BS 5918:2015

BSI Standards Publication

Solar heating systems for domestic hot water – Code of practice for design and installation

Publishing and copyright information

Published by BSI Standards Limited 2015

ISBN 978 0 580 61963 2

ICS 27.160, 97.100.99

The following BSI references relate to the work on this standard:
Committee reference RHE/25
Draft for comment 12/30177610 DC, 13/30274184 DC

Publication history

First published January 1980
Second edition, February 1989
Third (present) edition, January 2015

Amendments issued since publication

Date	Text affected

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 31 January 2015. It was prepared by Technical Committee RHE/25, *Solar heating*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This British Standard supersedes BS 5918:1989, which is withdrawn.

Information about this document

This is a full revision of the standard.

This standard is intended to help with the design and installation of solar heating equipment for domestic hot water (DHW). It is especially intended to help fill the gap for fitted systems that have not been tested to BS EN 12976 or BS EN 12977. Note that the use of the term "custom systems" in these standards tends to refer to a functional system provided by a single final supplier or manufacturer. An assembly comprising solar energy collection and storage components, and supplied or assembled by multiple providers, can be considered an "ad-hoc" system which is considered in this standard.

The documents available as downloads from the sites referenced in the Bibliography were last accessed on 19 January 2015.

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Presentational conventions

The provisions of this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word "should" is used to express recommendations of this standard. The word "may" is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word "can" is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Introduction

This code of practice applies to solar domestic water heating systems that incorporate a primary circuit that is indirect, such that the collected solar energy is transferred through a heat exchanger into storage that includes a volume dedicated to solar input. This applies to most systems that are available in the UK at present.

There are other system designs on the market that fall outside the scope, but the code of practice does not restrict or limit the installation of such designs. The methods and algorithms presented in this document that estimate the system performance do not apply to such designs. Nevertheless, several clauses are also relevant to system designs outside the scope. These include the clauses relating to the mounting of solar panels, safety issues and those relating to the provision of information to customers.

1 Scope

This British Standard gives recommendations and guidance for the installation of common indirect solar domestic hot water (SDHW) systems for all types of building in the UK. It includes recommendations and guidance for design, handling, installation, commissioning, handover, maintenance, decommissioning and fault-finding.

NOTE 1 SDHW is domestic hot water (DHW) that has intentionally received heat derived from solar radiation via a solar collector.

The standard covers systems:

a) in which solar radiation is converted to heat that is primarily intended for domestic hot water preparation;

b) that contain solar collector(s) intended to transfer heat using an aqueous-based liquid medium;

c) whose solar collectors conform to BS EN 12975-1 and BS EN ISO 9806;

d) which contain collectors that provide up to 20 kW instantaneous peak power output measured leaving the collector, when tested in accordance with BS EN ISO 9806 at 800 W/m^2 perpendicular to the collector aperture plane;

   NOTE 2 Depending on the characteristics of the system, this typically equates to a gross collector area of up to approximately 30 m^2.

e) in which heat is primarily stored in aqueous-based liquid media; and

f) in which the primary circuit is indirect with a heat exchanger that is internal to the solar storage vessel and which separates the primary heat transfer fluid that passes through the collector from the DHW.

This British Standard does not cover:

1) applications that are primarily intended to provide heat for applications such as space heating, cooling or swimming pools and any other than DHW preparation;

2) solar primary system layouts that use solar storage vessels that are outside the building;

3) solar primary system layouts with multiple collector fields;

4) DHW systems that comprise multiple solar or multiple DHW storage vessels; or

5) solar primary system layouts that incorporate a heat pump or other device that utilizes the Carnot cycle.

NOTE 3 It is assumed in the calculations in this British Standard that there is user-disinterest in the DHW settings, i.e. that default factory timer and thermostat settings are present. Extra heating required for bacterial disinfection is not assumed in these calculations.

NOTE 4 Where stated in the standard, the pressure is that exceeding atmospheric pressure at sea level.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 1566 (both parts), *Copper indirect cylinders for domestic purposes*

BS 4213, *Cisterns for domestic use – Cold water storage and combined feed and expansion (thermoplastic) cisterns up to 500 l – Specification*

BS 6213, *Selection of construction sealants – Guide*

BS 6920, *Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of water*

BS 7671, *Requirements for electrical installations – IET Wiring Regulations*

BS 8000 (all parts), *Workmanship on building sites*

BS 8000-15, *Workmanship on building sites – Part 15: Code of practice for hot and cold water services (domestic scale)*

BS 8558, *Guide to the design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages – Complementary guidance to BS EN 806*

BS 8580, *Water quality – Risk assessments for Legionella control – Code of practice*

BS EN 806 (all parts), *Specification for installations inside buildings conveying water for human consumption*

BS EN 1990, *Eurocode – Basis of structural design*

BS EN 1991-1-1, *Eurocode 1 – Actions on structures – Part 1-1: General actions – Densities, self-weight, imposed loads for buildings*

BS EN 1991-1-3, *Eurocode 1 – Actions on structures – Part 1-3: General actions – Snow loads*

BS EN 1991-1-4, *Eurocode 1 – Actions on structures – Part 1-4: General actions – Wind actions*

BS EN 1993-1-1, *Eurocode 3 – Design of steel structures – Part 1-1: General rules and rules for buildings*

BS EN 1995-1-1, *Eurocode 5 – Design of timber structures – Part 1-1: General – Common rules and rules for buildings*

BS EN 12897, *Water supply – Specification for indirectly heated unvented (closed) storage water heaters*

BS EN 12975-1, *Thermal solar systems and components – Solar collectors – Part 1: General requirements*

BS EN 12977, *Thermal solar systems and components – Custom built systems*

BS EN 12977-3, *Thermal solar systems and components – Custom built systems – Part 3: Performance test methods for solar water heater stores*

BS EN 12977-5:2012, *Thermal solar systems and components – Custom built systems – Part 5: Performance test methods for control equipment*

BS EN 14437, *Determination of the uplift resistance of installed clay or concrete tiles for roofing – Roof system test method*

BS EN 60730-2, *Automatic electrical controls for household and similar use*

BS EN 60730-2-9, *Automatic electrical controls for household and similar use – Part 2-9: Particular requirements for temperature sensing controls*

BS EN ISO 11600, *Building construction – Jointing products – Classification and requirements for sealants*

BS EN ISO 9488, *Solar energy – Vocabulary*

BS EN ISO 9806, *Solar energy – Solar thermal collectors – Test methods*

3 Terms and definitions

For the purposes of this British Standard, the terms and definitions given in BS EN ISO 9488, BS EN 12977 and the following apply.

3.1 active area
either the absorber or aperture area chosen dependant on collector type

NOTE 1 An active area is used for calculating or estimating system performance in the design stage.

NOTE 2 Some concentrating collectors with large reflective aperture areas do not work as well in predominately diffuse irradiation as found in the UK.

NOTE 3 Aperture area is the preferred option for a collector which concentrates solar radiation.

3.2 cold feed
pipe that contains cold water intended to be eventually heated as DHW

3.3 cold water storage (CWS)
cistern located at a high location in the building filled with cold water via a float valve

3.4 compound parabolic concentrator (CPC) collector
non-imaging collector that uses parabolic reflector segments to concentrate solar radiation

3.5 dedicated solar storage
vessel or part of a vessel that is normally only intentionally heated by the solar primary system

3.6 delivery or draw-off temperature
temperature at which water is drawn off at an outlet intended to supply DHW

3.7 DHW-only vessel
vessel that contains only DHW storage

3.8 differential temperature controller
electronic device that detects a temperature difference and controls pumps and other electrical devices accordingly

3.9 direct system
system in which there is no heat exchanger between the primary and secondary systems

NOTE The water passing from the cold feed can also pass through the solar collector.

3.10 domestic hot water (DHW)
water intended for sanitary bathing and cleansing that has been fully treated by heat or other processes making it suitable as domestic hot water

3.11 downstream
towards the draw-off points of the DHW

3.12 drainback system
system that, as part of the normal working cycle, automatically drains and refills the collector with heat transfer fluid, retaining the fluid within the system

NOTE A drainback system is different from a drain-down system, which is a system that drains the collector to waste, either manually or automatically, when freezing conditions are likely to occur.

3.13 effective solar storage
sum of the dedicated solar storage plus a proportion of volume that is available for additional solar storage where this volume is normally heated by other intermittent heat sources

3.14 flow
section in a circuit where the movement of heat is away from the source, i.e. the hottest part of the circuit

3.15 frost protection
protection offered by a heat transfer fluid at the final setting temperature for a fluid

3.16 heat transfer fluid (HTF)
fluid in the primary circuit which transports heat from the collector to the solar storage vessel

3.17 hydraulically secure
condition such that there can be no release of heat transfer fluid under any foreseeable conditions, with no user intervention required to reinstate system function after electrical power failure under all weather conditions

3.18 indirect system
system in which there is a heat exchanger between the primary and secondary systems

NOTE The water passing from the cold feed does not pass through the solar collector in an indirect system.

3.19 open-vented system
system that allows its liquid contents to be freely in contact with atmosphere

3.20 preheat storage vessel
vessel that stores heat prior to further heating downstream

3.21 primary
assembly of components that contain fluid acting as the source or generation of heat

3.22 return
section in a circuit where the movement of heat is away from the load, i.e. the coolest part of the circuit

3.23 sealed system
circuit that seals the heat transfer fluid from the atmosphere

3.24 secondary system
assembly of components that contains water to be heated as DHW and then discharged or consumed

NOTE This can include the storage vessel with a cold feed unless the DHW instead passes through a heat exchanger.

3.25 solar fraction
quotient between the energy supplied by the solar primary circuit to the storage tank and the total energy intentionally arriving at the storage tank, given by the following formula:

$$\text{solar fraction} = \frac{Q_{sol}}{Q_{sol} + Q_a} \quad (1)$$

where:

Q_{sol} is the solar yield, i.e. the net thermal energy gain entering the solar storage tank from the solar primary circuit; and

Q_a is the backup energy at point of transfer to DHW.

NOTE See also Figure 1.

3.26 solar heating
process by which heat above the stated reference temperature in a material is primarily derived from solar radiation transfer

3.27 solar primary system
assembly of components that allows passage of heat from a solar collector and transfers it to a storage vessel

NOTE This includes the heat exchanger, but not the storage vessel itself.

3.28 solar storage
volume of water held within a vessel or part of a vessel that is intentionally used to store heat from the solar primary system

NOTE This can include vessels or volumes that store heat from other sources. Non-aqueous methods of storage are outside the scope of this standard.

3.29 stagnation temperature
temperature of the collector during periods of no useful heat removal from the collector with high solar radiation and ambient surrounding temperatures

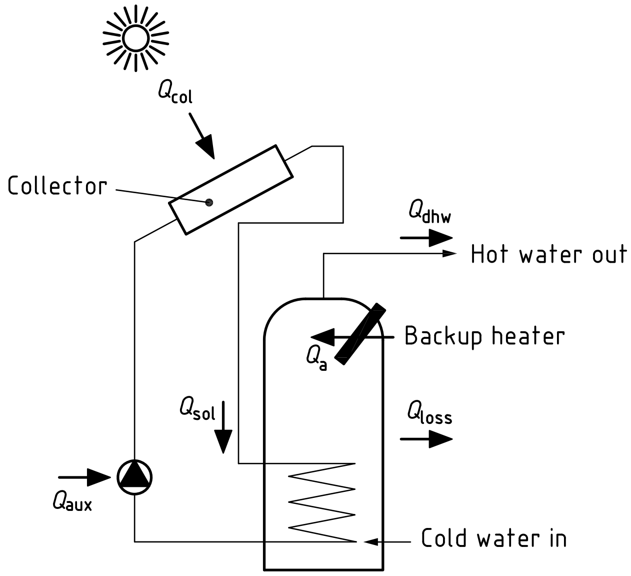
3.30 storage temperature
temperature at which water is stored in a vessel

3.31 thermosyphon circulation
system or process in which circulation of the heat transfer fluid is achieved by natural buoyancy or convection

NOTE Also known as "gravity circulation".

3.32 treated area
area that is intended to be habitable

Figure 1 **Schematic showing energy flows through the system**



Key

Q_{col} Irradiation incident normal to the collector's active area

Q_{dhw} Net thermal energy draw-off

Q_{loss} Thermal energy losses from storage

Q_{aux} Electrical primary energy used for circulation and solar primary controls

Q_{sol} Net thermal energy gain entering the solar storage tank

Q_a Backup energy at point of transfer to DHW

System efficiency = $Q_{dhw}/(Q_{col} + Q_A)$ (see Note 1)

Energy saving fraction = $(Q_u - Q_a)/Q_u$ (see Note 2)

NOTE 1 System efficiency is not to be confused with the collector loop efficiency of an installation, which is the quotient between the thermal energy produced by the solar installation (supplied to the storage tank) and the solar energy radiated onto the collector. Strictly speaking, the system efficiency ought to include the energy input to the system, Q_{aux}. It is recognized that some of the pump energy will contribute towards the heat gain of the loop, though this is difficult to determine. Usually, Q_{aux} is not included because it is not easily determined in practice.

NOTE 2 Q_U is the backup energy at the point of transfer when Q_{sol} is zero, i.e. no solar heating system is fitted.

3.33 upstream

towards the source of the cold feed

3.34 vaporization temperature

temperature at which the liquid boils, which varies according to the system pressure

3.35 volatile corrosion inhibitor

corrosion inhibitor which is able to protect system components when the heat transfer fluid is in either a liquid or vapour state

4 General recommendations

4.1 Climatic considerations

NOTE All areas of the UK are at risk of freezing temperatures for some part of each typical climatic year.

Water-carrying components should be protected from frost damage without the need for user intervention or electricity. All rigid components in a SDHW system that are outside the treated area of a building and at risk of frost damage should be protected with an inhibited heat transfer fluid (HTF) that has frost protection for the local climate; in all cases a minimum of –20 °C. Where practicable, components that are expected to carry heat should be well insulated and located internally where possible.

4.2 General layout of main components

NOTE The source of energy of a SDHW system is solar radiation, which first enters the system via a solar collector. A solar collector is mounted external to the building to optimally receive the solar radiation. The heat generated from the solar collector is stored in water-filled vessels inside the treated areas of the building.

The combination of pressures and volumes intended for a system determine whether the Pressure Equipment Regulations [1] apply, which might require further tests of the design by a third party. Further information is given in Pressure equipment – Guidance notes on the UK Regulations [2].

The storage vessels should be chosen based on their intended location in a treated area of a building, with consideration to reducing pipe lengths to the collectors and a backup heat source for DHW, as well as proximity to the principal draw-off locations. A compromise on the chosen location of the main components should be made that results in the best overall performance of the whole system.

4.3 General considerations for layout of solar collectors

For best performance, a solar collector should be located where it is least shaded, tilted up from horizontal and facing towards south, and at the shortest practicable distance from the heat storage. Collectors may be located in or on a variety of building components, such as roofs, facades, balustrades and canopies. Access for inspection or maintenance should be provided without detrimentally affecting the building's appearance or aesthetics. Locations near to trees should be avoided where possible as these are likely to suffer from significant overshading, with the added potential for leaves and tree sap to build up on the collector glazing. Consideration should be given to future tree growth. Locations in valley areas and near to high-rise buildings should be carefully assessed for the potential for shading.

NOTE Reflective landscape features located in front of inclined collectors can improve annual performance. Such surfaces might be relatively large, such as glazed facades or water features.

4.4 Mitigation of bacterial growth

The potential for the accumulation and growth of microorganisms, such as *Legionella*, should be determined by a risk assessment and appropriate mechanisms for microbial control identified, e.g. periodic heating of storage vessels, pipes to disinfection temperatures or/and continuously to the cold feed source such as by ultraviolet (UV) disinfection or other treatment, in accordance with Annex A.

NOTE In a place of work, there is a mandatory requirement for controls under the Control of Substances Hazardous to Health Regulations [3, 4]. Further guidance on controlling Legionella is given in HSE publications L8 [5] and HSG 274 Part 2 [6].

4.5 Layout of storage vessels

The design should take into account the strong effect of solar storage on the performance of the whole solar heating system, principally by the size of solar storage and stratification.

The effective solar storage, V_{eff}, is equal to the dedicated solar storage, V_s, only in the case of a separate preheat storage vessel. In combined stores, V_{eff} should be calculated in litres (L) using the following equation:

$$V_{eff} = V_s + (F \times V_b) \quad (2)$$

where:

F is a factor of stored water available in a combined cylinder for solar storage, given in Table 1;

V_b is the volume of standby or stored heat from backup heat sources, in litres (L); and

V_s is the volume of the dedicated solar storage, in litres (L).

Table 1 **Backup heat factor, *F*, for calculating effective solar storage**

Usage	*F*
Permanently switched on	0.1
Overnight (off-peak)	0.3
Timed twice daily	0.3

NOTE Default timer settings for loading stored DHW systems are assumed to be 08:00 to 10:00 and 18:00 to 23:00. The characteristics of an average DHW usage profile are shown in Annex B (see also ***7.4.2****).*

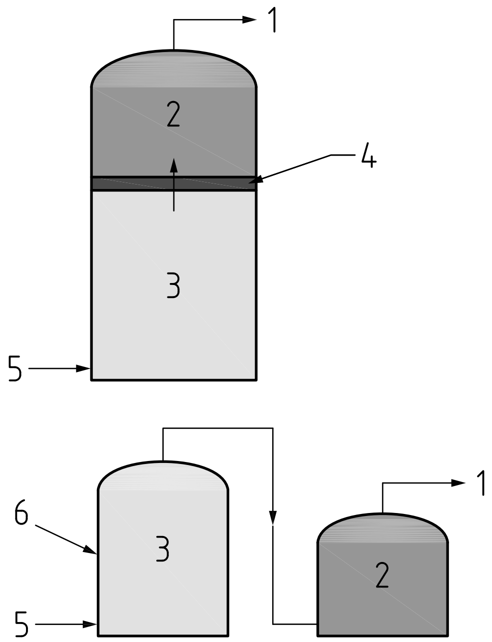
A SDHW system should include a means of storing heat in a volume of water dedicated to transferring heat to the secondary system. This dedicated solar storage should be located upstream of the DHW backup heat source so as not to be heated by other heat sources (see Figure 2) and may either be in a separate sole-purpose vessel or at the base of a vessel with other heat sources.

NOTE 1 The latter is often known as a "twin-coil storage vessel" when a lower coil is dedicated to solar heat and the upper coil from a backup heat source or suitable immersion heaters located in a similar position (e.g. on a horizontal axis). The second coil creates the backup heater volume and this is created more reliably with side entry heating as convection currents are evened out.

NOTE 2 The purpose of dedicated solar storage is to allow energy that comes in at any time of day to be stored by preheating incoming cold feed water. The preheated water is passed to the backup DHW heater. The volume that contains this preheat storage vessel is termed "dedicated" only when there is no other backup heat source normally heating in this volume. The functioning principle of an SDHW system is shown schematically in Figure 3.

NOTE 3 A SDHW system can be divided into two strategic functions of heating. The primary system is the source and transportation of heat from the point of collection to the point of heat exchange, whereas the secondary system uses the heat exchanged as part of the process to treat DHW.

Figure 2 **Two types of storage vessel layout**



Key

1 Total daily DHW draw-off, V_d
2 Volume of stored water that the backup heat source can heat, V_b
3 Volume of stored water dedicated for heat transferred from the solar primary loop, V_s
4 Theoretical additional volume available for heat transferred from the solar primary loop when backup heating is timed = $F \times V_b$

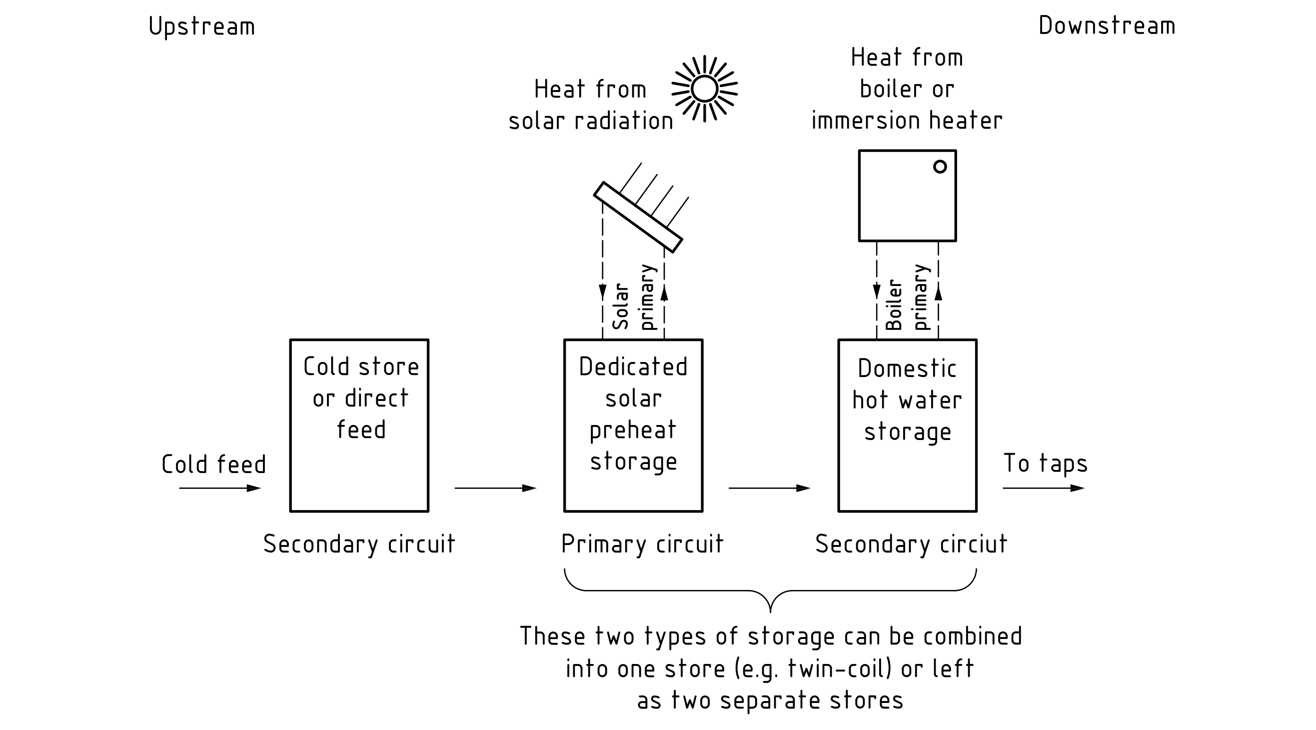
$$V_{eff}=V_s+(F\times V_b)$$

5 Cold feed
6 Separate preheat storage vessel

$$V_{eff}=V_s$$

NOTE There are two types of storage vessel layout, spatial and thermal. Therefore, the term "storage" if used alone might require clarification.

Figure 3 **Schematic of the functional principle and fluid movements in a typical solar hot water system**



4.6 Integration of the dedicated solar storage and the backup DHW heating appliances

Any dedicated solar storage should be integrated with the backup DHW appliance in one of four ways:

a) dedicated solar storage and DHW storage contained in a single vessel, as shown in Figure 4a);

NOTE 1 The vessel contains separate heat exchangers for each heat source. This is often known as a "twin-coil cylinder".

b) dedicated solar storage and DHW storage contained in a two separate vessels, as shown in Figure 4b);

c) dedicated solar storage with no DHW storage, as shown in Figure 4c), with the water supplied to the appliance limited to the temperature recommended by the manufacturer; or

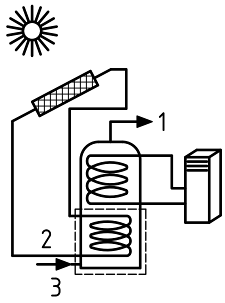
NOTE 2 DHW is provided by an instantaneous or storage hot water appliance with integral backup heat source.

d) dedicated solar storage and DHW storage contained in a single vessel, as shown in Figure 4d).

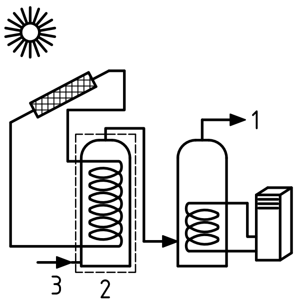
NOTE 3 The vessel contains one heat exchanger for solar and one electrical resistance heater.

In all cases, the format of the secondary system may include vented, unvented and DHW thermal stores using an internal heat exchanger.

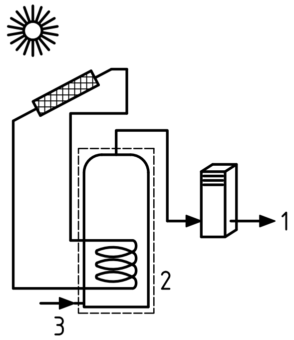
Figure 4 **Example layouts illustrating dedicated solar storage within common DHW systems**



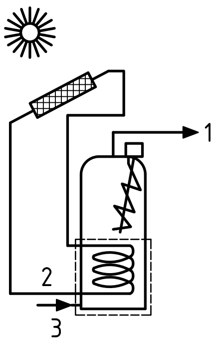
a) Single vessel with stored DHW above dedicated solar storage



b) Two separate vessels: one dedicated solar storage, the other DHW-only storage



c) Single vessel with dedicated solar storage and instantaneous DHW appliance



d) Single vessel with dedicated solar storage and electrical resistance heater

Key

1 Daily DHW draw-off, V_d (for clarity, connections and safety equipment not shown)

2 Dedicated solar storage, V_s (dotted lines)

3 Cold feed connection

NOTE External heat exchangers are not within the scope of this document.

4.7 Primary system design

NOTE Many different designs of solar water heating systems are possible and they can be classified in several ways. For examples of primary system layouts, see Annex C.

The solar water heating primary system should:

a) have provision for expansion of HTF without risk of long-term evaporation;

b) include control devices to provide limitation in case of over-pressure;

c) have a control mechanism to limit over-temperature in the solar storage vessel;

d) prevent any damage or malfunction due to freezing of fluid in the solar collector and other parts of the primary circuit;

NOTE This may be done by using an antifreeze solution or by ensuring that all parts of the circuit are freeze tolerant.

e) prevent the accumulation of limescale, dirt, silt and other debris which could impede circulation, reduce heat transfer, or compromise the operation of safety vents or expansion pipes; and

f) not permit deformation of pipes or vessels which drastically influences performance and safety.

4.8 Secondary system design

Regardless of the particular design of solar water heating, there should be reliable:

a) prevention of backflow or thermosiphoning of heated water into a cold water cistern containing wholesome water;

b) prevention of steam or scalding water from reaching hot water distribution pipes or terminal draw-off locations;

c) maintenance of water quality when in contact with materials and fittings, especially during high stagnation temperatures and pressures;

d) retention of storage heat capacity to maintain a system efficiency close to optimum assuming a typical DHW profile with a disinterested user;

e) prevention of overflow or evaporation of fluids from storage cistern;

f) prevention of disturbance due to pumps of the stratification in the solar storage vessel which unduly increases the solar primary return temperature;

g) prevention of discharge or waste of water; and

h) retention of system fluid levels without user intervention.

4.9 Primary protection from frost damage and corrosion

Primary system components should be protected from frost damage and corrosion by the use of, or a practical combination of, either:

a) HTF containing volatile corrosion inhibitors with antifreeze offering frost protection to at least –20 °C;

b) system layouts that automatically default to drainback the HTF containing volatile corrosion inhibitors from all components located in untreated areas of the building, including the collector; or

c) in systems that otherwise accommodate freezing, a HTF containing a volatile corrosion inhibitor, unless otherwise specified by the system manufacturer.

Protection from frost damage should not:

1) require user intervention;

2) compromise safety;

3) use electrical power;

4) cause loss of water; or

5) cause loss of useful heat from inside the treated area of the building.

NOTE Some collectors are designed as freeze tolerant, which can be tested in accordance with BS EN ISO 9806.

4.10 Service life

Each SDHW system should be designed to have a service life exceeding 25 years when correctly installed, without major component replacement.

NOTE 1 Some components might require replacement during the system life cycle.

NOTE 2 Further information on life cycle analysis can be found in BS EN ISO 14040.

4.11 Reducing loss of primary heat transfer fluid

The risk of fluid loss should be minimized by all of the following:

a) using a sealed system;

b) using pipe materials displaying material identification (see **7.10**);

c) using adequate pipe supports (see **7.10**);

d) using joint materials that are pressure-tested after installation (see **7.10** and **9.2**);

e) providing adequate accommodation for fluid expansion with a suitably-sized vessel; and

f) using metallic materials or other materials of equivalent performance of tear resistance, pressure tolerance, deformation strength, temperature limit, resistance to UV (where external), stability against work-hardening (cracking) and chemical leaching/corrosion.

NOTE For further details, see BS EN 1057 for copper requirements; BS EN 10255 for threaded medium weight steel; BS 7431 for assessing solar water heaters; ISO 9553 for testing preformed rubber seals and sealing compounds used in collectors; BS ISO 3302 for rubber tolerances for products; BS 903-0 for physical testing of rubber; BS 6920 for suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of water; and ISO/TR 10217 for guidance on material selection with regard to internal corrosion.

4.12 Circulation of primary heat

NOTE 1 The principal means of heat circulation in solar primary circuits is by electric pump circulators typically located as shown in Figure 5. Here the HTF is moved through the collector fluid passages in order to transfer useful heat towards the dedicated storage.

Where practicable, a pump, particularly if it is made from rigid components, should be located in the treated area of the building to:

a) protect against frost damage;

b) allow ease of access for maintenance and commissioning; and

c) allow benefit from heat losses to the internal room air during the space heating season.

A control device, such as a differential temperature controller, and system layout should be used to ensure that the pump circulates fluid through the dedicated storage only when there is a net energy increase in the storage and the average temperature of the stored water is raised within each pump cycle. The pump control or system layout should be designed such that, when the solar storage reaches its intended maximum temperature, the pump does not continue to increase this temperature or remove useful heat from the building. The pump should not be located to obstruct the pipes between multiple collectors or between collectors and any safety components. The pump should be chosen and adjusted to meet the minimum necessary system circulation characteristics for the least electrical demand.

The control device should ensure that the pump is not operated when the collector has reached its vapourization temperature since a vapour lock will form, preventing circulation. This in turn can cause unnecessary electrical consumption at the pump. When in use, the pump circulator should be inaudible in any other room in the building save for the room where it is installed, and should not exceed 20 dB where measured 1 m from the pump under any normal operating condition in normal service.

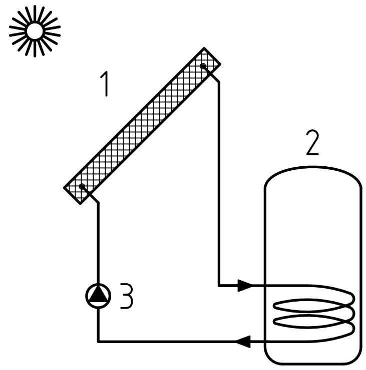
The HTF and system layout should be chosen in combination to achieve protection from frost damage to rigid components, have effective heat capacity and viscosity to reduce pump requirements, minimize internal corrosion, have low toxicity, and be resistant to stagnation temperatures, as well as minimize limescale build-up.

Where the pipes to the collector normally remain fully filled overnight, a non-return valve should be fitted in either or both of the flow and/or return pipes to prevent unwanted natural reverse circulation at night. These should have a low resistance (pressure drop) to minimize pump requirements.

A pump circulator should be fitted in the system pipework to best de-aerate itself, at a location at which it is least likely to suffer cavitation at its inlet or to encounter steam from the collector during stagnation.

NOTE 2 The pump circulator is normally located in the return part of the primary circuit.

Figure 5 **Means of primary circulation**



Key

1 Solar collector
2 Solar storage vessel
3 Pump

NOTE 1 The pump circulator is located in the return part of the primary circuit.

NOTE 2 Safety equipment omitted for clarity.

4.13 Accommodating primary temperatures

The maximum stagnation temperature can briefly appear in other parts of the solar primary system dependant on the design, which should be selected accordingly.

NOTE The maximum temperature in the SDHW primary system is limited only by the design of the collector. This temperature is measured in the BS EN ISO 9806 test conditions at irradiance of 1 000 W/m² and is known as the maximum stagnation temperature.

Where there is any component in or touching the primary system that is not rated for the maximum stagnation temperature of the collector, additional protection should be provided to that component by locating it on the return pipe so that at least 50% of the primary circuit volume is between the collector outlet and the component, using auxiliary vessels where required.

4.14 Heat efficiency

NOTE Although solar radiation can be considered abundant and freely available, once this energy is transferred into heat in the HTF it becomes indistinguishable from heat that comes from any other heat source.

4.14.1 Conservation of heat and avoidance of loss/waste

4.14.1.1 Heat in the solar primary circuit should be conserved and efficiently transferred to the solar storage with minimum losses. The system should be designed to avoid the following principal losses of heat:

a) excessive collector temperatures during circulation;

b) pipes that are external or in untreated areas of the building;

c) circulation of useful heat from within the building with the intention of a net export in the primary system, including at the collector; and

d) losses from the solar storage vessel.

4.14.1.2 The risk of loss of useful heat should be minimized by such measures as:

a) temperature control between the collector absorber and the solar storage;

b) insulation of pipes and fittings on the primary circuit;

c) automatic isolation of at least one pipe between the solar storage vessel and collector when no heat gain is available (typically achieved by spring-loaded valves, electrical-operated valves or drainback of liquid at night);

d) insulation of the solar storage vessel, including non-electrical vessel tappings and all adjoining pipes; and

e) sufficient solar storage volume (see **7.4**).

4.14.1.3 A SDHW system should be designed to avoid wastage of water for the purpose of removing heat in normal operation. Once the heat demand inside the building has been met and can no longer be effectively stored, further heat should not be circulated into the building from the solar collector.

4.14.1.4 Where there is no other hot water storage, a temperature interlock should be provided between the dedicated solar storage vessel and the backup heat source which switches off the backup heat source when sufficient temperature has been achieved. Where there is additional hot water storage, and the layout is designed to allow higher temperature heat in the dedicated storage to rise or be pumped to the additional storage, then the temperature interlock should be provided between the additional storage and the backup heat source.

4.14.1.5 A temperature interlock should be provided between the vessel that contains the dedicated solar storage volume and the backup heat source which switches off the backup heat source where sufficient temperature and volume has been achieved.

4.14.1.6 The heat efficiency measures should not compromise the insulation, weather-tightness, air tightness or fire resistance of the building.

4.14.2 Energy efficiency, disinfection and safety issues

NOTE Solar performance can be significantly reduced by other heat sources attempting to heat the dedicated solar storage. Incorrect location of secondary return circulation in dedicated solar storage, rather than the backup heated volume, has a similar effect.

The interaction of backup heating control, circulation pump control and any disinfection of the dedicated solar storage, and the impact of these on energy efficiency should be taken into account (see Annex A).

4.14.3 Backup heating control

Backup heating using stored water may be controlled using a time clock and thermostat, with a sensor located in the backup heated volume of the tank. The default switching time period (e.g. 07:00 to 09:00 and 16:00 to 22:00) with the temperature conditions (e.g. switch on <50 °C, switch off >60 °C) should be adjusted to enable the backup heating to meet the intended DHW demand, which by default for domestic households should be assumed to be the UK average unless clear evidence is found to the contrary (see Annex B).

NOTE 1 Timing of the backup DHW heater has a significant impact on extra effective solar storage additional to that dedicated to solar storage. The period of the day that has the least effect is when there is the smallest effect on solar gains. Typically, this is between 16:00 and 18:00, immediately before the peak evening draw-off and when the solar energy is starting to decline in its daily cycle.

NOTE 2 Where the backup heated volume is correctly specified for the expected DHW load and there is sufficient insulation, DHW can be made available for many domestic load patterns with only one backup heating period, which can improve backup system efficiency due to reduced primary pipework losses.

4.14.4 DHW secondary return (DHWSR) circulation control

NOTE Incorrect connection of any DHWSR can de-stratify the dedicated solar storage and raise its temperature to a point where the solar collector loses efficiency. In extreme cases, e.g. where a DHWSR connection enters the cold feed, the solar system is effectively disabled.

Any DHWSR should not normally enter the dedicated solar storage, taking account of any internal dip pipe arrangements. Separate arrangements should be made for store disinfection (see **A.2.2**).

4.15 Limiting maximum primary pressure

NOTE The absolute pressure measured in a primary SDHW system varies according to original filling pressure, height above sea level, relative height of components, position and activity of the pump circulator, temperature of the HTF and means of accommodating expansion of the fluid. Under a fault condition, the system pressure can start to approach the design limits of components. If any component catastrophically fails under high temperatures and pressure conditions there is a significant risk of explosion.

A control device should be fitted in the primary circuit to prevent the system pressure exceeding the design limit. This device should be accessible for maintenance and fitted without potential obstruction between it and the solar collectors. The device should be terminated so that, where operated, the discharge cannot cause personal injury or damage to the building (see **7.7.7**). The device should not permit passive evaporation of HTF, particularly during summer, or a build-up of moisture inside the building. The device should be capable of operating even in freezing conditions, since solar radiation can still heat up the solar collector.

4.16 Accommodating primary expansion

NOTE The volume of aqueous liquids increases by typically 8% from freezing conditions through to the maximum stagnation temperature in the solar collector.

The primary expansion should be accommodated by a method that does not rely on or allow the discharge of HTF or contamination or loss of water, or require user intervention. There are two common methods of expansion which may be used to meet these design criteria:

a) a metallic vessel encasing a flexible polymer membrane which retains a volume of gas to absorb expansion without mixing with the HTF; and

b) a metallic vessel retaining a volume of gas to absorb expansion which mixes with the HTF normally only used in a drainback primary system.

Either vessel should be capable of tolerating higher temperatures than might be experienced in a SDHW system, and be compatible with any HTF used.

4.17 Warnings and indicators of system status

NOTE During high solar radiation conditions, a SDHW system is capable of generating high-temperature pressurized liquids or gases that can appear unexpectedly in any part of the primary system, particularly during fault conditions or during maintenance, servicing or commissioning.

The risk of high-temperature liquids or gases being generated by a SDHW system should be minimized by the installer providing a suitably durable warning notice adjacent and within sight of the solar storage vessel. The warning notice should confirm the risk of high temperatures, identify the location of the solar collector and confirm the type of HTF. Further information should also be provided to:

a) confirm the level or pressure of HTF in the primary circuit;

b) display when the control system requires the pump to operate;

c) confirm the rate of primary circulation; and

d) confirm the collector (fluid in the absorber) temperature and the solar storage vessel temperature adjacent to the heat exchanger.

5 Site inspections and technical pre-installation surveys

A risk and structural assessment of load-bearing surfaces should be carried out before work commences on a site. A bacterial growth risk assessment should also be carried out to identify the measures required to minimize risk (see **4.4** and Annex A).

A technical survey should be conducted, either on site or remotely, using drawings or photographs. However, an on-site visit should be made for existing buildings. The assessment should be completed by a competent, experienced technical person.

The site visit should involve an assessment of the shading and reflectance. Where possible, this should be established from the viewpoint and same height as the intended collector fixing surface.

NOTE 1 An accurate recording of such information is essential for future validation of a design, such as where performance predictions are disputed. For larger areas, multiple measurements from representative parts of the intended array can be averaged.

The measurement and recording of the collector fixing area, such as on a pitched roof, should include the area dimensions, compass orientation and pitch angle.

NOTE 2 Electronic techniques can allow personnel to take all measurements from the ground level and make adjustment for height in computer software. Site information may be digitized for computer use in simulation software to obtain more accurate predictions of performance.

NOTE 3 An example survey form is shown in Annex D.

6 Provision of customer information

6.1 Technical information

The following technical information should as a minimum be provided to the customer before or at the point of presenting a quotation:

a) intended location of key equipment;

b) intended size of key equipment;

c) specification of key equipment;

d) reuse of any existing equipment;

e) intended indicators of information operation;

f) confirmation or otherwise of user intervention necessary to operate the quoted system;

g) an annual performance prediction, including solar yield, solar fraction, system efficiency and fractional saving (see Figure 1) on the existing DHW fuel and estimated electricity use;

h) assumptions of climate, DHW usage and water temperatures;

i) maintenance requirements;

j) expected lifetime before key component replacement; and

k) any other equipment fitted.

6.2 Financial information

Where financial information is passed to the prospective customer, the basis for the economic calculations, the assumptions and the method should be provided with the calculated figures. In particular, where a comparison is given with other investments, the cost of capital either as a loan or opportunity lost should be integrated into the calculated figures along with expected maintenance or servicing costs and the expected loss of efficiency over the stated period of analysis. The tax implications should be clearly stated as included or not included.

NOTE For further details see BS EN 15459 and BS ISO 15686-5.

6.3 Environmental information

Where environmental issues/CO_2 information is passed to the prospective customer, the basis for the calculations, the assumptions and the method should be provided with the calculated figures. In particular, the boundaries of the information should be made clear as to whether the figures include manufacture, transport and disposal at end-of-life, as well as issues caused when in use.

NOTE For further information see PAS 2050.

7 Details of key components

7.1 General

All materials, fittings and components used in the installation should conform to the applicable British Standards.

NOTE 1 Attention is drawn to the Building Regulations [7, 8, 9] which require that building work is carried out: a) with adequate and proper materials which: i) are appropriate for the circumstances in which they are used; ii) are adequately mixed or prepared; iii) are applied, used or fixed so as adequately to perform the functions for which they are designed; and b) in a workmanlike manner.

NOTE 2 The Water Fittings Regulations and Bylaws [10, 11, 12] require all water fittings to be adequately protected from frost damage.

7.2 Solar collector and fixing surfaces

7.2.1 Collectors

*COMMENTARY ON **7.2.1***

Condensation formation under the collector cover can be exacerbated by the differential temperature between the cold feed, the return to the collectors, the ambient external temperature, and the relative humidity.

The highest temperature is reached by an absorber when there is no fluid flow through it. For example, this can occur during normal operation, on power or pump failure, on shutdown for maintenance, or during installation. Under these conditions, the plate temperature can easily approach 150 °C and up to 250 °C in advanced collectors.

*Details of collector tests can be found in BS EN ISO 9806. Some collector test parameters are frequently used in energy calculations, and definitions of some of the common terms are given in **11.2.2**.*

The performance and durability of all new solar collectors should be in accordance with BS EN 12975-1 and BS EN ISO 9806.

The following should be taken into account:

a) collector cover impact resistance (to resist accidental, vermin or malicious damage);

b) spread of fire;

c) mountings (with sufficient strength to withstand wind and snow loads) (see **7.2.2**);

d) roof integration;

e) suitability for A-frames, flat roofs, wall mounting;

f) corrosion-resistance, e.g. to sea salt;

g) colour and aesthetics;

h) rainwater run-off and resistance to wind-driven rain; and

i) recyclability.

7.2.2 Collector mounting

Collectors may be mounted in various ways, e.g. on pitched roofs, on-roof or in-roof. Collectors may also be fixed to flat roofs, vertical walls, balustrades, facades and canopies, and mounted on frames to improve the tilt angle to the optimum.

The collectors of a solar heating system are subject to loading by the wind and accumulated snow. Frame-mounted panels are subjected to greater wind loads than those mounted parallel to the mounting surface. The fixings that support each collector should withstand these loads, together with the weight of the collector. They should also transfer the loads safely to the roof members or other foundations without impairing the weather-tightness or strength of the structure.

Collector fixings should be durable for the life of the installation and resistant to the forces given in **7.2.13**. The fixing method chosen should be influenced by these forces and might require the removal and replacement of cladding. The mounting surface should be inspected to ensure that it is sound and secure before installation.

NOTE 1 For further details on tiled, pitched roofs, see NFRC Guidance Document 01 [13].

Where direct contact with the mounting surface is unavoidable, a support frame should be used that evenly spreads the load on the roof cladding and allows for run-off. Where the collector array is readily accessible to the public without requiring tools or keys, a protective barrier should be constructed.

Provision should be made to prevent the accumulation of leaves and other debris, and to allow rain and snow run-off. The risk of ice/snow falling from a collector should be taken into account. A horizontal clearance from edges of 1.5 m around a collector array should be provided to allow future access for maintenance and to reduce wind loads. The risk from vibration effects from nearby mechanical or transport equipment should be taken into account. Where fixed in nearby rows, the prospect of mutual shading should be considered.

NOTE 2 Profiled roofs may incorporate such features naturally, but flat membrane roofs require a separation distance. Experience shows 50 mm is generally adequate.

7.2.3 Positioning of the collector

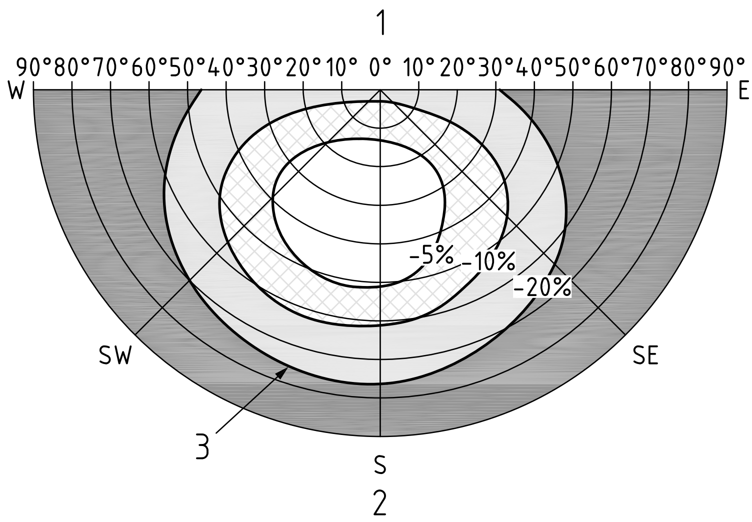
The estimated solar energy supplied by a system should be adjusted to account for the variation with the orientation and tilt of the collector, which is usually determined by the existing roof.

NOTE Figure 6 shows an example of where the variation is slight and a collector facing anywhere between southeast and southwest, with tilt angle between 5° and 60°, can provide an annual yield at least 90% of that obtained at the optimum position. However, systems designed for high solar fractions (e.g. >50%) are more sensitive to collector position.

Shading from trees, buildings, etc., can produce a significant decrease in system performance. Collectors should be positioned to minimize shading, especially between 10:00 and 14:00 when the solar radiation is usually at its highest.

The collector should also be positioned to allow ready future inspection of its installation for maintenance.

Figure 6 **Variation of the solar energy, Q_{col}, with orientation and tilt**



Key

1 Tilt angle

2 True South (applies to Northern Hemisphere only)

3 Percentage loss of Q_{col}

7.2.4 Structural forces

The installation of the solar collector should not impair the building structure's ability to withstand the combined primary forces of dead load, wind load and imposed loads expected during its service life.

Fixings and/or frames should be designed to be maintenance-free during the design life of the collector, i.e. not less than 20 years. In addition to the primary loads, fixings should be designed to withstand other effects, such as bending due to variation in wind forces, fatigue, differential thermal movement, abrasion against roof tiles and other nearby materials, and corrosion due to rain and accumulated debris. The structure of the fixing surface (e.g. concrete, wooden rafters, steel purlins, underfelt) should be checked before and after installation, with any penetrations made good where necessary.

The characteristic value of the uplift resistance should be determined from the measured failure loads and reported in accordance with BS EN 14437. For design purposes, the characteristic uplift resistance load should be divided by an appropriate partial (safety) factor obtained from BS EN 1993-1-1 and BS EN 1995-1-1.

The ultimate and serviceability limits should be calculated with consideration of the following:

a) breakage of the mechanical fixing between the roofing element and the structure;

b) pulling out or breakage of the connection of the mechanical fixing to the roof; and

c) breakage of covering elements.

7.2.5 Fire resistance

The addition of the installed system should not impair the fire resistance of the building element to which it is attached.

NOTE 1 Where a suitable test in BS EN 12975-1 has not been completed, roof-integrated collectors can be tested for fire resistance in accordance with BS 476-3. If an above-roof collector is used on roofs whose outer covering is non-combustible then an external fire test is not applicable. Otherwise, the solar collector together with the outer roof covering can be tested in accordance with BS 476-3 and the rating declared.

NOTE 2 Attention is drawn to the Building Regulations [7, 8, 9] regarding the type of roof used to mount the collector and any backup roof construction. For typical type testing procedures, see BS 476-3.

Where pipes pass through a separating wall or floor, protected structure or cavity barrier, they should be adequately fire-stopped without inhibiting movement from thermal expansion.

7.2.6 Thermal insulation for thermal performance

NOTE Insulation for frost protection and thermal performance are two different applications.

Where the collector forms an integral part of either the roof or external wall of a building, it should be thermally insulated on the side facing into the building to a level not less than that of the surrounding parts of the roof or wall in which it is situated.

The insulation should be as specified by the designer of the system and should be sufficient to prevent condensation that is likely to form on the pipe returning from the storage tank.

All tanks, cisterns, cylinders, pipes, etc., should be insulated using insulation board or other conventional or proprietary systems (see BS 5615 and BS EN 12828). Pipe insulation should retain its structural and thermal properties at all foreseeable operating temperatures.

Wall thickness of solar primary pipe insulation, where made from EPDM (ethylene propylene diene monomer)-based rubber insulation, should be in accordance with Annex E.

7.2.7 Bio-deterioration

The collector and associated equipment should be constructed and installed such as to inhibit the entry of small mammals, birds and large insects.

Materials that can be adversely affected or attacked by organisms such as fungi, mosses, bacteria and insects should be suitably treated. Collector covers and other exposed components should be sufficiently durable to resist attack from birds and vermin.

NOTE Methods of test to establish the fungal resistance of organic materials are given in BS 1982 and BS 838.

7.2.8 Constructional sealants used to facilitate weatherproofing

Where used, constructional, flexible sealants should conform to BS EN ISO 11600 or BS 6213, and should retain at least 50% flexibility throughout their life and be resistant to UV degradation. Where in contact with pipes, the sealant should be resistant to temperatures that exceed 150 °C.

Where the manufacturer’s instructions are unavailable, sealants should only be applied in dry conditions, with ambient air temperatures above 5 °C. Fixing should only be to a dust and oil-free clean surface and the sealant should be tooled to ensure adhesion.

7.2.9 Condensation and ventilation in voids

NOTE 1 Condensation might form where solar collectors are fixed to surfaces with metal straps or bolts that pass through the external covering. Excessive condensation can result in decay of the timbers and internal dampness. Condensation on cold pipework can be prevented by insulation.

Where a vapour barrier has been installed, its integrity should be maintained.

NOTE 2 BS 5250 gives further information for pitched roofs.

7.2.10 Weather resistance and external weatherproofing

Where the system is attached to, or forms an integral part of, an occupied building, including walls, facades and roofs, the positioning and method of attachment of the collector to the building should not impair the weather-tightness, insulation, corrosion resistance or resistance of the building to ingress of moisture, dust or wildlife for a design life exceeding at least 20 years. For all building surfaces used as collector fixing surfaces that also provide external weather resistance, the following should be taken into account:

a) visual access should be maintained to the building covering behind the collector for ongoing maintenance inspections;

b) loads should not be transferred (static, wind uplift or downforce with or without snow) onto the building covering that might exceed the covering's structural limits in all foreseeable circumstances;

c) where foreseeable loads exceed the covering's structural limits, the loads should instead be designed to be transferred directly onto substantial roof structures, i.e. rafters, purlins and trusses;

d) foreseeable negative pressure lifting during high winds of adjoining partly fixed building components (such as tiles) should be allowed for;

e) sufficient overlap of adjoining building components such as flashing or tiles should be present to counter any risk of leaking from impairment to drainage levels expected during intense storm-bursts; and

f) all unprotected gaps caused by the mounting and installation arrangement are not greater than those that would be present without the solar collector installation.

7.2.11 Effects on the roof structure

Where necessary, timber members and joints should be strengthened and/or additional members provided to distribute the loads more widely among the rafters.

NOTE The loads applied to the collector fixings are normally transmitted to the roof structure. The applied loads not only increase the magnitude of forces in the members of the truss, but by being applied asymmetrical can cause a member or joint designed for compression to be put in tension or torsion.

It might also be necessary to support an additional water tank in the loft space along with prevention of freezing to unprotected rigid components. Any additional load should be taken into account.

7.2.12 Sizing of the solar collector

The area of the proposed collector to be installed should be chosen on the basis of several factors related to the systems, location and usage. A site visit and accurate survey should be undertaken to provide the input data for the factors.

For an initial appraisal, the required solar energy contribution (kWh) intended to displace the DHW backup energy source should be identified using the following assumptions and Figure 7:

a) annual irradiation of 950 kWh/m^2 measured horizontally, of which 5/6 occurs between April and September inclusive;

b) residential average daily hot water use of 45 L per person drawn off at 50 °C (see Annex B);

NOTE 1 Commercial premises in particular might be substantially different from domestic properties. Some quantities of DHW draw-off from particular point-of-use appliances might not be suitable for solar preheating and ought to be discounted from these average figures. Examples of these are shown in Annex F.

c) desired solar fraction 40% to 65%;

d) collector orientated between southeast and southwest and pitched between 30° and 55°;

e) little or no shading on collector;

f) primary pipework 15 mm diameter with insulation not less than 13 mm minimum wall thickness;

g) cylinder insulation not less than 50 mm wall thickness;

h) dedicated solar storage with daily DHW usage ratio of V_s/V_d > 0.8 for preheat storage vessels and V_s/V_d > 0.4 for combined tanks; and

i) heat exchanger area >0.15 m^2 per square metre of the collector's active area.

After normalization to the indicated DHW usage, the quantity should be entered on the vertical axis of Figure 7. The collector area dependent on banded collector performance factor shown in Table 2 should be derived from the horizontal axis and multiplied by the normalized ratio of the DHW consumption.

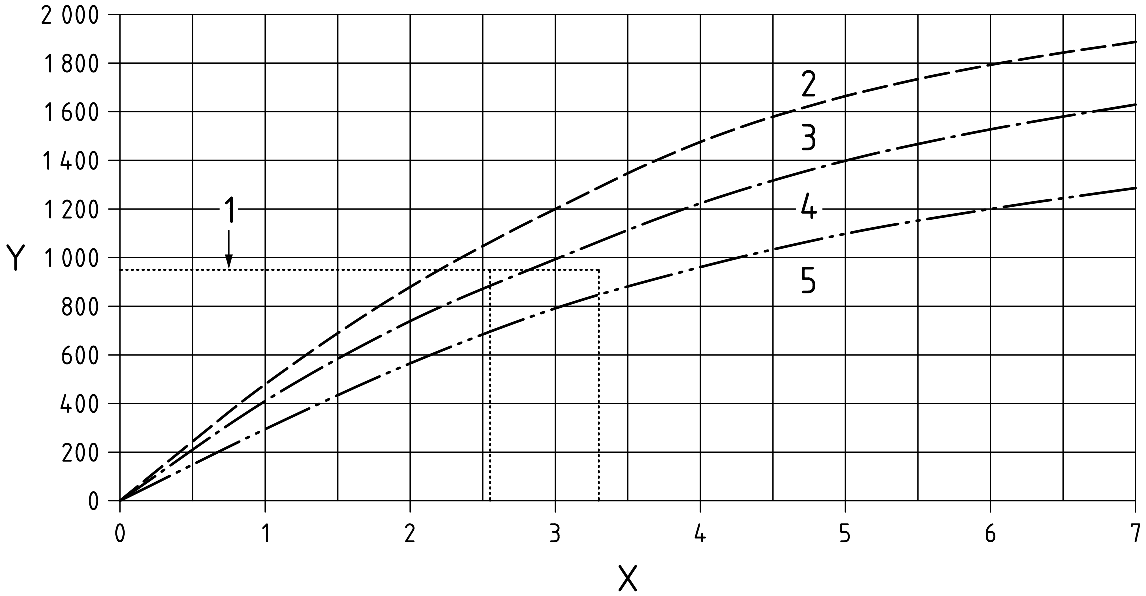
NOTE 2 Figure 7 assumes an average DHW consumption of 100 L/day of DHW at 50 °C, with a usage profile given in Table B.1, pipe insulation 19 mm and storage tank insulation 50 mm. To use Figure 7, the solar energy collection target is adjusted pro rata for these values. An example is given in Annex G.

Table 2 **Technology classes according to collector performance factor (see 11.9)**

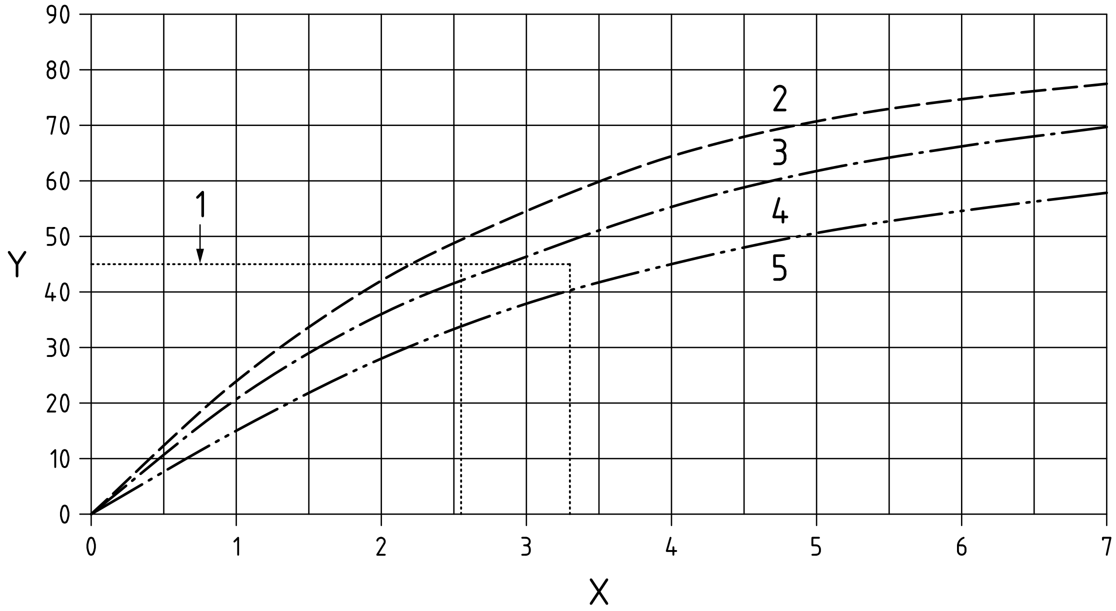
Collector performance factor $f(a^*/\eta_0)$	**Typical technology**
$f \geq 1.0$ ultra-high performance	CPC collector
$0.9 \leq f < 1.0$ high performance	Evacuated tube
$0.8 \leq f < 0.9$ medium performance	Flat plate
$f < 0.8$ low performance	–

Where the averages from Figure 7 are not met or a complex collector array, heat exchanger or storage layout is present, the manual method in **7.2.12** is not valid and proprietary software should be used instead.

Figure 7 **Sizing of collector active area**



a) Annual energy delivered by the solar collector loop (Q_{sol}, Figure 1) against collector active area, for 100 L DHW at 50 °C



b) Annual energy delivered by the solar collector loop (Q_{sol}, Figure 1) against collector active area, for 100 L DHW at 50 °C

Key

X Active collector area, m² per 100 L DHW at 50 °C

Y a) Energy delivered by collector loop, kWh per 100 L DHW at 50 °C

b) Solar fraction, %

1 Example in Annex G
2 Ultra-high performance
3 High performance
4 Medium performance
5 Low performance

7.2.13 Loads on collectors and fixings

Collectors and their fixings should be designed to the magnitudes, directions and lines of action of forces applied to the collector.

To determine the most unfavourable load cases, combinations of dead load, imposed load, snow load and wind load which might act at the same time should be taken into account. Where wind and snow act together, the lesser of the two loads may be reduced by an appropriate load combination factor, $\psi 0$ (see BS EN 1990).

NOTE These loads vary with the location and construction details of the roof and how the collector is mounted.

All design loads (and their load safety factors) relevant to the site should be obtained from BS EN 12975-1, BS EN ISO 9806 and the following Eurocodes:

a) BS EN 1990;

b) BS EN 1991-1-1;

c) BS EN 1991-1-3;

d) BS EN 1991-1-4;

e) BS EN 1993-1-1; and

f) BS EN 1995-1-1.

7.3 Water storage vessels

7.3.1 Specification of the water vessel

Water vessels intended to store heat from a solar primary system should be manufactured in accordance with BS EN 12977-3. The following information should be provided to describe the water vessels' suitability for stored heat from a solar primary system.

a) Stored water:
   1) volume;
   2) material and corrosion protection;
   3) maximum operation pressure;
   4) maximum operation temperature;
   5) thermal insulation;
   6) diameter and type of connections; and
   7) volume(s) heated by electrical heating element(s) or backup heat exchanger(s).

b) Electrical heating source(s):
   1) voltage;
   2) nominal heating power; and
   3) diameter and type of connection.

c) Heat exchanger(s):
   1) volume;
   2) material and corrosion protection;
   3) type of pipes (with/without ribs, coil, etc.);
   4) size of the area for heat transfer;
   5) position inside the store;
   6) maximum operation pressure;
   7) maximum operation temperature; and

8) diameter and type of connections.

d) Dimensions:

1) weight of the complete storage device (empty);

2) gross height of the complete storage device; and

3) gross diameter or corresponding characteristic dimension of the complete storage device.

e) Thermal parameters:

1) thermal capacity of the entire store;

2) thermal capacity of appropriate parts of the store (e.g. backup heated part);

3) standby heat loss capacity rate (optional: operating heat loss capacity rate);

4) parameter describing the degradation of thermal stratification during standby;

5) parameter describing the quality of thermal stratification during direct discharge; and

6) heat transfer capacity rate of the heat exchanger(s), UA_{hxs}, with the test conditions (fluid, temperatures, flow rate, transferred heating power) for the determination of the heat transfer capacity rate mentioned in the test report.

f) Temperature sensor pockets:

1) vertical positions of the temperature sensors;

2) tapping connections;

3) inlet and outlet connection(s) for direct charge and discharge;

4) inlet and outlet connection(s) of the heat exchangers; and

5) information on the ability for stratified charging/discharging.

7.4 Storage size method

7.4.1 General

Insulation applied to the preheat storage vessel and cylinder should be in accordance with BS 1566.

NOTE 1 For preheat storage vessels (i.e. where the backup heater cannot heat the solar storage volume) provided the volume of the dedicated solar storage, V_s, exceeds approximately 80% of the average daily hot water usage, its size does not significantly affect the annual solar energy supplied.

NOTE 2 Vessels that include backup heating (e.g. twin-coil type) can use a proportion of the backup volume as effective solar storage and the lower range of V_s may be considered. However, if the volume is significantly reduced then the annual solar energy supplied will be reduced considerably assuming an average DHW profile.

7.4.2 Effective solar storage volume calculation

In calculating effective solar storage volume using Table 3, the following constraints should be observed:

a) where a separate preheated cylinder is used, $V_{eff} = V_s$ and should be not less than 115 L; and

b) where a combined cylinder is used, $V_{eff} = V_s + F (V_{total} - V_s)$ and V_{total} should be not less than 140 L.

NOTE 1 Factor F is taken from Table 1.

For a thermal DHW store, larger sizes should be chosen due to the associated reduced stratification and higher DHW storage temperatures.

For low DHW usage the larger figure in the range should be used.

Table 3 **Storage ratio according to collector size**

Collector type	**V_{eff}: active collector area** L/m^2
Flat plate	45 – 30
Evacuated tube and CPC	60 – 40

The next commercially available size of store volume up from the calculated size should be selected, subject to sufficient clearance.

NOTE 2 Undersized solar storage has a decreasing ability to store peak summer gains from day to day and has a higher risk of stagnation and over-heating components unless suitable precautions are taken. Where a reduced risk of stagnation is required during prolonged reduction of DHW draw-offs coinciding with prolonged high radiation periods, then larger rates of storage are recommended.

The installer should limit the highest temperature of storage in areas of high limescale risk (see **A.4**).

Higher temperatures of storage allow more solar energy to be stored per litre, but can also increase the scalding risk, interfere with DHW terminal devices and reduce the life of components. Solar primary systems should allow accurate adjustment of maximum storage temperatures through the use of an electronic thermostatic control.

7.4.3 Solar heat exchanger sizing

To enhance system performance, the heat exchanger should be designed to maintain the return circuit to the collector as close as possible to the temperature of the incoming secondary cold feed to the store. The heat exchanger should be large enough to transfer lower temperature heat, and located as low as possible in the dedicated solar storage to benefit from stratification of the stored water.

As a minimum, the heat exchanger area should be >0.15 m^2 per square meter of the collector's active area. This assumes the heat exchanger is copper plain wall, spiral wound internal to the storage vessel. Different heat exchanger materials, designs and layouts should use areas that provide an equivalent rate of heat transfer.

7.5 Plumbing components

The components used should be suitable for the temperatures, pressures and other conditions found in solar heating systems. Where water is intended for human consumption, non-metallic components should conform to BS 6920.

NOTE 1 Particular attention is drawn to the high temperatures that can be experienced by components and the possibility of vermin attack.

The system plumbing should be designed to ensure that there is an approximately equal balanced circulation through matched collectors in an array.

NOTE 2 This may be checked under strong irradiance using an accurate, fast-responding electronic thermometer at each array junction.

7.6 Heat transfer and flow rates

To maintain collection efficiency of a solar collector, a minimum circulation rate and low return temperature should be maintained. Insufficient flow rates lead to elevated temperatures at the collector which reduces collector efficiency. To ensure adequate efficiency, flow rates should be in the region of 0.008 kg/s to 0.02 kg/s per square metre of the collector's active area. Flow velocities should not exceed 2 m/s, as excessive flow velocity can give rise to noise and erosion. This is adjusted with choice of pipe diameters.

NOTE 1 The ability of a fluid to store heat is based on its mass. The volumetric circulation rate can be calculated from the density at a known temperature.

NOTE 2 In considering peak heat exchange rates, the following can be assumed: max peak irradiance at 1 200 W/m^2 and collector efficiency at 60%.

NOTE 3 The thermal power reaching the heat exchanger inside the storage can be assumed to be that leaving the collector less the pipe losses.

NOTE 4 Typical HTF characteristics are: specific heat capacity of water at 50 °C = 4.2 kJ/kg.°C, aqueous glycol mixtures = 3.8 kJ/kg.°C, density water at 50 °C = 993 kg/m^3, specific gravity of polypropylene glycol at 50 °C @ 40% aqueous solution = 1.03.

7.7 Controls

7.7.1 General

Safety, performance and system status controls should be provided. These three functions may be combined into a single unit. The system control should ensure fluid is only pumped through the collectors when there is a useful energy gain and to ensure system and user safety. The pump control may be on/off or with modulation of the pump speed. Control of the backup heating, multiple collector fields or heat loads may also be provided.

7.7.2 Electrical connection

All wiring and apparatus should be installed in accordance with BS 7671.

A labelled, readily-accessible double-pole isolating switch should be provided for service and emergency disconnection.

NOTE Equipment that is not double insulated usually requires an electrical earth.

Heat-resistant flex should be used when in contact with components that are part of the primary system in accordance with BS 7671.

7.7.3 Testing

Controls for SDHW systems should be tested in accordance with BS EN 12977-5 and BS 7671.

All electrical wiring and apparatus associated with a solar heating system should be inspected and tested to determine the correct polarity, effectiveness of earthed equipotential bonding and adequacy.

7.7.4 Electrical interference

Electrical noise picked up through the sensor leads, the mains leads or otherwise should not alter the specified switching temperature differentials. Wiring should be in accordance with BS 7671 for separation and cable specifications for different voltage classes.

Control systems should not generate an amount of electrical interference sufficient to affect other electrical equipment.

7.7.5 Marking and information

Marking on and information supplied with a controller should conform to BS EN 60730-2 and BS EN 12977-5:2012, **12.2**.

7.7.6 Controls operating on the primary circuit for controlling storage temperatures

Controls for solar water heating systems should conform to BS EN 60730-2-9, BS EN 12977-5, BS 8558, BS 1566, BS EN 806 (all parts) and BS EN 12897.

Controls should be used to prevent heat passing from the solar primary circuit that would otherwise raise the temperature of the stored water beyond a maximum by both:

a) an automatic re-setting thermostat with user-adjustment; and

b) a manual re-settable limit thermostat.

*NOTE 1 For more details see **4.12**, **4.13** and **A.3**.*

NOTE 2 The control and limit of the temperature of stored or distributed DHW from any heat source is generally regulated to a maximum temperature according to regulations in each region. Special attention is drawn to the Water Fittings Regulations and Bylaws [10, 11, 12] and Building Regulations [7, 8, 9] applying to hot water storage.

NOTE 3 The maximum foreseeable temperature of the primary fluid in a solar collector is not normally restrained by any controls as it is a function of the maximum solar irradiance and the performance of the collector. The fluid in the collector is likely to vaporize to form a gas at a temperature dependent on the boiling point of the liquid and the system pressure. The vapour temperature will then rise to the maximum stagnation temperature of the collector if there is no circulation. This temperature can normally be assumed to be the same as tested to BS EN ISO 9806. The control of circulation, the type of fluid, the system pressure and system layout limit the extent that the stagnation temperature extends through the connected pipes and circuitry. The extent is minimized where the collector lies above the storage tank and the pump is controlled to switch off to cease circulation at a temperature less than the boiling point of the fluid.

Where the collector lies below the storage tanks, there is a high risk of natural thermosyphon circulation overriding an inoperative pump. In this case, further controls should be fitted to prevent super-heated vapour temperatures reaching the storage tanks. These may include motorized valves that default to a closed position on both flow and return, each controlled by an automatic resettable temperature device.

The use of thermostatic mixing valves (TMVs), either centrally located or close to DHW draw-off points, may be specified irrespective of solar input. This, though, does not alleviate control and limiting of the water storage temperature and should not be used alone without controls linked to primary energy input (see also **A.3**).

NOTE 4 For the use of TMVs, see BS EN 1111 and BS EN 1287.

NOTE 5 Keeping components in contact with secondary water below 60 °C can reduce use of backup fuel, although this might conflict with bacterial protection (see Annex A).

7.7.7 Pressure control and discharge arrangements

All primary systems should be fitted with an over-pressure relief valve and a pressure gauge. There should be an unobstructed path between the collectors and the safety over-pressure valve. For solar HTFs, manufacturer guidance should be sought. Any discharge should be captured in a purpose-made vessel or termination from an over-pressure relief valve, which should discharge into a ventilated tank conforming to BS 4213.

Discharge pipes should be copper or stainless steel, be as short as possible and not reduce in diameter relative to the outlet of the valve (ideally, not more than 1 elbow is to be used in the pipework from the valve to the discharge tank). Pipe should be fixed to prevent accidental movement or removal.

A high-temperature warning should be visible on the discharge tank which should be fixed in place to prevent accidental movement or removal. A means of inspecting and emptying the vessel should be provided.

The vessel volume selected should be capable of containing the contents of the primary system between the safety valve and the collectors, including the pipework in between. The primary system should not be sealed from atmosphere without a safety valve. Discharge to an internal gully or externally to a safe location at ground level should only be considered if such receptacles are not practical. Most solar HTFs are based on non-toxic propylene glycol and are biodegradable when unused.

To minimize the risk of discharge by designing a hydraulically secure system, the calculation of fluid contents and vessel size should be verified (see Annex H for a worked example).

7.7.8 System status indicators

System status indicators should be located in an easily visible location (e.g. an airing cupboard) and should include:

a) connected indicator lights for electrical supply and any control system fault;

b) digital display indicating the collector and storage temperatures;

c) pump activity;

d) pressure gauge in the primary circuit; and

e) circulation rate gauge or other means of verifying that the rate of flow through the solar collector is adequate.

Controls should provide system information to allow the greatest energy economy from the system, including the backup heating. Temperature measurement of collector, solar storage volume and backup heating volume should be provided to determine when to use backup heating for the greatest system efficiency. Heat quantity measurement (heat meters) may be used for financial, user information and regulatory purposes. Suitable T-pieces sensor pockets and valves may be considered to allow retrofit.

Heat quantity measurement (heat meters) may be used for financial, user information and regulatory purposes. Where a circulation (flow) meter for a heat meter is fitted, it should be done taking into account the high temperatures that can occur during collector stagnation. In general, such meters are fitted near the storage vessel on the return of the solar primary loop. They should be fitted either horizontally or vertically in accordance with the manufacturer’s instructions, match the HTF type, allow drainback where necessary and not obstruct any route to safety equipment.

7.7.9 Controls and parameters

Controllers may have parameters that enable the installation to be fine-tuned. Any change to the parameters should be recorded in the commissioning documentation and should in any case be automatically restored after power failure.

7.7.10 Sensor wiring

Data cabling should conform to BS 7671 in terms of cable choice, routing, differentiation and the avoidance of interference. Where practicable, sensor wiring should be >50 mm from any mains wiring, and durable cable with correct support should be used.

NOTE UV stability and mechanical protection from vermin/bird attack might be necessary, particularly for collector sensor wiring.

Any joints in sensor wiring should provide mechanical support for the connections and be correctly fitted into an enclosure suitable for the environment to prevent water ingress, e.g. IP54, should have cable entry at the base only, using the correct gland arrangement. Twisted pair or screened cable might be required for internal environments with high electrical interference. Screens should be earthed at one end only to avoid circulating currents.

7.7.11 Surge protection

Surge protection may be used to prevent problems with lighting damaging controller input channels. The manufacturer's advice should be followed.

7.8 Sensor temperature rating and position

7.8.1 General

Sensors and adjoining cables should be heat-resistant to the highest temperature likely in service at that point, e.g. for collector sensors this might exceed 150 °C.

NOTE 1 Where required, a lower temperature rated cable can be used for extending the cable.

Temperature sensors throughout the system should be insulated from ambient and positioned to measure the temperature of the fluid as closely as possible. A purpose-made sensor pocket should be used wherever possible. Where this is not possible due to the design of the collector, the temperature of the HTF should be measured as close as possible to the absorber towards the collector flow outlet.

External insulation should be protected from bird pecking using suitable weatherproofing tape or sheathing.

NOTE 2 Thermal contact is improved with heat transfer paste.

7.8.2 Sensor types

A sensor type specified for the controller should be used, as the characteristics vary according to type and are often not interchangeable.

7.8.3 Controller position

The controller should be located in a suitable environment for which it is designed. Dripping water, condensation, etc., should be avoided. The IP rating should be correct for any zone provisions relating to equipment position in BS 7671. Where indicators are fitted, they should be at an average eye-level and in an illuminated location.

7.9 Pumps

Pumps should be selected and located for suitability with the system HTF, the expected temperatures foreseeably occurring immediately after a stagnation period and the required hydraulic duty. Particular care should be taken for larger arrays that sufficient differential pressure across the array is available to permit an even distribution.

The installer should ensure that the pump is vented of excess air or gas and that it operates quietly. Multispeed pumps should be set at the lowest setting whilst ensuring minimum collector circulation rate is achievable in accordance with the collector manufacturer's recommendations. The pump control should ensure the pump is only activated when the fluid is liquid.

NOTE Pump speed, flow rate, pipe diameter and power consumption are closely related.

7.10 Pipework: mechanical properties

Solar circuits operate over a wider temperature range than conventional heating plant, so thermal expansion of materials can be greater. A minimum allowance of 3 mm expansion per linear metre should be allowed between the coldest days and stagnation temperatures near the collector.

Pipe joints should be compatible with expected temperatures and pressures (see Table 4 for typical limitations). Where necessary, specialist high-temperature jointing materials for solar systems should be used.

Pipe insulation should be selected for its high temperature resistance, e.g. 150 °C. Where in contact with metallic pipes in the solar circuits, pipe fixings should be metallic.

*NOTE Non-metallic pipe materials may be used providing they have evidenced equivalent performance of metallic joint materials, especially tear resistance, pressure tolerance, deformation strength, temperature limit, resistance to UV where external, stability against work-hardening (cracking), chemical leaching/corrosion and, in any case, display material identification, that are pressure-tested after installation (see **4.11** and **9.2**).*

There should be no direct contact of pipes with the building structure.

Pipes should be supported with metallic materials where in contact with metallic pipes in the solar circuits. For reduced heat loss, pipe fixings that clamp over the pipe insulation can alternatively be used. Maximum spacing for fixing should be in accordance with BS EN 806 (all parts) and BS 8558.

Table 4 **Characteristics of common metallic joints**

Joint type	Pressure limit bar A)	Operating temperature limit °C	Softening points of materials °C
Most non-metal bodied joints and non-metal pipes	6	95	110
Soft solder: lead-based	16	110	140
Soft solder: lead-free	16	110	160
Silver solder (hard solder)	16	110	200
Hard braze: copper phosphorus	16	110	850
Compression without support sleeves	6	120	—
O-ring with metal case low temperature	10	110	—
O-ring with metal case high temperature	16	200	—
Compression fast coupling joint (brass ring type)	10	180	—

A) 1 bar = 10^5 N/m^2 = 100 kPa

7.11 Heat transfer fluids (HTFs)

NOTE 1 Corrosion in metals in a solar water heating system can occur both internally within the fluid passages of the collector and system pipework, and externally on the surfaces of the collector box and absorber plate.

Temperatures in solar collectors can vary from approximately –20 °C to 300+ °C when the HTF is not circulating. Hence, a correctly-formulated HTF containing vapourizable corrosion inhibitors should be used and maintained, or collector manufacturer guidance should be followed.

NOTE 2 Corrosion can be reduced by using suitable HTFs incorporating corrosion inhibitors.

The HTF should be tested at least every two years and after any stagnation events for pH and antifreeze potency (e.g. using refractometer or hydrometer). Compatibility with pump glands, expansion membrane and seals should be ensured by reference to the HTF data sheets.

Flux residues, e.g. chlorides, can exacerbate pitting corrosion and should be flushed out.

NOTE 3 Pitting corrosion and antifreeze degradation can also be caused by the effects of microorganism growth, which can be reduced by the use of suitable biocides or suitable solar cleaning fluid.

Where a filling loop to a water supply is used, it should be disconnected after commissioning in a manner that prevents reconnection without tools [see also **9.2**c)].

7.12 Expansion vessels (plumbing)

7.12.1 General

Expansion vessel capacity should be calculated for all system designs. The volume of fluid in the primary system, V_{total}, should be determined from the sum of the total volume in the collectors, the heat exchange coil, plate exchangers where present and the interconnecting pipework. The values for the products should be obtained from the manufacturer.

The amount this volume expands when heated should be calculated.

7.12.2 Calculations of expansion vessel sizes

*COMMENTARY ON **7.12.2***

Calculation of expansion vessel sizes for solar DHW systems is different to ordinary central heating systems due to the greater temperature range.

The use of glycol antifreeze and the likelihood of vaporization of fluid in the solar collector during stagnation might be necessary.

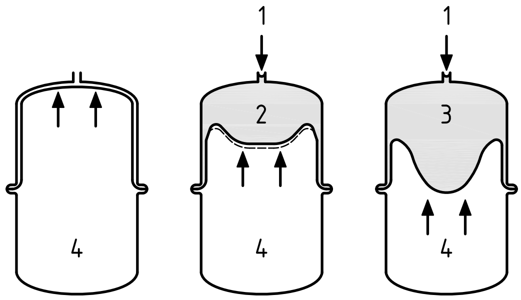
Pipework should provide more than 50% of the system fluid between the collector and the expansion vessel (see Figure 8) and this volume should exceed the expected movement of fluid into the expansion vessel during stagnation. If not, intermediate vessels may be fitted, sized >8% of the total system volume when hot (see also **4.13**).

NOTE 1 Figure 9 shows the operating pressures of the expansion vessel.

The expansion vessel volume and gas pressure should be chosen to ensure the normal operating range is suitably below the pressure at which the safety valve operates.

NOTE 2 See Annex H for a worked example for expansion vessel sizing.

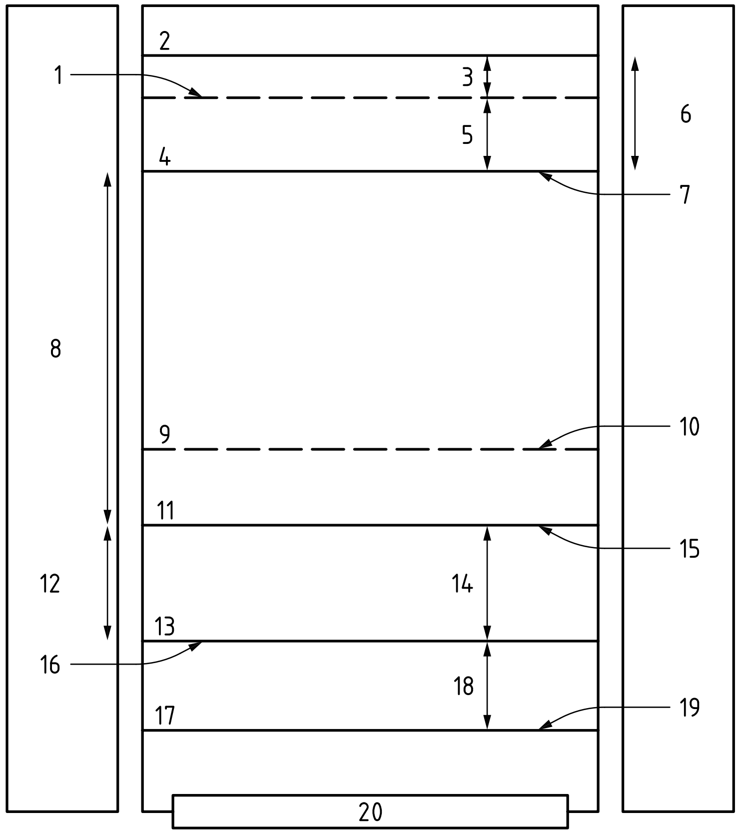
Figure 8 **Expansion vessel**



Key

1	Fluid	3	Fluid in vessel when hot
2	Fluid in vessel when cold. Dotted line indicates position when initially filled	4	Nitrogen gas

Figure 9 **Definitions and relationships of pressure in the system**



Key

1 Pressure at which safety valve closes after operation
2 Safety valve operating pressure, P_{sv}
3 Tolerance for manufacturing error
4 Safety allowance
5 Final pressure, P_{final}
6 Pressure margin for safe operation, P_{margin}
7 Pressure in system at stagnation temperature
8 Normal operating range
9 Initial filling pressure, $P_{initial}$
10 Pressure in system at time of filling
11 Minimum system pressure, P_{cold}
12 Allowance for fluid losses between maintenance cycles
13 Water seal in vessel, P_{wseal}
14 Adjusted gas side of vessel, P_{gas}
15 Foreseeable pressure in system on coldest day
16 Pressure to avoid cavitation, evaporation and formation of sub-atmosphere
17 Static pressure, P_{geo}
18 Extra over-pressure, P_{op}
19 Pressure of the liquid column corresponding to the static height difference within the system
20 Gauge pressure = 0
Absolute pressure = approximately 1 bar

8 Installation

8.1 General

Information about the layout and expected performance of the system, in terms of energy, power, temperature and pressures, should be provided to potential customers (see Clause **6** and Clause **9**).

8.2 Pre-installation procedure

The installer of the solar heating system should be prepared to carry out either of the following:

a) installations that form part of the construction of a new building where the solar heating system is part of the specification; or

b) installations added to existing buildings.

In each case, the installer should have the following:

1) a drawing indicating the required location on the outside of the structure for the collector;

2) the methods of fixing to be used, as recommended by the manufacturer or the designer, to ensure security and weather-tightness;

3) drawings showing the general layout of the solar heating system and, for existing buildings, details of the existing hot water supply and its interconnection with the new equipment;

4) a schedule of the components to be fitted;

5) a specification of the HTF to be used;

6) the suitability of existing or proposed roof structures to accommodate the installation; and

7) confirmation that clearance of the statutory requirements has been obtained.

8.3 Installation procedures

8.3.1 General

The systems should be installed in accordance with BS 8000 (all parts).

8.3.2 External work

The fixing position of the collector should be inspected by a competent, experienced person(s) with suitable knowledge of such operations or works. Before raising the collector up to the fixing position, fixings conforming to the manufacturer's recommendations should be installed. The collector(s) should be inspected for damage at ground level and disposed of if damaged.

The installation should be carried out employing suitable practices, with regard to the maintenance of the health and safety of all concerned. Any special lifting requirements detailed by the manufacturer should be observed.

Collectors should be shaded with a removable cover (e.g. elasticated cover or heavy paper secured by adhesive tape) during installation to reduce the risk of burns, and also to reduce the risk of damage to the collector or thermal shock degradation of the HTF.

NOTE 1 Solar collectors are specifically designed to convert the solar radiation into heat and can become extremely hot when exposed to sunlight.

NOTE 2 The handling and method of fixing solar collectors to roofs varies considerably for different roof types and collector designs.

9 Commissioning and documentation

9.1 Cleaning the system

The system should be thoroughly cleaned and flushed out with HTF to remove any impurities, and drained and refilled with fresh HTF solution. The flushing fluid may be retained for future use. Special solar cleaning fluids may be used to remove sludge and debris from old systems where encountered during service work. These fluids should be thoroughly flushed out with water before refilling with new HTF.

At this stage, all unions and glands may be checked to ensure they are watertight and free from leaks. Circuits should be given a second inspection once filled and with the pump operating, particularly in systems where a circulating pump is employed.

The installer should ensure that all non-return valves (where fitted) and the pump are connected the right way round (usually indicated by an arrow) for the direction of circulation, and that non-return valves and motorized or solenoid valves are operative. Caution should be applied to attempting different aqueous solutions with each other when refilling.

9.2 Filling and pressure test

Pipework should be filled and pressure-tested in accordance with BS EN 806 (all parts) and BS 8558, with special consideration of the following:

a) the design (working) pressure should be carefully defined (see Figure 9);

b) where the collector is left connected during testing, it should be covered to prevent solar radiation reaching the absorber and causing heating; and

c) during testing, any air pockets should be removed from the primary solar circuit, which might require using a temporary high flow-rate pump and reservoir.

9.3 Special considerations for drainback systems

A solar heating system that is susceptible to frost damage can incorporate a temperature-sensing device that monitors either freezing conditions at the collector or the ambient temperature adjacent to the array, or both. Frost control devices may be of a simple on/off logic or they can monitor the differential temperature irrespective of ambient temperature and drain the system when no temperature differential exists between the collectors and the preheat storage vessel.

Where drainback systems are used, the installer should test that the installation is operating correctly with a test button facility. Where there is no test button, the manufacturer should provide instructions for overriding the control so that the arrangements for drainback can be tested.

9.4 Thermal insulation for the system

All testing and inspection of the system should be conducted before the system connections are thermally insulated to ensure there are no leaks.

9.5 Housekeeping

Before an installation can be regarded as satisfactorily completed, the installer should ensure that any damage to the structure caused by the fitting of pipes, tanks, mounting brackets, etc., is made good in accordance with BS 8000-15.

In particular, any damage to the roof coverings and linings resulting from the installation of fixing brackets and pipes, etc., passing through the roof cover should be repaired and sealed. Damage to guttering, walls, garden and lawn by scaffolding, etc., should also be made good.

9.6 Start-up and handing over

Once the installation is complete, and depending on the time of year and the instructions of the customer, the system may be switched on and left operating or left in a safe condition for handing over. Where appropriate, the collector should be securely covered. In either event, the installer should present an appropriate document to the customer, certifying that the system has been installed and commissioned satisfactorily.

At handover, the customer should be supplied with the following documentation:

a) manufacturer's documentation;

b) operating instructions; and

c) description of the control system.

NOTE Document specifications can be found in BS EN 12977-1:2012, ***6.7****, BS EN 12976-1:2006,* ***4.6.3****, and BS EN 12977-5:2012,* ***12.4****.*

Where special additives are used in the HTF, the following should be attached to the appropriate system components in the most visible location:

1) durable identifying labels providing the necessary information as to:
   i) the formulation;
   ii) solution strength;
   iii) specific hazards;
   iv) source of supply; and
   v) expected life of the liquid; and

2) a separate label recording the date of the installation and the name and address of the installer.

The annual electrical consumption of pumps and controls should be assessed and presented to the customer.

9.7 Post-commissioning checks

A post-commissioning visit within a few weeks may be included in the supply and fixing cost, as part of a maintenance contract or as an arrangement with the installer. The following checks should be made as a minimum:

a) that all unions and glands are free of leaks;

b) that the glazing seals are weather-tight and sound;

c) that all air/gas has been expelled from the collector circuit unless the system is intended to operate with these present, i.e. drainback systems;

d) that the levels in cisterns are correct or that sealed systems are at the correct pressure and volume;

e) that electrical controls and warning indicators are operating correctly, according to the manufacturer's test instructions;

f) that the circulating pump is operating without undue noise;

g) that all insulation is firmly attached;

h) that all cistern covers are properly in place;

i) that no condensation or damp spots are apparent, particularly around the pipes and fixings in the roof space;

j) that roof fixings are firm and that the roof covering is free from cracks and abrasions beneath the collectors; also where brackets lift the tiles/slates/sheets, remedial work should be carried out to reduce the gaps to a level compatible with the main covering (e.g. some brackets lift tiles by 5 mm or 6 mm, so notches need to be taken out of the back of the tiles, or the slates/tiles need to be cut either side of a bracket and a soaker installed); and

k) that the collector mounting supports, etc., are secure.

A suitable checklist should be provided by the supplier for the inspection and it should be signed and dated by the person making the inspection. A copy should be left with the customer.

10 Maintenance

NOTE 1 While a properly designed and installed solar heating system can give a service life comparable to that of other types of domestic heating system, some maintenance might be necessary to maintain the efficiency of the installation.

During a maintenance inspection, the following checks should be made in addition to those in Figure 10.

a) Outside the building:

   1) that the glazing of the collectors is clean;

   2) that the glazing is sound and free of cracks;

   3) that there is no evidence of serious corrosion; and

   4) that any roof fixings are sound.

b) Inside the building:

   1) that the sensing devices are firmly and properly in place (this may also form part of the external examination);

   2) that there are no signs of corrosion;

   3) that labels are in position and updated at the time of the service visit;

   4) that the life of the HTF has not expired; and

   5) that the expansion vessel pre-charge is checked.

NOTE 2 For problems that can be identified by troubleshooting, see Annex I.

HTF should be checked at least every two years for chemical stability, chemical content and correct levels.

Where the system is designed such that stagnation events cause the collector to remain fully-filled whilst exceeding 140 °C for prolonged periods, then the HTF should be checked on a more frequent cycle and replaced as necessary.

Figure 10 **Example template commissioning form handed to user**

No.	Checks	
1	User instructions explained and handed over	Yes/No
2	Decommission schedule for collector and cylinder left on site	Yes/No
3	Installation and maintenance instructions left on site	Yes/No
4	Specialist maintenance schedule (including frequency, maintenance and list of parts to be replaced during normal maintenance) left on site	Yes/No
5	Store commissioning certificate completed and signed	Yes/No
6	System drawing indicating hydraulic, valve and electrical connections	Yes/No
7	Conformity declarations for EU Directives	Yes/No
8	All documentation to be kept visibly near store protected from heat, water and dust, including name of location where documentation is left	
9	Glazing format of solar collector	Tube/Flat
10	Absorber type	Selective/Non-selective
11	Net absorber or aperture area	m^2
12	Copy of BS EN ISO 9806 conformity certificate left on site	Yes/No
13	Manufacturer's name of collector	
14	Unique serial number of collector	
15	Maximum stagnation temperature of collector	°C
16	Maximum design pressure of collector	bar
17	Maximum design pressure of preheated store exchanger	bar
18	Maximum design pressure limit of system	bar
19	System pressure setting when filled	bar
20	Minimum allowable primary system pressure/level before user action required	bar
21	Procedure for user to follow if primary pressure/level is below limit	
22	Location of primary system pressure gauge	
23	Frequency of regular test of pressure safety device	Monthly/Yearly/Biennially
24	Location of pressure safety device	
25	Location of electrical fused isolating switch	
26	Fuse rating	amps
27	Electrical controls and temperature sensors operating correctly	Yes/No
28	Backup DHW heating fitted with a thermostat responding to the solar preheated storage vessel	Yes/No
29	DHW thermostat setting	°C
30	Differential pump control setting	°C
31	Hysteresis setting about differential switching points	°C
32	Expansion or drainback vessel pre-charge	bar
33	Expansion or drainback vessel capacity	L
34	Expansion capacity suitable to be hydraulically secure	Yes/No
35	Written warning left on site if there is potentially no automatic resumption of normal operation after stagnation	Yes/No/Not required
36	Lowest ambient temperature of primary system without frost damage	°C
37	The heat transfer fluid provides freeze protection to	°C
38	Manufacturer and product name of heat transfer fluid used	
39	Corrosion inhibitor used	
40	Maximum ambient temp for pump	°C
41	Minimum ambient temperature for pump	°C
42	Circulation rate setting	L/min
43	Noise at full circulation acceptable	Yes/No
44	Direction of circulation through collector and heat exchanger matched to sensor positions	Yes/No
45	If a drainback system, pipes fall greater than 1:33 or filled with antifreeze	Yes/No

Figure 10 **Example template commissioning form handed to user**

No.	Checks	
46	Solar preheated store type	Combined with DHW/separate from DHW
47	Solar primary heat exchanger type	Copper/Steel/Plain/Ribbed
48	Solar primary to secondary heat exchanger area	m^2
49	Volume of dedicated solar preheat	L
50	Location of DHW isolation valve	
51	Method of anti-scalding in DHW distribution	Pump control/TMV
52	Location of digital temperature gauge fitted to monitor risk of DHW overheating	
53	Limescale risk to heat exchanger	Low/Medium/High
54	Limescale control in heat exchanger	Cleaning hatch/Thermostat on primary circulation
55	Expected annual delivered solar energy to taps	kWh
56	Expected annual solar fraction of DHW	%
57	Method of performance calculation	SAP version/ CIBSE Solar Design Guide/ Other
58	Daily DHW load assumption	L/day at °C

Date of site visits for bacterial, water quality and access risk assessments:

Commissioned by:

Competent persons scheme unique identification number:

On behalf of:

Date system commissioned and handed over:

Signature of commissioning engineer:

Signature of user to confirm receipt and understanding (optional):

11 Performance predictions

11.1 General

A manual calculation allows a typical system design to be refined, but this does not necessarily provide an accurate performance prediction. Where conditions and system design are atypical, accurate performance predictions should be estimated using propriety simulation software. In all cases, to perform an accurate calculation, a minimum amount of data should be known about the location and proposed or installed system. An on-site survey should be carried out to establish the likely shading risks and reflective surfaces.

*NOTE The method described in **11.2** to **11.9** allows some of the factors relating to the location and shading to be included but is not sufficiently detailed to take account of particular properties of the more advanced collectors.*

11.2 Manual calculation method

*COMMENTARY ON **11.2***

This method refers to typical pumped circulation systems only. It provides an annual figure only.

The following climate and location factors can affect the calculation.

*a) The change in weather from year to year has been shown to cause variations of up to 10% in the annual solar energy supplied in a given system. The values quoted in **7.2.12** were calculated for a long-term average at Kew near London.*

b) In a given year, variations in performance between similar systems in the same locality can occur because of local conditions, e.g. exposure to wind, cold water feed temperature.

c) The effect of latitude can be significant. For example, systems located in the north of the UK can be expected to supply less energy than the amounts quoted here, but systems located in the southwest of the UK can be expected to supply more.

d) Actual performance observed can vary significantly, depending on the detailed usage pattern, e.g. when during the day hot water is used. Similarly, if no hot water is used for an extended period, e.g. during a summer holiday season, a significant fraction of the potential annual solar contribution is lost.

11.2.1 For this method, the following factors affecting performance should be taken into account:

a) average daily hot water usage;

b) collector performance;

c) collector active area;

d) collector orientation and tilt;

e) annual average solar irradiation reaching the collector;

f) cold water feed temperature; and

g) effective storage volume.

11.2.2 The annual solar contribution Q_{sol} to the solar storage, in kWh/year, should be calculated using the following equation:

$$Q_{sol} = H \times O_P \times Z_{panel} \times A_{ap} \times \eta_0 \times UF \times f_{\left(\frac{a*}{\eta_0}\right)} \times f_{\left(\frac{V_s}{V}\right)} \times R_{panel} \qquad (3)$$

where:

Q_{sol} is the solar input, kWh/year;

H is the total hemispherical unshaded solar radiation for the location kWh/m²/year (see **11.4**);

O_P is an orientation factor as a percentage (see **11.4**, Table 5);

Z_{panel} is the shading fraction representing the average effect on annual irradiation reaching the solar collectors after considering shading obstacles (see Annex J);

NOTE 1 The loss of solar radiation striking a collector area is a complex combination due to the reduction of beam, diffuse and reflected radiation. It varies according to time of day and year. It can be assessed on site using specialized site survey equipment and software that incorporates the sunpath directions and hourly radiation values. Where such data are not available, the percentage loss-of-sky area can be measured, for example, using a form of translucent graph paper that shows the sun-paths for the locality (see also Annex J).

R_{panel} is the reflectance fraction representing difference in reflectance where different from the average (see **11.8**);

A_{ap} is the active area of collector;

η_0 is the zero-loss collector efficiency, i.e. the efficiency of the collector when the collector fluid and ambient temperature are equal such that there is no heat loss through the casing, taken from BS EN ISO 9806, as a percentage (see **11.5**, Table 6);

NOTE 2 Glazing quality and absorber coatings can have a significant impact on the η_0 value. High values are desirable.

UF is the utilization factor (see **11.6**);

NOTE 3 Where the solar energy is high relative to the hot water demand, not all the solar energy can be used. The utilization factor allows for this and, in particular, ensures that the solar input does not exceed the annual hot water energy.

a^* is the sum of the linear (W/m².K) and quadratic (W/m².K²) heat loss coefficients of the collector taken from BS EN ISO 9806, derived as follows:

$a^* = 0.892 \times (a_1 + 45 \times a_2)$, where:

a_1 is the linear heat loss coefficient of collector, W/m².K, i.e. the linear heat loss (conductivity) through the collector casing; and

NOTE 4 Low values are desirable.

a_2 is the temperature dependence of the heat loss coefficient, W/m².K².

NOTE 5 Low values are desirable;

$f_{(Vs/V)}$ is the dependence on storage volume (see **11.7**); and

$f_{(a^*/\eta 0)}$ is the dependence on collector parameters (see **11.9**).

11.3 Energy conservation and backup heating interlock

Any backup DHW heating system should be fitted with thermostatic and time control to ensure it does not operate if the solar system has already heated the water to design temperature. Existing systems should be checked and upgraded if necessary, as backup heating fuel savings are critically dependent on good control.

*NOTE 1 The calculation in **11.2** assumes an interlock exists and that the default backup DHW timer heating DHW is set at 08:00 to 10:00 and 18:00 to 23:00.*

Cylinder thermostats should be located approximately 30% up from the base of the backup heated volume.

NOTE 2 User interaction or override of backup DHW heating or heating due to bacterial disinfection is not assumed in these calculations.

11.4 Radiation on collector, *H*

The annual solar radiation for the UK over a recent historical period is shown approximately in Figure 11. There might be significant local variances in coastal or mountainous areas (see also Table 5).

Figure 11 **Variation over the UK of the annual mean global irradiation on a horizontal surface (in kWh/m²)**

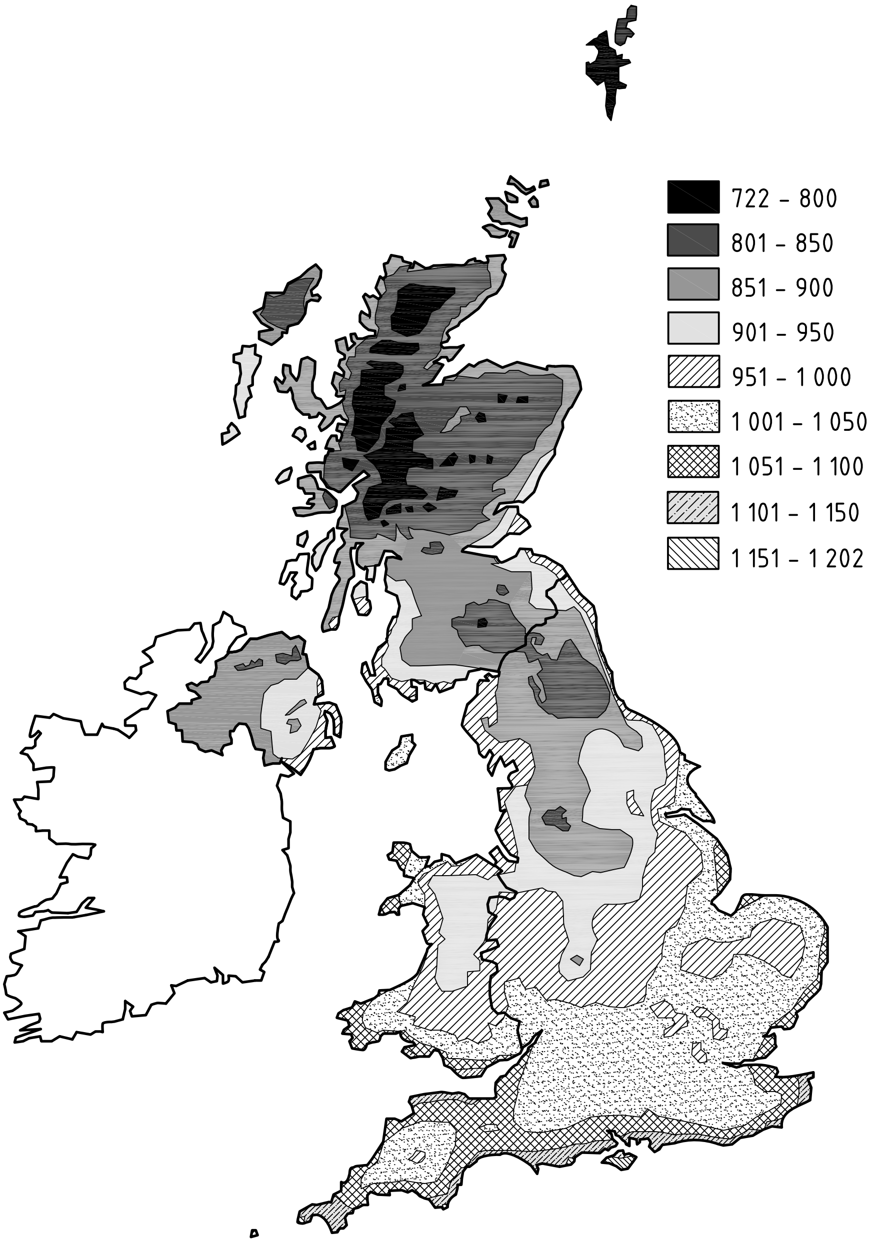


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Table 5 **Default factors for orientation, O_p, affecting annual mean daily global irradiation on a horizontal surface, *H*, according to inclination of surface and its azimuth, %**

	South	SE/SW	E/W	NE/NW	North
Horizontal, *H*	1.00	1.00	1.00	1.00	1.00
30°	1.12	1.07	0.95	0.82	0.76
45°	1.10	1.04	0.89	0.71	0.67
60°	1.03	0.96	0.81	0.62	0.52
Vertical	0.78	0.73	0.61	0.46	0.39

NOTE Table data derived for Sheffield from Page and Lebens, Climate in the United Kingdom [14]. Factors for other areas of the UK including extreme locations such as coastal and mountainous areas might require further localized data.

11.5 Collector performance

Data should be from testing the collector in accordance with BS EN ISO 9806. If test data are not available, the typical values in Table 6 should be used. Where the dedicated solar storage operates at higher average temperatures, e.g. for disinfection of bacteria such as *Legionella*, a higher average collector temperature, typically at 50 °C, should be assumed with a correspondingly lower efficiency taken from the BS EN ISO 9806 test data.

Table 6 **Typical collector parameters where BS EN ISO 9806 test data are not available**

Collector type	η_0	a^*/η_0	$f(a^*/\eta_0)$
CPC collector	0.65	1.50	1.19
Evacuated tube collector	0.70	3.40	0.97
Flat plate collector	0.80	5.70	0.83

11.6 Utilization factor, *UF*

The utilization factor, *UF*, should be defined in terms of the solar-to-load ratio, *SLR*:

$$SLR = \frac{H \times Z_{panel} \times A_{ap} \times \eta_0}{Q_u} \times R_{panel} \quad (4)$$

where:

Q_u is the annual energy for hot water (usage + secondary distribution losses).

NOTE The standing cylinder losses can be included in Q_u.

The utilization factor, *UF*, should be calculated using the following equation:

$$UF = 1 - \exp\left(\frac{-1}{SLR}\right) \quad (5)$$

11.7 Dependence on solar storage volume, $f_{(Vs/V)}$

Dependence on solar storage volume, $f_{(Vs/V)}$, should be calculated for a separate solar preheated store as follows:

$$f\left(\frac{V_{\text{eff}}}{V}\right) = 1 + 0.2\ln\left(\frac{V_{\text{eff}}}{V}\right) \quad (6)$$

with the constraint that $f(V_{\text{eff}}/V)$ is ≤1.0.

For a single cylinder with multiple heat sources, the function should be calculated using the dedicated solar storage plus 0.3 times the remainder of the cylinder:

$$f\left(\frac{V_{\text{eff}}}{V}\right) = 1 + 0.2\ln\left[\frac{\{V_{\text{eff}} + 0.3(V_{\text{total}} - V_{\text{eff}})\}}{V}\right] \quad (7)$$

where:

V_{eff} is the effective solar storage, L (see **4.5**); and

V_{total} is the total volume of the cylinder.

NOTE The factor 0.3 applied to the remainder of the cylinder conforms to BS EN 15316-4-3 where the cylinder is heated by the boiler or immersion overnight (or early morning).

11.8 Calculation of reflectance fraction, R_{panel}

The effect of reflected solar radiation from surfaces that lie in front of an inclined collector is related to the angle of the collector, the reflectivity of the surface, its angle of inclination and the relative area it occupies and its distance from the collector array.

NOTE 1 The effect is too complex to easily calculate from first principles as a simple annual figure, since surfaces often change through the seasons due, for example, to snow or leaf cover. In general, the gains made by increasing the inclination in front of a highly reflective surface cannot be as great as the increase in losses from beam and indirect solar radiation from the rest of the sky.

The average reflectance (albedo) of the planet earth as seen from space is 0.20, which is seen as a mixture of green, brown and blue colours. For many rural applications, this effectively suggests a value of R_{panel} = 1.0. A different value should be used only where the surface reflectivity is significantly different for longevity, relative areas and the reflecting area is immediately in front of the collector array.

NOTE 2 Albedo is a generalized term for the average reflectance of a defined surface area (usually of the earth or clouds). Its use is discouraged in technical applications, where the preferred term is “reflectance”.

NOTE 3 Table 7 provides indicative reflectance values of more specific surfaces and their likely effect on the value R_{panel} at typical collector inclinations where the reflecting surface is significantly larger than collector array area.

Table 7 **Reflectance values of surfaces and their likely effect on the value R_{panel}**

Surface type	Average reflectivity of horizontal surfaces	Example reflectance fraction, R_{panel}		
		Collector inclination 20°	Collector inclination 40°	Collector inclination 60°
Average blue, green, blue	0.20	1.000	1.000	1.000
Sand	0.40	1.004	1.016	1.040
Snow or ice	0.75	1.011	1.044	1.110
Water	0.10	0.998	0.992	0.980
Earth soils	0.14	0.999	0.995	0.988
Worn concrete	0.22	1.000	1.002	1.004
Fresh concrete	0.55	1.007	1.028	1.070
Green vegetation	0.25	1.001	1.004	1.010
Flowering plants	0.26	1.001	1.005	1.012
Bitumous or gravel roof	0.13	0.999	0.994	0.986
Dark coloured building surfaces	0.27	1.001	1.006	1.014
Light coloured building surfaces	0.60	1.008	1.032	1.080
Burnt or charcoal	0.04	0.997	0.987	0.968

11.9 Dependence on collector parameters, $f(a^*/\eta 0)$

Assuming $f(a^*/\eta_0)$ <20, the following calculation should be used:

$$f(a^*/\eta_0) = 1.3 - 0.27\ln(a^*/\eta_0) \quad (8)$$

where:

a^* is the sum of the linear (W/m².K) and quadratic (W/m².K²) heat loss coefficients of the collector taken from BS EN ISO 9806, derived as follows:

$a^* = 0.892 \times (a_1 + 45 \times a_2)$

NOTE $f(a^*/\eta_0)$ ought to be regarded as subsuming parameters that are not explicitly included in the calculation, such as tank insulation, pipe insulation and the assumption of adequate controls on the system.

Annex A (normative) Bacterial growth and safety in DHW systems

NOTE The subject of Legionella is covered extensively in BS 8580, but this does not specifically cover preheating of the cold feed water or the addition of heat from solar primary circuits. The risk reduction measures indicated in this Annex are intended to clarify to the assessment of volumes of dedicated solar storage.

A.1 General

Irrespective of the source of heat for providing DHW, cold feed water should pass through temperatures starting typically below 45 °C to reach the intended target DHW draw-off temperature, typically 45 °C to 60 °C.

NOTE 1 Key differences between solar preheating and using only a conventional backup heat source include secondary temperatures in summer can exceed 65 °C from the primary solar heat source alone; the power of the solar contribution varies through the day and seasons; and residence time of the water passing through the secondary system is similar to conventional DHW system, but the water spends longer below 46 °C in the dedicated solar storage.

The vessel that contains dedicated solar storage of water may be considered as preheating the cold feed water before passing the water to receive additional heat from a backup heat source, which completes the heat treatment before distribution of the water as DHW.

NOTE 2 Throughput and residence times are similar to a non-solar system, but if water is kept still for several days without draw-off at temperatures between 20 °C and 46 °C and where a biofilm is present on the walls containing the water, bacteria such as Legionella can start to colonize on the biofilm. These bacteria are already present intermittently in the cold feed in low concentrations and normally pass through cold and DHW supplies with little effect.

During typical occupancy, the volume of water dedicated to solar storage should pass through to the backup heating in less than one day. Occasional holiday periods will exceed this and should be considered in the risk assessment.

NOTE 3 For these reasons, cold feed and preheated water is not suitable for distribution as DHW until its temperature has been raised to a sufficient level and for sufficient time as to minimize or sterilize bacterial growth. In buildings with appliances that produce an atomized spray that is likely to be inhaled from DHW terminals, e.g. mixer showers, there is a higher risk of inhalation of bacteria such as Legionella if that water has not been fully treated as DHW. The highest risk of infection is to people who are immune-suppressed, such as those in hospitals. In buildings where there are long runs of DHW pipes (dead legs) or unused T-junctions (dead-ends), there is a much higher risk of bacterial growth irrespective of the heating sources.

A.2 Risk assessment

A.2.1 General

A risk assessment should be carried out for every installation of solar DHW. Where any part of the DHW system already exists, an on-site inspection should be carried out by a competent, experienced person(s). Where the building or DHW system has yet to be built, the person doing the inspection should be skilled enough to understand drawings of the proposed system. A minimum of the following components should be assessed:

a) location and size of the cold feed;

b) location, size and quality of any existing cold water storage (CWS) cisterns, including examination of silt build-up;

c) daily, weekly and annual regime of DHW use;

d) risk of immunosuppressed persons using mixer showers or spray mixer taps supplied by the storage;

e) type, thermostatic response and power output of any backup DHW heating;

f) length, diameter and insulation of DHW pipework;

g) length of time for furthest DHW outlet to reach at least 50 °C; and

h) presence of any secondary return pumped circulation systems.

The risk assessment should provide a basis for quantifying and recording the bacterial risk. The scoring method should be the responsibility of the person completing the risk assessment and an example is given in Figure A.1.

System design should have no greater risk of bacterial growth reaching atomized DHW terminals than would otherwise occur without solar heating. An overall positive score should be sought and Table A.1 should be adapted for each application.

NOTE 1 Some measures can cause extra use of electricity or backup DHW heating to the extent that the energy benefit of the SDHW system becomes nullified.

NOTE 2 Store de-stratification rarely succeeds as sufficient heat does not reach the bottom of storage vessel, i.e. where sediment bio-film exists. Where storage vessels are to be sterilized, see Table A.1.

Figure A.1 **Specimen bacterial risk assessment overview such as for *Legionella***

Features of DHW system	Typical score if item present	Example dwelling with twin-coil tank and automatic boiler
Absence of atomization of DHW (e.g. showers, spray taps or spray bidets)	+++	0
Solar preheating in series with backup heater prior to DHW distribution (for example, solar store or combination boiler)	+	+
Solar preheating in parallel with backup heater direct to DHW distribution (for example, combination boiler with bypass valve)	– – –	0
Diverter valve in parallel with backup heater	– –	0
Downstream disinfection of hot water on a periodic basis	See Table A.1	+++
Upstream disinfection of store on a periodic basis	See Table A.1	0
Dead legs	–	0
Dead ends	– – –	0
TMV set permanently to less than 43 °C at shower or spray tap	–	0
Central TMVs with less than 55 °C distribution	–	0
Greater than 55 °C DHW distribution	++	++
CWS and/or part of cold feed not meeting the Water Fittings Regulations [10, 11, 12, 15]	–	0
Peak DHW draw-off exceeding re-heat of backup heat source	–	0
Dedicated solar storage more than daily DHW use	– –	0
Secondary pumped return at >55 °C to include shower and spray taps	++	0
Heat exchanger hot water content less than 15 L	+	0
Chlorine permanently added on site to cold feed	+++	0
Holidays or no occupancy exceeding four days during winter	– –	– –
Inspection hatch and cleaning regime for all storage vessels	++	0
Total	N/A	++++

Table A.1 **Specimen bacterial risk assessment for disinfection temperatures and times**

Temperature °C	Residence time min
Above 55 °C >3 h	+++
Above 55 °C >2 h	++
None of above and high flush-rate	+
None of above and typical flush-rate	Neutral = 0
None of above and low flush-rate	– – –

A.2.2 Disinfection of dedicated solar storage

The surfaces of the dedicated solar storage container should be disinfected periodically where the need for this is identified by a risk assessment. Temperature alone may be used, but this often occurs anyway during the summer from the solar contribution alone. It occurs more regularly with higher performance collectors.

The frequency and timing of disinfection should be chosen in accordance with the DHW usage patterns, peak draw-off times and the relative power of the backup DHW heater.

NOTE 1 Where a backup heat source is chosen for disinfection, it implies that the volume is no longer dedicated to only the storage of solar energy, which can result in loss of solar performance and increased storage losses.

NOTE 2 In some cases, it is almost impossible to disinfect the base of a container where a draw-off is maintained due to the continual influx of the cold feed. A weekly disinfection regime might be sufficient in many instances. Many solar controllers provide a thermostatic and timer relay facility (a Legionella switch) to maintain a regular disinfection with least reduction of solar contribution.

NOTE 3 For combined tanks heated to 60 °C daily and with the backup heated volume exceeding the design daily DHW load, solar preheated water is likely to be resident within the backup zone for sufficient time to achieve thermal inactivation of the bacteria such as Legionella.

Where the base of the combined tank is to be disinfected, it should be attempted during periods of low draw-off rate as indicated in **4.14.2**. Where the DHW system has a secondary circulation system, a motorized valve connecting the DHWS return pipe to the cold feed may be used.

NOTE 4 The motorized valve can be controlled separately from the circulator (e.g. a time switch, enabled for several hours once per week). Systems without return circulation can use a shunt pump between DHW hot outlet and the cold inlet controlled in similar manner.

Separate preheated stores feeding storage calorifiers provide superior residence time and temperature bacterial control to instantaneous heaters, so store disinfection requirements similar to combined tanks may be used.

NOTE 5 Non-storage calorifiers and instantaneous appliances might require higher temperatures and/or more frequent disinfection. Water disinfection for showers is particularly important because of its aerosol effect. The use of flow limiters to maintain a target temperature might be required, particularly for instantaneous appliances, e.g. combi-boilers, single point electric heaters.

There is higher bacterial risk with large dedicated solar stores and seasonal intermittent draw-off patterns. A cleaning hatch to facilitate routine inspection and cleaning may be specified.

NOTE 6 Insulation to the base of storage vessels can maintain higher temperatures.

NOTE 7 The use of low power or low temperature backup heat sources, such as solid fuel stoves or heat pumps, might require an additional electric immersion heater to ensure disinfection under peak draw-off rates.

A.2.3 Bypass of backup heating

Automatic or manual diverter valves are sometimes used with a separate preheated cylinder (referred to as "sun-to-tap" systems) that acts to bypass preheated water past the backup heater. This arrangement should be avoided, taking into account the following:

a) the disinfecting DHW storage or other heat source is bypassed;

b) the motorized valve or thermostat might fail with the valve in the open position;

c) (motorized) valve materials can be incompatible with secondary water; and

d) the DHW cylinder can continue to heat to 60 °C, irrespective of solar storage with resultant loss of heat.

The valve should limit the inlet temperature to any instantaneous appliance in accordance with **4.6**c).

A.3 Scalding and safety issues

*NOTE 1 The temperatures used to treat preheated secondary water can present a scalding risk. High DHW temperatures can also encourage limescale formation (see **A.4**) and accelerated metallic corrosion with some water types. The risks of bacteria control and protection against scalding are closely related. Some measures intended to minimize scalding increase bacterial risks.*

Storage vessels over 25 L capacity should be prevented from exceeding 100 °C in accordance with BS 8580 for vented and BS EN 12897 for unvented cylinders. Unvented cylinders should be kept <75 °C to prevent nuisance cut-outs from safety thermostats.

A thermostatic mixing valve (TMV) in accordance with BS EN 15092 may be fitted to reduce scalding risks. This should be installed within 450 mm of the point of use of the DHW to reduce the DHW outlet temperatures. Where used in central locations, any TMV should be adjusted to allow mixed water temperature outlets to achieve a temperature of between 55 °C and 60 °C. The DHW draw-off rate should not be unduly affected and any safety vents should not be obstructed.

NOTE 2 Instead of using a centrally-mounted TMV, a system can be specified to be "hydraulically secure", i.e. that the primary input of solar heat can be thermostatically controlled without requiring user intervention or release of transfer fluids.

NOTE 3 Keeping components in contact with secondary water below 60 °C can reduce scalding issues although this might conflict with bacterial protection.

A.4 Limescale

Limescale deposition on heat exchange surfaces decreases system performance over time unless control measures are in place. In high-risk areas, the temperature of the stored water should be controlled to lower limits as the rate of deposition rapidly increases with temperature (see **7.4.2**).

A means of physically removing limescale deposition may be provided as part of a normal service, e.g. cleaning hatches located near the heat exchanger or using demountable plate exchangers.

NOTE Keeping components in contact with secondary water below 60 °C can reduce limescale deposition, although this might conflict with bacterial protection.

Annex B (informative) Characteristics of an average UK household DHW usage profile

The following are characteristics of an average UK DHW household:

a) desired hot water temperature as drawn off = 52 °C with a typical range shown in Figure B.1;

NOTE 1 Figure B.1 indicates that specific households might differ greatly from the average.

b) consumption drawn per day = 116 L with a typical range shown in Figure B.2; and

NOTE 2 Figure B.2 indicates that specific households might differ greatly from the average.

c) incoming cold water temperature average value 15 °C (this is an average over dwellings with and without CWS) with a typical range shown in Figure B.3.

NOTE 3 Figure B.3 indicates that specific households might differ greatly from the average.

NOTE 4 Incoming cold water temperature vary seasonally and can also be affected by ambient if a CWS is present.

NOTE 5 Incoming cold water temperatures north of 54° latitude can be assumed to be 2 °C less due to depressed ground temperatures.

Figure B.1 **Distribution of hot water delivery temperatures**

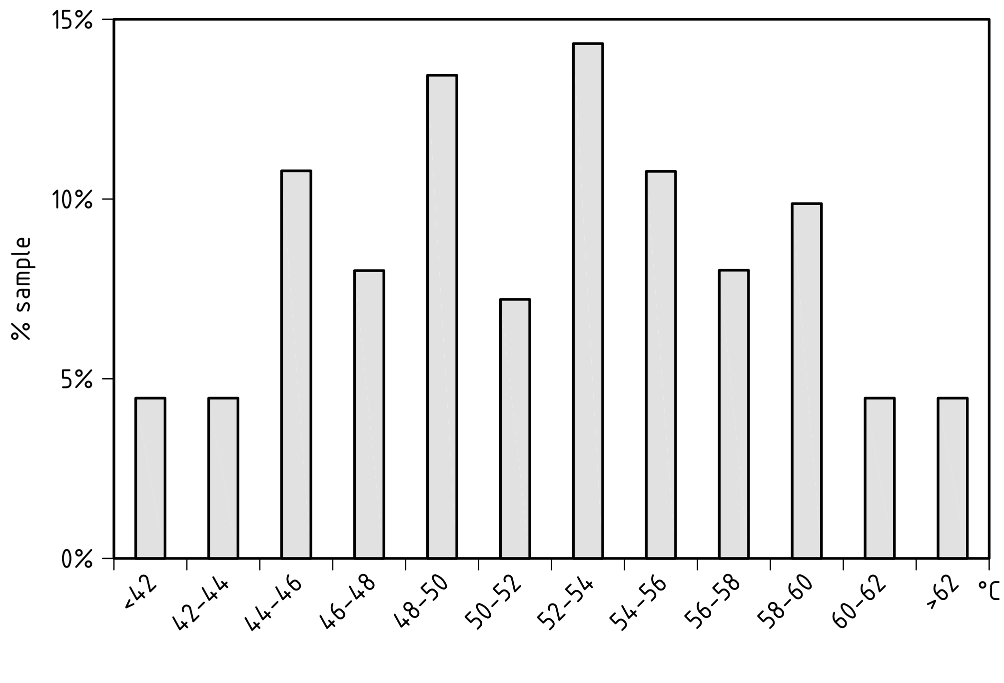


Figure B.2 **Typical range of daily DHW consumption per person**

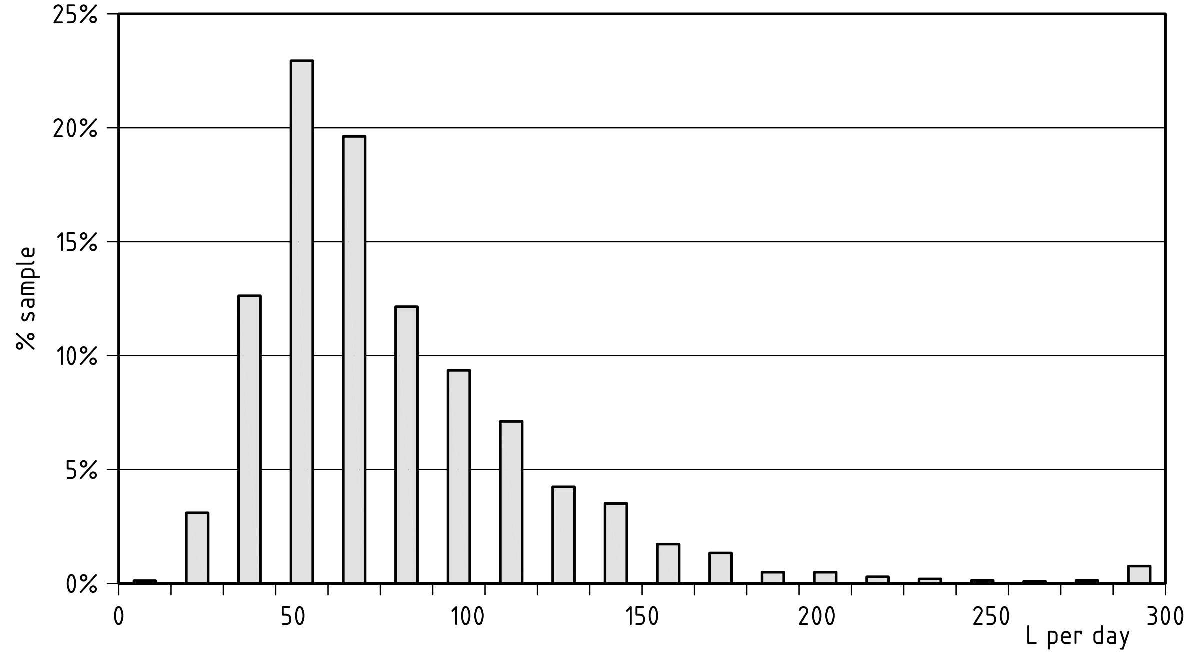


Figure B.3 **Range of cold water feed temperatures**

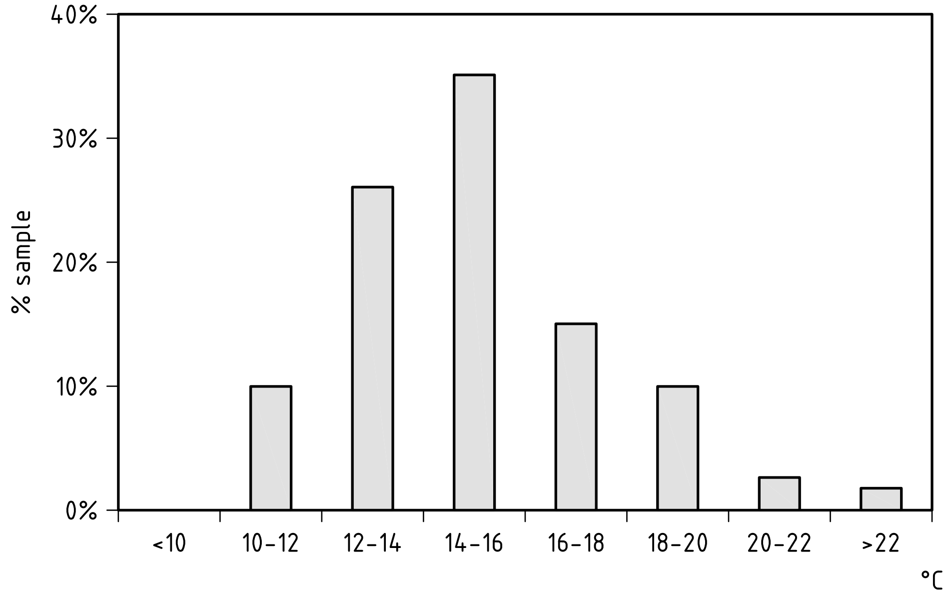


Table B.1 **DHW profile: proportion of maximum hourly average peak flow rates**

Daily DHW profile		Weekly DHW profile		Annual DHW profile	
Hour	**%**	**Day**	**%**	**Month**	**%**
0.00	20	Monday	100	Jan	90
1.00	10	Tuesday	100	Feb	100
2.00	2	Wednesday	100	Mar	100
3.00	0	Thursday	100	Apr	95
4.00	0	Friday	100	May	100
5.00	0	Saturday	80	Jun	85
6.00	0	Sunday	80	Jul	75
7.00	85			Aug	80
8.00	95			Sept	85
9.00	100			Oct	90
10.00	80			Nov	95
11.00	30			Dec	100
12.00	20				
13.00	15				
14.00	15				
15.00	20				
16.00	30				
17.00	30				
18.00	45				
19.00	35				
20.00	25				
21.00	20				
22.00	20				
23.00	20				

Annex C (informative)

Example primary system layouts

Two common primary system layouts used in the UK meet the design criteria in **4.7**:

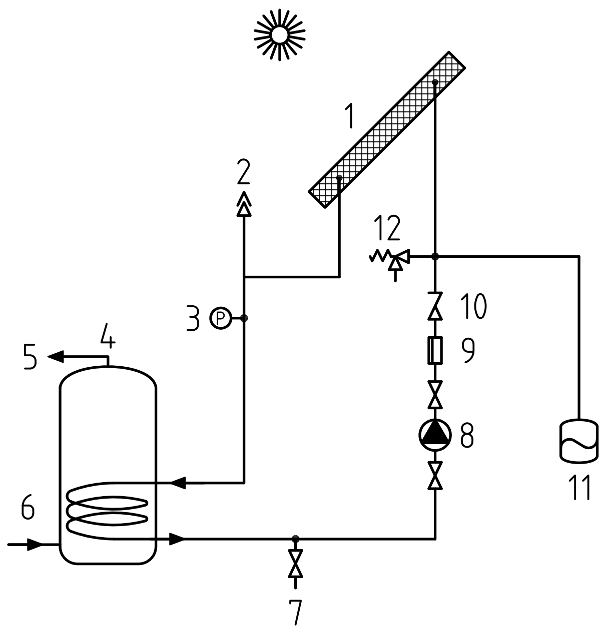
a) sealed, indirect and pressurized, as shown in Figure C.1a);

NOTE 1 No air or other gases are intentionally left in the primary system. The collector is intended to be full of HTF in normal operating conditions.

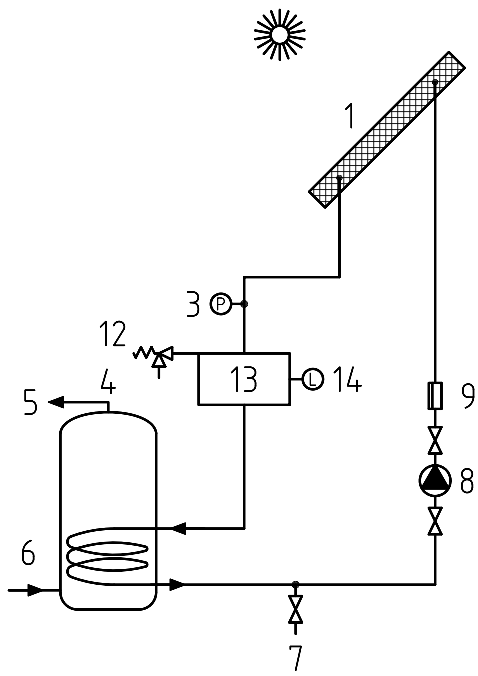
b) sealed, indirect and drainback, as shown in Figure C.1b).

NOTE 2 Air or other gases are intentionally left in the primary system to aid passive drainback of liquids. The collector is intended to be full of liquid only when the pump circulator operates. At other times the collector empties of liquid and is replaced by air or other gases.

Figure C.1 **Simplified schematic primary system layouts (not to scale)**



a) Sealed, fully-filled



b) Sealed, drainback

Key

1	Roof	8	Drain/fill valve
2	Solar collector	9	Pump
3	Air vent	10	Flow meter
4	Pressure gauge	11	Check valve
5	Hot water storage	12	Expansion vessel
6	DHW draw-off	13	Safety valve
7	Cold feed	14	Drainback vessel

NOTE Control sensors are not shown for clarity.

Annex D (informative) Site inspection

Figure D.1 provides an example survey form for a site inspection.

Figure D.1 **Site inspection example survey form**

Project reference		Date	
Project name		Address	
Contact details		Customer name	
What is the solar heating to be used for?		Budget limit	
Other energy sources heating the DHW and their compatibility with SDHW		Times of the year the building is to be used	
Existing fuel bills for DHW and space heating		Building code or planning restrictions	
What fraction of the annual DHW use is to be provided by solar?		How many occupants regularly in the building?	
Sketch of the building indicating dimensions of the roof or other location to mount the collectors, indicating compass direction and the pitch angle of the roof or flat roof or ground		Type of roof surface and any object in the roof, including chimneys and skylights	
Sketch of the horizon showing positions and heights of main objects that might shade the collectors		Restricted location immediately behind the roof such as attic rooms	
Height of roof from ground to roof edge (eaves)		Suggested high-level access equipment and obstructions to access, e.g. overhead lines, fragile structures	
Location for solar storage tank		Distance from collector to solar storage tank and pipework lengths on solar primary circuit, including significant bends	
Where internal, size of room or cupboard for solar storage tank		Other locations for solar equipment	
Other DHW storage tanks or instantaneous water heaters		Source of cold water supply	
Is the DHW fed direct from the water mains or is there a pump or CWS tank?		List of appliances that use DHW and can be fed from solar storage tank	
List of appliances that use DHW and cannot be fed from solar storage tank		DHW use per person that can be fed from solar storage tank	
Requirement for secondary DHW circulation		Timer or programmers for backup hot water	
A bacteria/*Legionella* risk assessment is required.			

Annex E (normative) Minimum wall thickness for high-temperature EPDM-based rubber insulation

Wall thickness of solar primary pipe insulation, where made from EPDM-based rubber insulation, should be at least that given in Table E.1.

Table E.1 **Minimum wall thickness for high-temperature EPDM-based rubber insulation**

Pipe outside diameter (mm)	10	12	15	22	28	35
Minimum wall insulation thickness (mm)	9	13	13	19	25	31
Or equivalent W/m heat loss if non-EPDM insulation						

Annex F (informative) Nominal amounts of DHW supplied by point-of-use appliances that are usually not available for solar preheating

Nominal volumes of DHW supplied by point-of-use appliances that are usually not available for solar preheating are:

a) single-fill washing machines = 3 L per day per person;

b) single-fill dishwashing machines = 5 L per day per person; and

c) if no baths and uses electric shower = 30 L per day per person.

Annex G (informative) Example sizing of collector active area

Table G.1 gives an example of how to use Figure 7a) or 7b) in **7.2.12** to estimate the active collector area needed to reach a target solar energy contribution to the domestic hot water requirements.

Table G.1 **Example sizing of collector active area**

Assume	Average cold water temperature over the year is 15 °C		
Assume	Average DHW usage of 125 L per day at 45 °C		
Assume	Annual heat loss from storage vessel and associated tappings is 25 kWh/K (typical for a cylindrical storage vessel with 50 mm insulation and with a volume two times the average DHW usage)		
Assume	Average temperature difference over the year between the storage vessel and its surroundings is 26 °C		
Calculate	Annual energy required to heat the water from 15 °C to 45 °C = (125 × 365) × (45 – 15) × (4.187/3 600)	1 592	kWh
Calculate	Annual losses from storage vessel and associated tappings = 25 × 26	650	kWh
Calculate	Total annual DHW load = 1 592 + 650	2 242	kWh
Assume	Desired solar fraction	45	%
Calculate	Target annual energy delivered to the storage vessel by the solar collector loop = 2 273 × (45/100)	1 009	kWh

Use of Figure 7a) requires the target annual solar energy delivered by the collector loop to be adjusted pro rata to a rate of 100 L per day at 50 °C. Since the calculations in Table G.1 are for 125 L per day at 45 °C, the target value to be used in Figure 7a) is found by multiplying that calculated in Table G.1 by the ratios of the draw-off rates and of the temperature differences:

$$1\,009 \times (100/125) \times [(50 - 15)/(45 - 15)] = 942 \text{ kWh.}$$

From Figure 7a), for 942 kWh to be delivered by the solar loop requires an active collector area of 2.6 m^2 or 3.3 m^2 for high and medium performance collectors respectively.

Alternatively, Figure 7b) shows the same areas are needed for a solar fraction of 45% to provide 100 L per day at 50 °C, which as the previous example calculations show is equivalent to 125 L per day at 45 °C.

Figures 7a) and 7b) were calculated for an unshaded collector facing due South at a tilt of 40° from the horizontal and located at a site for which the annual mean global irradiation is 961 kWh/m^2. For different orientations the estimate of collector area derived from Figure 7 is adjusted proportionally using Figure 6 in **7.2.3**. Similarly, Figure 11 in **11.4** is used to correct for different global irradiance and Annex J provides the information to correct for any shading at the design location.

NOTE This example is not valid where a complex collector array, heat exchanger or storage layout is present.

Annex H (informative) Worked example – Expansion vessel sizing

Assume a solar hot water system consisting of 6 m^2 of solar collector, with a collector circuit of 20 m of 15 mm diameter and 1 mm wall thickness copper pipework. The HTF is 60% water, 40% glycol. The system's heat exchange cylinder coil is 1.6 m of 15 mm finned tube. The expansion vessel is to be fitted 4.5 m below the highest part of the solar collector and the safety valve intended to be at 3 bar pressure.

The pump head upon stagnation is assumed at 0.5 bar. It is intended to design the system to at least be hydraulically secure and withhold fluid upon stagnation.

The following calculations are used.

- Nominal expansion coefficient 8.0% (for 60% water, 40% glycol, 130 °C temperature difference).
- Expansion volume, $V_{expanded} = 0.080V_{total} = 0.59$ L.
- Vessel "water seal" set to minimum, $V_{wseal} = 3.00$ L.
- Vapour volume, $V_{vapour} = 4.44 + 0.80$ L = 5.24 L.
- Required working volume of expansion vessel:

  $$V_{working} = V_{expanded} + V_{wseal} + V_{vapour} = 0.59 + 3.00 + 5.24 = 8.83 \text{ L.}$$
- Water gauge (geodetic) pressure, P_{geo} = 4.5 m × 1 bar /10 m = 0.45 bar.
- Desired collector field pressurization, P_{op} = 0.50 bar.
- Gas side pre-charge of expansion vessel:

  $$P_{gas} = P_{geo} + P_{op} = 0.45 \text{ bar} + 0.5 \text{ bar} = 0.95 \text{ bar.}$$
- Response pressure of safety valve, P_{sv} = 3.00 bar.
- Pressure margin for safe operation, $P_{margin} = P_{sv} \times 10\%$ = 0.30 bar.
- However, 0.5 bar is considered the lowest, so P_{margin} = 0.50 bar.

NOTE A P_{final} of 2.5 bar will cause a vaporization point around 115 °C.

- Final or maximum operating pressure:

  $P_{\mathrm{final}} = P_{\mathrm{sv}} - P_{\mathrm{margin}}$ = 3.0 bar – 0.5 bar = 2.50 bar.

- Pressure equivalent for water seal, P_{wseal} = 0.30 bar.
- Pressure factor, P_{final} + 1 bar = 2.50 bar + 1.00 bar

  $P_{\mathrm{final}} - (P_{\mathrm{gas}} + P_{\mathrm{pump}})$ = [2.50 – (0.95 + 0.30)] bar.

- P_{f} = (3.50/1.25) bar = 2.80 bar.
- Required nominal volume of expansion vessel:

  $V_{\mathrm{nominal}} > P_{\mathrm{f}} \times V_{\mathrm{working}}$ = (2.80 × 8.83) L = 24.72 L.

- Next available standard size of expansion vessel = 25.0 L.
- Initial filling pressure of system fluid:

  $P_{\mathrm{initial}} = P_{\mathrm{gas}} + P_{\mathrm{wseal}}$ = (0.95 + 0.30) bar = 1.25 bar.

Annex I (informative) Troubleshooting

Issues that could indicate that an SDHW system was not installed to BS 5918 or has experienced wear and tear over a period of use include:

a) scalding, including steam, metal contact or very hot water;

b) leaks, discharge, overflow or evaporation of fluids from a storage cistern, safety valve, joint or pipework due to overexpansion or overfilling;

c) reduction of quality of building structure or weather-tightness;

d) excessive pump/circulation noise;

e) poor circulation due to entrained gases/air;

f) heat damage of associated components, especially pipe insulation and cables;

g) deterioration of primary HTF and/or transfer surfaces;

h) damage to due to freezing of primary transfer fluid;

i) damage to pipes and cables from vermin or mechanical damage;

j) poor circulation and/or heat transfer;

k) blockage/deformation of safety vents or build-up of bacteria due to accumulation of limescale, silt and other debris;

l) damage caused by regular stagnation;

m) disturbance of stratification in the solar storage vessel due to pumps, which increase return temperature at the base of the store, or another heating appliance interfering with heat transfer within the DHW store;

n) loss of dedicated solar storage capacity due to interaction of other heat sources;

o) electrical controls or temperature sensors not operating (due, for example, to incorrect setting or dislocation);

p) collector glazing/seals damaged leading to condensation within collector;

q) incorrect pipe layout (pipe fall), orientation of flow/return or poor pipe supports; and

r) rupture/failure of collector absorber.

Annex J (informative) Methods for calculating loss of irradiation due to shading obstacles

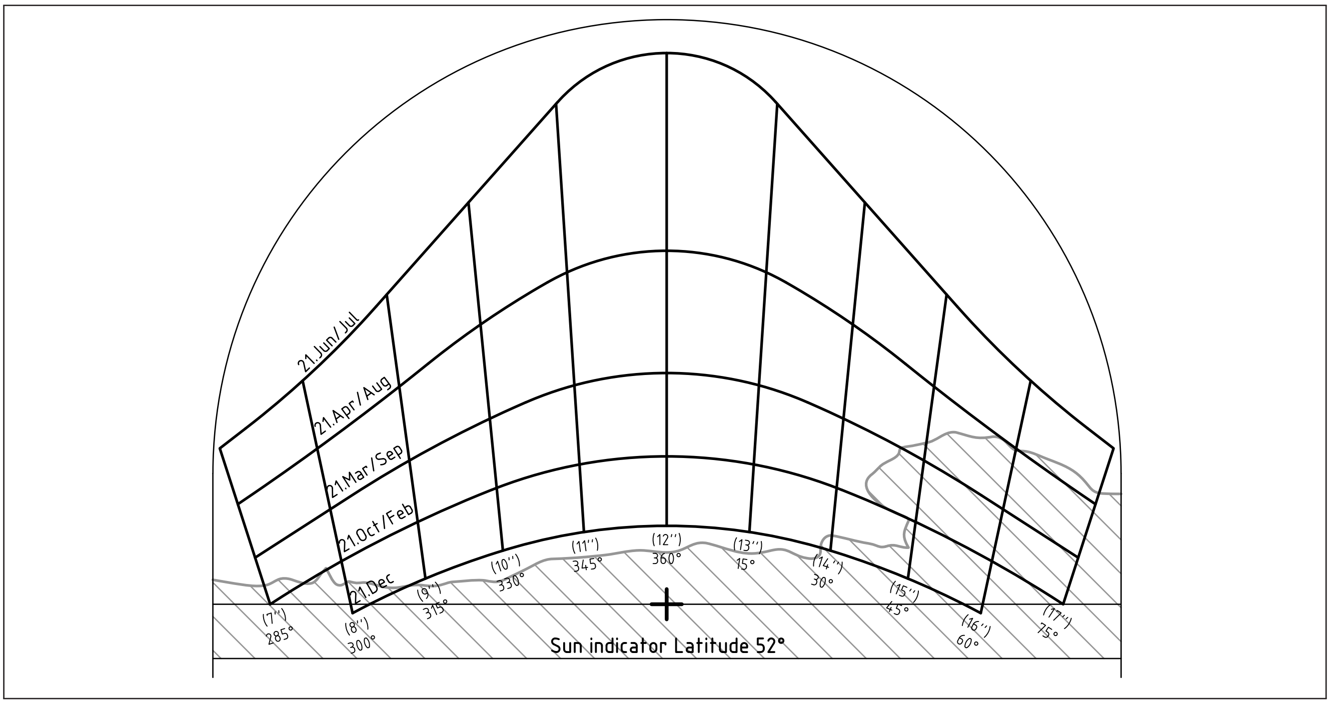
The loss of radiation on a collector array is a complex combination of loss of beam, indirect and reflected radiation. Once the radiation strikes the collector, there are further allowances that can be made according to the collector's characteristics, especially relating to the incidence angle modifier (IAM).

Additionally, objects that are closer than a nominal 100 m to the array can create differential shading across the width of the array such that one end can be fully irradiated whilst the other is in shade. Only a site visit using specialized survey equipment can acquire sufficient shading data suitable for proprietary computer software to accurately calculate the loss of solar radiation on the array. Where using a computer simulation, accuracy is best achieved by modelling shading objects closer than 100 m in three dimensions requiring details of height, width and azimuth to be entered. All further objects can be represented in two dimensions on a silhouetted horizon.

Without such electronic equipment, manual tools are available which place the paths of the sun over a view of the landscape and allow the fractional loss of sky to be measured. This can be converted into loss of solar irradiation. Such manual tools allow the particular local sunpaths that are affected to be identified. An example of a sunpath diagram is given in Figure J.1. Further information on sunpath diagrams can be found in BS 8206-2.

For the beam component of solar radiation, shading occurs mainly from low-lying objects during low solar altitudes. This occurs either during mornings all year round (for obstructions in an easterly direction), or evenings all year round (for westerly obstructions), or around midday during winter months (for southerly obstructions). For the diffuse component, the larger hemisphere of the sky is considered.

Figure J.1 **Example of sunpath viewer with shading objects sketched over**



For simple collector arrays, the section of hemisphere of sky that faces perpendicular to the array can be considered. For simplicity, the loss of area due to shading can be termed Z_{sky}. There is some fraction of Z_{sky}, e.g. $q.Z_{sky}$ (with $0 < q < 1$), as the effective fractional loss over the year of the beam irradiance. For the diffuse component, assuming an isotropic sky, the fractional loss all year round can be simply assumed as the shading area Z_{sky}.

Assume the total annual irradiance is made up of a fraction, I_{diff}, of diffuse irradiance and $(1 - I_{diff})$ of beam irradiance. The formula for the shading factor, Z_{panel}, affecting the collector array is:

$$Z_{panel} = (1 - Z_{sky}) \times \{I_{diff} - [(1 - I_{diff}) \times q \times Z_{sky}]\} = (1 - Z_{sky}) \times [I_{diff} \times (1 - q) + q] \quad \text{(J.1)}$$

Data for the UK relating the diffuse and beam radiation components is obtainable from metrological sources. For simplicity, these can be assumed as default values:

$I_{diff} = 0.6$; and

$q = 0.1$.

Hence, $Z_{panel} = 1 - 0.64Z_{sky}$.

Table J.1 **Default loss-of-sky area Z_{sky} as related to the loss of irradiation factor, Z_{panel}**

Over-shading category assessed from site visit	**% of sky blocked by obstacles** Z_{sky}	**Loss-of-sky factor to substitute for Z_{panel}**
Severe	$0.8 < Z_{sky} < 1.0$	0.45
Heavy	$0.6 < Z_{sky} < 0.8$	0.55
Significant	$0.4 < Z_{sky} < 0.6$	0.70
Modest	$0.2 < Z_{sky} < 0.4$	0.80
None or very little	$0.0 < Z_{sky} < 0.2$	1.00

NOTE This table is only to be used where the factor loss of radiation is not available from proprietary site survey equipment and software. The loss-of-sky factor, Z_{sky}, alone only provides a simplistic account of the reduction in solar radiation where it is shaded by trees or other buildings. This method does not take into account the IAM of collectors, the seasonal effect of tree cover or the relative greater importance of objects between southeast and southwest and in the summer between the equinoxes.

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