Building Engineering Services Association

Technical Standard for:

UK HIU TEST REGIME

UK/HIU

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UK HIU Test Regime Technical Specification

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In particular the contributions of the following should be noted:

Gareth Jones
Tom Naughton
Martin Crane

Foreword

The development of heat networks in the UK is a key component of the UK's future energy strategy. The UK market for heat networks demands high efficiency in order to make it viable both financially and in carbon terms. A key component of a heat network is the HIU, which ensures heat is delivered efficiently to individual properties. Therefore providing designers, specifiers and operators with impartial, accurate and useful information on the performance of HIUs, directly contributes to the success of the UK's energy strategy.

In order to support the deployment of low-carbon heat networks the Department of Energy and Climate Change (DECC) (now the Department for Business Energy and Industrial Strategy (BEIS), provided funding designed to stimulate innovation that will help address cost and performance efficiency challenges related to heat networks. This included funding to develop a technical specification for an HIU testing regime that is appropriate for typical UK heat networks and to test a number of the market leading HIUs.

Following the conclusion of the project, BESA adopted the standard and a steering group of industry experts - The HIU Test Standard Group - has been established in order to provide guidance on development of the test regime and to provide a reference sounding board for sign-off on how to treat data in reporting.

The following should be noted with respect to this test regime:

Customer Led
The BESA test regime is a consumer led initiative to ensure that the HIU market is meeting the needs of those developing heat networks and heat customers. As such, the explicit decision has been made to have no manufacturer representation on the HIU Test Standard Group, as the aim is to ensure that the test standard is independent and not subject to influence from any one HIU manufacturer / group of manufacturers. The aim is to introduce a pragmatic and practical way of testing and comparing HIUs in order to provide a basis for assessing performance for those developing and designing heat networks. In particular, the regime aims to raise performance at the bottom end of the HIU market.

Engagement
Although the HIU Test Standard Group is made up of consumer representatives, the aim is to engage with stakeholders right across the sector from developers, specifiers and purchasers, through to manufacturers, installers/suppliers to the ultimate heat customer. Suggested improvements to the regime are welcome and should be directed to BESA at HIU@theBESA.com

Voluntary
The BESA test regime is a voluntary scheme and aims to encourage ‘reasonable performance’ through testing and comparison. This test regime has been developed through voluntary resources and is run as a not for profit project within BESA. All income from testing is invested back into the future development of the scheme. The project is entirely non-partisan and the testing regime has been set up to be as fair as possible.

Replicability
Most of the changes made to the test regime have been designed to enable multiple test houses to test using the regime, with replicability of results within acceptable tolerances. Bringing three test houses rigs onto a common basis has not been an easy process. Extensive and detailed work has been undertaken by BESA, and the test houses, to standardise the test rigs. However, it needs to be acknowledged that the accuracy of replicability is difficult to establish with a high degree of accuracy. As such, all Volume Weighted Average Return Temperature (VWART) figures are to be published with a relatively wide margin of error (of +/-2^{o}C).

There is an ongoing process in place to carry out further investigation and analysis and it is expected that these tolerances will narrow over time, as more tests are conducted. However, until that time, those utilising data from the regime need to take into consideration that there is a relatively wide tolerance range on results. It should also be appreciated that this fit with the purpose of the test regime, which is to ensure a minimum standard of performance is achieved.

Ongoing Development
The test regime will continue to be improved and developed. Future updates to the regime will refine the testing process and the accuracy of the outputs. The test houses have agreed to carry out further re-testing throughout the next twelve months to improve replicability even further, in particular to reduce the error bands on the tests. BESA are seeking to appoint a suitable expert to give a more robust assessment of the level of confidence in the comparability of the approved test houses, and the error bands used to report VWART. Work is also underway to develop test regimes for other types of HIU and these will be issued as addenda throughout the next 12 months. All test reports clearly state the version of test regime used and this needs to be taken into consideration when reviewing test results.

Contents

Abbreviations

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	[°C]
t_{22}	connection Temperature, space heating system flow	[°C]
t_{31}	connection 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]
Δp_1	Primary pressure drop across entire HIU unit Pressure	[bar]
Δp_2	drop, space heating system across HIU Pressure	[bar]
Δp_3	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 Period	[°C]
$VWART_{HIU}$	Total Annual Volume Weighted Average Return Temperature	[°C]
SH_{PROP}	Annual Heating Period	
NSH_{PROP}	Annual Non-Space Heating Period	
TMV	Thermostatic Mixing Valve	
TRV	Temperature Regulating Valve	
UFH	Under Floor Heating	
DHW	Domestic Hot Water	

Scope

The BESA test standard was explicitly developed in relation to **one specific class of HIU** which is the most common HIU type in the UK for use in typical new build developments and for typical operating conditions for radiator and under floor heating (UFH) systems.

- Heat and DHW loads based on new build developments, with apartments or small to mid-sized houses, with a maximum output <70kW (Heat and DHW).
- Indirect HIUs with hydraulic separation, with instantaneous DHW production and space heating provided via two separate plate heat exchangers.
- Network primary flow temperatures that are maintained during periods of low use via an HIU keep-warm function.
- High temperature regime: simulating typical operating temperatures for a system with radiators.
- Low temperature regime: simulating typical operating temperatures for a system with UFH.

The test regime and the basis of VWART calculation is most representative of HIU operation in new build flats. It should be noted, however, that the VWART calculation can be modified to better represent HIU performance in larger properties with higher DHW demands and/or higher space heating loads.

Section 1

INTRODUCTION

This document provides a technical specification for testing domestic HIUs for typical UK Heat Network operating conditions for high density new build developments.

1.1 The test is **independent and voluntary** and designed to test the following features:

- Safety (e.g. pressure tests, DHW temperature overshooting)
- Customer comfort (e.g. ability to achieve and maintain DHW temperatures at different flowrates, DHW response time, Low DHW flow, keep-warm function)
- HIU performance on a DH network (e.g. VWART)

1.2 The purpose of this test regime is three-fold:

i) To enable the performance of different HIUs to be evaluated within the context of typical UK operating conditions, thereby enabling heat network developers to evaluate the performance of specific HIUs against design requirements.

ii) To generate operating data on the expected performance of specific HIUs given 'normal' operating parameters, to enable heat network operators to identify anomalous performance.

iii) To provide a framework for HIU manufacturers to evaluate the performance of their equipment within the UK context, thereby feeding into their continuous improvement development programmes.

1.3 It should be noted that in the context of (i) above, the purpose of this test regime is to ensure that a minimum standard of performance is achieved and that there is a basis for grading baseline performance across HIUs for standard UK operating conditions. As such, the tests do not explore high performance functionality that may be built into certain HIUs. Manufacturers with such features are encouraged to engage in further testing to present alongside these results of this test regime so that procurers have further information on which to base their decisions.

1.4 HIUs that are tested according to the test regime specified in this document will not be 'certified'. Rather, the intention is to provide test results that will enable performance evaluated within the UK context.

1.5 There are two main outputs from this test regime:

a) Plots of key metrics over the duration of each test; and

b) Calculation of the annual volume weighted return temperature from the HIU, with this being a composite of estimations of the annual volume-weighted return temperatures for domestic hot water, space heating and keep-warm.

1.6 In addition, the test regime will evidence compliance with other performance and reliability metrics, such as speed of temperature stabilisation.

1.7 This test procedure is for HIUs that: (a) heat DHW on demand via a plate heat exchanger; and (b) are 'indirect', in that there is a heat exchanger between the DH primary and the space heating system.

1.8 There is an assumption that HIUs will have an active keep-warm function to maintain primary system flow temperatures. However, it is recognised that heat network operators may wish to employ a non-keep-warm approach. As such, a separate set of non-keep-warm VWART metrics are calculated for those HIUs that do not have or which are able to deactivate the keep-warm function. It should be noted, however, that the test conditions are non-typical of a network that has been designed for a non-keep-warm HIU.

1.9 In addition, there is an assumption that HIUs will be able to accommodate different secondary operating temperatures for space heating. As such, there is a "high temperature" set of tests, consistent with a network in which the space heating system heat emitters are radiators and a "low temperature" set of tests, consistent with a network in which there is underfloor heating.

1.10 In the case that an HIU is not able to operate across both operating conditions, then an HIU may be tested to either "low temperature" or "high temperature" space heating conditions and only a "low temperature" or "high temperature" set of VWART metrics will be calculated.

1.11 It should be noted that due to a reduction in the primary system pipework volume, the results from the tests conducted as part of the SBRI project in 2015/16 are not directly comparable with results from tests carried out using the test regime set out within this document. In particular, this change may influence the keep-warm and DHW response time tests.

1.12 Conversely, results from Version 2 of this test regime (dated 05 January 2017) are comparable, as:

(a) the changes made to this test regime have primarily been made to ensure replicability across test houses, with tighter specification of testing conditions based on the original test procedures; and

(b) as key changes made (e.g. introduction of tighter dP control) will have an negligible impact or improve results, depending on HIU technology.

1.13 It needs to be appreciated that there are tolerances on the various tests within the Test Regime, which can impact on outcome, particularly with respect to reported VWART figures. In addition, there are invariably small differences between test houses. As such, the same HIU could be tested at different times, with a slightly different VWART result. To reflect this measurement error, the HIU Test Standard Group has been forced to place a quite wide +/-2ºC error band on VWART outputs. Further work will be undertaken to better quantify measurement uncertainty and the expectation is that this error band will be reduced in future.

Section 2

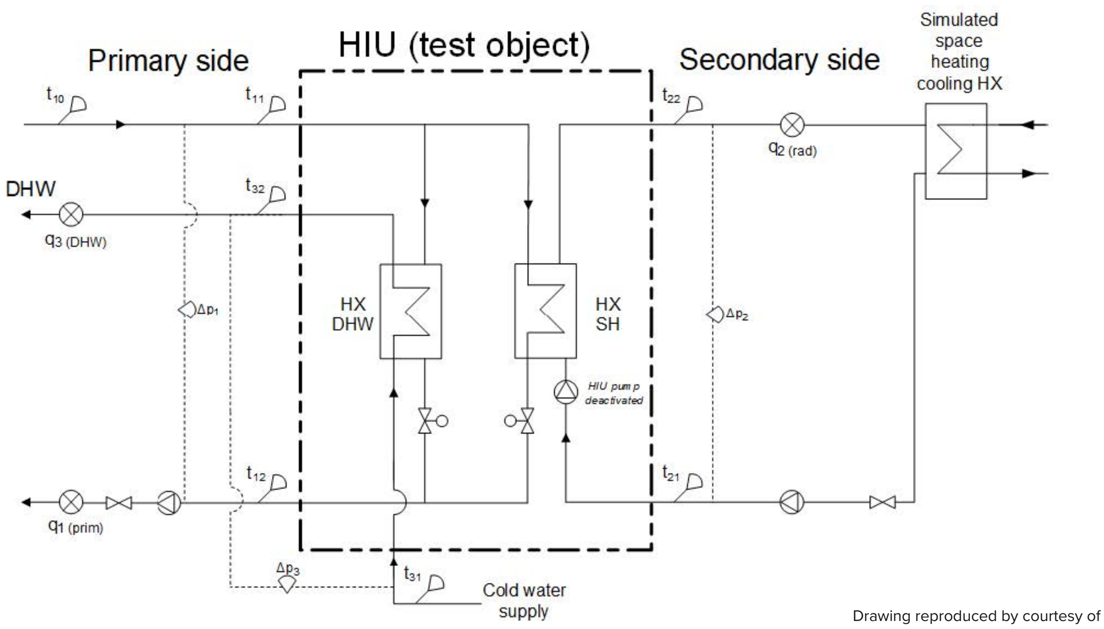
TEST FACILITIES

Tests are to be carried out by a Test House that is authorised by the HIU Steering Group, is under contract with BESA and, that is either a UKAS accredited test house or test house accredited under an equivalent national accreditation standard. Details of the approved test houses can be found on the BESA website. www.thebesa.com/ukhiu

Note: Unless there has been prior approval and sign-off by the HIU Steering Group, HIUs are not to be tested unless the test rig is prepared to the exact configuration as set out in this test regime and all required equipment is in place.

Test rig arrangement and uncertainty of measurement

2.1 Fig 1. Test rig configuration



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2.2 The test report shall include a schematic diagram of the test rig that has been used for testing.

2.3 The maximum permissible total uncertainties of measurement for the sensors in the test rig are:

Static pressure	+/-10 kPa
Differential pressure, domestic hot water	1 kPa
Differential pressure, space heating	1 kPa
Temperature	+/-0.1°C
Volume flow (≥ 0.06 l/s)	+/-1.5 %
Volume flow (< 0.06 l/s)	To be specified in conjunction with each measurement

2.4 The time constant of the temperature sensors on the DH primary flow and return (t_{11} and t_{12}), DHW (t_{32}) and CWS (t_{31}) shall not exceed 1.5 seconds.

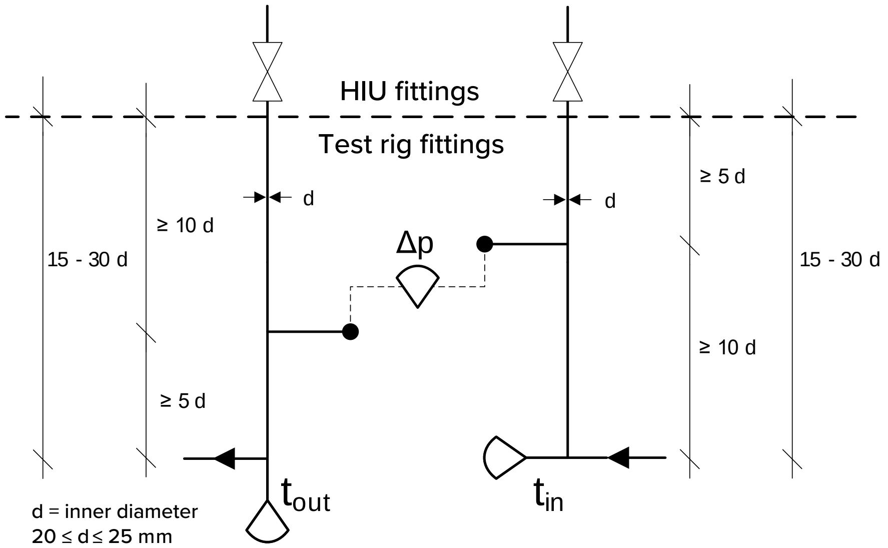
2.5 The positioning of the sensors shall be

a) Distance before pressure tappings shall be >10 diameters, and distance after pressure tappings shall be >5 diameters

b) Total length of piping between the HIU boundary and the test rig temperature sensor shall be between 15-30 diameters.

c) Inner diameter for the piping of the HIU fittings shall be between 20 and 25 mm

as illustrated in Fig.2 below.



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Test rig configuration and preparation

2.6 The HIU is to be tested in the same orientation (i.e. vertically) as when it is installed in a building.

2.7 The HIU's pipes and pressure vessel shall be filled and pressurised during the tests.

2.8 The test rig's instrumentation shall record the HIU's static and dynamic functions and performance at various loads.

2.9 The test rig heat loss shall be 155W +/-10 Watts heat loss based on a test at a ΔT between primary supply and ambient of 50°C and at 0.0055 l/s = 0.0198 m^3/h (with the aim to conduct the test as close to 20°C ambient as possible). This test shall be carried out annually to confirm the maintenance of the requirement.

2.10 The total volume of the primary flow pipework should be approx. 6 litres (+/-1 litre) and approx. 9m in length. The volume and length of the primary return pipework is not critical.

2.11 The HIU test rig must incorporate a rinsing loop for the DHW cold water circuit, to enable the DHW cold water supply temperature to have an average deviation throughout Tests 2a/b, 3a/b and 5a/b within +/-0.5°C from the stipulated 10°C cold water supply temperature requirement.

2.12 The primary system shall be pressurised to 3.0 bar +/-5% for all tests and the space heating system shall be pressurised to 1.5 bar +/-5% for all tests.

2.13 The cold water supply to the HIU on test rig shall be at 10°C and at 1.5 bar.

2.14 The cold water supply temperature is to have a maximum average deviation of +/-0.5°C from the stipulated temperature during stable conditions.

2.15 The primary flow temperature t_{11} is not allowed to deviate more than +/-0.5ºC from the stipulated temperature of the respective test point during stable conditions. If the performance of the HIU is such that primary flow is drawn in periods and is not constant, the validity of the primary flow temperature will be evaluated at the end of the periods where primary flow is drawn.

2.16 The validity of temperatures controlled by the test rig as well as requirements on temperatures controlled by the test object shall be evaluated to one decimal place.

2.17 The measured pressure drop across the HIU is to include the heat meter flow sensor. In the case that a heat meter has not been fitted, a restrictor of 25 kPa at 1 m^3/h will be fitted to simulate a typical heat meter.

2.18 The HIU control equipment shall have the same settings for all operating conditions to be tested within the test package, with the exception of enabling or disabling the space heating demand before and after the space heating test points.

2.19 The DH 'source' temperature shall remain at the t_{11} set point +/- 0.5ºC for the duration of test 4a/4b. t_{10} shall be recorded for tests 4a/4b.

2.20 All test rigs will use DN20 Herz 4002 DPCV (25-60 kPa) Product code: 1400262 and DN 20 Stromax GML Partner Valve, Product code: 1421712 to set primary dP (p_1) across the HIU. The dP upstream of the DPCV shall be at least 1 bar at all times.

2.21 The rig DPCV shall be set to 50 kPa +/-2 kPa when the HIU is delivering 4kW of space heat under the low temperature test condition - test 1f. Once the DPCV is set under this stated condition it shall not be changed for all the tests in the Test Regime.

2.22 The DPCV shall be located on the return leg of the district heating line before the flow meter. The partner valve shall be located on the supply leg of the district heating line after the 9m length of insulated reference pipe and hose.

2.23 For each test undertaken the ambient temperature should be controlled to 20ºC +/-5ºC

Cleaning of flow meter data

2.24 Any cleaning of data must be robustly justified. For example, removal of small flow rates on the standby test will only be accepted if the test house can demonstrate that these flows are not occurring. This can be demonstrated by confirming the actual volume that has been drawn by the HIU through alternative means e.g. such as weighing the volume of water that passes through the HIU and comparing this with the metered volume. If spurious flows are present, BESA retains the right to challenge the data supplied. If any 'cleaning' of data is agreed with BESA, this cleaning shall be applied to all tests carried out. As part of BESA's acceptance of any cleaning, the Test House will agree to periodic re-testing to confirm the continued validity of the agreed data cleaning.

HIU Mounting

2.25 The HIU shall be mounted with a 20mm air space behind the unit. The HIU shall be attached to a horizontal batten, at least the width of the HIU. The HIU shall be positioned between 0.8m and 1.5m off the floor, with a least 1m clearance above it.

Scaling Assessment

2.26 At temperatures above 60°C, the rate of scale precipitation significantly increases, hence the Test has some criteria that seek to indicate if the DHW exceeds 60°C at any time in DHW plate heat exchanger.

Scale will form at lower temperatures so the criteria is 55°C for conditions where the plate heat exchanger will be at the this temperature for longer periods e.g. during standby or at the end of a DHW draw-off. The build-up of scale will reduce the outputs of plate heat exchangers and lift return temperatures, so ultimately requiring the plate heat exchanger to be descaled or replaced. Scale also provides a medium for bacteria to grow on, so avoiding scaling can reduce associated risk from biological contamination.

HIUs that have a Thermostatic Mixing Valve or Temperature Regulating Valve (TMV/TRV) on the output of the DHW heat exchange result in the Test not measuring the heat exchanger output temperature, as TMVs/TRVs may require a temperature drop between hot water inlet and outlet temperatures.

As such the cautious approach is to assume HIUs with TMVs have higher scaling risks. The manufactures could discuss with the Test House the possibility of measuring the DHW temperature at the heat exchanger output. This measurement would be additional to the Test but, would allow the Test criteria for scaling to be applied on an HIU with a TMV/TRV.

These will be assessed to be a scaling risk on the basis of the following criteria:

1. During tests 2a and 3a, t_{32} shall not be above 60°C for more than 5 seconds
2. During test 2a and 3a t_{12} shall not exceed 55°C at any point of the test.
3. During keep-warm test t_{12} shall not exceed 50°C if the keep-warm flow passes through the DHW heat exchanger.
4. It shall be noted if the HIU has a TMV or TRV on the output of the DHW plate heat exchanger.

Section 3

HIU EQUIPMENT

HIU suppliers should take care to ensure that the HIU supplied for testing is of the exact specification as the HIU model to be sold to the UK market. Test results are only valid for the specification of the equipment supplied.

3.1 As such, suppliers should be cautious about fitting optional components to the supplied equipment, particularly if they add significantly to the cost. Those evaluating performance for specification purposes will have to assume that the model supplied is the "standard" model for cost comparison purposes.

3.2 In the case that there are minor modifications to the specification of the HIU over time (e.g. change in size of pressure vessel) then the details will need to be submitted to the test house for an assessment of whether or not this would have a material impact on the performance of the unit. In the case that the test house deems that the modifications would not have a material impact on performance then the test house will issue a compliance assessment stating whether or not it is likely that the test results are also applicable to the new model, with technical details stated. In the case that the test house deems that the changes would have a material impact, then the supplier will need to supply the new model for re-testing in order to utilise the test results.

Note for heat network developers/designers: Care should be taken in ensuring that the test results reviewed are applicable for the model being evaluated. Results should not be applied across models (e.g. from the same manufacturer) as changes in components can have a significant impact on performance.

HIU Rating

3.3 The maximum primary supply temperature of the HIU must be stated in the Test Report

Equipment

3.4 The HIUs shall be equipped as follows:

Primary side

- Strainer
- Space heating heat exchanger
- Domestic hot water heat exchanger for instantaneous Domestic Hot Water (DHW) delivery
- Control equipment for the space heating system
- Control equipment for the domestic hot water system
- Necessary drain and vent valves and connections

Secondary side

- Circulation pump
- Strainer
- A device that will easily allow the space heating circuit to be turned on and off for the tests (e.g. room thermostat or on/off switch)
- Isolating valve

3.5 A heat meter is to be fitted. If no meter is fitted a 25 kPa, at 1m^3/hr flow rate, restrictor will be fitted for the tests to simulate the pressure drop across the heat meter.

Documentation

3.6 The manufacturer is to supply sufficient information in order that the test house is able to:

a) Document the exact technical specifications of the HIU model tested;

b) Install, commission and operate the HIU for the purposes of the test program, without requiring technical input from the manufacturer.

3.7 More specifically, the following information is to be provided when an HIU is submitted for testing:

- The unit itself shall be marked with its model name, type number and serial number;
- Technical details and specification for all components, materials and methods of making joints, connections;
- A schematic diagram and drawings showing the structure and arrangement of the HIU, with dimensions and weights;
- Technical specification for electronic components (if any), including the version of software installed on the test model;
- Details of calculation programs used for the heat exchangers in the unit;
- Installation guide;
- Commissioning guide – Note: this should include sufficiently clear instructions that the test house is able to commission the HIU in preparation for the test procedure;
- Operation guide with a function and operation description and care instructions, as suited to the intended user category.
- Declaration of Conformity for CE-marked HIUs;
- Clear statement of the maximum primary side static operating pressure and maximum operating differential pressures. The pressure testing (Test 0) will be based on this data.

HIU setup

3.8 HIU settings are to be set at the start of testing, prior to recording any test results, and are not to be adjusted during the testing (within a specific test package e.g. low temperature/high temperature).

3.9 For DHW, the HIU settings are to be adjusted whilst delivering 0.13 l/s of DHW until the HIU delivers DHW in the range +/-0.5°C of set point as measured by the test rig (i.e. an electronic control on the HIU may read a figure that is different to the set point.)

3.10 For space heating, the HIU settings are to be adjusted whilst delivering a 4kW heat load until secondary flow temperature in the range +/-0.5°C of set-point as measured by the test rig is achieved. Where primary flow temperatures are set to 70°C, the space heating setting is to be set to 60°C for all tests (including DHW tests). Where primary flow temperatures are set to 60°C, the space heating is to be set to 45°C (including DHW tests).

3.11 Commissioning will be carried out based on the commissioning guide provided by the manufacturer. In the case that the HIU manufacturer alone can carry out commissioning (e.g. software based), full commissioning documentation must be completed, recording all inputs and supplied to the test house.

3.12 No electronic devices should be attached to the HIU during testing other than with prior agreement with the test house in order to change settings. This includes any device used for monitoring purposes only.

Section 4

TESTS

4.1 The total group of tests of the HIU to be performed in the test rig is as follows:

- Pressure test of primary circuit.
- Static performance tests of the space heating parts of the unit: Test 1.
- Dynamic performance tests of the domestic hot water and keep-warm function: tests 2, 3, 4 and 5.

Pressure test: Test 0

4.2 **Objective:** To test that there is a suitable margin of safety for the maximum pressure, the HIU will be pressure tested with cold water on the primary side at 1.43 times the design static pressure for 30 minutes.

4.3 **Test 0:** A static pressure of 1.43 times the HIUs rated maximum pressure (+/-5%) to be carried out, to be exerted simultaneously on both the DH flow and return HIU connections. The HIU will be inspected to check no signs of leaks or component distortion.

Static testing: Test 1

4.4 **Objective:** Perform static/steady state testing in order to investigate the performance characteristics of the HIU when meeting a specified space heating load.

Note: The static tests data will be recorded for a minimum of 300 seconds once HIU and test rig operation has stabilised. The results will then be presented in table form, derived from the mean average over the test period, as well as a plot of the key metrics for the same time period.

Static testing of the space heating circuit capacity (High Temperature): Test 1a, 1b, & 1c

4.5 **Objective:** Perform static testing in order to investigate the performance characteristics of the HIU when meeting a space heating load given a 60°C/40°C secondary heating circuit and 70°C primary flow temperature. It should be noted that the 60°C/40°C secondary heating temperatures have been selected as representative of temperatures utilised on new build developments where radiators are installed and are within the operating parameters outlined in the CIBSE/ADE Heat Networks Code of Practice, Objective 3.4 (Table 6).

Note: In the case that the HIU is unable to deliver space heating operating temperatures of 60°C/40°C (e.g. for an HIU configured specifically for UFH) then these tests may be omitted.

4.6 The return temperatures recorded from these tests are used as the inputs for calculating the High Temperature Space Heating Volume Weighted Average Return Temperature figure for the HIU – see Section 6.

4.7 In these tests the space heating load will be simulated by the heat exchanger on the test rig, with 60°C secondary flow temperature and 40°C secondary return temperatures. The HIU pump is to be deactivated, with flow rates adjusted within the test rig to deliver the required space heating load.

4.8 In all three tests the primary flow temperature t_{11} is 70°C +/- 0.5°C.

4.9 The average space heating flow temperature t_{22} is not allowed to deviate more than +/-0.5°C from the stipulated temperature during the test. The average space heating return temperature t_{21} is not allowed to deviate more than +/-0.5°C from the stipulated temperature during the test. The average space heating output is not allowed to deviate more than +/-10% or 0.25kW, whichever is the smallest, for the stipulated heat load during the test. For the 2kW and 1kW tests the HIU and test rig settings cannot be changed other than adjusting the flow rates on the test rig space heating circuit.

4.10 If temperatures are outside the permitted tolerances, no volume weighted average return temperature is to be calculated.

Test 1a: 1.0 kW heat output.
Test 1b: 2.0 kW heat output.
Test 1c: 4.0 kW heat output.

The HIU outer case will be in place for these tests.
No DHW will be drawn-off during these tests.

Static testing of the space heating circuit capacity (Low Temperature): Test 1d, 1e, & 1f

4.11 **Objective:** Perform static testing in order to investigate the performance characteristics of the HIU when meeting a space heating load given a 45°C/35°C secondary heating circuit and 60°C primary flow temperature. It should be noted that the 45°C/35°C secondary heating temperatures have been selected as being representative of typical Underfloor Heating operating temperatures.

Note: In the case that the HIU is unable to deliver space heating operating temperatures of 45°C/35°C (e.g. for an HIU configured specifically for radiator heat circuits) then these tests may be omitted.

4.12 The return temperatures recorded from these tests are used as the inputs for calculating the Low Temperature Space Heating Volume Weighted Average Return Temperature figure for the HIU – see Section 6.

4.13 In these tests the space heating load will be simulated by the heat exchanger on the test rig, with 45°C secondary flow temperature and 35°C secondary return temperatures. The HIU pump is to be deactivated, with flow rates adjusted within the test rig to deliver the required space heating load.

4.14 In all three tests the primary flow temperature t_{11} is 60°C +/-0.5°C.

4.15 The average space heating flow temperature t_{22} is not allowed to deviate more than +/-0.5°C from the stipulated flow temperature during the test. The average space heating return temperature t_{21} is not allowed to deviate more than +/-0.5°C from the stipulated temperature during the test. The average space heating heat output is not allowed to deviate more than +/-10% or 0.25 kW, whichever is smallest, from the stipulated heat load during the test. For the 2kW and 1kW tests, the HIU and test rig settings cannot be changed other than adjusting the flow rates on the test rig space heating circuit.

4.16 If temperatures are outside the permitted tolerances, no volume weighted average return temperature is to be calculated.

Test 1d: 1.0kW heat output.
Test 1e: 2.0kW heat output.
Test 1f: 4.0kW heat output.

The HIU case will be in place for these tests.
No DHW will be drawn-off during these tests.

Dynamic testing: Tests 2, 3, 4 & 5

4.17 **Objective:** To explore the performance of the HIU under changing loads, as would be the case in practical operation. Key performance criteria are: speed and consistency of DHW delivery to customer; DHW staying at a safe temperature at all times; and the volume weighted average return temperature when supplying space heating or DHW.

4.18 Load changes occur in the hot water system during the dynamic performance tests in accordance with the draw-off rates and durations detailed below. The average DHW flow rates for each 180 second flow period are to be within 5% of the target flow rates, and the time to achieve 95% of the target flow rates shall not exceed 5 seconds from the onset of the flow change.

Dynamic testing of the HIU operation –Tests 2a and 2b

4.19 **Objective:** To investigate the performance of the HIU when delivering DHW, at a range of flow rates, given 70ºC and 60ºC DH primary flow temperatures. The test investigates HIU operation in terms of DHW delivery and impacts on primary heat network return temperatures.

4.20 Comment should be provided on the stability of DHW flow temperature by stating the maximum and minimum DHW temperatures over the period of the test when there is a DHW flow.

4.21 Pass/fail on DHW (at t_{32}) exceeding 65ºC (to one decimal point) for more than 10 consecutive seconds as this poses a scalding risk.

4.22 Comment on scaling risk based on criteria detailed in 2.26 duration of temperatures (t_{12} and/or t_{32}) exceeding 55ºC.

4.23 For the High Temperature test (70°C primary flow) the DHW set point is to be 55°C DHW, while the Low Temperature tests (60°C) should be carried out with the DHW set point at 50°C.

4.24 It should be noted that the DHW set point temperatures have been selected in order to provide a more stringent test of HIU performance. The use of a 50ºC or 55ºC DHW set point should not be seen as an endorsement of this approach as, ideally, DHW set points would be set lower than this in order to optimise system performance.

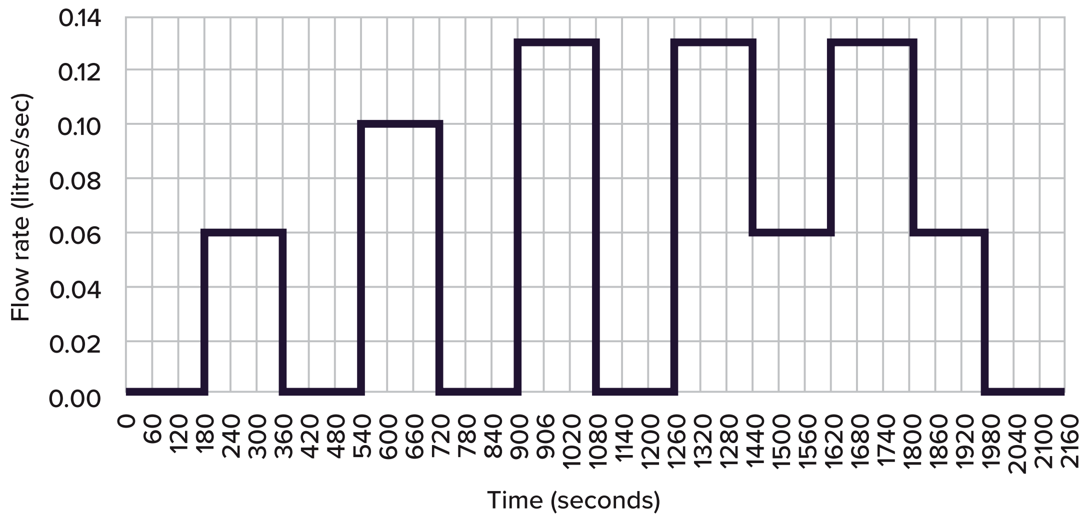
4.25 Prior to commencing the test, domestic hot water is to be drawn-off at 0.13 l/s for a minimum of 120 seconds, to establish steady-state conditions. The draw-off cycles set out below are to commence immediately following this.

4.26 The dynamic tests are to be carried out with varying domestic hot water draw-off rates. The draw-off cycles of domestic hot water flow rates to be used in 2a and 2b tests are as follows:

- 0.00 l/s for 180 seconds
- 0.06 l/s for 180 seconds
- 0.00 l/s for 180 seconds
- 0.10 l/s for 180 seconds
- 0.00 l/s for 180 seconds
- 0.13 l/s for 180 seconds
- 0.00 l/s for 180 seconds
- 0.13 l/s for 180 seconds
- 0.06 l/s for 180 seconds
- 0.13 l/s for 180 seconds
- 0.06 l/s for 180 seconds
- 0.00 l/s for 180 seconds

Test 2a: 70°C primary flow temperature; 55°C DHW flow temperature.
Test 2b: 60°C primary flow temperature; 50°C DHW flow temperature.

4.27 DHW profile for DHW only tests (Tests 2a and 2b)



Note: The test results from Test 2a and 2b for the 0.06 l/s flow, 0.10 l/s flow and 0.13 l/s flow are to be used for calculating the Volume Weighted Average Return Temperature for the HIU, utilising the 180 seconds at load and the 60 seconds directly preceding it for each flow rate - see Section 6 for the calculation methodology.

Testing the control equipment at low domestic hot water flow rates Test 3a or 3b

4.28 **Objective:** To investigate the stability of DHW temperature at low flow rates. During operation, domestic hot water is sometimes drawn-off at extremely low flow rates. Test 3 investigates the ability of the system to meet this condition by measuring the temperature at test point t_{32} at a flow rate of 0.02 l/s.

The test is to run on the following basis:

a. Domestic hot water is to be drawn-off at 0.13 l/s for a minimum of 120 seconds, then immediately

b. Domestic hot water is to be drawn-off at 0.02 l/s for 180 seconds.

4.29 For this test the DHW set point is to be 50°C or 55°C (dependent on whether testing at 60°C or 70°C primary flow temperature).

Test 3a: 70°C primary flow temperature.
Test 3b: 60°C primary flow temperature.

This test has a pass or fail criteria on DHW temperature at t_{32}. An HIU will fail if the DHW temperature exceeds 65°C (one decimal place) for more than 10 consecutive seconds.

Comment on scaling risk based on criteria detailed in 2.26.

Where an HIU: (a) did pass the non-scalding requirement but; (b) was not able to provide stable DHW at 1.2 l/min, then the following wording shall be reported:

The HIU met the requirement of not exceeding 65°C for more than 10 seconds in accordance with the test method (Maximum temperature reached was X°C). The HIU did not provide stable flow temperatures of (50°C/55°C) +/-3°C for >60 seconds under the stated conditions.

Where an HIU is not able to deliver a stable DHW flow at 1.2 l/min but has a higher declared minimum flow, then a test should be conducted at the declared minimum flow rate. Where the HIU is able to provide stable DHW at the declared minimum flow rate the following wording shall be reported and added after the text above:

At the minimum DHW flow rate claimed by the manufacturer (x/x l/min) the unit did not provide stable flow temperatures of (50ºC/55ºC) +/-3ºC for >60 seconds.

Where an HIU was not able to provide stable DHW at the declared minimum flow rate, then the following wording shall be reported:

The HIU did not provide stable flow temperatures of (50ºC/55ºC) +/-3ºC for >60 seconds under the stated conditions.

Where an HIU is tested at a declared minimum flow rate in excess of 1.2 l/min, the results should be reported as 3c (Low flow DHW, DH 70°C flow) and 3d (Low flow DHW, DH 70°C flow).

Note: If the HIU is to be tested at only the 70°C primary flow temperatures, then only Test 3a is to be conducted. However, if the HIU is being tested to using 60°C primary flow temperatures, then only Test 3b is to be conducted.

No-load characteristics of units in 'keep-warm' mode – Tests 4a and 4b

4.30 **Objective:** To establish HIU performance during periods of no load, when operating in keep warm mode.

4.31 During times of the year when no space heating is required, or at times when no domestic hot water is being drawn-off, various types of temperature-holding functions come into operation in order to ensure that domestic hot water will be quickly available. Test 4 investigates how this keep-warm function operates and the impact on the primary heat network.

4.32 For HIUs that can either have the 'keep warm' function turned on or off then this function should be turned on for all tests. The settings should be such that the following minimum Domestic hot water response is achieved in Test 5:

- 45°C DHW delivery temperature (at t_{32}) to be achieved within 15 seconds.

For HIUs with a range of keep-warm options the settings must be recorded.

Note: If an HIU does not manage to achieve the test requirements outlined above then a keep-warm VWART ($VWART_{KWM}$) will not be calculated and only a version of the VWART metric with no keep-warm will be calculated.

4.33 With no space heating load, draw-off domestic hot water at a rate of 0.13 l/s for a minimum of 120 seconds to establish steady state conditions and then turn off the hot water. Measure the primary flow rate and the primary flow and return temperatures for a period of at least 8 hours after the initial hot water draw-off has been completed.

4.34 The heat consumed by the HIU over the first 8 hours of the test period will be used as a measure of the keep-warm heat losses from each HIU. The HIU case will be fitted for this test to allow a representative estimate of keep-warm losses to be made.

Test 4a: 70°C primary temperature (t_{10}); 55°C DHW flow temperature.
Test 4b: 60°C primary temperature (t_{10}); 50°C DHW flow temperature.

Note: The test results from Test 4a and 4b are to be used for calculating the VWARTs for the HIUs – see Section 6 for the calculation methodology.

4.35 For these tests the DHW set point is to be 50°C or 55°C (dependent on whether testing at 60°C or 70°C primary flow temperature).

Domestic hot water response time – Test 5a and 5b

4.36 **Objective:** To investigate DHW delivery time after a period of at least 8 hours keep-warm only operation. This tests if the HIU can supply domestic hot water within an acceptable time of turning on the tap, which is a basic comfort requirement.

4.37 Immediately after testing the no-load characteristics for Test 4, steady-state conditions, without domestic hot water draw-off or space heating load, will have been established. At this point, DHW is to be drawn-off at 0.13 l/s. The time taken for the DHW, t_{32}, to achieve 45°C while not dropping below a temperature rise of 42°C thereafter, will be recorded. The time is taken from the first DHW flow reading above 0.001 l/s as recorded by q_3.

4.38 For this test, the HIU's keep-warm function will have been enabled during the previous no-load test. The HIU's service connection is represented by the connection hoses from the test rig, which is consistent for all HIUs tested (as detailed in Section 2 - Test rig configuration and preparation).

4.39 Note that in order for the HIU to be considered as providing a keep-warm facility for the purpose of this test, a 45°C DHW temperature (as measured at t_{32}) is to be achieved within 15 seconds while not dropping below 42C thereafter.

4.40 It should be noted that certain HIU's have a keep-warm cycle, with significant fluctuations in primary temperature (t_{11}) dependent on the stage of the cycle. As primary temperature has a significant impact on DHW response time, it is important that Test 5 is not conducted when primary temperatures are highest.

4.41 For HIUs that cycle during keep-warm with a cycle period of greater than 10 minutes, Test 5 will be timed to start at the three-quarter point of the keep-warm cycle (i.e. 75% of the cycle time after the DH primary flow has ceased).

4.42 The start of the keep-warm cycle is defined as the time at which the primary flow temperature, t_{11}, is at the highest temperature in the cycle.

4.43 An HIU is considered to be performing keep-warm cycling when the primary flow temperature (t_{11}) varies by more than +/-3°C during the final 3 hours of the test.

4.44 The period between keep-warm cycles during Test 4a/4b must be shorter than 4 hours, otherwise the HIU will be considered as not providing a keep-warm function.

4.45 For this test, the conditions are to be as for tests 4a and 4b i.e. DHW set point is to be 50°C or 55°C (dependent on whether testing at 60°C or 70°C primary flow temperature).

4.46 Cold water supply temperature (t_{31}) is to reach 10ºC +/-3ºC within 3 seconds of DHW flow.

Test 5a: 70°C primary flow temperature; 55°C DHW flow temperature.
Test 5b: 60°C primary flow temperature; 50°C DHW flow temperature.

Table 1: Test schedule

Test No	Test	Static pressure on primary flow	DHW setpoint	Primary flow temp	DHW setpoint	DHW flow rate	DHW heat load	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	-

The cold water supply to the HIU on the test rig shall be at 10°C and at 1.5 bar for all tests. t_{10} shall be 70°C +/- 0.5°C for test 4a and 60°C +/- 0.5°C for test 4b.

Section 5

TESTS TO BE CARRIED OUT

5.1 As noted in the introduction, there is an assumption that HIUs will be able to accommodate different secondary operating temperatures for space heating.

5.2 In the case that an HIU is not able to operate across both operating conditions, then an HIU may be tested to either “low temperature” or “high temperature” space heating conditions and only a “low temperature” or “high temperature” set of VWART metrics will be calculated.

5.3 Tables 2, 3 and 4 set out the tests to be conducted depending on whether both primary heating regimes are tested or where only one or other of the “high” or “low” temperature regimes is to be tested.

Table 2: Tests to be carried out where both High and Low Temp (60°C & 70°C) primary flows tested.

Test	Description
0	Pressure tests
1a	Space Heating 1 kW, 60/40°C secondary
1b	Space Heating 2 kW, 60/40°C secondary
1c	Space Heating 4 kW, 60/40°C secondary
1d	Space Heating 1kW, 45/35°C secondary
1e	Space Heating 2kW, 45/35°C secondary
1f	Space Heating 4kW, 45/35°C secondary
2a	DHW only, DH 70°C flow; 55°C DHW
2b	DHW only, DH 60°C flow; 50°C DHW
3a	Low flow DHW, DH 70°C flow; 55°C DHW
3b	Low flow DHW, DH 60°C flow; 50°C DHW
4a	keep-warm, DH 70°C flow; 55°C DHW
4b	keep-warm, DH 60°C flow; 50°C DHW
5a	DHW response time, DH 70°C flow; 55°C DHW
5b	DHW response time, DH 60°C flow; 50°C DHW

Table 3: Tests to be carried out where only High Temperature (70°C) primary flows tested.

Test	Description
0	Pressure tests
1a	Space Heating 1 kW, 60/40°C secondary
1b	Space Heating 2 kW, 60/40°C secondary
1c	Space Heating 4 kW, 60/40°C secondary
2a	DHW only, DH 70°C flow; 55°C DHW
3a	Low flow DHW, DH 70°C flow; 55°C DHW
4a	keep-warm, DH 70°C flow; 55°C DHW
5a	DHW response time, DH 70°C flow; 55°C DHW

Table 4: Tests to be carried out where only Low Temperature (60°C) primary flows tested.

Test	Description
0	Pressure tests
1d	Space Heating 1kW, 45/35°C secondary
1e	Space Heating 2kW, 45/35°C secondary
1f	Space Heating 4kW, 45/35°C secondary
2b	DHW only, DH 60°C flow; 50°C DHW
3b	Low flow DHW, DH 60°C flow; 50°C DHW
4b	keep-warm, DH 60°C flow; 50°C DHW
5b	DHW response time, DH 60°C flow; 50°C DHW

Section 6

PRESENTATION OF RESULTS

6.1 A test report shall be prepared showing the results of dynamic and static tests in diagrammatic form. Diagrams shall represent the raw data without the application of filters or smoothing. Diagram scales of temperature and volume flows shall be the same for all tests.

6.2 Notes, details of any actions taken and observations during the tests shall be recorded in the test report.

6.3 The test report should contain the following photographic evidence:

1. HIU with outer case off
2. Nameplate with model details and serial number.

Test Reporting and Assessment Criteria

6.4 HIU performance will be:

a) assessed against set criteria where appropriate;

b) qualitatively assessed based on observation of performance;

c) quantitatively assessed on a comparative basis (e.g. by deriving volume weighted average return temperatures).

The basis for reporting against each test is set-out in Table 5.

Table 5: Test reporting

Test	Description	Reporting
Static Tests		
0	Pressure tests	Pass/Fail as to whether HIU manages pressure test without leaks or damage.
1a	Space Heating 1 kW, 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.
1b	Space Heating 2 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.
1c	Space Heating 4 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.
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.
1e	Space Heating 2 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.
1f	Space Heating 4 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.
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
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 q_1, q_3 dp_1, dp_3 **Note:** Outputs used as input data to 'Low Temperature' Domestic Hot Water Weighted Average Return Temperature calculation.
3a	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 0.1 3 l/s flow and the subsequent 180 seconds of 0.02 l/s DHW flow.

3b	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 45ºC (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 55.0°C (1 decimal place) to be stated. Plot of key metrics for 60 seconds of 0.1 3 l/s flow and the subsequent 180 seconds of 0.02 l/s DHW flow. Maximum temperature achieved and +/-ºC variance around 50.0ºC (1 decimal place) to be stated.
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 Plot temperature t_{10}. Assessment of scaling risk, based on duration of temperatures in excess of 55.0°C (1 decimal place). 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 flow rate for the duration of the test. Note: Outputs used as input data to 'High Temperature' Keep-warm Volume Weighted Average Return Temperature calculation.
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 t_{10}. 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.
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 45.0ºC (1 decimal place) and not subsequently drop below 42.0ºC (1 decimal place).' Plot t_{32}, t_{31}, t_{12}, q_1 over duration of test.
5b	DHW response time, DH 60°C flow; 50°C DHW	State time to achieve a DHW temperature 45.0ºC (1 decimal place) and not subsequently drop below 42.0ºC (1 decimal place). Plot t_{32}, t_{31}, q_3, t_{12}, q_1 over duration of test.

Volume Weighted Average Return Temperatures Derivation

6.4 The VWART Calculation Model, which can be used for calculating the Volume Weighted Average Return Temperature (VWART) of an HIU, is available at www.thebesa.com/ukhiu

6.5 In order to assess overall performance of HIUs tested according to the UK HIU Test Regime Technical Specification, a number of derived results will be calculated from the output from the tests, assuming 'standard' UK operating conditions of:

- 70°C or 60°C primary flow temperature (test dependent)
- 55°C or 50°C DHW flow temperature set point (test dependent)
- 60°C / 40°C or 45°C / 35°C secondary flow and return temperatures (test dependent)
- 0.5 bar differential pressure across the HIU

6.6 The following six derived measures will be calculated based on the outputs of the test:

- Volume Weighted Return Temperature, $VWART_{DHW}$
- Space Heating Volume Weighted Return Temperature, $VWART_{SH}$
- Keep-warm Volume Weighted Return Temperature, $VWART_{KWM}$
- Annual Volume Weighted Return Temperature for Heating Period $VWART_{HEAT}$
- Annual Volume Weighted Return Temperature for Non-Heating Period, $VWART_{NONHEAT}$
- Total Annual Volume Weighted Return Temperature, $VWART_{HIU}$

6.7 These derived results will be calculated by the individual test houses using the methodology set-out below.

6.8 Calculated VWART figures are to be rounded to the nearest whole number when reported and presented with a reported measurement error of +/-2°C.

Interpretation of test data DHW draw-off

6.9 Each of the three domestic hot water draw-off events (3.6 l/min, 6.0 l/min, 7.8 l/min) are to be calculated between the following two data points:

Start: First non-zero hot water flow rate read as recorded by q_3.
End: The preceding hot water flow rate read to the first zero read for the relevant hot water test point as recorded by q_3.

DHW Post Draw-Off

6.10 Each of the three domestic hot water post draw-off events (3.6 l/min, 6.0 l/min, 7.8 l/min) are to be calculated between the following two data points: Start: First non-zero hot water flow rate read proceeding the relevant hot water test point as recorded by q_3.

End: 60 seconds post start point reading as recorded by q_3.
A zero flow rate is defined as a flow rate lower than 0.0006 l/s.

Space Heating

6.11 Each of the three space heating loss events (1kW, 2kW and 4kW) are to be calculated using the entirety of the dataset.

keep-warm

6.12 The keep-warm event is to be calculated between the following two data points:

Start: First zero hot water flow rate read as recorded by q_3.
End: 28,800 seconds (8 hours) post start point reading as recorded by q_3.

Annual Operational Distributions

6.13 **DHW Draw Volumes per annum**
Total annual domestic hot water demand calculated as 1,470 kWh using SAP v9.92 methodology for a typical sized modern flat in London.

6.14 Distribution of low, medium and high DHW draw-off events based on analysis of EST 'Measurement of Domestic Hot Water Consumption in Dwellings, 2008' data as follows:

Table 6: Domestic Hot Water Annual Demand

Description	Flow Rate (litres/min)	Estimated Annual Demand (kWh/year)
Low	3.6	729
Medium	6.0	297
High	7.8	444

6.15 DHW operating hours for each HIU and, therefore volumes, are to be calculated by dividing the respective annual kWh figures set out above by the average actual heat load output measured in the test.

Post DHW Draw Volumes per annum

6.16 Total annual number and average duration of low, medium and high DHW draw-off events based on analysis of EST Measurement of Domestic Hot Water Consumption in Dwellings, 2008' data, as below:

Table 7: Domestic Hot Water Annual Events and Duration

Description	Number of events, n (events/year)
Low	10,000
Medium	660
High	300

Space Heating

6.17 Total annual space heating demand calculated as 1,450 kWh using modified SAP v9.92 methodology for an 85 unit, 6-storey residential block built to 2013 Part L Building Regulations in London. Distribution of 1 kW, 2 kW and 4 kW consumption loads are based on analysis of Guru Systems data for a typical modern high-rise residential block in London as follows:

Table 8: Space Heating Estimated Annual Demand

Space Heating Load (kW)	Estimated Annual Demand (kWh/year)
1	98
2	787
4	565

6.18 Space heating operating hours for each HIU (and therefore volumes), are to be calculated by dividing the respective annual kWh figures set out above, by the average actual heat load output measured in the test.

Keep-warm

6.19 Keep-warm annual operational hours defined as subtraction of DHW draw-off and Space Heating operation hours from total annual hours (8,760).

Volume Weighted Average Return Temperature Calculations

6.20 The VWART Calculation Model, which can be used for calculating the Volume Weighted Average Return Temperature (VWART) of an HIU, is available at www.thebesa/ukhiu

6.21 For all relevant test points (as outlined in Clauses 6.8 - 6.11), the Volume Weighted Average Return Temperature (VWART) for each test is defined as follows:

$$\mathrm{VWART} = \frac{\sum(\mathrm{t}_{12,\mathrm{t}} \times \mathrm{q}_{1,\mathrm{t}})}{\sum \mathrm{q}_{1,\mathrm{t}}} \tag{1}$$

where t represents each read during the test period (i.e. every second).

Domestic Hot Water

6.22 The DHW VWART consists of the HIU performance during draw-off and all the primary volume bypassed after the draw-off stops in order to account for any delay in the DHW primary valve closing.

During DHW draw-off:

6.23 For each of the three tests described in Table 5, the following calculations should be made for the total test period as outlined in Clauses 6.8 - 6.11.

- arithmetic mean of domestic hot water heat load (P_3),
- arithmetic mean of primary volume flow rate (q_1),

6.24 The annual hours of operation for each of the three tests is then calculated as follows:

$$\text{Annual hours of operation, h} = \frac{\text{Estimated Annual Demand (from Table6)}}{\overline{P_3}} \tag{2}$$

6.25 The annual primary volume of each test is then calculated using (2) as follows:

$$\mathrm{V} = \overline{q_1} \times \mathrm{h} \tag{3}$$

Post DHW draw-off:

6.26 Directly following each of the three DHW draw-off tests, the annual primary volume of each test can be calculated as follows:

$$\mathrm{V} = \sum q_{1,t} \times n \tag{4}$$

where t represents each read during the test period (i.e. every second) and n refers to the number of events per year for each of three draw-off flow rates.

Total DHW:

6.27 The total DHW annual primary volume is defined as:

$$\mathrm{V}_{DHW} = (3) + (4) \tag{5}$$

6.28 The Domestic Hot Water VWART (VWART_{DHW}) can then be calculated by summing the product of the VWART and annual primary volume, V for each of the six tests and then dividing by the sum of the annual primary volumes, V for all of the six tests.

$$\mathrm{VWART}_{DHW} = \frac{\sum(\mathrm{VWART}_{\text{each test}} \times \mathrm{V}_{\text{each test}})}{\sum \mathrm{V}_{\text{all tests}}} \tag{6}$$

Space Heating

6.29 For each of the three tests described in Table 8, the following calculations should be made for the total test period as outlined in Clauses 6.8 - 6.11:

- arithmetic mean of domestic space heating heat load (P_2), 2
- arithmetic mean of primary volume flow rate (q_1), 1
- VWART as defined by equation (1)

6.30 The annual hours of operation for each of the three tests is then calculated as follows:

$$\text{Annual hours of operation, h} = \frac{\text{Estimated Annual Demand (from Table 8)}}{\overline{P_2}} \quad (7)$$

6.31 The annual primary volume of each test is then calculated using equation (3) and is referred to as VSH.

6.32 The Space Heating VWART, $VWART_{SH}$, can then be calculated by summing the product of the VWART and annual primary volume, V, for each of the three tests and then dividing by the sum of the annual primary volumes, V, for all of the three tests. See equation (6).

Keep-warm

6.33 For the single keep-warm test, the annual hours of operation is calculated as follows:

$$\text{Annual hours of operation, h} = 8760 - \left(\sum \text{h for all DHW draw-off tests} + \sum \text{h for all space heating tests}\right) \quad (8)$$

6.34 Note that the Standby Annual hours of operation calculation does not include the annual hours of operation for the three DHW post draw-off tests.

6.35 The annual primary volume, V, is then calculated using equation (3) and is referred to as V_{KWM}.

6.36 The Keep-warm VWART is calculated as per equation (1) for the total test period as outlined in Section 6 and is referred to as $VWART_{KWM}$.

Overall

6.37 In order to calculate the overall VWART for the HIU, the Annual Heating Period and Annual Non-Heating Periods must be defined.

6.38 The Annual Heating Period, SH_{PROP}, the proportion of the year estimated to require space heating equates to the sum of hours calculated for the three space heating tests in equation (7) divided by the number of hours in a year as shown in the following equation:

$$\text{Annual Heating Period, } SH_{PROP} = \frac{\sum \text{h for all space heating tests}}{8760} \quad (9)$$

6.39 The Annual Heating Period $VWART_{HEAT}$ is then calculated as follows:

$$VWART_{HEAT} = \frac{((VWART_{DHW}\ x\ V_{DHW}) + (VWART_{KWM} \times V_{KWM}))\ x\ SH_{PROP} + (VWART_{SH} \times V_{SH})}{(V_{KWM} + V_{KWM}) \times SH_{PROP} + V_{SH}}$$

(10)

6.40 Regarding the Annual Non-Space Heating Period, NSH_{PROP} the proportion of the year when there is no heating load is calculated as follows:

$$\text{Annual Non} - \text{Heating Period, } \mathrm{NSH_{PROP}} = 1 - \mathrm{SH_{PROP}} \tag{11}$$

6.41 The Annual Non-Heating Period $VWART_{NONHEAT}$ is then calculated as follows:

$$\mathrm{VWART}_{NONHEAT} = \frac{(VWART_{DHW} \times V_{DHW}) + (VWART_{KWM} \times V_{KWM})}{(V_{DHW} + V_{KWM})} \tag{12}$$

6.42 Finally, the overall HIU VWART, $VWART_{HIU}$, is calculated as follows:

$$\mathrm{VWART_{HIU}} = (VWART_{NONHEAT} \times NSH_{PROP}) + (VWART_{HEAT} \times SH_{PROP}) \tag{13}$$

Notes

Notes

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