Microgeneration Installation Standard: MIS 3005

REQUIREMENTS FOR CONTRACTORS UNDERTAKING THE SUPPLY, DESIGN, INSTALLATION, SET TO WORK COMMISSIONING AND HANDOVER OF MICROGENERATION HEAT PUMP SYSTEMS

Issue 3.1a

This standard has been approved by the Steering Group of the MCS.

This standard was prepared by the MCS Working Group 6 ‘Heat Pumps’.

REVISION OF MICROGENERATION INSTALLATION STANDARDS

Microgeneration Installation Standards will be revised by issue of revised editions or amendments. Details will be posted on the website at www.microgenerationcertification.org

Technical or other changes which affect the requirements for the approval or certification of the product or service will result in a new issue. Minor or administrative changes (e.g. corrections of spelling and typographical errors, changes to address and copyright details, the addition of notes for clarification etc.) may be made as amendments.

The issue number will be given in decimal format with the integer part giving the issue number and the fractional part giving the number of amendments (e.g. Issue 3.2 indicates that the document is at Issue 3 with 2 amendments).

Users of this Standard should ensure that they possess the latest issue and all amendments.

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FOREWORD

This standard identifies the evaluation and assessment practices undertaken by certification bodies of the MCS for the purposes of approval and listing of contractors undertaking the supply, design installation, set to work, commissioning and handover of heat pump systems. The listing and approval is based on evidence acceptable to the certification body:

- that the system or service meets the standard
- that the contractor has staff, processes and systems in place to ensure that the system or service delivered meets the standard

and on:-

- periodic audits of the Contractor including testing as appropriate
- compliance with the contract for the MCS listing and approval including agreement to rectify faults as appropriate

This standard shall be used in conjunction with document MCS 001 and any other guidance and / or supplementary material available on the MCS website specifically referring to this Microgeneration Certification Standard (MIS 3005). A catalogue of guidance and supplementary material to be read in conjunction with MIS 3005 can be found on the MCS website, www.microgenerationcertification.org.

Government defines Microgeneration as the production of heat and/or electricity on a small-scale from a low carbon source. The various technologies have the potential to help us achieve our objectives of tackling climate change, ensuring reliable energy and tackling fuel poverty.

The objective of Government's Microgeneration strategy is to create conditions under which Microgeneration becomes a realistic alternative or supplementary energy generation source for the householder, for the community and for small businesses.

NOTES:-
Compliance with this Microgeneration Installation Standard does not of itself confer immunity from legal obligations.
Users of Microgeneration Installation Standards should ensure that they possess the latest issue and all amendments.
The Steering Group welcomes comments of a technical or editorial nature and these should be addressed to "the Secretary" at mcs@gemserv.com
Listed products may be viewed on our website: www.microgenerationcertification.org

1 SCOPE

This standard specifies the requirements of the MCS for the approval and listing of Contractors undertaking the supply, design, installation, set to work, commissioning and handover of microgeneration Heat Pump systems supplying permanent buildings and either linked to the building's space heating and/or hot water system.

The building's space heating and/or hot water system are not included in this Microgeneration Installation Standard. However, the Contractor shall demonstrate that the Microgeneration Heat Pump system is provided in full knowledge of the heat distribution system being used to maximise the efficiency of the combined system.

Microgeneration Heat Pump systems utilise different primary heat sources (ground-, air- and water-sources), each of which requires different design and installation considerations. This Microgeneration Installation Standard includes the requirements for Microgeneration Heat Pump systems for heating or for heating and cooling. Cooling only systems and direct expansion (DX) ground-loop systems are excluded from this Standard.

For the purposes of this Microgeneration Installation Standard, Microgeneration Heat Pump systems are defined as those having a design output that does not exceed 45kW thermal.

The contractor shall be assessed under one or more of the following three categories of heat pump installation work:

- Ground source heat pump (GSHP) systems
- Air source heat pump (ASHP) systems
- Exhaust air heat pump systems

The certification body must identify the scope of works that the contractor wishes to be registered for and undertake the assessment in accordance with this standard using the clauses relevant to the category of heat pump installation work.

NOTE: It can be deemed that installers successfully assessed on GSHP systems can also undertake work on ASHP systems.

2 DEFINITIONS

This Microgeneration Installation Standard makes use of the terms ‘must’, ‘shall’ and ‘should’ when prescribing certain requirements and procedures. In the context of this document:

- The term ‘must’ identifies a requirement by law at the time of publication
- The term ‘shall’ prescribes a requirement or procedure that is intended to be complied with in full and without deviation
- The term ‘should’ prescribes a requirement or procedure that is intended to be complied with unless reasonable justification can be given

Contractor	An individual, body corporate or body incorporate, applying for or holding certification for the services detailed in Scope, Clause 1 above.
Contract	A written undertaking for the design, supply, installation, set to work and commissioning of Microgeneration systems and technologies
Design	The formulation of a written plan including a specific list of products and fixings to form a completed system for a defined Microgeneration technology. Including extensions and alterations to existing Microgeneration systems.
Installation	The activities associated with placement and fixing of a Microgeneration system
Set to work	The activities necessary to make the Microgeneration system function as a completed system.
Commissioning	The activities to ensure that the installed system operates within the boundaries and conditions of the design and the product manufacturers' claims.
Sub-contract	A written Contract between a certificated Contractor and another firm for supply of products and services in connection with the fulfilment of a Contract.

Handover	The point in a Contract where Commissioning and certification of the system have been satisfactorily completed to the Contract specification so enabling the installation to be formally handed over to the client.
Heat Pump	A device which takes heat energy from a low temperature source and upgrades it to a higher temperature at which it can be usefully employed for heating and/or hot water. Heat pumps may utilise different heat sources: • Ground Source, where heat energy is extracted from the ground (e.g. from boreholes, horizontal trenches or aquifers) • Water Source, in which heat energy is extracted from water (e.g. lakes, ponds or rivers) • Air Source, where heat energy is directly extracted from ambient air.
Closed-Loop Heat Exchanger	A sealed loop of pipe containing a circulating fluid used to extract heat from ground- or water- sources.
Ground Heat Exchanger	The arrangement of horizontally or vertically installed pipes through which the thermal transfer fluid circulates and collects low grade heat from the ground. Can be either closed or open loop.
Thermal Transfer Fluid	Generally comprises components of anti-freeze, biocide, corrosion and scale inhibitors that circulate through the closed loop heat exchanger.

3 REQUIREMENTS FOR THE CERTIFICATED CONTRACTOR

3.1 Capability

Certificated Contractors shall have the capability to undertake the supply, design, installation, set to work, commissioning and handover of Microgeneration Heat Pump systems.

Where Contractors do not engage in the design or supply of Microgeneration Heat Pump systems, but work solely as an installer for a client who has already commissioned a system design; then the Contractor shall be competent to review and verify that the design would meet the design requirements set out in this standard and this should be recorded.

3.2 Quality management system

Contractors shall operate a satisfactory quality management system which meets the additional requirements set out in the scheme document MCS 001.

3.3 Sub-contracting

In installations for private customers, any work within the scope of the scheme not undertaken by employees of the Contractor shall be managed through a formal subcontract agreement between the two parties in accordance with the policies and procedures employed by the certificated Contractor. These procedures shall ensure that the subcontractor undertakes the work in accordance with the requirements of this standard.

In other situations (for example new build, or for commercial customers), it is permissible for the physical installation, setting to work and commissioning to be undertaken by others (i.e. not sub-contracted to the Contractor) provided that:

3.3.1 A contract between the Contractor and the commercial client details obligations on the client to include that evidence of skills and training of those employed by the client to do elements of work not undertaken by the Contractor are to be made available to the Contractor to ensure that the competence requirements of this standard are met and that access to the site for training and supervision in accordance with the following sections is agreed in advance.

3.3.2 The certificated Contractor provides additional product-specific training for those undertaking the work not undertaken by the certificated Contractor.

3.3.3 The certificated Contractor assesses a sample number of installations under the contract which is not less than the square root of the number of installations rounded up to the nearest whole number (e.g. a new build site of 50 installations then a minimum of 8 are assessed).

3.3.4 The certificated Contractor assumes responsibility at handover that the installation is in full compliance with the standard.

3.4 Consumer code of practice

The Contractor shall be a member of and, when dealing with domestic consumers, shall comply with, a code of practice (consumer code), which is relevant to the scope of their business in the Microgeneration sector and which is approved by the Office of Fair Trading (OFT). In the absence of any approved codes the MCS will accept codes that have completed stage 1 of the OFT approval process, (e.g. REAL Code).

4 DESIGN AND INSTALLATION REQUIREMENTS

4.1 Regulations

4.1.1 All applicable regulations and directives must be met in full. It should be noted that regulations that must be applied may be different in England and Wales, Scotland and Northern Ireland. Some guidance on applicable regulations is given in the guidance document MCS 002. This guidance is not necessarily exhaustive and may change from time to time. Certificated contractors shall ensure they are working to the most recent documents and have a system to identify all applicable regulations and changes to them.

4.1.2 All work, and working practices, must be in compliance with all relevant health and safety regulations and where required a risk assessment shall be conducted before any work on site is commenced.

4.2 Design and installation

The areas of competence relevant to the design and installation of Microgeneration Heat Pump systems are included in Clause 5. The following principles shall be met when designing, specifying and installing Microgeneration Heat Pump systems.

Heat Pump Sizing

4.2.1 The following procedure shall be followed for the correct sizing and selection of a heat pump and related components for each installation:

a) A heat loss calculation should be performed on the building using a method that complies with BS EN 12831.

b) Heat loss calculations shall be based on the internal and external temperatures specified in this document in tables 1 and 2. Heat loss through the floor shall be determined using the local annual average external air temperature in appendix B.

Table 1 is reproduced from the UK national annex to BS EN 12831. Clients should be consulted to establish whether they have any special requirements and the internal design temperatures increased if required.

Room	Internal design temperatures (/°C) from the UK national annex to BS EN 12831
Living room	21
Dining room	21
Bedsitting room	21
Bedroom	18
Hall and landing	18
Kitchen	18
Bathroom	22
Toilet	18

Table 1: Internal design temperatures from the UK annex to BS EN 12831. CIBSE Guide A should be consulted for data for other applications. CIBSE Guide A also contains information on how to adapt this data for non-typical levels of clothing and activity.

Table 2 is reproduced using selected data from Table 2.4 in CIBSE Guide A. These values are the hourly dry-bulb temperatures equal to or exceeded for 99% of the hours in a year. In the absence of more localised information, data from the closest location may be used, decreased by 0.6°C for every 100m by which the height above sea level of the site exceeds that of the location in the table.

Location	Altitude (/m)	Hourly dry-bulb temperature (/°C) equal to or exceeded for 99% of the hours in a year
Belfast	68	-1.2
Birmingham	96	-3.4
Cardiff	67	-1.6
Edinburgh	35	-3.4
Glasgow	5	-3.9
London	25	-1.8
Manchester	75	-2.2
Plymouth	27	-0.2

Table 2: Outside design temperatures for different locations in the UK. Corrections can be applied to account for altitude and heat island effects. Further information on how to adapt and use this data is available in CIBSE Guide A: Environmental Design.

Monthly and annual average air temperatures for various UK regions are provided by the MET office in appendix B.

c) A heat pump shall be selected that will provide at least 100% of the calculated design space heating power requirement at the selected internal and external temperatures, the selection being made after taking into consideration the space heating flow temperature assumed in the heat emitter circuit and any variation in heat pump performance that may result. Performance data from both the heat pump manufacturer and the emitter system designer should be provided to support the heat pump selection. Heat pump thermal power output for the purposes of this selection shall not include any heat supplied by a supplementary electric heater. Where clauses 4.2.1c and/or 4.2.1d cannot be met, then clause 4.2.1e shall apply.

d) When selecting an air-source heat pump, the heat pump shall provide 100% of the calculated design space heating power requirement at the selected ambient temperature and emitter temperature, after the inclusion of any energy required for defrost cycles. Where clause 4.2.1c and/or 4.2.1d cannot be met, then clause 4.2.1e shall apply.

e) For installations where other heat sources are available to the same building, the heat sources shall be fully and correctly integrated into a single control system. A heat pump shall be selected such that the combined system will provide at least 100% of the calculated design space heating requirement at the selected internal and external temperatures, the selection being made after taking into consideration the space heating flow temperature assumed in the heat emitter circuit and any variation in heat pump performance that may result. Heat pump thermal power output for the purposes of this section shall not include any heat supplied by a supplementary electric heater within the design temperature range.

4.2.2 For installations where other heat sources are available to the same building, it shall be clearly stated by the contractor what proportion of the building's space heating and domestic hot water has been designed to be provided by the heat pump. The figures stated (i.e. the proportion of the annual energy provided by the heat pump) shall be based only on the energy supplied by the heat pump and shall not include any heat supplied by a supplementary electric heater.

Notes on section 4.2.1- Part C

Sizing a system to precisely 100% as defined in section 4.2.1 part c) will require supplementary space heating for the coldest 1% of the hours in a year. In addition, the system may require the use of supplementary heating if:

- The building is being heated from a cold state;
- The desired heating mode is not continuous, such as bi-modal heating or heating using a split-rate tariff;
- Large quantities of domestic hot water are required frequently during cold weather.

Installers trying to design a system capable of achieving these requirements without supplementary heat should consider increasing the heating capacity of the heat pump.

The clause in section 4.2.1 (c) requires the CIBSE external design temperature to be the temperature at which the heat pump heating capacity at least matches the building design load.

1st example of an installation that fulfils Clause 4.2.1- Part C

An average-size, 3-bedroom, semi-detached, well-insulated property is calculated to have a 6.2kW heat loss using BS EN 12831 and the internal, external and ground temperatures provided in this standard. The property is connected to a single-phase electricity supply.

Two heat pumps are available; one has an 8.4kW heat output at the local design external temperature (from CIBSE guide A) and the calculated emitter temperature; and the other has a 4.1kW heat output, with a 3kW supplementary electric heater.

Under the rule in clause 4.2.1 (c) (i.e. the 100% sizing rule), the heat pump should provide at least 100% of the design load at the design temperatures in section 4.2.1 (b) without the inclusion of any supplementary electric heater.

The second heat pump, whose total heat output is sufficient to meet the building heat loss but includes a 3kW supplementary electric heater, does not meet this rule; therefore, the first heat pump is selected for this job, even though it delivers more than the calculated heat loss at design conditions.

Notes on section 4.2.1- Part C (continued...)

2nd example of an installation that fulfils Clause 4.2.1- Part C

A small, well-insulated, 2-bedroom flat is being designed to have a 3.4kW heat loss at the design internal temperatures and local external temperature. The property is connected to a single-phase electricity supply.

After selecting a 3.5kW heat pump to meet the calculated load, the heat loss calculations are updated because the designer changes the specification of the building fabric (insulation) and windows. The new heat loss for the property is 3.9kW.

The heat pump originally chosen does have a 3kW supplementary electric heater, giving it a total heat output of 6.5kW. However, under the rule in clause 4.2.1 (c), the heat pump should meet at least 100% of the design load at the design temperatures in section 4.2.1 (b) without the inclusion of any supplementary electric heater.

For this reason, a new selection is made for a larger heat pump that has an output of 5.0kW at the local external temperature without use of any supplementary heater.

3rd example of an installation that fulfils Clause 4.2.1- Part C

A poorly-insulated, terraced house is calculated to have a 6.1kW heat loss using BS EN 12831 at the design internal temperatures and local design external temperature in this document. The property is connected to a single-phase electricity supply.

A 5.4kW heat pump would not meet 100% of the space heating power requirement at the design external temperature and calculated emitter conditions as required by clause 4.2.1 (c), so the ventilation and fabric heat loss have been reduced by upgrading several of the windows and insulating the walls. A number of radiators were also replaced with larger, deeper units to enable the emitter circuit to operate at lower temperatures. With the improvements, the heat loss of the property is reduced to 5.5kW. The lower emitter temperature has also increased the heat pump thermal capacity to 5.7kW (without the use of a supplementary electric heater).

The design now meets the rule is clause 4.2.1 (c) at the design temperatures in section 4.2.1 (b).

Notes on section 4.2.1- Part E

An example of an installation that fulfils Clause 4.2.1- Part E

A very large, well-insulated, domestic property is calculated to have a 23kW heat loss at the local CIBSE design temperatures. The property is connected to a single-phase electricity supply.

A heat pump is available that has a 24kW heat output at the local CIBSE external temperature and calculated emitter temperature. However, the Distribution Network Operator (DNO) has said that the existing power supply will not support a further electrical load of this size. The DNO provided a quotation to upgrade their network, but this was excessively expensive in this case.

Instead, a heat pump with a 10.5kW heat output at the local CIBSE external design temperature and calculated emitter temperature has therefore been selected for use with a 24kW oil-fired boiler. In this system, the control system consists of an external thermostat that automatically changes the heat source from the heat pump to the boiler below a certain quoted external ambient temperature.

The heat pump has a 6kW supplementary electric heater but no consideration of this is taken when sizing the system. The heat pump ground collector has been carefully sized to allow for the increased energy extraction associated with this type of heat pump operation, which reflects that the running hours of the 10.5 kW heat pump will be significantly greater than if it had met 100% of the space heating load.

Domestic Hot Water Services Design Considerations

4.2.3 Domestic hot water services design should be based on an accurate assessment of the number and types of points of use and anticipated consumption within the property, making appropriate adjustments for the intended domestic hot water storage temperature and domestic hot water cylinder recovery rate. Additional information for assessing hot water use is available in BS 6700: "Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages"; EN 806: "Specifications for installations inside buildings conveying water for human consumption"; and studies conducted by the Energy Saving Trust and Department of Energy and Climate Change, for example "Measurement of domestic hot water consumption in dwellings (Energy Monitoring Company) March 2008".

4.2.4 For domestic hot water cylinder heat exchanger specification, installers should follow the heat pump manufacturers' and / or cylinder manufacturers'/suppliers' recommendations. Domestic hot water heat exchangers for heat pump systems tend to require a much greater heat exchanger performance as compared to combustion-based heat sources. For coil-type heat exchangers, this usually requires a significantly greater heat exchanger area.

4.2.5 Domestic hot water systems shall incorporate a means to prevent bacterial growth (including Legionella bacteria).

NOTE: Further guidance can be found within the Health and Safety Executive Approved Code of Practice L8 document (HSE ACoP L8).

General Design Considerations

4.2.6 The contractor shall communicate and explain to the customer the implications of the space heating and domestic hot water system design on the costs associated with providing space heating and domestic hot water to the building, including but not limited to the following considerations:

- The estimated annual cost of electricity associated with operating the heat pump (this is provided in the estimate of annual energy performance calculated in section 4.3.1).

- The electricity costs associated with the operation of collector and emitter circulation pumps, particularly if these are intended to be operated on a continuous basis
- Heat losses associated with storage vessels
- The electricity costs associated with domestic hot water that may have been produced with an immersion element or supplementary electric heater.

4.2.7 All space heating and domestic hot water installations must comply with local building regulations and standards e.g. Part L in England & Wales and Section 6 in Scotland. The Domestic Building Services Compliance Guide, where applicable, provides further advice on compliance including cylinder and pipe insulation sizing.

Design of the Heat Emitter System

4.2.8 A tool to aid installers and customers to understand the relevance of building heat loss, heat emitter selection and heat emitter temperature on heat pump performance, has been created by the Joint Trade Associations, for use with this document. The "Heat Emitter Guide" can be downloaded from the following location:

- www.microgenerationcertification.org

Installers should make sure they are using the most recent version of the Heat Emitter Guide.

The heat loss power per square metre (in W/m^2) used to select a table in the Heat Emitter Guide is the *room* heat loss averaged over the *room* floor area, also known as the specific room heat loss. This may be greater than the heat loss of the building determined in section 4.2.1 part c) averaged over the total building floor area.

4.2.9 At or before the point at which the contract for the works is entered into with the customer, the installer shall, in writing:

a) Make the customer aware of all specific room heat losses (in W/m^2);
b) Identify the type of emitter(s) to be used in the system;
c) Make the customer aware of the design emitter temperature based on the worst performing room.

d) Agree with the customer the "Temperature Star Rating" for the design emitter temperature, also making clear the maximum achievable "Temperature Star Rating".

4.2.10 At or before the point at which the contract for the works is entered into with the customer, the installer should:

a) Show the customer a relevant extract of the Heat Emitter Guide;
b) Explain the Heat Emitter Guide, including how it is possible to achieve a higher system SPF;
c) Explain how the design emitter temperature will be achieved using the type of emitter selected.

Design of closed-loop horizontal and vertical ground heat exchangers

4.2.11 Designing ground heat exchangers is a complex engineering problem. If insufficient information is available to accurately design a ground heat exchanger, the installer shall adopt a conservative approach. For systems which require the heating capacity found in section 4.2.1 c) to be ≥30kW or incorporate ground loop replenishment through cooling or otherwise, the installer should undertake the design process making use of specialist recognised design tools and/or seek advice from an expert.

4.2.12 Manufacturers' in-house software or other commercial software packages (such as EED, GLHEPRO, and GLD) may be used to design the ground heat exchanger provided that the software is validated for UK use and the following parameters are used for each installation:

a) Site average ground temperatures (or annual average air temperatures). For horizontal ground loops, calculations shall incorporate the swing of ground temperatures through the year at the ground loop design depth.
b) Site ground thermal conductivity values (in W/mK), including consideration of the depth of the water table;
c) An accurate assessment of heating energy consumption over a year (in kWh) for space heating and domestic hot water for the dwelling as built;
d) An accurate assessment of the maximum power extracted from the ground (in kW) (i.e. the heat pump evaporator capacity);

e) An accurate assessment of the temperature of the thermal transfer fluid entering the heat pump.

4.2.13 The temperature of the thermal transfer fluid entering the heat pump shall be designed to be >0^{o}C at all times for 20 years.

4.2.14 Simplified design methods, including look-up tables and nomograms, should only be used where these have been designed and validated for UK ground conditions and installation practices and comply with clauses 4.2.12 and 4.2.13 in this standard.

4.2.15 If proprietary software is not being used, systems with a heating capacity ≤30kW that do not incorporate ground loop replenishment through cooling or otherwise shall use the following procedure for each installation for designing the ground heat exchanger[1]:

a) The total heating energy consumption over a year (in kWh) for space heating and domestic hot water shall be estimated using a suitable method. The calculation shall include appropriate consideration of internal heat gains, heat gains from solar insolation, local external air temperature and the heating pattern used in the building (e.g. continuous, bi-modal, with an Economy10 tariff or otherwise).

[1] This method has been designed to produce a conservative ground array design that should result in the temperature of the thermal transfer fluid entering the heat pump being >0^{o}C at all times in the vast majority of circumstances. Use of improved design input parameters and more sophisticated design techniques may result in a superior outcome.

Notes on determining the total heating energy consumption

The Standard Assessment Procedure for dwellings is not designed to accurately determine the heating and domestic hot water energy requirements of real dwellings. It assumes a fixed dwelling location and estimates occupancy based on floor area. If the Standard Assessment Procedure is used to estimate the total heating energy consumption over a year for space heating and domestic hot water, it shall be adapted to account for changes in heating energy requirements resulting from the differences in external air temperature. Monthly average external air temperatures are given for various UK regions in appendix B.

EN ISO 13790: "Energy performance of buildings - Calculation of energy use for space heating and cooling" gives a method for the assessment of the annual energy use for spacing heating and cooling of a residential or non-residential building.

CIBSE Guide A contains comprehensive degree day information for different locations around the UK. Heating degree days can be used in conjunction with EN 12831 and an assessment of the appropriate base temperature to determine a building's heating energy requirement.

The International Ground-Source Heat Pump Association (IGSHPA) provide guidance on determining heating and domestic hot water energy production, electrical energy consumption and running hours using a temperature bin method.

b) The total heating energy consumption calculated in section 4.2.15 part a) shall be divided by the heat pump capacity selected in section 4.2.1 part c) to create a parameter called the "Full Load Equivalent Run Hours" (in hours).

$$\text{FLEQ run hours} = \frac{\text{Total heating energy consumption}}{\text{Heat pump capacity}}$$

c) The amount of power extracted from the ground is to be limited by the average ground temperature. If a full assessment of the average ground temperature is not being conducted, the annual mean air temperature for the appropriate UK region is provided in the tables and charts and shall be used as the estimate of average ground temperature. The data in the tables and charts is compiled by the MET Office; it is the annual average air temperature measured in a Stephenson Screen at 1.25m. The averaging period is nominally 1981 - 2010. See appendix B.

d) The local ground thermal conductivity (in W/mK) shall be estimated. The British Geological Survey keep logs from hundreds of thousands of boreholes from all forms of drilling and site investigation work; these can be used to estimate the depth and thermal conductivity of solid geology for closed-loop borehole systems. The British Geological Survey also compiles reports with information on the estimated thermal conductivity of superficial deposits for horizontal loop systems. Experienced geologists and hydro geologists will also be able to estimate the local ground thermal conductivity. For larger systems, it may be beneficial to conduct a thermal response test. The Ground-Source Heat Pump Association "Closed-loop vertical borehole design, installation and materials standard" contains guidance on thermal response testing. See appendix C for ranges of thermal conductivity for different rock types.

e) Using the information established in 2.4.15 parts b) - d), the look-up tables and charts provided for vertical and horizontal systems shall be used to establish the maximum power to be extracted per unit length of borehole, horizontal or slinky ground heat exchanger. Online versions of these tables are kept on the MCS website www.microgenerationcertification.org. Installers should check for the latest release of these design aids. The ground heat exchanger design shall be compatible with the notes accompanying the tables, for instance concerning the minimum horizontal ground loop or slinky spacing and minimum borehole spacing.

   For horizontal ground loops, calculations performed to determine the maximum power extracted per unit length have incorporated the swing of ground temperatures through the year.

f) The seasonal performance factor, SPF, given in the heat emitter guide at the design emitter temperature should be used to determine the length of ground loop from the specific heat power extraction information found in the look-up tables and charts. The following formula shall be used to estimate the maximum power extracted from the ground (i.e. the heat pump evaporator capacity), G:

$$G = H\left(1 - \frac{1}{SPF}\right)$$

   where H is the heat pump heating capacity determined in the section 4.2.1 c).

g) The length of the ground heat exchanger active elements, L_b (in m), is determined according to the formula:

$$L_b = \frac{G}{g}$$

   where g is the specific heat power extraction from the ground (in W/m) found in the look-up tables. L_b is the length of the borehole heat exchanger; the length of pipe for the horizontal ground heat exchanger; and the length of trench required for the slinky ground heat exchanger.

h) For horizontal and slinky ground heat exchangers, the total ground heat exchanger area, A (in m^2), is determined according the formula:

$$A = L_b d$$

where d is the minimum centre-to-centre spacing of the horizontal or slinky ground heat exchanger specified in the look-up tables and charts.

i) The minimum length of ground heat exchanger pipe in the active elements, L_p (in m), is determined according to the formula:

$$L_p = L_b R_{pt}$$

where R_{pt} is a non-dimensional ratio. R_{pt} = 2 for boreholes; R_{pt} = 1 for horizontal ground heat exchangers; and R_{pt} is the minimum pipe length to trench length ratio specified in the look-up tables and charts for slinky ground heat exchangers.

j) The installer shall ensure that the flow of thermal transfer fluid is turbulent in the ground heat exchanger active elements. The viscosity of the thermal transfer fluid and therefore Reynolds number, which governs the development of turbulence, changes according to temperature. The Reynolds number of the thermal transfer fluid in the ground heat exchanger active elements should be ≥ 2500 at all times.

4.2.16 For all installations, should the geological situation on drilling or digging show substantial deviation from the conditions used in design or should drilling conditions become unstable or for some other reason the target depth or area not be achieved, the design of the ground heat exchanger shall be recalculated and the installation revised or adjusted if necessary.

4.2.17 For all installations, the installer shall complete and provide the customer with Table 3 on the following page.

NOTE: Where manufacturer's software is used to complete Table 3, boxes [4] through to [12] may not need to be manually filled in / calculated as they may be integral to the software. Where this is the case the installer / designer shall ensure a copy of the software calculation is given to the customer, where it is not the case the boxes must be completed.

4.2.18 For all installations, the hydraulic layout of the ground loop system shall be such that the overall closed-loop ground collector system pumping power at the lowest operating temperature is less than 2.5% of the heat pump heating capacity.

Parameter	Value			Comments
Estimate of total heating energy consumption over a year for space heating and domestic hot water		kWh	[1]	(State calculation method)
HP heating capacity at 0°C ground return temperature and design emitter temperature, H		kW	[2]	
FLEQ run hours [1]/[2]		hrs	[3]	
Estimated average ground temperature		°C	[4]	
Estimated ground thermal conductivity		W/mK	[5]	
Maximum power to be extracted per unit length of borehole, horizontal or slinky ground heat exchanger (from the charts and look-up tables), g		W/m	[6]	
Assumed heat pump SPF (from heat emitter guide)			[7]	
Maximum power extracted from the ground (i.e. the heat pump evaporator capacity) G = [2]*1000*(1 – (1 /[7]))		W	[8]	
Length of ground heat exchanger calculated using the look-up tables L_b = [8]/[6]		m	[9]	(i.e. 2 no. 50m slinkies)
Borehole, horizontal loop or slinky spacing, d		m	[10]	
Total length of ground heat exchanger active elements, L_p = [9]*R_{pt}		m	[11]	(NB: does not include header pipes)
Total length of ground heat exchanger active elements installed in the ground, L_p’		m	[12]	(NB: state if proprietary software has been used to determine the design length)

Table 3 – Details of Ground Heat Exchanger design to be provided to the customer

Installation

4.2.19 The heat pump system shall be installed such that all of the manufacturer's instructions are followed. Where the requirements of this standard exceed those of the manufacturer, the requirements of this standard shall take precedence.

4.3 System Performance

4.3.1 An estimate of annual energy performance shall be calculated or obtained and shall be communicated in writing to the client at or before the point at which the contract is awarded. Separate calculations for space heating and for hot water shall be performed and subsequently added together to give a combined annual energy performance figure.

The means of estimating the annual energy performance is as follows:

a) Assess the annual heat load for the building (space heating or hot water) using any suitable performance calculation method. Such calculation method shall be clearly described and justified.
b) Multiply the result from a) by the proportion of the relevant heat load provided by the Microgeneration Heat Pump system as determined in accordance with Clause 4.2.1.
c) Divide the result from b) by the default efficiency (expressed as a Seasonal Performance Factor or SPF) for Heat Pumps contained in the Heat Emitter Guide.
d) Calculate the energy supplied by the auxiliary heater by multiplying the result from a) by the proportion of the relevant heat load not supplied by the Heat Pump.
e) Add the result from c) to the result from d) to give the total energy required for the relevant heat load.
f) The results from e) for space heating and hot water are added together to give an overall energy requirement for the building for these heat loads.

This estimate, when communicated to the client, shall be accompanied by the following disclaimer:

'The performance of Microgeneration heat pump systems is impossible to predict with certainty due to the variability of the climate and its subsequent effect on both heat supply and demand. This estimate is based upon the best available information but is given as guidance only and should not be considered as a guarantee.'

Additional estimates may be provided using an alternative methodology and/or alternative SPF, but any such estimates shall clearly describe and justify the approach taken and factors used, shall not be given greater prominence than the estimate obtained using the method described above and shall have an associated warning that it should be treated with caution if it is significantly greater than the result given by the method described above.

4.3.2 This standard includes reversible systems, i.e. systems that may provide cooling in addition to heating. It is a requirement that such reversible systems be designed and optimised for heating.

4.3.3 The Contractor shall provide evidence of consultation and compliance with the requirements of the designers and installers of the building's heat distribution system (and hot water system if applicable) regarding specification and performance to ensure the correct and efficient operation of the system as a whole. This shall cover the selection of a Microgeneration Heat Pump of appropriate output for the building, and the design of heat distribution systems and controls compatible with efficient operation.

4.4 Site specific issues

4.4.1 Heat Pumps should be located according to the manufacturer’s instructions. For air source heat pumps, these will include consideration of factors that may detrimentally affect the performance of the heat pump system such as recirculation of chilled air.

4.4.2 The suitability of a proposed Heat Pump system installation site, including the location of ground loops or bore holes, where present, shall be assessed by a qualified professional experienced in Heat Pump systems. Contractors shall make their customers aware of all permissions, approvals and licences, for example for the abstraction and discharge of ground water, required for their installation. Where required the Contractor shall ensure that these permissions and approvals have been obtained before work is commenced.

4.4.3 Heat Pumps should not be located adjacent to sleeping areas or on floors that can transmit vibration.

4.4.4 Anti-vibration pads/mats/mounts and flexible hose connections should be installed according to the manufacturer’s instructions to reduce the effects of vibration on the building structure.

4.4.5 The location of external fans and heat pump compressors should be chosen to avoid nuisance to neighbours and comply with planning requirements.

4.4.6 Internal fans and ducts should be fitted with sound attenuation devices.

4.4.7 For air source heat pumps, consideration should be given to the removal of condensate water produced during a defrost cycle from the outdoor coil. The installation should make provision to deal with this water transferring it to a suitable drain or soak away thus preventing ice build within the unit or its location during extreme winter conditions.

4.4.8 Where installations wish to apply for Permitted Development rights for air source heat pumps in England and Wales, MCS 020 – Planning Standards must be complied with.

4.5 Commissioning

4.5.1 Heat pump systems shall be commissioned according to the manufacturer's instructions.

Closed-loop ground heat exchangers

4.5.2 The following commissioning procedure shall be followed for each installation:

a) Ground arrays (including header pipes and manifolds) shall be flushed as one system to remove all debris and purged to remove all air. Installers shall flush vertical and horizontal ground arrays in both directions and should flush slinky ground arrays in both directions. The heat pump (and its associated pipework) shall be isolated from the ground heat exchanger during this process to avoid damaging the heat exchanger inside the heat pump (e.g. by using 3-port valves).

b) The heat pump (and its associated pipework) shall be flushed and purged as another system, in isolation from the ground array system.

c) Once the ground array is free from debris and visible air bubbles/pockets, purging should continue on the entire system, including the heat exchanger inside the heat pump, for a at least 15 minutes with a minimum flow velocity of 0.6m/s. This is to remove micro air bubbles formed on the inside of the ground array pipes. Achieving this velocity will require different flow rates dependent on pipe diameter and ground loop layout. Flow rates for standard pipe diameters are given in Table 4.

NOTE: Flushing and purging of debris and visible air bubbles may require a significantly greater flow rate than the values shown for purging micro air bubbles. Recommended flow rates for flushing and purging horizontal ground arrays and slinky ground arrays of debris and visible air bubbles are also given in Table 4.

Pipe outer diameter /mm	Recommended flow rate for flushing and initial purging		Minimum flow rate for purging micro air bubbles after flushing and initial
	Horizontal ground arrays (1m/s) /litres/min	Slinky ground arrays (1.5m/s) /litres/min	All ground arrays (0.6m/s) /litres/min
25	20	30	12
32	32	48	20
40	50	76	31
50	79	118	48
65	133	200	81

Table 4: Flow rates required for different pipe diameters to achieve 0.6m/s flow velocity for purging micro air bubbles; 1m/s for flushing and purging horizontal ground arrays of debris and visible air bubbles; and 1.5m/s for slinky ground arrays. Parallel loops or layouts with variable pipe geometry may require higher flow rates to achieve these flow speeds.

d) Once purged of all micro air bubbles, installers shall conduct a pressure test on all closed-loop ground source heat pump installations in accordance with BS EN 805 section 11.3.3.4 to prove that they are watertight. The entire system, which usually comprises the heat pump, header pipes, manifold and all ground arrays shall be pressure tested.

e) The entire ground array system shall have antifreeze added to give freeze protection down to at least -10^{o}C. The quantity and type of antifreeze used shall be appropriate for the system design, in particular with respect to the flow rate stipulated by the heat pump manufacturer; the viscosity of the finished thermal transfer fluid; and the choice of ground array circulation pump.

f) A quantity of biocide recommended by the manufacturer and / or supplier of the antifreeze shall be added to each ground heat exchanger.

g) Two separate, random samples of the commissioned thermal transfer fluid should be tested using a refractometer to confirm that freeze protection down to at least -10oC has been achieved. Evidence should be provided to the customer that this has been achieved.

4.5.3 The Ground-Source Heat Pump Association "Closed-loop vertical borehole design, installation and materials standard" contains further guidance on commissioning vertical ground arrays.

4.6 Documentation

4.6.1 The installer shall provide the customer with a comprehensive document pack, including, where applicable:

Item	Included	Not included	Comments
Sizing			
Details of the heat loss calculations made on the building, including the value of the heat loss coefficient determined for the building, the design internal and external air temperatures and average external air temperature used for heat loss through the floor.	☐	☐	
The heat pump power output at the design ambient temperature and design emitter temperature.	☐	☐	
For air-source systems, evidence that the energy requirements of the heat pump's defrost cycles can be met inside the design temperature range.	☐	☐	
For installations where other heat sources are available to the same building, what proportion of the building's space heating and domestic hot water has been designed to be provided by the heat pump.	☐	☐	
Domestic hot water services			
Evidence for the choice of domestic hot water cylinder.	☐	☐	
Emitter design			
The heat pump power output at the design ambient temperature and design emitter temperature.	☐	☐	
All specific room heat losses (in W/m2);	☐	☐	
Type of emitter(s) to be used in the design;	☐	☐	
Design emitter temperature based on the worst performing room;	☐	☐	
The "Temperature Star Rating";	☐	☐	
The maximum "Temperature Star Rating"; if the maximum is not being achieved, a statement explaining the reasons why.	☐	☐	
Ground heat exchanger design			
A completed ground heat exchanger design table;	☐	☐	
System performance			
The estimate of annual energy use, system SPF and operating costs found in Section 4.3.	☐	☐	

4.7 Equipment

4.7.1 When making installations in accordance with this standard, the Microgeneration Heat Pumps used in installations shall be listed under the MCS (http://www.microgenerationcertification.org) or equivalent.

4.7.2 Equipment shall be suitable for its application and have a manufacturer's declaration of conformity for the appropriate standard.

4.7.3 All Microgeneration Heat Pumps that are installed within the European Union must be CE marked in compliance with the relevant European Directives. These are listed in MCS 002.

5 COMPETENCE OF STAFF

All personnel employed by, or sub-contracted to, the Contractor shall be able to demonstrate that they are trained and competent in the disciplines and skills, appropriate to the activities required for their role, in accordance with this standard.

Complete records of training and competence skills of personnel shall be maintained by the certificated contractor, in particular:

- Design staff, carrying out full conceptual design, shall be able to demonstrate a thorough knowledge of the technologies involved and the interaction of associated technologies.
- All personnel engaged in the actual installation are expected to have technical knowledge and installation skills, to install components and equipment within the designed system, in accordance with all appropriate codes of practice, manufacturer's specifications and regulations.
- All personnel engaged in the final inspection, commissioning, maintenance or repair, shall have a comprehensive technical knowledge of the products, interfacing services and structures to complete the specified processes.

Examples of qualifications that may be suitable for satisfying the training requirements are listed in Appendix A

Note: Due to the current development of the Sector Skills Agreement and the review in progress of the National Occupational Standards for this technology, the indicated suggested scope in the Appendix A, may change.

For personnel employed in the installation of Microgeneration Heat Pumps assessments of training and competence will cover the following underpinning knowledge areas:

Competences applicable to all heat pump technologies:

- Health and Safety knowledge and awareness including risk assessments
- Assessment of the suitability of a heat pump system for the building and the efficient operation of its heating system (and hot water system if applicable)

- Energy conservation including the requirements of the Building Regulations Schedule 1 Part L for new and existing buildings.
- Calculation of building heating requirements (including heat losses and the effects of insulation)
- Loop field materials, jointing methods, pressure testing and hydraulic performance, thermal transfer fluid, antifreeze protection, corrosion inhibitors and other constituents
- After-sales service and warranty
- Awareness of different electricity tariffs
- Fault diagnosis
- Effects of source/sink temperatures on performance
- UK electricity network implications for heat pumps
- Power supplies
- Awareness of BS EN 14511
- Refrigerants
- Performance data to be supplied
- System testing (including pressure, electrical and performance testing)
- Commissioning
- Site assessment, including heat pump selection and selection of heat source
- Optimising heat pump capacity and, if appropriate, use of an auxiliary heating system
- Heat pump equipment siting, mounting and installation including secure fixing and connection of all components
- Environmental considerations – e.g. minimising risk of contamination due to leakage of materials, noise and vibration pollution. See Environment Agency Good Practice Guide listed in Section 8.
- How heat pumps work – principles and components
- Electrical connections and relevance of the Building Regulations Schedule 1 Part P
- Hydraulic circuits and connections
- Understanding of noise, vibration and insulation requirements and IP rating.

Competences applicable to specific heat pump technologies

Required Knowledge	Ground/ Water	Ground/ Air	Water / Water	Water / Air	Air/ Water	Air/ Air
Closed-Loop Heat Exchanger design and trenching/drilling (including back-filling or grouting)	✓	✓	✓	✓		
Closed-Loop Heat Exchanger materials, jointing methods, pressure testing and hydraulic performance	✓	✓	✓	✓		
Closed-Loop Heat Exchanger pipe specification	✓	✓	✓	✓		
Purging and filling of Closed-Loop Heat Exchangers	✓	✓	✓	✓		
Circulation around Closed-Loop Heat Exchangers	✓	✓	✓	✓		
Aspects of heating distribution systems relevant to warm water heat pumps	✓		✓		✓	
Controls: Underfloor systems	✓		✓		✓	
Radiator systems	✓		✓		✓	
Air distribution systems		✓	✓	✓	✓	✓
Aspects of heating distribution systems relevant to warm air heat pumps		✓	✓	✓	✓	✓
Heat source water/brine pump performance	✓	✓	✓	✓		
Air flow checks						
Indoor - inc. discharge temperature		✓		✓		✓
Outdoor					✓	✓

6 HANDOVER REQUIREMENTS

At the point at which the Microgeneration Heat Pump system is handed over to the client, the documentation as detailed in 4.6 should be provided by the Contractor and explained to the client along with:

- The maintenance requirements and maintenance services available;
- a certificate signed by the contractor containing at least the following:
  - A statement confirming that the Microgeneration Heat Pump system meets the requirements of this standard
  - Client name and address
  - Site address (if different)
  - Contractors name, address etc.
  - List key components installed
  - Estimation of system performance calculated according to 4.3

All MCS Installations shall be registered to the MCS Licensee through the MCS Installation Database. A certificate shall be obtained from the MCS Installation Database for each installation showing that the installation has been registered with the scheme and shall be provided to the customer no later than 10 working days after the date of commissioning the system; on provision of the certificate the customer shall be instructed to include it within the handover pack.

The generation of the certificate shall be undertaken in full compliance with the terms and conditions of use of the MCS Installation Database[2] and the registration of the system on the MCS installation database shall only be undertaken after the system has been fully installed and commissioned.

A “per installation” fee is levied on installers for each registration added to the database. Details of any such fee will be advised from time to time through MCS Certification Bodies.

[2] The terms and conditions of use can be found on the MCS Installation Database website.

7 REGIONAL OFFICES

Where the Contractor wishes to design, install and commission under the Certification Scheme in regional offices, then these offices shall meet the requirements of this standard to be eligible for Certification.

8 PUBLICATIONS REFERRED TO

In the following list reference to undated publications implies the latest edition and amendments:

- MCS 001- MCS – Installer certification scheme document. Available from www.microgenerationcertification.eu
- MCS002 – Guidance on regulations and directives for Microgeneration installations. Available from www.microgenerationcertification.org
- BS EN 12831: Heating systems in buildings
- Guide A: Environmental Design. A CIBSE publication.
- CIBSE Domestic Heating Design Guide. A CIBSE publication.
- BS 6700: Specification for design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages
- EN 806: Specifications for installations inside buildings conveying water for human consumption
- Closed-loop Vertical Borehole – Design, Installation & Materials Standard Issue 1.0 2011 www.gshp.org.uk
- HSE Approved code of practice (ACOP) L8 - The control of legionella bacteria in water systems approved code of practice and guidance
- Environmental good practice guide for ground source heating and cooling. GEHO0311BTPA-E-E. Published by Environment Agency 2011. www.environment-agency.gov.uk
- MCS 022 – Ground heat exchanger look-up tables. Supplementary Material to MIS 3005. Available from www.microgenerationcertification.org
- Heat Emitter Guide. Available from www.microgenerationcertification.org
- MCS 020 – Planning Standards. Available from www.microgenerationcertification.org
- "Report for DECC: Measurement of domestic hot water consumption in dwellings", Energy Monitoring Company, March 2008. Available from http://www.decc.gov.uk/publications/DirectoryListing.aspx?tags=98&PageNumber=2&resultsNumber=10
- EN ISO 13790: Energy performance of buildings- Calculation of energy use for space heating and cooling

APPENDIX A: QUALIFICATIONS OF STAFF

The following qualifications may be suitable to satisfy the training requirements detailed under Clause 5:

- Certified EU-CERT.HP installer (Arsenal research, Business Unit Sustainable Energy Systems, Giefinggasse 2, A-1030 Wien, Austria)
- Ground Source Heat Pump Association Installer Training (Ground Source Heat Pump Association, National Energy Centre, Davy Avenue, Knowl Hill, Milton Keynes, Bucks, MK5 8NG)
- International Ground Source Heat Pump Association Accredited Installer (International Ground Source Heat Pump Association, 374 Cordell South, Stillwater, OK 74074, USA)
- Certified Geoexchange Designer (Association of Energy Engineers, 4025 Pleasantdale Road, Suite 420, Atlanta, GA 30340, USA)
- Relevent Engineering Services SKILLcard (Engineering Services SKILLcard Ltd, Old Mansion House, Eamont Bridge, Penrith, Cumbria CA10 2BX) – relevance of the holder's skills and experience would require independent verification
- Relevant Construction Skills Certification Scheme (CSCS) card (PO Box 114, Bircham Newton, Kings Lynn, Norfolk, PE31 6XD. www.cscs.uk.com) – relevance of the holder's skills and experience would require independent verification.
- Relevant NVQ/SNVQ level 3 or, in the case of S/NVQ Land Drilling, level 2 – relevance of the qualification would require independent verification. Enterprises providing geothermal drilling services will, from September 2011, be able to apply for UKAS geothermal drilling certification.
- Accreditation from a relevant training course – relevance of the course would require independent verification
- Membership of a relevant Competent Person Scheme – relevance of the Competent Person Scheme would require independent verification
- Manufacturer's product training – Would be product specific and require independent verification
- Experience gained through a mentoring process – would require independent verification

- Demonstrable track record of successful installation – would require independent verification

APPENDIX B: MET office mean monthly & annual air temperatures (°C) for selected stations based on the Long Term Averaging period 1981-2010

Region	Mean monthly and annual air temperature /°C (1981-2010)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
NE Scotland (Dyce)	3.5	3.8	5.3	7.2	9.6	12.4	14.6	14.4	12.2	9.1	5.9	3.6	8.5
NW Scotland (Stornoway)	4.8	4.7	5.6	7.1	9.3	11.5	13.4	13.5	11.8	9.3	6.8	5.1	8.6
E Scotland (Leuchars)	3.6	4.0	5.7	7.5	10.0	12.9	15.0	14.8	12.7	9.5	6.1	3.6	8.8
Borders (Boulmer)	4.4	4.5	5.9	7.4	9.8	12.6	14.7	14.8	12.9	10.1	6.9	4.6	9.0
W Scotland (Abbotsinch)	4.0	4.2	5.9	8.0	10.9	13.5	15.4	15.0	12.6	9.4	6.2	3.8	9.1
N Ireland (Aldergrove)	4.4	4.5	6.2	8.1	10.9	13.5	15.4	15.0	13.0	9.9	6.8	4.7	9.4
North-eastern (Leeming)	3.8	4.1	6.1	8.1	11.0	13.9	16.2	15.9	13.5	10.0	6.5	3.9	9.4
North-western (Carlisle)	4.3	4.5	6.2	8.2	11.1	13.7	15.7	15.4	13.2	10.1	6.8	4.2	9.4
Midlands (Elmdon)	4.1	4.1	6.4	8.4	11.5	14.5	16.8	16.5	13.9	10.3	6.7	4.2	9.8
Wales (Aberporth)	5.3	5.1	6.6	8.2	10.9	13.4	15.2	15.3	13.7	11.0	8.0	5.9	9.9
E Pennines (Finningley)	4.2	4.4	6.6	8.6	11.7	14.6	16.9	16.8	14.2	10.6	6.9	4.4	10.0
W Pennines (Ringway)	4.5	4.6	6.6	8.7	11.9	14.5	16.6	16.3	14.0	10.6	7.1	4.6	10.0
East Anglia (Honington)	4.1	4.1	6.5	8.6	11.9	14.8	17.3	17.2	14.6	11.0	7.0	4.4	10.1
South-eastern (Gatwick)	4.3	4.4	6.7	8.7	12.0	14.9	17.3	17.0	14.3	10.9	7.1	4.6	10.2
Southern (Hurn)	4.9	4.9	6.8	8.7	12.1	14.8	17.0	16.8	14.4	11.2	7.6	5.2	10.4
Severn Valley (Filton)	5.0	5.0	7.2	9.2	12.4	15.3	17.3	17.1	14.7	11.3	7.8	5.3	10.6
South-western (Plymouth)	6.4	6.2	7.7	9.3	12.2	14.6	16.6	16.7	14.8	12.1	9.0	7.0	11.0
Thames Valley (Heathrow)	5.2	5.2	7.6	9.9	13.3	16.4	18.7	18.4	15.6	12.0	8.0	5.5	11.3

Notes:

1) All values are provisional
2) Monthly station data are included where the number of missing days each month is 2 or fewer. For months with more than 2 missing days, estimated monthly values are taken from the monthly mean temperature grid for that particular month. The long-term average is therefore based on the combination of monthly station data where there are 2 or fewer missing days, and monthly grid estimates, for more than 2 missing days. The method used to produce the monthly gridded datasets is described in Perry MC and Hollis DM 2005, The generation of monthly gridded datasets for a range of climatic variables over the UK, Int. J. Climatology. 25: 1041-1054 and available here: http://www.metoffice.gov.uk/climate/uk/about/Monthly_gridded_datasets_UK.pdf

The table B1 below lists the number of missing months for each station (with more than 2 missing days) where grid estimates are used.

Station	Comments
NE Scotland (Dyce)	Complete record
NW Scotland (Stornoway)	Complete record
E Scotland (Leuchars)	Complete record
Borders (Boulmer)	Complete record
W Scotland (Abbotsinch)	Missing from May 1999 to December 2010
N Ireland (Aldergrove)	Complete record
North-eastern (Leeming)	Complete record
North-western (Carlisle)	Several months missing between 1994 and 2001 inclusive
Midlands (Elmdon)	Missing from April 1999
Wales (Aberporth)	Complete record
E Pennines (Finningley)	Missing from October 1995 to December 2010
W Pennines (Ringway)	Missing from November 2004 to December 2010
East Anglia (Honington)	Missing from October 1992 to July 1997 and April 2003 to December 2010
South-eastern (Gatwick)	Missing from January 1981 to March 2003
Southern (Hurn)	Complete record
Severn Valley (Filton)	Missing from January 1981 to February 2001
South-western (Plymouth)	Several months missing between 1995 and 2000
Thames Valley (Heathrow)	Complete record

Table B1: The number of months missing in the long-term averaging period 1981-2010 for each

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APPENDIX C: Values for thermal conductivity

	Type of rock		Thermal conductivity (/W/mK)		
			Min	Max	Recommended
Unconsolidated rock	Sand, dry		0.3	0.8	0.4
	Gravel, dry		0.4	0.5	0.4
	Peat, soft lignite		0.2	0.7	0.4
	Clay/silt, dry		0.4	1.0	0.5
	Clay/silt, water saturated		0.9	2.3	1.7
	Gravel, water saturated		1.6	2.0	1.8
	Claystone, siltstone		1.1	3.5	2.2
	Sand, water saturated		1.5	4.0	2.4
Solid Sediments	Hard coal		0.3	0.6	0.4
	Gypsum		1.3	2.8	1.6
	Marl		1.5	3.5	2.1
	Sandstone		1.3	5.1	2.3
	Conglomerates		1.3	5.1	2.3
	Limestone		2.5	4.0	2.8
	Dolomite		2.8	4.3	3.2
	Anhydrite		1.5	7.7	4.1
	Salt		5.3	6.4	5.4
Magmatites	Tuff		1.1	1.1	1.1
	Vulcanite, alkaline to ultra-alkaline	e.g. andesite, basalt	1.3	2.3	1.7
	Plutonite, alkaline to ultra-alkaline	Gabbro	1.7	2.5	1.9
		Diorite	2.0	2.9	2.6
	Vulcanite, acid to intermediate	e.g. latite, dacite	2.0	2.9	2.6
		e.g. rhyolite, trachyte	3.1	3.4	3.3
	Plutonite, acid to intermediate	Syenite	1.7	3.5	2.6
		Granite	2.1	4.1	3.4
Metamorphic rock	Slightly metamorphic	Clay shale	1.5	2.6	2.1
		Chert	4.5	5.0	4.5
	Moderately to highly metamorphic	Mica schist	1.5	3.1	2.2
		Gneiss	1.5	3.1	2.2
		Marble	1.3	3.1	2.5
		Amphibolite	1.9	4.0	2.9
	Vulcanite, acid to intermediate	e.g. rhyolite, trachyte	2.1	3.6	2.9
		Quartzite	5.0	6.0	5.5

Table C1: Ranges of thermal conductivity for different rock types, indicating recommended values.

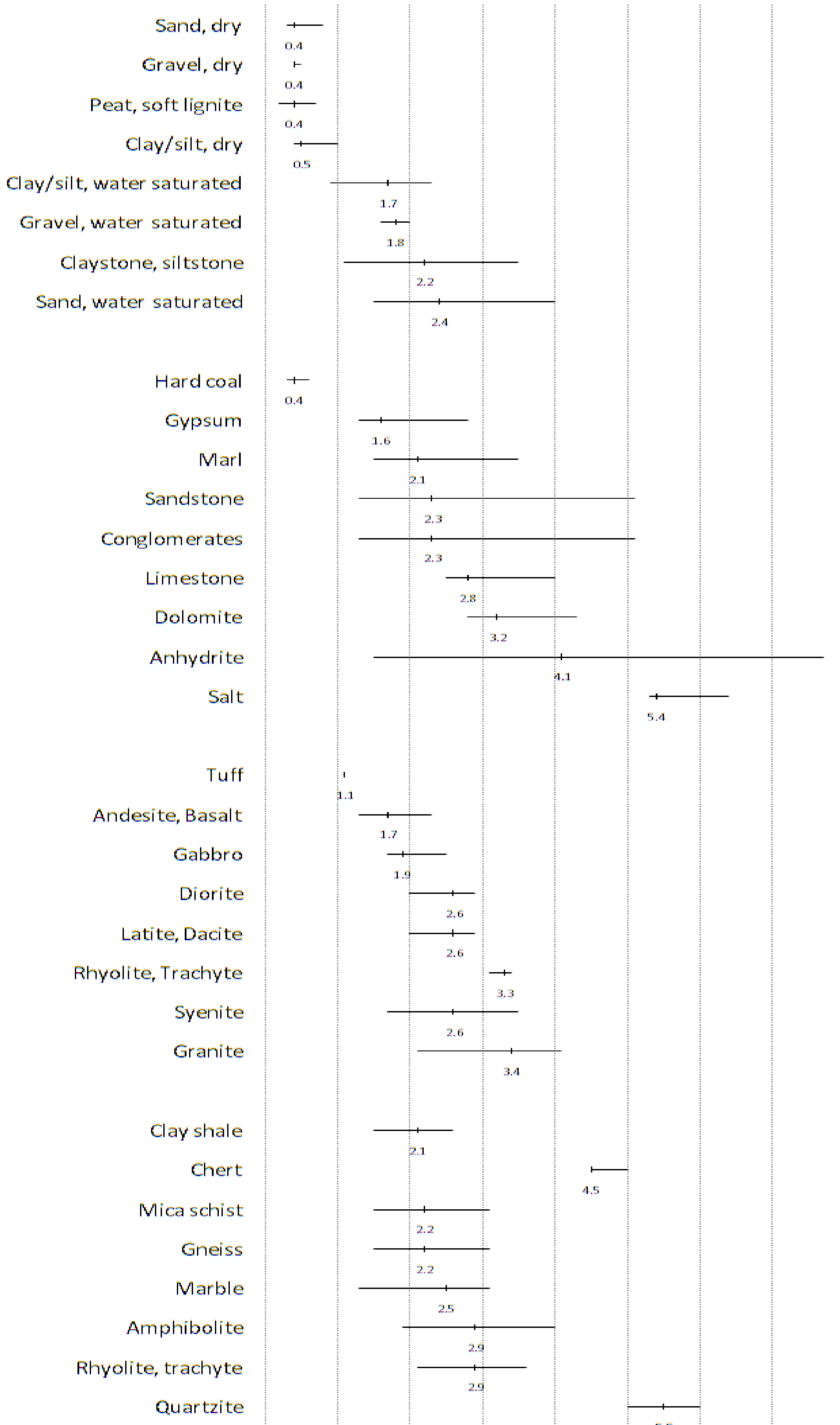

Figure C1: Ranges of thermal conductivity for different rock types, indicating recommended values. The data is the same as that in table B1. Horizontal lines represent the range of thermal conductivity for each rock type. Recommended values are written on the chart.

AMENDMENTS ISSUED SINCE PUBLICATION

Document Number:	Amendment Details:	Date:
1.2	Amended 3.4 Consumer Code of Practice wording Updated e-mail and website addresses	25/02/2008
1.3	Gemserv details added as Licensee. Document reformatted to reflect brand update. References to BERR updated to DECC, MCS logo updated accordingly. Website and email addresses updated to reflect new name.	01/12/2008
1.4	Quality review	10/01/2009
1.5	MCS Mark Updated	25/02/09
1.6	Additional contacting options were added to clause 3.3. As agreed in the MCS Steering on 27/10/2009. References to Clear Skies have been removed from clause 4.7 and a link to the MCS website added.	28/01/2010

2.0	Addition of text under Section 6 – Handover incorporating the generation of MCS Certificates from the MID for each installation. Changes are as agreed at SG meeting of May 27th 2010.	26/08/2010
3.0	Significant updates full document. Readers are advised to read all sections.	05/09/2011
3.1	Update to figure for Plymouth in Table 2 from -1.2 to -0.2, as detailed in CIBSE Guide A. Updated clause 4.2.1c, d and e. Corrected clause 4.2.18. Updated 4.3 to refer to Heat Emitter Guide and SPFs instead of SAP. Addition of note to clause 4.2.17. Addition of CIBSE Domestic Heating and Design Guide to Publications referred to.	01/02/2012
3.1a	A note has been added below Clause 4.2.17, and update to Section 6 Handover Requirements.	20/02/2012