

# Displacement efficiency takes centre stage

The challenges of confined spaces, combined with the delivery of energy efficient, comfortable conditions were overcome by award winning innovation and design at a new performing arts centre in Sydney, as Sean McGowan discovers.



Located in the inner western Sydney suburb of Croydon, Presbyterian Ladies College Sydney sits on five hectares of historic grounds, having occupied the site since 1891.

In 2003, the school began a large infrastructure project to develop a new performing arts centre and theatre, as well as a large, twin-pool aquatic institute. Involved in these projects were architects Noel Bell Ridley Smith (NBRS) and Partners, along with mechanical consultant Paul Stevenson of Stevenson and Associates, who was selected for the project based on his expertise in swimming pools and 'unusual' air conditioning systems.

At the heart of the project was the college's desire to achieve energy efficiency while minimising plant size, both because of the site's space constraints and also to limit the environmental impact on the historical grounds.

"The main objectives in the Performing Arts Centre theatre were to maintain constant temperature under a range of uses and number of people in the theatre, while minimising noise intrusion and keeping operating costs low," says PLC's property and project manager, Keith Smith.

In response, Stevenson specified a full outside-air plant, with the theatre using an 'underneath supply system'.

"This is a thermal displacement system ensuring that occupants only receive full fresh air without drafts, giving rise to thoughts of 'how is this place air conditioned' and 'I don't feel the air conditioning but I am neither cool or hot'," explains Stevenson.

Supply air to the theatre was designed to be delivered via a ground-connected plenum void under the auditorium's seating, with low velocity air under each seat discharged at a relatively high temperature of 18°C. The ground connection aids in the stability of the air supply, with Sydney's ground temperature averaging 18°C.

## Innovative equipment choice

Traditionally auditoriums are air conditioned from an overhead fully mixing supply air system by conventional air handling equipment. The air is delivered at high velocity and at a temperature of around 13°C, resulting in an auditorium which is fully air conditioned from top to bottom.

"As only the lower two metres are occupied and therefore required to be air conditioned, this is seen as a significant waste," says Stevenson.

Through thermal displacement, however, the PLC auditorium is cooled from the bottom up. The air is introduced at low level and at a warmer temperature than is the norm, and a 'pond' of cool air is created at low level without drafts. In this zone the occupants are seated and as heat is given into the space, the warm air rises along with pollutants until it reaches a higher level with temperatures of 30°C not uncommon.

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The effect that the thermal displacement system arrangement has on equipment is one of control and of energy efficiency.

Stevenson says traditional chilled heated water coils are best suited for displacement systems because the control of the off-coil temperature and moisture content can be very accurate. Unfortunately, in the case of this project, there was insufficient space for chilled water and heating plants and budgets were tight.

"Due to the large quantities of fresh air required in an auditorium, energy consumption can be very high indeed but there are many heat recovery systems on the market, such as




Centre entrance

thermal wheels, plate heat exchangers and the like, which can deal with this issue."

Due to past involvement in equipment design and development, Stevenson called on Air Change to provide the air handling unit requirements for the project, utilising two specially-designed 82kW air cooled package units featuring DX cooling/heating with energy reclaim and humidity control.

The system used in this project is the same one that received the Excellence in HVAC Award at the AIRAH Awards in November 2007. According to Air Change's engineering manager, Herman Chiu, the packaged DX units supplied featured patented enthalpy air to air heat exchangers which reduce the outside air load by 75%.



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Inside the performing arts centre

“We also included a ‘free reheat’ option which diverts heat that would ordinarily be rejected to the atmosphere, to a two stage reheat coil, allowing for precise control of supply air temperature and humidity – a major design requirement for the air handling plant.”

Chiu says a significant amount of focus was placed on the reheat option in the unit, with controlling and staging the amount of reheat proving particularly difficult.

Due to limited available space, the design and installation within the plantroom proved challenging.

“We had to ensure the condensing temperatures were carefully monitored and controlled while maintaining the correct supply air temperature and humidity according to the indoor and outside air conditions.”

The outside air is cooled and dehumidified through the heat exchange process from 35°C 14.2g/kg moisture to 29.8°C 10.5g/kg moisture. The airflow of each unit is 3600 L/s combining to total design airflow for the building of 7200 L/s. Chiu says using these conditions, one can calculate that a total 121.33kW has been saved through using heat reclaim.

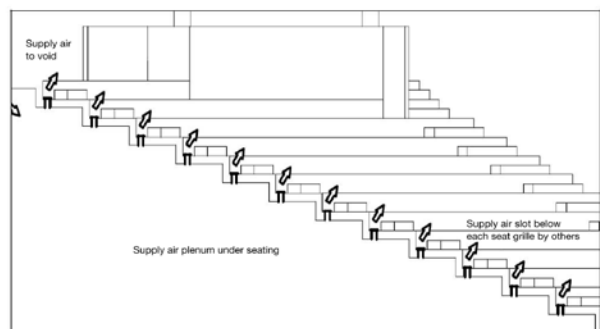
Control over the amount of reheat required is ultimately handled by electronic pulse solenoids and variable outside air over the condenser coil ensuring stability of the refrigeration system, while internal conditions are controlled via a supply air thermostat and humidistat linked to an external direct digital control (DDC) or building management system (BMS) which monitors room temperature and humidity, adjusting supply air temperature accordingly.

Further, a counterflow plate heat exchanger is utilised in the system, which uses cooler spill air in summer, or warmer spill air in winter, to precool or preheat the incoming outside air, with no cross contamination of air paths, and high transfer efficiencies.

“Another important aspect of the heat exchanger design is that it will operate at high velocities without the usual associated disadvantages of high pressure drops and reduced transfer rates,” explains Chiu, adding that it is sized to operate at 2.5 m/s on its face, with a nominal effectiveness of 0.75 at 150Pa.

Filling the void

To condition the Performing Arts Centre’s 538 seat theatre, air is introduced at low velocity into a large void located underneath the theatre’s tiered seating, with the supply air flowing through tubes pre-set into the concrete seating structure before discharging into the auditorium under the seats of occupants (see figure).



Elevation of seating arrangement

Elevation view of seating arrangement

<b>Client:</b>	Presbyterian Ladies College, Sydney
<b>Design engineer:</b>	Stevenson and Associates
<b>Installing contractor:</b>	Crest Air Conditioning
<b>AHU supplier:</b>	Air Change



Plantroom

Due to limited available space, the design and installation within the plantroom proved challenging for Stevenson, Air Change and installing contractor Crest Air Conditioning.

"Insufficient space was available for plant during (the design approval stage) and this caused the design to be more compact than desired, however the potential for major installation difficulties was avoided through careful design documentation and thorough installation documents from the contractor," says Stevenson.

### Maximising efficiency and comfort

Despite overcoming the challenges of space and installation, Stevenson cites the control strategy of the displacement system as one of the most important components of the project.



Under floor air supply holes

"An unusual control strategy is required for displacement systems, especially when using a DX system of heating/cooling and this was not initially recognised by both the controls supplier and Air Change, with the integration of the two being difficult. This was, however, corrected during commissioning."

Stevenson says the initial problem was that the plant was set up with conventional controls with wide ranging supply air temperatures. It was solved eventually by modification to the Air Change unit controls.

According to Smith, both the performing arts centre and aquatic institute are performing exceptionally well and are the subjects of compliments, both by those using the facilities on a daily basis, and those visiting for the first time, including interstate and overseas visitors interested in the design outcomes.

"Comfort levels prevail under all conditions. We are very happy with the outcomes, and would change nothing for the main spaces," says Smith. ■



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