#4352

Melting away the costs

Low temperature air supply allows reduced plant and distribution equipment as well as lower running costs, particularly when coupled with ice storage. *David Long* outlines two City developments where this design philosophy has been adopted.

Thermal storage, low temperature air, and variable volume and temperature air conditioning are three innovative yet proven concepts incorporated into two recently completed City office block developments. Designed to allow the occupiers to have complete flexibility and control over their environment, the buildings are also energy efficient with low running costs.

The two developments in question are 1 Aldermanbury Square, a new nine storey, 9000 m^2 office building adjacent the Guildhall and 13-15 Moorgate a 4300 m^2 six storey development behind a retained gothic facade in the City of London.

The requirements for the two developments were similar, driven by market forces and planning constraints. The air conditioning was to include ceiling mounted all air systems with facility to cater for heat gains from tenant's office equipment up to a maximum of 60 W/m^2. Operation on a half floor by half floor basis was to be achieved while maintaining a maximum net to gross area ratio bearing in mind the high value of commercial office space in this part of London. Another major constraint on the system design was the stringent planning restrictions on building height, roof plantroom space and, at 13-15 Moorgate, the retaining of the external facade.

Above left: The gothic facade of 13-15 Moorgate. ***Above:*** The glass and stone exterior of 1 Aldermanbury Square sits harmoniously in its historic location.

Initial design considerations

Preliminary calculations by services consultant Brian Warwicker Partnership showed that the ceiling void requirements for distribution ductwork using a conventional vav system would have resulted in unacceptable office ceiling heights.

Hence the design teams investigated the possibility of lowering the primary supply air temperature from 12°C to 9°C – a technique which is is widely adopted in the USA where the technology has been developed in conjunction with thermal storage systems. Services plant, riser and ceiling void space requirements were reassessed resulting in 30% smaller air handling plant and ductwork distribution and 50% smaller pipes and circulating pumps.

The lower supply temperature has a number of knock-on effects. First, the space relative humidity is reduced from 50% for conventional vav systems to 40%. It has been found in the USA that with a lower rh in the space the dry bulb temperature can be allowed to rise – in this country 23°C 40% rh is acceptable while still maintaining equivalent comfort conditions.

Secondly, an additional 44% cooling capacity is achieved for the same quantity of air or, conversely, the air volume can be reduced by 44% to meet the same cooling demand. Clearly this substantially reduces air handling plant and ductwork sizes.

Thirdly, it is obvious that low temperature systems mean that standard design practice must be reviewed. To achieve 9°C at the terminal unit the central air handling plant must supply air at 6°C, allowing 3°C for duct and fan gains. Duct gains are higher than with conventional temperature systems due to the greater temperature differential between supply air and the ceiling void. These become even greater on part volume and must be carefully considered. To achieve 6°C off coil, refrigeration plant was selected to produce chilled water at 3°C.

Building energy analysis calculations indicated the air conditioning running costs would be a major contributor to the operating costs and possible cutbacks were investigated in both buildings.

Ice storage

At Aldermanbury Square the approach used to reduce the electrical costs for the cooling system was the provision of an ice storage system, operating the refrigeration machines during the night to utilise offpeak electricity tariffs and to store the cooling in

Above: The high quality reception area at Aldermanbury Square.

the form of ice which can be used the following day when electrical charges are much greater.

A number of ice storage systems were considered including ice tanks, ice on pipe systems and ice harvesters. The ice tank option was selected as it was a closed system, with a low pumping power requirement and no need for water treatment, filtration or a heat exchanger between the storage and air conditioning system. It provides even burn-off (ice melting) characteristics, has low standing losses as the tanks are frozen solid and there are no ice thickness controls or danger of freeze-up damage which can be a problem with ice on pipe systems. The modular, cylindrical plastic tanks are easily installed, use conventional packaged chillers, do not require refrigeration field work and require minimal maintenance.

As installed the storage system comprises two standard packaged semi-hermetic reciprocating chilling machines and eight ice tanks located at sub-basement level with space for two more for future expansion. During the night off-peak period, refrigeration machines chill an ethylene glycol/water solution down to -7°C, this solution then being circulated through heat exchange tubing housed within the water-containing ice tanks. Gradually through the night the water in the tanks is formed into ice around the tubes, until finally the tanks become frozen solid and are ready to release their stored cooling as required during the following day.

To store the total amount of cooling required during a day would require the chillers to produce the same amount of cooling at night that would be required during the day over a similar time period. This would result in large amounts of ice being stored with associated penalties in plantroom space requirements. Hence the chillers were selected to meet 60% of the peak cooling load, with the ice store similarly sized, thus ensuring a degree of standby capacity.

This approach not only reduces the electrical requirement for the refrigeration plant but also means that less space is required for the roof mounted heat rejection plant. The system also halves the quantity of refrigerant used within the refrigeration circuit, reducing the system's ozone depleting potential.

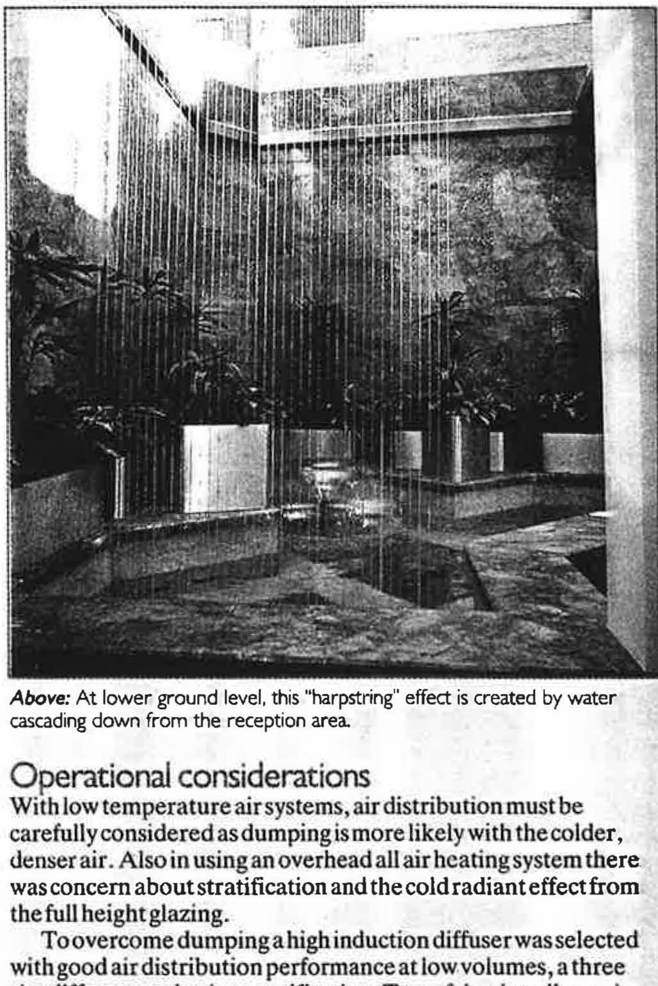
During the daytime, the chilled water is circulated through the ice tanks and chillers and distributed to the air handling plant cooling coils which supply the office air conditioning system. As the water passes through the heat exchanger tubing it melts the ice which surrounds it from the centre of the tank outwards. Therefore should any ice be left at the end of the day then during the next ice build period the water surrounding the tubing is available for refreezing, thus allowing the chillers to operate as efficiently as possible.

The installation of smaller chillers results in the refrigeration plant being able to run at full load for longer periods, hence increasing efficiency. The automatic control system allows for either the chillers to operate initially up to full capacity with the peak cooling loads being satisfied from the ice storage (chiller priority) or for the ice melt rate to be controlled during the day with the chillers being used to satisfy the peak conditions (ice priority).

As the cooling load provided by the ice is cheaper, greater economy of operation can be realised by using the ice store for cooling in preference to the chillers. However, the ice melt rate must be carefully controlled to ensure sufficient capacity throughout the day.

At 13-15 Moorgate, plantroom space at basement level was insufficient to accommodate a thermal storage system. A conventional refrigeration plant was therefore selected using two packaged semi-hermetic water-to-water heat pumps which also provide low grade heat in the winter.

A load is put on the heat pumps by a reclaim coil on the discharge air duct from the air handling unit. At times when there is insufficient heat recovery available the heat pumps are supplemented by a gas-fired high efficiency low water content modular boiler.



Above: At lower ground level, this "harpstring" effect is created by water cascading down from the reception area.

Operational considerations

With low temperature air systems, air distribution must be carefully considered as dumping is more likely with the colder, denser air. Also in using an overhead all air heating system there was concern about stratification and the cold radiant effect from the full height glazing.

To overcome dumping a high induction diffuser was selected with good air distribution performance at low volumes, a three slot diffuser combating stratification. Two of the slots direct air into the offices and one on to the glazing. On sensing cool air a temperature-controlled deflector blade within the diffuser covers the outer slot throwing cool air across the ceiling to maximise the coander effect. On sensing warm air the blade moves to cover the centre slot, directing warm air down the glazing as well as into the office area.

Client demands also required the air conditioning system to provide maximum letting flexibility with respect to partitioning and floor by floor letting. A cost study showed floor by floor air handling plant to each office to be impractical. Therefore a fan assisted variable volume and temperature (vvt) system was chosen with central air handling plant. This would provide facility for individual office temperature control, half floor system

Above: Calmac ice tanks were chosen for their inherently flexible nature.

operation and, using ddc controls, enable each office user to individually adjust their set point, set back temperature, set back and start up times.

Mixing boxes

Side-pocket fan-powered mixing boxes (fpmb) were selected, inducing secondary air from the ceiling void and mixing this with primary air as required. The side-pocket fan operates only where there is a ventilation or heating requirement in order to reduce running costs.

The air conditioning system is able to operate if a minimum of four fpmb, anywhere within the building, are requesting air from the central air handling plant. The damper in the fpmb regulates the volume of primary cooling air supplied to a number of vvt control dampers located at high level in the false ceiling. These in turn regulate the volume supplied to suit the local space cooling/heating requirements.

On a reduction in cooling load the vvt dampers reduce the volume of air to the space and at the same time the fpmb damper modulates to match the reduced cooling demand maintaining

Above: High induction diffusers are used to combat dumping.

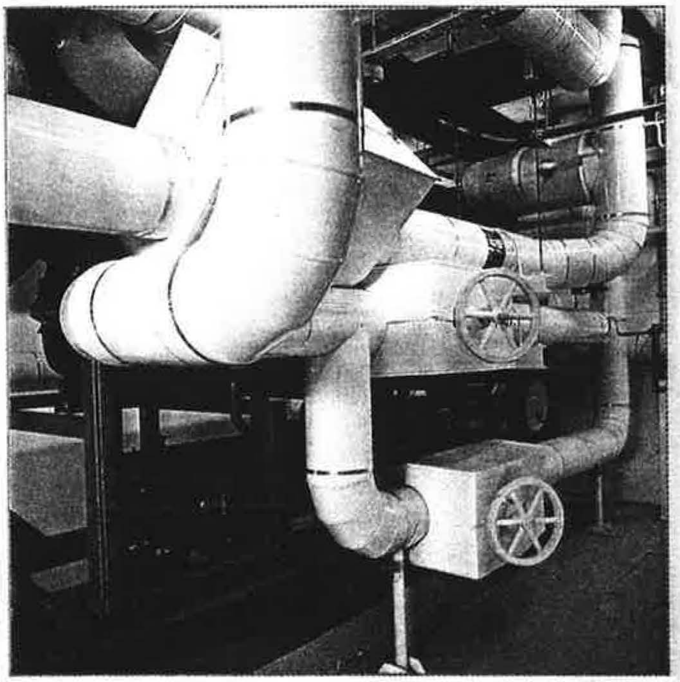
constant system pressure. When heating is required, the fpmb damper modulates to the minimum fresh air position and the fan starts utilising the heat available from the return air light fittings directly.

If additional heat is required the heating valve serving the fpmb coil opens and the vvt dampers regulate the volume required to suit the individual heating demands of each office.

When the heating and/or cooling loads are satisfied within the spaces, the primary air damper will be partially open and the fan operated to provide air at room temperature for ventilation purposes.

To achieve small office zone control requirements, each vvt damper can be individually controlled from a thermostat within the office or via a common thermostat to suit an open plan arrangement. Via a communication bus the system can be monitored, adjusted and commissioned from an IBM pc or compatible, either located in the building or from a remote pc via the modem link. By measuring airflow the maximum positions of the fpmb and vvt dampers can be adjusted via the computer thus reducing the system balancing time for the whole building to a few days.

On the Moorgate project, using the modem facility, the majority of the commissioning was carried out by the vvt controls



Above: Note the high standard of distribution insulation.

system designers, Parker Electronics, from their offices in the USA. This remote monitoring also allows quicker analysis and response to system failures as hardware and software faults can be determined through the control system.

Costs

The ice storage and low temperature air distribution systems offer similar capital costs but lower running costs when compared to conventional vav systems. First costs are less owing to reduced refrigeration plant, the smaller air handling plant and ductwork distribution and smaller pipes and circulating pumps owing to the higher chilled water differentials which can be used. However, the benefits are partially ruled out by the extra duct and cooling system distribution insulation costs.

Running costs are lower due to reduced fan and pump energy and, in the case of Aldermanbury, use of offpeak electricity for the thermal store, although these are partially negated by the slight increase in cooling energy as more dehumidification is performed than is required for comfort. It is estimated that in excess of 20% lower running costs can be achieved over a conventional vav system.

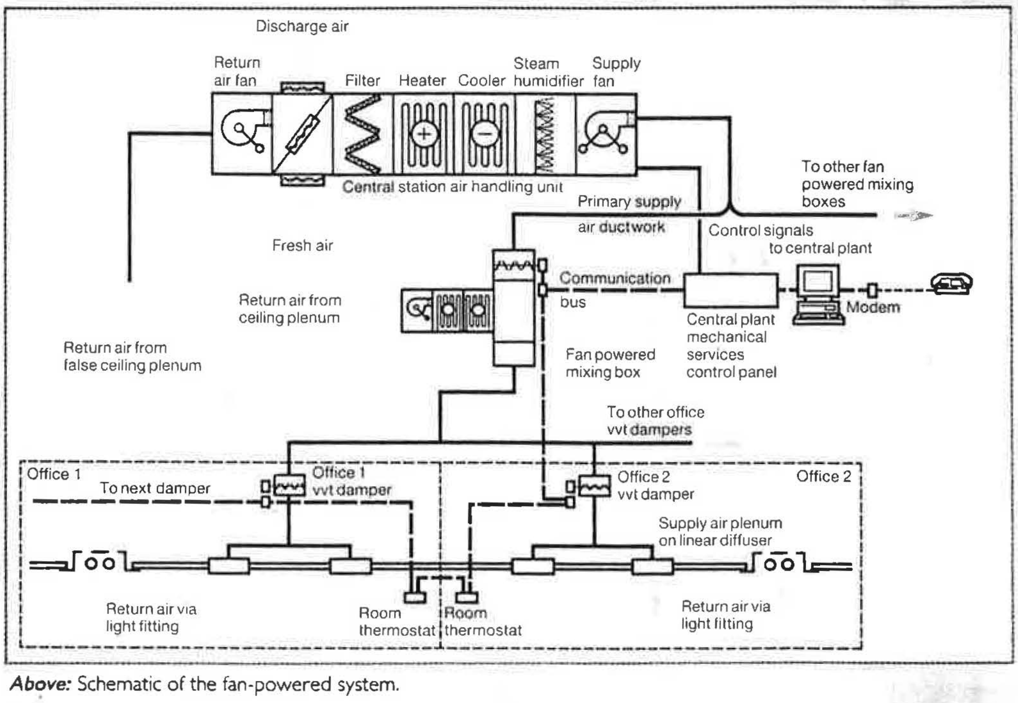
Also improved are the environmental conditions. The warmer, crisper atmosphere associated with the low temperature

Above: Fan-powered mixing box.

air system has been found to be popular with occupants and ASHRAE is currently reviewing its comfort zone guidelines in line with these findings. Air circulation is another area which is improved. The problem with conventional vav systems is that when there is a heating requirement a minimum quantity of air is delivered resulting in poor distribution which can lead to stuffiness. The vvt system overcomes this problem by operating the fan to maintain air circulation when there is a heating requirement. Couple this with the ability for occupants to control setpoints in their own workplace – an obvious attraction to letting agents in speculative office buildings – and office comfort is greatly improved.

The design philosophy on these two projects has been recognised by the LEB as an energy efficient form of air conditioning, with 13-15 Moorgate being awarded the 1989 Beta Energy Efficiency Award for category II buildings (over 1000 m²of floor space).

David Long BEng CEng MCIBSE is an associate director with building services consultants Brian Warwicker Partnership.



Above: Schematic of the fan-powered system.

13-15 Moorgate, Lodon EC2

Client
Great Portland Estates
Architect
The Fitzroy Robinson Partnership
M&E consultant
Brian Warwicker Partnership
Structural engineer
Pell Frischmann Consulting Engineers
Quantity surveyors
Cyril Sweett and Partners
Acoustic consultants
Hann Tucker Associates
M&E contractors
Kelvin Ross Engineering

Principal suppliers
Terminal units: Carrier Distribution
Air handling plant: P M Luft
Diffusers: Carrier Moduline Optimix
Refrigeration plant: Carrier Distribution
Boiler plant: Stelrad
VVT controls: Carrier/Parker
Central plant controls: Staefa
Ductwork: Femwork Ventilation
Insulation: Excel Insulations
Cooling towers: BAC

Engineering data
Total area gross: 4300 m²
Net useable area: 3030 m²
Offices: 2950 m²
Computer suite: 80 m²

External design conditions
Winter: -4°C/sat
Summer: 28°C/19°C wb
Internal design conditions
Offices
Winter: 21°C
Summer: 23°C (a/c)
Computer room
21°C constant at 50% rh
Loads
Equipment: 60 W/m²
Lighting: 20 W/m²
Air volumes
Primary: 18 m³/s
Heating
Boiler capacity: 400 kW
LPHW: 60°C

Cooling
Chillers: 2 × 250 kW
Water at 3°C
Computer room
Chillers: 2 × 17 kW
Water at 5·5°C
Electrical services
Supply: 415 V/3 phase
1000 kVA transformers
60 kVA ups

Cost
M&E: £1·3 million (£429/m²)

1 Aldermanbury Square, London EC2

Client
Hereditable Land Investment Company
Architect
Amos Broome Associates
M&E consultant
Brian Warwicker Partnership
Structural engineer
Amos Broome Associates
Quantity surveyors
Amos Broome Associates
Acoustic consultant
Hann Tucker Associates
M&E contractors
Benham Building Services

Principal suppliers
Terminal units: Carrier Distribution
Air handling plant: P M Luft
Diffusers (internal): Carrier Moduline Optimix
Refrigeration plant: Carrier Distribution
Boiler plant: Stokvis
VVT controls: Carrier/Parker
Central plant controls: Staefa
Ductwork: Adrian Sheet Metal Works
Insulation: Excel Insulations
Cooling towers: BAC
Calmac ice tanks: Ice Storage Systems

Engineering data
Total area gross: 9000 m²
Net useable area: 6100 m²

External design conditions
Winter: -4°C/sat
Summer: 28°C/19°C wb
Internal design conditions
Winter: 21°C
Summer: 23°C (a/c)
Loads
Equipment: 60W/m² max
Lighting: 20 W/m²
Air volumes
Primary: 39 m³/s
Heating
Boler capacity: 810 kW
LPHW: 80°C
Cooling
Chillers: 2 × 340 kW
Water at 2°C
Ice tanks: Eight - total capacity 9464 kWh
Electrical
Supply: 415 V/3 phase
1600 kVA transformers

Cost
M&E: £2·6 million (426/m²)