FUNDAMENTAL SERIES 4 MODULE 07

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME JANUARY 2007

CURRENT THINKING ON...

UNDERFLOOR HEATING

BY JAMIE GOTH, MSC BSC CENG MEI, MANAGING DIRECTOR, GOTH ENERGY MANAGEMENT LTD

Space heating energy use represents a significant proportion of total UK primary energy use. In the domestic and service sectors, it accounts for an estimated 60 per cent and 50 per cent of total energy use respectively (1). In 2004 energy consumption by final users in the UK rose by 1.6 per cent (2), with increases in the domestic and service sectors and decreases in manufacturing. Despite improvements in energy efficiency in the domestic sector, for example through higher levels of insulation and tighter building regulations, modern lifestyles are driving increases in energy consumption. The number of households rose by 9.5 per cent between 1990 and 2004 and homes are kept much warmer than they used to be. Average indoor temperatures are estimated to have risen from 16˚C in 1990 to 18˚C in 2004, helped partly by the installation of central heating systems. With space heating forming such a significant proportion of UK energy use, more efficient systems will have to be installed if the UK is to reduce greenhouse gas emissions by 12.5 per cent by 2012 as its part of the EU's Kyoto commitment. Underfloor heating (UFH) systems offer one approach to achieving this.

Underfloor heating falls primarily into two categories: wet systems, based on the circulation of water through pipework under floors, and electrical systems, deriving their heat from electric heating elements under floors. This article addresses wet systems only.

UFH systems warm the floor structure by conduction, causing the surface to radiate heat into the space. The primary source of heat in a wet UFH system is typically a boiler, although there are many other options, as outlined later in this article. The boiler heats water, typically to a temperature of 40-50˚C, which is distributed in plastic or plastic/metal composite pipes to manifolds. Each manifold comprises a flow and a return header from which loops are taken to serve the building. In a typical three-bed house, or a small, two-storey office, the ground floor is served by a single manifold and the first floor by a second one. Small rooms are served by a single loop of up to 100m, whereas larger rooms are served by multiple loops. Each loop is a continuous pipe, leaving the flow header and returning to the return header with no breaks or fittings, minimising future maintenance problems such as leaking joints, or air ingress.

Heat Transfer from UFH Systems

Getting good conduction between UFH loops and the floor structure is essential. The floor structure must either be conductive, or conductive elements must be in contact with it and the UFH pipe loops. Different methods of transferring heat from the pipes to the floor are applied for different

WELCOME...

Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative.

This is the seventh module in the fourth series and focuses on underfloor heating. It is accompanied by a set of multiple-choice questions. To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to **Energy in Buildings & Industry** for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course, for a fee of £15 (for members) or £25 (for non-members).

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject. The following topics will appear in the forthcoming issues of **Energy in Buildings & Industry**: air conditioning, heat pumps, and biomass.

If you miss any of the previous modules so far pubished in the series on emissions trading, Building Regulations, heating design, variable speed drives, heat pumps and photovoltaics, let me know (mark.thrower@btinternet.com) and we will send the missing modules in 'pdf' format to you either by either e-mail or on a CD.

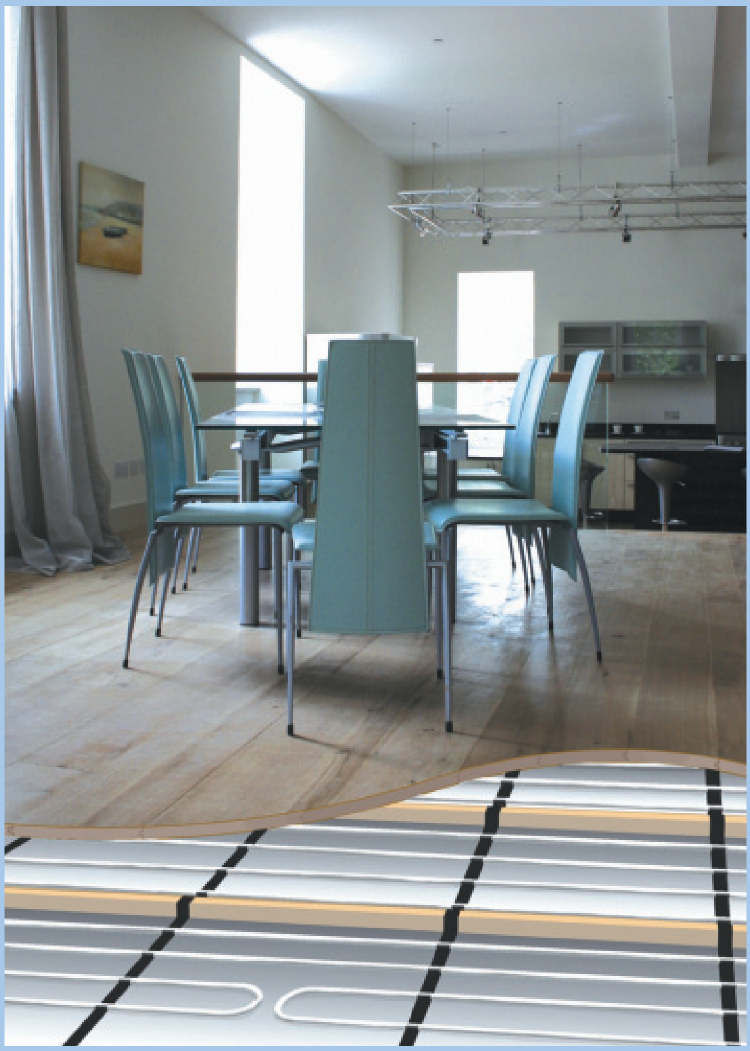
The previous 30 modules from the first three series are also available free of charge.

MARK THROWER, MANAGING EDITOR

Produced in association with energy institute

floor structures. For solid floor construction, UFH pipes are usually fixed to the floor insulation and a concrete screed is laid over them. Floor tiles, carpets, or other finishes are then laid over the screed. Heat is transferred from the pipes through the screed by conduction to the finished floor surface. Where floor tiles are used heat radiates into the room at an average output of 100W/m2.

More complex systems are available for suspended timber floors. A number of UFH system suppliers recommend the inclusion of a sand / cement mix for suspended timber floors, particularly at ground floor level to boost heat output. Battens are installed on the sides of joists onto which insulation or board is fixed; the UFH loops are then fixed to the insulation and a sand / cement dry mix is laid over the pipe loops. Floorboards or other floor finishes can then be laid over the joists in the normal manner. Alternatively, for suspended timber floors, grooved aluminium emission plates, or bespoke insulation panels with a high emissivity surface may be used to span the joists. The UFH loops are pushed into the grooves in the emission plates or insulation panels and floorboards laid over them. Where there is a gap between the UFH loops and the floorboards it is essential that it is tightly sealed, allowing no air movement. The design heat output achievable with suspended timber floors at 70W/m2 averaged across the floor is 30 per cent lower than for screed floors.



Controlling UFH Systems

Each loop has a flow regulator to enable the water flow rate through it to be manually adjusted, allowing them to be balanced on commissioning. It is advisable to install an automatic control valve on each loop. For small systems with areas of similar occupancy patterns and heat loads, a single thermostat or temperature sensor and time programme may be provided for each manifold. However, where there is variation between areas served, a temperature sensor may be advisable for each room. For larger rooms served by multiple loops a single temperature sensor should be installed to control all of its loops. It is not uncommon for all rooms in a building heated by UFH systems to have individually automated time and temperature controls. This is more practicable to achieve than with radiator heating systems due to the use of manifolds which allow actuators and controls to be grouped out of sight.

Convection and comfort

Heat is transferred from UFH systems into the heated space by using the floor as a heat emitter. The large area of this emitter compared to conventional heat emitters, such as radiators allows the required heat output to be achieved at a much lower surface temperature. The design surface temperature of a radiator on a conventional radiator heating system would typically be approximately 77˚C (3). By contrast, the design surface temperature of the floor on an UFH system should be below 29˚C (3). The lower temperature of an UFH emitter results in a reduction in heat output from convection compared to radiators, increasing the proportion of heat transferred by radiation. Radiation accounts for only 30 per cent of heat transfer from a radiator operating at a mean water temperature of 77˚C, compared to 50-60 per cent of an UFH system, with the balance in both cases made up of convection. The transfer of heat by convection from radiators, natural and fan convector heaters leads to air movement both in the vicinity of the heat emitter and in other parts of the heated space. In rooms with large windows or other cold spots, air volume flow rates are greater, as warm, buoyant air rises from the heat emitter, is cooled by the cold spots, becoming denser, dropping back to the floor and returning to the heat emitter to complete the circuit. Conventions in radiator heating system design mitigate this effect by avoiding placing radiators opposite windows or other cold spots. Placing radiators under windows will reduce the formation of convective currents across rooms, however, it can increase heat loss through the glazing.

Even with such measures in place, heating systems that rely upon convection for transfer of heat into the space subject occupants to air movement that they perceive as draught. Providing the buildings they serve are reasonably air tight and well insulated, UFH systems, by having reduced reliance upon convection, are able to produce a similar level of thermal comfort to conventional systems at lower space temperatures. CIBSE recommends an internal design temperature of 21˚C for radiator systems in most areas, but only 20˚C for UFH systems (3). This 1˚C reduction in space temperature would save an estimated 8 per cent in space heating energy use (4).

The surface temperature of radiators can be reduced and indeed in many applications, such as hospitals and care homes, it is recommended as a safety measure to avoid the risk of scalding. The fitting of guards to existing radiators will reduce the surface temperature exposed to the room. However, it would also reduce the heat output of the radiator by an estimated 60 per cent, leading to a requirement for more, or larger radiators. The preferred method of reducing radiator surface temperatures is to install low surface temperature radiators, with a design surface temperature of 43˚C. However, these tend to increase convective heat transfer rather than to reduce it (5).

Reduced stratification and heat loss

Convective systems cause warm air to rise to the top of the heated space where it increases heat loss by conduction through the ceiling or roof and offers no benefit to the building occupant. Conversely, colder, denser air drops to floor level. In standard sized rooms, the effect can generally be ignored in terms of system design. However, as the room height increases, heat loss increases. The increase in heat loss for a ceiling height of 4.5m is estimated at 2.5 per cent, rising by a further 2.5 per cent for every 1m increase in ceiling height up to an additional 10 per cent heat loss for a ceiling height of 7.5m (6). For UFH systems these factors can be ignored as there is little stratification with this system type. The converse is more likely, with temperature inversion occurring: the air at head height being at approximately 20˚C and that at floor level reaching 24˚C. Having the feet slightly warmer than the head is considered to provide optimum comfort (6).

Improved boiler efficiencies

UFH systems operate at low mean water temperatures, promoting good combustion performance from boilers. Typically flow temperatures are 40-50˚C with a 10˚C drop, ensuring that the return temperature is consistently below the dew point of either natural gas (57˚C) or fuel oil (47˚C), theoretically enabling heating-only systems to operate in condensing mode continuously. However, the boiler manufacturers' instructions may preclude operating condensing boilers below the dew point temperature for extended periods, particularly for oil-fired boilers, as the condensate can have a pH value as low as 2, approaching the acidity of battery acid.

Furthermore, where domestic hot water is also provided by the boiler, either by a cylinder or thermal store, a higher boiler flow temperature will be required, reducing the incidence of heat recovery from flue gases by condensation. For carefully designed and operated systems, the seasonal efficiency of a gas-fired condensing boiler serving a UFH system could be expected to average 90 per cent compared to 87 per cent for a condensing boiler serving a heating system with standard sized radiators and weather compensation control to depress heating water flow temperatures in mild weather (7).

UFH and renewables

The low mean water temperatures of UFH systems also lend themselves well to the application of combined heat and power (CHP) and renewable sources of energy such as ground source heat pumps (GSHP) and solar thermal collectors. Low-temperature CHP systems are typically designed to operate at conventional low temperature hot water temperature range of 82˚C flow, 72˚C return. However, this generally leads to heat from engine lubricating oil being rejected as the oil must typically be cooled to below 50˚C. GSHPs that use solar energy stored in the ground as their primary source of heat have the greatest coefficient of performance when supplying water at below 40˚C. UFH systems can be designed to operate with flow temperatures below 40˚C, providing they are serving areas with low heat losses and there is sufficient, unobstructed floor area in which to install pipes. The use of a thermal store, or other arrangement for storing and mixing hot water from multiple sources should be carefully considered. The specification of a thermal store can help to reduce plant over-sizing, reducing the capital costs of systems such as GSHPs and can reduce boiler cycling. Where multiple heat sources are applied, such as solar thermal collectors and a boiler, the thermal store provides a single point of heat input into the UFH system. However, a heat exchanger or a heating coil would have to be introduced into either the boiler or solar collector circuit to separate their primary flows from each other. In the case of solar thermal, the introduction of a heating coil would reduce the secondary flow temperature it could achieve, either reducing its effectiveness, or leading to an increase in the design collector area and associated capital costs.

Advantages and Disadvantages of Underfloor Heating

ADVANTAGES	DISADVANTAGES
Lower running costs & CO2 emissions	Slower response time
Optimises thermal comfort	Heat output limited to ~100 W/m2
Enhances appearance by concealing heating	Supplementary heating may be required in: - small rooms & bathrooms with two external walls small conservatories corridors with large glazed areas
Flexible for use with renewable sources of energy and CHP	Remains a 'novel' technology in the UK, despite recent growth, causing: - fewer installers less competitively priced construction industry less familiar with installation requirements
Ease of access to manifolds for maintenance	Introduces restrictions on use of some types of floor finish, such as underlays for carpets, laminate and veneer flooring
Concealed heat emitters improve access for cleaning floors and skirtings	Noise from pumps near occupied rooms, whilst generally acceptable is greater than that of radiator heating systems where boilers and pumps can be installed in remote plant areas
Enhances property value	Deep floor required to accommodate pipework and insulation
Widespread use on the continent; becoming increasingly popular in the UK	Not generally suitable for installation in existing buildings unless flooring is being replaced
Extended warranty of up to 25 years available on pipework loops of many UFH systems	Risk of damaging pipework if flooring is penetrated, leading to potentially costly damage and repair work

Heat output and response times

The heat output of UFH systems in screeded floors is on average 100 W/m2; for timber floors it is generally 70 W/m2. An average of 98 per cent of modern buildings can be heated by UFH alone. However, in 1-2 per cent of cases, supplementary sources of heat may be required either in cold weather, or in selected areas such

UNDERFLOOR HEATING

SERIES 4 / MODULE 7

Questions

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

1. What proportion of total service sector energy use is used for space heating?
- ☐ 25 per cent
- ☐ 50 per cent
- ☐ 60 per cent
- ☐ 40 per cent

2. What is the average heat output of UFH systems in screeded floors?
- ☐ 70 W/m^2
- ☐ 80 W/m^2
- ☐ 100 W/m^2
- ☐ 90 W/m^2

3. What proportion of the heat output from UFH systems is by radiant heat?
- ☐ 50-60 per cent
- ☐ 40 per cent
- ☐ 20-30 per cent
- ☐ 70 per cent

4. What proportion of modern buildings can be heated by UFH systems alone?
- ☐ 98 per cent
- ☐ 56 per cent
- ☐ 25 per cent
- ☐ 78 per cent

5. For which system type would it typically be more expensive to rectify fundamental errors
- ☐ Conventional
- ☐ UFH
- ☐ Both
- ☐ Neither

6. How much should the space temperature be setback by outside of occupancy on UFH systems?
- ☐ 8˚C
- ☐ 10˚C
- ☐ 5˚C
- ☐ 3˚C

7. Which typically has a faster response time UFH systems, or radiator heating systems?
- ☐ Radiators
- ☐ UFH
- ☐ Both
- ☐ Neither

8. What is the typical water flow temperature of UFH systems?
- ☐ 40-50˚C
- ☐ 65-70˚C
- ☐ 25-35˚C
- ☐ 75˚C

9. What is the typical mean water temperature of a radiator heating system?
- ☐ 72˚C
- ☐ 82˚C
- ☐ 77˚C
- ☐ 40-50˚C

10. How much can the space temperature be depressed by in buildings heated by UFH systems compared to those heated by radiator heating systems to achieve a similar level of thermal comfort?
- ☐ 1˚C
- ☐ 2˚C
- ☐ 3˚C
- ☐ 4˚C

Name.. (Mr. Mrs, Ms)..............................

Business Address ....

Town ....

....

Post Code ....

email address..

Tel No. ....

Completed answers should be mailed to:
The Education Department, Energy in Buildings & Industry,
P. O. Box 825, GUILDFORD, GU4 8WQ

FUNDAMENTAL SERIES 4 MODULE 07

as small rooms or bathrooms with two or three external walls, narrow rooms with large glazed areas, conservatories and rooms with high or poorly insulated external walls.

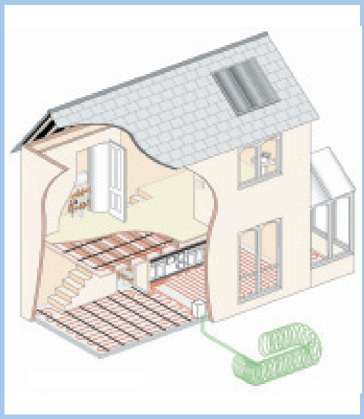
UFH systems have slow response times compared to radiator heating systems. Consequently, they are not ideally suited to applications with intermittent occupancy or significant variation in local heat gains. They should be designed to operate with a setback of the space temperature set point of 3˚C outside of occupancy, for example reducing a daytime or in occupancy temperature set point of 20˚C to 17˚C at the end of occupancy. This ensures a reasonably short heat up period at occupancy start. In well insulated, air tight buildings this relatively small setback in space temperature should have only a modest penalty in energy use outside of occupancy. For older, poorly insulated or draughty properties, UFH can use more energy than radiator heating systems without necessarily achieving the design internal temperature.

Installation in existing properties

It is usually impracticable and costly to retrospectively install underfloor heating systems in older properties, unless flooring is to be extensively replaced. The heating pipes for UFH systems must be installed below the floor finish and on upper floors, the additional work required in lifting and relaying floorboards cannot usually be justified by the savings in running costs compared to well designed radiator heating systems. Furthermore, it can be impracticable to dig out solid ground floors to install the insulation required to enable UFH systems to function satisfactorily.

Whole-life costs

The material cost of UFH system components is usually significantly higher than that of radiator heating systems. The installation of manifolds, actuators and other control items requires



specialist skills and must be carried out by trained, experienced installers. However, the majority of the pipework installation is a quick, low cost operation that can be carried out as a first fix operation under the supervision of UFH specialists. On balance, where the installation procedures of UFH systems are fully understood by all members of the construction team, savings in labour costs can be expected to reduce the difference in installed cost between UFH and radiator heating systems. Providing no fundamental errors are made in the design and installation, which would be considerably more expensive to rectify than on conventional systems, the overcost of UFH systems is repaid through energy and maintenance cost savings, leading to its being amongst the lowest whole life cost options for space heating provision.

References

- Energy – its impact on the environment and society 2006, DTI, 2006
- 2005 Digest of UK Energy Statistics, DTI, 2005.
- Underfloor heating design and installation guide, CIBSE, 2004
- Carbon Trust Website: Heating, Control and Housekeeping, Carbon Trust, 2006
- Safe Surface Temperatures Databyte, Institute of Plumbing & Heating Engineering, 2005.
- Domestic heating design guide, CIBSE, 2004.
- Energy efficiency in buildings, Guide F, CIBSE, 2004.