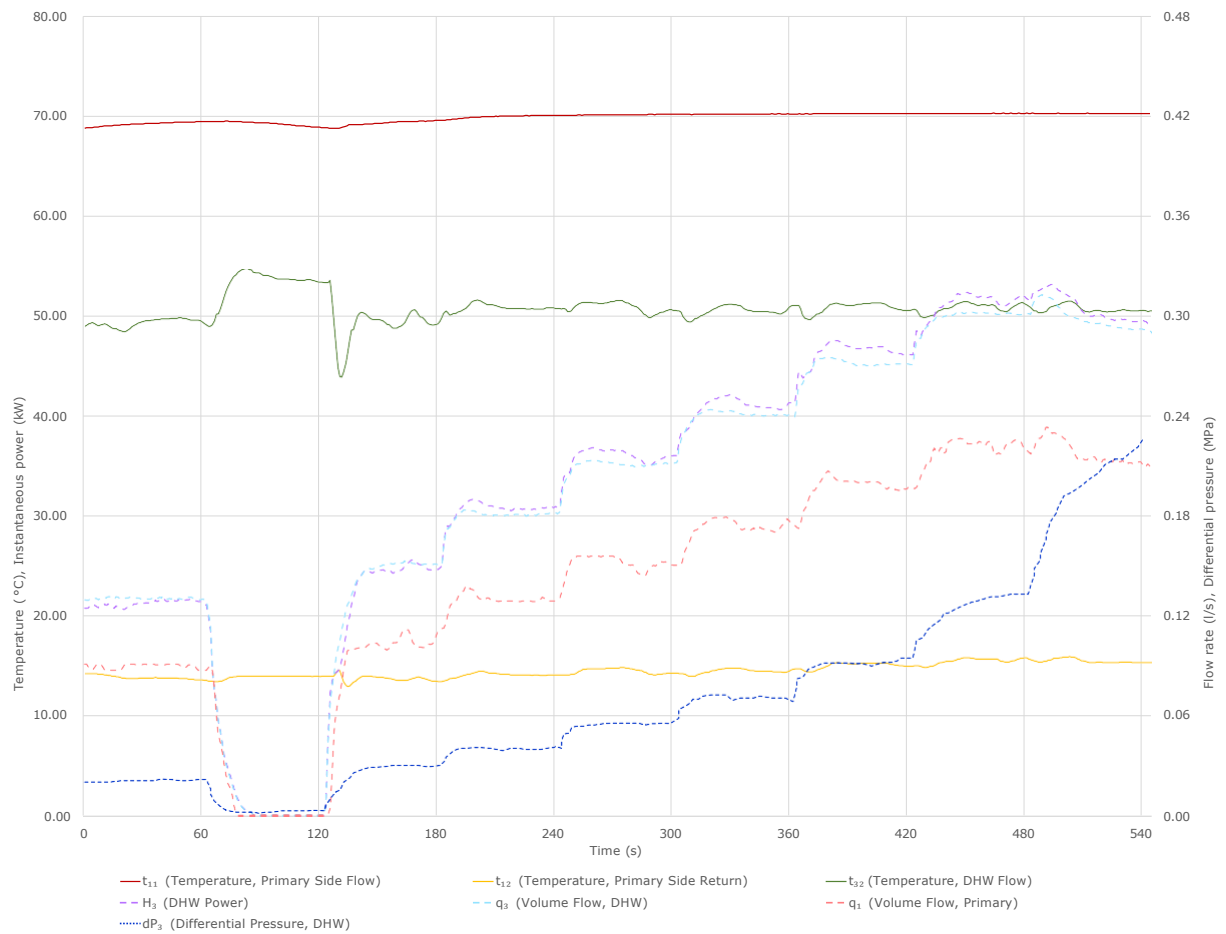


Figure 17: Example of performance for a HIU with a low maximum DHW capacity for Test 13a (Module 7 – high temperature regime).

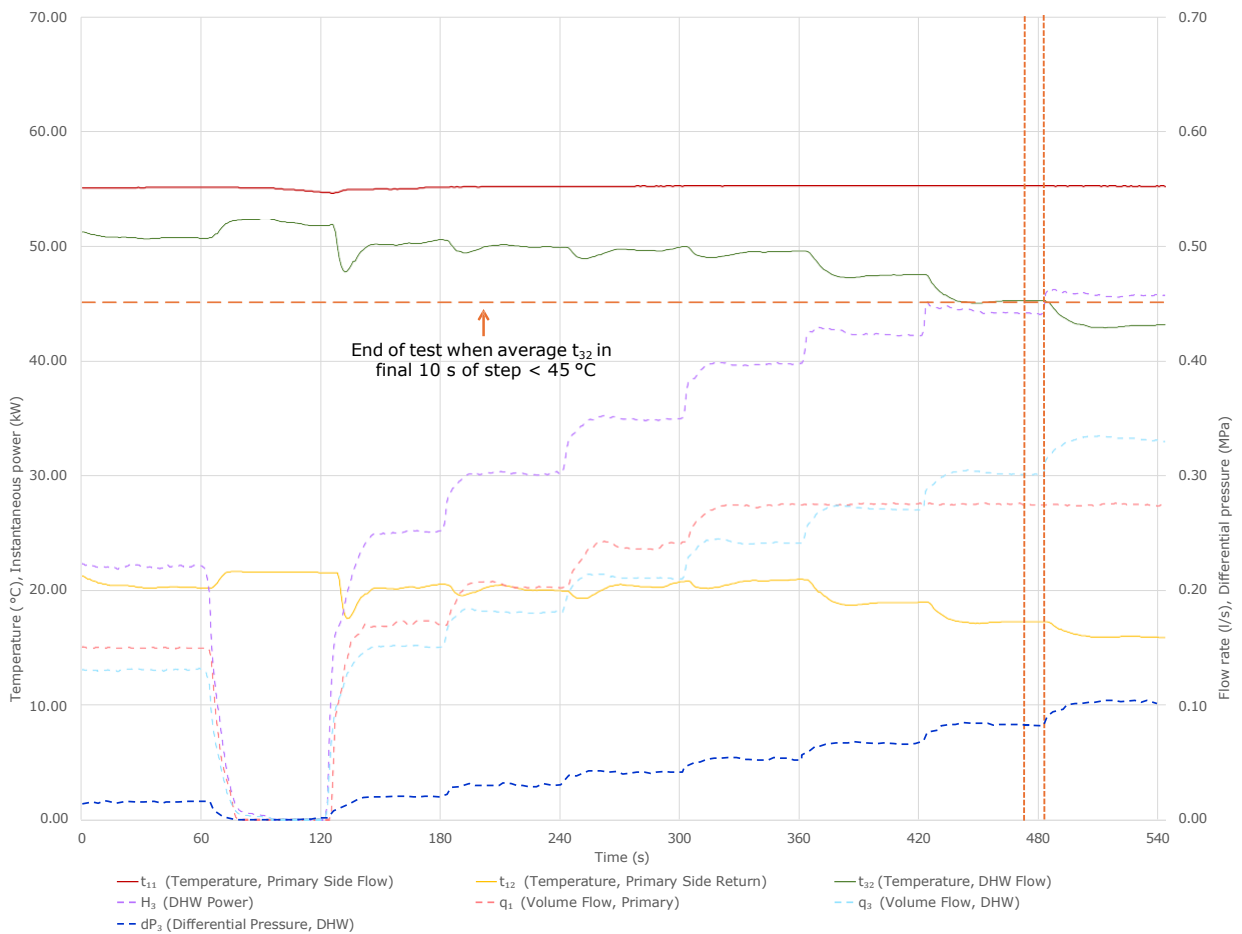


Figure 18: Example of performance for a HIU with a high maximum DHW capacity for Test 13b (Module 8 – low temperature regime).

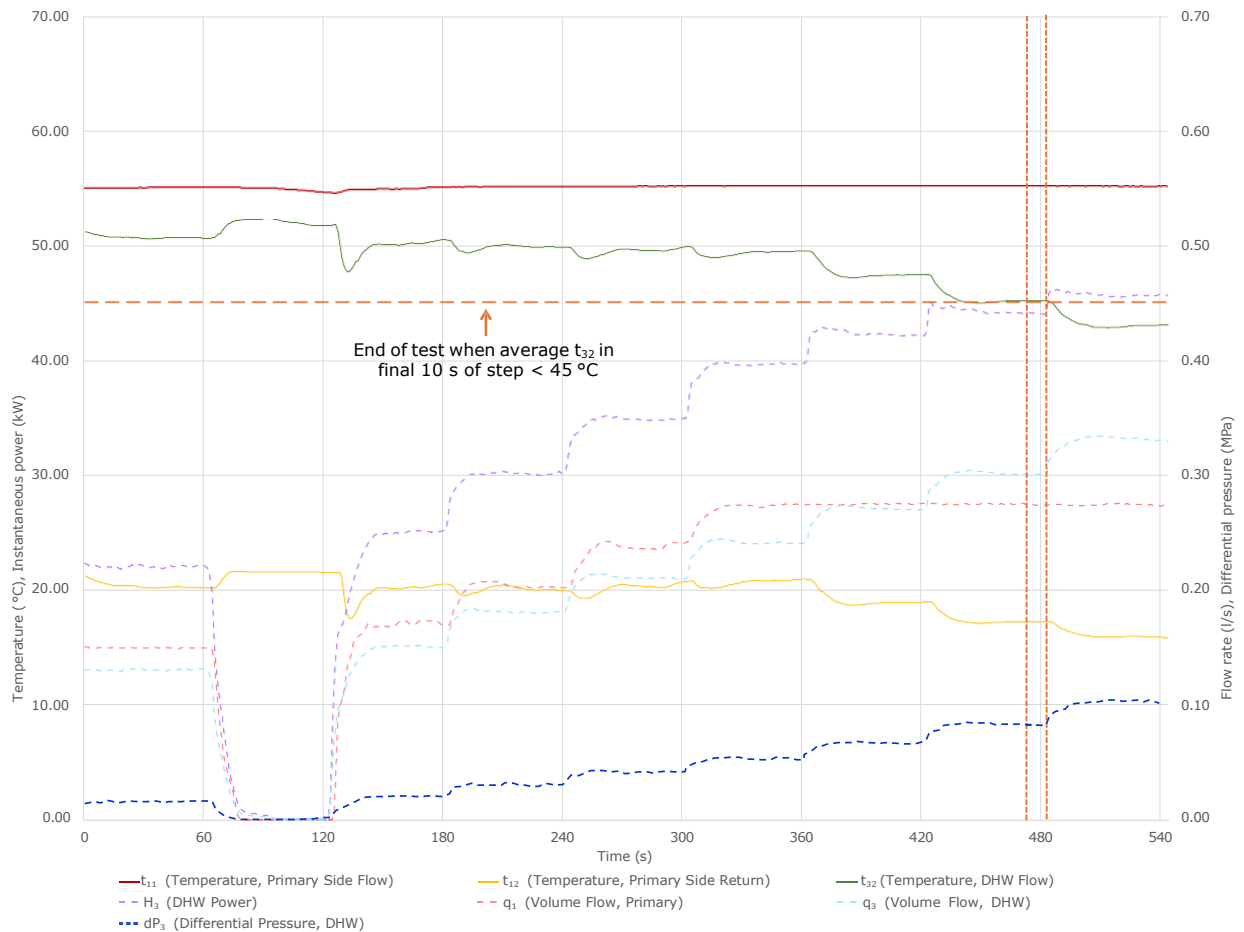


Figure 19: Example of performance for a HIU with a low maximum DHW capacity for Test 13b (Module 8 – low temperature regime).

3.3.3.1 DHW power (H_3)

The end of the test is reached when the average value of t_{32} over the last 10 seconds of a particular step in q_3 falls below 45.0 °C or if H_3 is sustained at 70 kW (corresponding to $q_3 = 0.42$ l/s). At this point, it is important to identify the maximum DHW output that has been reached.

This figure is also given in written format ahead of the graphical outputs.

For Module 8/Test 13b, the lower primary flow temperatures of 55 °C require higher primary flow rates to enable sufficient heat transfer to achieve $t_{32} = 50$ °C. This means that control may become more difficult for some HIUs, and it is expected that the DHW control system will allow the maximum possible primary flow rate through the plate. Any further increases in DHW demand cannot be met as no additional primary flow can be supplied. This will be reflected in the results as a plateau in the primary flow rate and subsequent decreases in DHW power, DHW flow temperature and primary return temperature with each step towards the end of the test.

Figure 18 and Figure 19 display this behaviour.

3.3.3.2 DHW flow rate (q_3)

The DHW flow rate is another useful parameter worth noting at the end of the test, as this will correspond to the final DHW power. Again, this value of q_3 is provided alongside H_3 in written format, ahead of the output figures.

3.3.3.3 DHW pressure drop (dP_3)

The test rig is set to provide a DHW gauge pressure of 3 bar, with a maximum allowable pressure drop of 1 bar across the tertiary side of the HIU (dP_3). The final value of dP_3 at the end of these tests is another parameter worth noting. This value provides information about the resistance to DHW flow within the HIU's hot water system at maximum DHW loads. This may place constraints on the resulting cold water pressure required on a heat network to supply the required DHW flow rate during maximum DHW demand events. However, designers must also consider the increased pump electricity consumption associated with operating at higher system pressures.

The final value of dP_3 can also have significant design implications for the tertiary system. Heat network designers must be aware of how the DHW line pressure drop for a particular HIU will affect the available dP for the tertiary system and must ensure this has been carefully considered when specifying tertiary equipment (especially pressure reducing valves).

For example, thermostatic mixing valves (TMVs) are commonly fitted onto DHW outlets to mix down the DHW outlet temperature and minimise the risk of scalding, particularly on medical or residential developments with vulnerable residents. TMVs allow a maximum inlet pressure ratio between DHW and cold water, which if exceeded, will not operate correctly. Thus, designers must exercise caution when specifying HIUs with large final values for dP_3 , to ensure hot water delivery is not adversely affected at high DHW demands.

3.4 Tests 21a–b: DHW no-load characteristics of units in 'Keep Warm' mode

3.4.1 Purpose

Tests 21a–b assess the performance of a HIU under scenarios where there is zero hot water/ space heating load.

Test 21a is done under the high temperature regime (Module 7) with a primary flow temperature (t_{11}) of 70 °C, whilst Test 21b is carried out under the low temperature regime (Module 8) with $t_{11} = 55$ °C.

To ensure an appropriate DHW response time is achieved after an extended period of no load (see [Section 3.5](#)), the DHW PHE must be kept warm, to respond rapidly to changes in DHW demand. This mode of operation is often described as standby or Keep Warm (see [Appendix C: Keep Warm](#)).

The BESA HIU Test Standard considers HIUs with a functioning Keep Warm as those which:

- Maintain the primary flow temperature (t_{11}) at or above 39.0 °C at all times during standby in tests 21a–b
- Provide a DHW temperature (t_{32}) of 45.0 °C within 15 seconds when tested under Keep Warm tests 22a–b, and not drop below 42.0° thereafter (see [Section 3.5](#))

There are several different methodologies that HIUs adopt to achieve this Keep Warm – generally, most HIUs use periodic pulses of primary flow through the DHW plate or allow a continual trickle flow. As such, the outputs of these tests are useful to illustrate how primary flow rates and return temperatures are controlled in Keep Warm mode. This can give information about the Keep Warm approach used for a particular HIU.

3.4.2 Pass/fail and best practice criteria

Fail if:
VWART > 44 °C
VWART > 48 °C
Primary return temperature (t_{12}) > 55 °C at any point (due to scaling risk)
Primary flow temperature (t_{11}) < 39 °C
HIU overall energy losses > 1.0 kWh/day
Test 22 DHW temperature response time test fails (i.e. the HIU Keep Warm operation is not a valid Keep Warm)

Table 7: Test 21 pass/fail criteria. Any criteria specific for the high temperature regime (Test 21a) and low temperature regime (Test 21b) are highlighted in **red** and **blue** respectively.

Best practice if:
VWART < 38 °C
VWART < 44 °C
HIU overall energy losses < 0.7 kWh/day

Table 8: Test 21 best practice criteria. Any criteria specific for the high temperature regime (Test 21a) and low temperature regime (Test 21b) are highlighted in **red** and **blue** respectively.

3.4.3 Comparative performance assessment

The outputs of these tests are reported as a single figure of the key metrics over the course of the tests, with additional parameters tabulated. There are several features of this graph and accompanying table, however the following points are the most important to assess:

- Keep Warm methodology
- Overall HIU energy losses
- Primary flow rate (q_f)

Again, for Tests 21a-b, it is not straightforward to identify best practice performance from the graphical outputs alone, as HIUs can exhibit several different Keep Warm strategies and the best practice criteria depend on other key parameters (see Table 8 above). However, the following sections discuss each of the attributes above and the necessary considerations to keep in mind when interpreting the results of these tests.

3.4.3.1 Keep Warm methodology

As indicated in Section 3.4.1, the two major Keep Warm strategies that HIUs typically use are pulsing or trickle flow.

For HIUs that adopt a pulse Keep Warm approach, it is worth noting the frequency and duration of pulses, as well as the maximum primary flow rate during the pulses. This gives an indication of how much primary flow is allowed through the DHW PHE, and subsequently how much the primary flow and return temperatures rise by with each pulse. An example of a HIU with a consistent pulse Keep Warm function is given in Figure 20.

For those which experience trickle flow, the stability of q_v , t_{11} and t_{12} are important once steady state has been established. Excessive primary flow rates can lead to bypassing through the DHW PHE, which elevates the primary return temperature, VWART and the thermal losses of the HIU during Keep Warm. Figure 21 provides an example of a HIU with a stable trickle Keep Warm function. Note that short term pulsing behaviour is expected before the steady state trickle function is activated as the DHW control system undergoes hysteresis.

For both examples, the DHW flow temperature (t_{32}) is expected to fall and stabilise onto a low temperature. This confirms that during these tests, there is no DHW draw-off (purely in Keep Warm operation).

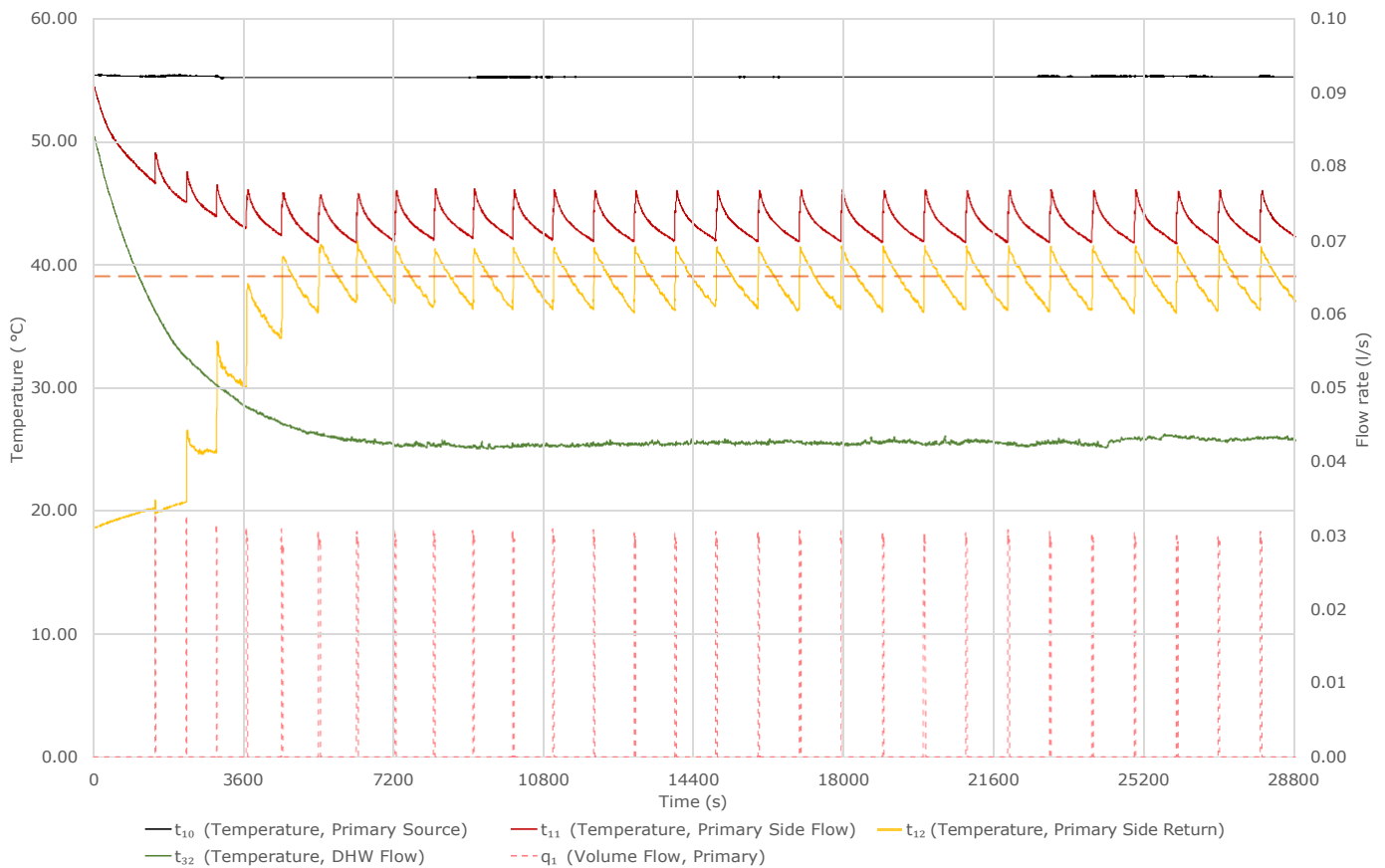


Figure 20 : Example response during Tests 21a-b for a HIU with a pulse Keep Warm function.

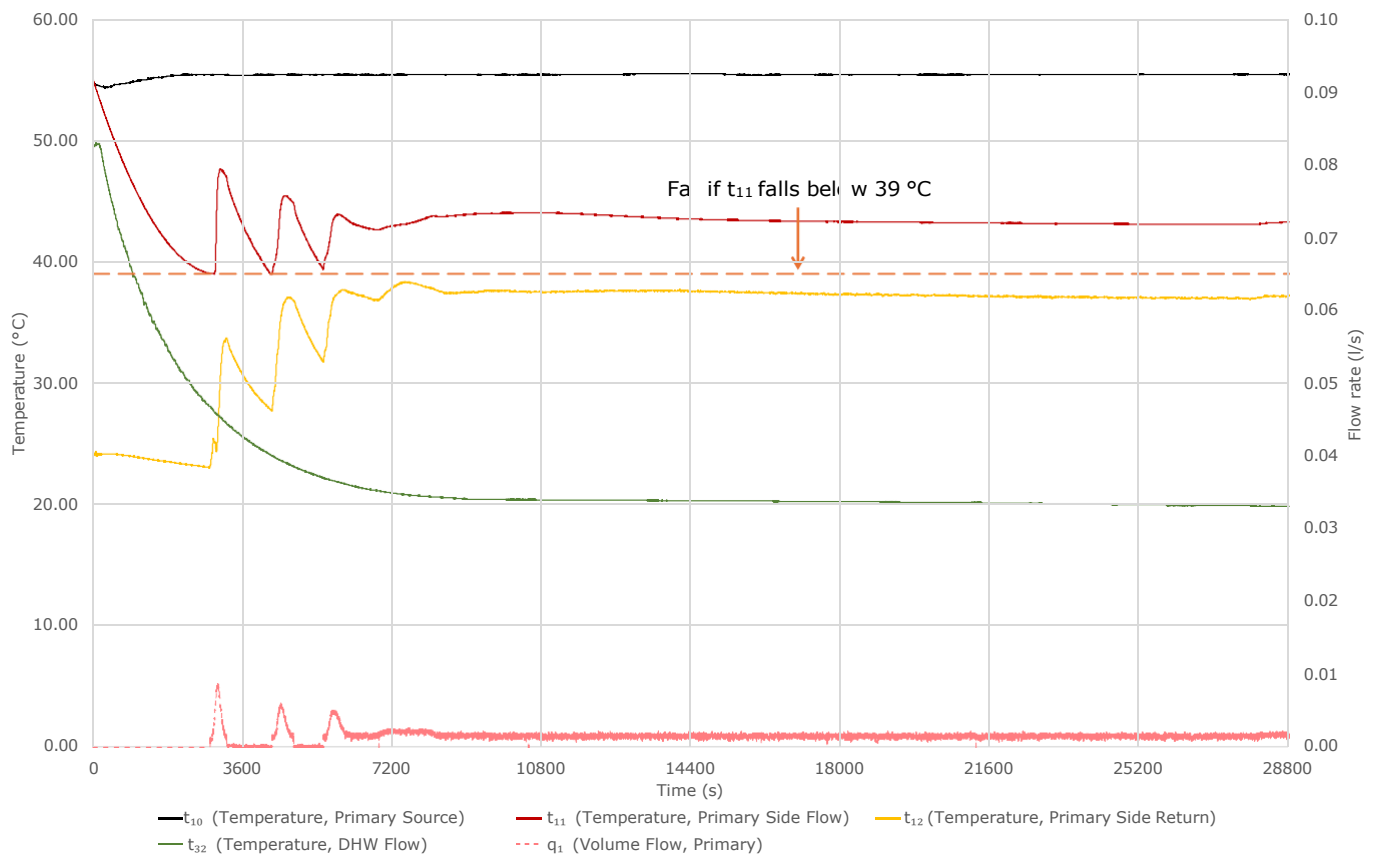


Figure 21: Example response during Tests 21a-b for a HIU with a trickle-flow Keep Warm function.

3.4.3.2 Overall HIU energy losses

Another crucial parameter reported for Tests 21a-b but not included in the graphical outputs are the HIU overall energy losses, which incorporate both the electrical losses ($W_{\text{electrical}}$) and thermal losses (W_{thermal}). Typically, thermal losses dominate the overall figure. To prove compliance with Building Regulations Part L, the Home Energy Model, which is expected to supersede the Standard Assessment Procedure (SAP), will be required for a new build residential development. Note that the HIU heat loss values from the results of Tests 21a-b can be inputted into the Home Energy Model, otherwise a value of 1.0 kWh/day (i.e. the maximum allowable value for the tests) is assumed.

The majority of a HIU's time is spent in Keep Warm mode, so any losses in this state are substantial and can have considerable cost implications. A simplified cost saving calculation has been performed to illustrate this, with the results given in [Table 9](#).

Three HIUs have been compared, with Keep Warm losses of 2.50, 0.95 and 0.60 kWh/day. Whilst HIU 1 would not pass under the current version of the Test Standard, this has been included to represent poorly performing HIUs on older operational schemes, which may exhibit very high standby losses. HIUs 2 and 3 represent HIUs which would have not, and would have, met the best practice criteria respectively.

As seen in [Table 9](#), reductions in standby losses can lead to significant cost savings for heat network operators and ultimately residents. This calculation assumes a network of 200 HIUs (as with the Reference Building) and typical heat and electricity tariffs of 8 and 30 p/kWh, respectively. It has also been assumed that 92% of the overall standby losses are due to thermal losses, with the electrical losses accounting for the remaining 8%.

Parameter	HIU 1	HIU 2	HIU 3	Unit
Overall standby losses	2.50	0.95	0.60	kWh/day
W_{thermal}	95.8	36.4	23.0	W
$W_{\text{electrical}}$	8.3	3.2	2.0	W
Overall cost saving	–	11,000	13,500	£/annum
Cost saving per dwelling	–	55	68	(£/annum)/dwelling

Table 9 : Cost saving calculation for three HIUs with different standby losses. The cost saving values for HIUs 2 and 3 are based on comparisons with HIU 1.

3.4.3.3 Primary flow rate (q_p)

As well as the features of q_p mentioned in Section 3.4.3.1, the average primary flow rate during Keep Warm is an important value. If information is available about the rest of the network, this HIU minimum flow rate can provide useful information about the network minimum flow rate. For designers, this can be important for network pump sizing and determining the minimum pump turndown, as highlighted in [Appendix C: Keep Warm](#).

Those involved with specifying HIUs must be cautious that some HIUs have enhanced Keep Warm functionality, which may not be reflected in the test results. For those HIUs, designers should be aware that BESA-tested HIUs quoted by manufacturers must operate with the same Keep Warm modes as those used in Tests 21a–b. Otherwise, real HIU performance during any additional Keep Warm functions may differ considerably from the test results. This point also applies to the components and ancillaries of the BESA-tested HIU, which is detailed further in [Appendix D: HIU Procurement Considerations](#).

3.5 Tests 22a–b: DHW response time in ‘Keep Warm’ mode

3.5.1 Purpose

Following the extended period of steady state Keep Warm operation during Tests 21a–b (see [Section 3.4](#)), Tests 22a–b examine how quickly DHW delivery can be achieved at acceptable DHW outlet temperatures, as this directly affects resident comfort.

Test 22a is done under the high temperature regime (Module 7) with a primary flow temperature (t_{f1}) of 70 °C, whilst Test 22b is carried out under the low temperature regime (Module 8) with t_{f1} = 55 °C.

As per HSE guidance in HSG274 Part 2 (which states that water becomes painful and can cause burns at or above 44 °C), DHW at temperatures of 45 °C or above is considered “hot” and therefore acceptable for the purpose of these tests.

The BESA Test Standard for UK HIU Testing Regime defines a valid Keep Warm facility as one which passes the requirements for Tests 22a–b. This means that the system temperatures are maintained at a level that is sufficient to enable the delivery of “hot” water following a long period of standby operation. As such, the results of these tests are important prerequisites and are included in the pass/fail criteria for Tests 21a–b, as mentioned in [Section 3.4.2](#) and [Table 7](#).

As well as DHW outlet temperature (t_{32}), the outputs of these tests also demonstrate the response of the primary flow rate (q_p) and return temperature (t_{12}) during DHW draw-off following long periods of Keep Warm mode.

3.5.2 Pass/fail and best practice criteria

Fail if:

DHW response time > 15 seconds to reach $45.0\text{ }^{\circ}\text{C}$ at t_{32} while not dropping below $42.0\text{ }^{\circ}\text{C}$ thereafter.

DHW temperature (t_{32}) $> 60\text{ }^{\circ}\text{C}$ for more than 1 second (due to scalding risk)

Primary return temperature (t_{12}) $> 55\text{ }^{\circ}\text{C}$ at any point (due to scaling risk)

Table 10: Test 22 pass/fail criteria. Any criteria specific for the high temperature regime (Test 22a) and low temperature regime (Test 22b) are highlighted in **red** and **blue** respectively.

Best practice if:

DHW response time at $t_{32} < 10$ seconds

Table 11: Test 22 best practice criterion. This criterion is the same for both temperature regimes/test modules

3.5.3 Comparative performance assessment

The outputs of these tests are reported a single figure of the key metrics over the course of the tests, with additional parameters tabulated. There are several features of this graph and accompanying table, however the following points are the most important to assess:

- DHW response time
- DHW flow temperature (t_{32})

The following sections provide technical description about how each parameter affects test performance. [Figure 22](#) displays a typical output graph for Tests 22a–b, depicting best practice performance. However, [Figure 23](#) shows the corresponding output for a HIU with less responsive control, which would have narrowly met the pass/criteria for this test.

Note that the graphs produced here are not from specific test reports, but have been generated with exaggerated features to display certain performance characteristics. The figures given in the following sections use the same dataset as that used for [Figure 22](#) and [Figure 23](#).

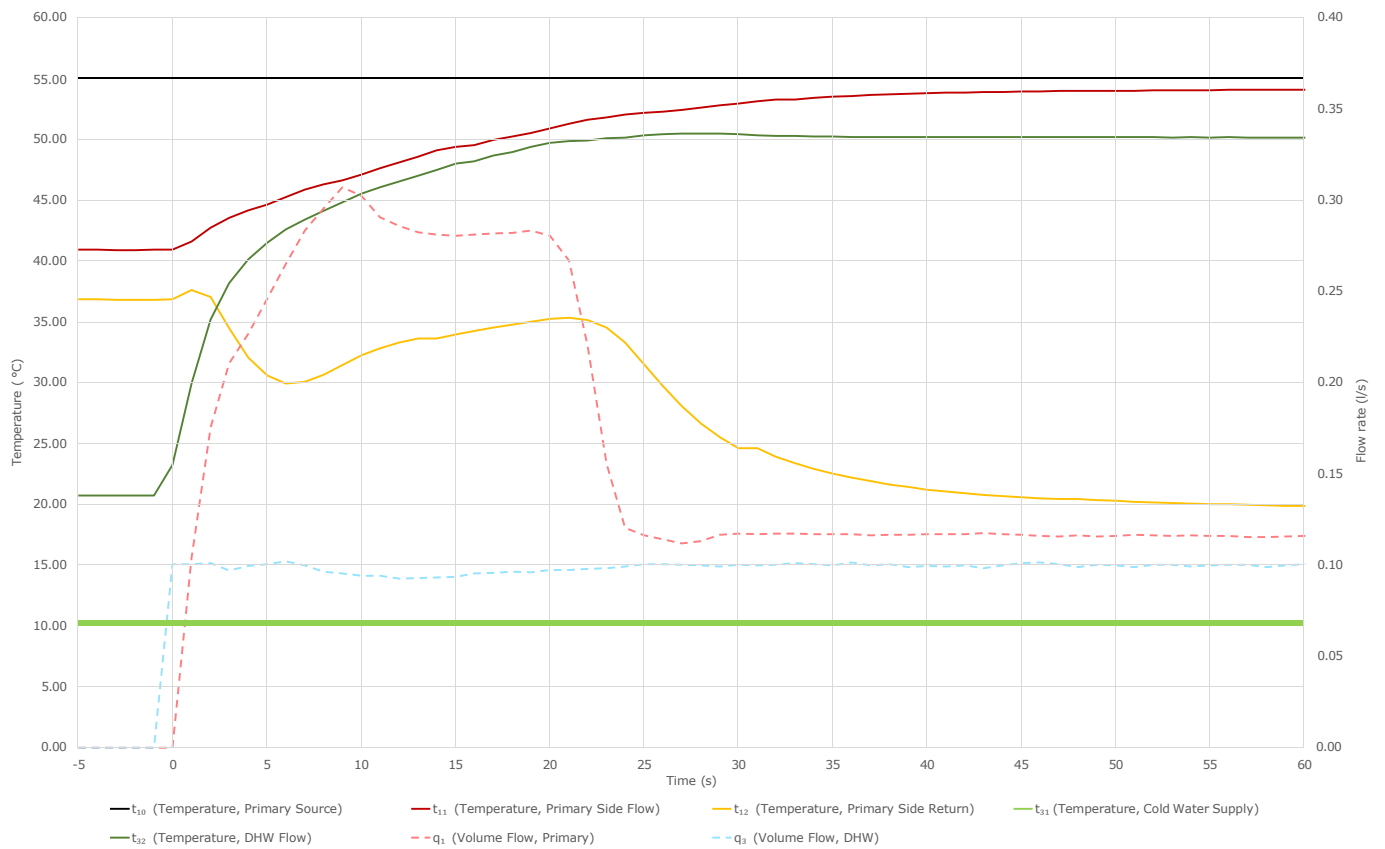


Figure 22 : Example of best practice overall performance for Tests 22a-b.

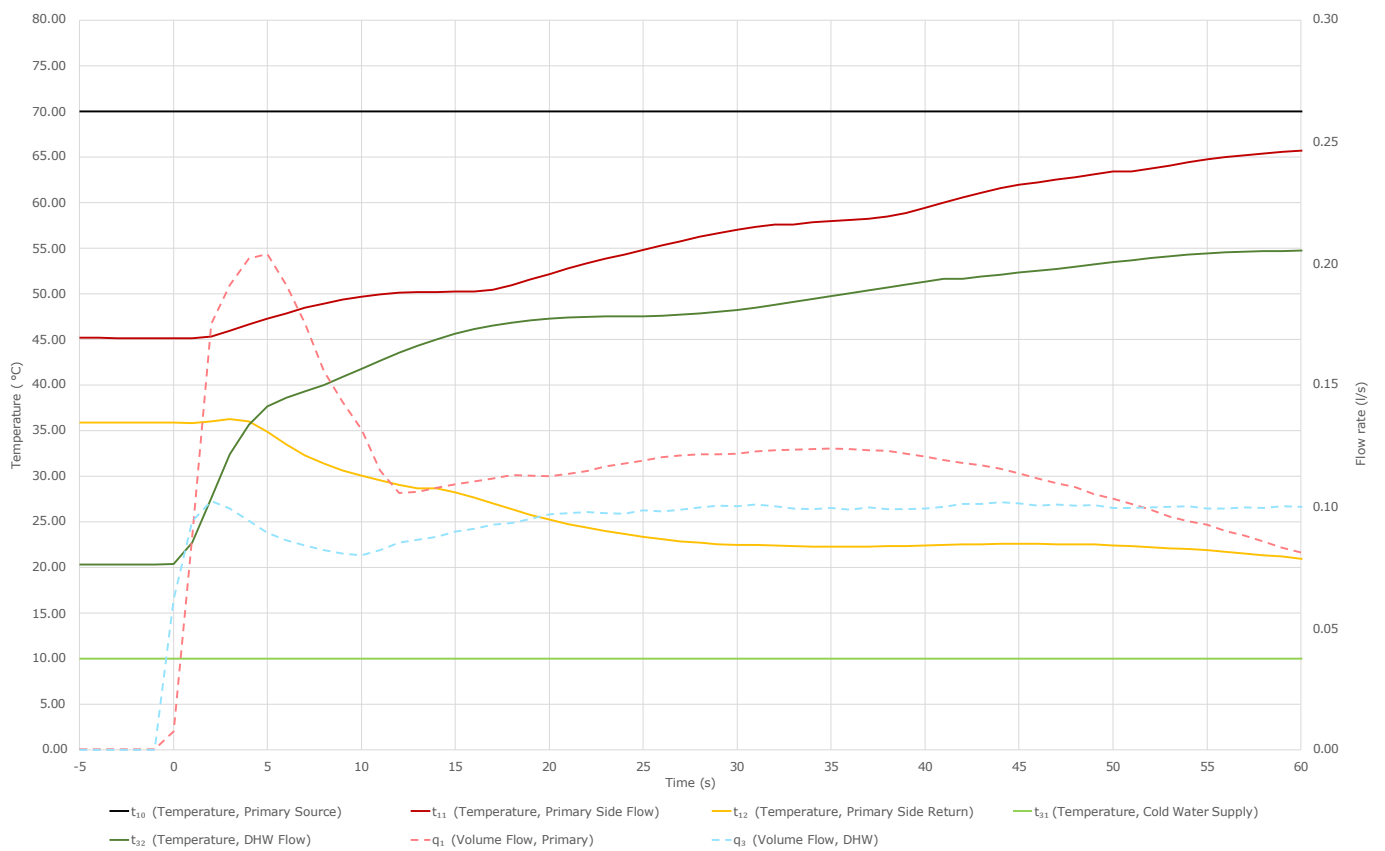


Figure 23: Example of overall performance for Tests 22a-b for a HIU with less responsive control.

3.5.3.1 DHW response time

The most important parameter from these tests is the DHW response time, which is the time taken for the HIU to generate DHW at a temperature of 45 °C or above. As indicated in [Table 10](#), this is set at an upper limit of 15 seconds as the pass/fail threshold, with a best practice threshold of 10 seconds (see [Table 11](#)).

CIBSE CPI – Heat Networks Code of Practice (2020) and CIBSE Guidance Note: DHW from instantaneous HIUs outline resident comfort requirements for DHW delivery. These guidelines mention that hot water should be delivered to the kitchen tap to achieve a minimum of 45 °C within 45 seconds.

Of this, 15 seconds is allowed for the DHW generation time within the HIU, and the remaining 30 seconds represents the time delay in DHW reaching outlets due to the need to flush out colder water and warm the pipes. However, this division varies considerably based on the DHW pipework design and sizing within a particular dwelling. Therefore, reducing DHW generation times to under 10 seconds is desirable, and as such, sets out the best practice threshold for delivery time.

For HIUs tested under both the high and low temperature regimes (Tests 22a and 22b respectively), the response time is expected to be lower for Test 22a/the high temperature regime. This is because the larger temperature differential between the incoming primary flow and cold water enables more effective heat transfer and thus a DHW temperature of 45 °C can be more quickly attained. The converse also applies for Test 22b/the low temperature regime.

[Figure 24](#) provides an example results graph of a HIU with a DHW response time which meets the best practice criterion, whilst [Figure 25](#) shows the same response but for a HIU with less responsive control.

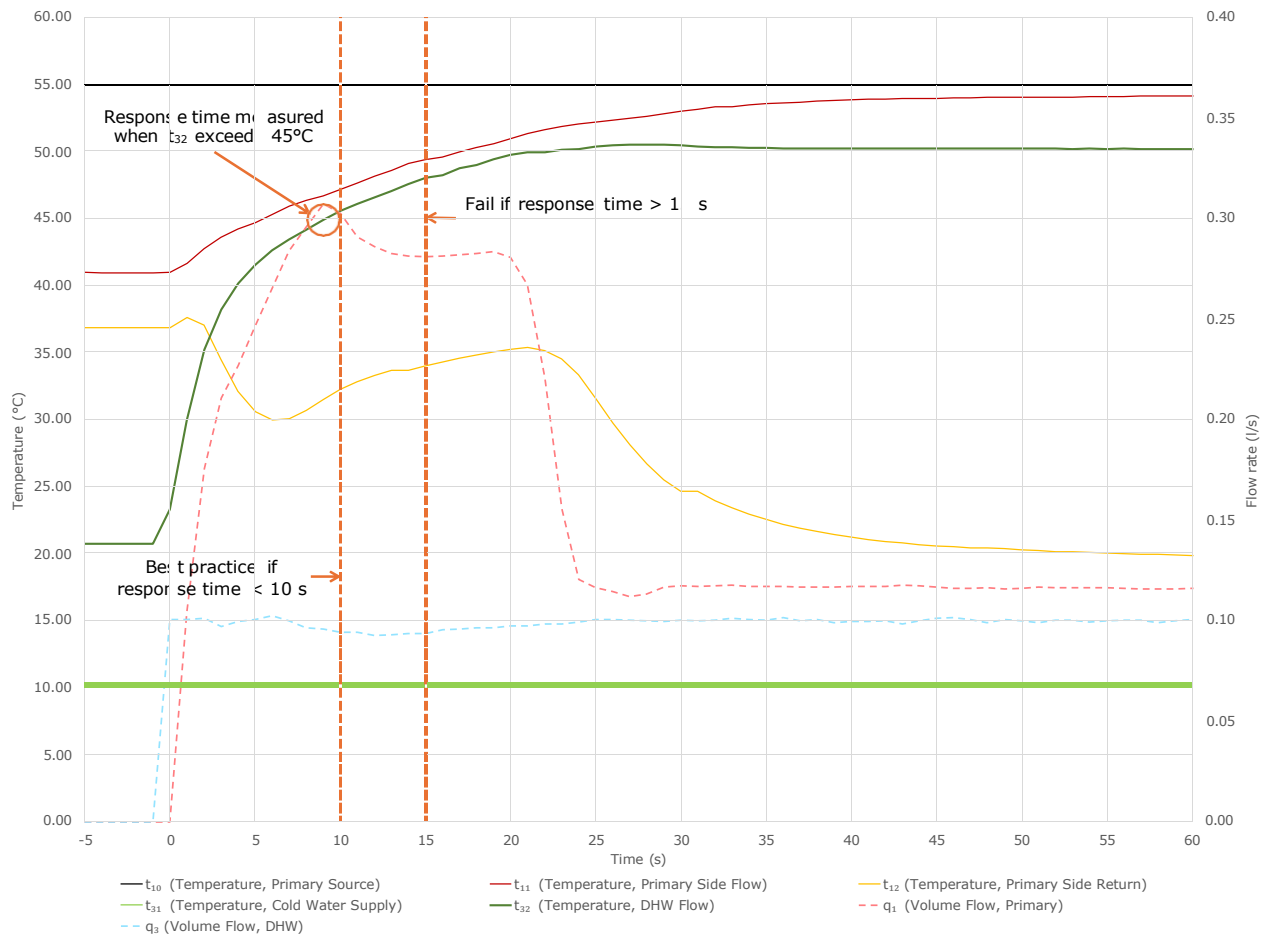


Figure 24 : Example of best practice DHW response time for Tests 22a-b.

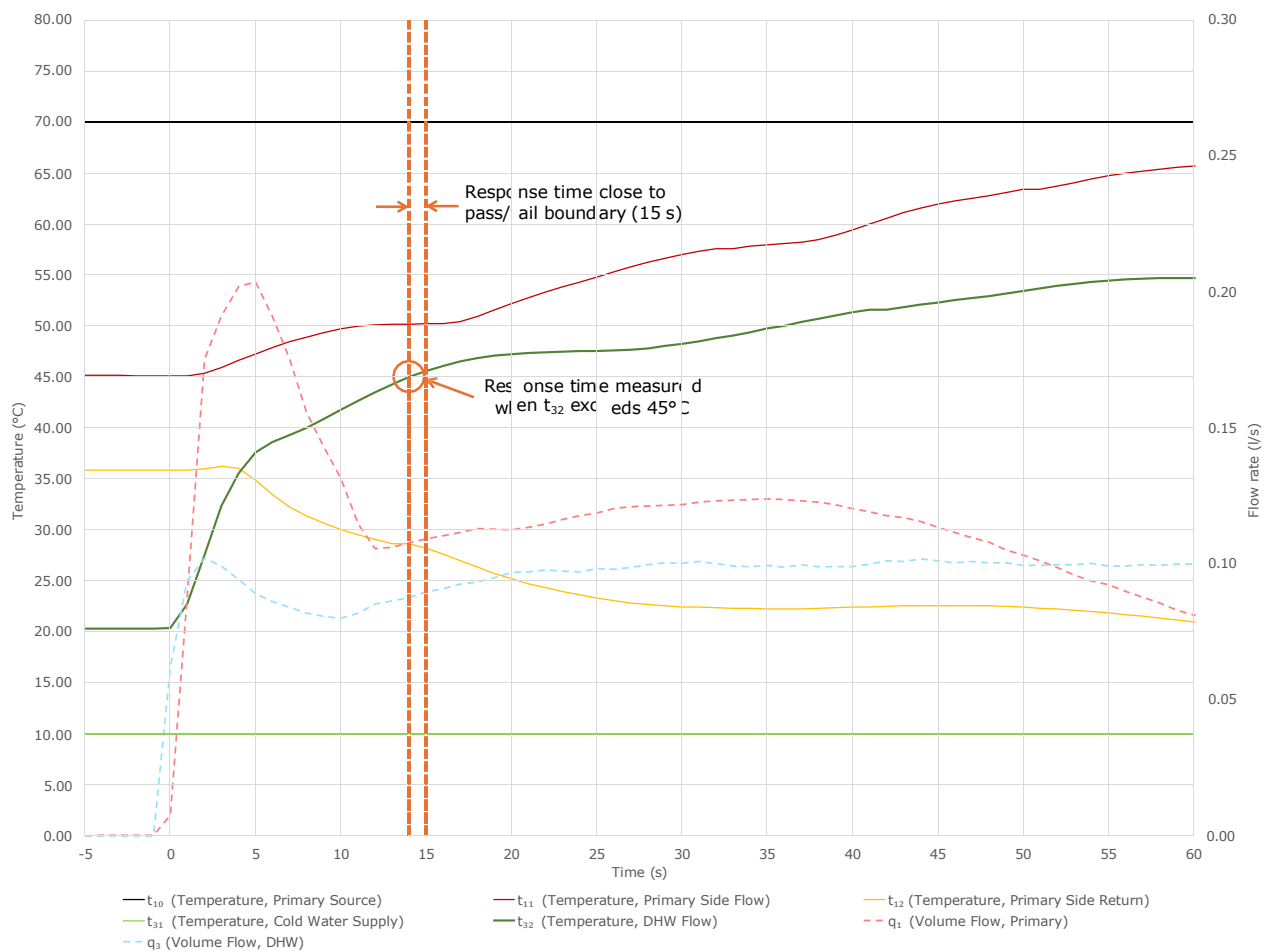


Figure 25 : Example of DHW response time for Tests 22a-b for a HIU with less responsive control.

3.5.3.2 DHW flow temperature (t_{32})

Please note that delivery time is the primary feature for Tests 22a-b and the response of t_{32} during DHW is assessed more comprehensively in Tests 11a-b (see [Section 3.1.3](#)). Therefore, it is recommended that this is not as strictly assessed as response time for these tests.

However, it is useful to note whether t_{32} plateaus at 50 °C towards the end of the tests, and the degree to which this is controlled. Above 45 °C, minor instabilities in DHW flow temperature are expected as the hot water control system responds to t_{32} rising, however this is expected to settle onto 50 °C at the end of the tests. As t_{32} approaches its setpoint (50 °C), HIUs exhibit different behaviours to achieve suitable delivery times, which can also lead to variation in t_{12} and q_1 .

This is depicted in Figure 26. Significant fluctuations towards the end of the test or t_{32} stabilising at temperatures far from 50 °C are indicative of performance for a HIU with reduced control capability, as shown in [Figure 27](#).

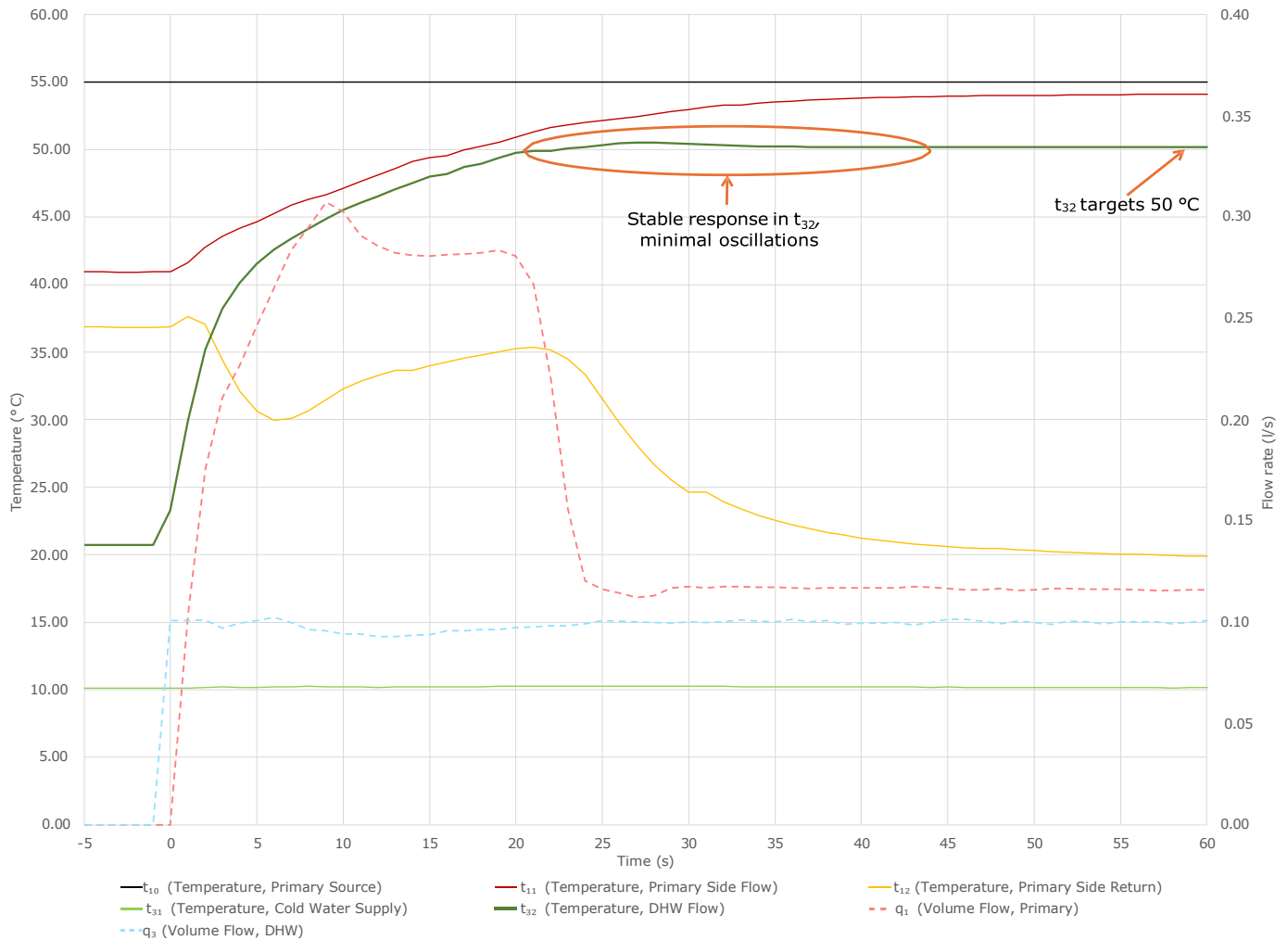


Figure 26 : Example of best practice DHW temperature response during Tests 22a-b.

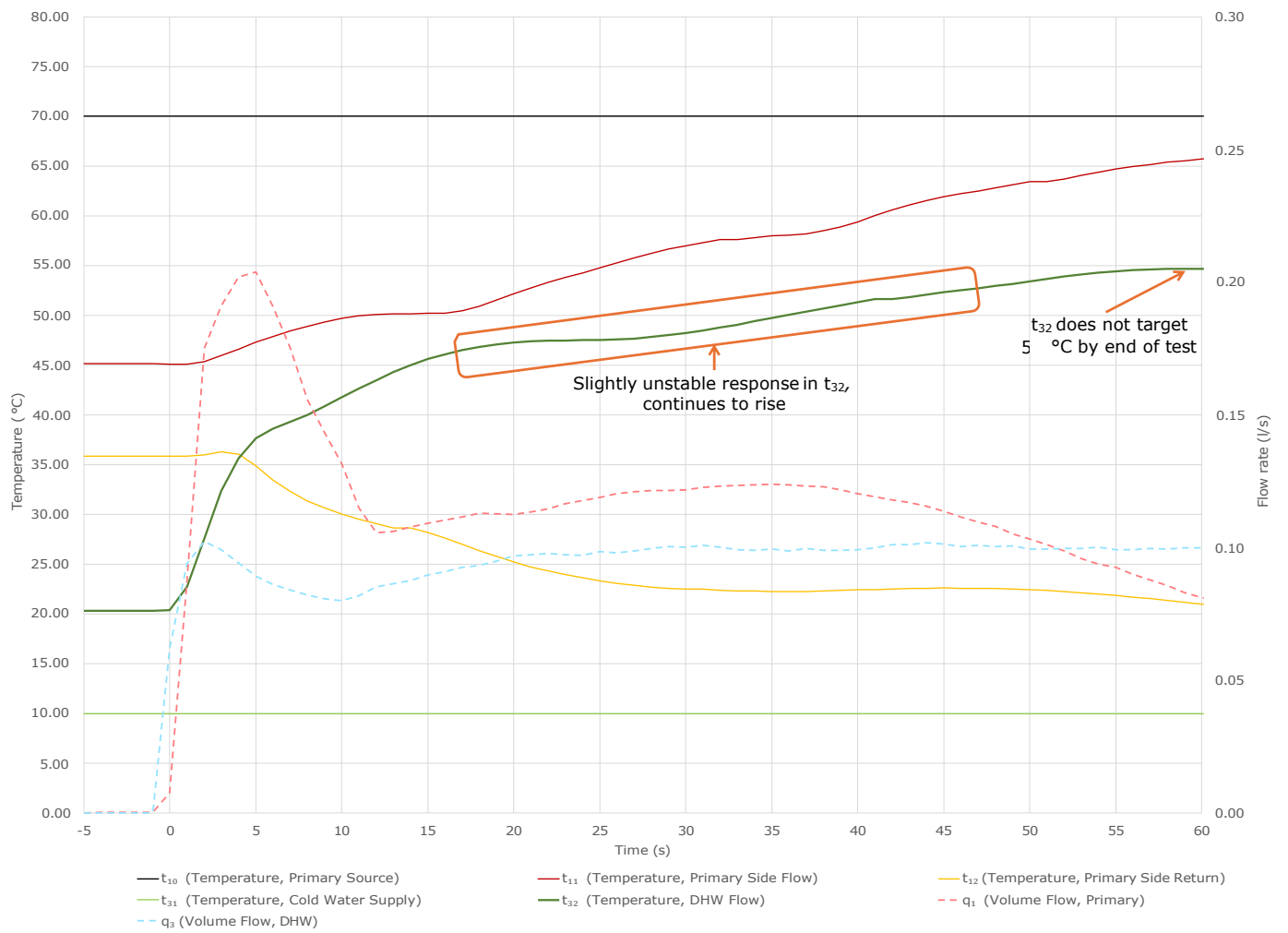


Figure 27: Example of DHW temperature response during Tests 22a-b for a HIU with less responsive control.

The BESA Test Standard for the UK HIU Testing Regime defines Modules 1–6 as the modules which test the HIU's performance under space heating operation. As mentioned in Section 2, this guidance only covers Indirect HIUs (those with hydraulic separation for space heating), which relates to Modules 1 and 2. Module 1 refers to the high temperature regime, where the primary flow temperature (t_{f1}) is 70°C, whilst Module 2 relates to the low temperature regime, where this is 55°C. All further information for each module is available within the individual BESA HIU Test Module documents.

The objective of these modules is to perform static/steady-state testing in order to investigate the performance characteristics of the HIU when meeting a specified space heating load.

Note that during indirect space heating testing, the HIU pump is deactivated, in order to test the performance of the space heating PHE and control system alone. This is noted in the test rig schematic provided in [Figure 1](#).

4.1 Tests 01a–f: Indirect heating HIU, space heating circuit capacity

4.1.1 Purpose

Tests 01a–f identifies the performance of the HIU during different space heating load scenarios. These tests aim to assess the stability of space heating performance, particularly the flow and return temperatures and flow rates under these scenarios.

For each temperature regime/test module, three different tests are conducted at space heating loads of 0.5 kW to model a reference radiator load, 1 kW for a typical heating load and 4 kW to represent a high load scenario.

Tests 01a–c are done under the high temperature regime (Module 1) with a primary flow temperature (t_{f1}) of 70 °C and a tertiary space heating profile of 55 °C/35 °C, simulating an existing network with radiators. On the other hand, Tests 01d–f are carried out under the low temperature regime (Module 2) with t_{f1} = 55 °C and a tertiary space heating profile of 45 °C/35 °C, typical of a new build network with underfloor heating (UFH).

For these tests, the primary differential pressure is also varied to confirm whether space heating delivery is consistent across the network.

As described in Sections 3.1.1 and 3.2.1, HIUs at different points in a typical heat network experience a range of primary differential pressures (dP_1). From calculations based on the Reference Building, this varies from approximately 50 kPa to 200 kPa. Tests 01a, 01c, 01d and 01f (at the 0.5 kW and 4 kW space heating loads) are performed at dP_1 = 50 kPa, to reflect HIUs located at the index point of a typical heat network. However, Tests 01b and 01e, at the typical space heating load of 1 kW, are performed at dP_1 = 200 kPa to simulate HIUs near the energy centre.

4.1.2 Pass/fail and best practice criteria

Fail if:

VWART > 40 °C

Table 12: Test 01 pass/fail criteria. These criteria are the same for both temperature regimes/test modules.

Best practice if:

VWART < 37 °C

Table 13: Test 01 best practice criteria. These criteria are the same for both temperature regimes/test modules.

4.1.3 Comparative performance assessment

The outputs of these tests are reported with three figures of the key metrics over the course of the tests, one for each space heating load scenario, with additional parameters tabulated. There are several features of these graphs and accompanying tables, however the following points are the most important to assess:

- Space heating flow temperature (t_{22})
- Space heating return temperature (t_{21})
- Primary flow rate (q_1)
- Space heating flow rate (q_2)
- Space heating pressure drop (dP_2)

The following sections provide technical description about how each parameter affects test performance. [Figure 28](#) displays a typical output graph for Tests 01a-f, depicting best practice performance. However, [Figure 29](#) shows the corresponding output for a HIU with less responsive control, which would have narrowly met the pass/criteria for this test.

Note that the graphs produced here are not from specific test reports, but have been generated with exaggerated features to display certain performance characteristics. The figures given in the following sections use the same dataset as that used for [Figure 28](#) and [Figure 29](#), but with certain parameters emboldened for clarity.

The pass/fail and best practice thresholds in Section 4.1.2 (above) only assess the response of the primary return temperature (t_{12}), which influences the VWART for each test (see [Appendix B: Volume Weighted Average Return Temperature \(VWART\)](#)).

Manufacturers should ensure space heating PHE capacities are specified properly and designers should be careful when selecting HIUs on this basis. This is because the VWARTs and thus performance in Tests 01a-f is largely dependent on PHE sizing. If a HIU contains undersized plates, there will be a lack of heat transfer through the plate at higher space heating loads, leading to lower primary temperature differentials and higher VWARTs. However, oversized plates result in higher VWARTs again but at lower space heating loads, due to laminar flow across the plate and so inefficient heat transfer.

Another factor to consider is how the space heating performance varies with changes in primary differential pressure. During tests 01b and 01e, where $dP_1 = 200$ kPa, the control system may be challenged to deliver the 1 kW heating load, leading to undesirable fluctuations in primary flow rate. More sensitive HIU control will result in very similar outputs for both dP_1 scenarios.

As discussed later, stability of temperatures and flow rates is indicative of responsive HIU control and ultimately best practice performance. However, some fluctuations are expected, so long as the space heating output is consistent over the course of the tests. Unlike in the DHW tests, oscillations in parameters during space heating testing do not necessarily highlight HIU performance flaws. This is because, in general, space heating operates over a much longer time frame than DHW, therefore the effects of any short-term fluctuations in space heating parameters are minimal.

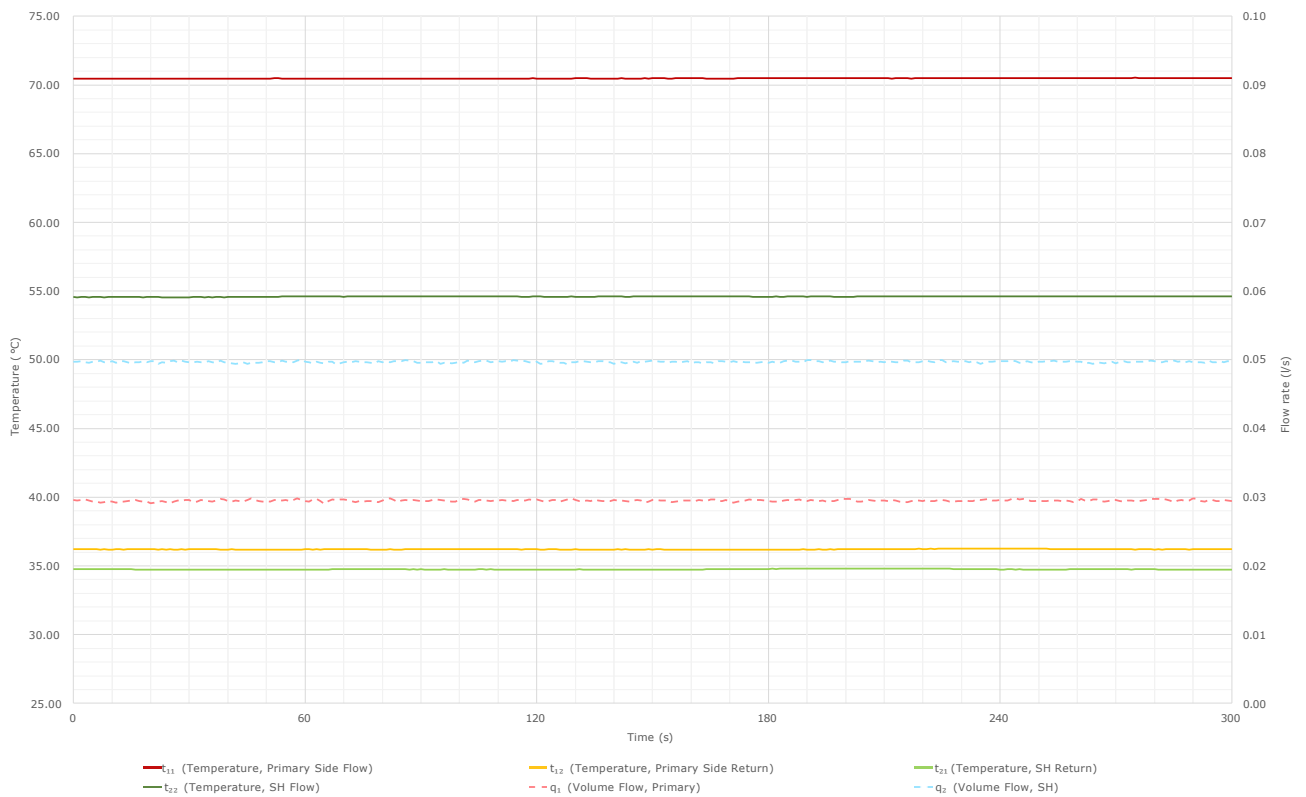


Figure 28 : Example of best practice overall performance for Tests 01a-f.

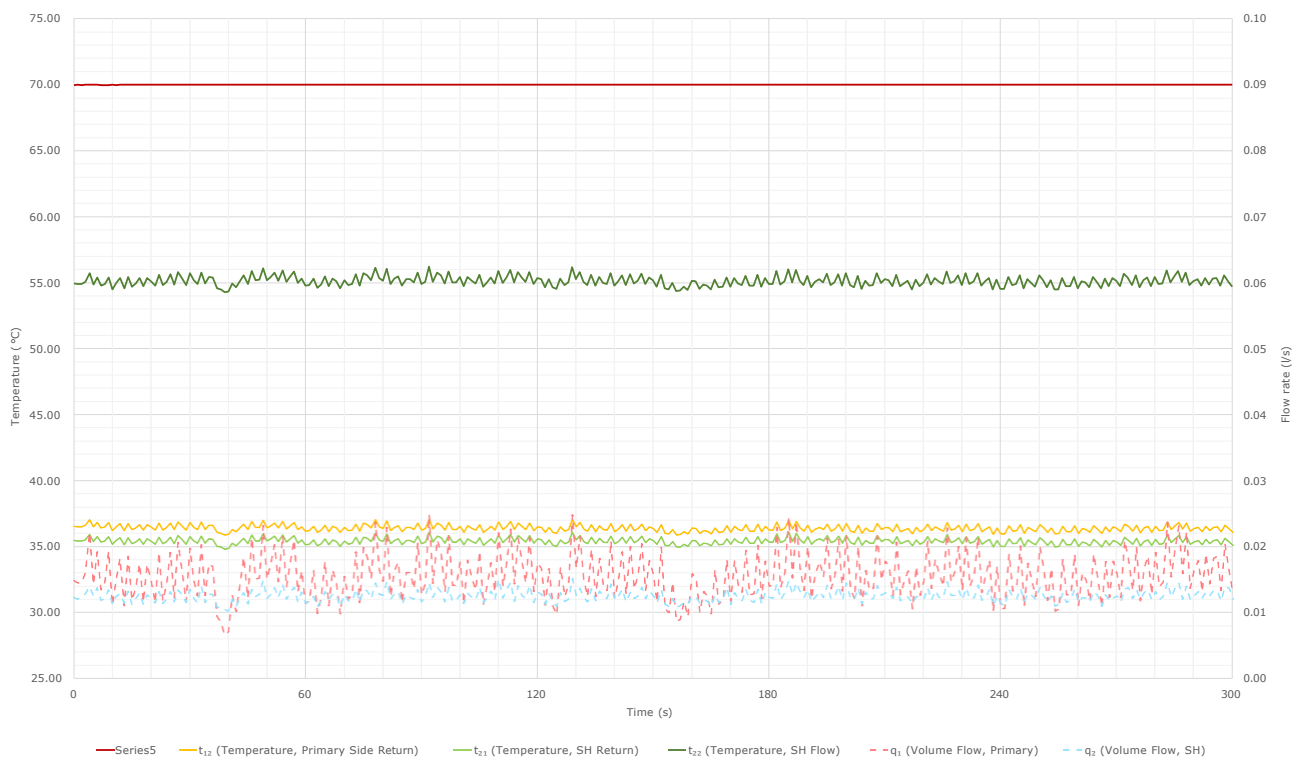


Figure 29 : Example of overall performance for Tests 01a-f for a HIU with less responsive control.

4.1.3.1 Space heating flow temperature (t_{22})

It is expected that the space heating flow temperatures will remain stable during these tests. This is highlighted in Figure 30 (below). However, some variation around the set points (55 °C/45 °C) is expected for the space heating flow temperatures, so long as the space heating output (H_2) is consistent.

Excessive oscillations, such as those shown in [Figure 31](#), indicate that the HIUs control system struggles to maintain a consistent heat output, leading to disruptions in space heating delivery. Fluctuations like these may result in space heating flow temperatures rising to unacceptable temperatures, resulting in safety concerns (e.g. burning at radiators), damage to the tertiary system (e.g. floor finishes/screed due to maximum UFH temperatures being exceeded) or a shut off of heating supply (if a safety thermostat/interlock is in place).

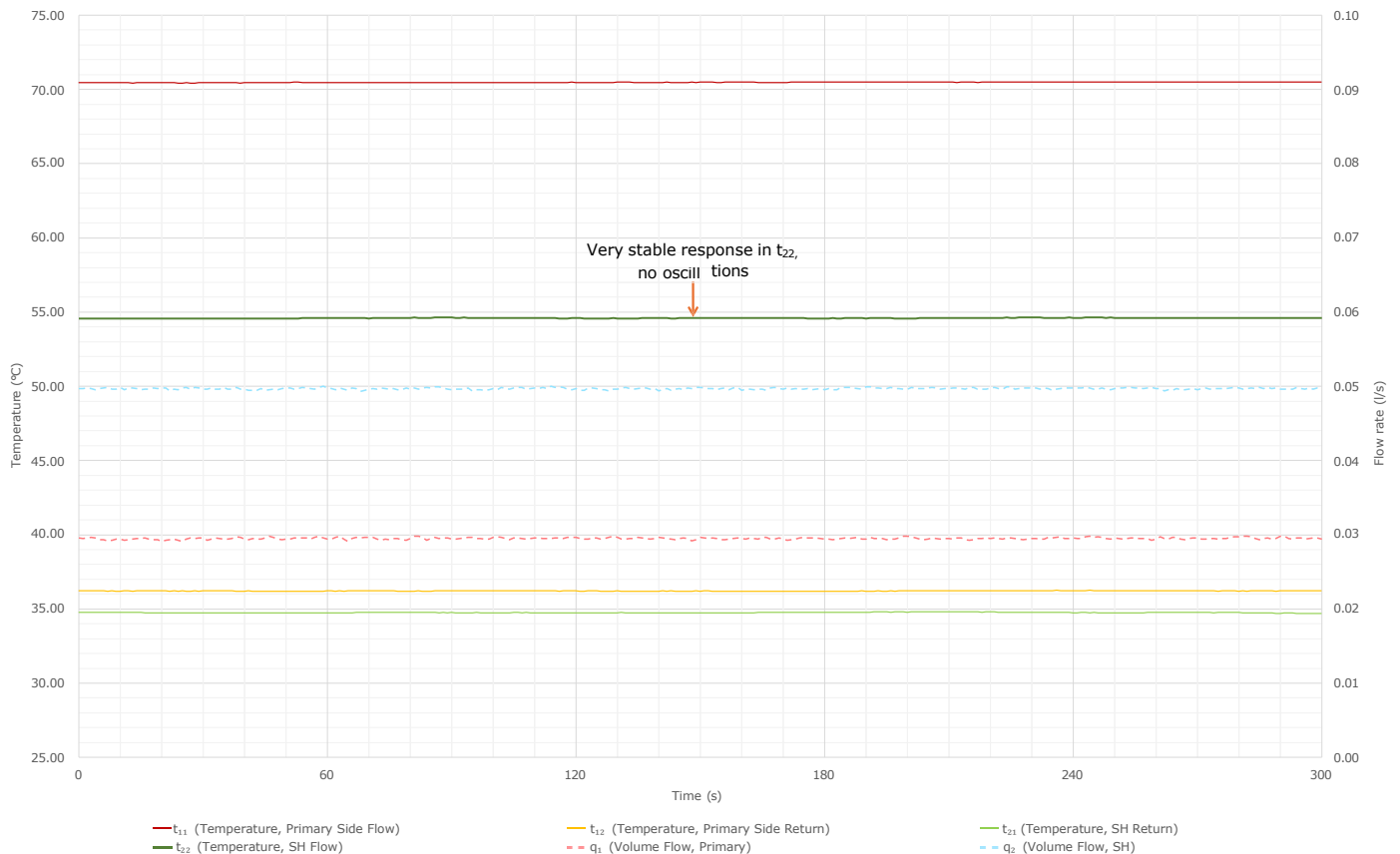


Figure 30 : Example of best practice space heating flow temperature response during Tests 01a-f.

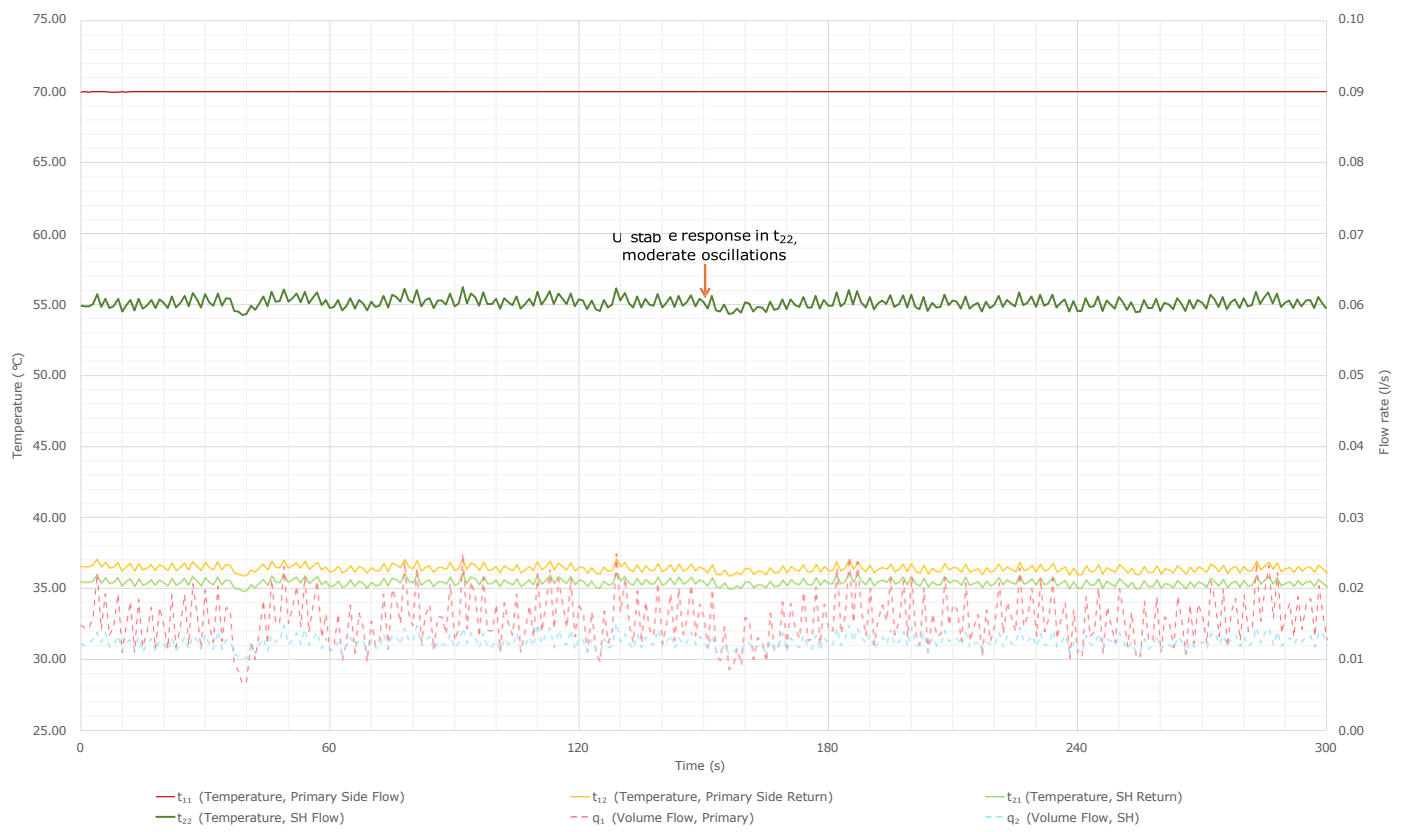


Figure 31: Example of space heating flow temperature response during Tests 01a-f for a HIU with less responsive control.

4.1.3.2 Space heating return temperature (t_{21})

Temperature stability for the space heating return temperature is also expected during these tests, as depicted in Figure 32. Again, there may be some variation in t_{21} around the set point (35 °C), so long as the space heating output (H_2) is consistent.

Figure 33 is an example of an output graph showing significant oscillations in space heating return temperature. As before, this demonstrates that the HIUs control system struggles to maintain a consistent heat output, leading to disruptions in space heating delivery.

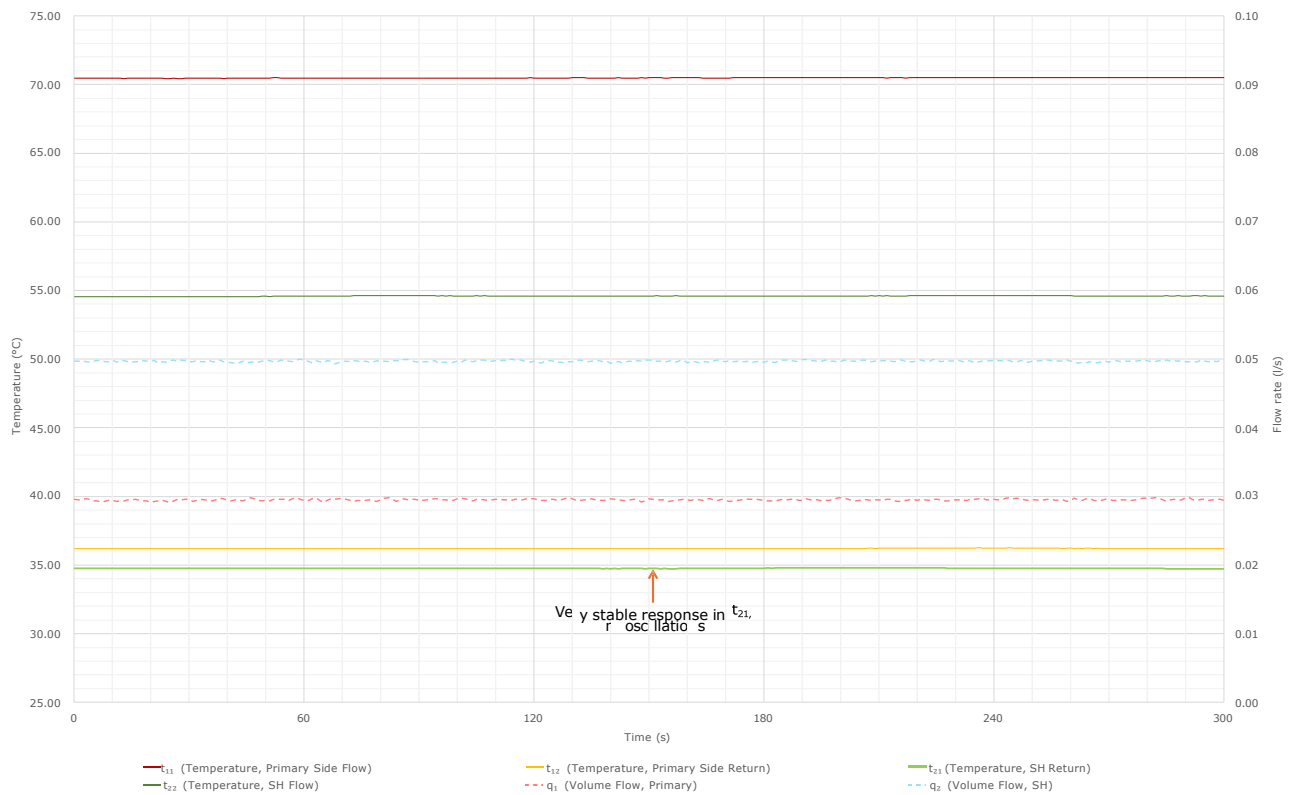


Figure 32 : Example of best practice space heating return temperature response during Tests 01a-f.

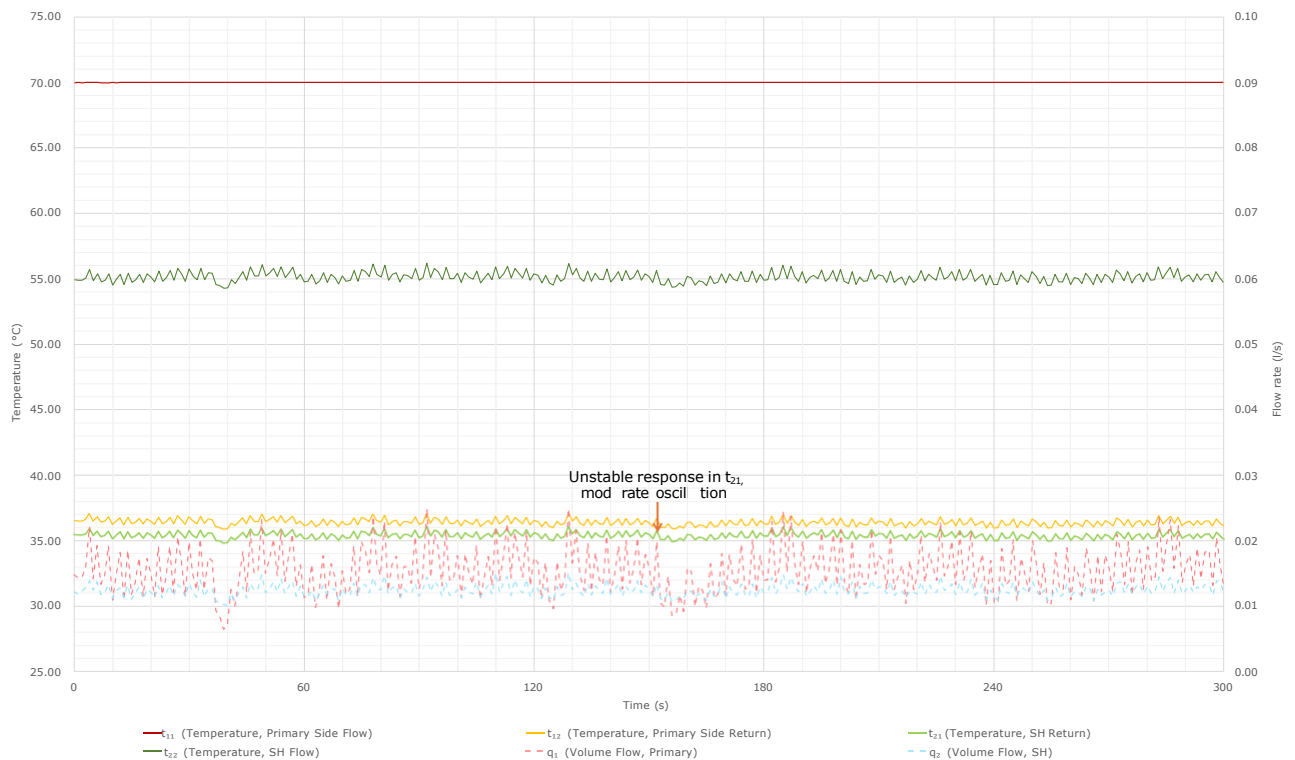


Figure 33 : Example of space heating return temperature response during Tests 01a-f for a HIU with less responsive control.

4.1.3.3 Primary flow rate (q_1)

Flow rates are expected to be stable for best practice performance. For the primary flow rate, this is critical, as it often dictates the behaviour of the space heating temperatures and primary return temperature (influencing the VWARTs).

To ensure space heating power is maintained at a consistent value, q_1 is expected to also remain constant, as displayed in Figure 34. Based on the HIU's control strategy, there may be some fluctuations in primary flow rate. However, these should be minimised to reduce wear on the HIU and avoid causing fluctuations in t_{22} and t_{21} , which may lead to the issues discussed in Section 4.1.3.1.

Figure 35 displays the primary flow rate response for a HIU with less responsive space heating control.

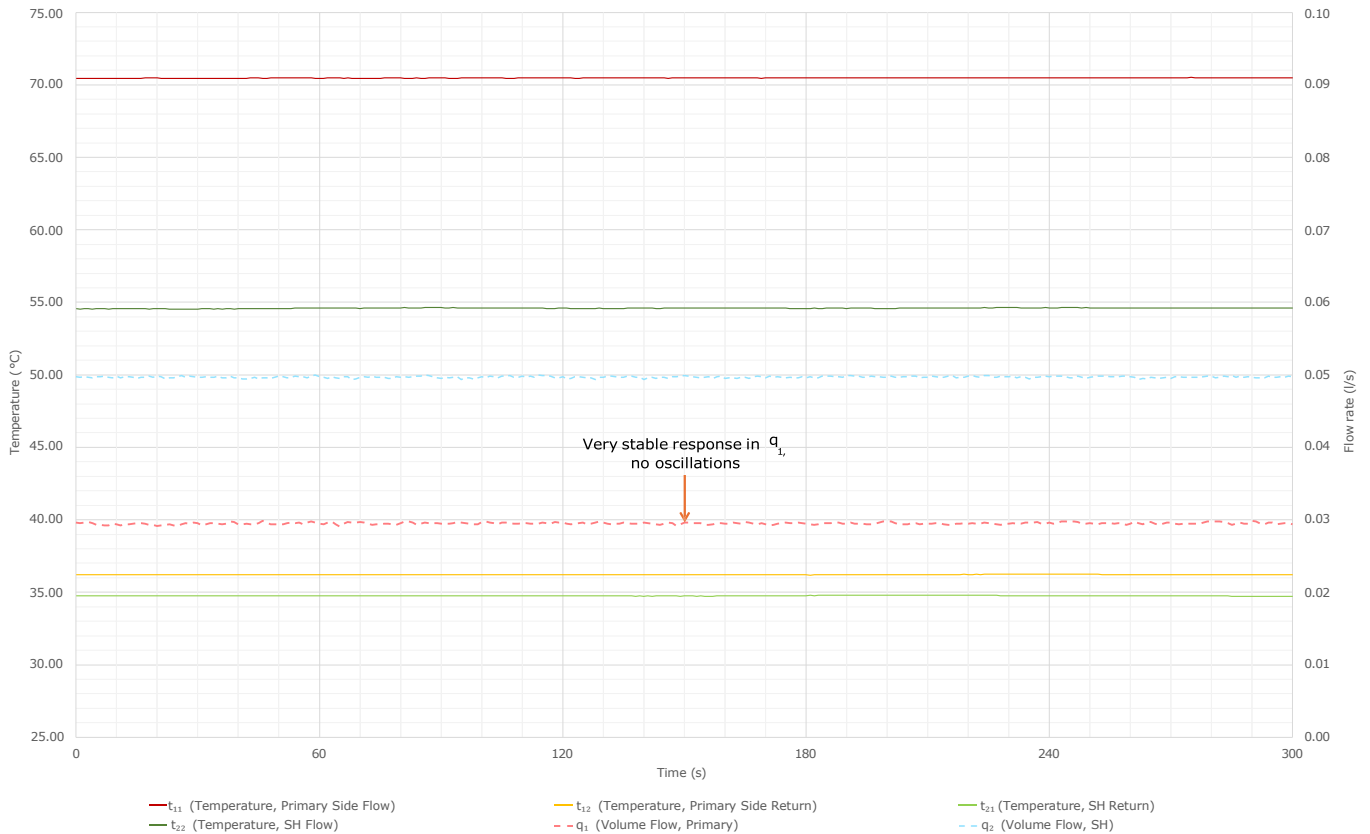


Figure 34 : Example of best practice primary flow rate response during Tests 01a-f.



Figure 35 : Example of primary flow rate response for Tests 01a-f for a HIU with less responsive control.

4.1.3.4 Space heating flow rate (q_2)

All the same points as those described in the previous sections also apply to the space heating flow rate. As long as H_2 is maintained at a constant output, q_2 should remain stable throughout the course of the tests, as illustrated in Figure 36.

Again, there may be minor oscillations in space heating flow rate, but these should not be as exaggerated as those given in Figure 37. This is because disruptions to space heating delivery may arise if the control system cannot sustain a consistent space heating output.

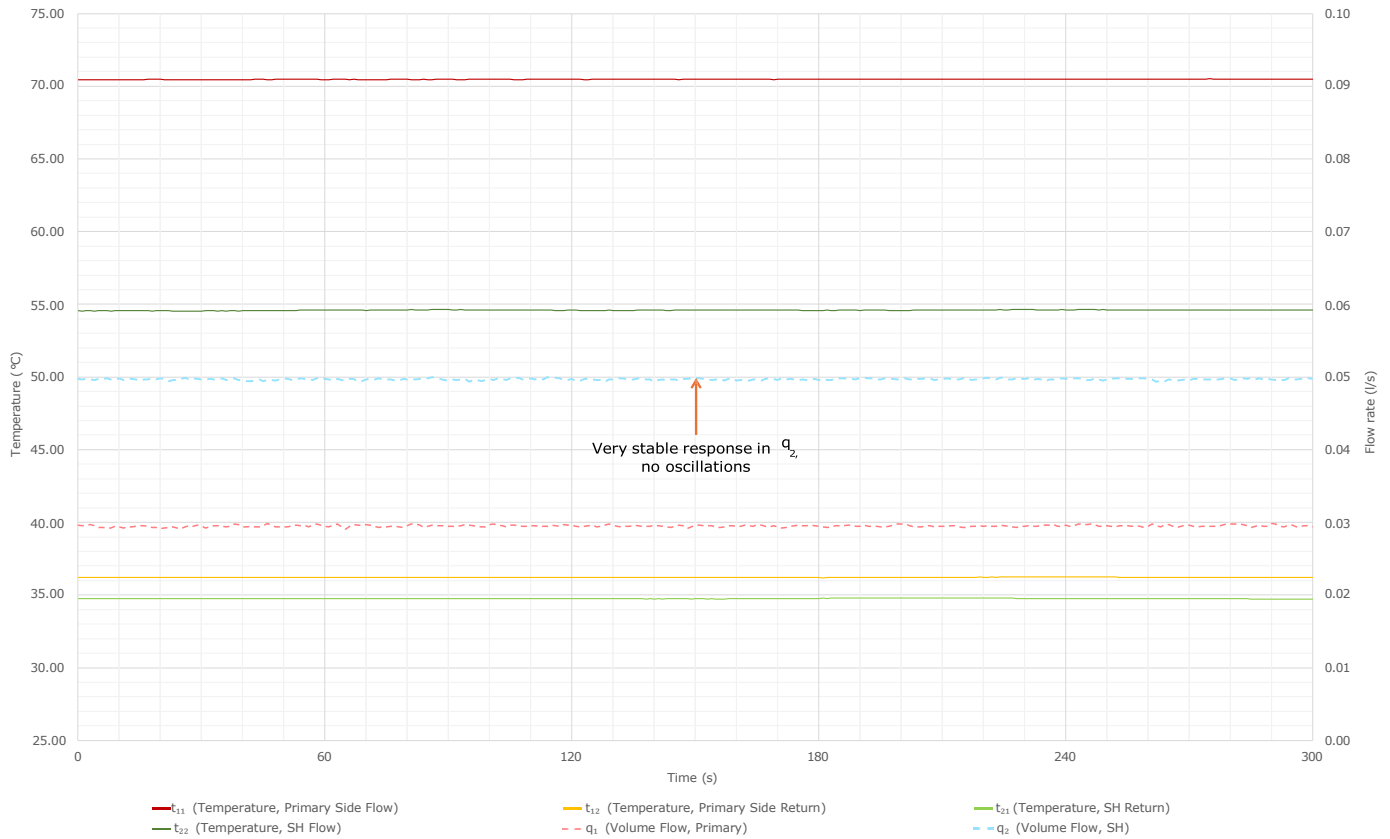


Figure 36 : Example of best practice space heating flow rate response during Tests 01a-f.



Figure 37 : Example of space heating flow rate response during Tests 01a-f for a HIU with less responsive control.

4.1.3.5 Space heating pressure drop (ΔP_2)

Although it is not reported in the output figures but instead given for each test in the preceding table, the space heating pressure drop (ΔP_2) is another useful parameter to note.

As with DHW Tests 13a-b (see [Section 3.3](#)), knowledge of ΔP_2 can have significant implications on the tertiary system. This can specifically influence the settings on the space heating pump within the HIU or the commissioning of the space heating emitters. Again, designers must consider any differential pressure limitations of tertiary space heating equipment (e.g. underfloor heating manifolds or thermostatic radiator valves) when specifying HIUs.

1. BESA Technical Standard for UK HIU Test Regime (V3-Rev001), September 2023
2. BESA Technical Standard for UK HIU Test Regime (V3-Rev001) – Test Module 7, September 2023
3. BESA Technical Standard for UK HIU Test Regime (V3-Rev001) – Test Module 8, September 2023
4. BESA Technical Standard for UK HIU Test Regime (V3-Rev001) – Test Module 1, September 2023
5. BESA Technical Standard for UK HIU Test Regime (V3-Rev001) – Test Module 2, September 2023
6. CIBSE/ADE CPI – Heat Networks Code of Practice (2020)
7. Technical Guidance HSG274 Part 2: The control of legionella in hot and cold water systems, 2024
8. Building Regulations 2010: Approved Document L Volume 1, 2021
9. The Home Energy Model: Future Homes Standard Assessment, December 2023
10. The Government's Standard Assessment Procedure for Energy Rating of Dwellings – SAP 2012 v9.92
11. CIBSE Guidance – Note – Domestic hot water temperatures from instantaneous heat interface units (HIUs) CIBSE Guidance Note (2021)
12. BESA/MEHNA Engineering Change Process

The assumptions behind all tests, and this overall Test Standard, are available in Technical Notes and Change Notes that form part of the Test Standard change process. These are available in the downloads area of the BESA HIU website at: www.thebesa.com/heating-interface-units

6.1 Terms

Term	Definition
dP	Pressure difference
Heat Exchanger	A device in which heat is transferred from one fluid stream to another without mixing. There must obviously be a temperature difference between the streams for heat exchange to occur. Heat exchangers are characterised by the method of construction or operation, e.g. shell-and-tube, plate, rotary.
Heat meter	A device that measures thermal energy provided by a heat source or delivered to a heat demand by measuring the flow rate and change in temperature of the heat transfer fluid between the outward and return legs of the system. Heat meters are typically used to measure the heat output from each technology and from the overall energy centre, and to measure the heat delivered to consumers.
Heat network	The flow and return pipes that convey heat from the energy centre to the customers. The pipes are frequently buried but may be above ground or within buildings. Heat networks can be either communal heating or district heating networks. • Communal heating: the heat network serves a single building that contains more than one customer (the building does not need to contain the plant). • District heating: the heat network serves more than one building and the building owners are not the asset owners (also called 'decentralised energy networks').
HIU	Heat Interface Unit or Hydraulic Interface Unit: the interface between the primary (or secondary) heat network and the tertiary heat network (a dwelling's heating system). HIUs, which usually have the external appearance of a wall-hung boiler, typically consist of a small, prefabricated assembly of components that includes: isolating valves, strainer, heat meter and control valves, and may also include a plate heat exchanger for the production of domestic hot water. An HIU may include a heat exchanger to separate the dwelling's space heating circuit from the heat network (indirect connection option).
Overall energy losses	The sum of the average thermal heat losses and average electrical consumption measured over the course of the 8 hour Keep Warm or Non-Keep Warm Test. Defined as equal to $((W_{\text{thermal}} + W_{\text{electrical}}) \times 24) / 1,000$ [kWh/day].
Primary heat network	The distribution pipes that connect the energy centre to the buildings served by the network — mostly buried pre-insulated pipes.
Secondary heat network/system	The pipes within buildings, and up to the dwelling in residential blocks, even if no hydraulic break is installed.
Tertiary heat network/system	The internal circuits, radiators etc. within dwellings, even if no hydraulic break is installed.
Direct space heating (HIU)	A 'Direct' space heating HIU has no hydraulic separation and the water from the primary side passes straight through and into the tertiary circuits.
Indirect space heating (HIU)	An 'Indirect' space heating HIU has a hydraulic separation between the tertiary space heating circuits via a plate heat exchanger.
VWART	Volume-weighted average return temperature from an HIU.

6.2 Abbreviations

Symbol	Description	Unit (if applicable)
t_{10}	Temperature, primary source	[°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]
q_2	Volume flow, space heating system	[l/s]
q_3	Volume flow, domestic hot water	[l/s]
dP_1	Differential pressure, primary system across HIU	[bar]
dP_2	Differential pressure, space heating system across HIU	[bar]
dP_3	Differential pressure, domestic hot water across HIU	[bar]
H_1	Arithmetic mean of primary side power recorded during test	[kW]
H_2	Arithmetic mean of DHW power recorded during test	[kW]
H_3	Arithmetic mean of space heating power recorded during test	[kW]
$Prop_{Summer}$	Proportion of year HIU is operating in “summer” mode	-
$Prop_{Winter}$	Proportion of year HIU is operating in “winter” mode	-
$VWART_{HIU}$	Total Annual Volume Weighted Average Return Temperature	[°C]
$W_{thermal}$	Thermal energy use	[W]
$W_{electrical}$	Electrical energy use	[W]
LTHW		-
TMV	Thermostatic Mixing Valve	-
UFH	Underfloor Heating	-
DHW	Domestic Hot Water	-
HIU	Heat Interface Unit	-
BESA	Building Engineering Services Association	-
MEHNA	Manufacturers of Equipment for Heat Networks Association	-

Table 15 : Definitions of the abbreviations and symbols used in this guidance document.
A complete list of definitions is provided in [Appendix A](#) of the Test Standard.

7. Appendix B: Volume Weighted Average Return Temperature (VWART)

The BESA Test Standard defines the overall Volume Weighted Average Return Temperature (VWART) of a HIU as a composite of estimates of the annual average return temperatures for domestic hot water, space heating and Keep Warm functions, but weighted by the volume of water passing through the HIU. This provides a reasonable proxy for the impact of the tested HIU on the aggregated performance of the heat network.

It should be noted that, while the VWART calculation does provide an indication of the expected performance of a HIU when operating under typical conditions on a heat network, other factors will affect the overall operational cost and reliability of a HIU. For example, the BESA test records electrical losses of a HIU, but this is not reflected in the VWART figure calculated for the unit.

As such, VWART values should **not** be considered as 'scores' by which to assess overall HIU performance. The other elements of the test results highlighted in this guidance document must be acknowledged for an objective and comprehensive assessment of HIU performance. This is particularly crucial for those involved in HIU selection with a non-technical background, for example in procurement. [Appendix D: HIU Procurement Considerations](#) covers other useful disclaimers when using BESA test results for HIU selection decisions.

In order to assess overall performance of HIUs tested according to the Test Standard, a number of derived results are calculated from the output of the tests, assuming 'standard' UK operating conditions of:

- 70 °C or 55 °C primary flow temperature (module dependent)
- 50 °C DHW flow temperature set point
- 55 °C/35 °C or 45 °C/35 °C tertiary flow and return temperatures (module dependent)
- 50 kPa/200 kPa differential pressure across the HIU

Note that, due to the difficulty of achieving high levels of replicability with the test rig, calculated VWART figures are rounded to the nearest whole number and presented with a measurement error of ± 2 °C, as mentioned in [Section 2.2](#).

The Test Standard assumes that DHW and Keep Warm/Non-Keep Warm are the only HIU operating modes during summer, with Space Heating operation also occurring during the winter period. Within the overall VWART (VWART_{HIU}) calculation process, it is assumed that the summer and winter period are the same length (6 months each per year), with an equal proportion of the year when the HIU operates in summer or winter mode (PropSummer = PropWinter = 0.5). Space heating usage is highly dependent on external ambient conditions and hence geographical location and weather. Therefore, this is a crude approximation and can result in the skewed values for the overall VWART, that may not reflect real HIU performance.

Please consult [Appendix C](#) of the Test Standard for the full VWART calculation methodology.

The purpose of a Keep Warm function is to, in the event of DHW demand, allow rapid delivery of hot water to the tertiary network at the target temperature (50 °C).

The Test Standard defines two distinct Keep Warm strategies, aside from those outlined in [Section 3.4.1](#), which are the following:

- **HIU Keep Warm** – In residential blocks, the Keep Warm strategy has typically been for each HIU to have a ‘Keep Warm function’ that results in the HIU always being ready to supply DHW. This HIU Keep Warm function effectively maintains the heat network at the temperature required for the HIU to deliver DHW sufficiently quickly.
- **Network Keep Warm** – An alternative Keep Warm strategy is to keep the risers warm and the pipework between the risers and HIU of sufficiently low volume that the DHW response time is acceptable, and with no Keep Warm function operating in the HIU (i.e. the pipework between the riser and the HIU is not kept warm).

In order to estimate the real-world performance of an installed HIU in a residential development, a “typical” heat network has been modelled as a standardised Reference Building in the BESA Test Standard. For both strategies, the Test Standard has modelled a Reference Building for the high and low temperature regimes, resulting in four different Reference Buildings.

With the HIU Keep Warm strategy, knowledge of the Keep Warm primary flow rate through the HIU allows designers to determine minimum network flow rates. This can be useful for network pump sizing and estimating pump turndown. Overall standby losses (comprised of thermal and electrical losses) will also have significant design implications, especially when designing networks to meet heat loss targets with incoming regulations.

As previously mentioned, the Test Standard considers a valid HIU Keep Warm function as one which:

- Maintains the primary flow temperature (t_{11}) at or above 39.0 °C at all times during standby in Tests 21a-b
- Provides a DHW temperature (t_{32}) of 45.0 °C within 15 seconds when tested under Keep Warm Tests 22a-b, and does not drop below 42.0 °C thereafter (see [Section 3.5](#))

However, for the Network Keep Warm option, designers will need to consider the bypass specifications and pipework arrangements required to ensure suitable DHW delivery times and network circulation (for water quality), whilst also ensuring that return temperatures are not adversely affected. This approach is typically associated with a multi-riser network arrangement and short lateral/terminal pipework.

9. Appendix D:

HIU Procurement Considerations

For individuals involved in HIU procurement processes, BESA test results can be useful for distinguishing and selecting HIUs based on performance. However, there are several caveats to be aware of, in addition to those outlined in [Section 2](#).

Most notably, there are several other factors besides tested performance that are important for HIU selection:

- **Installed performance**
 - Since the HIU performance is tested under controlled conditions, the performance on a live heat network may differ considerably due to different network parameters (e.g. temperature/pressure set points, network flow rates, pipework arrangement and dimensions, etc.).
 - It is recommended that manufacturers provide operational data over an extended period of time to confirm tested performance and provide confidence that BESA test results can be achieved in practice.
- **Metering solutions**
 - It should be noted whether the HIU is compatible with the client/operator's preferred metering and billing solution (i.e. does it enable prepayment and/or credit billing?).
 - Ideally, the metering strategy should also enable storage and/or analysis of HIU performance data.
- **Reliability/maintenance**
 - The BESA HIU Testing Regime assumes there are no faults within the HIU that would affect performance. As such, it is useful to identify the primary failure modes for the HIU that impact network performance or customer satisfaction, and how often these occur.
 - Some HIUs may not be supplied with necessary components for ease of maintenance (e.g. isolation valves, binder points, etc.) or may have poor availability of replacement parts. Other HIUs may have complex maintenance procedures, involving dismantling several HIU components, or require the manufacturer to attend site to carry out maintenance (instead of any qualified maintenance contractor). All of these scenarios reduce the ease of maintenance and so the ability to sustain optimal HIU performance.
- **Price**
 - When comparing HIUs on a price basis, CAPEX is often a clear driver on selection, so long as BESA-tested HIUs are being compared like for like.
 - The balance of OPEX and CAPEX must also be assessed. Based on the design/maintenance requirements, it is worth investigating whether a specific HIU provides lower operational costs in the long term compared to others.

- **Remote access to dwelling/HIU data**
 - If a HIU can be investigated or have performance issues diagnosed remotely, this reduces the need for maintenance call outs and operational costs. This also applies to remote HIU commissioning, which can significantly reduce the complexity and time taken for initial commissioning.
 - Licenses or other fees may be required for the remote access software and should therefore be factored into the overall cost
- **Strength of manufacturers' UK support team**
 - The manufacturer's ability to resolve technical issues, provide onsite or remote commissioning/maintenance/troubleshooting support or offer training services can play a critical role in maintaining high-performing HIUs in the long term.
- **Financial standing of manufacturer**
 - The ongoing cost and complexity of HIUs can be strongly linked with the continued distribution of the products within the UK, therefore the financial position of the manufacturer may be important.

It is essential to remember that, just because a specific HIU passes or has impressive BESA test results, this does not necessarily mean that the HIU is suitable for a network. The attributes above should be considered holistically, alongside the BESA test results, to allow an informed HIU procurement decision to be made.

It should also be noted that in any selection decision, BESA registered HIUs quoted by manufacturers must have the exact make, model, components (plates, valves, sensors, controllers, etc.) and modes of operation (e.g. Keep Warm modes) as the units that underwent testing. Results should not be applied across models (e.g. from the same manufacturer) as changes in components or modes of operation can have a significant impact on performance.

BESA and MEHNA have introduced a formal change process which allows variances and modifications to the specification of an HIU over time to be assessed, to determine the correct route in order to retain the validity of the test results obtained. The process categorises HIU changes with appropriate retesting requirements for each. This can range from a minor modification requiring a declaration from the manufacturer to more significant changes that would alter the performance of the HIU and therefore require partial or complete re-test of the HIU.

Please consult the BESA/MEHNA Engineering Change Process for further information about this.

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