Air Distribution in Rooms, (ROOMVENT 2000)
Editor: H.B. Awbi

13366

PARTIAL COOLING IN A NATURALLY VENTILATED BUILDING IN THE TROPICS

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ABSTRACT

The objective of this project was to provide cool working conditions for a small number of Customs Department staff in a turn-of-the-century heritage building in Townsville at 19° S latitude. A ducted air conditioning system was initially proposed but rejected as it would have been incongruent with the Victorian elegance of the space, as well as its high cost. As the working area in the three storey high space was surrounded by ornate timber counter and partitions, a scheme was developed using fan coil direct expansion units. These were located behind the counter to the public space. The jet of cooled air was directed toward a line approximately 2 metres above floor level along the opposite wall 5 metres away. Return air was drawn into the fan coil units near floor level. Entrance doors and selected windows to the space were kept open during office hours for natural ventilation and the cool air was retained by gravity behind the counter and partitions. The installation, which received an Australian Institute of Architects award, saved 85% of the original ducted system cost, and has been operating to the user's satisfaction for 2 years. Estimated savings in annual operating costs are around 15%.

KEYWORDS

Displacement ventilation, partial cooling, gravity containment, heritage, humid tropics

INTRODUCTION

At the turn of the century the city of Townsville had developed a busy port. To meet the growing customs and excise controls a new Customs House was constructed (1900-2) overlooking Cleveland Bay. This handsome two storey Federation Style building on the corner of The Strand and Wickham Street Townsville was built with red brick, decorated with stone surrounds to windows and doorways. The interior wall and ceiling surfaces were decorated with federation style embellishments. Ground floor rooms included offices and a grand Long Room over two storeys high with a long polished timber counter where the public presented documentation of cargo discharged in the port. Deep verandahs provided shade to most windows and the narrow L-shaped plan allowed cross ventilation from the prevailing northeast summer onshore breeze to cool the occupants.

Townsville is located on the northeast coast of Australia is in the tropics at 19 degrees south latitude and 146 degrees east longitude. Climatic conditions in Townsville during the hottest summer month of January, are mean monthly maximum air temperature 31.3°C with relative humidity between 60-70% and a typical peak air temperature around 34°C. Mean monthly minimum air temperature is 23.8°C with a monthly minimum around 21°C (Bureau,1975).

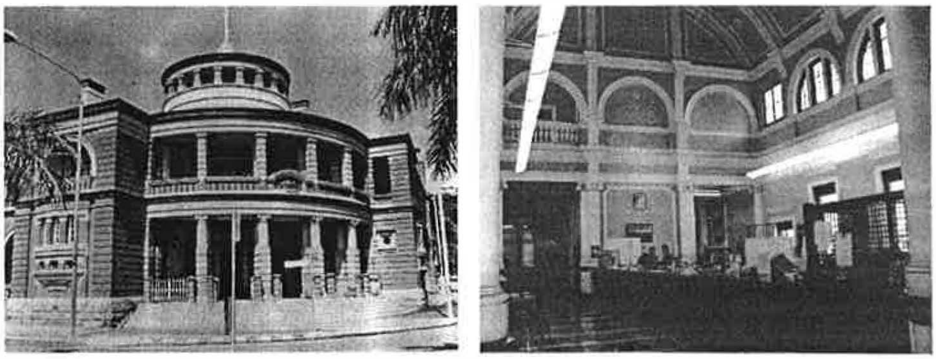

Figure 1: Townsville's heritage listed Customs House, exterior and interior of the Long Room

On 7th January 1994, Townsville experienced its maximum recorded temperature of 44.3°C . This prompted staff in the Customs house to request that their workspaces be air conditioned. The cost for A ducted air conditioning system was designed and estimated to cost AU$1,300,000 plus consultant's fees. There was concern that a ducted system would result in damage to the ornate plastered walls which would not be permitted in this heritage listed building. Macks and Robinson Architects of Townsville, with experience in air conditioning heritage buildings, were commissioned to develop an acceptable air conditioning system for the building and engaged the writer as a consultant. It was established that the principal need was summer cooling, and a proposal for partial cooling system (Aynsley et al, 1992) particularly for the large volume of the Long Room utilising gravity contained cool air was accepted. The ability to also enjoy copious natural ventilation from the prevailing summer onshore northeast breezes through the open main entry doors and upper level windows also appealed to the staff.

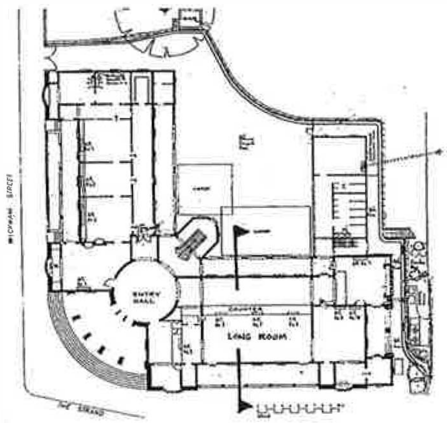

Figure 2: Floor Plan of Custom House

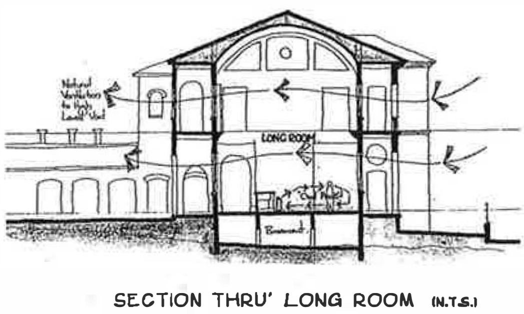

Figure 3: Section through Long Room

STRATEGY

The high ceilings in the work spaces and particularly in the Long Room led to consideration of stratified partial cooling. Earlier trials of the COOL POOL technique (Aynsley, Orr and Neels, 1992) indicated that such a system could work provided the cooled air could be contained by gravity within the work spaces. To address the loss of cooled air new self closing doors were proposed at openings where work spaces linked with the building entry and public space. In the Long Room the timber counter separating the public area from the workspace was proposed as a means for containment of cooled air in the workspace. With such an arrangement, it was envisaged that the heavy main entry doors could remain open during normal office hours, as had been the tradition and that window sashes near ceiling level could be opened to allow natural venting of warm indoor air. Small exhaust fans were installed above doorhead height in a number of locations to meet minimum ventilation requirements during calm conditions. It was proposed that only the air in the lower 2 metres of workspaces would be cooled.

INSTALLATION

Equipment chosen for the installation included a packaged air-cooled reciprocating (R-22) chiller feeding chilled water to 11 floor mounted fan coil console units through 25 to 50 mm diameter pipes with 25 mm insulation cover. Consoles in enclosed offices with concrete floors on grade were mounted on timber plinths to accommodate pipes. The system COOL POOL was designed to maintain the following condition under full and partial load : Room Temperature 24°C ± 1K. The summer conditions on which the design was based were : 34°C dry bulb and 27°C wet bulb.

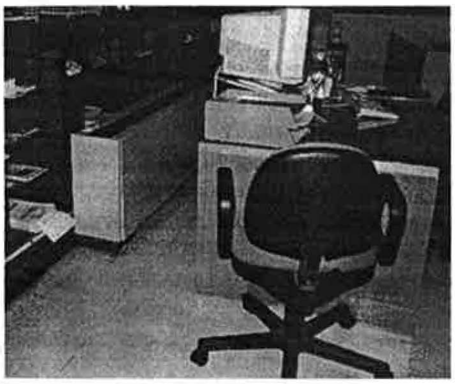
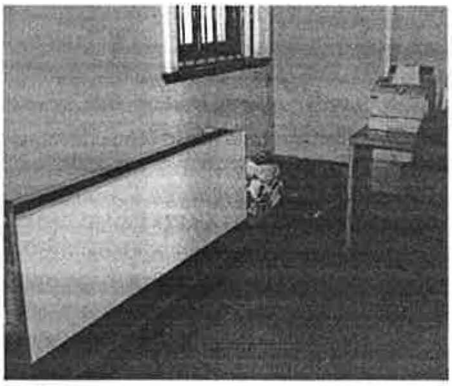

Figure 4: Fan Coil Installations behind Counter to Public Space and on Raised Plinth in Staff Offices

Four face areas of cooling coils ranging from 0.150 to 0.262 m^2 were used in fan coil consoles to meet the cooling loads in each of the workspaces. The cooling coils were staggered tube (3 rows deep, 473 fins per metre), aluminium lanced, sine wave fin coils with copper tubing to ensure efficient heat transfer. Variable speed supply air fans in the console units had capacities ranging from 161 l/s to 431 l/s. Cooling loads were determined using the conventional cooling load software used to size the plant for the ducted air conditioning option as software was not available to deal with the novel aspects of the COOL POOL option. Monitoring of the COOL POOL system after commissioning indicated the plant had excess capacity, as staff in the building chose to adjust the thermostats downward and regularly achieved air temperatures around 21°C. This substantially increased both the sensible cooling and latent loads on the system. It should be noted that often when energy saving cooling is provided in buildings, occupants see energy efficient cooling as an opportunity to lower air temperatures below those adopted for thermal comfort zone in the design of the system (Stein, 1997).

MONITORED INDOOR AND OUTDOOR CONDITIONS

During the summer of 1997/98, indoor air temperature and relative humidity conditions were monitored in the Long Room workspace and external shade air temperature and relative humidity were monitored in the adjacent colonnade around the courtyard. A few days of these data are provided in Figure 5 which include indoor conditions when cooling was not operating during Xmas holidays.

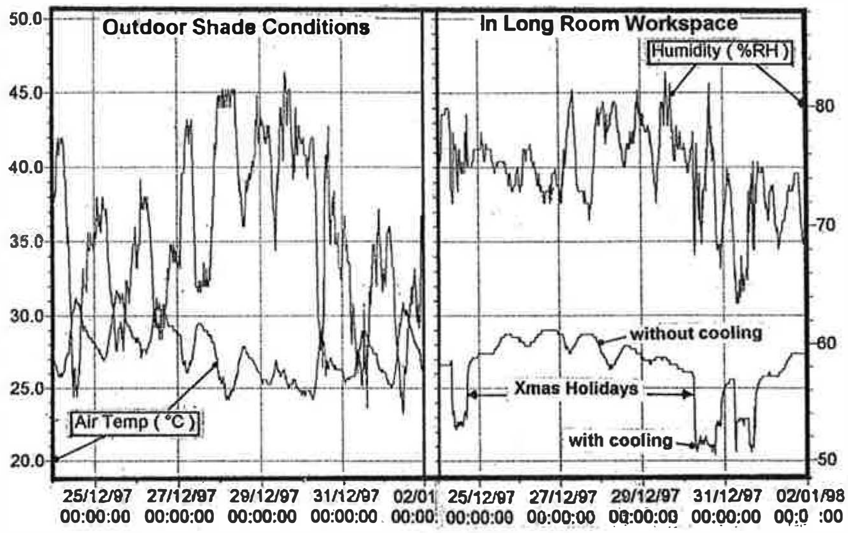

Figure 5: Outdoor and Indoor Air Temperature and Relative Humidity Data during Dec.97/Jan.98

COMPARATIVE ESTIMATED COST AND ENERGY SAVINGS

Total installed cost of the COOL POOL system including consultant's fees was AU$173,000, a saving of 85% over the split ducted system.

Power consumption rating for the COOL POOL system was:

Water chiller unit including condenser fans	26.0kW
Chilled water pump	1.5kW
Fan coil units (11 units)	1.4kW
Condensate pumps (intermittent operation)	0.3kW
Total	29.2kW

Equivalent power consumption for the alternate ducted split air conditioning system was:

Compressor	23.1kW
Condenser fans	1.3kW
Supply air fan	4.5kW
Total	28.9kW

However, to condition the workspaces with a ducted system, the Public areas would need to be included. This would create an additional cooling load of 23.4 kW with an additional power input of 10.27kW, giving a total power requirement of 33.67kW.

Hours of operation are based on a 10 hour day for 250 days per year or 2,500 hours per year. Power consumed by the COOL POOL system based on a service factor of 0.65 that was 18.98kW for 2500 hours or 47,450kWhr PA. This is 26.1kWhr PA less than the ducted system which represents an annual reduction of 7572 kg of released CO_2 at the coal-fired power station providing the electrical energy At 12 cents/kWhr the annual operating cost would be AU$5,694.

Estimated power consumed by a minimum sized ducted system based on a service factor of 0.65 that was 21.88kW for 2500 hours or 54,700 kWhr PA. At 12 cents/kWhr the annual operating cost would be AU$6,564 an additional AU$870 annual operating cost, 15% over the COOL POOL system.

CONCLUSIONS

The COOL POOL system has now provided satisfactory service for more than two years. Although indoor relative humidity reaches high levels there have been no problems or complaints from the staff operating personal computers in the Long Room workspace. This installation indicates that significant equipment cost and energy savings are possible by adopting a gravity contained partial cooling approach to indoor cooling in humid tropical locations. Greater savings in equipment cost and operating costs are likely if more appropriate cooling load software can be developed for gravity contained partial cooling applications. As demands increase for energy efficiency in comfort cooling in the humid tropics, indoor air temperature settings may rise toward 26°C which would not only provide reasonable thermal comfort, but reduce the sensible cooling load and eliminate the latent cooling load to around 10% of daylight hours in Townsville (AIRAH, 1995).

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