

Harry Barron MIHEA* – Australia

Air con upgrade achieves major savings

The West Moreton Health Service District in Queensland, Australia, was among the first to participate in the Queensland Health Energy Performance Contracting (EPC) programme, and this article describes the resulting major energy-saving benefits experienced by the district's largest public hospital.

The scope of works evaluated in this report involves heating ventilation and air conditioning (HVAC) systems installed at Ipswich Hospital, Queensland. The works comprised:

- Upgrading the existing constant volume by-pass system to a variable air volume (VAV) system.
- Installing variable speed drives (VSD) on supply and return air fans.
- Measuring supply air quantities and re-balancing them where necessary.

The existing building management system (BMS) was reconfigured and reprogrammed to provide these additional automatic control features. Key elements of this work included:

- Reviewing the HVAC operation and configuring it to match space occupied and unoccupied time.
- Resetting the temperature set points on 24-hour units serving 12-hour areas.
- Temperature set back control to unoccupied areas.

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The air conditioning modifications commenced in June 2006 and were completed in January 2007 – with an energy saving of 142,363 kWh per month realised. This figure equates to around 15% of the hospital's electricity usage and an annual saving of A\$106,000, giving an internal rate of return of 36%. The Energy Conservation Measures (ECMs) resulted in the reduction of 1,807 tonnes of CO₂ per annum. A small but noticeable improvement to the power factor was also achieved.

Introduction to the hospital

Ipswich is a large provincial city approximately 40 km west of Brisbane in Queensland. The Ipswich Hospital is the largest public hospital serving the local population of over 110,000 people in the West Moreton South Burnett Health Service District.

The hospital, having 363 beds and employing around 1,400 staff, has been located on its current site atop Denmark Hill in the centre of Ipswich for well over a century. The site has seen many changes in that time.

Existing air conditioning

The last refurbishment undertaken at the Ipswich Hospital was a major re-build and update of clinical and patient areas in the late 1990s. Needless to say, not all areas benefited from this refurbishment and some of the older areas retained their unique charm: this included their buildings' services. This hospital is an excellent place to follow the advances made in building services through the 20th Century.

HVAC upgrade details

Converting the existing constant air volume systems to variable air volume systems: The supply air quantity to each zone in the multi-zone systems had been designed to satisfy maximum load conditions. However, the maximum load conditions in each zone in these systems do not occur simultaneously, due to various factors – such as solar heat gain and internal loads.

Before EPC modifications, the supply air quantity into each zone of more modern areas of the hospital was kept constant while varying the supply air temperature using a chilled water valve, face and by-pass dampers



The existing building management system was reconfigured and reprogrammed.

* Technical services co-ordinator, West Moreton South Burnett Health Service District, Queensland Health.

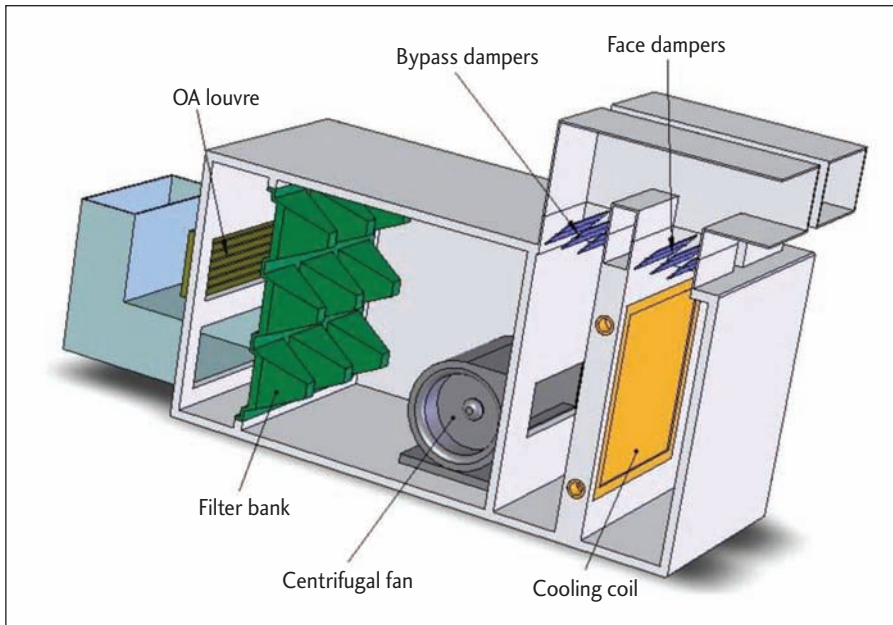


Figure 1: Typical 2 zone air handling unit before modification.

and electric duct heaters. In the older air conditioning systems, the temperature of supply air delivered to each zone was varied using only electric duct heaters. Thirty-seven existing air-handling units were modified (see Fig. 1 – pre-modification) and Fig. 2 – post modification) as follows:

- The bypass dampers to each zone (where existing) were disconnected. Linkages were fixed in the closed position.
- New volume control dampers were installed in the existing ductwork in the very old air handling units where no suitable control dampers existed prior to these works.
- Variable speed drives (VSDs) were installed on the supply and return air fans.

The newly installed or existing motorised face dampers on zone supply air ducts are now used to modulate the supply air quantities according to the space conditions in each zone. The building management system (BMS) controls the fan speed according to the static duct pressure to each conditioned zone. The VSDs were installed with shielded electrical cable and earth wires. The types of VSD installed were ABB brand ACH550-01 and ACS 400 low voltage AC drives.

Ensuring required outdoor air quantities: The outdoor air quantities in air conditioning systems were designed for the maximum occupancy level in conditioned spaces based on the gross floor area. The outdoor air supply requirement for healthcare facilities varies between 10 and 50 litres/second per person according to the latest standards (AS 1668.2-2002). The outdoor air quantities were re-measured and altered where necessary. The quantity of outside air entering the air handling unit was kept constant by opening the economy cycle damper in response to a detected decrease in fan speed.

Controls/building management system (BMS)

Existing BMS: The BMS installed at Ipswich Hospital is the t.a.c. I/net 7 system, which was upgraded for this project. The BMS has been evolving since the mid 1980s, when the first elementary system was installed. Some of the original digital control units are still in service. Several generations of hardware technology have been integrated into the present functional set-up. The BMS control system philosophy was discussed at length with the Ipswich Hospital engineering staff during the design stage. The control system was then installed and commissioned with extensive consultation with senior Health

Service Building Engineering and Maintenance Service (BEMS) staff.

Alterations to controls and control functions: The existing BMS system was reconfigured and reprogrammed to provide additional automatic control, by means of the following air handling units, or air conditioners (AHUs), as follows:

- Optimum start control – 22 AHUs.
- Resetting temperature set points using occupancy sensors – 14 AHUs.
- CO₂ monitoring and control – 4 AHUs.
- Automatic seasonal adjustment of temperature set points – 43 AHUs.
- Matching fan loads to cooling or heating loads using a new variable air volume (VAV) system, reducing supply air in response to reduced load, and regulating supply air fan speeds through the differential pressure sensor – 37 AHUs.
- Monitoring and regulating the space's cooling and heating loads – 55 AHUs.
- Installation of “after hours” push button controls – 6 AHUs.

The BMS also monitors temperature and some humidity conditions and provides equipment status and performance reports on the air conditioning system.

Indoor condition system operation – optimum start and stop: The start and stop times had been programmed to enable the conditioned spaces to have comfortable conditions well before the spaces are occupied and well after the spaces are vacated. The installed optimum start program calculates the optimum time to switch on the air handling unit serving a particular space so as to bring the space conditions to comfortable levels just in time for occupation. The program calculates the latest possible time to start up air handling units

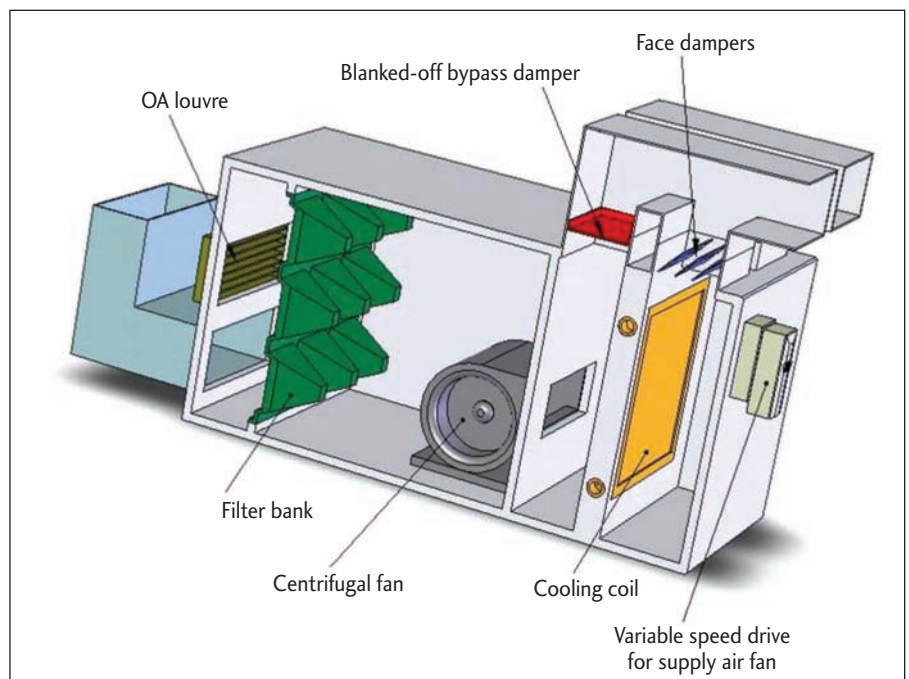


Figure 2: Typical 2 zone air handling unit after modification.

using indoor and outdoor temperature, historical data, and a sophisticated computer algorithm. For areas with an irregular need for after-hours use, an after hours push button inputs to the BMS to activate the appropriate unit for an agreed time period.

CO₂ sensors to control the outdoor air supply: The outdoor air quantities to open spaces are designed for the maximum occupancy level based on the seating/room capacity, e.g. outpatient clinics. The actual number of people in these spaces varies widely and continuously. CO₂ sensors are installed in the return air ducts to modulate the outdoor air supply quantity to the actual room occupancy. The system will always supply the minimum outdoor air quantity required to maintain air quality standards using the control of the outdoor air damper according to the CO₂ level in the return air duct, using the BMS.

Temperature set back control to unoccupied areas (occupancy sensors): Air conditioning units were maintaining optimum conditions during the entire time periods scheduled in the BMS, even when these areas were not occupied. Such areas include operating theatres and birthing suites. Sensors now signal to the BMS the occupancy status of the controlled space. The set point of the associated air conditioning zone is reset according to the current ambient temperature when an "unoccupied" signal is received from the occupancy sensors by the BMS.

Reset the temperature set points on 24 hour units serving 12 hour areas: The air handling units in some areas of the main buildings serve a mixture of areas operating for 24 hours and 12 hours a day. The set point of the supply air serving the particular zones that operated only 12 hours per day was reset according to the outside temperature during after hours times and on unoccupied days, controlled from a BMS time clock.

Difficulties encountered during installation

Duct heater protection: The reduced air flows from the VSD-controlled supply air fan caused the duct heater over-temperature protection to trip. This occurred during the coldest part of the morning when the heaters were required. The problem was overcome by adjusting the sensitivity of the heater protection to avoid tripping at lower flows. If the sensitivity adjustment alone would not prevent the heater tripping, then the flow of supply air was increased as the space temperature fell below a set point.

Additional fire relay: The response to fire in the hospital required that the zones around the fire alarm zone pressurise in

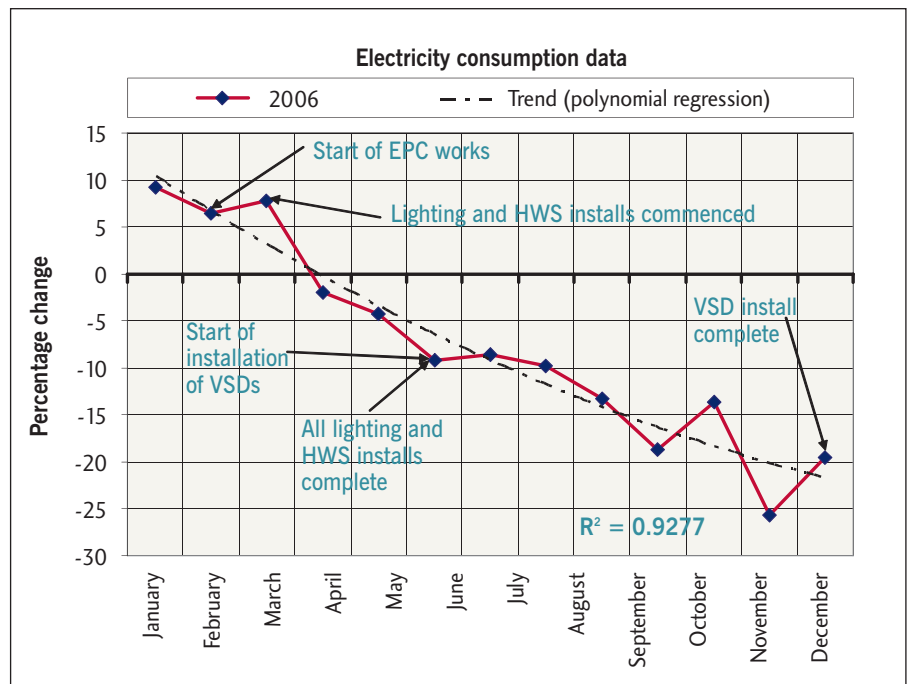


Figure 3: Ipswich Hospital electricity consumption.

order to contain the smoke to that fire zone. To achieve this pressurisation, an additional fire relay was fitted to the fire control switchboard to force the supply air fan VSDs to run to 100% speed on receipt of a fire alarm.

Return air fan VSD: The fitting of a VSD to the supply air fan led to the fitting of a VSD to the return air fan (where installed on the AHU). However, the centrifugal supply air fan has a different air delivery characteristic from the axial return air fan. This difference in the delivery characteristics was overcome by installing an algorithm in the return air fan VSD, so that this fan slowed at a faster rate than the supply air fan. The algorithm was tuned to maintain a constant amount of fresh air over the entire range of speeds of both fans.

Technical evaluation

The installation phase took considerably longer than was originally envisaged. While there were many reasons for this, what actually happened (although this was not planned) was a phased installation with the different energy conservation measures (ECMs) being installed in separate time periods (see Fig. 3). This enabled assessment of the effect of the various ECMs individually.

Expected magnitude of energy savings:

To estimate the magnitude of the energy savings, it is necessary to make certain assumptions. Let us assume the major contribution to the savings will come from speed reductions in supply air and return air

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fans. This is a reasonable assumption due to the number of these fans involved (37), and the fact that most of these fans operate 24 hours a day.

The total power rating of the 37 fans is 364 kW. From the Fan Laws (*Marks Standard Handbook for Mechanical Engineers*, pp15-55) we know that the power consumed by a fan is proportional to the cube of its speed. If we assume that the fan speed is likely to be reduced on average by around 15% then the power used in the new installation would be $(0.85/1)^3$ or 0.51 of the original power used. Thus the power saving is likely to be 0.49 of 364 kW, i.e. 178 kW. If the average running time of all fans is 20 hours per day, the average energy saving is 107,000 kWh per 30-day month.

If we then assume that all the other aspects of ECMs 1 and 2 will save another 15% of the total power used by the AHU fans, the additional predicted energy saving is 33,000 kWh per month. The total predicted monthly saving from these ECMs is thus 107,000+33,000, i.e.140,000 kWh per month.

Actual energy savings: The installation of the air conditioning modifications commenced in June 2006 and was completed in January 2007. Table 1 shows the savings

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– with an energy saving of 142,363 kWh per month realised.'

Table 1: Ipswich Hospital electricity consumption.

Electricity (kWh)		Variance from same month of previous year	
		kWh	%
2006	January	98,274	9.3
	February	63,492	6.4
	March	77,077	7.8
	April	-18,285	-2.0
	May	-38,384	-4.3
	June	-83,215	-9.2
	July	-78,748	-8.6
	August	-89,666	-9.8
	September	-117,933	-13.3
	October	-188,929	-18.7
	November	-135,787	-13.6
	December	-291,173	-25.7
2007	January	-225,578	-19.5
	February	-253,104	-24.1

from other ECMs in June 2006 relative to June 2005 amounted to 83,215 kWh. In January 2007 the savings were 225,578 kWh relative to January 2006. An energy saving of 142,363 kWh per month was realised over this period. This figure equates to around 15% of the hospital's total electricity usage.

Actual reductions in CO₂ emissions: The reduction in the amount of energy used means there is a reduction in the amount of CO₂ produced. The ECMs discussed here resulted in a reduction of 1,807 tonnes of CO₂ per annum (using a coal-based

conversion of 1.058 kg per kWh).

Agreed cost savings: The agreed cost of each kilowatt-hour of electricity at the commencement of the project was 6.2259 cents. This equates to an annual saving of A\$106,000. The cost of both ECMs was A\$474,285, giving a payback period of 4.5 years.

Improvement in power factor: The reduction in reactive power used by the AHU motors also had a desirable result in improving the power factor of the electrical supply from 0.82 to 0.89. There is

no immediate saving financially from this improvement. There is little doubt, however, that in the future, when billing will reflect reactive power used by a facility, this improvement will be valued greatly.

At the completion of installation, a general e-mail was sent to every person in the address book at Ipswich Hospital stating that the air conditioning part of the project was complete and asking for feedback from the addressee's area. Only 16 responses were obtained. Fourteen respondents reported being too hot (and possibly stuffy) and two were too cold. This is considered a good result, as the survey was conducted throughout the entire facility and taken in the middle of summer. Fine tuning will continue for the next 12 months, to ensure that the winter (and spring and autumn) conditions will be satisfactory.

Conclusion

In these times of increasing demands to reduce energy use, and in particular electricity, the reduction in the energy usage of 15%, along with a high consumer satisfaction rate, is considered a good outcome. Agreed cost savings of A\$106,000, representing an internal rate of return of 0.36, were achieved. The ECMs discussed here resulted in the reduction of 1,807 tonnes of CO₂ per annum. All the works of the installation phase were achieved with little disruption to the hospital's operations thanks to co-ordination between contractor and hospital.

Credit to all involved

Credit must be paid to the skilled designers, tradesmen and technicians (staff and contractors) who took on the task of imposing a new generation of technology onto an existing installation which, in parts, was 30-plus years old (but still in excellent condition). The task of integrating the different technologies into a workable unit was, at times, challenging. Credit must also go to all the health service staff who professionally carried on despite the changing conditions around them. The vast majority recognised the benefits to be gained economically and environmentally by the completion of these works.

References

- 1 Marks' *Standard Handbook for mechanical Engineers*, Baumeister *et al*, McGraw-Hill, 1978.
- 2 Energy Performance Contract Work Specification – Ipswich Hospital, Energex, 2005.

This article has been published in *The Australian Hospital Engineer*, the journal of the Institute of Hospital Engineering, Australia (IHEA) and in *Health Estate Journal*, the publication of the Institute of Healthcare Engineering and Estate Management (IHEEM), UK.

Ipswich Hospital, Queensland, Australia.



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