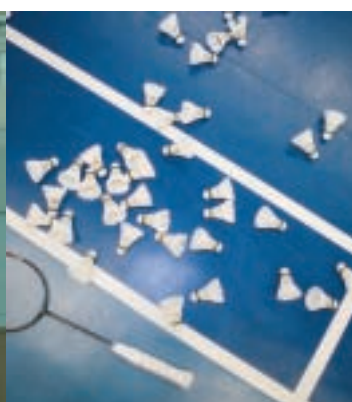


# Facilities Report 02

A designer's guide to underfloor heating in sports halls



# Foreword

**sportscotland** aims to promote the development of quality facilities so that they are fit for purpose, inclusive, sustainable and enjoyable to be in. This guidance report looks at the design issues of providing underfloor heating, a feature which can have environmental benefits if correctly designed and integrated with other environmental services. It also aims to provide the designer with sufficient information to help make key decisions about providing underfloor heating alongside other alternatives.

Sports halls are very functional spaces where many sports place different demands on the facility. Whilst there are many environmental, cost, health and visual benefits of providing underfloor heating, the complexities require considerable understanding. The guidance looks at:

- compatibility of underfloor heating with floor surfaces and suitability for the range of sports;
- the need to control the thermal comfort with ease and with effect, eg. fast response times;
- the capital and running costs;
- integrating underfloor heating with renewable energy systems, eg. ground source heat pumps;
- ongoing maintenance, future floor fixings and the like;
- consideration of programming (peak and off peak use);
- the visual consequences of concealing the heating, eg. decluttering the ceiling area of unsightly heating pipes or panels.

These all need to be examined in detail and also considered collectively so that the designer can make a well informed choice, which reconciles the various requirements of the facility with the needs of its users.

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# 01 Introduction

Designers do not often have the opportunity to design a sports hall floor for a dedicated activity. Most sports hall floors are multi-use and are required to meet a large number of competing and sometimes conflicting demands. Whether they are required to provide for different uses, e.g. congregation and sport, or to meet the varying demands of different sports, e.g. hockey and aerobics there are generally compromises to be made. 'Floors for indoor sports' provides good coverage of the general issues.<sup>1</sup>

There will be an impact on the choice of sports hall heating depending on the range of uses and the types and levels of sports provision. The available choices are electric infrared emitters, gas radiant tubes, wet radiant panels, warm air and underfloor. The choice may be affected by a range of factors including fuel options, occupancy patterns and building type.

Sports halls are increasingly being heated with wet underfloor systems. One reason is that this provides an efficient and uniform means of heating large spaces whilst keeping lower walls, ceiling and upper wall space free from the clutter that can occur with other radiant systems or warm air heating. Such clutter can be distracting to players and it is generally considered best to avoid it. However, as it is likely to be only one of a number of issues that the designer needs to address, it is important to recognise that in any particular situation there may be other advantages and also possible limitations of specifying an underfloor heating system.



**Donald Dewar Sports Hall, Drumchapel, heated by underfloor heating.**

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<sup>1</sup> For general information on sports floors please refer to Floors for Indoor Sports, Design Guidance Note, Sport England 2007.

## 02 Background

### Thermal comfort

Human thermal comfort in any environment is sensed as a combination of the exchange of radiant heat between the body and all surrounding surfaces; and the air temperature, modified by speed of air movement. For example, the body can experience discomfort if the air speed gives rise to draughts, or in circumstances of overheating this air movement may be welcome. Also, the body can gain heat from a warm radiant wall or floor, and simultaneously lose radiant heat to a cold window. Systems should be designed to ensure that there is overall comfort – typically defined by a comfort temperature – and no local discomfort at any part of the human body (be it hot or cold). For sporting activities in a multi-purpose hall the design temperature may vary from 12-18°C depending on the type of activity.<sup>2</sup> It is worth noting that for comfort, the optimum floor temperature range should be 21-28°C.<sup>3</sup>



**John Wright Sports Centre, heated by warm air heaters.**

### Occupancy patterns and thermal Mass

The choice of heating system may depend on the thermal response of the building and the occupancy patterns of a space. If a building is intermittently occupied then it may not be appropriate to keep it at a temperature above that necessary for the security of the building fabric and systems for most of the time. However, this then requires it to be brought up to temperature quickly when needed. So it will need a quick-response, high-power heating system.

Warm air heating and high temperature radiant systems have a much faster response time than underfloor heating and are generally suited to spaces with a fluctuating heat demand. A thermally lightweight building would have shorter preheat periods and use less heating energy in these circumstances. If designing a sports hall that will provide a significant proportion of natural daylight, it is important to factor in any resulting solar gain.

If a building is continually occupied or the occupancy pattern is unknown or unpredictable, as is the case with many sports halls, then it may benefit from being kept at a constant temperature during the possible hours of use. In this case a low power/low temperature heating system may be most suitable. Benefits include the compatibility with low temperature/low power generation and emitters. A high thermal mass (heavyweight) building that heats up slowly and gives out heat slowly may be most suitable, provided that the time lag of building and heating system are well understood.

<sup>2</sup> CIBSE Guide B, Heating, ventilating, air conditioning and refrigeration 2005.

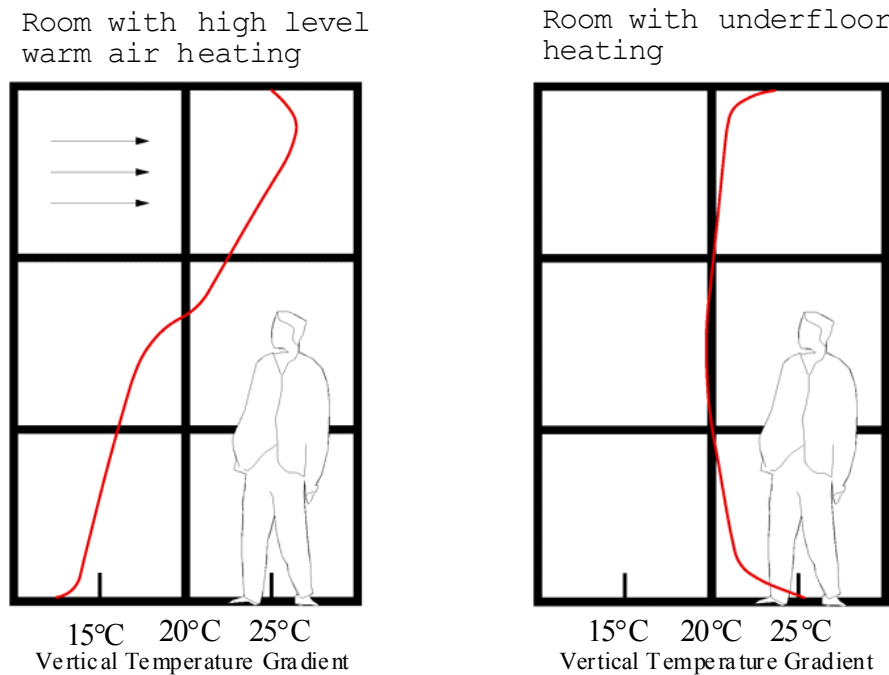
<sup>3</sup> Note; further temperature restrictions apply to underfloor heating. CIBSE Guide B, Heating, ventilating, air conditioning and refrigeration 2005.

## Stratification

Stratification of air temperature occurs, to a greater or lesser degree, with all heating systems. Figure 1 shows the vertical air temperature gradients for high-level warm air heating and underfloor heating. With a warm air system, the air temperature increases dramatically with height, with the hottest areas occurring in unoccupied areas near the ceiling. Warm air outside the occupied zone does not contribute to comfort and represents a waste of energy. Systems like dynamic insulation, pioneered by **sportscotland**, have addressed this situation by encouraging downward ventilation air at high level.<sup>4</sup>

The air temperatures experienced for underfloor heating remain more consistent with height, rising slightly near the floor and ceiling. However, with underfloor heating the radiant temperature component that also contributes to comfort is greatest in the occupied areas. This is due to the vicinity of the large radiant floor surface relative to other colder surfaces. Hence the suitability of underfloor heating for many high buildings, especially where there are additional advantages, such as freeing up roof space to optimise daylighting and encourage clarity.

**Figure 1: Air temperature gradients in rooms (3 m high)**



<sup>4</sup> Halliday S.P (2000) Dynamic Insulation Past Present & Future, Gaia Research.



**Craig MacLean Leisure Centre in Grantown, heated by underfloor heating.**



# 03 Characteristics of underfloor heating

- The floor surface radiates heat to lower temperature objects and surfaces;
- The large surface area of the floor means that a low to moderate floor temperature; can provide enough radiant heat to maintain a comfortable temperature for the occupants. These low temperatures are compatible with high efficiency condensing boilers and a range of low temperature heat sources;
- The radiant heat contribution means that the air temperature can be lower to achieve the equivalent comfort level of a warm air system;
- Lower air temperatures produce less stratification than in a warm air convection system, and maintain the highest comfort temperatures in the occupied zone of a space;
- Low air movement, resulting in reduced sensation of draught;
- Underfloor heating does not radically disrupt the internal airflow in the building, unlike forced air systems. This benefits sports such as badminton where this would be an issue, as well as minimising the airborne circulation of dust particles;
- It is best suited to well insulated buildings where it can provide the total heat load and the expense of paying for a secondary 'top-up' system can be avoided;
- It can be inflexible to future changes such as a change of use that requires the installation of sports posts, although these can generally be readily incorporated if designed at the outset;
- Requires wet trades and increased dry out time during construction;
- Underfloor heating is not compatible with all floor types.

## Water-based (wet) systems

In a water-based underfloor heating system, water (max temp 50°C)<sup>5</sup> is circulated through a network of pipes that lie either in screed or concrete as part of a preparatory floor system. A wet system using a pipe grid cast into a concrete slab with insulation below the slab is a low temperature/high thermal mass heat store with slow response to heating and cooling. It is designed to emit off low-level background heat. Pipes can also be attached above the subfloor using thermal diffusion plates laid on insulation.

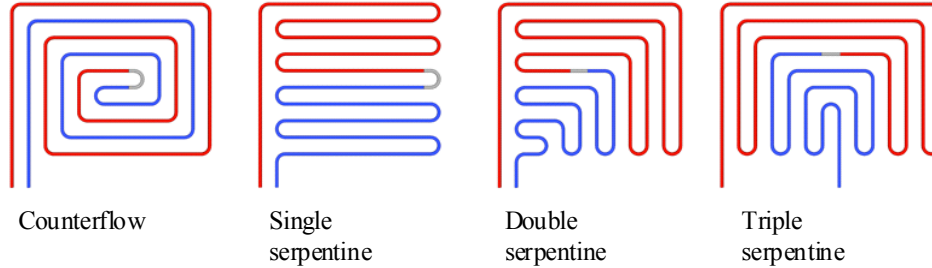
The design of the pipe layout will depend on heat loss and floor type. The layout needs to be designed to provide an even spread of heat and therefore needs to allow for increased heat near cooler surfaces. Typically, the distance between the pipes will be 200mm – 300mm. See figure 2 for some basic pipe layouts.

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<sup>5</sup> Systems are normally designed to operate at 40-50 °C with a 5-10°C temperature drop over the system. See Figure 2.



**Figure 2: Simple Laying Patterns for Underfloor Heating Pipes**



### **Electrical systems**

Electric underfloor heating systems operate on the same principles as the water-based systems except that electrical resistance cables deliver the heat. However, there are both environmental and financial penalties and they should only be considered in situations where electricity is the only available heat source or preferably where there is an abundance of electricity produced from a non-grid connected renewable source. Although no conclusive studies have been completed, there is an element of concern surrounding increased exposure to electro magnetic frequencies (EMFs). For those who share these concerns, avoidance of electric heating is one of the recommendations for reducing exposure. <sup>6</sup>

### **Floor selection**

Selecting the correct sports surface for underfloor heating is important both in terms of physical sporting attributes and the overall heating performance of the building.

The key is to identify the principal requirements of the sports hall. If the facility is to be used for competitions, then selecting the optimum floor surface is of paramount concern and the relevant governing body should be contacted for more information. If a general sports surface or multi-use sports surface is desired, then careful consideration must be given to the non-sporting activities as these may restrict the type of floor surface or the suitability of underfloor heating. It is important to recognise that the integration of underfloor heating into a sports floor may require a compromise between sporting performance and suitability for underfloor heating.

### **Floor finishes**

Many of the issues surrounding the use of underfloor heating in sports halls are associated with the compatibility of certain floor finishes. When considering any floor surface for a sports hall it is necessary to identify which sports will be played on the surface and consequently, the physical attributes required of the surface. For example, rollerblading requires a surface that has a high wear resistance and low rolling resistance.

In some guise most forms of sports hall surfaces (timber, polyurethane, PVC, rubber and textiles) are compatible with underfloor heating. However, many sports surfaces contain a significant portion of insulative materials – it is essential to ensure that the thermal resistance of the floor is lower than 0.15 m<sup>2</sup>K/W, as specified in BS EN 1264-4.

<sup>6</sup> Halliday S.P (2008) Sustainable Construction Butterworth-Heinmann.

This limits the suitability of many indoor sports surfaces. It should also be noted that the efficiency of an underfloor heating system is reduced if there is an insulating “air layer” between the heating elements and the floor surface.

It is apparent that many sports surface manufacturers have not fully evaluated the implication of underfloor heating on the performance or durability of their floor surfaces. At an early stage in the design process, seek guidance from the manufacturer/specialist on which surfaces are suitable for underfloor heating and how it affects performance (such as impact resistance) and durability. Establish operational parameters for the underfloor heating system and ensure that this forms part of the warranty.

### **Floor types**

There are four main classifications of floor types used in sports halls:

- area elastic;
- combined elastic;
- mixed elastic;
- point elastic.<sup>7</sup>

These relate to the elastic properties of the floor type specifically vertical deformation and force reduction, and are important factors in the reduction of injuries.

Timber provides area elastic flooring and comes in a range of forms including hardwood, veneer on softwood or composite. Underfloor heating can be provided in a clipped or glued system laid directly onto the subfloor (see figure 3); as a batten system (figure 4); or as a floating floor (figure 5). Underfloor heating can be located in the concrete/screed subfloor (as in figure 3) or above the subfloor (as in figure 4 & 5). The latter results in the loss of the thermal mass of the subfloor and requires a diffusion plate (attached to the floor and laid on an insulating floor panel) to achieve even distribution of heat – a number of manufacturers can provide details. A faster response time will be experienced when compared to systems set in the subfloor but maximum thermal output will be reduced.

It is also possible in a batten system to lay the pipe network between the battens and encase it in a semi-dry screed (see Figure 6). This loses the thermal contact and results in the loss of the floor slab as a heat store creating a fast response/fast cooling heating system that reduces efficiency.

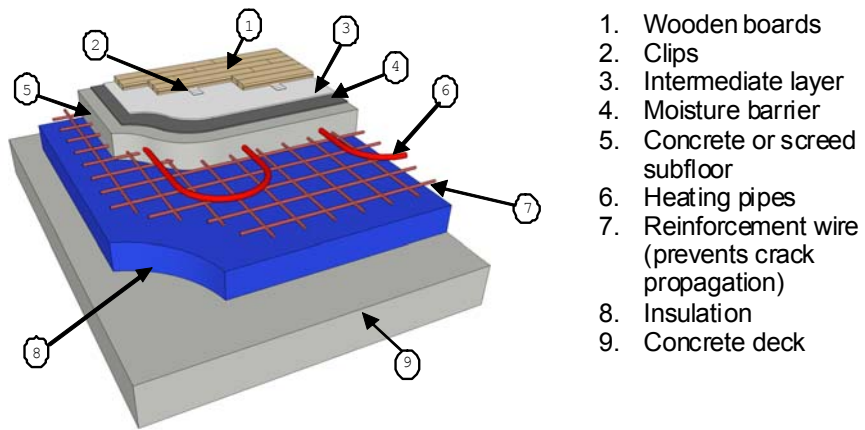
Engineered boards are generally considered to be more thermally stable: they do not react to heat or humidity to the same degree as hardwoods. To avoid impact injuries and those associated with the lack of a sprung floor, the most common solution for the designer/specifier of the floor finish is to provide a clipped hardwood floor.

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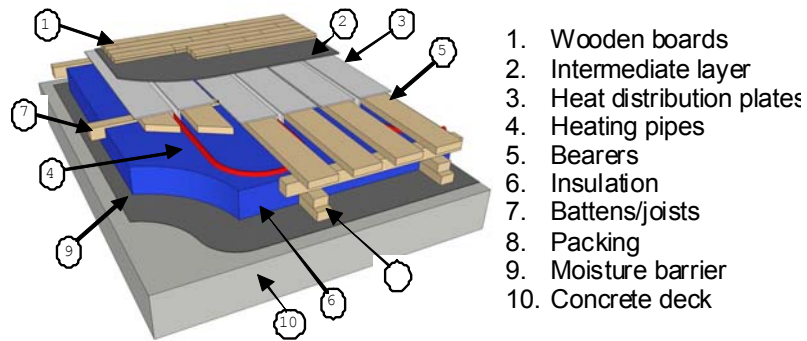
<sup>7</sup> BS EN 14904 Surfaces for sports areas. Indoor surfaces for multi-sports use 2006.

When used in conjunction with underfloor heating polyurethane, PVC, rubber and textile finishes are applied directly to the subfloor or occasionally onto plywood decking fixed to wooden battens. However, careful attention needs to be paid to the overall thermal conductivity of the surface and sublayers.

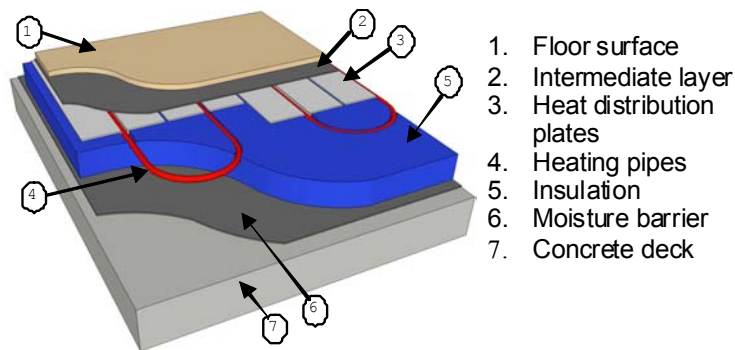
**Figure 3: Clipped hardwood floor with underfloor heating**



**Figure 4: Batten hardwood floor with underfloor heating**



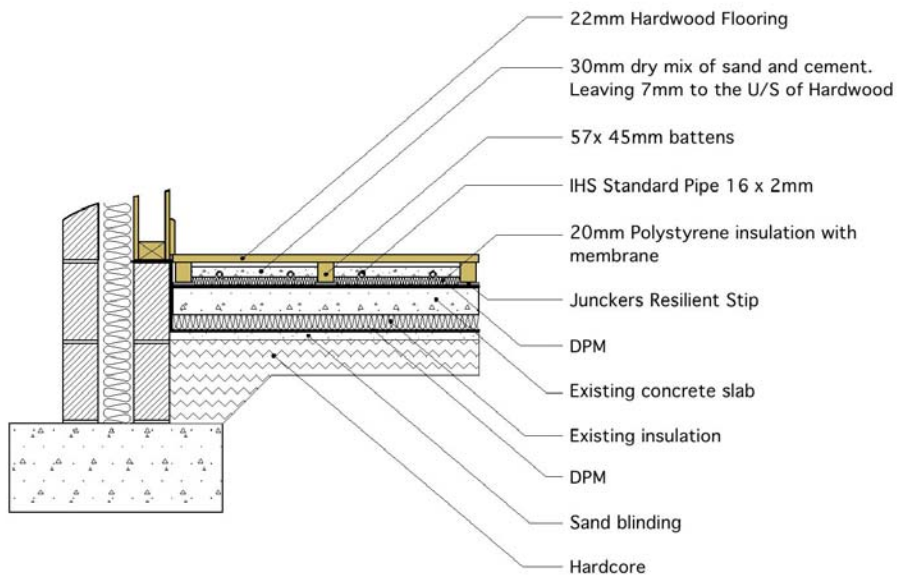
**Figure 5: Floating floor with underfloor heating**



For resilient (vinyl and rubber) floor coverings it is recognised that the temperature should not exceed 27°C at the underside of the floor cover. The surface temperature of timber floors should be generally restricted to 27°C to ensure that there is not significant moisture loss and resultant dimensional change<sup>8</sup>. Some manufacturers recommend floor thermostats although it appears that in general designers opt to control using wall thermostats or boiler-flow temperatures.

### Case study examples

**Figure 6: Craig MacLean Leisure Centre, Grantown**

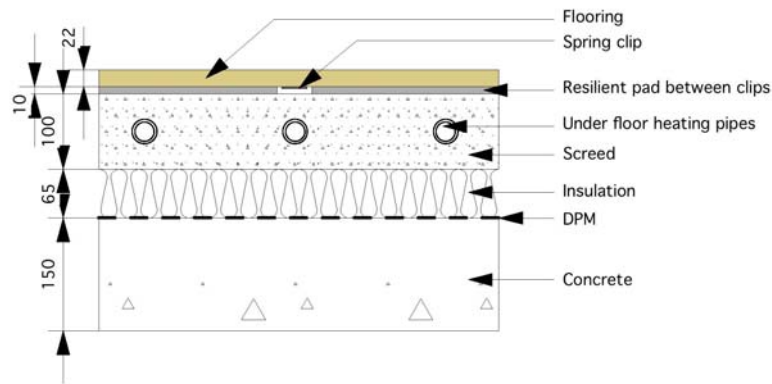


As can be seen from the diagram above, a batten system was installed at the Craig MacLean Centre. In this example the pipes sit on insulation in between the battens and

<sup>8</sup> Wood floor with underfloor heating, Timber Floor Technology 2005.

are set in screed. There is a 7mm air gap between the screed and the underside of the hardwood flooring which is necessary to maintain the sporting characteristics of the floor. It will, however, have an impact on heat transfer from the underfloor heating system.

**Figure 7: McLaren Leisure Centre, Callander**



The diagram above shows a cross-section of the flooring system at the McLaren Leisure Centre, where a clipped system has been installed. The underfloor heating pipes are located in screed, which is separated from the concrete hardcore by a layer of insulation. The hardwood boards rest on a resilient pad that provides bounce to the floor but also impacts thermal transfer from the screed.



**McLaren Leisure Centre, heated by underfloor heating.**

# 04 Lifecycle installation and management

## Thermal design

- The laying pattern of the pipe will depend on the heating requirements of the room (including consideration of points of potential heat loss) and the floor surface selected;
- In sports halls, the maximum power output of the floor is generally regarded to be  $100 \text{ W/m}^2$  for pipes embedded in the screed/concrete subfloor and  $70 \text{ W/m}^2$  for floating/suspended floors;
- Inlet temperatures will depend on the floor type, pipe spacing, water flow rate, required heat output and floor finish – temperatures typically range from  $40\text{-}50^\circ\text{C}$ . Generally temperature drops of around  $5\text{-}10^\circ\text{C}$  are experienced across the system;<sup>9</sup>
- Close coordination with both the flooring and underfloor heating contractor will direct attention to both the heating and sporting needs;
- The underfloor heating manufacturer should deem the thermal resistance of the floor surface adequate;
- To ensure an optimum operating efficiency, a high element of control needs to be designed into the heating system. Systems should be zoned to accommodate varying occupation patterns and heating regimes in different parts of the building;
- Appropriate time should be put aside for the installation of the underfloor heating system and a full understanding of the subfloor requirements should be obtained as early as possible.

## Construction

### New buildings

In the case of new buildings the decision to opt for underfloor heating is one that needs to be made in full consultation with future users. If they are insistent on a fully sprung floor with significant resilience then the requirements of the underfloor heating will slightly compromise this. The reason for this is that underfloor heating needs to have close contact with the underside of the floor and there can be no air gaps, as these will act as an insulant.

If a decision is made to go for underfloor heating then it is virtually certain that a solid – and probably concrete – sub-floor will be installed. There are only a small range of products available for this situation in order to achieve a degree of bounce in the floor while retaining the integrity of the heat conduction through the floor finish (see above underfloor types). It is essential that the drying time of concrete be considered – this must be taken into account when the contractor is programming subsequent work elements. It is advisable that the floor is laid as early as possible and given the opportunity to dry out before the floor finish is installed. This is likely to be months not

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<sup>9</sup> see Figure 2.

days (consult BS 8204-1 for further information)<sup>10</sup>. Once the system has been installed, any residual moisture in the concrete will seek to escape through the floor and will cause, firstly, expansion; and then, as the drying concludes, contraction. In the first cycle this can cause the floor to bow up, and then in the second cycle to open up cracks between floorboards or floor elements. This process is accelerated once the underfloor heating has been switched on and places the building structure under a greater degree of both structural and thermal stress than would happen with air drying over time.

It is worth noting that in some situations it may be possible to lay a surface-applied damp proof membrane (DPM) in order to regulate moisture flow from concrete or screed, therefore allowing floors to be laid quicker. Consult BS8203 and DPM manufacturers for more information<sup>11</sup>.

### **Existing buildings**

With existing buildings the installation of a new floor for sports purposes will depend on the nature of the existing floor and the extent of the refurbishment. The primary consideration will be the appropriateness of the floor to the proposed range of activities. A secondary consideration will be the way in which this can also deal with the space heating and whether underfloor heating is an option. In an existing sprung, lightweight construction the opportunities for underfloor heating are very limited unless the floor is removed and completely rebuilt. There may be significant structural implications with this approach, depending on the existing structural system and whether it can tolerate the additional weight and thermal stresses associated with underfloor heating.

### **Floor Fixings**

Consideration needs to be given to the location of floor sockets and fixing points in relation to the pipes. Some fixing points will require localised raising of the concrete to give the appropriate anchor properties.

Furthermore, consideration must be given to floor markings well in advance of deciding on fixing points and this can often take time as part of the briefing process with the client.

### **Commissioning**

The contractor generally installs the heating circuit with handover taking place after commissioning the system, which includes the completion of pressure test criteria where each manifold is pressure tested.

The type of floor surface used will dictate the timescale for warming up the underfloor heating system e.g. cement screeds have to be left for at least 21 days before the warming up can start. It is important to ensure that the subfloor is completely dry before installing the surface layers – an equilibrium relative humidity test should be carried out

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<sup>10</sup> BS 8204 – 1 (2003) Screeds, bases and in situ floorings. Concrete bases and cement sand levelling screeds to receive flooring Code of Practice.

<sup>11</sup> BS 8203 (2001) Code of practice for installation of resilient floor coverings.



in accordance with BS 8201:1987<sup>12</sup>. If using timber flooring, it is also important to ensure that the moisture content of the timber is correct for installation.

When the floor system is complete, the floor temperature should be increased gradually over a long period (this will range from a few days to several weeks depending on the floor type). Details of this process should be agreed with the flooring contractor, underfloor heating contractor and the screed contractor.

### **Maintenance and operational issues**

If operated correctly, an underfloor heating system will require a minimum amount of maintenance.

It is important that the floor temperature is maintained within the operational temperature range. If temperature rises above recommended levels this may cause a range of problems to the floor surface such as over-expansion of materials, degradation of physical properties, discoloration, premature ageing and delamination of finishes.

If the underfloor system is decommissioned for maintenance or repair, supplementary heating must be provided to ensure that the floor surface temperature does not drop below recommended levels.

Care needs to be taken to ensure that there is no accidental overheating of the floor space due to the placement of gym mats or solid-based furniture.

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<sup>12</sup> Appendix A, BS 8201:1987 Code of practice for flooring of timber, timber products and wood based panel products, British Standard.

## **05 Sound proofing**

It is advisable to consider any necessary sound proofing that may need to be incorporated into the design. This will depend on the intended function of the sports hall as well as what materials have been selected for the floor covering. Often, a poor acoustic regime can result from the incorrect installation of floor surfaces.

In clip systems it is necessary before laying the floor to ensure that it is level and there is an expansion gap between the floor and the wall.

In batten systems, there must be a gap between pipes and the battens avoiding any acoustic bridging. Battens can also be raised using soft materials as wedges to absorb some of the vibrations.

# 06 Costs

## Typical costs of sports hall heating systems

There is a lack of guidance on capital and running costs of real buildings, but this is typical of the construction industry and not specific to sports buildings. Running costs are dependent on the operating temperature and the relationship between control, usage and system response.

A review of the comparative capital and running costs of different heating systems indicates that, in broad terms, the capital cost of a sports hall heating system in ascending order is shown below.

Heating system	Running costs	Installation cost	Description
<b>Electric radiant (infra-red)</b>	High	Low	Will heat the participant and fabric but not the air in a building. Suitable for large tall spaces. May suffer from cold spots if inappropriate coverage pattern is established.
<b>Gas radiant</b>	Moderate – Low (if well controlled)	Low	Will heat the participant and fabric but not the air in a building. Suitable for large tall spaces. May suffer from cold spots if inappropriate coverage pattern is established. Effectiveness depends on required temperature.
<b>Electric panel</b>	High	Low	Expensive to operate and therefore undesirable as main source of heat.
<b>Electric underfloor</b>	High	Moderate	Expensive to operate and therefore undesirable as main source of heat. Cheaper alternatives available for supplementary heating applications.
<b>Gas wet radiant panel</b>	Moderate	Moderate	May suffer from cold spots if inappropriate coverage pattern is established. Effectiveness depends on required temperature.
<b>Gas radiator</b>	Moderate	Moderate	Typical radiator systems are unlikely to provide adequate coverage and predominant mode of operation is convective leading to high stratification and inefficiency.
<b>Gas underfloor</b>	Moderate – Low	Moderate	Good coverage and low stratification, running costs depend on relationship between control, usage and system response.
<b>Solar panel (wet)</b>	Minimal	High	Still expensive to install per kWh output, but in theory can contribute a 'free' portion of total heat.
<b>Geothermal</b>	Moderate	High	Expensive to install, but in theory picking up a contribution of the heat, running costs depends on location and system design.
<b>Photovoltaic</b>	Minimal	High	Incredibly expensive to install, but in theory free electricity. To date have limited life expectancy and unless linked to either the National Grid or a battery storage system are unlikely to provide power at the time most needed.

Generally, oil and LPG will only be considered in rural locations where gas is not available. An oil boiler will cost slightly more than a gas boiler, an LPG boiler slightly more than an oil boiler and a biomass boiler more than either oil or LPG. Biomass is a relatively recent development and has tended to be used in rural locations as an alternative to oil or LPG. The fuel type (e.g. wood chip versus wood pellet), storage capacity, size and type of biomass boiler will affect its cost. Problems with the reliability of the fuel supply chain have somewhat limited the uptake of biomass to date though these problems are now being addressed.

Geothermal heat sources have tended to be used more in the heating of domestic properties but could be compatible with underfloor heating installations in sports halls provided a large enough collector network (e.g. a car park) could be established.

The variations in energy consumption between different facilities and systems will be largely attributable to management, operating regimes, control and usage. Good management and control is vital to efficient operation. This along with choice of fuel and tariff will impact on the running costs.

The energy market is currently in a state of flux with rising prices in some areas and subsidy and taxation affecting others. Full consideration needs to be given to current and projected costs. Research will be necessary to establish localised fuel prices. For woodchip and wood pellet suppliers consult the Log Pile database.<sup>13</sup>



**Jock Stein Centre in Hamilton, heated by gas radiant pipes.**

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<sup>13</sup> <http://www.nef.org.uk/logpile/index.htm>.

## 07 Conclusion

The least intrusive heating installation in common use in terms of the performance of a sports hall is undoubtedly underfloor be it either electric dry (note environmental and financial provisos explained earlier) or any form of wet.

Any alternative form of heating introduces intrusion into the ceiling or wall space which will need to be overcome e.g. by detailing radiators to flush with wall surfaces. It will either preclude the use of natural day light due to the size/position of emitters, e.g. radiant ceiling panels, or will create visual distractions that may effect the sporting performance of users. The simplicity introduced by the use of underfloor heating is often a deciding factor in the choice of an underfloor system. There is scope to investigate the use of wall embedded radiant heating. Wall embedded radiant heating, like underfloor heating, provides low-level radiant heat and would avoid the complication of heating through a performance sports floor. There are very few examples in the UK of wall-embedded radiant heating systems, in sports halls or in other applications. Further research is required to establish information relating to the costs and efficiencies of such systems.

Underfloor heating systems result in lower air temperatures for equivalent comfort; this reduces both energy wastage resulting from stratification and disruption to internal airflow. Due to the low temperatures associated with underfloor heating they are compatible with energy efficient generation options such as condensing boilers, ground source heat pumps and even solar thermal panels if properly applied and controlled. Whilst effective at providing a constant low-level heat, underfloor heating systems have a slower response time than warm air heating or other radiant systems. It is important to understand the building and the system response and lag time in relation to use patterns.

However, unlike other heating systems, underfloor heating restricts the floor type and surface that are suitable for selection. The constraints on floor construction can also conflict with some sporting needs, reducing some of the efficiency benefits of underfloor heating. If incorrectly operated, permanent damage to the floor surface may occur. Many companies are wary of recommending underfloor heating for use with their floor surfaces.

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Weitzer Parkett <http://www.weitzer-parkett.com/site/index.php?id=5&L=2>  
John Guest, Underfloor Heating Basics, <http://www.johnguest.com/linkpages/UFHinstADV.htm>  
Contract Flooring Association <http://www.cfa.org.uk/index.php>  
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# sportscotland

Caledonia House  
South Gyle  
Edinburgh  
EH12 9DQ  
Tel: 0131 317 7200  
Fax: 0131 317 7202

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