

FUNDAMENTAL SERIES 4

MODULE 03

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME JULY/AUGUST 2006

CURRENT THINKING ON...

LOW ENERGY HEATING SYSTEM DESIGN

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The primary aim of a suitably designed, well maintained and correctly operated heating system is to achieve prescribed or set temperatures within the space during the winter season with the aim of achieving occupant thermal comfort. Thermal comfort is defined as "that condition of mind which expresses satisfaction with the thermal environment.¹"

Temperatures during winter can fall and remain below zero degrees celsius for long periods. Prolonged exposure to low temperatures can cause discomfort, and significant harm to human health. Buildings with suitable heating systems offer a comfortable temperature controlled environment for their occupants. The function of the heating system is to offset building heat loss. However, not all buildings are occupied, and a secondary important service of the heating system is to maintain the

building fabric and its services from damage during extreme winter weather conditions. For conventionally occupied buildings this facility is also required during hours of non occupancy.

Heating systems in buildings today commonly consist of central natural gas-fired boilers generating hot water within specific temperature ranges. Hot water is circulated within a system of pipe work around the building connecting to heat emitters (such as radiators) located within rooms capable of transfer heat to the area or zone. The thermal heat energy supplied to the room offsets the heat lost through the fabric of the building that occurs due to internal and external temperature differences.

The integration of biomass fuelled boilers is popular within various applications. The use of sustainably grown and sourced renewable fuels within heating systems results in major

reductions in carbon emissions and a reduction in finite fossil fuel consumption.

Table 1 (See below): The carbon dioxide emissions applicable to various fuels used for heating.

Statistics published by the DTI indicate energy consumption within the domestic sector increased by approximately 32 per cent in the thirty years from 1970 to 2000². A proportion of this was due to an increase in the

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number of households in the UK. However, it has recently been reported that approximately 60 per cent of all energy consumed in the domestic sector in 2000 was for space heating. Domestic gas use has quadrupled in the period between 1970 to 2004².

Historically, the energy requirements proportioned to space heating have been double that required for domestic hot water and four times the energy required for lighting and appliances. This is forecast to change as building stock is refurbished and replaced. Building space heating requirements will reduce and

Table 1: The carbon dioxide emissions applicable to various fuels used for heating

Emission Factors for different fuels (kgCO₂/kWh)

Natural Gas	0.19
LPG	0.21
Gas / Diesel Oil	0.25
Heavy Fuel Oil	0.26
Electricity	0.43*
Renewables	0.00

For electricity the real emissions vary from year to year due to the different mix of fuels used in the power stations. However the figure quoted above has been held constant since 2000. (Reference: www.carbontrust.co.uk/knowledgecentre/conversion_factors)

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 third module in the fourth series and focuses on Low-energy heating system design. 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 EIBI 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 EIBI: variable speed drives; metering/monitoring; photovoltaics; underfloor heating; air conditioning; and heat pumps.

If you miss any of the modules in the series 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. Please contact me by e-mail if you would like to receive these.

MARK THROWER, MANAGING EDITOR

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domestic hot water demand will become more prominent.

Within the services sector, (including retail, hotel and catering, education, commercial offices, warehouses, government buildings, health, sport and leisure, and communication and transport) space heating and hot water accounted for 64 per cent of energy consumption.²

Overall, buildings in the UK accounted for 45 per cent of carbon dioxide emissions in 2003.³

Thermal comfort is defined by six basic factors:

- air temperature (dry bulb);
- mean radiant temperature;
- air velocity,
- humidity,
- clothing insulation (clo); and
- metabolic heat (met).

Until this year, CIBSE used the term “dry resultant temperature” as a temperature index for moderate thermal environments involved in defining thermal comfort. The term operative temperature is now used to reflect the convention utilised as part of international standards. The operative temperature is defined by CIBSE as: See Below

The HSE (Health and Safety Executive) states there should be achievement of a reasonable temperature to ensure reasonable comfort⁴. Although there is a minimum temperature outlined, maximum heating temperatures are not specified within buildings in the UK.

The minimum internal temperature of 16 °C is listed within the approved code of practice although it is stated this temperature may not always provide reasonable comfort⁴. Buildings not capable of maintaining the minimum temperature are likely to cause cold temperature discomfort for occupants. On the other hand buildings with inadequate control systems to limit temperatures will continue to emit heat to the building and cause overheating and cause warm temperature discomfort.

It is important to recognise that the type and use of the building and profile of the occupancy can alter the heating temperature requirements.

Recommended internal temperatures are listed by CIBSE.

The heating system can be optimised through the application of low energy design and a combination of factors can be considered. The first of these is often referred to as passive design.

Passive design considers the orientation of the building, its location adjacent to other buildings, along with the integration of structure and services with the aim of reducing the heating requirement during winter through the contribution of solar energy. A key element is the analysis of the proportion of external glazing to external wall. This requires particularly careful consideration and analysis as there are clear risks for the building and its occupants. First, the concept requires suitable controls to monitor the internal temperature during different times of the day and avoid heating when the building has increased levels of solar gain. Second, outside the heating season the concept needs to avoid increasing the potential for overheating, resulting in an energy-intensive requirement for comfort cooling.

The selection and specification of building materials with very low thermal transmittance or U Value properties will directly result in low fabric steady state heat loss requirements. The material with the greatest potential regarding the reduction of energy through the specification of material with low thermal transmittance are external glazing systems.

Of all the material requirements of the building, external glazing systems generally have higher U Value properties. Heat can easily pass

through glass due to its low density properties and parameters. It is preferable to select glazing and façade systems that both reduce the heat loss through the glass and balance solar gain and daylight requirements.

A further requirement is that the engineer, in conjunction with the architect, needs to consider other factors not associated with energy consumption, such as the seasonal ventilation strategy, level of natural daylight required and the ratio of external glazing to external fabric, which can have considerable impact on the heat loss levels but also have influence on other parameters important for overall occupant comfort.

Combining passive design methods and the specification of materials with low thermal transmittance values can reduce the capacity requirements of the heating system resulting in subsequent reduction in annual energy consumption.

Prior to the detailed design of the heating system there are important factors that influence the outline design of the system:

- type and occupational use of building - consideration of whether the building is to be occupied intermittently or constantly has importance regarding the type and use of heating system. For example, larger capacity heating equipment may be required for intermittently heated buildings;
- occupant thermal comfort requirements. Will areas within the building have any particularly different temperature requirements? Are the building systems going to achieve good occupant comfort;

- reference to local weather data - is the building near the coast? The buildings location and geographical factors have influence on the selection of external design temperatures required for reference during detail design.

- health and safety requirements - for the majority of buildings there are areas that will require low surface temperature (LST) emitters to avoid risk of occupant injury as required for children, the elderly or disabled.

- reduction in energy consumption, fuel source - what options are there to reduce energy consumption considering building thermal material properties and what are the possibilities regarding the selection and the type of fuel the building could possibly utilise. Are there any buildings within the vicinity that are utilising CHP where exported heat could be used within adjacent buildings heating systems? Application of renewable fuels should be considered.

- system integration with other buildings services equipment and systems - What other mechanical services systems proposed will require provision for low temperature hot water from the heating system? What are the buildings generic, heating, hot water and ventilation strategies and system parameters and requirements?

In order to understand a building's heating capacity requirements and individual room heating requirements the steady state heat loss calculation needs to be carried out.

The heat loss calculation / thermal characteristics of the building are assumed to be in a steady state mode (i.e non-transient extreme mode). The key parameters required as part of the calculation are:

- internal design temperatures (°C)
- external design temperatures (°C)
- material thermal transmittance properties (W/m²K)
- infiltration (usually expressed

The operative temperature is defined by CIBSE

$$T_c = T_a \sqrt{\frac{(10v) + T_r}{1 + \sqrt{(10v)}}}$$

When:

- T_c - Operative Temperature (°C)
- T_a - Air dry bulb temperature (°C)
- T_r - Mean Radiant temperature (°C)
- V - Air velocity (m/s)



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in air changes per hour)
The internal design temperature for heating is given at a national level. Internal design temperatures within the UK are set at maximum of 19 °C as prescribed within the heating controls amendment of the 1980 Fuels and Electricity Order⁵. Made under the Energy Act of 1976, the order lowered to 19°C the temperature above which premises may not be heated.

As previously mentioned the internal design temperatures can vary depending on the building and the use of space. However, for the purposes of calculation of steady state heat loss the internal air temperature or design temperature is assumed to be uniform.

External temperatures are based on recorded or historical weather data; a good reference is the CIBSE J Guide, which has information on external design temperatures for many national and international locations.

Material thermal transmittance characteristics and properties also known as U Values are influential in dictating the ratio of heat loss per metre of surface area. The introduction of the revised Part L calculations has driven down the performance requirements of building fabric material transmittance.

An assessment of the level of air infiltration to the building is required to ensure that the overall level of air changes is considered as part of the heating load. It is necessary to also calculate the ventilation and infiltration levels to ensure that ventilation is adequate to meet the occupancy or other ventilation requirements.

CIBSE provide tabulated data that provides an indication of air infiltration. Guide A stipulates that for a six-storey, 6,000m² floor area non-residential building with air permeability of 5 m³/(m²h) at 50 Pa (classed as an airtight building) the peak air change rate is 0.2ac/hr and the average 0.15ac/hr.

It is important to note that the information provided is a very approximate estimate of the contribution that air infiltration rate makes to the overall air

PARAMETER	REQUIREMENT
External design temperature	Determine the external design temperature and the annual mean external temperature
Internal design temperature	Specify the status of each space (heated or unheated) and the values of the internal design temperature of each heated space
Dimensional and thermal characteristics of materials	determine the dimensional and thermal characteristics of all building elements for each heated and unheated space
Design transmission heat loss	calculate the design transmission heat loss coefficient and multiply by the design temperature difference to obtain the design transmission heat loss of the heated space
Design ventilation heat loss	calculate the design ventilation heat loss coefficient and multiply by the design temperature difference to obtain the design ventilation heat loss of the heated space
Total design heat loss	obtain the total design heat loss of the heated space by adding the design transmission heat loss and the design ventilation loss
Heating capacity of the space	calculate the heating-up capacity of the heated space, i.e. additional power required to compensate for the effects of intermittent heating
Total design load	obtain the total design heat load of the heated space by adding the total design heat loss and the heating-up capacity.

change rate of a building.

The procedure for the steady state calculation process is defined by standard BS EN12831:2003 and has the following procedure: See above

The definition of heat transfer (or heat) is “energy in transit due to a temperature difference⁶” this definition considers the principle that where there is a temperature difference heat transfer must occur in accordance with the fundamentals of heat and mass transfer.

Heating systems transfer their heat to a space or room via the three fundamental methods or modes of heat transfer: conduction, convection and radiation.

The three methods of heat transfer are reflected within the principles of system heat emitter design and configuration. The selection of an emitter to deliver the heat to the space or room of a

building requires to consider both building design and integration, output capability, and calculated steady state heat loss (with reference to the design parameters).

The emitter works on the principle of heating flow and return water being circulated through their sections to provide an output based on the temperature difference between the mean water temperature and the room temperature. Popular heat emitters (and their methods of heat transfer are):

- Radiator - Convection and Radiation
 - Underfloor heating - Convection and Radiation
 - Perimeter or trench heating - Convection
 - Radiant panel systems - Convection and Radiation
- Radiators are still the most common form of heat emitter within the UK. The radiator is

conventionally placed and positioned beneath external windows on an external wall to offset cold draughts and increase occupant thermal comfort through the avoidance of radiant asymmetry. The definition of radiant asymmetry is when a person is in close proximity to a cold or warm surface such as a window or ceiling when the room temperature parameters are outside a specific range. The occupant can feel discomfort due to a cold or warm effect in comparison to other areas of the room.

Underfloor heating usually consists of a primary manifold header pumped system with secondary individual pumped circuits. Flexible flow and return pipework located beneath a screeded floor serves individual zones with temperature detectors within the space linked to the manifold regulating flow

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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 is the primary aim of a heating system?

- to achieve prescribed or set temperatures within a space with the aim of achieving thermal comfort
- to achieve maximum temperatures within a space during the winter season
- to offset heat loss and prevent condensation
- maintain the building fabric and its services from damage during extreme winter weather conditions

2. What is the minimum heating temperature requirement in the UK?

- 16°C
- 17°C
- 18°C
- 19°C

3. By what percentage has UK domestic energy consumption approximately increased by since 1970?

- 19 per cent
- 32 per cent
- 45 per cent
- 60 per cent

4. What was the percentage of energy consumed by space heating systems within the domestic sector in the UK in 2005?

- 20 per cent
- 45 per cent
- 60 per cent
- 85 per cent

5. In 2005, what percentage of carbon emissions were buildings accountable for?

- 10 per cent
- 20 per cent
- 30 per cent
- 45 per cent

6. What is the percentage carbon reduction of using natural gas for heating as opposed to using electricity?

- 45 per cent
- 55 per cent
- 60 per cent
- 75 per cent

7. What is the internal temperature above which a premises may not be heated as amended under the order of the Energy Act of 1976

- 16
- 17
- 18
- 19

8. What is the definition of the total design heat load?

- summation of the total design heat loss and the heating-up capacity.
- summation of the total vent loss and the total fabric loss
- summation of the design transmission and the design vent loss
- summation of the design fabric loss and the design vent loss

9. What building element / material has the greatest potential regarding reduction of heat loss, should low thermal transmittance properties be applied.

- external wall
- external glazing
- external facade
- floor or roof

10. What is the peak air change rate for a six-storey, non-residential building with an air permeability of $5\text{m}^3/\text{m}^2/\text{hr}$ at 50Pa?

- 0.1
- 0.15
- 0.2
- 0.25

Name (Mr. Mrs, Ms)

Business Address

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email address

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Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry,
P. O. Box 825, GUILDFORD, GU4 8WQ

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temperatures. Underfloor heating typically has lower flow and return water temperatures and subsequently a reduced output. During the peak winter season the type of heating is often operated 24hrs of the day to maintain minimum temperatures. Commonly used in transient areas of buildings due to its slower response times.

Perimeter heating consists of flow and return heating pipework with finned elements mounted within a casing. It is often best utilised parallel with the external wall or windows, usually directly beneath large areas of glazing, where it is difficult to install conventional radiators. Pipework is often adjacent or within the trench heating unit. Air is induced to the emitter due to the temperature difference and is in effect a natural convector.

Radiant panel heating systems often use flow and return heating pipework mounted onto a metal plate, the pipework is heavily insulated to encourage the heat to transfer to the front of the plate. Usually ceiling mounted or mounted at high level at an angle facing the area to be heated the units can be installed within a ceiling void or within a wall. To avoid asymmetry low temperatures are encouraged.

The building services engineer is limited regarding the options for central plant and boiler configuration in particular with regards to the distribution of the heat and the control methodology for the pipework systems. Conventionally, boiler systems utilise what is known as the reverse return header system which consists of a loop of pipework with connections to each boiler (i.e. connections in parallel), this assumes that more than one boiler is considered.

The utilisation of multiple boiler installations can assist in maximising operating efficiencies and increase reliability. The use of the reverse return header system ensures equal flow through each of the boilers. The flow pipework connection from each boiler is then circulated utilising a pump (also often duty and standby) and connected to a "low loss primary header".

Within conventional boilers

water vapour within the flue gas, produced from the combustion process, passes into the flue and leaves the system. In condensing boiler systems the water is condensed and heat extracted and added to the heat output of the boiler. This results in increased levels of boiler efficiency and reduced boiler standing losses.

There are a number of basic requirements for a heating system to utilise condensing boilers. These include a lower water return temperature, a system designed specifically for condensing operation, and means for safe disposal of the condensate, as this can be slightly acidic. And consideration that the lead boiler, within a multi-boiler installation system, be allocated as the condensing unit.

The purpose of a compensated heating controls philosophy is to regulate the flow temperature of heating circuits in accordance with the external and internal temperature levels. This is achieved through the mixing of the return water temperature with constant temperature flow water, utilising a three port motorised control valve linked to a building energy management system.

Weather compensation incorporates intelligent methods of monitoring internal and external temperatures with flow and return water temperatures.

References

- 1 BSENISO 7730 - Ergonomics of the thermal environment –Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria
- 2 DTI Energy consumption tables: domestic energy consumption 2005 URN No: 05/2010 www.dti.gov.uk
- 3 CIBSE Briefing on the Energy Performance of buildings directive 2003 www.cibse.org.uk
- 4 Workplace (Health, Safety and Welfare) Regulations 1992 www.hse.gov.uk
- 5 Statutory Instrument 1980 No.1013 – The fuel and electricity (Heating) (Control) (Amendment) Order 1980 HMSO
- 6 Fundamentals of heat and mass transfer Incropera.F, DeWitt.P.D 4th Ed 1996

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