hot water association

DEVELOPING HOT WATER

Performance Specification for Thermal Stores

Direct integrated thermal stores

Indirect integrated thermal stores

Hot water thermal stores

Buffer stores

HWA Performance Specification for Thermal Stores^{2010}

Final Version: 21/03/2010

HWA Performance Specification for Thermal Stores^{2009}

This revised document replaces the current *HWA* document titled *'Performance Specification for Thermal Stores'* published in 2008. This revised specification specifies the performance requirements for the direct and indirect integrated thermal stores, buffer stores and hot water stores: -

a) In which either the primary i.e. non-potable water or combination of primary water and phase change material (PCM) is used for storing the thermal energy.

b) Which are designed for use in individual dwellings and in a group heating schemes for the apartment blocks.

c) In which the temperature of the storage media is limited to below 100^{o}C.

Although this document does not specify the maximum value for the effective storage capacity of a thermal store covered by this specification. the Building Regulations Approved Document Part G3(3) (2009 edition) specifies different routes for compliance for the unvented stores over 500 litre capacity or over 45kW power input.

The compliance requirements and the associated test procedures have been revised to reflect the recent and the proposed changes to the Building Regulations, the British and the European standards and the Eup directives relating the heating and hot water appliances, systems and storage vessels.

This revised version now includes the use of primary thermal stores with the low carbon and renewable technology systems e.g. solar thermal heating, heat pump, mCHP and solid fuel appliances.

HWA Performance Specification for Thermal Stores^{2009}

Contents

1. SCOPE

The '*HWA Performance Specification for Thermal Stores*^{2009}' specifies the hydraulic design, the thermal performance, and the test procedures for the thermal stores, which are designed for use either in the individual dwellings or in the group heating schemes for the apartment blocks.

The thermal stores covered by this document use either non-potable (i.e. primary) water or combination of primary water and phase change material (i.e. PCM) for storing thermal energy and in which the maximum temperature of the energy storage medium is limited to below 100^{o}C.

This specification does not cover the materials and manufacturing of the thermal stores and the associated components but the manufacturer must comply with the requirements of BS EN ISO 9001 or an equivalent quality audit system. The manufacturer must also ensure that the product is fit for purpose and it complies with the relevant standards and approvals.

Thermal stores with factory fitted electrical wiring must also comply with the current and relevant IEE and BS3456 requirements.

The construction of the thermal store and the fittings and the components used or specified must also comply with the requirements of the 'Model Water Bylaws' and the relevant national, European and international Standards.

Both vented and unvented thermal stores must also comply with the relevant sections of the Building Regulations Approved Document, Part G3-(3), 2009 edition.

At the time of the publication, this document took account of the standards, regulations, etc prevailing at that time. The appropriate standards and regulations are listed in section 2. No responsibility can be taken for subsequent changes or product developments.

The system and thermal store diagrams in this document are schematics only to illustrate the basic principles only and therefore all necessary system components are not always shown. Therefore, these diagrams should not be used for designing the systems.

The generic types of open vented or sealed thermal stores covered by this document are described below.

1.1 INTEGRATED THERMAL STORES (ITS)

In an Integrated Thermal Store (*ITS*), the stored energy is used indirectly by means of a heat exchanger for producing instantaneous domestic hot water and (directly or indirectly) for space heating. The *ITS* may be heated by more than one heat sources and it is suitable for both individual dwellings and for group heating schemes for apartment blocks.

1.2 HOT WATER ONLY THERMAL STORES (HWTS)

The stored energy in a Hot Water only Thermal Store (*HWTS*) is only used indirectly (by means of a heat exchanger) for producing instantaneous domestic hot water. The *HWTS* is suitable for both individual dwellings and for group heating schemes for apartment blocks and it may be heated by more than one heat sources.

1.3 BUFFER STORES (DBS & IDBS)

The direct and indirect Buffer Stores (*DBS* & *IDBS*) are typically used in a group-heating scheme for an apartment block for buffering the flow of energy between one or more types of heat sources connected to it and the thermal energy demands from the building.

2. NORMATIVE REFERENCES

The following documents are indispensable for the application and use of this HWA specification for thermal stores.

2.1 SAP 2009: 'The Government's Standard Assessment Procedure for Energy Rating of Dwellings', 2005 Edition.

2.2 Building Regulations 2000 : Approved documents L1 & L2, 'Conservation of fuel and power', 2009 edition.

2.3 Building Regulations 2000 : Approved document G, 'Sanitation, hot water safety and water efficiency', 2009 edition

2.4 Domestic Heating Compliance Guide, May 2006, 1st Edition

2.5 BS EN 12897:2006, Water Supply – Specification for indirectly heated unvented (closed) storage water heaters.

2.6 BS 1566-1:2002, Copper indirect cylinder for domestic purposes. Open vented copper cylinders. Requirements and test methods.

2.7 BS 1566-1:1984, Copper indirect cylinder for domestic purposes. Specification for single feed indirect cylinders.

2.8 BS 6700:2006 + A1:2009, Design, Installation, testing and maintenance of services supplying water for domestic use within buildings and their cartilages specification

2.9 BS3198:1981, Specification for copper hot water storage combination units for domestic purposes

2.10 BS 6920-1:2000, BS 6920-2:2000, Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

2.11 BS EN 12977-3:2008, Thermal solar systems and components. Custom built systems. Performance test methods for solar water heater stores.

2.12 BS EN 12828:2003, Heating systems in buildings. Design for water-based heating systems.

2.13 BS En 12831:2003, Heating systems in buildings. Method for calculation of the design heat load.

2.14 BS En 14336:2004, Heating systems in buildings. Installation and commissioning of water based heating systems.

2.15 VDI 6002 Part 1: Solar heating for domestic water – General principles, system technology and use in residential building.

2.16 CIBSE guide TM 13: Minimising the risk of Legionnaires' disease.

2.17 CIBSE guide G: Public health engineering.

2.18 CIBSE Solar Heating Design and Installation Guide.

2.19 The Institute of Plumbing – Plumbing Engineering Services Design Guide

2.20 Pressure Equipment Directive (PED) (97/23/EC)

3. DEFINITIONS OF TERMINOLOGY

3.1 OPEN VENTED THERMAL STORE

The storage vessel of an open vented thermal store (figure 3.1) is open to the atmosphere and it uses either primary (non-potable) water or combination of primary water and phase change material (PCM) to store thermal energy. The temperature of the energy storage media in an open vented store is limited to below 100°C.

An open vented thermal store must meet the relevant requirement of the Building Regulations Approved Document Part G3(3) (2009 edition). The guidance for compliance with this approved document is given in appendix D of this document. The requirements will be met if: -

3.1.1 the storage vessel has a suitable vent pipe of adequate size but not less than 19mm internal diameter connecting the top of the vessel to a point open to the atmosphere above the level of the water in the feed and expansion cistern and over it; and,

3.1.2 in addition to any control thermostat, either the heat source or the storage vessel is fitted with a non-self-resetting device that will prevent the temperature of water at any time exceeding 100°C; and,

3.1.3 the hot water system has pipework that incorporates a provision for discharge of hot water from the safety device to an appropriate place open to the atmosphere where it will cause no danger to persons in or about the building.

Figure 3.1

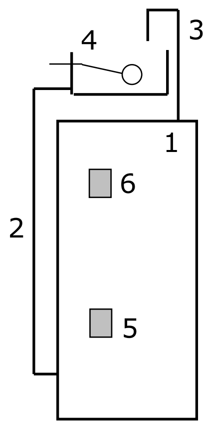
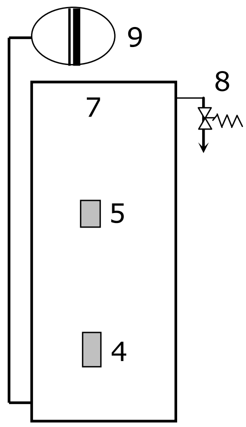


Figure 3.2



1 Vented thermal store
2 Cold feed pipe
3 Open vent pipe
4 Feed and expansion cistern
5 Control thermostat [CT]
6 Non-self-resetting over heat thermostat [OHT]
7 Unvented thermal store
8 P & T relief safety valve - See section 3.2 (b)
9 Expansion vessel

3.2 UNVENTED THERMAL STORE

The storage vessel of an unvented thermal store (figure 3.2) is not open to the atmosphere and it uses either primary (non-potable) water or combination of primary water and phase change material (PCM) to store thermal energy. The temperature of the energy storage media in an unvented store is limited to below 100°C.

An unvented thermal store must also comply with the relevant requirement of the Building Regulations Approved Document Part G3(3) (2009 edition). This will be met if in addition to any control thermostat provided to control the temperature of the stored water to a desired temperature, the unvented thermal store should incorporate a minimum of two temperature activated safety devices operating independently in series. Further guidance on unvented thermal stores is given in appendix D, normally:

3.2.1 A non-self-resetting energy cut-out to disconnect the supply of heat to the storage vessel in the event of storage system overheating; and plus either an option (b) or an option (c).

3.2.2 If the unvented thermal storage system is fitted with an approved device (e.g. RPZ Valve [1]) which automatically replenishes the stored water then either a temperature relief valve or a combined temperature and pressure relief valve located directly on a storage vessel, such that the stored water does not exceed 100°C.

Note:
[1] Since the introduction of the Water Supply (Water Fittings) Regulations 1999 in England and Wales and the Water Bylaws 2000 in Scotland, it is permitted to use the backflow prevention device instead of an air gap for category 1 fluid, at certain risk levels. A reduced pressure zone (RPZ) valve is an example of such backflow prevention device.

[2] The automatic filling and topping devices are usually set at low flow rates and therefore will limit the discharge rate from the P&T valve and hence the power input of the heat source. This will have to be determined during the certification process.

3.2.3 If the unvented thermal storage system has no provision to automatically replenish the stored water then there should be a second non-self-resetting energy cut-out, which stops the flow of energy from the heat source to the thermal store using alternative and independent of method (a), such that the stored water does not exceed 100°C.

3.3 WORKING PRESSURES (HEAD)

The working pressure or working head is defined as the maximum pressure to which the storage vessel or a heat exchanger of a thermal store can be subjected to normal use.

3.4 HEAT LOSS FACTOR (Q_{HLF})

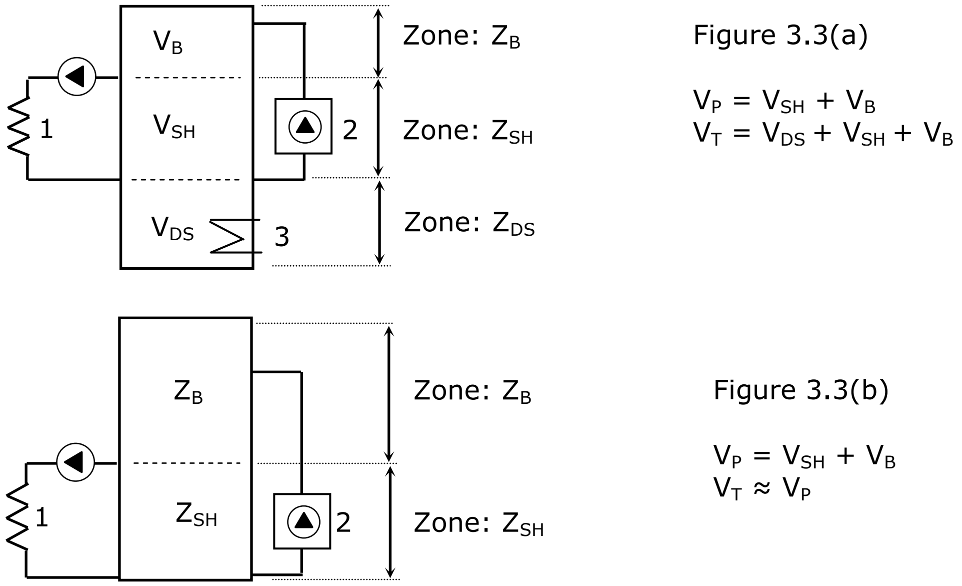
The heat loss factor, Q_{HLF}, is defined as the 'standby heat loss rate' from a thermal store or an appliance based on it that has been measured at the specified test conditions and using the test procedure specified in this document.

3.5 STORE ZONES AND STORAGE VOLUMES

As illustrated in figure 3.3, the hydraulic input and output connection arrangement creates different functioning zones in a thermal store. The water content, volume or the capacities associated with different zone in a thermal store are described below.

In the system illustrated in figure 3.3 (a), solar system heats the primary water in zone, Z_{DS}, and the remaining volume, V_P, in the zones, Z_{SH} and Z_B, is heated by the boiler and the solar system. In the system illustrated in figure 3.3 (b), the boiler heats the whole store i.e. total primary water volume, V_T.

Figure 3.3: An example of zones, storage volumes and equivalent volumes in a thermal store by input and output connections



1 Space heating 2 Primary heat source 3 Solar heat source

3.5.1 Nominal storage volume [V_T]

The net total volume of primary water in a thermal store, which is available for storing the thermal energy from all heat sources, connected to it. This is also referred to as the capacity of a thermal store.

The nominal storage volume, V_T, is the sum of the primary net water content of all zones in a thermal store. For example,

In figure 3.3(a), $V_T = V_P + V_{DS} = (V_B + V_{SH}) + V_{DS}$
In figure 3.3(b), $V_T = V_P = V_{SH} + V_B$

3.5.2 Dedicated solar volume [V_{DS}]

The 'dedicated solar volume' is defined as the net volume, V_{DS}, of primary water in the thermal store zone, Z_{DS}, which can only be heated by the solar thermal energy.

3.5.3 Dedicated space heating volume [V_{SH}]

The net storage volume, V_{SH}, of primary water in an integrated thermal store zone, Z_{SH}, which is available for space heating directly as preheated water or indirectly as thermal energy by means of space heating heat exchanger.

3.5.4 Primary storage volume [V_P]

The net storage volume of primary water, V_P, in a thermal store zones which can be heated by the main primary heat source. The primary storage volume may also receive heat from other heat sources or from other zones in a thermal store.

3.5.5 **Primary storage volume [V_B]**

As illustrated in figure, the primary water volume, V_B, in zone Z_B, is not used for space heating. In an integrated thermal store, this may be reserved for producing domestic hot water.

3.6 EQUIVALENT STORAGE VOLUMES IN A THERMAL STORE

If a zone, Z_N, in a thermal store contains water only, then its energy storage capacity is proportional to the net volume of water, V_Z, in that zone. However, if zone, Z, contains mixture of water and phase change material (PCM) then its energy storage capacity is not directly related to its volume.

In this document, if a zone, Z, in a thermal store contains PCM, then its equivalent volume of water, V_{EZ}, is calculated using equation 3.1. This equation calculates the energy storage capacity of the zone in equivalent water content. This allows the performance of the stores with and without PCM to be measured and compared using the same reference parameters.

The equation 3.1 can be used to calculate equivalent volume of water for all zones in a thermal store which contain PCM i.e. V_{ET}, V_{EDS}, V_{EP}, V_{ESH} which correspond to the thermal store zone volumes, V_T, V_{DS}, V_P, V_{SH} without PCM.

$$V_{EZ} = [V_{WZ}/V_Z] + m_Z[C_{PS}(T_M - T_0) + L_H + C_{PL}(T_1 - T_M)]/[V_Z \rho Cp(T1 - T0)] \quad \text{---- 3.1}$$

Where :

V_{EZ}	=Equivalent volume of water in zone, Z, with PCM	[l]
V_{WZ}	= Net volume of water in zone, Z, with PCM	[l]
V_Z	= Net volume of water in zone, Z, without PCM	[l]
m_Z	= Mass of PCM in zone, Z	[kg]
Cp	= Average specific heat of water between T_0 and T_1	[J/Kg.K]
ρ	= Average density of water between T_0 and T_1	[kg/l]
C_{PS}	= Specific heat of PCM in solid phase	[J/Kg.K]
C_{PL}	= Latent heat of PCM in liquid phase	[J/kg.K]
L_H	= Latent heat of PCM	[J/kg]
T_M	= Phase change temperature of PCM	[^{o}C]
T_0	= Lower reference temperature (= 20^{o}C)	[^{o}C]
T_1	= Upper refernce temperature	[^{o}C]

3.7 PRIMARY HEAT EXCHANGER

A heat exchanger in zone, Z_P, in an indirect thermal store that is used to transfers the heat from a primary heat source e.g. a boiler circuit, to the energy storage media (e.g. primary water) in a thermal store.

3.8 SPACE HEATING HEAT EXCHANGER

A heat exchanger in an integrated thermal store zone, Z_{SH}, that is used to transfers the thermal energy from the storage media in a thermal store to the space heating circuit.

3.9 SOLAR HEAT EXCHANGER

An internal heat exchanger inside a thermal store in a dedicated solar zone *'V_{DS}'*, or an external heat exchanger, that is used to transfers the thermal energy from the solar heating system to the storage media in a thermal store.

3.10 DOMESTIC HOT WATER (DHW) HEAT EXCHANGER

An integrated or a hot water thermal store may be fitted with an external or an internal dhw heat exchanger and this can be either forced or natural convection type. Commonly used types are described below.

3.10.1 **Natural convection hot water heat exchanger**

A water to water heat exchanger inside a thermal store (figure 3.4) which transfers heat from the primary water to the domestic hot water during a hot water draw-off without using motive power (e.g. a pump) to circulate the primary water.

3.10.2 **Forced convection hot water heat exchanger**

A water to water heat exchanger outside (figure 3.5) or inside a thermal store (figure 3.6) which requires a motive power (e.g. a pump) to circulate the primary water through the heat exchanger during a hot water draw-off. The pump used for circulating the primary water through the heat exchanger during the hot water draw-off may also act as a boiler and/or a heating circuit pump.

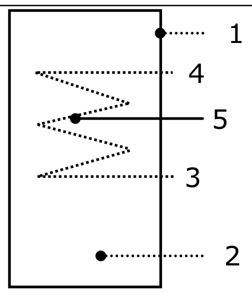


Figure 3.4: Natural convection
Hot water heat exchanger

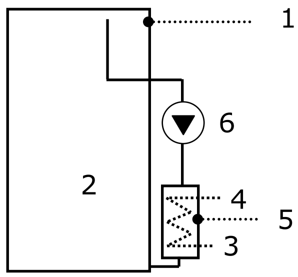


Figure 3.5: Forced convection
external hot water heat exchanger

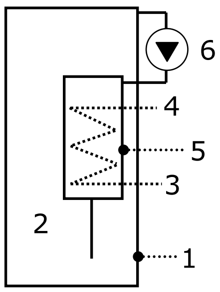


Figure 3.6: Forced convection
internal hot water heat exchanger

1	Thermal store
2	Primary water
3	Mains cold water inlet
4	Hot water to taps
5	Hot water heat exchanger
6	Primary pump

3.11 DOMESTIC HOT WATER OUTLET TEMPERATURE CONTROLLER

A device (e.g. a thermostatic non-electric blending valve) which is fitted to thermal store for regulating the domestic hot water outlet temperature and which also limits the 'hot slug' of water reaching the outlets.

3.12 HOT SLUG

The volume of hot water above 60°C passed during a domestic hot water draw-off when the temperature-regulating device is set to control the outlet temperature at 50 - 55°C.

3.13 DATA BADGE

A permanent badge fitted to a thermal store, which gives information about safety, identification and essential performance information for the service and installation engineers.

3.14 INSTALLATION AND DESIGN MANUAL

One or more comprehensive sets of documents supplied with every thermal store containing system design, installation, performance, application and service information for that store.

3.15 STORE THERMOSTATS/SENSORS

One or more thermostats or temperature sensors, which are used to control the temperature of the primary water in the thermal store by controlling the operation of the heat sources, for example: -

- Primary heat source e.g. a boiler
- Standby i.e. backup heat source e.g. immersion heater
- Secondary heat source e.g. Solar thermal system, wood burning stove

4. DEFINITION OF THERMAL STORES

4.1 INTEGRATED THERMAL STORE (*ITS*)

4.1.1 A thermal store that is designed to store primary (non-potable) hot water which can be used indirectly for producing domestic hot water and either directly or indirectly for space heating.

4.1.2 The *'ITS'* may also contain phase change material (PCM) in addition to the primary for storing thermal energy and the temperature of the primary water in an *'ITS'* is limited to below 100^{o}C.

4.1.3 In an 'ITS' the domestic hot water (dhw) is heated instantaneously by transferring the stored heat to the mains water flowing through the dhw heat exchanger. The dhw heat exchanger may be internal or external type as described in section 3.10.

4.1.4 If the *'ITS'* storage vessel is designed for an open vented system, then it may have an integral feed and expansion cistern.

4.1.5 Both the vented and the unvented *'ITS'* must comply with the requirements of the relevant sections in the Building Regulations 2000, Approved Document G, 2009 edition. Methods of compliance are specified in section 5.7 of this document.

4.1.6 In an *'ITS'*, the energy for space heating is supplied from the store for rapid heating of the heat emitters and thereby reducing the preheat time and energy consumption. To achieve this, minimum storage capacity must be available for space heating [1]. therefore: -

(a) If the store does not contain PCM [2], then the minimum storage volume, V_{SH}, given by equation 4.1 should be available for space heating.

(b) If the store contains PCM, then the minimum equivalent storage volume, V_{ESH}, given by equation 4.2 should be available for space heating. The method for calculating the equivalent volumes for thermal stores, which contain PCM, is described in section 9.

$V_{SH} = 45 + 0.25V_{P}$ ----- (4.1)
$V_{ESH} = 45 + 0.25V_{EP}$ ----- (4.2)

Where: -

V_{SH}	= Minimum storage volume available for space heating	[l]
V_{ESH}	= Minimum equivalent storage volume available for space heating	[l]
V_{P}	= Net volume of store heated by the primary heat source	[l]
V_{EP}	= Net equivalent volume of store heated by primary heat source	[l]

Note
[1] The equations 4.1 and 4.2 are based on typical water content of radiator heating system in a dwelling. For under floor heating systems bigger thermal stores should be considered.

[2] The phase change material (i.e. PCM) is either encapsulated or contained inside a primary thermal store by other means so that it cannot mix or dissolve in primary water and therefore cannot circulate through either the radiator or the boiler circuits.

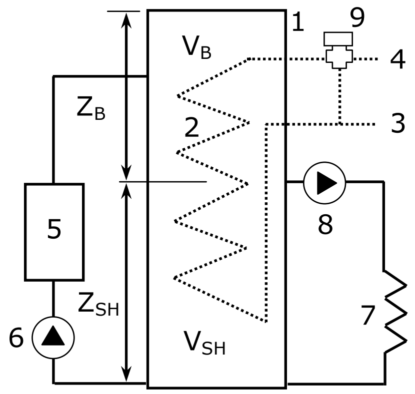
4.1.7 In addition to heating by the main primary heat source, the *'ITS'* may also be heated directly or indirectly by an external or internal secondary/standby heat source (e.g. an immersion heater).

4.2 DIRECT AND INDIRECT INTEGRATED THERMAL STORE (*DITS* & *IDITS*)

4.2.1 A direct integrated thermal store, *DITS*, is an integrated thermal store which complies with the requirements of section 4.1 and in which the energy storage medium (e.g. primary water or combination of primary water and phase change material i.e. PCM) is heated directly by an internal or an external main heat source e.g. a gas boiler.

4.2.2 An example of *DITS* fitted with a natural convection dhw heat exchanger and a thermostatic mixing valve for regulating the dhw temperature is shown in figure 4.1. In this example, the boiler heats total storage volume, V_T, and the storage volume, V_{SH}, in zone, Z_{SH}, is available for space heating. The storage volume, V_B, in zone, Z_B, is only used for producing domestic hot water.

Total storage volume, V_T = V_P, The volume heated by primary heat source
= $V_B + V_{SH}$



1	Thermal store
2	DHW heat exchanger
3	Mains water inlet
4	Hot water outlet
5	Primary heat source e.g. boiler
6	Primary circuit pump
7	Space heating circuit
8	Space heating circuit pump
9	DHW thermostatic blending valve

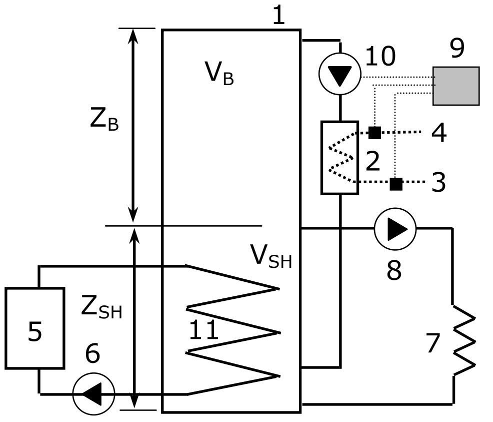
Figure 4.1: A typical DITS with a natural convection dhw heat exchanger and a thermostatic mixing valve for regulating the dhw outlet temperature

4.2.3 An indirect integrated thermals tore, *IDITS,* is an integrated thermal store which complies with the requirements of section 4.1 and in which the energy storage medium (e.g. primary water or combination of primary water and phase change material i.e. PCM) is heated indirectly by means of an internal primary heat exchanger.

4.2.4 An example of an indirect integrated thermal store (*IDITS*) fitted with an electronic hot water temperature control device and an external forced convection dhw heat exchanger is shown schematically in figure 4.2.

In this example, the boiler heats total storage volume, V_T, and the storage volume, V_{SH}, in zone, Z_{SH}, is available for space heating. The storage volume, V_B, in zone, Z_B, is only used for producing domestic hot water.

Total storage volume, V_T = V_P, The volume heated by primary heat source
= $V_B + V_{SH}$

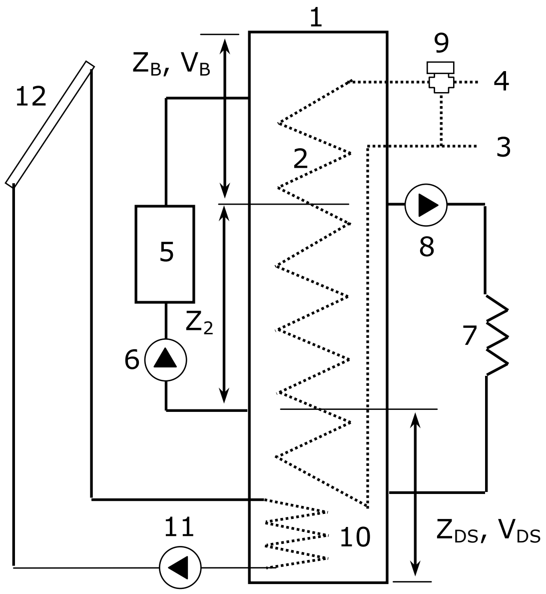


1 Thermal store
2 DHW heat exchanger
3 Mains water inlet
4 Hot water outlet
5 Primary heat source e.g. boiler
6 Primary circuit pump
7 Space heating circuit
8 Space heating circuit pump
9 DHW temperature controller
10 DHW heat exchanger pump
11 Primary heat exchanger

Figure 4.2: A typical IDITS with an external forced convection dhw heat exchanger and electronic controls for regulating the dhw temperature

4.3 DIRECT AND INDIRECT INTEGRATED SOLAR THERMAL STORES (*DITS-SOL* & *IDITS-SOL*)

4.3.1 Both the direct and the indirect integrated thermal stores may be designed for use with solar thermal systems. A typical example of direct integrated solar thermal store designed for use with a solar thermal system (*DITS-SOL*), is shown in figure 4.3.



1 Thermal store
2 DHW heat exchanger
3 Mains cold water inlet
4 Hot water outlet
5 Primary heat source e.g. boiler
6 Primary circuit pump
7 Space heating circuit
8 Space heating pump
9 DHW thermostatic blending valve
10 Solar heat exchanger
11 Solar circuit pump
12 Solar thermal panels

Figure 4.3: A typical example of a direct integrated thermal store, *DITS–SOL* for use with solar thermal systems.

In this example, dedicated solar volume, V_{DS}, in the store zone, Z_{DS}, can only be heated by the solar thermal system. However, the volumes in zones, Z_B and Z_2

can be heated by both the primary heat source and the solar system. The volume in zones, Z_{DS} and Z_2 is available for space heating.
The total storage volume, $V_T = V_{ZB} + V_{Z2} + V_{DS}$

4.3.2 Both *DITS-SOL* and *IDITS-SOL* must comply with the generic requirements for an integrated thermal stores listed in section 4.1.

4.3.3 In a *DITS-SOL*, the energy storage zone, Z_P, is heated directly by the primary heat source and in an *IDITS-SOL*, the energy storage zone, Z_P, is heated indirectly by means of a primary heat exchanger.

4.3.4 In both the *DITS-SOL* and *IDITS-SOL*, the hydraulic design and the control system must ensure that the dedicated solar zone, Z_{DS}, cannot be heated by either the main primary heat source (e.g. a boiler) or the secondary standby heat source (e.g. a immersion heater).

4.3.5 The zone, Z_{DS}, in both *DITS-SOL* and *IDITS-SOL* is only heated by solar thermal system via the solar heat exchanger (10). 'The Domestic Heating Compliance Guide, May 2006' specifies the requirements for the solar heating systems for compliance with the Building Regulations 2000, Approved Documents L1 and L2 (2009 edition). To comply with the Building Regulations, both *DITS-SOL* and *IDITS-SOL* should meet the following requirements : -

(a) If the solar circuit flow rate, $F_{SOL} \geq 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL\text{-}HE} \geq 0.2 \times A_{SC.}$

(b) If the solar circuit flow rate, $F_{SOL} < 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL\text{-}HE} \geq 0.1 \times A_{SC}$

(c) If the solar zone, Z_{DS}, does not contain phase change material (PCM), then the net dedicated solar volume, V_{DS}, must comply with either equation 4.3 or 4.4.

$V_{DS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4$ ---- [4.3]
$V_{DS} \geq 25 \times A_{SC}$ ---- [4.4]

(d) If the solar zone, Z_{DS}, contains phase change material (PCM), then the net dedicated equivalent solar volume, V_{EDS}, must comply with either equation 4.6 or 4.7.

$V_{EDS} = [V_{WDS}/V_{DS}] + m_{DS}[C_{PS}(T_M-T_0) + L_H + C_{PL}(T_1-T_M)]/[V_{DS}\ \rho\ Cp(T_1-T_0)]$ - [4.5]
$V_{EDS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4$ ---- [4.6]
$V_{EDS} \geq 25 \times A_{SC}$ ---- [4.7]

Where : -

V_{EDS}	= Equivalent volume of dedicated solar zone, Z_{DS}, with PCM	[l]
V_{DS}	= Net volume of zone, Z_{DS}, without PCM,	[l]
V_{WDS}	= Net volume of water in zone, Z_{DS}, with PCM	[l]
m_{DS}	= Mass of PCM in dedicated solar zone, Z_{DS}	[kg]
Cp	= Average specific heat of water between T_0 and T_1	[J/Kg.K]
C_{PS}	= Specific heat of PCM in solid phase	[J/Kg.K]
C_{PL}	= Latent heat of PCM in liquid phase	[J/kg.K]
ρ	= Average density of water between T_0 and T_1	[kg/l]
L_H	= Latent heat of PCM	[J/kg]
T_M	= Phase change temperature of PCM	[^oC]
T_0	= Lower reference temperature (= 10^oC)	[^oC]
T_1	= Upper reference temperature (= 60^oC)	[^oC]

A_{TF} = Maximum total floor area of a dwelling specified for the store [m^2]
A_{SOL-HE} = Surface area of the solar heat exchanger [m^2]
A_{SC} = Net surface area of the solar collector specified for the store [m^2]
F_{SOL} ` = Solar circuit flow rate per m2 of net collector area [l/min]

4.3.6 Appliances based on either *DITS-SOL* or *IDITS-SOL* will use solar energy accumulated in a thermal store for space heating and for producing domestic hot water. Therefore in order to maximise the utilisation of solar energy: -

(a) The control system should not allow the primary heat source to operate if solar gains are sufficient to supply heating and hot water requirements. Some of the means of achieving this are: -

- Factory fitted integrated and intelligent control system, which only allows the primary heat source (e.g. a boiler) to fire if the input from the solar system is not sufficient to meet the demands for heating and hot water.

- Using either the 'thermal startifiers' inside a thermal store or combination of hydraulic design and controls to prioritise the heating of the store from top to bottom when solar energy is available.

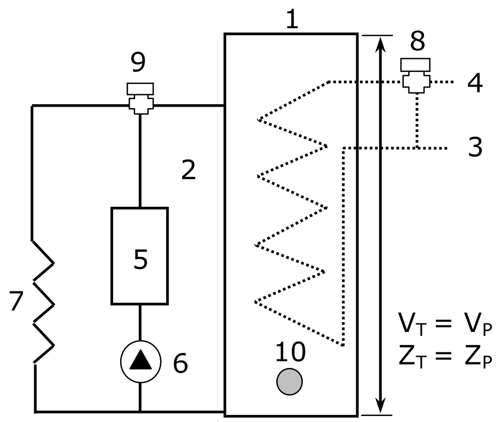
- The information should be provided for the installer to implement the control strategy on site and for the occupant on how best to use the system.

(b) The domestic hot water heat exchanger should be designed such that the heat is removed from the dedicated solar zone during a hot water draw-off.

Note:
The water content of a domestic hot water heat exchanger is usually small (2 – 10 litres) and therefore the stagnant time of domestic hot water in the heat exchanger is very low compared to a hot water cylinder. This combined with higher primary water temperature, it not necessary to provide facility for pasteurising the solar thermal stores.

4.4 DIRECT & INDIRECT HOT WATER THERMAL STORES [*DHWTS* & *IDHWTS*]

4.4.1 A direct hot water thermal store, *DHWTS*, is a thermal store designed to provide domestic hot water only and in which the energy storage media in zone, V_P, is heated directly by the primary heat source e.g. a boiler. A typical example of a *DHWTS* fitted with an internal natural convection heat exchanger and a standby electric immersion heater is shown in figure 4.4.

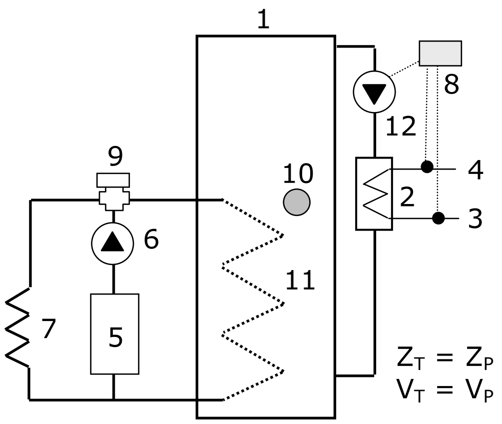


1 Hot water thermal store
2 DHW heat exchanger
3 Mains cold water inlet
4 Hot water outlet
5 Primary heat source e.g. boiler
6 Primary system pump
7 Space heating circuit
8 DHW Blending valve
9 3-Port valve
10 Standby immersion heater

Figure 4.4: A typical example of an *IDHWTS* with a natural convection DHW heat exchanger and thermostatic dhw blending valve

4.4.2 An indirect hot water thermal store, *IDHWTS*, is a store designed to provide domestic hot water only and in which the energy storage media in zone, V_P, is heated indirectly by the primary heat source by means of primary heat exchanger. A typical example of an *IDHWTS* fitted with an external forced convection hot water heat exchanger and a standby electric immersion heater is shown in figure 4.5.

4.4.3 In both *DHWTS* and *IDHWTS*, the domestic hot water is heated instantaneously by transferring the stored heat to the mains water flowing through the dhw heat exchanger. The dhw heat exchanger may be an internal or an external type as described in section 3.10.



1 Hot water thermal store
2 DHW heat exchanger
3 Mains cold water inlet
4 Hot water outlet
5 Primary heat source e.g. boiler
6 Primary system pump
7 Space heating circuit
8 DHW controller
9 3-Port valve
10 Standby immersion heater
11 Primary heat exchanger
12 DHW heat exchanger pump

Figure 4.5: A typical *IDHWTS* with a external forced convection DHW heat exchanger and electronic dhw controller

4.4.4 Both *DHWTS* and *IDHWTS* may contain phase change material (PCM) in addition to the primary water for storing thermal energy.

4.4.5 Both direct (*DHWTS*) and indirect (*IDHWTS*) hot water thermal stores may have either open vented or sealed (i.e. unvented) primary storage vessel.

(a) If the storage vessel is open vented, then it may have an integral or remote feed and expansion cistern.

(b) If the storage vessel is unvented i.e. sealed type, then it must be fitted with safety devices and controls to comply with the requirements of the Building Regulations 2000, Approved Document G, 2009 edition. Methods of compliance are specified in appendix D of this document.

4.4.6 Both direct and indirect (*DHWTS* and *IDHWTS*) hot water thermal stores are suitable for individual dwellings. *IDHWTS* are also suitable for group heating and district heating schemes.

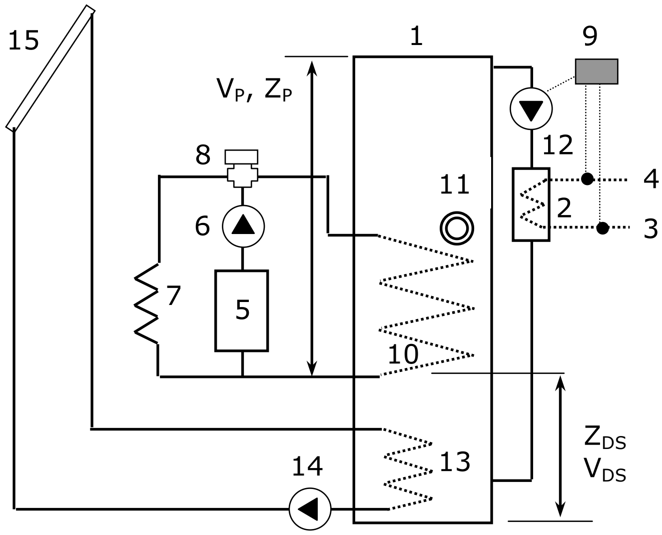
4.5 DIRECT AND INDIRECT HOT WATER SOLAR THERMAL STORES [*DHWTS-SOL* AND *IDHWTS-SOL*]

4.5.1 Both the direct and the indirect hot water thermal stores are suitable for use with solar thermal systems. An example of an indirect hot water solar thermal store (

IDHWTS-SOL), designed for use with a solar heating system is shown in figure 4.6.

4.5.2 Both *DHWTS-SOL* and *IDHWTS-SOL* must comply with the relevant generic requirements for hot water thermal stores listed in section 4.4.

Figure 4.6: Typical configuration of an *IDHWTS-SOL* fitted with an external forced convection DHW heat exchanger and electronic controller



1	Hot water thermal store	2	DHW heat exchanger
3	Mains cold water inlet	4	Hot water outlet
5	Boiler	6	Primary circuit pump
7	Space heating circuit	8	3-Port valve
9	DHW temperature controller	10	Primary heat exchanger
11	Standby immersion heater	12	DHW heat exchanger pump
13	Solar heat exchanger	14	Solar circuit pump
15	Solar panels		

4.5.3 In both the *DHWTS-SOL* and *IDHWTS-SOL*, the hydraulic design and the control system must ensure that the energy storage media in the dedicated solar zone, Z_{DS}, can not be heated by either the main primary heat source (e.g. a boiler) or the secondary standby heat source (e.g. an immersion heater).

4.5.4 The zone, Z_{DS}, in both *DHWTS-SOL* and *IDHWTS-SOL* is only heated by solar thermal system via the solar heat exchanger (13). 'The Domestic Heating Compliance Guide, May 2006' specifies the requirements for the solar heating systems for compliance with the Building Regulations 2000, Approved Documents L1 and L2 (2009 edition). To comply with the Building Regulations, both *DHWTS-SOL* and *IDHWTS-SOL* must meet the following requirements : -

(a) If the solar circuit flow rate, $F_{SOL} \geq 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL-HE} \geq 0.2 \times A_{SC.}$

(b) If the solar circuit flow rate, $F_{SOL} < 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL-HE} \geq 0.1 \times A_{SC}$

(c) If the solar zone, Z_{DS}, does not contain phase change material (PCM), then the dedicated solar volume, V_{DS}, must comply with either equation 4.8 or equation 4.9.

$V_{DS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4$ ---- [4.8]
$V_{DS} \geq 25 \times ASC$ ---- [4.9]

(d) If the solar zone, Z_{DS}, contains phase change material (PCM), then the equivalent dedicated solar volume, V_{EDS}, must comply with either equation 4.11 or equation 4.12.

$V_{EDS} = [V_{WDS}/V_{DS}]+m_{DS}[C_{PS}(T_M-T_0)+L_H+C_{PL}(T_1-T_M)]/[V_{DS}\ \rho\ Cp(T_1-T_0)]$ -- [4.10]
$V_{EDS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4$ -- [4.11]
$V_{EDS} \geq 25 \times A_{SC}$ -- [4.12]

Where : -

V_{EDS}	= Equivalent volume of dedicated solar zone, Z_{DS}, with PCM	[l]
V_{DS}	= Net volume of zone, Z_{DS}, without PCM,	[l]
V_{WDS}	= Net volume of water in zone, Z_{DS}, with PCM	[l]
m_{DS}	= Mass of PCM in dedicated solar zone, Z_{DS}	[kg]
Cp	= Average specific heat of water between T_0 and T_1	[J/Kg.K]
C_{PS}	= Specific heat of PCM in solid phase	[J/Kg.K]
C_{PL}	= Latent heat of PCM in liquid phase	[J/kg.K]
ρ	= Average density of water between T_0 and T_1	[kg/l]
L_H	= Latent heat of PCM	[J/kg]
T_M	= Phase change temperature of PCM	[^{o}C]
T_0	= Lower reference temperature (= 10^{o}C)	[^{o}C]
T_1	= Upper reference temperature (= 60^{o}C)	[^{o}C]
A_{TF}	= Maximum total floor area of a dwelling specified for the store	[m^2]
A_{SOL-HE}	= Surface area of the solar heat exchanger	[m^2]
A_{SC}	= Net surface area of the solar collector specified for the store	[m^2]
F_{SOL}	= Solar circuit flow rate per m^2 of net collector area	[l/min]

4.5.5 The heating systems based on either *DHWTS-SOL* or *IDHWTS-SOL* will use solar energy accumulated in a thermal store for producing domestic hot water only. In order to maximise the utilisation of solar energy: -

(a) The control system should not allow the primary heat source to operate if solar gains are sufficient to supply hot water requirements. Some of the means of achieving this are: -

- Factory fitted integrated and intelligent control system, which only allows the primary heat source (e.g. a boiler) to fire if the input from the solar system is not sufficient to meet the demands for heating and hot water.

- Using either 'thermal startifiers' inside a thermal store or combination of hydraulic design and controls to prioritise the heating of the store from top to bottom when solar energy is available.

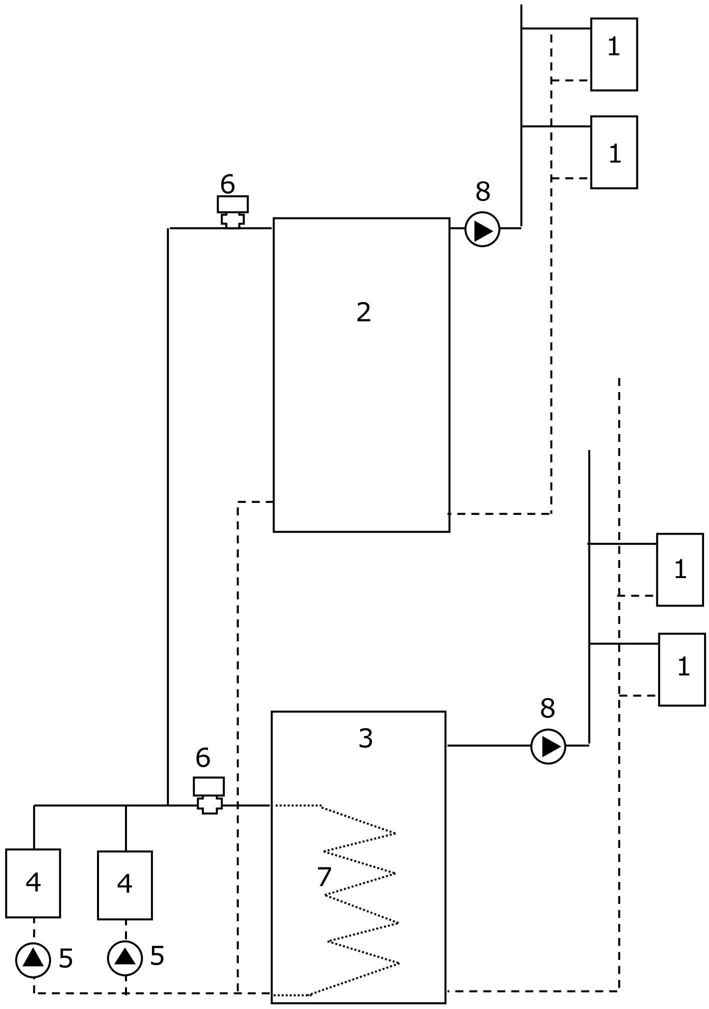
- The information should be provided for the installer to implement the control strategy on site and for the occupant on how best to use the system.

(b) The domestic hot water heat exchanger should be designed such that the heat is removed from the dedicated solar zone during a hot water draw-off.

Note:

The water content of a domestic hot water heat exchanger is usually small (2 – 10 litres) and therefore the stagnant time of domestic hot water in the heat exchanger is very low compared to a hot water cylinder. This combined with higher primary water temperature, it not necessary to provide facility for pasteurising the solar thermal stores.

Figure 4.7 : Schematic diagram of a thermal storage based group heating scheme for an apartment block



1. Indirect integrated thermal stores in individual dwellings
2. Direct buffer store (DBS)
3. Indirect buffer store (IDBS)
4. Boilers
5. Boiler pump
6. Buffer store charge control valve
7. IDBS primary heat exchanger
8. Distribution pump

4.6 DIRECT AND INDIRECT BUFFER STORES (DBS AND IDBS)

4.6.1 A direct buffer store, *DBS,* is a thermal store, which is heated directly by one or more boilers in a group-heating scheme [1]. An indirect buffer store, *IDBS,* is a thermal store, which is heated indirectly by one or more boilers by means of an internal primary heat exchanger.

In these heating systems, *DBS* and *IDBS* are used for supplying primary hot water to thermal stores located in the individual dwellings.

4.6.2 Both direct and indirect buffer stores (*DBS* and *IDBS*) may contain phase change material [2] (PCM) in addition to the primary water for storing thermal energy.

4.6.3 Both *DBS* and *IDBS* may have either an open vented or a sealed (i.e. unvented) primary storage vessel. However, both unvented and vented buffer stores must comply with the requirements of the relevant sections in 'The Building Regulations 2000, Approved Document G, 2009 edition'. Methods of compliance are specified in section 5.7 of this document.

4.6.4 If the storage vessel is open vented, then it may only have a remote feed and expansion cistern. However, it can be used to supply stores in the apartments at higher levels by means of intermediate heat exchangers.

4.6.5 One or more buffer store thermostats control the operation of central boilers in a thermal storage group-heating scheme. A typical schematic arrangement of a group-heating scheme is shown in figure 4.7.

4.6.6 Both *DBS* and *IDBS* do not have built in heat exchangers for supplying domestic hot water.

Notes

[1] The thermal storage group heating systems - a separate publication

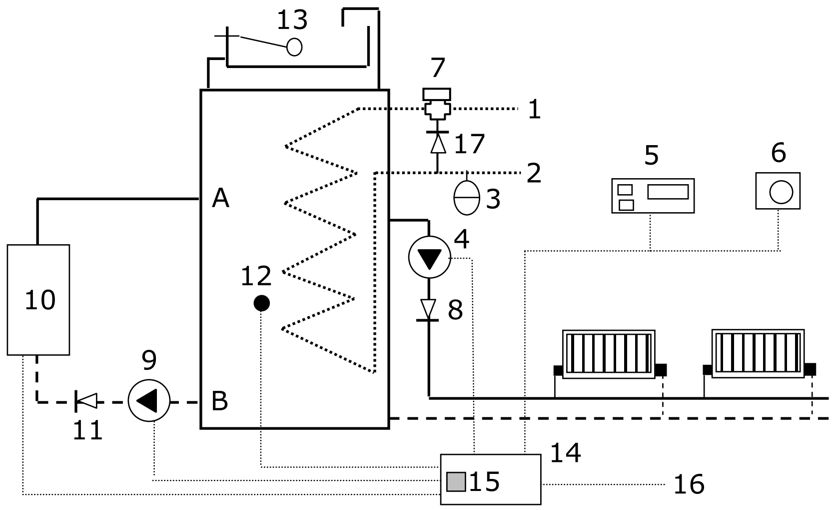
[2] The phase change material (i.e. PCM) is either encapsulated or contained inside a primary thermal store by other means so that it cannot mix or dissolve in primary water and therefore cannot circulate through either the radiator or the boiler circuits.

5. GENERAL AND PERFORMANCE REQUIREMENTS

5.1 INTEGRATED THERMAL STORES FOR INDIVIDUAL DWELLINGS

A typical example of a direct integrated thermal store (*DITS*) based heating system for an individual dwelling is schematically shown in figure 5.1. Both *DITS* and *IDITS* having either natural or forced convection domestic hot water heat exchangers are suitable for individual dwellings. The integrated thermal stores (*DITS* and *IDITS*) designed for the

Figure 5.1: An example of a DITS based individual dwelling heating system



1	Hot water outlet to taps	2	Mains cold water inlet
3	Expansion vessel(1)	4	Space heating pump
5	Heating programmer	6	Room thermostat
7	Thermostatic mixing valve	8	Heating circuit check valve
9	Boiler pump	10	Boiler
11	Boiler circuit check valve	12	Store thermostat/sensor
13	Integrated feed and expansion cistern	14	Wiring centre
15	Boiler pump over-run timer	16	Mains supply 230V ac, 50Hz
17	Hot water heat exchanger check valve		

individual dwellings should meet the requirements of sections 5.1.1 -5.1.4 below: -

Notes on figure 5.1:

(1) Expansion vessel, 3, can be an integral part of the dhw heat exchanger or it can be supplied as a separate item to be fitted on site if required.

(2) The requirement for the boiler circuit check valve, 11, to prevent gravity circulation depends upon the system design and layout.

(3) In an IDTS thermal store, there will be a primary heat exchanger across the boiler connections, A & B. The boiler circuit can then either be sealed or open vented type.

5.1.1 One or more store thermostats in conjunction with the hot water programmer (if fitted) should control the operation of the primary heat source e.g. boiler and the primary circuit pump.

5.1.2 The user space heating controls e.g. room thermostat and a central heating programme should control the operation of the central heating pump and not the operation of the main heat source. A timer based pump overrun control should be used for the boiler circuit.

Note:
The control of both space heating and boiler circuits can be achieved using a conventional 2-channel programmer/controller, but care must be taken to ensure that the boiler is available when only space heating demand is active.

5.1.3 An integrated thermal store can either be supplied with all the components fitted and wired or full wiring details and a list of recommended components (e.g. pumps, delay timers) must be provided. Outline specification of common components is contained in section 8 of this document.

5.1.4 Both *DITS* and *IDITS* designed for individual dwellings should meet the following requirements: -

(a) The relevant generic definition of integrated thermal stores (Section 4.2).
(b) The relevant sub sections of general specification (Section 6).
(c) The relevant sub sections of performance specification (Section 7).

5.2 THE INTEGRATED THERMAL STORES DESIGNED FOR GROUP HEATING

Typical examples of a direct (*DITS*) and an indirect (*IDITS*) integrated thermal store based apartment heating systems for a group heating schemes are shown in figures 5.2 and 5.3 respectively. The *DITS* and the *IDITS* designed for a group-heating scheme should meet the requirements of sections 5.2.1 – 5.2.6 below: -

5.2.1 The integrated thermal store for a group heating scheme does not directly control the operation of the central heating plant, but the store thermostats control the operation of the charge control valve and/or a pump.

5.2.2 A *DITS* designed for a group heating scheme can not have an integral feed and expansion system provided there is a pressure break (e.g. a plate heat exchanger) between the group heating system and the DITS as shown in figure 5.2.

5.2.3 The *DITS* is not normally suitable for use in a group-heating scheme without an external plate heat exchanger to provide a pressure break as shown schematically in figure 5.2.

5.2.4 The user space heating controls e.g. room thermostat and a central heating programme should control the operation of the central heating pump and not the operation of the charge control device.

5.2.5 The *DITS* and the *IDITS* designed for a group heating scheme may be fitted with a heat metering system. An integrated thermal store for a group heating scheme can either be supplied with all the components fitted and wired or full wiring details and a list of recommended components (e.g. pumps, delay timers) must be provided. Outline specification of common components is contained in section 8 of this document.

5.2.6 Both *DITS* and *IDITS* designed for a group heating scheme should comply with the following requirements: -

(a) The relevant generic definition of integrated thermal stores (Section 4.2).
(b) The relevant sub sections of general specification (Section 6).
(c) The relevant sub sections of performance specification (Section 7).

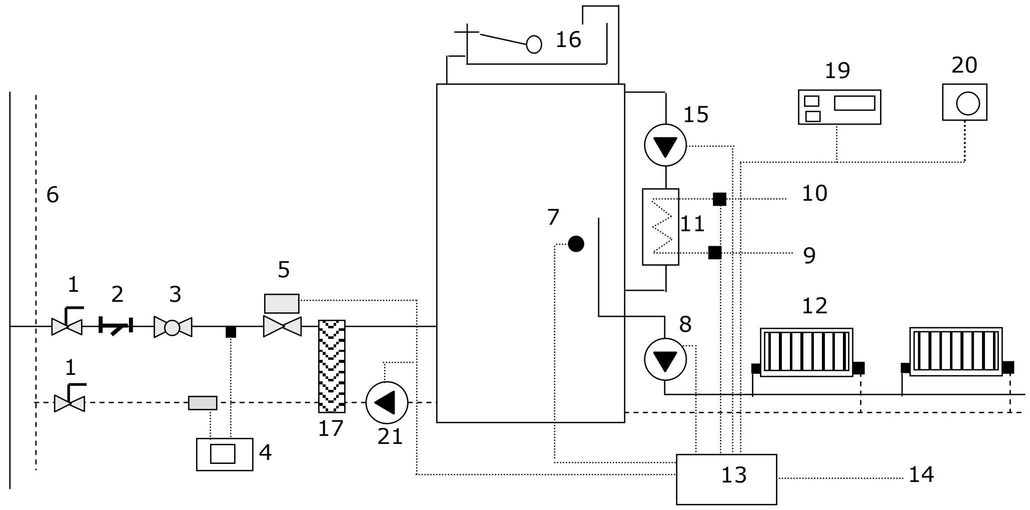
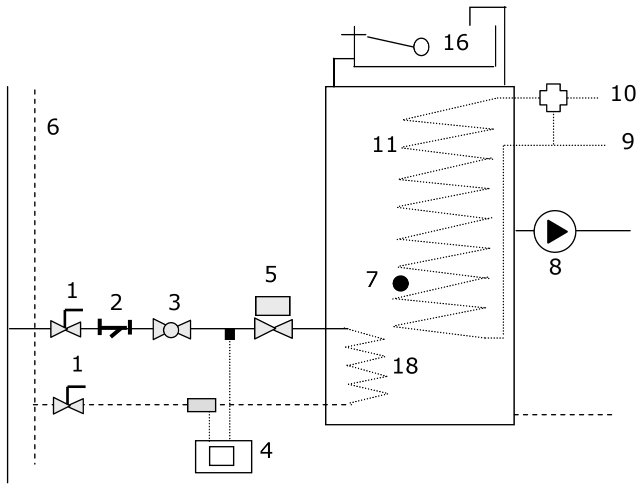


Figure 5.2 : A typical arrangement of a *DITS* based heating system for an apartment in a group heating scheme



1 Isolating valve
2 In line filter
3 Balancing valve
4 Heat meter
5 Store charge control valve
6 Distribution network
7 Store thermostat
8 Space heating pump
9 Cold water inlet
10 Hot water outlet
11 Hot water heat exchanger
12 Space heating circuit
13 Wiring & controls
14 Mains electricity supply
15 DHW HE pump
16 F & E cistern
17 Primary plate heat exchanger
18 Primary heat exchanger
19 Programmer
20 Room thermostat
21 Primary circuit pump

Figure 5.3 : A typical arrangement of an *IDITS* based heating system for an apartment in a group heating scheme

5.3 THE HOT WATER THERMAL STORES FOR INDIVIDUAL DWELLINGS

Typical example configurations of a direct hot water thermal store (*DHWTS*) and an indirect hot water thermal store (*IDHWTS*) based heating systems for individual dwellings are shown in figure 5.4 and 5.5 respectively.

Both *DHWTS* and *IDHWTS* having either a natural or forced convection heat exchangers are suitable for individual dwellings and these should comply with the requirements of section 5.3.1 – 5.3.4: -

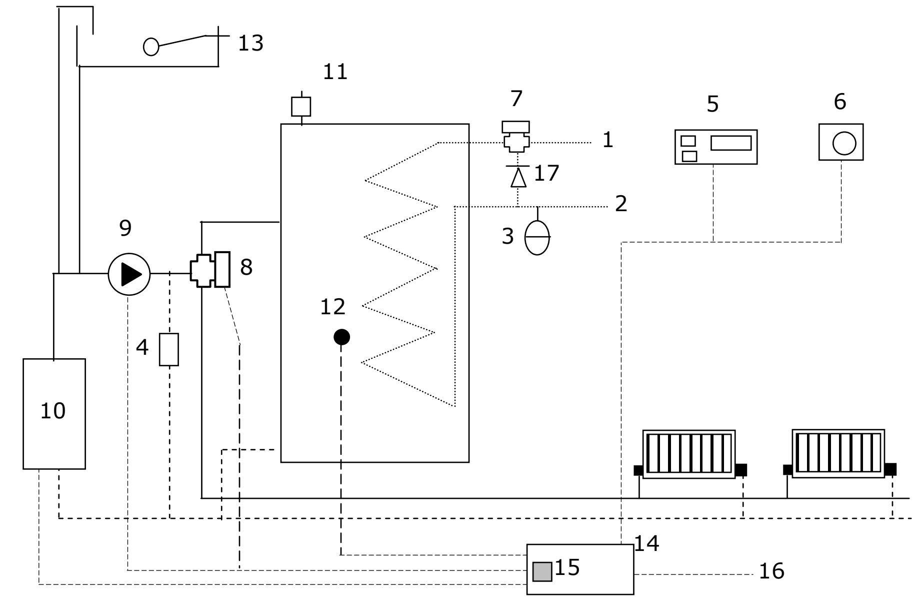


Figure 5.4 : Typical *DHWTS* based heating system for individual dwellings

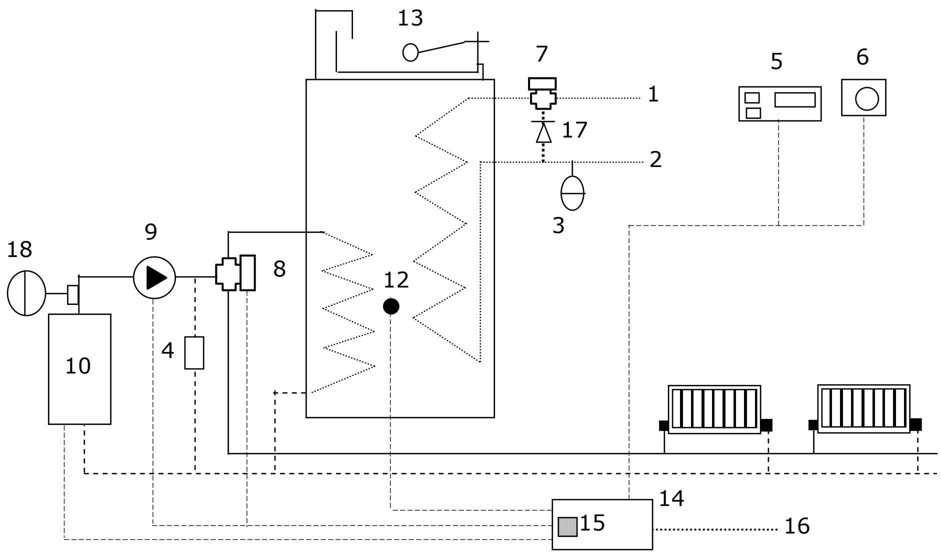


Figure 5.5: Typical *IDHWTS* based heating system for individual dwellings

1	Hot water outlet to taps	2	Mains cold water inlet
3	Expansion vessel [(1)]	4	Bypass valve
5	Heating programmer	6	Room thermostat
7	Thermostatic mixing valve	8	3-Port valve
9	Boiler/system pump	10	Boiler
11	Air vent & anti-vacuum valve	12	Store thermostat/sensor
13	Integrated feed and expansion cistern	14	Wiring centre
15	Boiler pump over-run timer	16	Supply 1 x 230V ac, 50Hz
17	Hot water heat exchanger check valve	18	Sealed system kit

5.3.1 Both *DHWTS* and *IDHWTS* designed for individual dwelling may have an integral or remote feed and expansion cistern. Alternatively, it may be fitted with sealed system components, which must comply with the requirements of the Building Regulations and the appropriate British Standard.

5.3.2 The operation of the heating system based on a hot water thermal store is similar to a traditional system based on a hot water cylinder.

If the hot water has priority then the store thermostat controls the operation of the boiler, system pump and the control (e.g. 3-port diverter) valve.

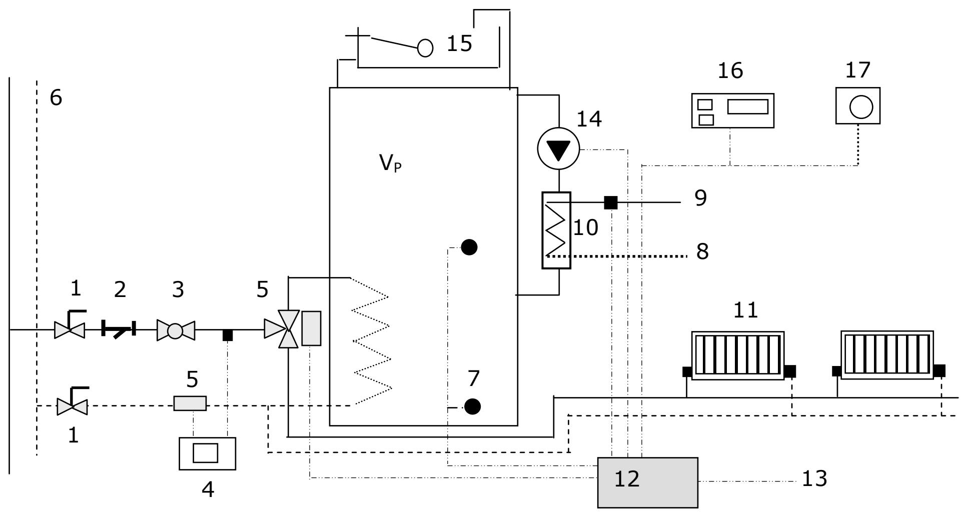
If a flow share arrangement is used then the user space heating controls e.g. a room thermostat, store thermostat and heating programmer, should control the operation of the boiler, system pump and the position of either 2-port zone valves or position 3-port mid-position valve.

5.3.3 A hot water thermal store can either be supplied with all the components fitted and wired or full wiring details and a list of recommended components (e.g. pumps, delay timers) must be provided. Outline specification of common components is contained in section 8 of this document.

5.3.4 Both *DHWTS* and *IDHWTS* designed for individual dwellings should comply with the following general and performance requirements: -

(a) The relevant generic definition of hot water thermal stores (Section 4.4).
(b) The relevant sub sections of general specification (Section 6).
(c) The relevant sub sections of performance specification (Section 7).

Figure 5.6: Typical configuration of an *IDHWTS* based apartment heating system in a group heating scheme



1 Isolating valve	2 In line filter	3 Balancing valve
4 Heat meter	5 Store charge control valve	6 Distribution network
7 Store thermostat	8 Cold water inlet	9 Hot water outlet to taps
10 DHW heat exchanger	11 Space heating circuit	12 Wiring centre & controls
13 Mains supply	14 DHW HE pump	15 F & E cistern
16 Programmer	17 Room thermostat	

5.4 THE HOT WATER THERMAL STORES FOR GROUP HEATING

Only indirect hot water thermal stores (*IDHWTS*) are suitable for group heating schemes and a typical example of the arrangement is shown in figure 5.6. The *IDHWTS* designed for a group-heating scheme should comply with the following requirements: -

5.4.1 The *IDHWTS* does not control the operation of the central heating plant directly but the store thermostat controls the operation of the charge control valve.

5.4.2 The *IDHWTS* designed for a group-heating scheme may be fitted with a heat metering system.

5.4.3 *IDHWTS* for a group-heating scheme can either be supplied with all the components fitted and wired or full wiring details and a list of recommended components must be provided. Outline specification of common components is contained in section 8 of this document.

5.4.4 The *IDHWTS* designed for a group heating scheme should comply with the following general and performance requirements: -

(a) The relevant generic definition of hot water thermal stores (Section 4.4).
(b) The relevant sub sections of general specification (Section 6).
(c) The relevant sub sections of performance specification (Section 7).

5.4.5 When an *IDHWTS* is used in high-rise (e.g. tower block) group heating scheme, a pressure break should be installed to control the primary heat exchanger operating pressure within design parameters.

5.5 THE SOLAR THERMAL STORES FOR INDIVIDUAL DWELLINGS

Both integrated thermal stores (*DITS & IDITS*) and hot water thermal stores (*DHWTS & IDHWTS*) can be designed for use with solar thermal systems. Typical configurations of a indirect hot water thermal store for use with solar heating (*IDHWTS-SOL*) and an direct integrated thermal store for use with solar heating (*IDITS-SOL*) are shown in figures 5.7 and 5.8 respectively.

With *DHWTS-SOL* and *IDHWTS-SOL*, the solar energy is only used for producing domestic hot water. However with *DITS-SOL* and *IDITS-SOL*, the solar energy can be used for both space heating and domestic hot water heating.

The thermal stores designed for use with solar thermal energy in individual dwellings should comply with the following requirements: -

5.5.1 All solar thermal stores either be supplied with all the components fitted and wired or full wiring details and a list of recommended components (e.g. pumps, valves, controls) must be provided. The outline specification of common components is contained in section 8 of this document.

5.5.2 For the integrated solar thermal stores (*DITS-SOL and IDITS-SOL*): -

(a) One or more store thermostats in conjunction with the hot water programmer (if fitted) should control the operation of the primary heat source e.g. boiler and the primary circuit pump.

(b) The user space heating controls e.g. room thermostat and a central heating programme should control the operation of the central heating pump and not the operation of the main heat source.

(c) A timer based pump overrun control is recommended for the boiler pump.

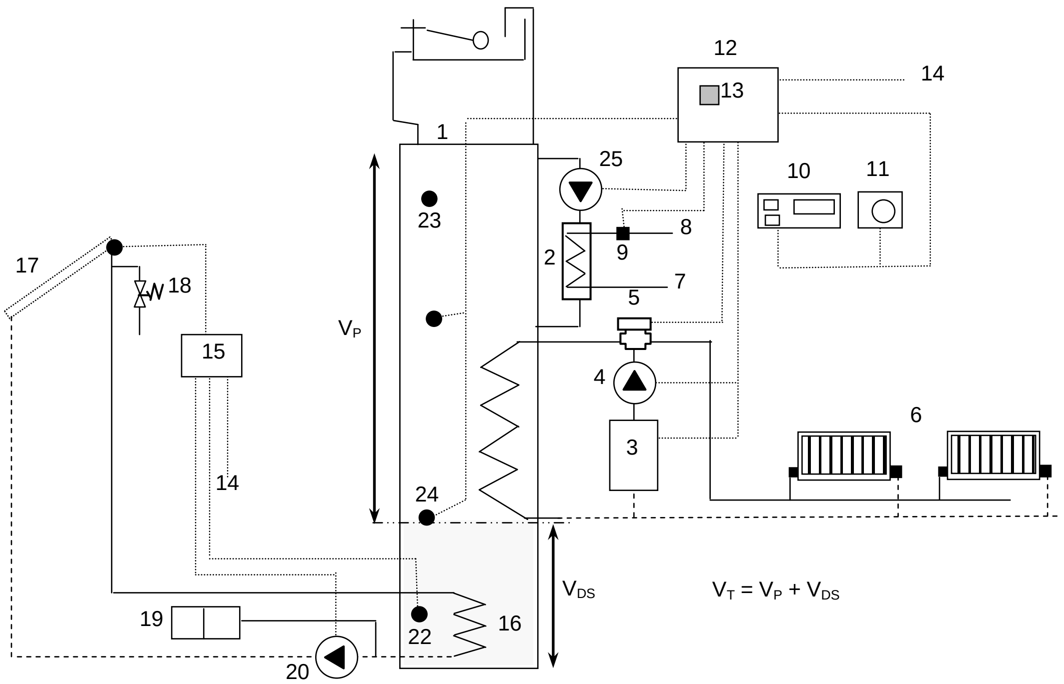
5.5.3 For the hot water thermal stores (*DHWTS-sol* and *IDHWTS-sol), t*he operation of the heating system based on a hot water thermal store is similar to a traditional system based on a hot water cylinder.

If the hot water has priority then the store thermostat controls the operation of the boiler, system pump and the control (e.g. 3-port diverter) valve.

If a flow share arrangement is used then the user space heating controls e.g. a room thermostat, store thermostat and heating programmer, should control the operation of the boiler, system pump and the position of either 2-port zone valves or position 3-port mid-position valve.

5.5.4 For all solar thermal stores, means must be provided or recommended to control unnecessary operation of the primary heat source in order to maximise the utilisation of solar energy.

Figure 5.7: A typical example of a ***IDHWTS-SOL*** heating system for an individual dwelling

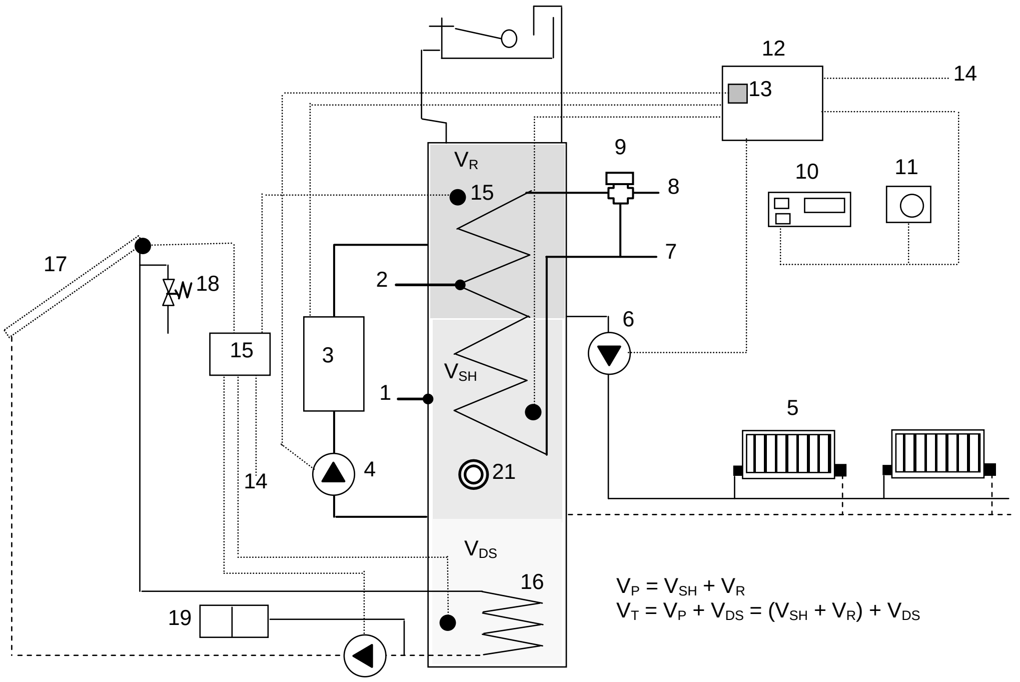


1	Hot water thermal store type	2	dhw heat exchanger	3	Primary heat source (e.g. boiler)
4	System pump	5	3-port flow share valve	6	Space heating circuit
7	Mains cold water inlet	8	Hot water outlet to taps	9	DHW temperature sensor
10	Heating and hot water Programmer	11	Room thermostat	12	System controller/ wring centre
13	Boiler pump overrun timer	14	Mains electricity supply	15	Solar system controller
16	Solar heat exchanger	17	Solar panels	18	Pressure relief valve
17	Solar circuit expansion vessel	20	Solar heating circuit pump	22	Store solar zone temperature sensor
23	Store over heat temperature sensor - solar controller				
24	Store temperature sensors/thermostats	25	DHW circuit primary pump		

5.5.5 All thermal stores designed for use with solar thermal systems in individual dwellings must comply with the following general and performance requirements: -

(a) The relevant generic definition of thermal stores for solar heating (Section 4.5).
(b) The relevant sub sections of general specification (Section 6).
(c) The relevant sub sections of performance specification (Section 7).

Figure 5.8: Typical example of an open vented ***DITS-SOL*** based heating system with solar heating controlled by a separate dedicated controller



1 Integrated thermal store ***DITS-sol***	2 dhw heat exchanger	3 Primary heat source (e.g. a boiler)
4 Primary (e.g. boiler) circuit pump	5 Space heating circuit	6 Space heating pump
7 Mains cold water inlet	8 Hot water outlet to taps	9 DHW thermostatic mixing valve
10 Heating & hot water Programmer	11 Room thermostat	12 System controller/ wring centre
13 Boiler pump overrun timer	14 Mains electricity supply	15 Solar system controller
16 Solar heat exchanger	17 Solar panels	18 Pressure relief valve
19 Solar circuit expansion vessel	20 Solar heating circuit pump	21 Immersion heater
22 Store solar zone temperature sensor	23 Store temperature sensor - solar controller	
V_{SH} Storage volume available for space heating	V_{DS} : Dedicated solar volume heated by solar only	
V_T Total storage volume of ***DITS-sol***	V_P : Storage volume heated by all heat sources	

5.6 HEAT PUMP THERMAL STORES FOR INDIVIDUAL DWELLINGS

The flow temperature from heat pumps range from about 55°C to about 65°C and the domestic hot water in a thermal store is heated instantaneously by means of a heat exchanger. Therefore to maximise the in use COP of a heat pump, only direct thermal stores (*DHWTS-hp* and *DITS-hp*) should be used with both ground and air source heat pumps.

A typical heat pump heating system configurations based on a direct hot water thermal store (*DHWTS-hp*) and a direct integrated thermal store (*DITS-HP*) are shown in figures 5.9 and 5.10 respectively.

The direct hot water or integrated thermal stores (*DITS-HP* and *DHWTS-HP*) designed for use with heat pumps should comply with the following requirements: -

5.6.1 All heat pump thermal stores should either be supplied with all the components fitted and wired or full wiring details and a list of recommended components (e.g. pumps, valves and controls) must be provided. The outline specification of common components is contained in section 8 of this document.

5.6.2 For the direct integrated heat pump thermal stores (*DITS-HP*): -

(a) One or more store thermostats or sensors in conjunction with the programmer should control the operation of the heat pump and the primary circuit pump.

(b) The user space heating controls e.g. room thermostat and a central heating programme should control the operation of the central heating pump and not the operation of the heat pump.

Note:
The control of both space heating and boiler circuits can be achieved using a conventional 2-channel programmer/controller, but care must be taken to ensure that the boiler is available when only space heating demand is active.

(c) The heating of a thermal store for producing dhw should have the priority over the heating of a thermal store for space heating.

5.6.3 For the direct hot water thermal stores (*DHWTS-hp), t*he system and controls should be designed to give priority to heating of a thermal store for producing hot water.

5.6.4 If it is necessary to boost the temperature of the water in a thermal store to satisfy the dhw requirements, then, the following control logic is recommended to minimise the use of direct electricity for heating: -

(a) The boost heater should only be switched ON, after the heat pump has completed the store heating cycle.

(b) The boost heater should only heat the minimum storage volume necessary to satisfy the dhw requirements.

(c) It may not be necessary to use the boost heater after each store heating cycle during a 24h period.

(d) The means must be provided or recommended to achieve the above control logic.

(e) There must be some means of overriding the automatic operation settings if the user wants to manually boost the store temperature. This should be done through the runback timer.

5.6.5 The thermal stores designed for use with heat pumps should comply with the following general and performance requirements: -

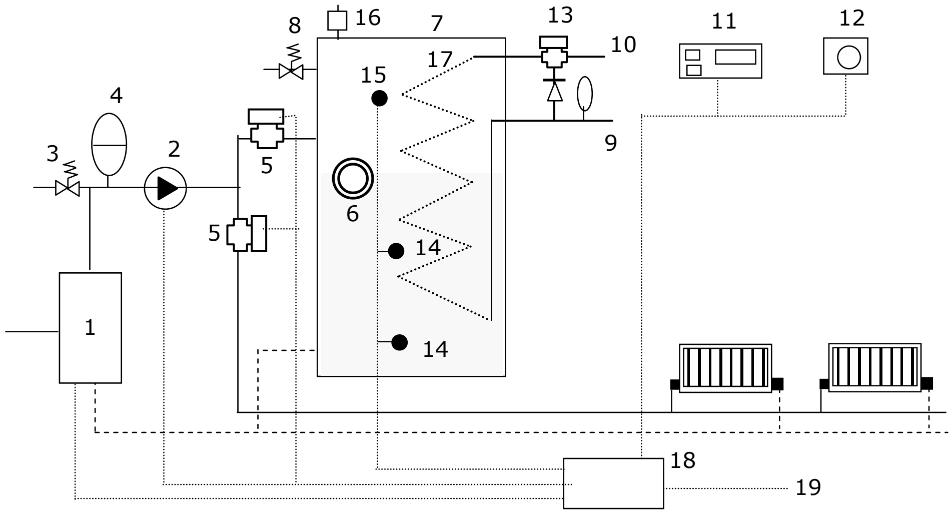
(a) For the type *DITS-HP*, the relevant generic definition of integrated thermal stores (Section 4.2).

(b) For the type *DHWTS-HP*, the relevant generic definition of hot water thermal stores (Section 4.3).

(c) For types *DITS-HP* and *DHWTS-HP*, the relevant sub sections of the general specification (Section 6).

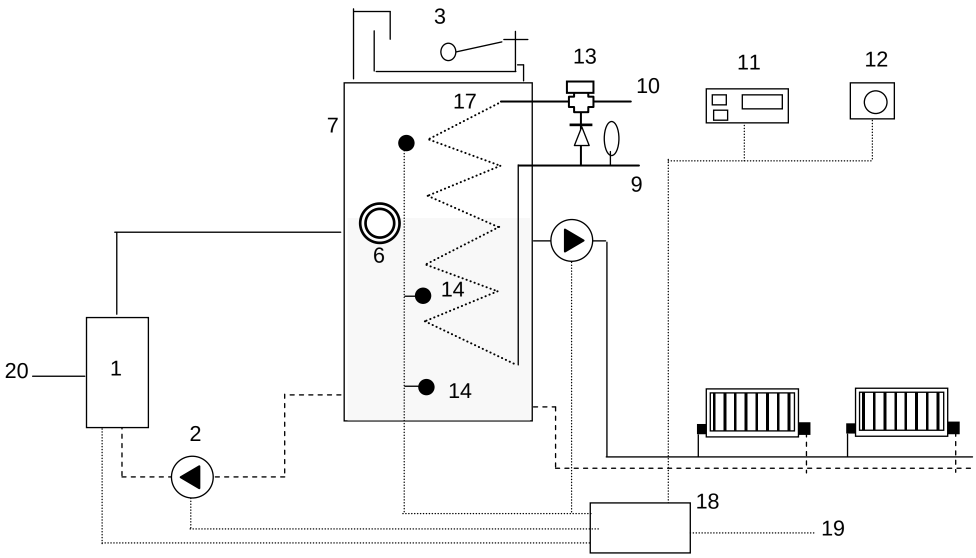
(d) For types *DITS-HP* and *DHWTS-HP*, the relevant sub sections of the performance specification (Section 7).

Figure 5.9 : Typical configuration of an unvented DHWTS-HP and a heat pump for a heating system in an individual dwelling.



1	Heat pump	2	Primary pump	3	PRV
4	Expansion vessel	5	Zone valve	6	Boost immersion heater
7	*DHWTS-hp*	8	P & T valve	9	CW inlet
10	DHW outlet	11	Programmer	12	Room thermostat
13	DHW blending valve	14	Store thermostats/sensors		
15	OHT	16	Air vent	17	DHW heat exchanger
18	Control system/wiring centre			19	Power supply – control
20	Power supply – heat pump				

Figure 5.10 : Typical configuration of an vented ***DITS-HP*** and a heat pump for a heating system in an individual dwelling.



1	Heat pump	2	Primary pump	3	F & E cistern
4	CH pump	6	Boost immersion heater	7	*DHWTS-hp*
9	CW inlet	10	DHW outlet	11	Programmer
12	Room thermostat	13	dhw blending valve	14	Store thermostats/sensors
15	OHT	16	Air vent	17	DHW heat exchanger
18	Control system/wiring centre	19	Power supply – control	20	Power supply – heat pump

5.7 THERMAL STORES FOR USE WITH SOLID FUEL BOILERS (e.g. wood burners)

5.7.1 The solid fuel boilers normally are not fitted with water temperature control and/or overheat safety devices. Therefore, only an open vented thermal store should be used with a solid fuel boiler e.g. wood burning stove. A typical example system is shown in figure 5.11.

5.7.2 A wood burning stove usually heats the thermal store by gravity circulation. Therefore, the minimum size of connections should be 28mm or equivalent.

5.7.3 A thermal store designed for use with a wood burning stove can also have other heat sources (e.g. a gas boiler, solar heating system) connected to it. However the control of these heat sources must comply with the relevant requirements for thermal stores designed for individual dwellings described in previous sections.

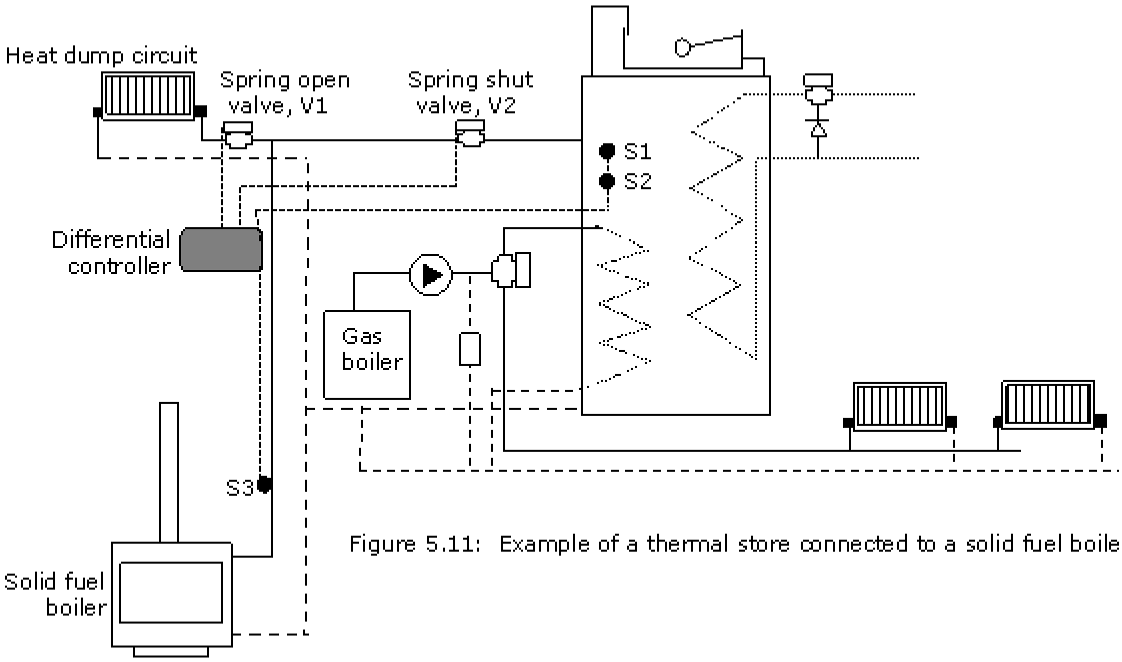


Figure 5.11: Example of a thermal store connected to a solid fuel boiler

1	Hot water outlet to taps	2	Mains cold water inlet
3	Expansion vessel [1]	4	Bypass valve
5	Heating programmer	6	Room thermostat
7	Thermostatic mixing valve	8	3-Port valve
9	Boiler/system pump	10	Boiler
11	Air vent & anti-vacuum valve	12	Store thermostat/sensor
13	Integrated feed and expansion cistern	14	Wiring centre
15	Boiler pump over-run timer	16	Supply 1 x 230V ac, 50Hz
17	Hot water heat exchanger check valve	18	Sealed system kit

5.7.4 The general installation and the solid fuel appliance selected must comply with the requirements of HETAS.

5.7.5 A heat dump radiator circuit and a suitable control system must be used with a solid fuel boiler to prevent the thermal store from overheating. The example shown in figure 5.11 uses: -

(a) Normally spring open zone valve, V_1, and a normally spring close zone valve, V_2.

(b) A store control thermostat, S_1, high limit store thermostat, S2, and a pipe thermostat, S_3, mounted on the flow pipe connecting the wood burning stove to the thermal store.

(c) A differential controller

(d) The control wiring is arranged to provide the following control logic: -

- If the temperature differential 'S3-S1' is greater than the set point and the store temperature, S1, is less than the set point then the differential controller will open the zone valve V1 and close the zone valve, V2, to allow the store to be heated by the wood burning stove.

- If either the store temperature, S1, is greater than the set point or if the overheat condition is detected by the overheat sensor, S2, then the differential controller will not allow the store to be heated and the heat will be diverted to the heat dump circuit.

6. GENERAL SPECIFICATION

6.1 THERMAL STORE DATA BADGE OR LABEL

The following information shall be provided in form of a permanent 'Data Badge' or a label fixed to the thermal store. The 'data badge' should be accessible without the use of tools.

Note:
The information marked with *** *is only required if the thermal store contains phase change material (PCM).*

6.1.1 For all types of thermal stores

(a)	Manufacturers name and address etc.	[……]
(b)	Type, Model ID number	[……]
(c)	Compliance with HWA specification	[e.g. HWA logo[1]]
(d)	Total storage volume, V_T	[l]
(e)	Total equivalent storage volume, V_{TE}	[l]*
(f)	Maximum working pressure or head	[bar or mWG]
(g)	Heat loss factor, Q_{HLF}	[kWh/24h]
(h)	Store thermostat settings	[^oC]
(i)	Maximum working temperature – store	[^oC] - if special component fitted.
(j)	Over heat thermostat setting	[^0C]

Note:
The compliance with this specification is demonstrated by approved HWA Logo restricted to members only

6.1.2 Additional data for direct integrated and direct hot water thermal stores (*DITS, DHWTS, DITS-sol, DHWTS-sol, DITS-hp, DHWTS-hp*)

(a)	Maximum working pressure for DHW heat exchanger	[bar]
(b)	DHW volume, V_{HW-N} at test flow rate, F_{DHW}	[… l at … l/min]
(c)	Domestic hot water outlet temperature setting	[^oC]

6.1.3 Additional data for indirect integrated indirect hot water thermal stores (*IDITS, IDHWTS, IDITS-sol, IDHWTS-sol*)

(a)	Maximum working pressure for dhw heat exchanger	[bar]
(b)	DHW volume, V_{HW-N} at test flow rate, F_{DHW}	[… l at … l/min]
(c)	Domestic hot water outlet temperature setting	[^oC]
(d)	Maximum working pressure for primary heat exchanger	[bar]
(e)	Thermal rating of primary heat exchanger, Q_{R_PHE}	[kW]

6.1.4 Additional information of thermal stores for use with solar heating (*DITS-sol, IDITS-sol, DHWTS-sol, IDHWTS-sol*)

(a)	Maximum working pressure for solar heat exchanger	[bar]
(b)	Thermal rating of solar heat exchanger, Q_{R-SHE}	[kW]
(c)	Surface are of solar heat exchanger, A_{SHE}	[m^2]
(d)	Dedicated solar volume, V_{DS}	[l]
(e)	Dedicated equivalent solar volume, V_{DS-E}	[l]*

6.1.5 **Additional information for unvented thermal stores**

(a)	Pressure relief valve (PRV) setting	[bar]
(b)	Pressure and temperature relief valve (P&T) setting	[bar / °C]
(c)	Overheat thermostat setting	[°C]
(d)	Expansion vessel size	[l]
(e)	Expansion vessel charge pressure	[bar]

6.2 THERMAL STORE SYSTEM DESIGN AND INSTALLATION MANUAL

The system design and installation manuals should be provided with all thermal stores and these should include, where appropriate, the following information:-

6.2.1 Installation and service instructions with examples.

6.2.2 Recommended space heating system designs and controls.

6.2.3 Recommended hot and cold water distribution networks in a dwelling (e.g. supply to shower and pipe sizes).

6.2.4 Performance and design information listed tables 6.1.

Table 6.1 Minimum design information to be included in the design manuals

Thermal store type	Information
All types of thermal stores	• Overall dimensions of the unit : [mm] • Clearances required for installation and service • Size and type of connections • Maximum working head/pressure : [mWG/bar] • Heat loss factor, Q_{HLF} : [kWh/m^2] • Total storage volume, V_T : [l] • Total equivalent storage volume, V_{TE} : [l]***** • Store thermostat setting : [°C] • Maximum rating for primary heat source : [kW]
DITS, DHWTS, DITS-sol, DHWTS-sol, DITS-hp, DHWTS-hp	• Maximum working pressure for dhw heat exchanger : [bar] • DHW performance graph at nominal test flow rate as shown in figure A2, appendix A. • Nominal dhw test flow rate, F_{DHW} : [l/min] • Pressure flow characteristics of the dhw heat exchanger as shown in figure A3, appendix A.
IDITS, IDHWTS, IDITS-sol, IDHWTS-sol,	• Maximum working pressure for dhw heat exchanger : [bar] • DHW performance graph at nominal test flow rate as shown in figure A2, appendix A. • Nominal dhw test flow rate, F_{DHW} : [l/min] • Pressure flow characteristics of the dhw heat exchanger as shown in figure A3, appendix A. • Maximum working pressure for the primary heat exchanger : [bar] • Pressure flow characteristics for the primary heat exchanger as shown in figure B1, appendix B • Thermal rating of the primary heat exchanger, Q_{R-PHE} : [kW]

Table 6.1 Minimum design information to be included in the design manuals ……..…. continued	
Thermal store type	Information
DHWTS-sol, DITS-sol, IDITS-sol, IDHWTS-sol,	• Dedicated solar volume, V_{DS} : [l] • Dedicated equivalent solar volume, V_{DSE} : [l]***** • Maximum working pressure for the solar heat exchanger : [bar] • Surface are of solar heat exchanger : [m^2] • Thermal rating of solar heat exchanger : [kW] • Pressure flow characteristics of the solar heat exchanger as shown in figure B3, appendix B
DITS, IDITS, DITS-sol, IDITS-sol, DITS-hp	• Maximum installed radiator capacity ; [kW]
*The information marked with ***** is only required if the thermal store contains phase change material (PCM).*	

6.3 DIRECT FLOW AND RETURN CONNECTIONS TO THERMAL STORE

6.3.1 These should be designed to prevent short circuit of flow and return in the store for all direct circuits connected to the primary store. For example, the primary heat source (e.g. boiler) circuit and the space heating circuit.

6.3.2 The aim should be to achieve uniform flow (up or down) across the area of the store. This can be achieved by using sparge pipes, diffusers or other similar methods.

6.3.3 The sizes of connections and/or internal baffles should be designed to minimise the turbulence and mixing inside direct type of thermal stores as this reduces its utilisation efficiency.

6.4 PRIMARY HEAT SOURCE CONTROL SENSOR/THERMOSTAT POCKETS

6.4.1 This section applies to all thermal stores heated by a (internal or external) primary heat source e.g. a boiler with the exception of direct thermal stores heated by immersion heaters with integral control and overheat thermostats.

6.4.2 The thermostat and sensor pockets for controlling the system should be designed and located to sense the bulk water temperature in the active zone of the store.

6.4.3 Thermal stores of total capacity up to 250 litres should be fitted with at least <u>one</u> store thermostat/sensor pocket (figure 6.1) and its position must comply with equation 6.1.

$$0.25\,V_P \le V_{S1} \le 0.35V_P \quad ..... [6.1]$$

Where: -

V_P = Nominal primary storage capacity of a thermal store [l]
V_{S1} = Volume of water in zone, Z_P, below store thermostat/sensor pocket, S1 [l]

6.4.4 The thermal stores of capacity greater than 250 litres would benefit when its operation is controlled by two thermostats. If this method is used then their position (see figure 6.2) must comply with equations 6.2 and 6.3.

$0.05\ V_P \leq V_{S1} \leq\ 0.10V_P$ ..... [6.2]
$0.60\ V_P \leq V_{S2} \leq 0.70V_P$ ..... [6.3]

Where:-

V_P = Nominal primary storage capacity of a thermal store [l]
V_{S1} = Volume of water in zone, Z_P, below store thermostat/sensor pocket, S1 [l]
V_{S2} = Volume of water in zone, Z_P, below store thermostat pocket, S2 [l]

6.4.5 When two control thermostats / sensors (S1 and S2) are fitted their operating control logic should be as follows: -

(a) The primary heat source should be switched 'ON' when both sensors (thermostats), S1 and S2 are calling for heat.

(b) The primary heat source should only be switched 'OFF' when both sensors (thermostats), S1 and S2 stop calling for heat.

Note:
A typical wiring arrangement for 2 thermostats is shown in figure 8.1, section 8 of this document

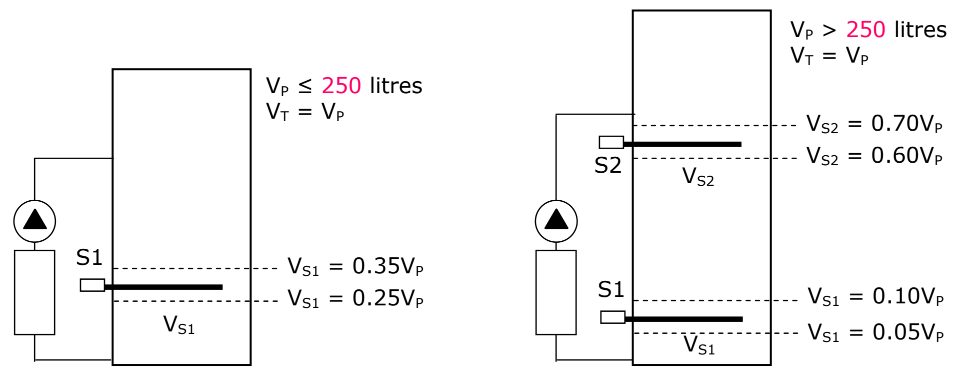


Figure 6.1 : Position of store temperature control thermostats or sensor pockets

6.5 SOLAR CIRCUIT CONTROL SENSOR/THERMOSTAT POCKETS

6.5.1 This section only applies to thermal stores designed for use with solar thermal systems.

6.5.2 Solar thermal stores of primary storage volume, V_P, up to 250 litres should be fitted with at least 3 store thermostat or sensor pockets. Solar thermal stores of primary storage volume greater than 250 litres should be fitted with at least 4 thermostat or sensor pockets (figure 6.2).

S0 = Solar heating control sensor pocket
S1 = Main heat source control sensor-1
S2 = Main heat source control sensor-2 (above 250 litres V_P)
S3 = Store overheat sensor pocket

6.5.3 For all sizes of stores, the position of thermostat/sensor pockets S0 and S3 should comply with equations 6.4 and 6.5.

$0.25V_{DS} \le V_{S0} \le 0.35V_{DS}$ ---- [6.4]
$0.70V_T \le V_{S3} \le 0.85V_T$ ---- [6.5]

Where: -

V_{DS} = Dedicated solar volume [l]
V_{S0} = Solar volume below sensor, S0 [l]
V_T = Total storage volume (V_T=V_P+V_{DS}) [l]
V_{S3} = Storage volume below sensor, S3 [l]

6.5.4 Thermal stores of primary storage capacity, V_P, up to 250 litres must be fitted with at least one store thermostat/sensor pocket and its position must comply with equation 6.6. The thermal stores of primary storage capacity, V_P, greater than 250 litres must be fitted with at least two thermostat/sensor pockets and their position must comply with equations 6.7 and 6.8.

$0.25\,V_P \le V_{S1} \le 0.35V_P$ ..... [6.6]
$0.05\,V_P \le V_{S1} \le 0.10V_P$ ..... [6.7]
$0.60\,V_P \le V_{S2} \le 0.70V_P$ ….. [6.8]

Where: -

V_P = Nominal primary storage capacity of a thermal store [l]
V_{S1} = Volume of water in zone, Z_P, below store thermostat/sensor pocket, S1 [l]
V_{S2} = Volume of water below store thermostat pocket, S2 [l]

Notes:-

(1) The exact requirements may depend upon the solar system and controls used in the installation.

(2) However, additional sensor/thermostat pockets may be required to optimise the utilisation of solar energy but this will depend upon the system and control designs etc.

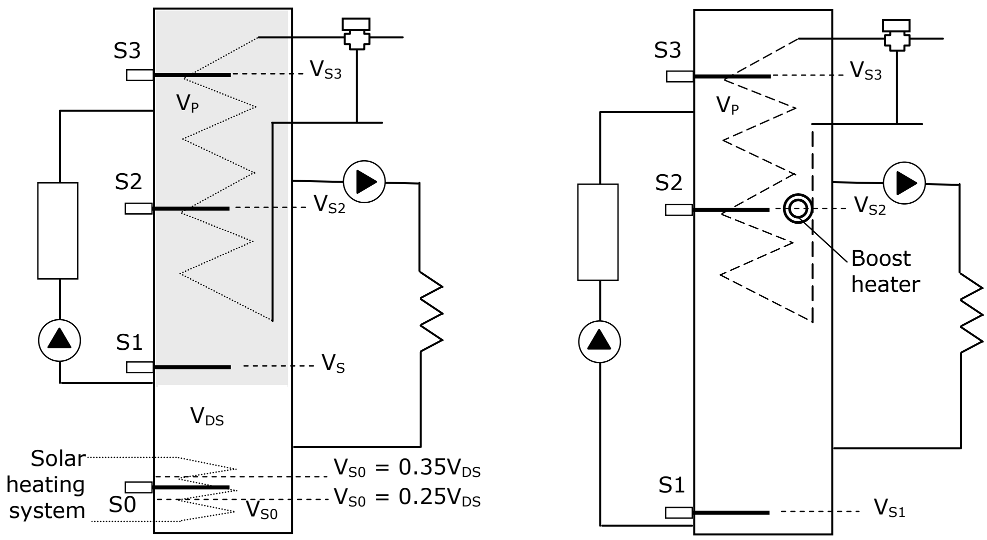


Figure 6.2:
Position of store temperature control thermostats or sensor pockets for solar thermal stores

6.6 HEAT PUMP THERMAL STORE THERMOSTAT/SENSOR POCKETS

6.6.1 This section only applies to the thermal stores designed for use with heat pumps.

6.6.2 The thermal stores designed for use with heat pumps should be fitted with at least 3 store thermostat or sensor pockets for controlling the heat pump and boost heater and their position should comply with equations 6.9, 6.10 and 6.11 unless specified by the heat pump manufacturer.

$0.05\ V_P \leq V_{S1} \leq 0.10V_P$ ..... [6.9]
$0.45\ V_P \leq V_{S2} \leq 0.55V_P$ ..... [6.10]
$0.75\ V_P \leq V_{S2} \leq 0.85V_P$ ….. [6.11]

Where: -

V_P = Nominal primary storage capacity of a thermal store (= V_T) [l]
V_{S1} = Volume of water in zone, Z_P, below store thermostat/sensor pocket, S1 [l]
V_{S2} = Volume of water below store thermostat/ sensor pocket, S2 [l]
V_{S3} = Volume of water below OH store thermostat/sensor pocket, S3 [l]

6.7 LABELLING OF CONNECTIONS

6.7.1 The thermal store should have clearly labelled connections where applicable.

6.7.2 Pictorial labelling of components is acceptable provided it is securely fixed to the thermal store.

6.8 SIZE AND TYPE OF CONNECTIONS

6.8.1 The thermal store pipe connections should be designed to minimise the heat losses from the thermal store.

6.8.2 The size of connections will depend upon the capacity and type of store and the size of heat loads connected to it. For standard products, normally 22mm for stores up to 180 litres, 28mm for stores up to 250 litres, 35mm for stores up to 500 litres will be adequate.

6.8.3 The sizes of connections and/or internal baffles should be designed to minimise the turbulence and mixing inside direct type of thermal stores.

6.9 DESCALING OF HOT WATER HEAT EXCHANGER

A means of de-scaling the hot water heat exchanger in the field must be provided and the procedure must be outlined in the design and installation manuals.

7. PERFORMANCE SPECIFICATION

7.1 DOMESTIC HOT WATER PERFORMANCE

7.1.1 General requirements

(a) The requirements of sections 7.1.2 and 7.1.4 apply to both the integrated thermal stores (*DITS* and *IDITS*) and the hot water thermal stores (*DHWTS* and *IDHWTS*) having forced or natural convection heat exchangers defined in section 3 of this document.

(b) The requirements of section 7.1.3 only apply to direct and indirect integrated thermal stores (*DITS* and *IDITS*).

(c) For both the individual dwellings and the group heating applications, the hot water test flow rates and the volume are related to the capacity of a thermal store, its operating conditions and application. The test procedures and the requirements are designed to reflect this.

(d) The hot water performance of thermal store should be measured at the test temperature, $T_{S\text{-}N}$, specified in tables 7.2 using test rig and test procedures set out in appendix A. The suggested test flow rates, F_{DHW}, are listed 7.1. The test flow rate used for quantifying the performance of the thermal store should be declared on the data badge and in the manual.

[***NOTE****: If necessary the hot water performance of the thermal store can be measured at different temperatures in addition to those listed in table 7.2, but this should be declared on the data badge and in the manuals etc.*]

Table 7.1: DHW default test flow rates, F_{DHW}, for measuring the hot water performance of a thermal store	
Storage volume, V_P (l)	DHW test flow rate, F_{DHW} (l/s)
≤ 100	0.15
101 – 250	0.21
251 - 350	0.35
351 - 500	0.50
> 500	0.75
V_P = Thermal store volume heated by the primary heat source	

Table 7.2: Default store charge temperature, $T_{S\text{-}N}$, measured by the temperature sensor, S_{T4}. for measuring the hot water performance of a thermal store	
Primary heat source type	$T_{S\text{-}N}$ (^oC)
Gas, oil or LPG boilers	75
Electric boiler, immersion heater	75
mCHP unit	70
Ground or air source heat pumps	60 & 65
Note : *The test temperatures have been selected to match the performance of the average heat source in each category without any modification.*	

7.1.2 **Hot water performance with dhw temperature control device and no space heating load [Test A1, Appendix A]**

(a) The hot water performance of a thermal store with the dhw temperature control device fitted and set at 55°C should be measured at the flow rate and charge temperature specified in tables 7.1 and 7.2 as per test A1 defined in appendix A.

(b) Following test A1, the following parameters should be calculated using procedures defined in sections A2.2 and A2.3 in appendix A1.

- The hot water draw-off volume, V_{HW-N}, at reference conditions
- The rating of the dhw heat exchanger, Q_{R-HW-N}, at the reference test conditions. (***Note:*** *This is an optional requirement*).

(c) In order to comply with this specification, the hot water draw-off volume, V_{HW-N}, should not be less than the values given in table 7.3.

(d) The hot water draw-off volume, V_{HW-N}, should be declared on the appliance data badge and the manuals.

(e) The hot water performance of the test appliance should be presented in the graphical form as shown in figure 7.1 inn the thermal store manuals.

Table 7.3 Minimum hot water volume acceptable for compliance

Storage volume, V_P (l)	Minimum V_{HW-N} acceptable	Minimum V_{HW-L} acceptable
	Test A1 – Section 7.1.2	Test A2 – Section 7.1.3
≤ 100	0.65 x V_P	0.50 x V_P
101 – 250	0.62 x V_P	0.48 x V_P
251 - 350	0.61 x V_P	0.47 x V_P
351 - 500	0.60 x V_P	0.47 x V_P
> 500	0.55 x V_P	0.45 x V_P
V_P = Thermal store volume heated by the primary heat source		

7.1.3 **Hot water performance with the dhw temperature control device fitted and with a simulated space heating load [Test A2, Appendix A]**

(a) This test only applies to integrated thermal stores (*DITS* and *IDTS*).

(b) The hot water performance of a thermal store with the dhw temperature control device fitted and set at 55°C should be measured at the flow rate specified in tables 7.1 as per test A2 defined in appendix A.

(c) Following test A2, the following parameters should be calculated using procedures defined in sections A3.2 in appendix A1.

- The hot water draw-off volume, V_{HW-L}, at reference conditions

(d) In order to comply with this specification, the dhw draw-off volume V_{HW-L}, should not be less than the values given in table 7.3.

(e) The hot water draw-off volume, V_{HW-L}, with the simulated space heating load, should be declared on the appliance data badge and the manuals.

(f) The hot water performance of the test appliance with the simulated space heating load should be presented in the graphical form as shown in figure 7.1 in the thermal store manuals.

Figure 7.1: Example of a dhw performance of a thermal store___

[Test flow rate = ___ l/s, Test store temperature = __ oC]

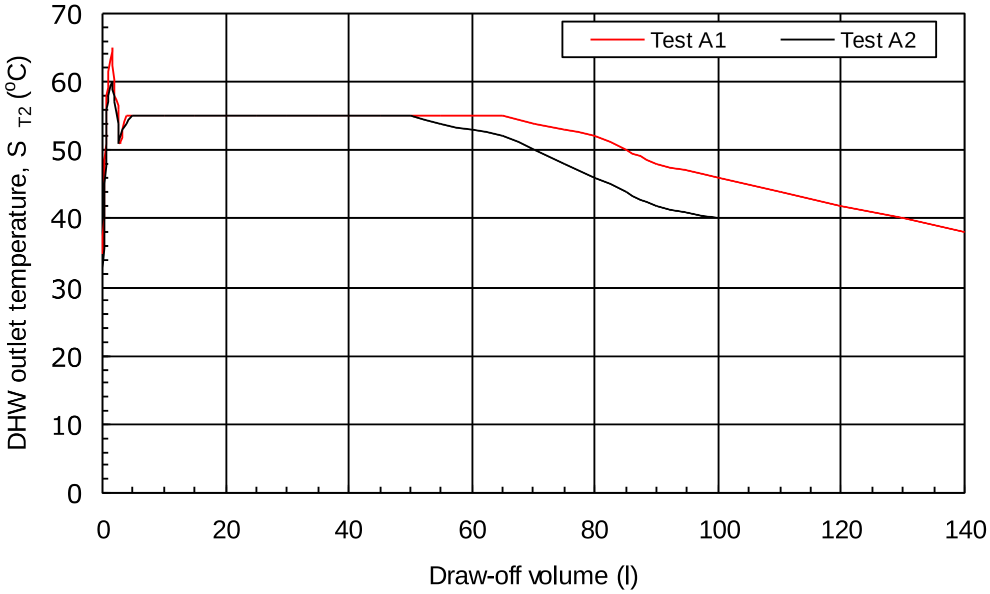
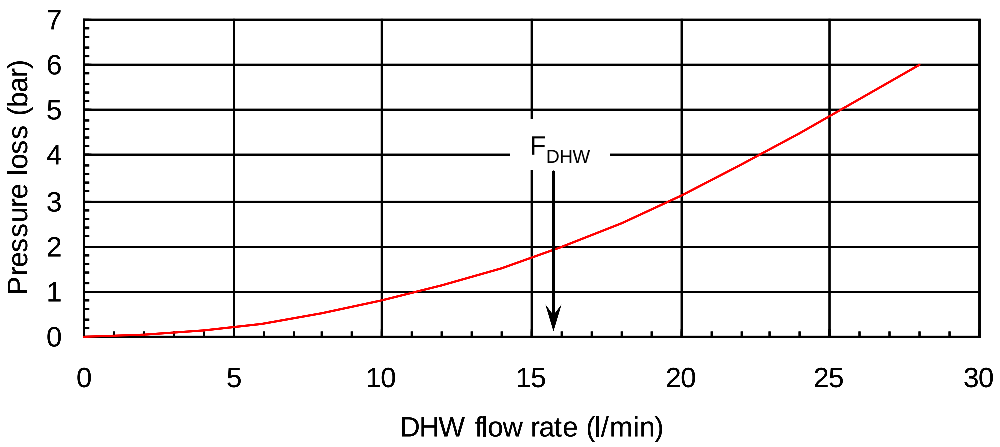


Figure 7.2: Example of pressure loss characteristics of a DHW heat exchanger of thermal store ______



7.1.4 Pressure loss characteristics of a DHW heat exchanger

(a) The pressure loss characteristics of the DHW heat exchanger should be measured using the test procedure A4 in appendix A.

(b) The pressure loss at the nominal test flow rate, F_{DHW}, should be declared on the data badge. The Full pressure flow characteristics of the DHW heat exchanger should be presented in the design manual in the format shown in figure 7.2.

(c) The maximum pressure loss through the dhw heat exchanger at the nominal test flow rate, F_{DHW}, should not be greater than 2.0 bar.

7.2 PERFORMANCE OF PRIMARY HEAT EXCHANGER

7.2.1 **General**

(a) The requirements of this section apply to indirect integrated thermal stores (*IDITS, IDITS-SOL*), indirect hot water thermal stores (*IDHWTS, IDHWTS-SOL*) and indirect buffer stores (*IDBS*).

(b) The performance of the primary heat exchanger is measured using the primary test flow rates listed in table 7.4 and using the test rig and the test procedures (test B1) defined in appendix B.

In this test the store temperature is raised from 35±1°C to 75±1°C by circulating pre-heated water at constant temperature of 82±1°C through the primary heat exchanger.

Table 7.4 : Primary heat exchanger test flow rates, F_{PHE}, for measuring the thermal rating of a primary heat exchanger in a thermal store	
Storage volume, V_P (l)	Primary circuit test flow rate (l/s)
≤ 100	0.15
101 – 250	0.25
251 - 350	0.30
351 - 500	0.35
> 500	0.45
V_P = Thermal store volume heated by the primary heat source	

(c) In a sealed primary heating system, the pressure relief valve is normally set at 3.0bar. Therefore, the maximum working pressure for the primary heat exchanger should not be less than 3.0bar.

7.2.2 **Thermal rating**

(a) The thermal rating of the primary heat exchanger, Q_{R-PHE}, measured using the test rig and test procedure described in appendix B, should not be less than the value given in table 7.5.

(b) The thermal rating of the primary heat exchanger, Q_{R-PHE}, should be declared on the appliance data badge and in the appliance manuals.

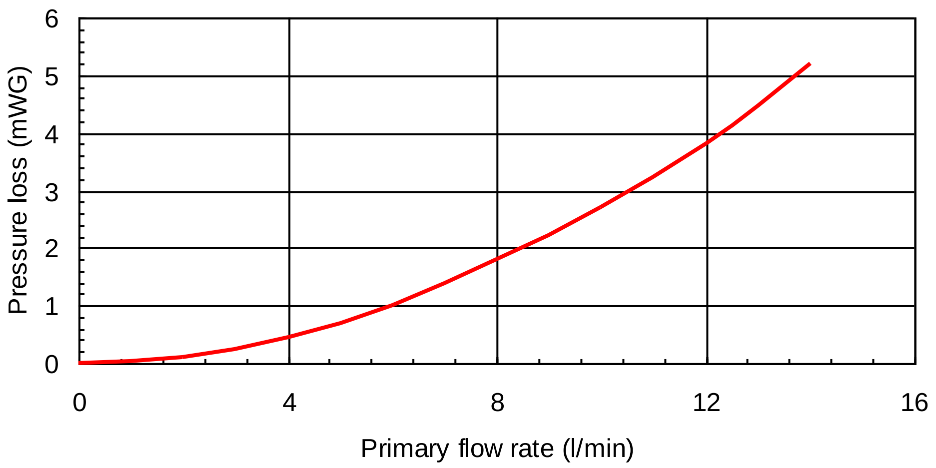
Table 7.5 Minimum rating of the primary heat exchanger, $Q_{R\text{-}PHE}$	
Storage volume, V_P (l)	$Q_{R\text{-}PHE}$ (kW)
≤ 100	15
101 – 200	20
201 - 300	30
302 – 400	35
401 – 500	40
> 500	45
V_P = Thermal store volume heated by the primary heat source	

7.2.3 **Pressure loss characteristics**

(a) The pressure loss characteristics of the primary heat exchanger should be measured using the test B2 procedure in appendix B.

(b) The pressure loss at the nominal test flow rate, F_{PHE}' should be declared on the data badge and the full pressure flow characteristics of the primary heat exchanger should be presented in the design manual in the format shown in figure 7.3.

Figure 7.3 : Example of pressure loss characteristics of a primary heat exchanger [Model: ____]



7.3 PERFORMANCE OF SOLAR HEAT EXCHANGER

7.3.1 **General**

(a) The requirements of this section apply to integrated thermal stores (*DITS-SOL*) and hot water solar thermal stores (*DHWTS-SOL*) designed for solar thermal heating systems.

(b) The performance of the solar heat exchanger is measured using the solar circuit test flow rates listed in table 7.6 and using the test rig and the test procedures (test B3) defined in appendix B.

In this test, the store temperature is raised from 35±1°C to 60±1°C by circulating pre-heated water at constant temperature of 70±1°C through the primary heat exchanger.

(c) In a sealed solar heating circuit, the pressure relief valve is normally set at 6.0bar. Therefore, if the solar heat exchanger is designed for this application, then the maximum working pressure for the primary heat exchanger should not be less than 6.0bar.

Table 7.6 : Solar heat exchanger test flow rates, F_{SHE}, for measuring the thermal rating of a solar heat exchanger in a thermal store	
Dedicated solar volume, V_{DS} (l)	Solar circuit test flow rate (l/s)
≤ 50	0.05
51 – 100	0.10
101 - 150	0.15
> 150	0.25
V_T = Total volume of a thermal store V_{DS} = Dedicated solar volume of a thermal store	
Note: *For most solar thermal stores currently in the market, the ratio* $V_D/V_T \approx 0.3$	

7.3.2 Thermal rating

(a) The thermal rating of the solar heat exchanger, Q_{R-SHE}, measured using the test procedure described in appendix B, should not be less than the value given in table 7.7.

(b) The thermal rating of the solar heat exchanger, Q_{R-SHE}, and the surface area of the solar heat exchanger, A_{SHE}, should be declared on the appliance data badge and in the appliance manuals.

(c) 'The Domestic Heating Compliance Guide, May 2006' also specifies the requirements for the solar heat exchanger for compliance with the Building Regulations 200, Approved Document L1 (2006 edition). To comply with the Building Regulations, the solar heat exchanger should also meet the following requirements : -

- If $F_{SOL} \geq 0.5$ l/min per m^2 of net collector area, then, $A_{SOL-HE} \geq 0.2 \times A_{SC}$
- If $F_{SOL} < 0.5$ l/min per m^2 of net collector area, then, $A_{SOL-HE} \geq 0.1 \times A_{SC}$

Where: -

F_{SOL} = Solar circuit flow rate [l/min]
A_{SOL-HE} = Surface area of the solar heat exchanger [m^2]
A_{SC} = Net surface area of the solar collector specified for the store [m^2]

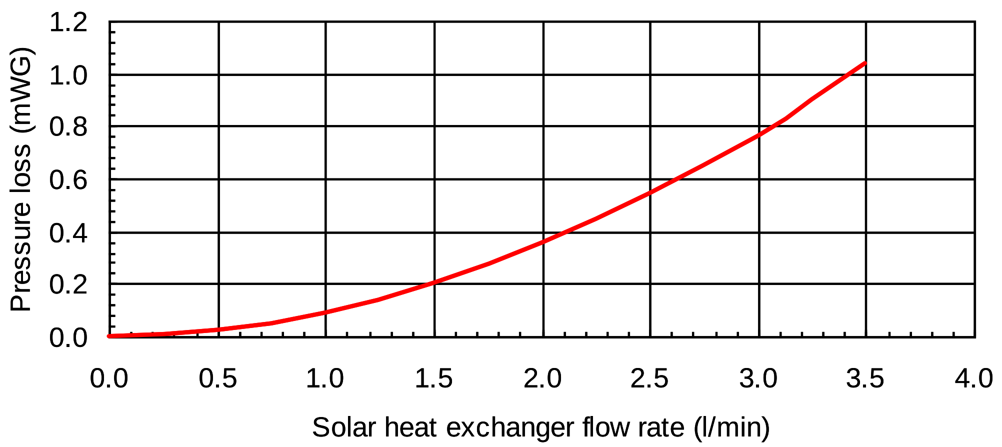
Table 7.7 Minimum rating of the solar heat exchanger, Q_{R-SHE}	
Total storage volume, V_{DS} (l)	Q_{R-SHE} (kW)
≤50	5.0
51 - 100	8.0
101 – 150	12.0
> 150	18.0
V_{DS} = Dedicated solar volume of a thermal store	

7.3.3 **Pressure loss characteristics**

(a) The pressure loss characteristics of the solar heat exchanger should be measured using the test B4 procedure in appendix B.

(b) The pressure loss at the nominal test flow rate, F_{SHE}' should be declared on the data badge and the full pressure flow characteristics of the primary heat exchanger should be presented in the design manual in the format shown in figure 7.4.

Figure 7.4 : Example of pressure loss characteristics of a solar heat exchanger



7.4 STANDBY HEAT LOSS RATE

7.4.1 **Heat loss requirements**

(a) This section applies to all types of thermal stores including buffer stores.

(b) The standby heat loss rate, Q_{HL}, should be measured using the test procedures and the test rig defined in appendix C of this document.

(c) For new built dwellings, the measured heat loss rate, Q_{HL}, should not be greater than the value, Q_{HL-MAX}, given by equation 7.1. This applies to all primary heat source fuel types (e.g. gas, electricity etc.).

(d) For the retro-fit dwellings, the measured heat loss rate, Q_{HL}, for thermal stores heated by electricity (i.e. where electricity is the primary fuel) should not be greater than the value, Q_{HL-MAX}, given by equation 7.1.

(e) For the retro-fit dwellings, the measured heat loss rate, Q_{HL}, for thermal stores heated by other (i.e. not electricity) should not be greater than the value, Q_{HL-MAX}, given by equation 7.2.

$$Q_{HL-MAX} = 1.28 \times [0.2 + (0.051 \times (V_T)^{2/3})] \qquad \text{----- [7.1]}$$

$$Q_{HL-MAX} = 1.6 \times [0.2 + (0.051 \times (V_T)^{2/3})] \qquad \text{----- [7.2]}$$

Where: -

Q_{HL-MAX} = Maximum permitted heat loss from a thermal store, [kWh/24h]
V_T = Total storage capacity of a thermal store, [l]

Notes:

(i) This figure should be regarded as an absolute maximum and efforts should be made to reduce it.

(ii) The actual measured value shall be declared on the data badge in the coded form and also in the appliance manuals etc.

7.4.2 Heat loss rate for SAP calculations

The In-Use heat losses from thermal stores will be less than the measured values (see 7.4.1. This is because:-

(a) The thermal stores are normally installed in airing cupboards like a conventional cylinder. Therefore, the ambient temperature will be higher than 20°C specified for the test procedures and therefore the heat losses will be lower.

(b) The thermal storage systems are now being installed with two channel programmers for controlling both space heating and hot water. Therefore, the thermal store is not maintained at nominal maximum temperature of 75°C. When the boiler is not charging the thermal store, it will provide 40-50% of hot water demands in a dwelling resulting in a significantly lower 24h mean store temperature.

(c) The field studies have shown that the usage pattern of thermal storage heating systems is similar to that for conventional systems.

(d) Unlike the integrated thermal stores, the hot water only thermal stores are not maintained at high temperature when space heating is on. Therefore its 24h average heat loss is lower than ITS.

The heat loss factors for Hot Water Only and Integrated Thermal Stores (HWTS and ITS) for use in SAP procedures must be calculated using appropriate equations as detailed in the separate loose sheet contained at the back of this document.

7.5 WATER TEMPERATURE IN AN INTEGRATED FEED AND EXPANSION CISTERN

7.5.1 This section applies to all thermal stores fitted with an integral feed and expansion tank. The 24-hour average temperature of water in the feed and expansion tank during the heat loss measurements (see appendix C).

7.5.2 The measured average temperature of the water in the feed and expansion tank should not exceed 38°C.

7.5.3 The design of the feed and expansion tank, the lid and the overflow pipe connection (e.g. dipped) should be such that the water loss due to evaporation is minimised.

8. SPECIFICATION OF COMPONENTS

8.1 GENERAL

All types of thermal stores can either be supplied with all the components ready fitted and wired or full wiring and system configuration details, and the list of recommended components (e.g. pumps, delay timers) should be provided in the design and installation manuals.

8.2 STORE THERMOSTAT(S) FOR CONTROLLING PRIMARY HEAT SOURCE

8.2.1 The specified store thermostat setting for controlling the primary heat source should prevent unnecessary cycling of the heat source (e.g. the boiler) on its internal thermostat for efficient operation.

8.2.2 All types of thermal stores must be supplied with one or more thermostats or electronic controls with an adjustable range of up to 90°C and span not greater than 70°C. The switching differential of the thermostat should be 6±1°C.

8.2.3 A strap on surface cylinder thermostat is not considered suitable for this application.

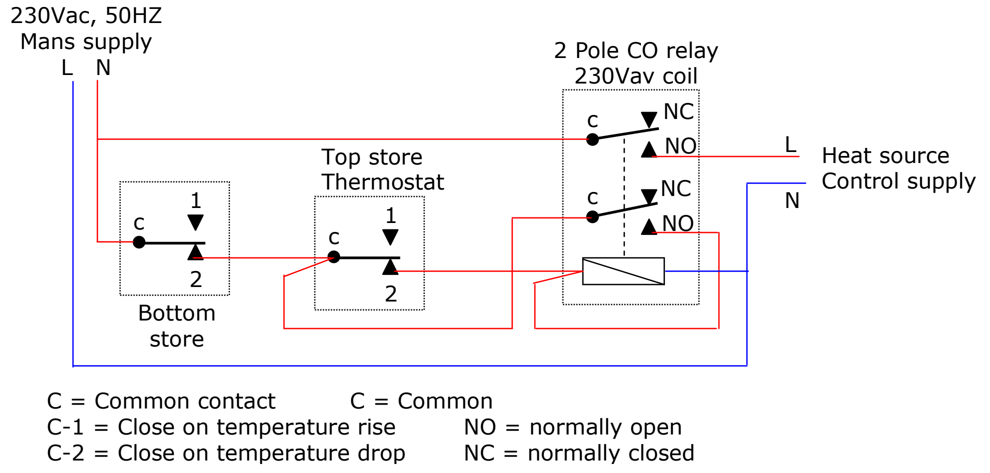


Figure 8.1 : Example of twin thermostat control circuit wiring for thermal stores

8.2.4 The store control thermostats should be either:-

(a) Non-user adjustable and pre-set to switch off at the specified temperature to guarantee the performance.

OR

(b) Capable of being locked in the correct user zone and should switch off at the specified temperatures within the zone to guarantee the performance.

8.2.5 For improved utilisation of thermal store and lower in-use system losses, it is recommended that the thermal stores of capacity greater than 250 litres can be fitted with two thermostats and wired as shown in figure 8.1 to control the operation of heat source (e.g. a boiler) or a store charge control zone valve.

8.3 DOMESTIC HOT WATER BACK EXPANSION

8.3.1 All types of integrated thermal stores (*ITS*) and hot water thermal stores (*HWTS*) must be supplied with a suitable expansion vessel for the domestic hot water heat exchanger if necessary or a correct type and size should be specified in the installation manual.

8.3.2 This expansion vessel is required to accommodate the expansion of water (due to heating) in the heat exchanger because expansion back in to the mains may not always be possible. (For example, a double check valve may be fitted in the mains supply).

8.3.3 The method and equipment provided or specified for accommodating the expansion must comply with the Model Water Bylaws and relevant standards.

8.4 HOT WATER TEMPERATURE CONTROL DEVICE

8.4.1 All types of integrated thermal stores (*ITS*) and hot water thermal stores (*HWTS*) must be supplied with a domestic hot water outlet temperature regulating device to prevent a hot slug reaching the hot water outlets.

8.4.2 The performance of the hot water temperature control device must meet the requirements of section 7.1.2.

8.5 PUMP OVER-RUN CONTROL

8.5.1 If an integrated thermal store intended for an individual dwelling is used with a boiler that requires pump over-run, then it must be supplied with a suitable additional pump over-run delay timer or similar device.

8.5.2 The normal boiler flow temperature sensing thermostat used in majority of boilers to control the pump over-run is not suitable for this application.

8.5.3 Integrated thermal stores for group heating applications do not require a pump over-run delay timer.

8.6 ANTI-VACUUM AND AIR RELEASE VALVE(S)

8.6.1 Normally, direct integrated thermal stores (*DITS*) and direct hot water thermal stores (*DHWTS*) are not recommended for group heating schemes without an external heat exchanger. However if these are used in a group heating scheme, then, they must have connections for fitting an air vent and anti-vacuum valves. These items must be supplied with the store.

8.6.2 Indirect integrated and hot water thermal stores (*IDITS* and *IDHWTS*) may be supplied without these devices.

8.7 CHARGE CONTROL VALVE

8.7.1 An integrated thermal store (*DITS* and *IDITS*) that is intended for group heating scheme must be supplied with either a 2-port motorised zone valve or a 3-port diverter valve controlled by the store thermostats.

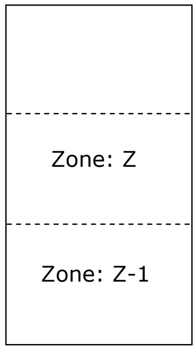
8.7.2 The performance specification of this valve e.g. maximum working pressure differential and flow rate must be included in the installation and design instructions.

8.8 METERING SYSTEMS

8.8.1 Unless the customer specifies otherwise, a thermal store that is intended for a group-heating scheme must either be supplied with a metering system or a suitable system should be specified for apportioning the running costs

9. ENERGY STORAGE CAPACITY, Q_{ST-Z}, & EQUIVALENT VOLUME, V_{EZ}, CALCULATION METHODS

When the thermal store is in dynamic mode, the temperature in zone, *Z*, will cycle between upper and lower limits (say T_{Z1} and T_{Z0}). For example, a boiler may heat the zone, Z, to 80°C and then when the central heating is switched on and the cold water from the radiators is returned to zone, Z, its temperature may drop to 30°C.



9.1 ZONE WITH WATER ONLY AS ENERGY STORAGE MEDIA

If a zone, Z, in a thermal store only contains water, then its thermal energy storage capacity and the equivalent volume can be calculated using equations 9.1 and 9.2.

$$Q_{ST-Z} = [V_Z \, \rho_{AZ} \, C_{P-WAZ} \, (T_{Z1} - T_{Z0})] \, / \, 1000 \quad \text{-----} \quad [9.1]$$
$$V_{EZ} = V_Z \quad \text{-----} \quad [9.2]$$

Where: -

Q_{ST-Z}	= Energy storage capacity of zone, Z,	[kJ]
V_Z	= Capacity i.e. volume of water in zone, Z,	[l]
V_{EZ}	= Equivalent volume of water (i.e. capacity) of the zone	[l]
ρ_{AZ}	= Average density of water in zone, Z,	[kg/l]
C_{P-WAZ}	= Average specific heat of water in zone, Z,	[J/kgK]
T_{Z1}	= Upper temperature limit for zone, Z,	[°C]
T_{Z0}	= Lower temperature limit for zone, Z,	[°C]

9.2 ZONE WITH WATER AND PCM AS ENERGY STORAGE MEDIA

If the zone, Z, contains mixture of water and phase change material (PCM), then its thermal energy storage capacity, Q_{ST-Z}, and its equivalent volume, V_{EZ}, can be calculated using equations 9.3 – 9.6. In this case, the volume of water and the PCM has been assumed to be, V_{ZW}, and V_{PCM-Z}, respectively. The mass of the PCM material in this zone is, M_{PCM-Z}, and occupies the volume, V_{PCM-Z}.

$$Q_{ST-W} = [V_{ZW} \, \rho_{AZ} \, C_{P-WAZ} \, (T_{Z1} - T_{Z0})] \, /1000 \quad \text{----} \quad [\ 9.3\ ]$$
$$Q_{ST-PCM} = M_{PCM-Z} \, [L_H + C_{P-PCM-S} \, (T_{PCM} - T_{Z0}) + C_{P-PCM-L} \, (T_{Z1} - T_{PCM})]/1000 \quad \text{----} \quad [\ 9.4\ ]$$
$$Q_{ST-Z} = (Q_{ST-W} + Q_{ST-PCM}) \quad \text{----} \quad [\ 9.5\ ]$$
$$V_{EZ} = V_{ZW} + V_{PCM-Z} \, (Q_{ST-PCM} \, / \, (V_{PCM-Z} \, \rho_{AZ} \, C_{P-WAZ} \, (T_{Z1} - T_{Z0})/1000)) \quad \text{----} \quad [\ 9.6\ ]$$

Where: -

Q_{ST-W}	= Energy storage capacity of water in zone, Z	[J]
Q_{ST-PCM}	= Energy storage capacity of PCM in zone, Z,	[J]
Q_{ST-Z}	= Total energy storage capacity of zone, Z,	[kJ]
V_{ZW}	= Volume of water in zone, Z	[l]
V_{PCM-Z}	= Volume of the PCM in zone, Z	[l]
M_{PCM-Z}	= Mass of PCM in zone, Z,	[kg]
ρ_{AZ}	= Average density of water in zone, Z,	[kg/l]
C_{P-WAZ}	= Average specific heat of water in zone, Z,	[J/kgK]
$C_{P-PCM-S}$	= Specific heat of PCM in solid phase	[J/kgK]
$C_{P-PCM-L}$	= Specific heat of PCM in liquid phase	[J/kgK]
L_H	= Latent heat of PCM	[J/kg]

T_{Z1} = Upper temperature limit for zone, Z, [^oC]
T_{Z0} = Lower temperature limit for zone, Z, [^oC]
T_{PCM} = Phase change temperature of PCM [^oC]

9.3 EXAMPLE

A store zone, Z, contains PCM and it has the following functional, construction and storage media parameters: -

Lower operating cycle temperature,	T_{Z0}	=	40.0	^oC
Upper operating cycle temperature,	T_{Z1}	=	75.0	^oC
Volume of PCM in zone, Z	V_{PCM-Z}	=	25.0	l
Mass of PCM	M_{PCM-Z}	=	35.0	kg
PCM phase change temperature	T_{PCM}	=	65	^oC
Volume of water in zone, Z	V_{ZW}	=	25.0	l
Average density of water	ρ_{AZ}	=	0.992	kg/l
Average specific heat of water	C_{P-WAZ}	=	4,187	J/kg^oC
Average specific heat of PCM - Solid	$C_{P-PCM-S}$	=	2,000	J/kg^oC
Average specific heat of PCM – Liquid	$C_{P-PCM-S}$	=	2,000	J/kg^oC
Latent heat of PCM	L_H	=	250,000	J/kg

(1) Energy storage capacity of zone without PCM [Using equation 9.1]

$$Q_{ST-Z} = [(V_{ZW} + V_{PCM-Z})\ \rho_{AZ}\ C_{P-WAZ}\ (T_{Z1} - T_{Z0})] / 1000$$
$$= [(25.0 + 25.0) \times 0.992 \times 4187.0 \times (75.0 - 40.0)/1000$$
$$= 7268.63 \text{ kJ}$$
$$= 2.02 \text{ kWh}$$

(2) Equivalent volume of zone without PCM [Using equation 9.2]

$$V_{EZ} = (V_{ZW} + V_{PCM-Z}) = 50.0 \text{ l}$$

(3) Energy storage capacity of zone with PCM [Using equations 9.3 – 9.6]

$$Q_{ST-W} = V_{ZW}\ \rho_{AZ}\ (T_{Z1} - T_{Z0})/1000$$
$$= 25.0 \times 0.992 \times 4187.0 \times (75.0 - 40.0)$$
$$= 3{,}634.32 \text{ kJ}$$

$$Q_{ST-PCM} = M_{PCM-Z}\ [L_H + C_{P-PCM-S}\ (T_{PCM} - T_{Z0}) + C_{P-PCM-L}\ (T_{Z1} - T_{PCM})]/1000$$
$$= 35.0[250000.0 + 2000.0(65 - 40) + 2000.0(75 - 65)]/1000$$
$$= 11{,}200.00 \text{ kJ}$$

$$Q_{ST-Z} = Q_{ST-W} + Q_{ST-PCM}$$
$$= 3{,}634.32 + 11{,}200.00$$
$$= 14{,}834.32 \text{ kJ}$$
$$= 4.12 \text{ kWh}$$

(4) Equivalent volume of zone with PCM

$$V_{EZ} = V_{ZW} + V_{PCM-Z}\ (Q_{ST-PCM} / (V_{PCM-Z}\ \rho_{AZ}\ C_{P-WAZ}\ (T_{Z1} - T_{Z0})))$$
$$= 25.0 + 25.0 \times (11{,}200 / (25 \times 0.992 \times 4187.0 \times (75.0 - 40.0)/1000))$$
$$= 25.0 + 25.0 \times (11{,}200 / 3{,}634.32)$$
$$= 25.0 + 77.0 \quad = 102.0 \text{ litres}$$

Note:
Therefore, the effective volume of zone, Z, with PCM is equivalent to 102.0 litres of water storage capacity i.e. the use of PCM in this example doubles storage capacity of this zone.

APPENDIX: A

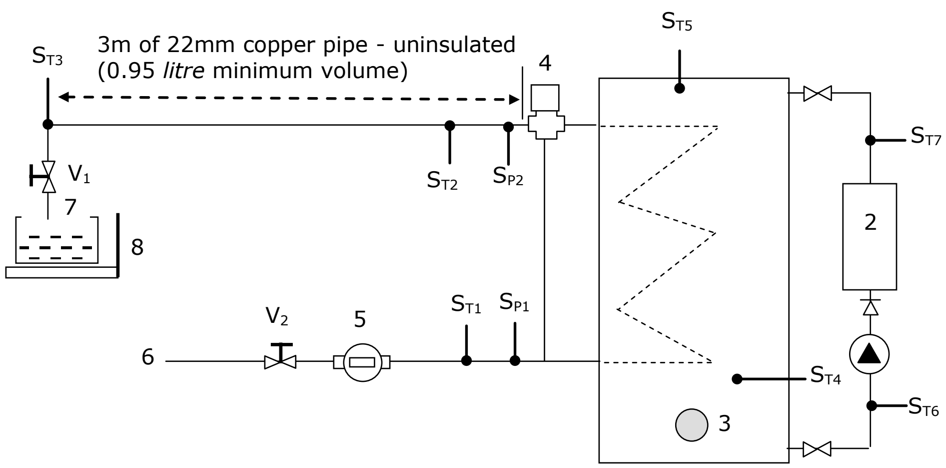
TEST RIG AND TEST PROCEDURES FOR EVALUATING THE PERFORMANCE OF AN INTERNAL AND AN EXTERNAL HOT WATER HEAT EXCHANGER OF *DITS, IDITS, DHWTS AND IDHWTS*

A.1 TEST RIG AND TEST CONDITIONS

A.1.1 The schematic layout of the test rig for determining the hot water performance of direct and indirect integrated and hot water thermal stores (*DITS, IDITS, DHWTS and IDHWTS*) is shown in figure A1. *[Note: Temperatures t1, t2 …. t7 are measured by temperature sensors, ST1, ST2 … ST7 respectively]*

A.1.2 Either a gas boiler or an in-line electric heater is connected to the primary heat source connections of the test sample so that the volume, V_P, in a thermal store can be heated. The flow rate in the heating circuit is adjusted to give temperature difference of 5±1°C across the heater (i.e. t6 – t7) during the heating cycle to ensure uniform heating of the thermal store from top to bottom.

Figure A1 : Test rig for measuring the hot water performance of a thermal store



1 Thermal store under test
2 Gas or electric boiler for heating a thermal store
3 Immersion heater for heating a thermal store (Alternative method)
4 Hot water temperature control device e.g. thermostatic mixing valve
5 Volume flow rate meter – Should be calibrated and certified
6 Cold water inlet at 10±1°C
7 Volume measurement (An alternative method)
8 Weighing machine (Alternative method
V_1 On-Off valve
V_2 Regulating valve
S_{T1} … S_{T7} Temperature sensors immersed in water
S_{P1} … S_{P2} Pressure sensors/gauges

A.1.3 Alternatively, an immersion heater may be used to heat the thermal store but in this case the volume heated by it should not be greater than, V_P, heated by the primary heat source in normal operation

A.1.4 Calibrated pressure transducers or pressure gauges (SP1 and SP2) or a manometer may be used for measuring the pressure drop across the domestic hot water heat exchanger fitted with temperature control device as shown in figure A1 provided tolerances set out in A1.10 can be met.

A.1.5 Although the cold water inlet temperature, t1, during a test can be allowed to vary between 9°C and 11°C, the average temperature over a complete draw-off should be $10^{\pm}0.5$°C.

A.1.6 The dhw flow rate used for determining the hot water performance of a thermal store depends upon the declared volume, V_P, of a thermal store. The flow rates to be used for these tests are listed in table A1.

Table A1 : DHW performance default test flow rates, F_{DHW}, for measuring the hot water performance of a thermal store	
Storage volume, V_P (l)	DHW test flow rate (l/s)
≤ 100	0.15
101 – 250	0.21
251 - 350	0.35
351 - 500	0.50
> 500	0.75
V_P = Thermal store volume heated by the primary heat source	

A.1.7 The hot water performance of the dhw heat exchanger in a thermal store is measured at its nominal operating temperature, T_{S-N}, defined in table A2. When carrying out the domestic hot water performance tests, the store is heated to the test temperature, T_{S-N}, measured by the temperature sensor, S_{T4}.

Table A2 : Default store charge temperature, T_{S-N}, measured by the temperature sensor, S_{T4}. for measuring the hot water performance of a thermal store	
Primary heat source type	T_{S-N} (°C)
Gas, oil or LPG boilers	75
Electric boiler, immersion heater	75
mCHP unit	70
Ground or air source heat pump	65 & 60
Note : *The test temperatures have been selected to match the performance of the average heat source in each category without any modification.*	

A.1.8 The maximum uncertainty in the measurement of water temperature should not exceed $^{\pm}0.5$°C and the location of the temperature sensors (figure A1) should be: -

(a) S_{T1} : Cold water inlet – The pipe work between the sensor, S_{T1}, and the thermal store should be insulated.
(b) S_{T2} : Hot water outlet immediately after the dhw temperature control device.
(c) S_{T3} : Hot water outlet temperature at the end of an unisulated draw-off pipe
(d) S_{T4} : Lower primary heat source control thermostat/sensor pocket.

(e) S_{T5} : Inside the thermal store approximately 25mm below the dome of the storage vessel or below the water level in the vessel.
(f) S_{T6} : External heating source return temperature
(g) S_{T7} : External heating source flow temperature

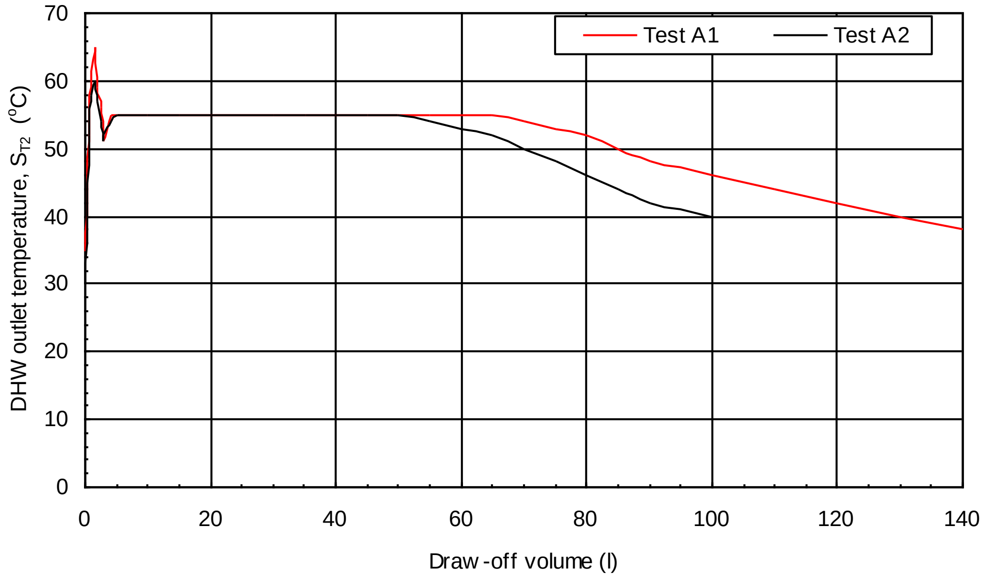
A.1.9 The maximum uncertainty in the measurement of the draw-off volume and the draw-off flow rate should not exceed $\pm$0.5 litres/minute respectively.

A.1.10 The maximum uncertainty in the measurement of pressure drop across the heat exchanger should not exceed 3% of the measured value.

A.1.11 The hot water performance of the thermal store should be presented in the graphical form as shown in figure A2.

Figure A2: Example of a dhw performance of a thermal store___

[Test flow rate = ___ l/s, Test store temperature = __ °C]



A.2 TEST_A1: DHW PERFORMANCE WITH DHW TEMPERATURE CONTROL DEVICE FITTED AND NO SIMULATED SPACE HEATING LOAD

The object of this test is to determine the hot water performance of a thermal store complete with a dhw temperature regulating device (e.g. thermostatic mixing valve) and with no simulated design space heating load.

This test applies to the following thermal stores fitted with all types of domestic hot water heat exchangers:-

- Direct and indirect integrated thermal stores (DITS, IDITS)
- Direct and indirect hot water thermal store (DHWTS, IDHWTS)

A.2.1 Test procedure

A.2.1.1 Before carrying out the hot water draw-off test, the thermal store under test is heated until the temperature measured by sensor S_{T4} reaches reference test temperature, $T_{S\text{-}N} \pm 0.5^{o}C$ (see table A2).

A.2.1.2 When the temperature measured by the store sensor, S_{T4}, reaches $T_{S\text{-}N} \pm 0.5^{o}C$, both the heat source, 2, and its circulating pump are switched off.

A.2.1.3 The hot water draw-off tests with the dhw temperature control device set at $55\pm1^{o}C$ should be carried out at flow rate specified in table A1.

A.2.1.4 The cold water inlet temperature, T_{S1}, and the hot water outlet temperatures, T_{S2} and T_{S3} and the flow rate, F_{CW}, shall be continuously recorded at intervals not greater than 10 seconds during a test so that the average temperatures can be calculated to an accuracy of $\pm 0.5^{o}C$.

A.2.1.5 The hot water draw-off should be started 1 minutes after the store charge cycle has been completed and should continue until the dhw outlet temperature measured by sensor, T_{S2}, drops to $40^{o}C$.

A.2.1.6 Calculate the average cold water inlet temperature, T_{ACW}, the average hot water outlet temperatures, $T_{AHW\text{-}1}$, and $T_{AHW\text{-}2}$ from the temperature recordings of sensors, T_{S1}, T_{S2} and T_{S3} respectively.

Calculate the hot water draw-off volume, $V_{HW\text{-}A1}$ and the average hot water draw-off rate, $F_{A\text{-}A1}$ using the flow rate measured by sensor F_{CW} and recorded during the test run.

Alternatively, the hot water draw-off volume, $V_{HW\text{-}A1}$ and the average hot water flow rate, $F_{A\text{-}A1}$ can be measured using a weighing machine and a timer.

A.2.1.7 If the average flow rate, $F_{A\text{-}A1}$, is less than the appropriate test flow rate, F_{DHW}, listed in table A1, then the test should be repeated.

A.2.2 Power rating of the DHW heat (Optional)

A.2.2.1 The power rating of the DHW heat exchanger at the specified flow rate, F_{DHW}, should be calculated using equation a6 and the data measured during test A2.1.

A.2.2.2 The DHW heat exchanger rating, $Q_{R\text{-}HW}$, should be declared on the 'data badge' and in the appliance design and installation manual.

$$Q_{R\text{-}HW} = [C_{P1} \times \rho_1 \times F_A \times (T_{AHW} - T_{ACW})]/1000 \qquad \text{----} \quad [\text{ a6 }]$$

Where:-

$Q_{R\text{-}DHW}$	= Power rating of the DHW heat exchanger,	[kW]
C_{P1}	= Average specific heat of water (10 – 55°C),	[kJ/kg°C]
P_1	= Density of water at 10°C,	[kg/m^3]
F_A	= Average hot water flow rate,	[l/s]
T_{AHW}	= Average hot water outlet temperature,	[°C]
T_{ACW}	= Average cold water inlet temperature,	[°C]

A.3 TEST A2 : DHW PERFORMANCE WITH DHW TEMPERATURE CONTROL DEVICE AND WITH SIMULATED SPACE HEATING LOAD

A.3.1 Description

A.3.1.1 The object of this test is to determine the DHW performance of the thermal store when the space heating is switched on and the space heating pump is cycling on the room thermostat i.e. winter operation.

Under these conditions, the hot water in the bottom of the thermal store is periodically replaced by the cold water from the space heating circuit (e.g. radiators) and thus reducing the average temperature of the water in the thermal store.

A.3.1.2 This test only applies to the Direct and Indirect integrated thermal stores (*DITS and IDITS*).

A.3.1.3 The store charge temperature, $T_{SC\text{-}A3}$, for this test should be calculated using equation a7.

$$T_{SC\text{-}A3} = [T_{S\text{-}N}\,(0.75V_P - 45) + 50(45 + 0.25V_P)] / V_P \qquad \text{-----}\ [\ a7\ ]$$

Where: -

$T_{SC\text{-}A3}$	= Store charge temperature for test A3,	[°C]
$T_{S\text{-}N}$	= Store charge temperature used for test A2	[°C]
V_P	= Store volume heated by main i.e. primary heat source,	[l]

A.3.2 Test procedure

A.3.2.1 The test procedure is the same as for test A1 described in section A2 but before a hot water test is started, the thermal store is charged to calculated temperature, $T_{SC\text{-}A3}$.

A.3.2.2 Before carrying out the hot water draw-off test, the thermal store under test is heated until the temperature measured by sensor T_{S4} reaches $T_{SC\text{-}A3} \pm 0.5^{o}C$.

A.3.2.3 When the temperature, T_{S4}, reaches $T_{SC\text{-}A3} \pm 0.5^{o}C$, both the heat source, H_1, and the circulating pump, P_1, are switched off.

A.3.2.4 The hot water draw-off tests with the dhw temperature control device set at $55 \pm 1^{o}C$ should be carried out at flow rate specified in table A1.

A.3.2.5 The cold water inlet temperature, T_{S1}, and the hot water outlet temperatures, T_{S2} and T_{S3} and the flow rate, F_{CW}, shall be continuously recorded at intervals not greater than 10 seconds during a test so that the average temperatures can be calculated to an accuracy of $\pm 0.5^{o}C$.

A.3.2.6 The hot water draw-off should be started 1 minutes after the store charge cycle has been completed and should continue until the dhw outlet temperature measured by sensor, T_{S2}, drops to $40^{o}C$.

A.3.2.7 Calculate the average cold water inlet temperature, T_{ACW}, the average hot water outlet temperatures, $T_{AHW\text{-}1}$, and $T_{AHW\text{-}2}$ from the temperature recordings of sensors, T_{S1}, T_{S2} and T_{S3} respectively.

Calculate the hot water draw-off volume, V_{WH-A1} and the average hot water draw-off rate, F_{A-A1} using the flow rate measured by sensor F_{CW} and recorded during the test run.

Alternatively, the hot water draw-off volume, V_{WH-A3} and the average hot water flow rate, F_{A-A1} can be measured using a weighing machine and a timer.

A.3.2.8 If the average flow rate, F_{A-A1}, is less than the appropriate test flow rate, F_{DHW}, listed in table A1, then the test should be repeated.

A.3.2.9 The dhw draw-off volume, V_{HW-2}, should be declared on the appliance data badge and in the appliance design and installation manuals

A.4 TEST A3 : PRESSURE LOSS CHARACTERISTICS OF DHW HEAT EXCHANGER

A.4.1.1 This test applies to the following thermal stores fitted with all types of domestic hot water heat exchangers:-

- *Direct and indirect integrated thermal stores (DITS, IDITS)*
- *Direct and indirect hot water thermal stores (DHWTS, IDHWTS)*

A.4.1.2 The pressure loss across the hot water heat exchanger should be measured with the inline temperature control device (e.g. thermostatic mixing valve) fitted at set at 55^{o}C and when the store temperature is cold i.e. with no significant extraction of heat.

A.4.1.3 The cold water inlet temperature should be 10$^{\pm}$0.5^{o}C.

A.4.1.4 The pressure loss should be measured at the following flow rates. F_{DHW}, is the nominal domestic hot water test flow rate for the thermal store under test (see table A1).

- 0.5 x F_{DHW}
- 0.75 x F_{DHW}
- F_{DHW}
- 1.10 x F_{DHW}
- 1.25 x F_{DHW}

A.4.1.5 The data should be presented in the design and installation manual in a graphical form as shown in figure 7.2 in section 7. and the pressure loss at nominal flow rate, F_{DHW}, should be declared on a thermal store 'data badge'.

APPENDIX : B

TEST RIG AND THE TEST PROCEDURES FOR EVALUATING THE THERMAL PERFORMANCE AND RATING OF THE PRIMARY AND THE SOLAR HEAT EXCHANGERS IN THERMAL STORES

B.1 TEST RIG AND TEST CONDITIONS

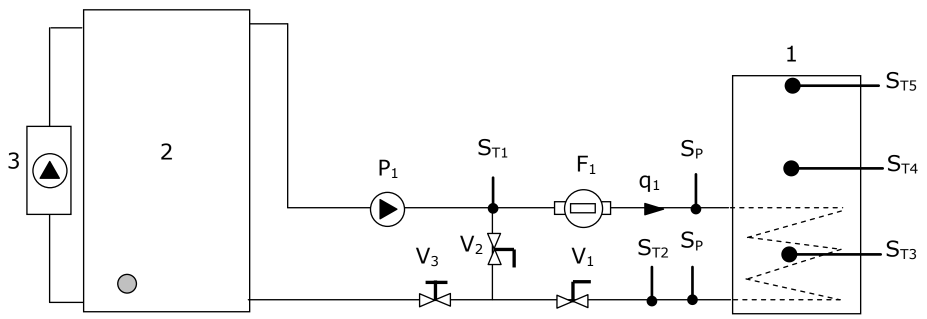
B.1.1 The schematic layout of the test rig for determining the rating of the primary heat exchanger used for heating indirect thermal stores is shown in figure B1. The same test rig is used for determining the rating of the solar heat exchanger inside a thermal store designed for solar thermal systems.

B.1.2 The maximum uncertainty of in the measurement of temperatures should not exceed $\pm 0.25^{o}C$.

B.1.3 Accurate and certified flow meter, F_1, should be used for the measurement of primary circuit flow rate, q_1. The maximum uncertainty in the measurement of flow rate through the heat exchanger should not exceed $\pm 1.5\%$.

B.1.4 Pressure gauges or pressure transducers may be used for measuring the pressure drop across the thermal store heat exchangers. The maximum uncertainty in the measurement of pressure loss across the heat exchanger should not exceed 3% of the measured value.

Figure B1 : Primary & solar heat exchanger performance measuring test apparatus



1 Thermal store under test
2 Hot water (HW) storage vessel
3 Boiler for heating HW storage vessel
4 Electric heater for heating HW store
F_1 Calibrated flow rate/volume meter
P_1 Circulating pump
V_1 Isolating valve
V_2 Isolating valve
V_3 Regulating valve
q_1 Primary flow rate
S_{P1} Calibrated pressure gauge or pressure transducer
S_{P2} Calibrated pressure gauge or pressure transducer
S_{T1} Calibrated temperature sensor – (immersed in water type)
S_{T2} Calibrated temperature sensor – (immersed in water type)
S_{T3} Calibrated temperature sensor
– in lower primary heat source or solar system control pocket
S_{T4} Calibrated temperature sensor – in upper primary heat source control pocket
S_{T5} Calibrated temperature sensor – in store approximately 25mm below top dome

B.1.5 The indirect thermal store and or the solar thermal store under test should be heated by passing hot water from a pre-heated hot water vessel at a constant temperature and flow rate to determine the thermal rating, $Q_{R\text{-}PHE}$, of the primary heat exchanger or the rating of the solar heat exchanger, $Q_{R\text{-}SHE}$.

B.1.6 The default flow rate, F_{PHE}, through the primary heat exchanger depends upon the primary storage volume, V_P, of a thermal store. Unless specified by the manufacturer, the flow rates listed in table B1 should be used for evaluating the performance of primary heat exchangers.

Table B1 : Primary heat exchanger test flow rates, F_{PHE}, for measuring the thermal rating of a primary heat exchanger in a thermal store	
Storage volume, V_P (l)	Primary circuit test flow rate (l/s)
≤ 100	0.15
101 – 250	0.25
251 - 500	0.35
> 500	0.45
V_P = Thermal store volume heated by the primary heat source	

B.1.7 The default flow rate, F_{SHE}, through the solar heat exchanger depends upon the total storage volume, V_T, of a thermal store. Unless specified by the manufacturer, the flow rates listed in table B2 should be used for evaluating the performance of solar heat exchangers.

Table B2 : Solar heat exchanger test flow rates, F_{SHE}, for measuring the thermal rating of a solar heat exchanger in a thermal store	
Storage volume, V_T (l)	Solar circuit test flow rate (l/s)
≤ 150	0.05
151 – 300	0.10
301 - 500	0.15
> 500	0.25
V_T = Total volume of a thermal store	

B.2 TEST B1 : THERMAL RATING OF THE PRIMARY HEAT EXCHANGERS

This test applies to the primary heat exchangers in indirect integrated thermal store (*IDITS*), indirect hot water thermal store (IDHWS) and the indirect buffer store (*IDBS*).

S_{T3} : Lower primary heat source control sensor/thermostat pocket
S_{T4} : Upper primary heat source control thermostat/sensor pocket – if fitted.
S_{T5} : Inside the thermal store approximately 25mm below the dome of the storage vessel.

B.2.1 Test procedure

B.2.1.1 Before commencing the test, ensure that the hot water storage vessel, 2, of sufficient capacity is heated to a uniform temperature of 82±1°C with valve V_1 closed and valve V_2 open. The hot water storage tank shall be capable of supplying pre-heated water at 82±1°C during this test.

B.2.1.2 Also ensure that primary flow rate is adjusted to the value, F_{PHE} specified in table B1 by means of a regulating valve V_3. This may require further adjustment when the thermal store heating test is started.
.

B.2.1.3 Open valve, V_1 and close valve V_2 so that the thermal store starts to heat up. If necessary adjust primary flow rate, q_1, to value, F_{PHE}, specified in table B1.

B.2.1.4 Set the flow rate, Q, through the primary heat exchanger to the appropriate nominal charge flow rate, F_{PH}, specified in table B1 in section B1.3.

B.2.1.5 When the thermal store temperature measured by sensor, S_{T3}, reaches 35±1°C, start reading and recording the following parameters at maximum interval of 60s.

- Thermal store temperatures S_{T2}, S_{T3} and S_{T4}
- Primary flow and return temperatures, S_{T1} and S_{T2}
- Primary circuit flow rate, q_1

B.2.1.6 Continue heating the thermal store and the data logging until the store temperature measured by sensor, S_{T3}, reaches 75±1°C.

B.2.2 Calculations and presentation of results

B.2.2.1 The average thermal rating of the primary heat exchanger, $Q_{R\text{-}PHE}$, should be calculated using equation 'b1' and the data collected during test B1.

B.2.2.2 The heat exchanger rating, $Q_{R\text{-}PHE}$, and the test flow rate, F_{PHE}, should be declared on the thermal store 'data badge' and the design manuals.

$$Q_{R\text{-}PHE} = \Sigma[Q_1 \times C_{p1} \times \rho_1 \times (T_{S1\text{-}1} - T_{S2\text{-}1}) + Q_2 \times C_{p2} \times \rho_2 \times (T_{S1\text{-}2} - T_{S2\text{-}2}) + \ldots\ldots Q_N \times C_{pN} \times \rho_N \times (T_{S1\text{-}N} - T_{S2\text{-}N})] / (1000 \times N) \qquad \text{----} \quad [\ b1\ ]$$

Where:-

$Q_{R\text{-}PHE}$ = Thermal rating of the primary heat exchanger, [kW]
Q_n = Primary circuit flow rate at measurement 'n' (n = 1…..N), [l/s]
C_{pn} = Specific heat of water at measurement 'n' (n = 1…N), [kJ/kg°C]
P_n = Density of water at measurement 'n' (n = 1…N), [kg/m³]
$T_{S1\text{-}n}$ = Primary flow temperature at measurement 'n' (n=1….N), [°C]
$T_{S2\text{-}n}$ = Primary return temperature at measurement 'n' (n=1….N), [°C]
N = Number of readings

B.3 TEST B2 : FLOW RESISTANCE CHARACTERISTICS OF THE PRIMARY HEAT EXCHANGER

B.3.1 This test applies to the primary heat exchangers in indirect integrated thermal store (*IDITS*), indirect hot water thermal store (*IDHWS*) and the indirect buffer store (*IDBS*).

B.3.2 The pressure drop across the primary indirect heat exchanger should be measured at ambient conditions i.e. when both flow and return temperatures are at 20±5°C.

B.3.3 The pressure loss should be measured at the following flow rates. F_{PH}, is the nominal primary heat exchanger test flow rate (see table B1)

- 0.5 x F_{PHE}
- 0.75 x F_{PHE}
- F_{PHE}
- 1.10 x F_{PHE}
- 1.25 x F_{PHE}

B.3.4 The data should be presented in the design and installation manual in a graphical form as shown in figure 7.3 in section 7. and the pressure loss at nominal flow rate, F_{PHE}, should be declared on a thermal store 'data badge'.

B.4 TEST B3 : THERMAL RATING OF THE SOLAR HEAT EXCHANGERS

This test applies to all thermal stores (e.g. IDITS-sol, DITS-sol, DHWTS-sol, IDHWTS-sol) which are designed to be used with solar thermal systems and are heated indirectly by means of solar heat exchanger.

S_{T3} : Solar zone sensor pocket designed for controlling solar thermal system
S_{T4} : Lower primary heat source control thermostat/sensor pocket – if fitted.
S_{T5} : Inside the thermal store approximately 25mm below the dome of the storage vessel.

B.4.1 Test procedure

B.4.1.1 Before commencing the test, ensure that the hot water storage vessel, 2, of sufficient capacity is heated to a uniform temperature of 70±1°C with valve V_1 closed and valve V_2 open. The hot water storage tank shall be capable of supplying pre-heated water at 70±1°C during this test.

B.4.1.2 Also ensure that solar heat exchanger flow rate is adjusted to the value, F_{SHE} specified in table B2 by means of a regulating valve V_3. This may require further adjustment when the thermal store heating test is started.
.

B.4.1.3 Open valve, V_1 and close valve V_2 so that the thermal store starts to heat up. If necessary adjust primary flow rate, q_1, to value, F_{SHE}, specified in table B2.

B.4.1.4 Set the flow rate, Q, through the primary heat exchanger to the appropriate nominal charge flow rate, F_{SHE}, specified in table B2 in section B1.4.

B.4.1.5 When the thermal store temperature measured by sensor, S_{T3}, reaches 35±1°C, start reading and recording the following parameters at maximum interval of 60s.

- Thermal store temperatures S_{T2}, S_{T3} and S_{T4}
- Solar heat exchanger flow and return temperatures, S_{T1} and S_{T2}
- Solar heat exchanger circuit flow rate, q_1

B.4.1.6 Continue heating the thermal store and the data logging until the store temperature measured by sensor, T_{S3}, reaches 60±1°C.

B.4.2 Calculations and presentation of results

B.4.2.1 The average thermal rating of the primary heat exchanger, $Q_{R\text{-}SHE}$, should be calculated using equation 'b2' and the data collected during test B3.

B.4.2.2 The heat exchanger rating, $Q_{R\text{-}SHE}$, and the test flow rate, F_{SHE}, should be declared on the thermal store 'data badge' and the design manuals.

$$Q_{R\text{-}SH\,E} = \Sigma[Q_1 \times C_{p1} \times \rho_1 \times (T_{S1\text{-}1} - T_{S2\text{-}1}) + Q_2 \times C_{p2} \times \rho_2 \times (T_{S1\text{-}2} - T_{S2\text{-}2}) + \ldots\ldots Q_N \times C_{pN} \times \rho_N \times (T_{S1\text{-}N} - T_{S2\text{-}N})] / (1000 \times N) \quad \text{----} \quad [\ b2\ ]$$

Where:-

$Q_{R\text{-}SHE}$	= Thermal rating of the solar heat exchanger,	[kW]
Q_n	= Solar circuit flow rate at measurement 'n' (n = 1…..N),	[l/s]
C_{pn}	= Specific heat of water at measurement 'n' (n = 1…N),	[kJ/kg^{o}C]
P_n	= Density of water at measurement 'n' (n = 1…N),	[kg/m^3]
$T_{S1\text{-}n}$	= Solar HE flow temperature at measurement 'n' (n=1….N),	[^{o}C]
$T_{S2\text{-}n}$	= Solar HE return temperature at measurement 'n' (n=1….N),	[^{o}C]
N	= Number of readings	

B.5 TEST B4 : FLOW RESISTANCE CHARACTERISTICS OF THE SOLAR HEAT EXCHANGER

B.5.1 This test applies to all thermal stores designed to be used with solar thermal systems and in which the energy storage medium (e.g. primary water) is heated indirectly by means of a heat exchanger.

B.5.2 The pressure drop across the solar heat exchanger should be measured at ambient conditions i.e. when both flow and return temperatures are at 20±5^{o}C.

B.5.3 The pressure loss should be measured at the following flow rates. F_{SOL}, is the nominal solar heat exchanger test flow rate (see table B2)

- 0.5 x F_{SOL}
- 0.75 x F_{SOL}
- F_{PH}
- 1.10 x F_{SOL}
- 1.25 x F_{SOL}

B.5.4 The data should be presented in the design and installation manual in a graphical form as shown in figure 7.4 in section 7. and the pressure loss at nominal flow rate, F_{SHE}, should be declared on a thermal store 'data badge'.

APPENDIX : C

TEST RIG AND THE TEST PROCEDURES FOR MEASURING THE STANDBY HEAT LOSS OF A THERMAL STORE AND THE TEMPERATURE OF THE WATER IN THE INTEGRATED FEED AND THE EXPANSION TANK (IF FITTED).

D.1 GENERAL

D.1.1 The objectives of this test are to determine the standby heat loss from a thermal store and the temperature of water in the integral feed and expansion cistern (if fitted) at reference test conditions without any components fitted. This test applies to all types of thermal stores (i.e. integrated, hot water only and buffer stores).

D.1.2 During this test, all exposed pipe work, which is integral part of a thermal store, should be insulated as recommended in the installation instructions supplied with the test sample.

D.1.3 If the thermal store (e.g. ITS & HWTS) is fitted with an external hot water heat exchanger as shown in figure C1.1 then it should be tested with this heat exchanger and the associated components.

D.2 TEST RIG AND TEST SAMPLE

D.2.1 The standing heat loss measurement test shall be performed on a thermal store (i.e. primary water storage vessel of types covered by this document) fitted with a horizontally mounted immersion heater or a fixed electrical element of 3 kW output mounted so as to heat at least the storage volume specified in table A1. For primary stores of up to 250l total storage volume (V_T), a 3kW element shall be used. For larger primary stores (V_T > 250l) an element of greater output can be used as specified by the manufacturer.

This condition shall be checked by heating the primary store under test by means of the immersion heater or an element until the temperature at the measuring point (T_W on figure C1) reaches 75±1°C.

The thermal store temperature, T_W, is measured using the boiler control sensor pocket (Lower pocket if a thermal store has two boiler control sensor pockets). If suitable sensor pockets for measuring temperature, T_W, is not provided on the test sample, then these temperatures may be measured on the metal surface of the vessel (under the insulation).

D.2.2 Apart from the introduction of the immersion heater or element in the test sample, all other aspects of the primary store design shall be as identical as possible to the production model, particularly with regard to the insulation characteristics and hydraulic connections.

D.2.3 In circumstances where it is impossible to fit an immersion heater, then an external electrical flow heater and a circulating pump can be substituted as indicated in figure C1.2. The electric flow heater shall be controlled such that it energises in response to temperature T_{WH} and the temperature difference between T_{WL} and T_{WH} should not be greater than 2°C.

The circulator shall operate whilst the flow heater is energised but only the electrical input to the flow heater shall be measured.

All connecting pipes, the flow heater and the circulator shall be well insulated.

D.2.4 The primary store sample to be tested shall be mounted on a base of 20mm thick medium density fibreboard at a height of 400±100mm above the floor level. Units without the integral feed and expansion cistern should be provided with a temporary means of filling and well insulated vent/overflow pipe of 22mm diameter as shown in figure A.2. After filling the inlet valve used for filling can be covered with temporary insulation if desired (units without integral feed and expansion cisterns only).

The test rig shall be in a draught free environment where it is shielded from direct radiation and has controlled ambient temperature of 20±2°C during the test period.

The thermal store test sample shall be positioned at least 700 mm from any wall or other vertical surface.

D.2.5 Three thermocouples (T_{A1}, T_{A2} and T_{A3}) or similar temperature measuring devices capable of measuring temperature to an accuracy of ±1°C shall be positioned at a height equating to half way to the storage vessel (±25 mm) and at a distance of 350±25 mm from the outside of the vessel insulation/casing. These devices shall be positioned away from any wall or vertical surface as shown in figures A.1 and A.2. A thermocouple (T_W) or similar temperature measuring devices capable of measuring temperatures to an accuracy of ±1°C should be positioned on or inside the storage vessel as follows: -

D.2.6 T_W should be positioned at a point approximately 100±20 mm above the top of the test immersion heater if no suitable pockets have been provided.

D.2.7 For units fitted with integral feed and expansion cistern, a thermocouple (T_{FE}) or a similar temperature measuring device capable of measuring temperature to an accuracy of ±1°C should be positioned in the feed and expansion cistern 25 – 30 mm below the water level (figure A.1).

D.2.8 The electricity supply to the immersion heater shall be connected via a kilowatt hour meter with an accuracy of ±0.01 kWh.

D.3 TEST PROCEDURE

D.3.1 Fill the test sample of a thermal store with cold water via temporary connection to a valve connected to the feed and expansion cistern or other suitable connection on the test appliance or thermal store.

In units without integral feed and expansion cistern, when the storage vessel is full, water will flow from the vent/overflow and the water supply can be disconnected. *[Note: In these types of units, water will drip out of overflow during initial stages whilst heating occurs and therefore a suitable temporary receptacle or a drain arrangement may be required]*

In units with integral feed and expansion cistern, fill the storage vessel and the cistern up the water mark level specified by the manufacturer.

D.3.2 The immersion heater shall be switched on and the temperature control adjusted to give a temperature at T_W of 75±2°C.

D.3.3 Determine the heat losses over successive 24h test periods as follows: -

D.3.3.1 After a stabilisation period of at least 24 h, confirmed by consistent temperature readings, record an initial kilowatt hour reading to the nearest 0.01 kWh.

D.3.3.2 Record the subsequent meter readings at 24h intervals and determine the energy consumptions (E_1, E_2, E_3 etc) for each 24h test period by subtraction.

D.3.3.3 For each 24 h period calculate and record the mean ambient temperature T_A (which is the mean of T_{A1}, T_{A2} and T_{A3}), mean water temperatures T_{WH} and T_{WL} and mean feed and expansion cistern temperature T_{FE}.

D.3.3.4 Continue the test regime until the standing loss calculated as per section A.4. is within 2 % for the at least two successive 24h periods. The standing loss shall be taken as the mean of these results.

D.3.3.5 If it is not possible to achieve a variation of less than 2 % between the results, then continue the test for at least 168 h and record the results for the last three 24 h periods. The standing loss shall be taken as the mean of these three results.

D.3.4 Calculate the mean temperature of water in the feed and expansion cistern using same 24 h periods used for calculating the standing loss of the appliance.

D.4 CALCULATION RESULTS

D.4.1 Calculate the heat loss for each test period, corrected for a 55°C differential between stored hot water and the ambient temperatures as follows:

Heat loss rate, $Q_{HL} = E[55/(T_W - T_A)]$

Where:-

E = Energy consumed in 24 h test period [kWh]
T_W = Mean water temperature over a 24 h test period measured by T_{WH} [°C]
T_A = Mean ambient temperature over a 24 h test period [°C]
= $(T_{A1} + T_{A2} + T_{A3})/3$

D.4.2 Calculate the average temperature of water in the feed and expansion (F & E) cistern as follows: -

$T_{AFE} = (T_{FE1} + T_{FE2} + T_{FE2})/3$

Where:-

T_{AFE} = Average temperature in F & E cistern during test period (°C)
T_{FE1} = Mean temperature of water in F & E cistern for 24h test period 1 (°C)
T_{FE2} = Mean temperature of water in F & E cistern for 24h test period 2 (°C)
T_{FE3} = Mean temperature of water in F & E cistern for 24h test period 3 (°C)

Figure C1: Schematic diagram of heat loss test rig

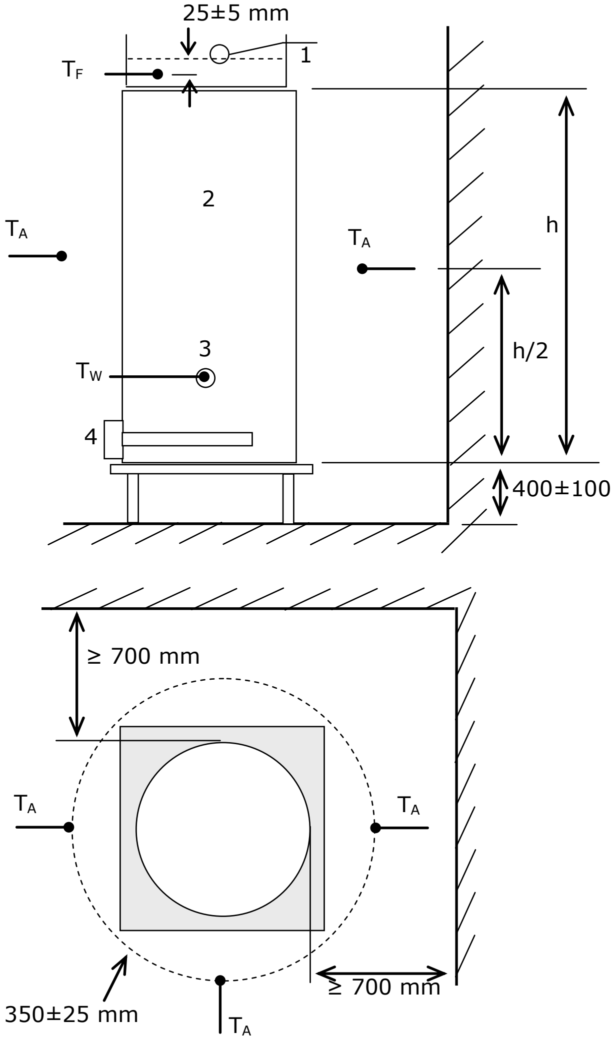
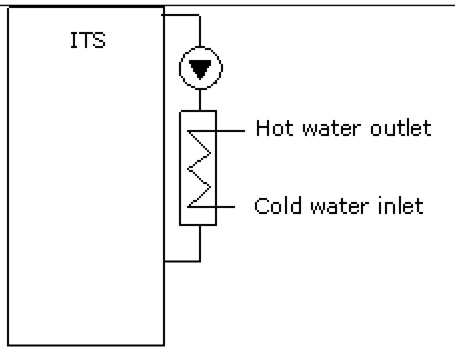


Figure C1.1 Thermal stores fitted with external hot water heat exchanger should be tested with it and its associated components fitted



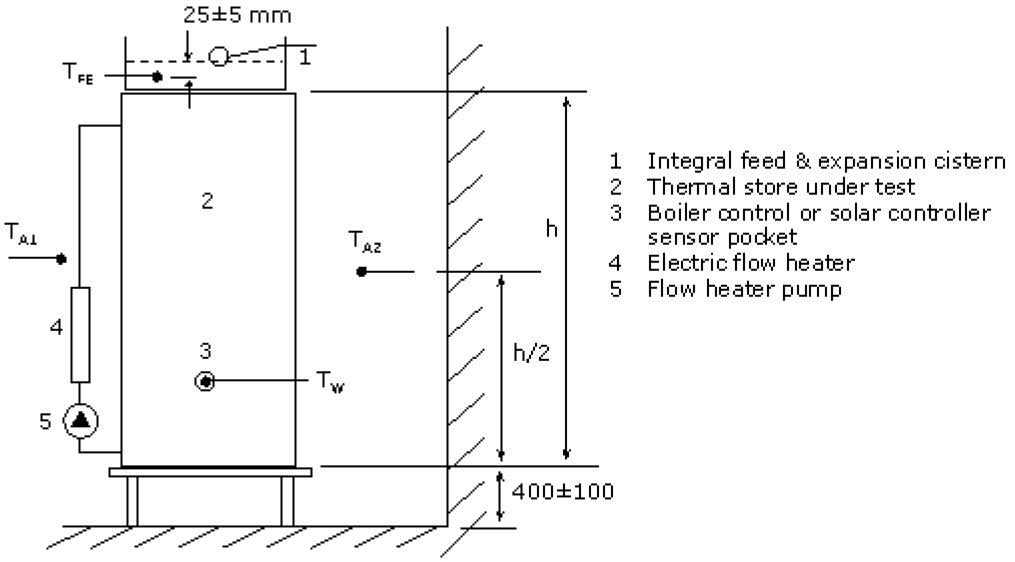


Figure C1.2: Schematic diagram of heat loss test rig with electric flow boiler

APPENDIX D

COMPLIANCE WITH THE BUILDING REGULATIONS

D.1 THE BUILDING REGULATIONS APPROVED DOCUMENT PART G3, (3) (2009 EDITION).

Both open vented and unvented (i.e. sealed) primary thermal stores must comply with the requirements of the Building Regulations Approved Document Part G3(3) (2009 edition) i.e.

- All thermal stores shall incorporate means to prevent the water stored in the vessel exceeding 100°C at any time.

- The design should ensure that any discharge from the safety devices is safely conveyed to where it is visible but will not cause a danger to persons in or around the dwelling.

Note: *Either the devices or means for achieving the above requirements could be factory fitted or methods should be specified in the installation manual for fitting the appropriate devices during the system installation.*

D.1.1 Open vented thermal stores

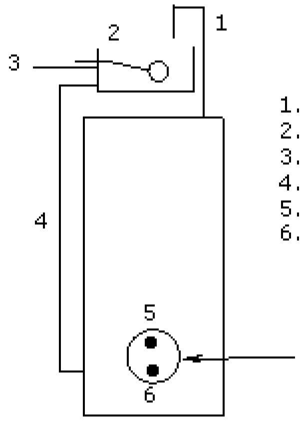
For the open vented thermal store (see figure D1), these requirements will be met if: -

D.1.1.1 the storage vessel has a suitable vent pipe of adequate size but not less than 19mm internal diameter connecting the top of the vessel to a point open to the atmosphere above and over the level of the water in the feed and expansion cistern; **and**,

D.1.1.2 in addition to any control thermostat, either the heat source or the storage vessel is fitted with a non-self-resetting device that will prevent the temperature of water at any time exceeding 100°C; and,

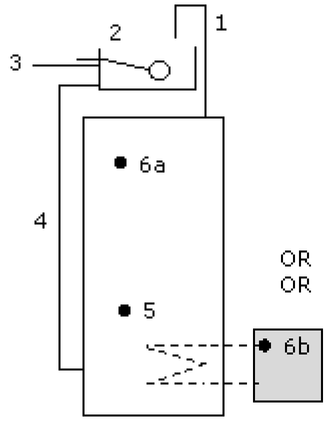
D.1.1.3 The pipework from the feed and expansion overflow pipe and any other pressure or a temperature safety relief valve should discharge to an appropriate place open to the atmosphere where it will cause no danger to persons in or about the building.

Figure D1 : Vented primary thermal store – Typical examples of controls for compliance with the Building Regulations, Part G3(3)



1. Vent pipe of internal diameter not less than 19mm
2. Feed and expansion cistern
3. Overflow discharge pipe
4. Cold feed
5. Control thermostat [CT]
6. Manual rest overheat thermostat [OHT]

Note: The temperature or combined temperature and pressure relief valve may be fitted to the vessel in place of an overheat thermostat (OHT)



1 Vent pipe of internal diameter not less than 19mm
2 Feed and expansion cistern
3 Overflow discharge pipe
4 Cold feed
5 Control thermostat [CT]
6a Overheat thermostat [OHT] in the store
OR 6b Overheat thermostat [OHT] in the heat source
OR Temperature relief valve fitted to the store (not shown)

Note: The temperature or combined temperature and pressure relief valve may be fitted to the vessel in place of an overheat thermostat (OHT)

D.1.2 The unvented thermal stores

For the unvented thermal stores, these requirements will be met if in addition to any control thermostat provided to control the temperature of the stored water to a desired temperature, the unvented thermal store should incorporate a minimum of two temperature activated safety devices operating independently in series, normally (Figure D2):

D.1.2.1 A non-self-resetting energy cut-out to disconnect the supply of heat to the storage vessel in the event of storage system overheating; and plus either an option (D.1.2.2) or an option (D.1.2.3).

D.1.2.2 If the unvented thermal storage system is fitted with an approved device (e.g. RPZ Valve [1]) which automatically replenishes the stored water then either a temperature relief valve or a combined temperature and pressure relief valve located directly on a storage vessel, such that the stored water does not exceed 100°C. Provided that:-

- The discharge rate from the P&T valve with RPZ valve fitted is sufficient to prevent the temperature of the stored water in the vessel exceeding 100°C.

- The thermal store package fitted with these devices is approved by the appropriate approved test house.

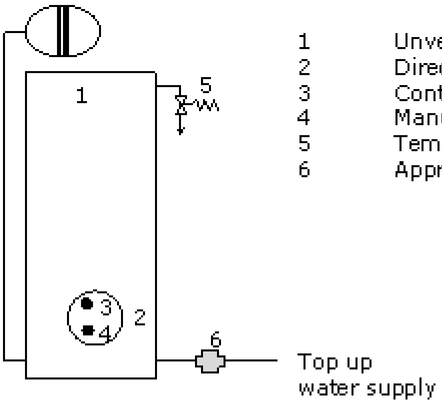
Note:
Since the introduction of the Water Supply (Water Fittings) Regulations 1999 in England and Wales and the Water Bylaws 2000 in Scotland, it is permitted to use the backflow prevention device instead of an air gap for category 1 fluid, at certain risk levels. A reduced pressure zone (RPZ) valve is an example of such backflow prevention device.

D.1.2.3 If the unvented thermal storage system has no provision to automatically replenish the stored water then there should be a second non-self-resetting energy cut-out, which stops the flow of energy from the heat source to the thermal store using alternative and independent of method (D.1.2.1), such that the stored water does not exceed 100°C.

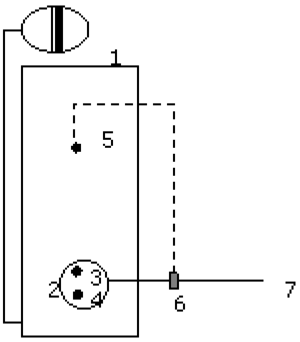
D.1.2.4 Unvented thermal storage systems up to 500 litre capacity and 45kW power input should be in the form of a package. The package and the components should be appropriate to the appropriate to the circumstances in which they are used and should be approved by an accredited third party product conformity certification scheme.

D.1.2.5 Unvented thermal storage systems over 500 litre capacity or over 45kW power input will generally be bespoke designs for specific projects and as such are inappropriate for approval by the third party. Where this is the case, the unvented thermal store should be designed to satisfy the requirements, (D.1.2.1) to (D.1.2.3) above, by an appropriately qualified engineer.

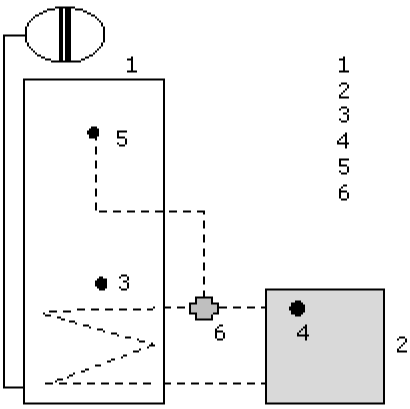
Figure D2 : Unvented primary thermal store – Typical examples of controls for compliance with Building Regulations, Part G3(3)



1 Unvented primary thermal store
2 Direct heat source e.g. Immersion heater
3 Control thermostat
4 Manual reset overheat thermostat
5 Temperature or combined P&T valve
6 Approved automatic top up device e.g. RPZ valve



1 Unvented primary thermal store
2 Direct heat source e.g. Immersion heater
3 Control thermostat
4 Manual reset overheat thermostat
5 Store manual reset overheat thermostat
6 Supply cut of device e.g. contactor
7 Mains supply to the immersion heater



1 Unvented primary thermal store heated indirectly
2 Remote heat source
3 Control thermostat
4 Manual reset overheat energy cut-out device
5 Manual reset store overheat thermostat
6 Energy supply cut off valve

D.2 The Building Regulations Approved Document Part L

D.2.1 Solar thermal stores

The zone, Z_{DS}, in thermal stores designed for use with solar thermal heating systems is only heated by solar energy. 'The Domestic Heating Compliance Guide, May 2006' specifies the requirements for the solar heating systems for compliance with the Building Regulations 2000, Approved Documents L1 and L2 (2009 edition). To comply with the Building Regulations, these thermal stores must meet the following requirements: -

D.2.1.1 If the solar circuit flow rate, $F_{SOL} \geq 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL-HE} \geq 0.2 \times A_{SC}$.

D.2.1.2 If the solar circuit flow rate, $F_{SOL} < 0.5$ l/min per m^2 of net collector area, then the surface area of the solar heat exchanger, $A_{SOL-HE} \geq 0.1 \times A_{SC}$

D.2.1.3 If the solar zone, Z_{DS}, does not contain phase change material (PCM), then the dedicated solar volume, V_{DS}, must comply with either equation 1 or equation 2.

$$V_{DS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4 \qquad \text{---- [1]}$$
$$V_{DS} \geq 25 \times A_{SC} \qquad \text{---- [2]}$$

D.2.1.4 If the solar zone, Z_{DS}, contains phase change material (PCM), then the equivalent dedicated solar volume, V_{EDS}, must comply with either equation 4 or equation 5.

$$V_{EDS} = [V_{WDS}/V_{DS}]+m_{DS}[C_{PS}(T_M-T_0)+L_H+C_{PL}(T_1-T_M)]/[V_{DS}\ \rho\ Cp(T_1-T_0)] \quad \text{--[3]}$$
$$V_{EDS} \geq 0.56 \times A_{TF} - 0.00076 \times (A_{TF})^2 + 30.4 \qquad \text{-- [4]}$$
$$V_{EDS} \geq 25 \times A_{SC} \qquad \text{-- [5]}$$

Where : -

V_{EDS}	= Equivalent volume of dedicated solar zone, Z_{DS}, with PCM	[l]
V_{DS}	= Net volume of zone, Z_{DS}, without PCM,	[l]
V_{WDS}	= Net volume of water in zone, Z_{DS}, with PCM	[l]
m_{DS}	= Mass of PCM in dedicated solar zone, Z_{DS}	[kg]
Cp	= Average specific heat of water between T_0 and T_1	[J/Kg.K]
C_{PS}	= Specific heat of PCM in solid phase	[J/Kg.K]
C_{PL}	= Latent heat of PCM in liquid phase	[J/kg.K]
ρ	= Average density of water between T_0 and T_1	[kg/l]
L_H	= Latent heat of PCM	[J/kg]
T_M	= Phase change temperature of PCM	[°C]
T_0	= Lower reference temperature (= 10°C)	[°C]
T_1	= Upper reference temperature (= 60°C)	[°C]
A_{TF}	= Maximum total floor area of a dwelling specified for the store	[m^2]
A_{SOL-HE}	= Surface area of the solar heat exchanger	[m^2]
A_{SC}	= Net surface area of the solar collector specified for the store	[m^2]
F_{SOL}	= Solar circuit flow rate per m^2 of net collector area	[l/min]

D.2.2 Standby heat loss rate (All types of thermal stores)

The maximum permitted heat loss rate, Q_{HL-MAX}, from a thermal store depends upon the application and the fuel used by the primary heat source as defined in sections 2.2.1 and 2.2.2.

The maximum permitted figure, Q_{HL-MAX}, should be regarded as an absolute maximum and efforts should be made to reduce it.

The actual measured heat loss value shall be declared on the data badge in the coded form and also in the appliance manuals etc.

D.2.2.1 New built dwellings

For new built dwellings, the measured heat loss rate, Q_{HL}, should not be greater than the value, Q_{HL-MAX}, given by equation 6a for all types of thermal stores (e.g. direct, indirect, heated by electricity or other fuels).

$$Q_{HL\text{-}MAX} = 1.28 \times [0.2 + (0.051 \times (V_T)^{2/3})] \quad \text{----- [6a]}$$

Where: -

$Q_{HL\text{-}MAX}$ = Maximum permitted heat loss from a thermal store, [kWh/24h]
V_T = Total storage capacity of a thermal store, [l]

D.2.2.2 **Retro-fit dwellings:**

For the retro-fit dwellings, the measured heat loss rate, Q_{HL}, of the thermal stores heated by electricity (i.e. where electricity is the primary should not be greater than the value, $Q_{HL\text{-}MAX}$, given by equation 6b.

For the retro-fit dwellings, the measured heat loss rate, Q_{HL}, of the thermal stores heated by other fuels should not be greater than the value, $Q_{HL\text{-}MAX}$, given by equation 7.

$$Q_{HL\text{-}MAX} = 1.28 \times [0.2 + (0.051 \times (V_T)^{2/3})] \quad \text{----- [6b]}$$
$$Q_{HL\text{-}MAX} = 1.6 \times [0.2 + (0.051 \times (V_T)^{2/3})] \quad \text{----- [7]}$$

Where: -

$Q_{HL\text{-}MAX}$ = Maximum permitted heat loss from a thermal store, [kWh/24h]
V_T = Total storage capacity of a thermal store, [l]

D.3 Heat loss rate for SAP calculations

The In-Use heat losses from thermal stores will be less than the measured values. This is because:-

(a) The thermal stores are normally installed in airing cupboards like a conventional cylinder. Therefore, the ambient temperature will be higher than 20°C specified for the test procedures and therefore the heat losses will be lower.

(b) The thermal storage systems are now being installed with two channel programmers for controlling both space heating and hot water. Therefore, the thermal store is not maintained at nominal maximum temperature of 75°C. When the boiler is not charging the thermal store, it will provide 40-50% of hot water demands in a dwelling resulting in a significantly lower 24h mean store temperature.

(c) The field studies have shown that the usage pattern of thermal storage heating systems is similar to that for conventional systems.

(d) Unlike the integrated thermal stores, the hot water only thermal stores are not maintained at high temperature when space heating is on. Therefore its 24h average heat loss is lower than ITS.

The heat loss factors for Hot Water Only and Integrated Thermal Stores (HWTS and ITS) for use in SAP procedures must be calculated using appropriate equations as detailed in the separate loose sheet contained at the back of this document.

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