Technical Research Paper 05

Heating and Cooling in the CH_2 Building

city of Melbourne

Study Outline

This study outline summaries key points raised in one of the 10 technical papers in the pre-occupancy study series that investigates the City of Melbourne's world leading Council House 2 (CH_2) office building. Each technical paper has been developed by independent authors from Australian universities as part of the CH_2 Commercial Green Building Technology Demonstration Project. To obtain copies of the full technical papers visit www.ch2.com.au

This project forms a major part of the CH_2 Study and Outreach Program – a coordinated effort to consolidate the various opportunities for study, research, documentation and promotion generated by the CH_2 office building. The primary aim of this program is to raise awareness of sustainable design and technology throughout the commercial property sector and related industries.

The target audience for these papers is professionals involved in the design, engineering, construction and delivery of office buildings, which explains the technical detail, length and complexity of the studies. Although these papers may be of interest to a wider audience, readers who possess a limited knowledge of the subjects covered should obtain further information to ensure they understand the context, relevance and limitations of what they are reading.

Significant funding for the technical papers was provided through an AusIndustry Innovation Access Program grant and supported by cash and in-kind contributions from the City of Melbourne, Sustainable Energy Authority Victoria, the Building Commission of Victoria, the Green Building Council of Australia and the CH_2 Project, Design and Consulting Team. The Innovation Access Program is an initiative of the Commonwealth Government's Backing Australia's Ability action plan.

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6 star rating

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This rating represents World Leadership

CH_2

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Study Outline – Heating and Cooling in the CH_2 Building

Study Three critically assesses whether the proposed heating and cooling system for the CH_2 building, under construction in Melbourne, will provide the desired thermal conditions for the building's occupants. The system being used in CH_2 is of interest to the expanding green building market because the system is expected to deliver thermally comfortable conditions, and will also result in financial savings, and reduced energy use and carbon dioxide emissions. Achieving comfortable working conditions is important, as they have been shown to increase worker productivity.

Indoor thermal comfort is affected by the interaction of temperature, humidity and air flow within a space. A widely accepted definition of thermal comfort is "that state of mind that expresses satisfaction with the thermal environment"[1]. Many factors – physical, psychological, seasonal, and those related to clothing – determine an individual's thermal comfort. The intention of a conditioning system is to maintain a thermally comfortable indoor environment by moderating the relation between temperature, humidity and air movement, within set limits that satisfy occupants' comfort expectations.

Climate controlled office spaces at CH_2 have been designed to ensure a resultant temperature in the range of 21-23ºC. Active and passive systems will combine synergistically and have positive outcomes for occupant satisfaction, energy efficiency, cost savings and the reduction of greenhouse gas emissions. The cooling system includes various components including chilled ceilings and beams, a phase change material (PCM) thermal store, shower towers, cooling towers, absorption and electric chillers, a night purging process to cool the thermal mass, and under-floor ventilation.

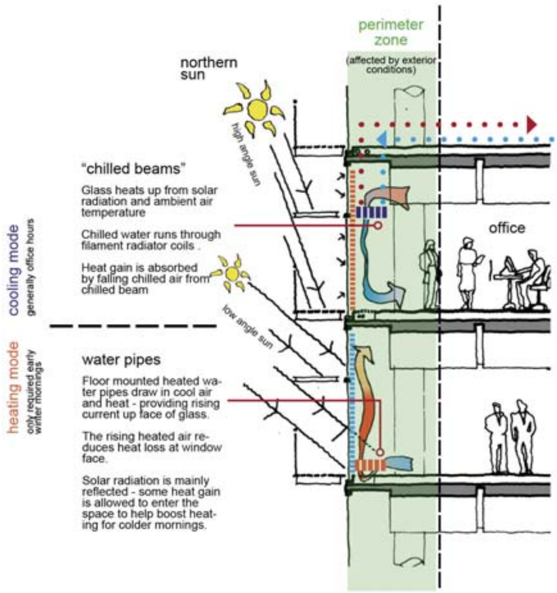


Figure 1: Cooling and heating in the north perimeter zone.

System Overview

During the daytime, offices will be actively cooled by a combination of the ceiling panels distributed across the floorplate, and chilled beams located above windows around the perimeter. The beams produce cooled air, at approximately 18ºC, which descends in front of the windows to reduce penetration of summer heat into the workspace. Passive cooling of the office will occur via the absorption of heat into the concrete ceilings, which will be removed by the natural ventilation of cool night air through the building during 'night purging' operations. Natural ventilation, achieved through opening windows and further induced by the stack effect, assisted by extraction turbines mounted on top of the north façade, occurs when the outdoor temperature falls below the temperature of the concrete ceilings. Around 70 per cent of the curved concrete ceilings is exposed to the effects of night purging, and is predicted to reduce cooling energy by around 14 per cent.

1 ASHRAE (1992). Thermal Environmental Conditions for Human Occupancy. ANSI/ASHRAE Standard 55-1992. American Society of Heating, Refrigeration and Air conditioning Engineers, Atlanta.

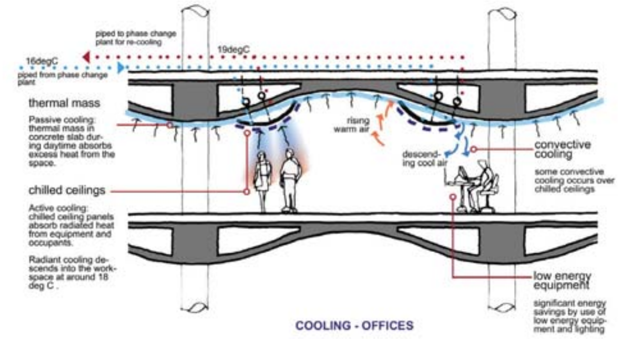


Figure 2: Diagram showing use of radiant systems such as chilled ceilings to provide cooling to the office space. Large surface area concrete ceilings, with high quality exposed concrete surface, help reduce cooling costs by slowly absorbing heat during daytime operation and releasing heat at night during the night purge (DesignInc Melbourne).

The combined effect of conventional electric chillers, shower towers and cooling towers will fulfil daytime cooling loads, by creating a thermal store of cooling energy in the form of charged phase change material. The cooling potential generated by this system will be stored in the phase change material, and be used to chill the water circulated through the beams and ceiling panels during the day. In very warm seasons, when ambient conditions and evaporative cooling alone are inadequate, absorption and the electric chiller will fulfil cooling requirements under their most efficient operating conditions.

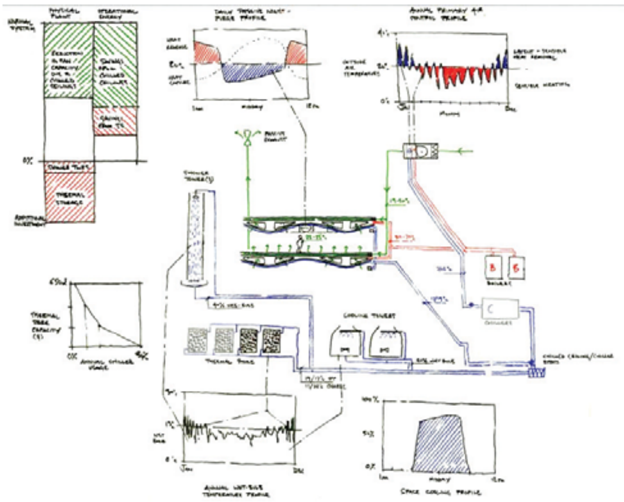
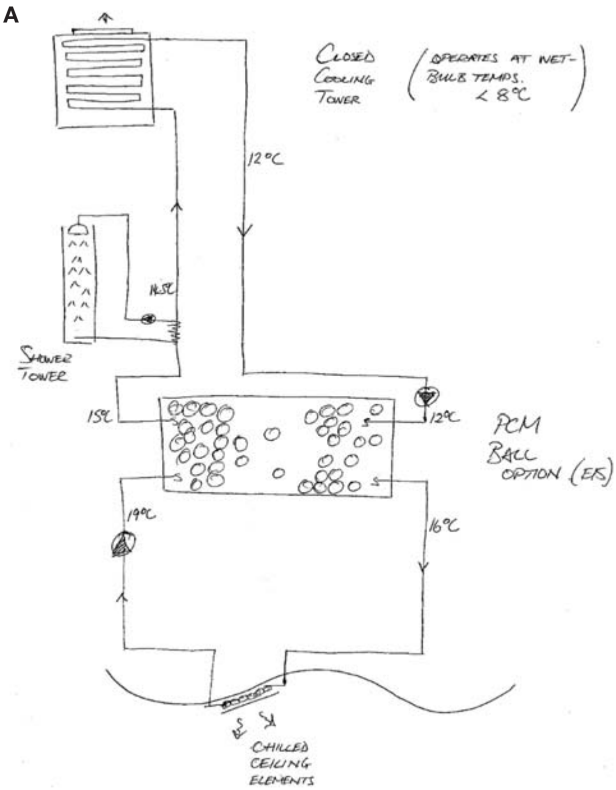


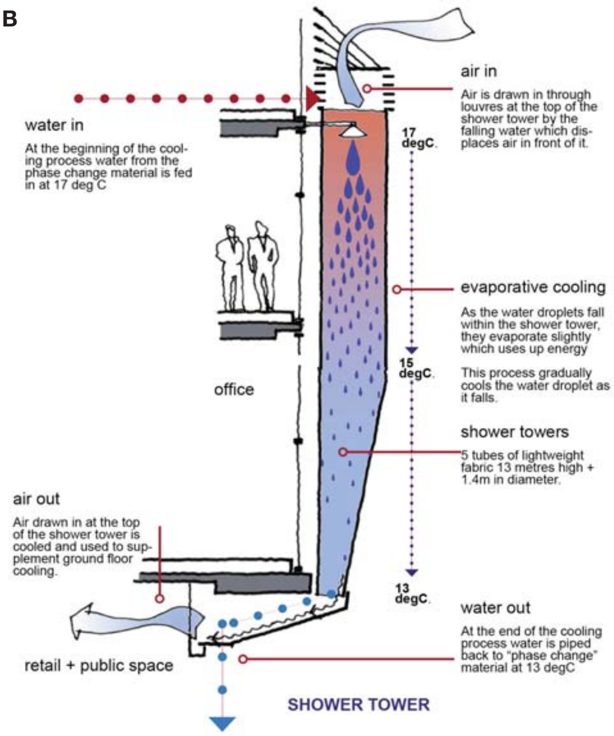
Figure 3: Overall heating and cooling system diagram used by design team to tune final configuration and conduct performance modelling.

A



A: PCM storage and thermal heat exchange system in detail.

B



B: Shower towers provide low energy cooling to assist lowering temperature of the PCM thermal storage system and retail ventilation air.

Figures 4: Cooling system components.

Heating for offices will be minimal since the heat generated by the occupants, office equipment and lighting will generally require cooling to maintain the desired thermal comfort level. Some early morning space heating may be required in winter, which will be provided by heat from a traditional gas fired boiler, or recovered from heat generated by the natural gas-fired micro-turbine.

A: Finished north façade prior to placement of the plants on balconies to create a living façade. Darkened north exhaust flue chimneys leading to the roof mounted air extraction and electricity generating wind turbines are also shown.

B: Mounted wind turbines showing the air extraction dampers (prior to connection to turbine).

Figures 5: Construction progress on north façade and turbines.

Radiant Cooling System

Chilled ceiling panels, fixed to the curved ceilings in offices, have been sized to cater for the internal cooling loads generated by occupants, lighting and equipment. The chilled panels cover 35 per cent of the curved ceilings. Chilled beams are to be located in front of the windows around the perimeter of each office zone. Their function is to cater for the loads generated by direct solar gain, and heat conducted through the windows. The radiant temperature of the panels is designed to be 18ºC, achieved by pumping water at 16ºC through the panels. The shower/cooling tower-phase change material combination will provide this chilled water. The internal cooling loads in the central office zone are estimated to be 35.5 Wm^{-2} for 95 per cent of the time. The air temperature design criterion for this zone is 21-25ºC, but since the panels will provide radiant cooling, the objective of the system is to achieve a maximum resultant temperature of 23ºC.

A. PCM balls during testing.

B. Bank of three PCM storage tanks located in basement (end insulation not fitted).

C. Single PCM tank showing access openings for loading PCM balls and connections for circulating chilled ceiling panel supply and return water through tank.

Figures 6: Phase-change-thermal-energy storage system.

Shower Towers

A component of the cooling system is the five shower towers. The shower tower concept is based on passive downdraught evaporative cooling. The shower towers will be constructed of lightweight fabric tubes, 1.4 metres in diameter and 8 metres in height, fixed to the outside of the south façade. Small droplets of water are released at the top of the tower. The combination of the force of gravity on the falling droplets, and the downwards flow of the evaporatively cooled air due to increasing density, sets up a downdraught in the towers. The cooled air will exit the bottom of the towers and be directed into the ground level retail spaces.

At night-time the evaporatively-cooled water collected at the base of the shower towers will be directed to the cooling towers, where it will undergo further evaporative cooling using fan-forced air. From here it will be piped to the phase change material storage tanks, to cool and consequently recharge the thermal energy storage system.

A: Primary under-floor air duct for supply to centre of floor.

B: Raised service floor in position, with swirl diffusers shown distributed across the floor plate. Undulating exposed concrete ceiling with chilled ceiling panels in position.

C: Perforated plate chilled ceiling panels showing copper piping connection, which continuously circulates water for radiant cooling via panels and the PCM storage tank in the basement.

D: Floor mounted swirl diffuser, with rotating occupant controlled grill for directing and varying air flow.

Figures 7: Radiant cooling system combined with underfloor ventilation air supply.

Productivity and Comfort

The literature surveyed on productivity indicates that worker comfort is associated with the physical environment. Temperature variations, and stale, dry or humid air, all have the potential to affect productivity. Improving the value of buildings, from a business and occupiers' perspective, is increasingly acknowledged as a source of potential gains achieved from productivity and workspace quality. If even small improvements to occupant productivity can be achieved, they will far outweigh other costs associated with improving the ecological performance of buildings. Buildings should perhaps no longer be seen just as places of work, but rather as one of the components that determine the productivity of an enterprise.

The thermal system in the CH_2 building will combine the benefits of innovative and conventional technologies, fulfilling occupant comfort needs as well as making good business and environmental sense.

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