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HVAC THERMAL STORAGE:
Practical application and performance issues

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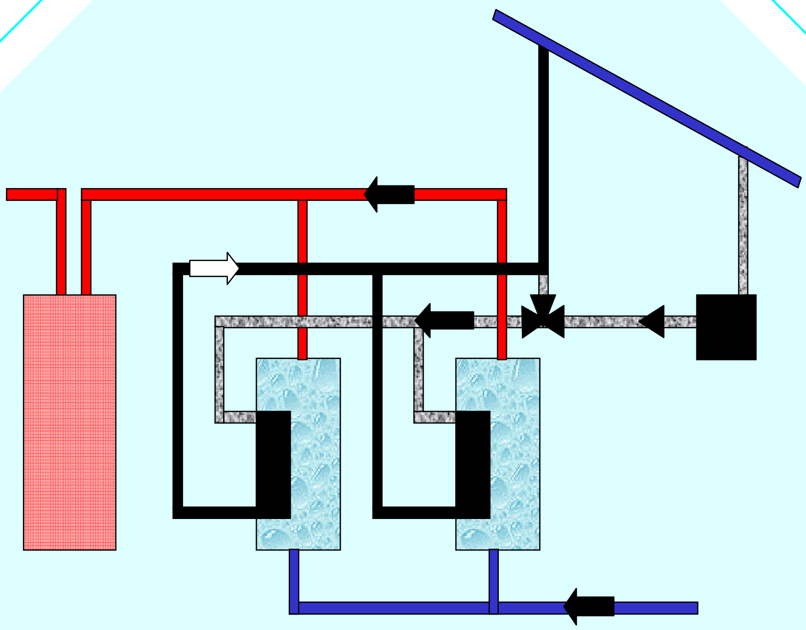

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EXECUTIVE SUMMARY

Thermal storage is used in many forms in the UK, storing energy collected from the sun, ground, air and water to partially or fully meet future heating or cooling loads.

The storage of heating and cooling energy at times when they are readily available allows a more effective matching of demand which can be achieved at a lower overall energy or financial cost than heating and cooling provision ‘on demand’. Energy savings vary with system type but are particularly dependent on design and operating parameters. Each system also offers different criteria in terms of capital, operating and maintenance costs as well as available hours of operation, control and operational requirements. Some thermal storage systems have limitations regarding thermal comfort while others have practically none.

Examples of the following thermal storage systems have been particularly considered in this study:

- ice storage
- warm/cool water store
- fabric energy storage
- embedded pipework slab heating and cooling
- active solar storage
- ground source.

Monitoring of these systems has shown that with forethought and attention to monitoring of system performance and operational procedures, economic savings can be readily achieved. However, proper planning is required to achieve this. The following points were particularly noted:

Ice Storage

Monitoring of two sites with ice storage identified several operational and control problems causing detrimental effects to system performance. For example, a fundamental problem encountered, albeit for short periods, was failure to coincide charging of an ice store with the off-peak electricity tariff. Other problems included operation of circulation pumps when not required as well as more conventional issues such as incorrect temperature setpoints. The site that utilised regular monitoring of the ice storage system via a BMS service provider, together with continuing input form the building services consultant, achieved the best performance.

Fabric energy storage

Although fabric storage technologies, such as slab cooling passing air over the slab surface and via hollow slabs, are less controllable than ice storage systems, they can be very effective at limiting internal temperatures in areas of average internal heat gain. Monitoring showed that peak temperatures can be reduced and, in combination with other passive measures such as solar shading, can provide comfortable conditions throughout the summer months. Capital costs are substantially lower than for the more complex systems and running costs are minimal.

Slab heating and cooling using embedded pipework

Underfloor heating is becoming much more widespread throughout the UK and is competing favourably in capital cost terms with other more traditional systems. The running costs are generally low and, when combined with very high efficiency heating plant, maybe reduced further.

The embedded pipework system monitored satisfactorily provided comfortable conditions in both heating and cooling modes. The controls operated well in switching between the two modes and the system proved to be robust in its operation.

Active solar storage

Monitoring demonstrated an average monthly contribution to the building's hot water requirements of between 6% and 12%. The maximum contribution recorded between 08:00 and 20:00 hours was approximately 30%.

The need to ensure the system is adequately flushed during installation and the consequent need to check filters are clean to prevent blocked flows was highlighted at the start of monitoring. Weekly checks of system temperatures should be undertaken to verify correct operation. These systems are more dependent on the vagaries of the UK climate than the other systems monitored.

Ground source

Systems may be closed loop or open loop, and both types typically take water from a borehole, river or well. Although not directly monitored as part of this project, consideration of the application of these systems showed that expert advice is required to assess the characteristics of ground sources as this can vary widely. System sizing and heat pump selection needs to match these characteristics as well the energy requirements of the building.

This publication is primarily for building services designers, to provide them with independent information concerning practical application and operating issues for thermal storage systems and to assist them with achievement of optimum performance of thermal storage systems.

The publication is also of benefit to those responsible for operating thermal storage systems as it highlights the principal problems encountered as part of the project in using thermal storage and recommends solutions to these.

It is suggested that both designers and system operators read the introduction followed by the relevant parts from each of the remaining sections.

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FIGURES

1 INTRODUCTION

Thermal storage, or energy storage, is defined as the charging and discharging of a store of finite thermal capacity in response to the flow of heat to and from the system where supply and demand for heat are out of phase. When the energy store operates as a source of heat the process is known as heat storage and when it acts as a sink it is known as cool storage.

Thermal storage may involve energy collection from the sun, ground, air or water. Air and water (or water mixtures) are typically used for transporting energy to and from the store. The storage/discharge cycle is dependent on the building load and the availability of energy to be stored for later use. Most systems use a daily cycle, although weekly and seasonal cycles are also used.

Active thermal storage systems (where additional mechanical systems are added as part of the thermal storage system) typically offer a high degree of control of the internal environment. Some active systems, such as ice thermal storage, store energy when it is available at a lower cost ready for use during higher tariff periods. These systems are generally considered to 'load shift' rather than to conserve energy. Other active systems, such as active solar heating, store energy when it is readily available for later use and are thus reducing demands on fossil fuels that form the primary energy supply (gas, electricity, oil) into a building.

Passive systems, such as passive night cooling or passive solar heating 'temper' the internal environment and are therefore less precise in the degree of comfort control provided. They are also used to attenuate loads where active systems are employed. Passive systems generally benefit from very low running costs. ‘Hybrid’ or ‘semi-passive’ systems, such as ground cooling loops, use minimum amounts of plant (eg heat pump) to increase or reduce the temperature of the ‘passive’ energy supply. In this way thermal comfort in the occupied space is improved. Examples of each system type are shown in Table 1.

The ASHRAE Applications Handbook[1] lists the benefits of thermal storage as follows:

- reduced equipment size
- capital cost savings
- energy cost savings
- energy savings
- improved system operation.

Equipment size can be reduced due to the use of the thermal store to meet part, or all of the design cooling load. Where plant is used to charge the thermal store (eg a chiller) it can operate continuously, if necessary, to either charge the thermal store or to help to meet the load directly during peak periods, in conjunction with the store. Thus, smaller plant can be installed to meet the same overall design load. The reduction in plant size may also allow a reduction in electric cable sizes producing further capital cost savings. Other cost savings can be realised by using electricity and other fuels during low tariff periods to drive the plant supplying the thermal store.

Table 1
Thermal storage system classification

Active systems
The primary function is to shift loads from high energy tariff periods to low tariff periods. • ice storage • chilled water storage
Semi-passive systems (semi-active systems)
These systems use metered energy supplies (normally electricity), either in transporting heat between the thermal store and the point of use, or where metered energy is used to enhance the heat output from the passive energy source. • systems incorporating heat pumps • systems where significant pumping energy is used to transport heating or cooling (eg dry coolers, ground cooling systems) • waste heat recovery • rock stores (fan energy used)
Passive systems
Where no metered energy supply is used in storage or transportation between energy source and point of use. • passive night cooling • passive solar heating • active solar heating (small amount of circulating pump energy) • passive roof pond systems

Energy savings vary according to the thermal storage technology used and the basis used for comparison, eg replacement of active cooling systems with passive cooling systems. Energy used for transporting heat or cooling to and from the thermal store represents only a small percentage of the total energy stored and thus the systems remain economically viable. A review of literature concerned with the main criteria affecting energy consumption and other environmental issues concerning thermal storage systems is provided in *Thermal storage: environmental benefits*[2].

Other benefits associated with thermal storage are the de-coupling of the thermal load profile from the operation of the equipment. This provides a degree of backup in the event of plant failure. This is more important for industrial process systems where interruption of heating or cooling may cause defects in the manufactured products, or where water cooled computers must be shut down under controlled conditions to minimise disruption.

ASHRAE Applications Handbook[1] notes other benefits including the use of ice storage with cold air distribution and the use of water based thermal storage systems as part of the fire protection (sprinkler) system, such as at the Lloyds building in London[3]. Other benefits include the ability to extend the available capacity of an existing chiller system by the use of cool water storage, often at less cost than provision of additional chillers[4]. This may be particularly important where electrical systems are at or near maximum capacity. Further, the requirements of storage equipment are generally less onerous than those of the conventional plant, for example, they do not require large power supplies and may be sited in enclosed spaces without the need for mechanical ventilation.

This publication describes the practical application and performance of the most common thermal storage systems in use. System case studies are also provided, together with feedback of the lessons learnt during the course of monitoring these systems. Having read this introduction it is suggested designers and system operators now read the text describing their system type in each of the remaining sections.