Submission in response to the EIS for the Expansion of the Museums Discovery Centre, Castle Hill SSD-10472

Lionel Glendenning

Architect of Record, Powerhouse Museum

65 Bouvardia St, Russell Lea, 2046

I am happy to have my submission published.

I object to the Expansion of the Museum Discovery Centre

1.The addition of the building J Store - purports to be a replacement for the Harwood Building, an integral part the Powerhouse Museum.

1.1 The Harwood Building is the former Ultimo Tram Depot, Mary Ann Street, Ultimo and is a fully functioning 'fit for purpose' (designed for a 100yr life span) element that provides both a fully functioning part of the Powerhouse Museum and a uniquely adjacent, coherent and vital professional museum support and storage facility in a purpose-built building. (AIRAH Journal, January 87, Vol 41, No 1. pp11 – 20, att.)

2. It seems that whenever the Minister for Arts, Harwin, wants to satisfy his edifice complex', he determines that the offending building that thwarts his ambition is 'not fit for purpose'. Without consideration of sensible, timely maintenance and fit-out upgrades at a (relative to the proposal at Castle Hill) – much reduced cost at the Ultimo Powerhouse Museum - is irrational and fiscally irresponsible.

3. Furthermore, given that it is now apparent that the Parramatta 'move' of the Powerhouse Museum is NOT going ahead (see Government media announcement 4 July 2020) and, that the Parramatta project brief has been greatly modified from a 'quasi museum' to a 'Carriageworks lite' or even less - an arts and entertainment 'cultural' building currently subject to a Green Ban by multiple NSW and national unions over the gross decision by the Berejiklian Government decision to demolish Willowgrove – a critical part of women's history in NSW and Parramatta. The need for expansion of the existing, adequate museum store at Castle Hill is moot.

3.2 This fallacy is once again offered as a reason for his political 'ploy' seeking replacement of a fully functioning professional support facility 'the Harwood building', an essential part of the Powerhouse Museum for a $100m (total?) move to a constrained, distant site in Castle Hill.

3.3 Matters that have arisen from this 'Baird/Berejiklian Parramatta' obsession have given rise to pathetic untruths, excessive costs, fateful planning missteps and sustained widespread community, media, legal protests and a damning NSW Upper House

Parliamentary Inquiry – ongoing and revealing extraordinary confusion, mismanagement, conflicting agendas and major budget and brief extravaganzas.

4. The Harwood Building is 'fit for purpose' (100year designed life - 1981). It is an intrinsic component of the Powerhouse Museum.

- 4.1 Its design is 'bullet-proof' and secure with back-up systems that have never failed –the 3 so-called leaks above the basement store were minor and the consequence of human error and lack of proper maintenance.
- 4.2 Double basement waterproof walls.
- 4.3 Double alarmed subsoil pumps and alarms for any emergency.
- 4.4 Bespoke collection conservation, restoration and maintenance facilities
- 4.5 Fit for purpose facilities and equipment for collection handling and exhibition construction and installation.
- 4.6 Access for very large objects
- 4.7 Publicly accessible – adjacent to public transport and car parks.
- 4.8 Purpose designed facilities for exhibition design, development and preparation.
- 4.9 Collection easily accessible to students, researchers, designers, collectors, donors etc and complementary to the Powerhouse Museum exhibitions, public and education programs.

5. Museum Discovery Centre, Castle Hill

- 5.1 Parking at Castle Hill is inadequate now for the TAFE function and will be overstretched even with the addition of the few extra parking spaces at the MDC, especially with the projected visitor numbers and poor, unsafe entry & exit onto busy main roads.
- 5.2 The local traffic at the intersection of Windsor Road and Showground Road is considered dangerous and conflicted for entry to the Museum site, particularly for large objects - aircraft, trains - locomotives, rolling stock, buses and bulky large objects on heavy/wide transport vehicles manoeuvring at entries and access ways.
- 5.3 The site is the location of a heritage landscape in the Museum's **historic eucalyptus plantation** – a fine example of historic industrial/silvi-cultural study of essential oils and arboriculture by the MAAS from its early beginnings in the late 1880s. The remnant stand of mature trees represent a 'living museum' exhibit and should be retained IN PLACE. (See Chris Betteridge 2020 paper att to his separate submission and objection.)

6. The NSW Government has, over its 'reign' in NSW been responsible for the gross neglect of our landscape and heritage – vis the 100 venerable fig trees cut down in the dead of night - supposedly for the Randwick Light Rail; the Parramatta Light Rail cutting through what should be UNESCO World Heritage listed Female Factory site and destroying more mature botanic heritage landscape – open green space for over-developed Parramatta.

6.1 Minister Constance proposing the removal of roadside trees on NSW roads – incidentally, a known seed bank and a resource of rare remnant plant species.

The planned destruction of the Castle Hill Experimental Plantation is another example of this destructive bent ignoring a heritage landscape artefact.

7. Public transport to the site is very limited and visitors and staff will be reliant on private car or hired bus transport – hence the limited parking on the site is totally inadequate and will limit the public accessibility to the MDC. Travel times and disruption will adversely affect staff adversely.

8. Collection management risks vis-à-vis the main Museum home in Ultimo, Powerhouse Parramatta and Sydney Observatory are multiplied by the distances and frequency of collection object handling and movements to service exhibition, education and public programs at these public cultural destinations.

8.1 Costs of collection management and handling will be far higher for both staff and materials.

8.2 It is ***not*** best practice to replace the functioning Ultimo support facility, with a distant store 38km away in dense traffic. Collection handling – the safety and security of objects – is compromised and risks are increased. Critical staff access is disrupted to the point of disfunction.

9. Access to the collection will be limited for staff, students, visitors, researchers, tourists, schoolchildren.

10. The Museum's Trust has had minimal input into this whole sorry planning mess concocted by Infrastructure NSW, Create NSW, premiers, ministers and lobbyists.

10.1 There is a disturbing lack of serious input by museum experts with deep knowledge and experience in all of this 'madness' surrounding the PHM Baird ill-fated move announced over 6 years ago.

11. The Expansion of the Museum Discovery Centre is yet another ill-thought-out scheme, devised against good museum practice, to change the purpose and function of the Harwood Building to the detriment of the operability and functioning of the Powerhouse Museum. Furthermore, this project will make the collection far less accessible and put its safety and security at serious risk.

12. This SSD project fails in all the planning and consultants' reports to prepare and consider a viable alternate approach – one that sees the purpose designed MAAS Powerhouse Museum Ultimo Support and Professional Services Harwood Building refurbished for far less cost. Over the past 20 years, maintenance and small upgrades have been deferred or ignored by increasingly poor management - staff and executives with a lack of building and museum experience and, facilities management.

13. For far less cost, a simple refurbishment project for finishes, fitouts and services updates would give a new lease of life to this adjacent essential, efficient and effective Powerhouse Museum collection and museum program facility.

13.1 The Harwood Building was effectively new in 1981 as the Ultimo Tram Depot is extant in the original perimeter, brick walls dating to c1899. The intervention - basement, ground floor and first floors, roof structure, services – were all brand new in 1981 – a 100year design life!

13.2 A current upgrade cost of $10.65m maximum against the $65 - $100m at Castle Hill to effectively replicate a facility which, from the Government's July 4th announcement that the Powerhouse Museum would be retained **as is** in Ultimo, makes the failure to cost the Harwood Building upgrade irrational and irresponsible. There are far more pressing priorities in Culture, (regional museums), Health, Education, regional Transport, Environment etc.

13.3 The SSD should assess the alternative of refurbishing the Harwood Building as a necessary part of the renewal of the Powerhouse Museum in Ultimo – as announced by the NSW Government on 4 July 2020. Since 1981, the Harwood building has been essential to the Museum's Ultimo operations and the public accessibility of its collection, archives and library since inception.

14. The Castle Hill site is not owned by the Government. Under the MAAS Act 1945 the Trustees of the Museum are custodians of the Museum's land, buildings and collection on behalf of the people of NSW.

14.1The applicant for this DA is the Department of Premiers and Cabinet – not as required, the owner of the site – or an assigned entity of the Trust. The DA should be immediately withdrawn and this serious illegality reported and investigated by the appropriated authorities. (LC, Ombudsman, ICAC).

14.2 Why was the Trust not the signatory on the DA?

14.3 Another example of this NSW Government's failure to follow proper process as it rushes politically driven, 'contested', ill considered infrastructure through now obviously politically charged planning processes. (Shades of Barangaroo coffee shop meetings to discuss critical planning issues outside of a proper process. (The Australian, March 6-7, page 1.)

15. This SSD project is a waste of taxpayers' money and threat to the long term viability of the Powerhouse Museum as there will be greatly increased operational costs, staff disruption, high risk to the collection and not ignoring unnecessarily challenging and risky, naïve Museum project management and delivery.

Lionel Glendenning

4 March 2021

Brief Resume

Lionel Glendenning AA STC Hons, B,Arch Hons 1 UNSW, M.Arch. Harvard, Dip. Environ St. Macq.

Inaugural Robert Gordon Menzies Scholar, 1968 to Harvard University Graduate School of Design

Life Fellow, Powerhouse Museum

Architect (retd), Design tutor: UNSW, Syd U, UTS.

Design Director HBO+EMTB 1988 - 2012

Principal Architect Public Buildings, NSW Government Architect's Office 1984 - 1988

RAIA NSW Merit Awards:

- Claymore Public School
- IMAX Theatre, Darling Harbour
- Bicentennial Park, Homebush Bay;

Architect of Record: Powerhouse Museum

Powerhouse Museum Awards: 1988

Sulman Award for Architectural Merit, Royal Australian Institute of Architects New South Wales

President's Award for Recycled Buildings, Royal Australian Institute of Architects National Awards

Belle Awards for Interiors, Royal Australian Institute of Architects

Meritorious Lighting Award – Institutions, the Illuminating Engineering Society of Australia

Australian Council for the Rehabilitation of the Disabled Award for Barrier-free Circulation

Winner, Tourist Attractions, Australian Tourism Awards

New South Wales Tourism Award for Excellence, New South Wales Tourism Commission

Best Museum Category A, Westpac Museum of the Year Awards

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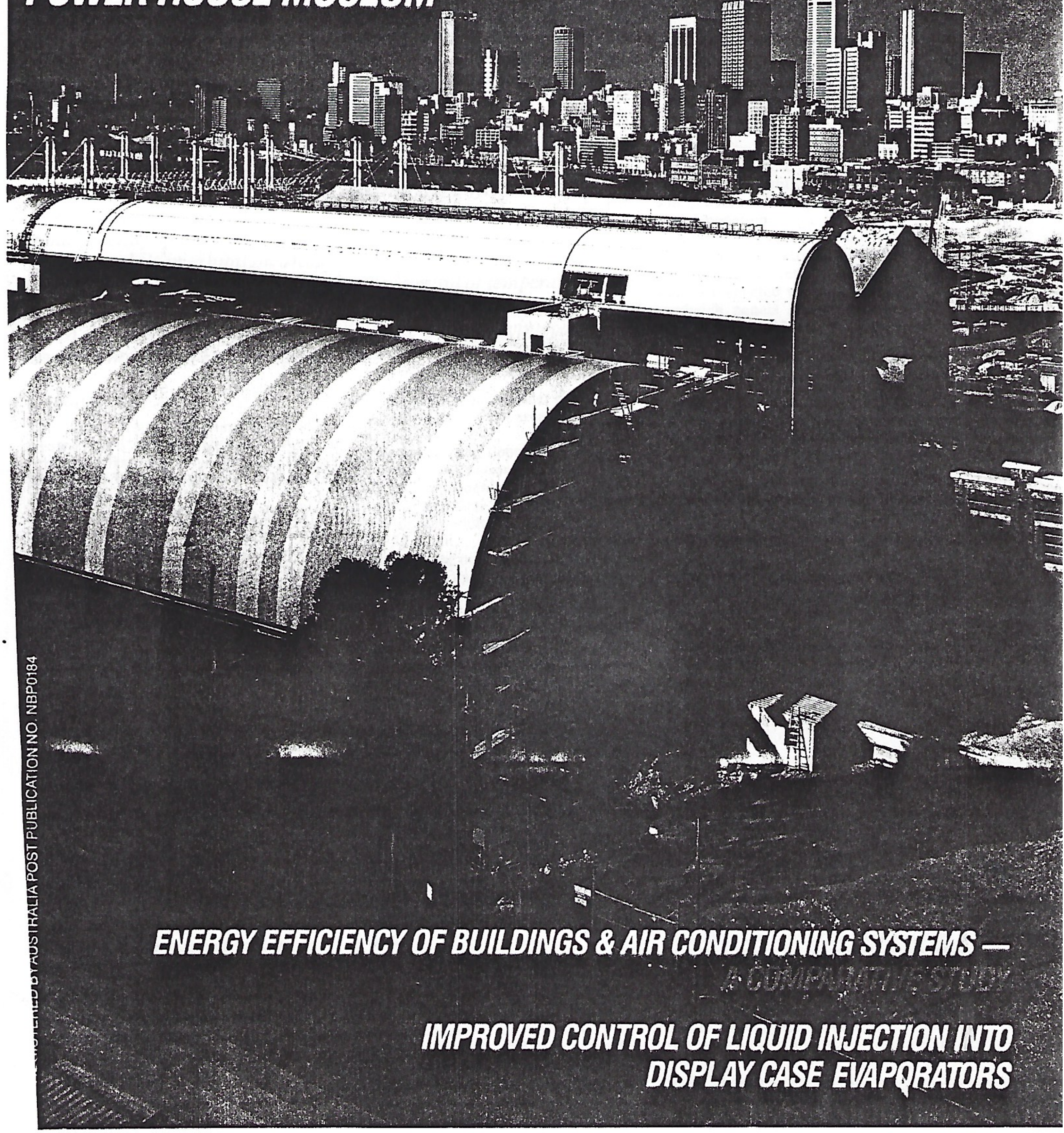
AUSTRALIAN REFRIGERATION AIR CONDITIONING AND HEATING

AIR CONDITIONING IN THE NEW POWER HOUSE MUSEUM



ENERGY EFFICIENCY OF BUILDINGS & AIR CONDITIONING SYSTEMS — A COMPARATIVE STUDY

IMPROVED CONTROL OF LIQUID INJECTION INTO DISPLAY CASE EVAPORATORS

REGISTERED BY AUSTRALIA POST PUBLICATION NO. NBP0184

AUST. REFRIGERATION,
AIR CONDITIONING & HEATING

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COVER STORY

Air conditioning in the new Power House Museum

By D. M. Rowe Dip. Mech. Eng (ASTC), M.AIRAH*

The Power House Museum, Sydney, requires two different approaches to air conditioning — offices, theatres, lecture rooms and public amenity spaces are conditioned for the comfort of their occupants while in exhibition areas the primary requirement is for the supply of clean air under close tolerance control of temperature and relative humidity as part of an environmental control system which will assist in preserving the collections. The following paper discusses how both requirements are met.

Introduction

The Power House Museum is being created from the old Ultimo Power House and Tram Depot buildings for the New South Wales Museum of Applied Arts and Sciences.

Re-Construction of the Tram Depot (Stage 1) is complete. The remainder of the project (Stage 2) includes comprehensive re-building of the Power House comprising the Boiler House, Turbine House, Engine House and Switch Building and construction of the new West Building between the Turbine House and Harris Street. This work will be completed in 1987 and the building will open to the public in 1988.

Two different approaches to air conditioning are required by the Museum. Offices, theatres, lecture rooms and public amenity spaces are conditioned for the comfort of their occupants. Plants serving these areas are programmed to run only during the hours they are occupied. Zero energy band thermostats control space temperature between 20°C and 24°C. Close tolerance control of relative humidity is not provided.

In exhibition areas the primary requirement is for the supply of clean air under close tolerance control of temperature and relative humidity as part of an environmental control system which will assist in preserving the collections. Comfortable conditions will be provided for visitors and staff as a by-product.

The buildings

Stage 1

In its original form as the Ultimo Tram Depot, Stage 1 was a large shed of one ... mainly brick walls and an uninsulated corrugated sheet steel saw-tooth roof system. Plan area was about 5000 m².

The roof system, floor and end walls of mixed construction were in poor repair and were demolished. The floor was excavated and the roof line was raised to gain additional space needed by the Museum.

This building now contains basement and ground floors and a 10 m wide mezzanine above the ground floor.

Main storage areas for the Museum collections are located in the basement which also contains the chiller plant room for the air condition system and is surrounded by a service tunnel approximately 1.5 m wide.

On the ground floor are located a small exhibition area with associated coffee shop and amenities, the restoration workshops containing bays for each of the main artisan trades, conservation department, photographic studio and accommodation for the registrar. Curatorial offices, library, computer workshop and radio broadcast station are on the mezzanine level.

The air conditioned area of Stage 1 is almost 10,000 m².

Stage 2

The old Ultimo Power Station began supplying electricity to Sydney's tramway system in 1899. Consisting of the Boiler, Turbine and Engine Houses and Switch Building, it is regarded as an important example of late nineteenth and early twentieth century industrial architecture and will be restored as nearly as possible to its original condition. When re-rebuilding is complete the Power House will provide almost 12,000 m² of exhibition space.

six levels, it will provide about 8000 m² of air conditioned space and will include two theatres, a suite of six lecture rooms, administrative offices, meeting rooms, amenities for visitors and staff and additional exhibition space.

Figure 1 shows a typical plan of Stage 2 at level 4. A cross section is shown at figure 2.

The Power House buildings are of massive load bearing brickwork. The Boiler, Turbine and Engine Houses have steel trussed roofs with corrugated steel sheeting. The Switch Building has a flat reinforced concrete roof. On this a new penthouse of lightweight construction will provide additional administrative accommodation.

In contrast the New West Building is of lightweight construction surrounding a reinforced concrete core. Much of the walls are sheeted with glass. Insulated sandwich panels are applied in non-glazed areas. Main roof areas are sheeted in corrugated steel.

Roofs of both old and new buildings will be insulated with 75 mm of mineral wool immediately below the outer sheeting and 50 mm above the inner linings.

The Boiler House, Turbine House and vault and atrium areas in the West Buildings are very large and tall spaces. For example the Boiler House is some 84 m long by 26 m wide by 21 m high from the main exhibition floor at Level 2 to the lower chord line of the roof trusses. The adjoining Turbine and Engine Houses have almost the same plan area and the Turbine House is the same height as the Boiler House although it does contain two mezzanine levels which to some extent break up the volume. In the West Building the vault rises above the main concourse to a height of 15.5 m and the atrium between this building and the turbine hall has a maximum height of 22 m.

Requirements of air conditioning for preservation of collections

Over the past twenty years or so intensive study has been undertaken by conservation departments of museums and art galleries throughout the world to determine the conditions most suitable to reduce the rate of deterioration of objects in their keeping.

A comprehensive review of the factors involved in such deterioration and detailed specifications for suitable preventative conditions are contained in the book "The Museum Environment" by G. Thomson.[1]

It has emerged that the main requirements for air conditioning are a high degree of freedom from airborne particulates, absence of atmospheric pollu-

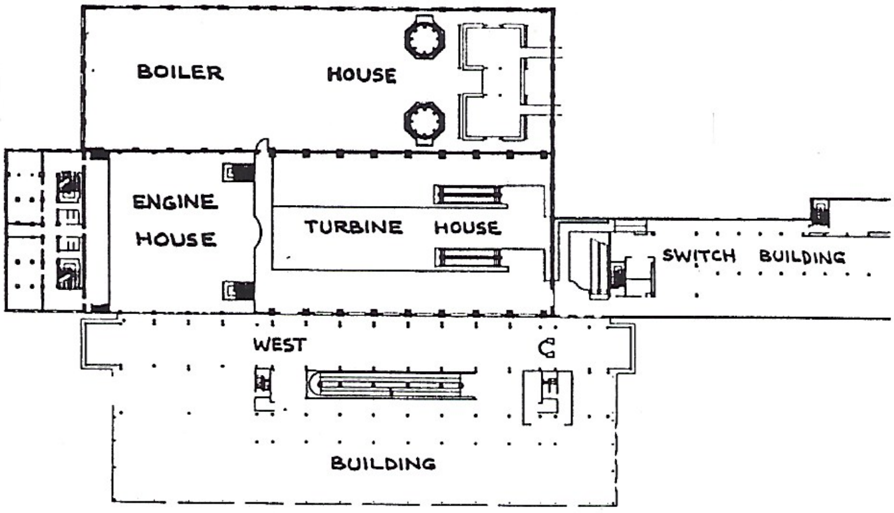

Figure 1: Powerhouse Museum plan at level 4 stage 2.

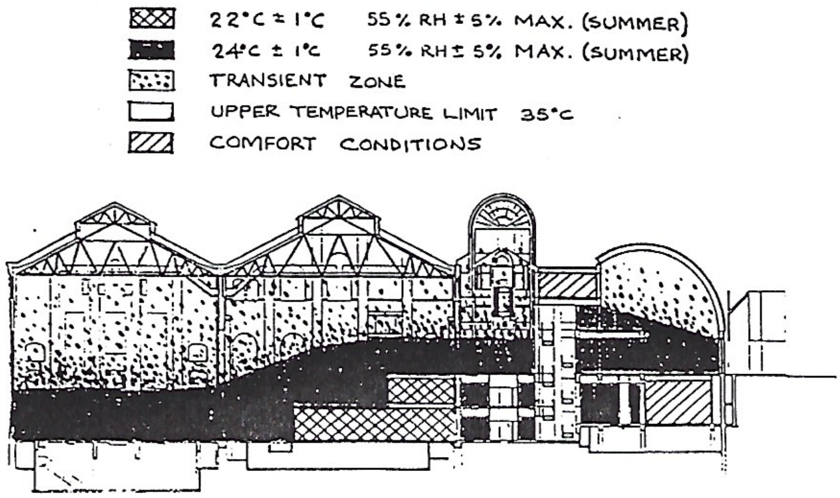

Figure 2: Powerhouse Museum typical cross section.

lesser extent, temperature.

Thomson emphasises the corrosive effect of acid oxides of sulphur and nitrogen and chlorides and the destructive action of ozone on organic materials. He points out that as well as rendering objects unsightly, dirt sooner or later necessitates "the risky operation of cleaning". He summarises the importance of stable relative humidity (R.H.) as follows:

> "A change of R.H. causes changes in the size and shape of moisture containing materials. High R.H. causes mould to flourish (above 65-70 per cent R.H.) and metals to corrode. Low R.H. (below 40-45 per cent R.H) causes embrittlement of moisture containing materials. Dyes fade more rapidly at high R.H. than low. Bio-degradation is greater at high R.H. but cannot be prevented through R.H. control alone" (p. 85).

Many of the objects in the Museum's collection are rare and valuable. Also the Museum has plans to arrange loan exhibitions from its major overseas counterparts, most of which will insist on a guarantee that their objects will be displayed in a benign atmosphere. The museum management therefore requires that specified environmental conditions for exhibition or storage purposes be maintained year round on a twenty four hours per day basis.

The Museum specification

Relative humidity:	55 per cent ± 5 per cent
Particulates:	Filter efficiency at least 65 per cent on AS1132 No. 1 dust.
Oxides of Sulphur:	< 10μg/m^3
Oxides of Nitrogen:	< 10μg/m^3
Ozone:	< 2μg/m^3
Chlorides:	Very significant but should be removed by water spray.
Temperature:	From a conservation viewpoint a stable temperature is required in exhibition areas between 15°C and 24°C with a ± 2°C variation on the selected setting.

Air treatment

To meet the Museum specification for air quality in exhibition and storage areas a two stage process has been adopted.

Outside air required to meet people and building pressurisation needs is passed through a pre-treatment plant which filters the air to remove large particulate matter and washes the air to remove gaseous pollutants, particularly oxides of nitrogen and sulphur. In addition the air is heated or cooled and dehumidified to maintain a leaving dew point condition which will result in the correct relative humidity being maintained in the space.

Pre-treated outside air is reticulated by ranges of ductwork to factory built single or multi-zone conditioners in which it is mixed with return air and further conditioned by high efficiency filtration, cooling, heating and steam vapour humidification as necessary to meet zone temperature and R.H. requirements. A typical disgrammatic arrangement as employed in Stage 2 is illustrated in figure 3.

Stage 1 air conditioning: general considerations

Stage 1 provides mainly support services for the museum e.g., storage, restoration workshops, photographic, conservation and registrar's departments library and small exhibition area. In order to meet the various needs of these occupancies at low operating cost a variety of conditions is maintained.

Storage

Except for a small plant area, the whole of the basement is used for storage of the Museum's collections. It is divided into two parts. In the smaller, 36 m², temperature is held at 18°C ± 1°C and R.H. at 55 per cent ± 5 per cent. It is used mainly for storage of delicate organic materials.

The remainder is used for a wide variety of objects including furniture, musical instruments, models, metal and ceramic objects etc. In this space temperature is held at 22°C ± 2°C and R.H. is controlled to an upper limit of 60 per cent. In practice a little moisture from the surrounding service tunnel permeates through the blockwork walls and the R.H. is maintained year round at just below 60 per cent.

Relief air from both basements is vented into the surrounding service tunnel and is exhausted via the main chiller plant room. This has the effect of surrounding the basement walls with spent conditioned air and therefore reducing heat transmission as well as ventilating the plant room.

Exhibition space

A space 40 x 28 m at the southern end at ground level is used for public exhibition of a sampling of the collections. Beside it a 40 x 10 m area contains a bookshop, coffee shop, public amenities and a small space for the exhibition of decora-

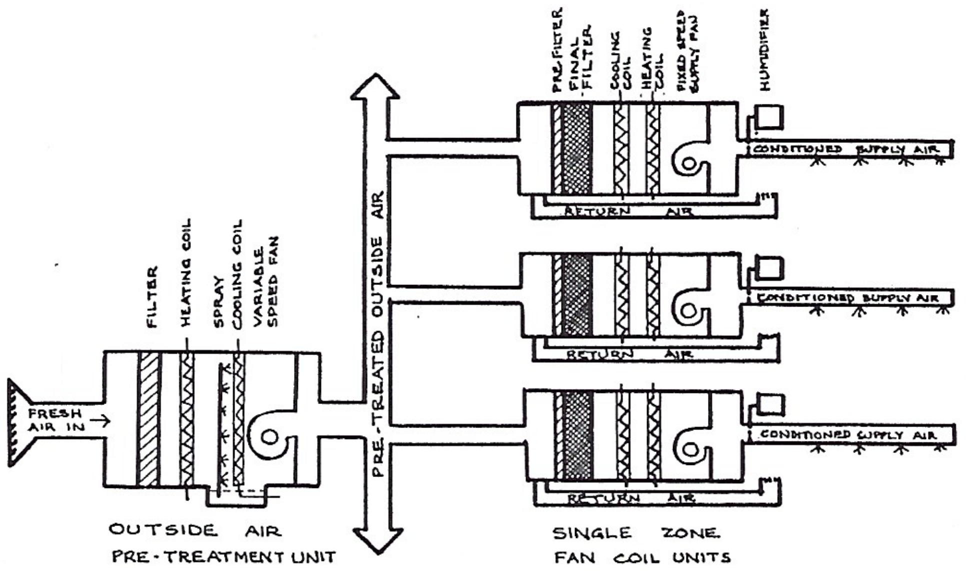

Figure 3: Powerhouse Museum — air handling and distribution system schematic diagram.

tive arts. Above this on a mezzanine level is the museum library, a computer training area and the museum radio broadcast station. Because these areas are open to each other conditions in all of them are maintained at 22°C ± 1°C and 55 per cent ± 5 per cent R.H.

Workshops

North of the exhibition hall at ground level are the restoration workshops with bays for each of the main artisan trades in an area 100 x 28 m on the western side.

A requirement of the Museum for the workshops was mechanical ventilation to maintain a slight positive internal pressure and thus exclude infiltration of untreated outside air. This area is supplied with air from the primary outside air treatment plant, re-heated to 16°C. To maintain comfortable working conditions three fan coil units are installed at high level within the space. These recirculate room air only and are provided with heating and cooling coils to maintain temperature within the limits of 20°C and 24°C.

Conservation and photographic departments

In the enclosed conservation department and photographic studio temperature is controlled at 22°C ± 2°C and R.H. is controlled to 55 per cent ± 10 per cent. Within the conservation unit a small instrument room is maintained at 20°C ± 1°C and 50 per cent ± 2 per cent R.H. This is required to permit measurements to be made under international standard conditions.

Curatorial offices

The space on the mezzanine above the conservation and photographic departments is used as open planned office accommodation for curatorial staff and is comfort conditioned between 20°C and 24°C.

All areas of ground floor and mezzanine north of the exhibition hall are time switch controlled to maintain conditions only during working hours. Remaining areas operate around the clock.

Stage I chiller and heating plant

The building covers a very large horizontal area and were it not for the requirement to maintain close temperature and R.H. control, decentralised package direct expansion plant would probably have been chosen to minimise capital cost.

In the event it was decided to employ central chilled water and hot water heating plant and reticulate to factory built fan coil units suitably dispersed around the building.

Two Westinghouse centrifugal chillers each of 840 kW cooling capacity supply chilled water at 5°C to the system. The peak cooling load is 1200 kW so for all but a few days per year a full standby unit is available. The low supply temperature is necessary to enable the maintenance of specified conditions in the southern basement area and the instrument room, both of which require an apparatus dew point of 8.5°C in their fan coil units. Heat is rejected to a twin cell timber cooling tower which stands at ground level on the eastern side of the building.

A small air cooled packaged chiller plant having four stages of unloading with a maximum output of 180 kW was subsequently added to provide for winter cooling and thus avoid operating the centrifugal equipment at very low load conditions.

Heat for the building is provided from a six stage Lucas electric resistance element water heater of 600 kW total capacity. Electric heating was selected for low capital cost as a temporary measure. On completion of Stage 2 which includes a heat recovery heat pump system heat will be supplied to Stage 1 and this boiler will be taken out of service.

Heating water is circulated at 40°C leaving temperature and 35°C return to permit future interconnection with Stage 2.

Stage 1 air handling and distribution

Two built up outside air pre-treatment plants are provided on each of the eastern and western sides of the basement in the service corridors. In these air passes through washable dry media panel filters, spray washers and cooling and heating coils. It is de-humidified by cooling to 13°C, is re-heated to 16°C and is then distributed to fan coil units for final conditioning.

A total of nineteen Trane factory built single zone constant volume fan coil units is provided throughout the building, each located immediately adjacent to the zone it serves. Those for the basement storage and ground floor exhibition areas are provided with built on filter chambers housing washable dry media panel pre-filters and nominated efficiency particulate arrestance filters of 95 per cent efficiency on No. 1 dust to AS1132.

The units serving the remaining zones are provided with panel filters only.

Where lower limit R.H. control is required i.e., in the exhibition space, the southern basement storage area, conservation department and photographic studio, packaged electrode type steam generators have been provided to discharge vapour when necessary through distribution spreaders into the air streams leaving the fan coil units.

Air distribution is generally by way of short horizontal duct runs in the spaces. Rectangular side blow registers are provided from concealed rectangular ductwork in mezzanine upper areas. In other areas horizontal discharge jet diffusers are mounted on exposed spiral ductwork to gain the necessary long throws of up to 12 m.

One example of this arrangement is in the exhibition hall where such a duct is mounted at each side of the 17 m wide space. The duct on the east side is three metres above the floor and blows both ways into the main display area and back under the mezzanine. The western side duct is five metres from the floor and blows one way only into display hall. Air is thus blown approximately twelve metres from each side and is returned through the space to return grilles at one end and each side. Branch ducts with modulating thermostatically controlled dampers provide air to the coffee shop and decorative arts room and satisfactorily cater for occupancy variations. This arrangement has proved very satisfactory as to maintenance of temperature and relative humidity. Maximum variation in temperature measured between any two points in the space is 1°C and maximum R.H. variation is 2 per cent.

Air cleaning in the exhibition hall has been less satisfactory however. It has been found that due to the large number of visitors, appreciable amounts of fluff and lint accumulate on the tops of showcases and some of the larger exhibits. These contain 95 per cent of the clothing fibre which is evidently held in suspension by turbulence of the air distribution system until it accumulates and settles out without passing through the filtration system. In an effort to prevent this occurring in Stage 2, air will generally be supplied to spaces at high level and extracted at low level although there is no certainty that this will solve the problem.

In another variation two fan coil units are installed on each side of the large northern basement area in staggered pattern. These discharge air directly into the space through short pieces of ductwork provided for sound attenuation. Again a very satisfactory uniformity of temperature and relative humidity is maintained in this room of approximately ninety by thirty six metres.

Stage 2: general considerations

The Museum requirements for air conditioning in Stage 2 are the same as for Stage 1 and similar concepts have generally been employed in the air conditioning systems. There are however some differences in response to differences in the nature and use of the buildings.

In order to reduce capital and operating costs, the Museum has agreed that specified conditions be maintained only to a height of 4 m above the floors. Temperature and relative humidity gradients will be permitted above this level. This has enabled adoption of the ASHRAE recommendation to include only one third of roof heat gains in the heat load calculations. As a further means of reducing cooling loads the Museum agreed to accept a summer temperature of 24°C with 55 per cent R.H. in these spaces.

Large glazed areas in the east and south walls of the boiler hall and the north, west and south walls of the west building gave rise to concern that condensation on inside faces could be a problem in cold weather. Studies indicated that if internal conditions were maintained at 24°C and 55 per cent R.H. in winter, condensation on single glazed surfaces would occur at an outside temperature of approximately 12°C the actual value depending on wind velocity.

In Sydney overnight outside temperatures at or below 12°C are not uncommon at night in winter. If however the inside conditions were reduced to 20°C and 50 per cent R.H. then formation of condensate would commence at an outside temperature of about 6°C, a much less frequent condition.

It has therefore been arranged with the agreement of the museum, that temperature and R.H. set points in exhibition areas in the Boiler House, West Building and upper level of the Turbine House will be reset on a daily schedule from a high value of 24°C and 55 per cent R.H. in January to a low value of 20°C and 50 per cent R.H. in July. A direct digital control system adopted for the building will greatly simplify this process by generating re-set points on a sinusoidal distribution.

Double glazing the windows would have overcome this difficulty but is not practicable for reasons of historic accuracy in the Boiler House and of cost.

The selection of "solar bronze" heat absorbing glass for the West Building will to some extent reduce peak solar gains. On the north facade, which is the most affected, air will be delivered vertically from slot diffusers in the floor in order to cool the surface of the glass and thus limit secondary radiation into the building.

The successful maintenance of close tolerance conditions in critical areas of Stage 1 and the low capital cost of that installation ($780,000 in 1978 dollars) led to the adoption of similar concepts for Stage 2. Thus chilled water and heating water are reticulated from a central energy plant to three outside air pretreatment conditioners and to a total of forty-three single and multi-zone factory built fan coil units located close to the areas they serve.

To avoid encroaching into museum space, plant rooms have been established in basement areas in the Boiler and Turbine Houses and West Building. In addition two small plant rooms on level six of the West Building supply air to the mezzanine floors on level 5 and 6. In the Switch building the Museum require space for a future secure passage to Stage I at the lowest level. It was therefore not possible to provide plant space here and a plant room is located instead on each of the four occupied levels.

Stage 2: central chilled water and heating plant

Air conditioning is required year round twenty four hours per day in all exhibition spaces in Stage 2 i.e., about three quarters of the floor area. This, together with the requirement for close tolerance on the upper and lower limits of relative humidity in those spaces will result in substantial energy costs in operation.

Frequent co-incidence of heating and cooling loads led to the consideration of heat recovery from chiller condenser water as a possible option. Also the existence of the old condenser water tunnels connecting the Power House with Darling Harbour suggested their use as a heat source and sink.

Another possibility was the use of the north facing saw tooth roofs of Stage 1 to support a solar absorber system to provide supplementary heat for a heat recovery system.

A life cycle cost study was therefore undertaken in which three options were examined.

These were:

- A chilled water system with heat recovery using centrifugal chillers supplemented by a gas fired water heater and rejecting surplus heat to cooling towers.
- A heat recovery/heat pump system using centrifugal chillers rejecting excess heat to or extracting supplementary heat from sea water pumped via the old condenser water conduits from Darling Harbour.
- A heat recovery/heat pump system using centrifugal chillers rejecting excess heat to cooling towers and extracting supplementary heat from solar absorbers on the Stage 1 roof.

The solar option was eliminated from further consideration by the very high capital cost of the absorber installation even though this was based on the comparatively low cost option of plastic tube in strip as used for swimming pool heating.

Taking into account the cost of larger piping, allowance for repairs and modifications to the sea water conduits and sea water pumping and heat exchange equipment, the sea water heat pump option showed an estimated saving in owning and operating cost over twenty years of $60,000 per year (1980 dollars) and it was accordingly adopted.

At that stage the sea water tunnels were flooded. Subsequently they were de-watered and thoroughly examined. They were then found to be in very good condition requiring much less cleaning and repair than had been allowed for the in comparision study so that the cost advantage was enhanced.

The estimated peak cooling loads are 3400 kW for Stage 2 and 1200 kW for Stage 1 (total 4600 kW) and peak heating loads are 2700 kW for Stage 2 and 600 kW for Stage 1 (total 3300 kW).

Chiller plant consists of four York centrifugal machines having the following capacities:

	Cooling	Heating
Chiller No 1 Chillers Nos. 2 & 3 Chiller No. 4	800 kW 1300 kW each 1450 kW	985 kW 1515 kW each cooling only
	4850 kW	4015 kW

The four machines are arranged with independent primary chilled water and condenser water loops to maintain circulation through the vessels at all times. Secondary loops reticulate chilled and heated water throughout the buildings. These secondary loops are arranged so that when total cooling load exceeds total heating load, condenser water is by-passed under modulating control to sea water heat exchangers. When heating demand exceeds cooling load chilled water is by-passed through the sea water heat exchangers and heat is pumped from the chilled water to the condenser water circuit.

As heating and cooling loads will fluctuate widely throughout the year four chillers were selected to enable output to be increased incrementally, thus improving part load efficiency. To provide for very low loads No. 1 chiller is arranged for hot gas by-pass.

Chiller No. 1 (800 kW cooling) will always operate at a condenser water leaving temperature of 40°C to provide for the base heating load. Chillers 2 and 3 can be operated either at this condition or at the condensing temperature available from the circulating sea water. Chiller No. 4 will always be connected directly to the sea water heat exchangers so as to operate at the lowest available condenser water temperature to a minimum of 20°C.

Each chiller control system maintains leaving chilled water temperature at 5°C when the machine is operating. A sensor in the heating water secondary loop maintains heating water flow temperature at 40°C; calls on additional machines as required for heating; and controls the diversion of condenser water or chilled water to the sea water heat exchangers as necessary to maintain the heat balance of the system.

A single centrifugal pump is provided for each of the chilled and heating water secondary loops with a third pump installed between them which can be used as a standby to either. Each of these pumps has a variable frequency variable speed drive which will be controlled to maintain 5°C temperature difference in the chilled water and heating water circuits. The cost of variable speed drive is $22,000 per pump. However, a very satisfactory payback is provided by the estimated saving of $70,000 per pump in energy cost.

Three Alfa Laval plate heat exchangers will provide for heat exchange with sea water. Titanium metal plates are used to withstand the corrosive action of sea water dosed with sodium hypochlorite to control growth of marine organisms.

Stage 2: air handling and distribution systems

Three outside air pre-treatment conditioners are provided to pre-condition outside air for exhibition spaces by spray washing to remove chlorides and acid oxides and adjusting moisture content to approximately that required to produce the specified relative humidity. One of these units is installed in the basement of the Boiler House and supplies 13,690 litres per sec. of outside air to fan coil units serving the Boiler, Turbine and Engine Houses. A second unit supplies 7525 litres per sec. to fan coil units in the West Building and a third provides 3840 litres per sec. to multizone units on the three exhibition levels of the Switch Building.

Fresh air quantities were calculated from the recommendations of AS 1668 Part 2 i.e., 3.5 litres per sec per person and 1.4 sq. m per person. These values were applied to 60 per cent of the floor area, it being assumed that exhibits would occupy the remaining 40 per cent.

These pre-treatment conditioners are provided with roughing filters followed by heating coils and all copper water sprayed cooling coils. Spray chambers are of type 316 stainless steel. Because of the requirement for washing the air, sprays will be operated continuously. Heating and cooling valves will be modulated under the control of a dry bulb sensor in the discharge duct to maintain scheduled leaving air temperature between a maximum of 13.5°C in summer and 9.0°C in winter. Set point will be reset daily in accordance with a sine law as described above for space temperature and relative humidity. Experience with the Stage 1 plant shows that a saturation efficiency of 95 per cent can be expected in the spray washers. The correspondence between leaving dry bulb temperature and dewpoint will therefore be very close.

The conditioner in the West Building has an automatic roll type filter to provide substantial dust holding capacity whereas the units for the Boiler, Turbine and Engine Houses and the Switch Building have 305 mm deep extended surface replaceable dry media filters to achieve adequate dust holding capacity at lower capital cost.

Because of the difficulty of effectively sealing junctions between walls and roofs and around timber framed windows in the old parts of the complex, no specific provision has been made for relieving spill air. It is expected that leakage will provide for the necessary relief and thus to maintain an outward flow and avoid infiltration of untreated outside air.

The treatment and delivery of outside air will represent a substantial part of the energy consumed by the air conditioning systems. Variable frequency speed control has therefore been provided on the fans for the pre-treatment units to reduce the air quantity supplied for low occupancy levels and for occasions when infiltration is lessened by low wind speed.

Fans will be controlled in accordance with variation in

(a) building occupancy and
(b) Outside wind velocity as a measure of pressure distribution around the building and hence infiltration of untreated outside air.

Counters on entrances and exits, monitored by the direct digital control system will indicate the number of people in the building and hence ventilation requirement at any given time. An anemometer mounted on the roof of the Boiler House will monitor wind speed.

Variable speed drives on these fans will produce operating cost savings of a similar order to those on heating and chilled water pumps.

For the secondary treatment of air in exhibition areas in the West Building and Boiler, Turbine and Engine Houses, single zone factory built fan coil units are located in basement plant rooms adjacent to the zones served. In the Switch Building a multi-zone unit with face and by pass damper control is installed on each of the three exhibition levels to serve two perimeter and one centre zones. Re-heat coils are installed in zone ductwork to facilitate R.H. control.

Because of the requirement for the high efficiency filtration of small particle sizes, site constructed filter boxes are attached to these units. Extended surface dry media replaceable filters are fitted to extend the life of the main filters which are also of extended surface replaceable types. Pre-filters are of 95 per cent efficiency on No. 2 test dust to AS 1132. Final filters have efficiencies greater than 85 percent on No. 1 test dust to AS 1132.

Alternative filters of the electrostatic

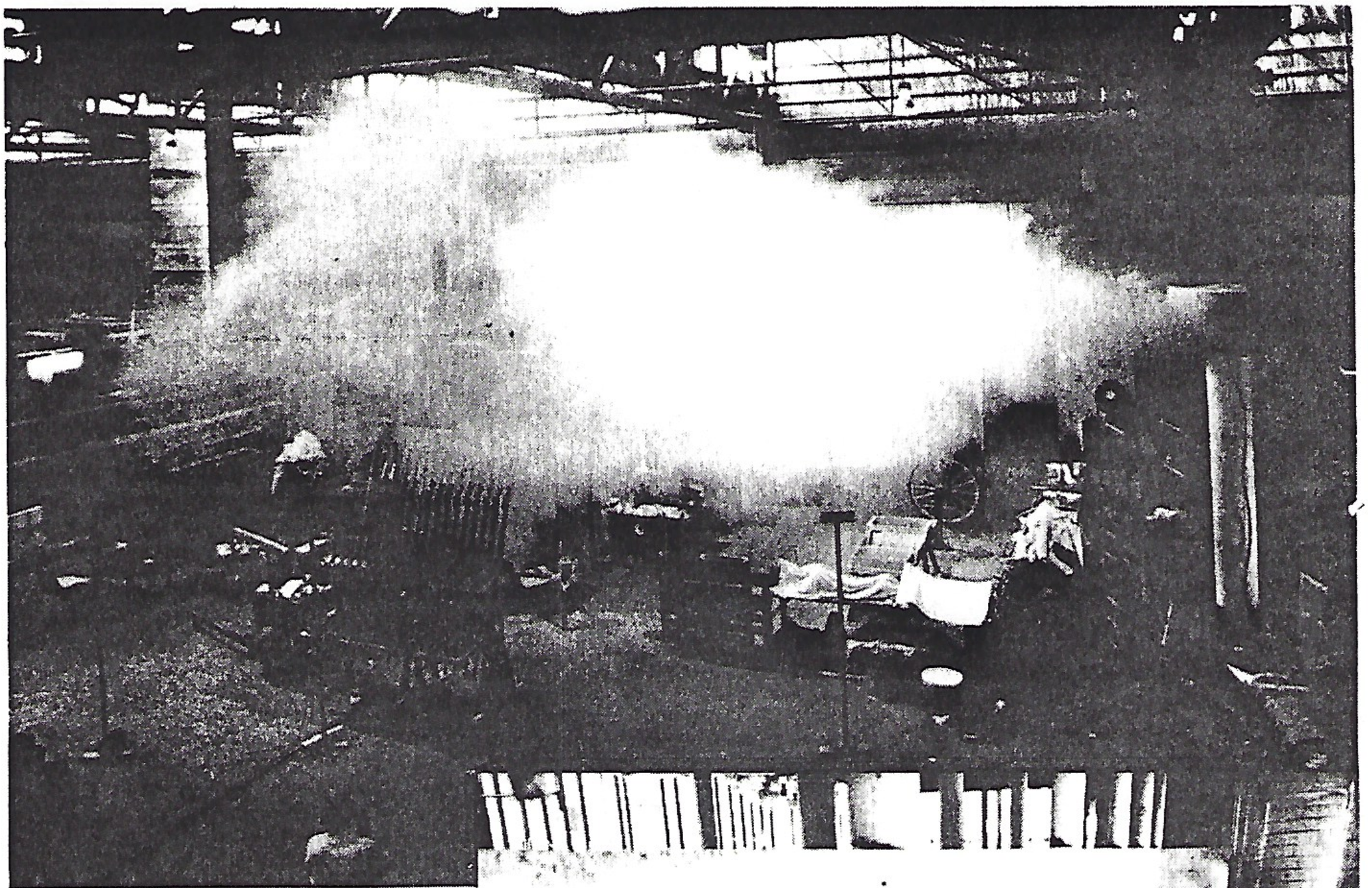

Figure 4: Prototype air delivery column under test.

type were considered because of their low resistance. It was found however that estimated owning and operating costs over a twenty year life cycle were approximately equal due to the higher capital cost of the electrostatic devices. The Museum had a preference for the dry media types due to the risk, small though it might be, of the generation of ozone by flash over in the electrostatic filters. Hence the dry media filters were adopted.

After filtration the mixture of fresh and return air is cooled and if necessary de-humidified and heated as required. A small electrode type packaged steam humidifier is provided to discharge vapour into the leaving air stream of each fan coil unit if required to trim relative humidity to the specified condition.

Stage 2: air distribution

Because of the varied shapes, ceiling heights and uses to which spaces will be put, a variety of air distribution strategies was adopted.

Other considerations included the need to avoid structural alteration to the old parts of the complex; the desire of the Museum that the services installation be as unobtrusive as possible to avoid competition with exhibits; and the need to provide for flexibility of use of

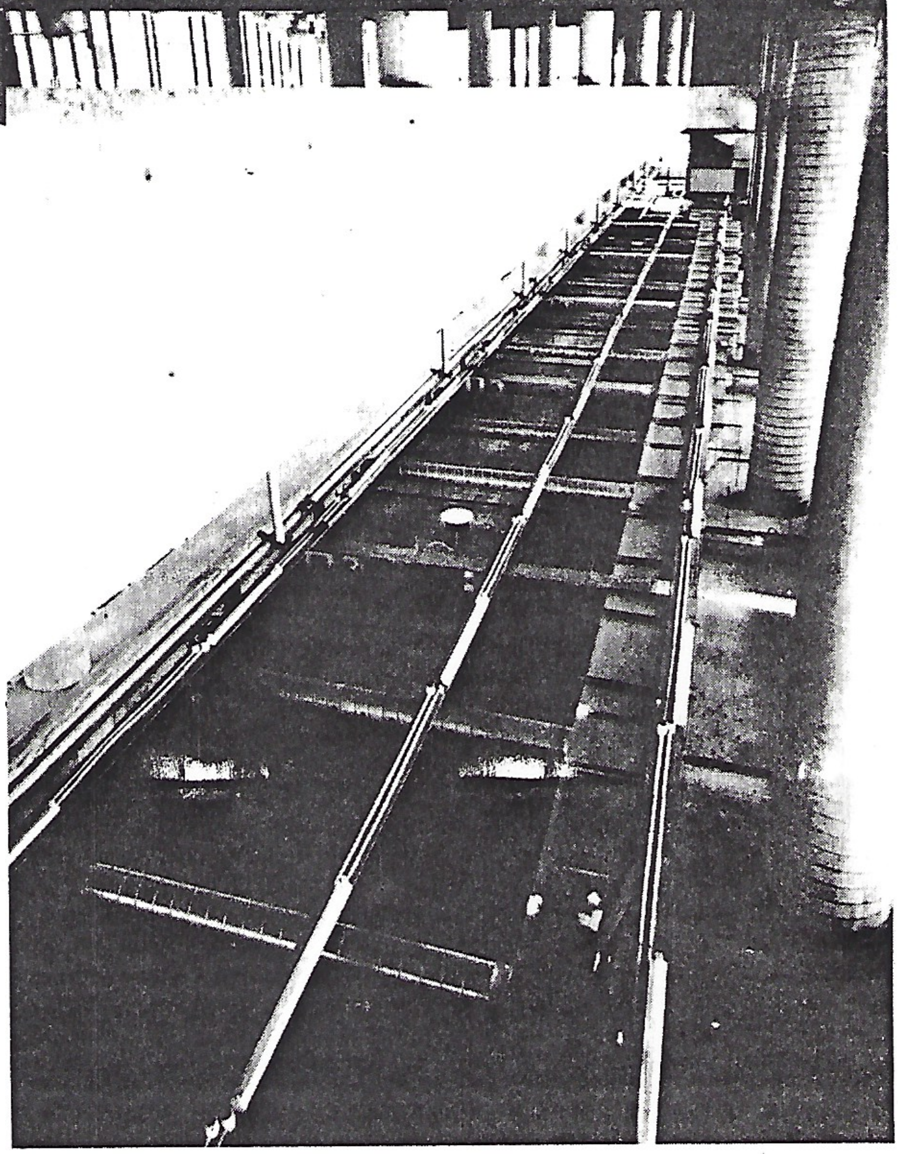

Figure 5: Air distribution system above open grid ceilings.

spaces to cater for the many and varied exhibits which are only now being designed and which will in any case be replaced and re-built from time to time.

For the very tall spaces in the Boiler, Turbine and Engine House and the concourse level (level 4) of the West Building, free standing air delivery columns have been designed. Figure 4 shows a prototype of one of these under smoke test to establish the exit area necessary to achieve throws of up to 12m.

These columns will stand along the walls of the large halls and will be supplied with air from ductwork below the floors. They have the ability to deliver air at four metres above floor without any alteration or connection to the existing walls and are also used to house loudspeakers for the public address system, motion detectors for the security system and emergency light fittings. In the West Building they are augmented by jet diffusers installed in the western edges of the levels 5 and 6 slabs.

Many areas under mezzanines in the West Building and Turbine House and in the exhibition levels in the Switch House have open gridded ceilings of metal slats at 75 mm centres. In these spaces ranges of rectangular ductwork above the ceilings supply air to "fingers" of spiral circular ductwork which have 50 mm dia. holes along each side of approximately 300 mm centres. Figure 5 shows a typical arrangement. The "fingers" are approximately three metres apart and air is diffused from them above the ceiling. Smoke tests indicate that satisfactory circulation through the open grid ceilings will be established by the entrainment of room air into the supply air streams. Return air is taken from spaces at low level.

Non-exhibition areas of interest include the six lecture rooms and the two theatres located on level 3 of the West Building.

Occupancy of the lecture rooms will vary between empty and full from time to time each day. It was therefore decided to adopt a variable air volume system for these spaces. A V.A.V. box is provided for each room and air is delivered through linear slot diffusers incorporated with light fittings.

Occupancy of the theatres will also vary from empty to partly or completely full from time to time. Each theatre has a single zone fan coil unit which will supply air to linear diffusers incorporated into the profiled ceilings. Operation of the units will be programmed from the direct digital control system to suit programme schedules.

Direct digital control system

A Thomas Clark TC-8088 direct digital control system will control and monitor all HVAC functions in Stage 2 except chiller leaving water temperature.

Controlled functions include, chiller sequencing, sea water heat exchanger sequencing, heating water leaving temperature, variable speed control on fresh air supply fans and chilled and heating water circulating pumps, space temperature and relative humidity set point daily re-set in exhibition spaces, and stop-start programmes for plant not required to run continuously.

Chilled and heating water and all air flows will be monitored by differential pressure sensors. This method was chosen rather than a simple indication of contactor on/off as being the more reliable. Digital pressure switches have been selected as these will give a positive indication of flow and are about one tenth the price of their analogue counterpart.

A similar differential pressure indication is provided on all filters to signal when they are dirty.

The system is connected to a total of 800 points and is based on distributed intelligence. A data processor will be installed in each of the main plant rooms and will hold all necessary control algorithms for connected items. Provision will be made at each of these points for full keyboard entry of data and a display unit capable of fully listing programmes, status and alarm information. These control units will be connected to a central workstation in the building managers office consisting of an IBM compatible personal computer with hard disc and floppy disc drives, colour monitor and printers for status and alarm signals. A separate monitor will be placed in the security control centre to give selected alarm indications outside normal working hours.

Advantages of the TC-8088 system include complete local design of system software, local sourcing of almost all of the hardware and simplicity and transparency of program language.

It is expected that direct digital control will have the benefit over alternative systems of stability of set points and reduced dependence on system hardware. Uninterruptible power supply units will isolate the system from spikes and irregularities in the mains supply.

Conclusion

Collections held by the Museum are a large and important part of our cultural heritage. Much of the material is unique and irreplaceable.

Many of these are liable to deteriorate more or less rapidly in uncontrolled atmospheres and even in those usually regarded as comfortable and relatively clean.

Surface discolouration, corrosion of metals, cracking and warping of wooden objects and deterioration of paper and textile items are all observable in material at present stored by the Museum in warehouses where of necessity the atmosphere is not controlled. Restoration is a painstaking, time consuming and costly process.

Because of the requirements for round the clock operation and close tolerance control of relative humidity in exhibition and storage areas operating costs will be high. One of the design aims has therefore been to incorporate cost effective energy conservation systems. Measures to achieve reduced energy consumption include; programmable control of air conditioning and lighting systems, heat recovery central energy heat pump system, variable speed drives on outside air fans and chilled and heating water circulating pumps, incremental chiller plant to improve part load efficiency, thermal insulation of roofs, temperature gradients in tall spaces, seasonal re-set of space temperature and relative humidity set points, and direct digital control and monitoring of systems.

It is believed that these provisions represent a reasonable balance between first and on-going costs and will assist the Museum in its important task of preserving and displaying unique material for study and enjoyment by future generations.

Acknowledgments

The Power House Museum is being constructed by the N.S.W. Public Works Department on behalf of the Museum of Applied Arts and Sciences. Air conditioning for Stage 1 was designed by D. Rudd and Partners Pty. Ltd., consulting engineers under the supervision of Mr. J. Cunningham. Mr. Cunningham also assisted with preliminary investigations for the air conditioning systems for Stage 2 which was subsequently designed by engineers of the Public Works Department with significant contributions by Malcolm Morgan, John Moore, Garry Hogan, Tony Dawes, and Barry Johnston.

Construction Authority and Construction Manager: N.S.W. Public Works Department; Architect: J. W. Thomson, Government Architect; Project Architect: Lionel Glendenning; H.V.A.C. Contractor: Haden Engineering Pty. Ltd.; Controls System Contractor: Thomas Clark & Son Pty. Ltd.

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