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MARK THROWER MANAGING EDITOR

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SERIES **17** | MODULE **09** | **SPACE HEATING**

Choosing your space heating

By Neil Peacock, managing director of Energy International

In the UK, and many other parts of the world it is necessary, for comfort and health to heat the spaces that we live and work in. As well as providing comfortable and healthy living and working conditions there is also, sometimes a need to space heat for other reasons such as frost protection or plant raising.

Around 20 per cent of UK energy consumption is used for space heating. Over 70 per cent of space heating systems are currently fuelled by natural gas. Clearly, space heating is an important area for consideration of energy efficiency. If we are to de-carbonise the UK's energy systems, there is much to do in the area of space heating. It is important that we have a good understanding of space heating systems, where efficiencies can be improved and how renewable energy systems can be integrated into them.

There are many and various methods of providing space heating. For the purposes of this article we may consider the following segmentation: wet, radiant, air handling, underfloor, direct expansion heat pump. Each of these systems will be considered with this article.

Conditions within the building

Before considering the type of system that may be suitable to employ in any particular situation we may first consider: The conditions that we wish to achieve within the building. The external conditions that we expect the building to experience.

One of the most widely accepted, authoritative sources of space heating design criteria in the UK are the Chartered Institution of Building Services (CIBSE) guides.

When considering internal space conditions, the internationally accepted standard term used to

describe the space temperature is Operative Temperature (θc).

$$\theta c = H\,\theta ai + (1-H)\,\theta r$$

Where: -

θai = Dry bulb temperature

H = A dimensionless factor calculated from surface convective and radiative heat transfer coefficients

θr = Mean radiant temperature

We can see from this formula that both dry bulb temperature and radiant temperature play a part in providing a comfortable environment.

One commonly referred to piece of UK legislation is The Fuel and Electricity (Heating) (Control) Order of 1974. This prohibits the use of fuels or electricity to heat premises above 19°C. In reality, space heating design temperatures range from c.16°C in factories and warehouses to c.22°C in offices and dwellings. Hospitals may require higher temperatures possibly up to 24°C.

Considering external conditions, space heating system design is usually based purely on dry bulb temperature. Very often a figure of -1°C is used as the minimum external temperature on which to base the calculation of the maximum plant sizing. Of course, winter temperatures well below -1°C are frequently experienced in the UK. The ability of the space heating system to provide the desired internal conditions under extreme external conditions will depend on a number of factors including: The degree of plant oversizing, the thermal mass of the building.

It is a well-accepted fact that people are thermally dissimilar. Where a group of people are subjected to the same environment not everyone will be satisfied all of the time. Space heating systems and their controls need to be capable of providing conditions to meet the needs of a range of occupants of the space. In addition to temperature this may also include factors including ventilation rate, air velocity, humidity and thermal radiation.

In order to ensure that any space heating system meets the design criteria some form of heat loss calculation will need to be performed. There are numerous calculation methodologies in common use. These range from relatively simple 'manual' and steady state analysis to sophisticated, computer-based, dynamic models. There are also some well-tried 'rules of thumb'. A more detailed description of this aspect of space heating is beyond the scope of this article. The choice of the design/calculation methodology employed will generally depend on the size and complexity of the project.

Wet systems are probably the most commonly found systems in the UK. They are used in many types of building including: homes, hospitals, schools, and offices. Here, a central thermal energy generating plant distributes its output through a system of pipes. While low-temperature hot water (LTHW) is an extremely common media, medium (MTHW) or high temperature hot water (HTHW) or steam may also be used. LTHW poses a much lower safety risk than the other fluids.

The maximum recommended temperature for exposed heating surfaces in health care establishments in the UK is 43°C. Steam, MTHW & HTHW all involve fluid temperatures in excess of 100°C. Typical flow and return temperatures for LTHW systems range from 35°C to 80°C. In some situations, care must be taken, even when using LTHW to avoid the risk of injury due to burning.

The central heat-raising plant may be some form of hot water or steam-raising boiler. This may be fuelled by fossil or renewable fuel. The most common boiler fuel in the UK is currently natural gas. Liquid petroleum gas (LPG), oil and coal are also commonly used fossil fuels. Probably the most common renewable fuel is biomass in the form of wood chip or pellets.

Heat pumps grow in popularity

Heat pumps are growing in popularity and will most likely continue to do so as we attempt to decarbonise. Whatever the source of energy: slinky, borehole, air or water it is always desirable to deliver the heat at the lowest temperature that is practicable and economical. Delivering heat at low temperatures promotes the all-important coefficient of performance of the heat pump.

Modern wet LTHW heating systems are normally designed on the 'two-pipe' system. Here the heat emitters are connected to a flow and return system. It is common to design the system to deliver its maximum output with flow and return temperatures of around 80–70°C respectively. Older systems often operated on a 'one-pipe' system. The obvious disadvantage of this is that the circulating fluid got progressively cooler on its route around the system.

All wet systems require that the delivery network is carefully designed, installed and commissioned such it is capable of delivering the correct amount of heat energy to the whole of the system and its individual parts. This involves correct pump and pipework sizing and well as appropriate control and balancing valves.

The term emitter is commonly used to describe any component which takes heat energy from the delivery network and provides it to the space. There is a wide range of different types of emitter commonly in use:

• **bare pipework** – this method of space heating is not commonly seen in recent times. Generally, lengths or loops of pipework are arranged at high or low level to provide space heating. Usually larger diameter pipe than that required for flow purposes is used to increase the heat transfer area. The advantages of this system is that it is very robust / vandal proof and generally low cost. This type of emitter is commonly found in prisons and sports changing rooms.

• **panel radiators** – possibly the most commonly used of all types of wet system emitter. They are usually made of pressed steel and very low cost. The term 'radiator' is really a misnomer in this case. Most of the heat energy delivered from panel LTHW fed radiators is by convection. Panel radiators are the most common form of heat emitter found in dwellings and small/medium-sized rooms of all uses. Panel radiators can be single or double thickness and may have extended surface finning added to increase their output. In the same category similar radiators are often found made of cast iron or aluminium. A derivation of panel radiators are towel rails.

Panel radiators can, of course be electrically heated (direct resistance) in which case they usually incorporate electronic temperature and time controls in an attempt to ameliorate the high cost of electricity.

• **perimeter or sill line radiators** – a subset of panel radiators, these are 'short' radiators. They are often used in conjunction with air handling systems particularly in front of glazing to prevent cold spots and / or condensation.

• **low-temperature radiators** – another subset of panel radiators but designed such that no 'touchable' area exceeds 40°C usually for safety reasons but also for enhanced aesthetics appearance. These are often constructed from a serpentine of pipe with added extended surface finning.

• **fan convectors** – these are capable of greater thermal output than panel radiators for a given wall area. They consist of an extended surface heat exchanger (fan coil) and a fan, usually centrifugal. They are commonly found in larger offices and meeting rooms. The fan speed is usually controllable, and they are often controlled by individual thermostats.

Heating the occupants

In radiant systems, by definition, the heat transfer mechanism employed is radiation rather than convection. The main aim of a radiant system is to reduce energy consumption by heating the occupants of the space rather than the space itself. To better understand how this is achieved we need to briefly consider the calculation of operative temperature shown earlier. We can see from this that radiant heat plays a significant part in providing comfortable environmental conditions.

Radiant heating is commonly employed in buildings with high ceilings and in open spaces. Factories, indoor markets and churches are good examples of the former. Smoking areas and outdoor dining are very common applications in open spaces.

In the past, radiant heating using panels fed with steam were very common in factories. As the use of steam has declined so natural gas-fired radiant tubes and plaques have become more common. In some applications liquid petroleum gas (LPG) is also a commonly used fuel.

Gas-fired radiant tubes may be flued or un-flued depending on the space ventilation rate. They consist of a metal tube with a forced draught natural gas burner at one end. They may comprise one long tube or serpentine or a herring bone configuration.

Radiant plaques comprise ceramic plaques on the surface of which natural gas burns to heat the ceramic to red heat. They are always un-flued. Because of the higher radiant temperature of the plaques compared to tubes they can be mounted at higher levels than radiant tubes.

Electrically powered radiant systems are now very popular. These generally utilise halogen type heating elements which emit heat energy in the infra-red frequency range.

The claimed energy efficiency benefits of radiant heating can be savings in the order of 30 per cent.

Enormous number of variations

Air is very commonly used as a medium for providing space heating. This is particularly true in larger buildings such as: hospitals, theatres and offices. There are an enormous number of variations on the air handling systems. To attempt to describe them all is way beyond the scope of this article.

The majority of air handling systems are 'mechanical' i.e. air movement is created by fans. Natural ventilation relying on the buoyancy effect to create air movement is also used. These offer some energy efficiency advantages.

The basic components of a mechanical system ventilation system are: inlet duct, supply fan, heat exchanger, supply duct and grilles, extract duct and grilles, extract fan, outlet or exhaust duct. The centralised components of a mechanical ventilation system are usually housed in an air handling unit (AHU).

In addition to these basic components air handling systems may also contain other components including: frost protection heat exchangers, filters, heat recovery heat exchangers, recirculation dampers and ductwork, variable air volume boxes.

Where air conditioning is also incorporated into the air handling system cooling heat exchangers and humidification systems may also be required.

Thermal energy can be supplied to air handling systems via: steam, HTHW, MTHW, LTHW, or refrigerant (in heat pumps).

Once a favourite of the Romans in recent years underfloor has become increasingly popular in the UK. Underfloor systems may utilise LTHW or direct resistance electricity.

The advantages of underfloor systems include: no air movement, no visible emitters, works well with the lower temperature LTHW and therefore a good match to heat pumps.

Direct Expansion Heat Pumps are another alternative heating system. You may be wondering why the term 'direct expansion' (DX) has been used here. The purpose of this is to differentiate between heat pumps whose output is delivered via LTHW systems and those in which heat energy is delivered directly via the condenser side of a heat pump system.

DX systems can be further segmented into 'split' and 'multi-split systems' although, for the purposes of this article they can be described as one type.

It is probably true to say that this form of space heating came about as a natural progression from 'through the window' and then 'split' comfort cooling systems. There is now a plethora of available heating and cooling systems using the vapour compression cycle.

One of simplest forms of DX system is where one evaporator / condenser is mounted externally connected via refrigerant pipe work to one internal evaporator / condenser expanding on this we now see buildings where a whole network of indoor units is fed from a single outdoor unit.

Indoor units providing both heating and cooling are available in many types: wall mounted, ceiling mounted, floor mounted.

Heating and cooling of different spaces within the same building simultaneously can be achieved with heat recovery being utilised. Most of these systems are air source however they could also use the other available sources: ground or water as appropriate.

There are numerous different types of space heating control system. Some are applicable to all types of system and some are system specific.

The thermostat is a very common, simple form of control, a temperature activated switch which switches on or off the heat source. The heat source could be a direct electric resistance heater, fan convector, heat pump, fluid control valve, etc.

In the past these tended to always be of the bimetallic strip type with not very repeatable accuracy. More modern thermostats are electronic and may incorporate a digital display and / or a timer.

Sophisticated controls

More modern sophisticated controls are likely to yield benefits both in terms of energy efficiency and comfort. It is worth reminding that 1ºC overheating results in around 15 per cent more energy use.

Thermostats are very commonly used on LTHW systems to provide individual room temperature control. They can now be electronic, with internet connectivity and digital displays etc.

Weather compensation is another very commonly used technique in LTHW systems to adjust the flow temperature (control the heating output) in relation to the outside air temperature.

Optimum start/stop is a control system designed to ensure that the heating system starts and stops at the correct time to provide comfort conditions. It relies on automatically acquired knowledge of the building dynamics and outside air temperature.

Regarded as the ultimate in control system sophistication, building management systems are now available in many guises and levels of affordability. BMS can be used to control any type of space heating system. With the continued growth of the 'internet of everything' we can imagine increasing levels of sophistication at all levels of system size and complexity. Systems such as Hive are a portent of this growing sophistication.

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SPACE HEATING

Please mark your answers below by placing a cross in the box. Don't forget that some questions might have more than one correct answer. 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, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. Which is the most common heating media in wet systems?

- ☐ High temperature hot water
- ☐ Steam
- ☐ Low temperature hot water
- ☐ Cold water

2. What is the most common space heating fuel in the UK?

- ☐ Fuel oil
- ☐ Electricity
- ☐ Natural gas
- ☐ Coal

3. What is a typical dry bulb space temperature for a home?

- ☐ 16ºC
- ☐ 19ºC
- ☐ 22ºC
- ☐ 24ºC

4. What is currently the most common construction material for panel radiators?

- ☐ Cast iron
- ☐ Pressed steel
- ☐ Cast aluminium
- ☐ Copper

5. Which of these is a key component of a mechanical ventilation system?

- ☐ A fan
- ☐ An atrium
- ☐ A chimney
- ☐ Opening windows

6. Which is the 'delivery end' of a vapour compression heat pump system?

- ☐ The evaporator
- ☐ The condenser
- ☐ The compressor
- ☐ The slinky

7. Which of these factors is used by a weather compensation control system?

- ☐ Building thermal inertia
- ☐ Time of day
- ☐ Outside air temperature
- ☐ Date

8. Which of these factors is used by an optimum start control system?

- ☐ Level of building occupancy
- ☐ Outside air temperature
- ☐ Boiler capacity
- ☐ Boiler flow temperature

9. Which types of space heating system can building management systems be used to control?

- ☐ Any
- ☐ Wet systems
- ☐ Air handling plant
- ☐ Boilers

10. What is a thermostat?

- ☐ A temperature sensitive switch
- ☐ A temperature sensor
- ☐ A proportional control device
- ☐ A digital display device

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