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FEATURE

Environmental control of a tropical conservatory

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This paper reviews the factors to be considered in providing environmental control within a tropical conservatory, and in particular for a site in Adelaide. The system developed departs from traditional evaporative cooling and uses a variation of the principle by direct injection of a fine spray into the conservatory air space.

Introduction

To talk on the environmental control of a tropical conservatory, it should be borne in mind that Adelaide is the site and its environment was a significant design parameter. The principles however will be applicable to other locations.

Australia has several tropical conservatories already — the pyramids of Perth and Sydney, the dome of Brisbane and, in a related way, the butterfly house of Melbourne. All use evaporative cooling units, standard commercial type or custom built, as their main environment control equipment. Used with these units are heating systems of one form or another.

The system designed for Adelaide employs principles being used widely in commercial glasshouses and greenhouses in the USA and in some locations in Australia. The use of evaporative cooling units, or pad and fan systems as the American growers call them, is being phased out by fogging spray systems controlled in conjunction with openable vents at high and low level. Fans and ducts are retained in some greenhouses as an aid for heating or for re-circulation, depending on the site — but their air supply rate is well below that of a traditional evaporative cooling unit.

Why a tropical conservatory (in Adelaide)

With areas of tropical forests available to people in Australia, why build a conservatory? A few of the many reasons are:

(i) difficulty in getting to see many of the plants.
(ii) some species endangered and a conservatory can offer a breeding source.
(iii) allows the display in one area of related species (from different areas) to allow comparisons in a manner that creates interest and aids their study.
(iv) allows the display of tropical plants from other tropical areas, e.g. Oceania, New Guinea, Indonesia.

To achieve these aims a structure is needed in which the environment can be created and maintained.

The structure and its services must also provide to its owners and visitors an area of display and interest that becomes part of that community and a quiet advertisement for their culture.

What is a tropical environment?

The weather patterns vary with latitude and locations. An equatorial zone is said to exist in a band 10° either side of the equator, with the tropical zone extending to the Tropics of Cancer and Capricorn.

The following data on equatorial and tropical zones provided design parameters for the building's environment.

Temperature

The mean annual temperature range in both zones is similar and is on average 5°C. By contrast, the diurnal range is quite large. The following temperatures occur in the respective climatic zones:

	Equatorial	*Tropical*
Minimum	16°C	20°C
Maximum	38°C	33°C
Diurnal Range	22°C	13°C

Humidity

The following humidity levels occur in each of the climatic zones:

Equatorial		Tropical	
Night	near saturation	Night	near saturation
Day	65-90%		65% or greater

Precipitation

The annual precipitation is similar in both zones ranging from 1250 mm to 4000 mm and locally can be as high as 5000 mm.

In general terms, the seasonal distribution of rainfall within the tropics is a function of latitude. At the equator rain falls at all seasons, while in the zone from about 3° to 10°, north or south there are two wet and two dry seasons, while further from the equator there is a single wet and single dry season in the year. The periods when the sun is in the zenith tend to be periods of heavy rainfall and the intervening periods are comparatively dry.

Light

The equatorial zone has a more or less permanent cloud belt where cloudless days are rare. In the tropical zone, the percentage of cloudiness varies during the year, being usually greatest during the wet season. Since even light cloud can cut down the light intensity and hours of sunshine appreciably, the difference in cloud cover in these two zones is important.

One of the characteristics of rainforest is the contrast between the low light level of the undergrowth and the dazzling brightness in the tree tops. From the tree tops down, the various layers of vegetation receive a decreasing amount of light.

On a clear day in the equatorial/tropical zones, the hours of daylight and light levels are as follows:

	hours of day light	light/day
maximum	12.5	717,000 lux hours
minimum	11.5	507,000 lux hours

By comparison the hours of day light and light levels in Adelaide are as follows:

	hours of day light	light/day
maximum	14.0	768,000 lux hours
minimum	9.0	278,000 lux hours

Information is readily available on radiation values in either MJ/m^2 or mWh/cm^2, related by

$$1\ MJ/m^2 = 27.8\ mWh/cm^2$$

To convert these to light levels an empirical relationship exists that gives reasonable results

$$1\ W/m^2 = 105\ lux$$

This then gives $1\ MJ/m^2 = 29{,}190$ lux hours

The information that is harder to determine is the minimum light levels a plant requires to remain healthy during the shorter and cooler days.

Air movement

In many parts of the tropical zone thunderstorms are preceded by squalls of strong wind lasting for only a few minutes. These winds may momentarily reach very high velocities and penetrate deep into the forests causing damage to plants. Further away from the equator the tropical zone is influenced by hurri-

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canes and cyclones, which, in the limited area in which they occur, cause considerable damage.

Characteristically the equatorial/tropical belt is a region of calm or very light winds creating moist stagnant air. One of the most noticeable features of the lower layers of the forest is the extreme stillness of the air. The mean annual wind velocities in tropical rainforest localities are commonly less than 5 km/hour. This is an important ecological factor as the amount of air movement affects the rate of evaporation and is therefore one of the factors controlling the transpiration rates and moisture requirements of the forest plants.

For this reason a low air movement within the conservatory is desirable and this leads one to think of systems other than evaporative cooling and its high air change rates.

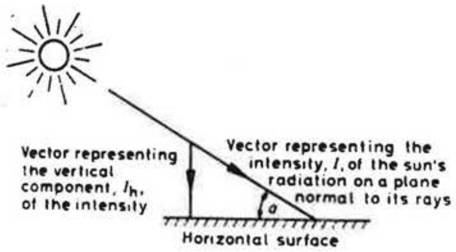
Heat load calculations

The energy balance equation [2] for a glass house can be written
R = P + S + G + E
where
R = radiation converted to heat inside the glass house
P = energy used in photosynthesis (typically < 1%)
S = heat flux into the soil (about 8%)
G = heat conducted through the glass = U.Ag (Ti-To)
E = heat given to the air in the form of an increase in enthalpy as it passes through the glass house.

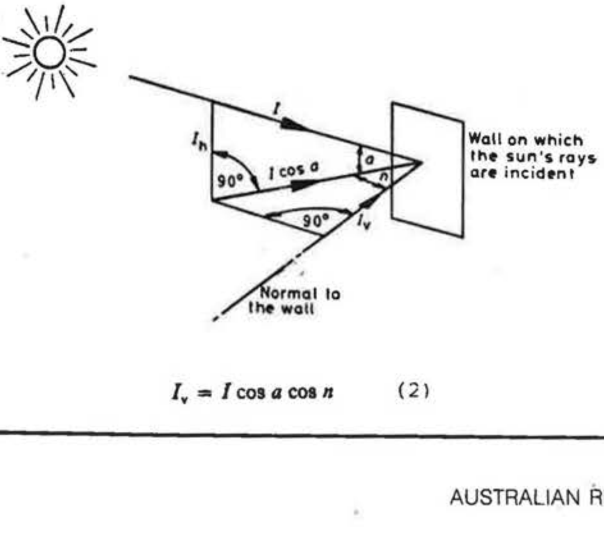
The energy entering the conservatory is a function of the glass, structure and the angle of incidence of the radiation falling on it. Standard tables are available for vertical and horizontal glass. Mr Ron Ballantyne, CSIRO, was good enough to provide ratings for glass inclined at 45° for the four cardinal and four subcardinal points of the compass.

This data was not directly applicable to our conservatory due to the angle of the glazing but was helpful in a checking sense. First principles had to be applied.

If the intensity of direct solar radiation incident on a surface normal to the rays of the sun is I W/m^2, the values for the components normal to the horizontal (Ih, and vertical Iv) surfaces can be calculated.

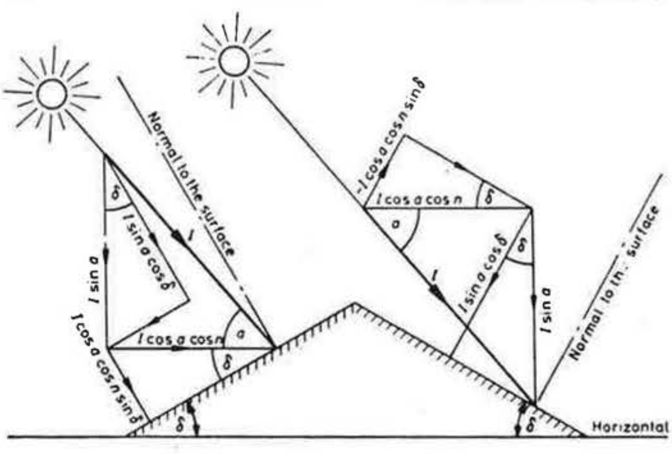


$$I_h = I \sin a \qquad (1)$$



$$I_v = I \cos a \cos n \qquad (2)$$

This then leads to the installation of the component of direct radiation normal to a tilted surface (Iδ), where δ is the angle the surface is tilted to the horizontal.



$$I_\delta = I \sin a \cos \delta \pm I \cos a \cos n \sin \delta \qquad (3)$$

This equation degenerates to eqn. (1) where δ = 0°, and eqn. (2) where δ = 90°. The significance of the alternative signs in eqn. (3) is that if the tilted surface faces the sun, a positive sign should be used and vice versa if the surface is tilted away from the sun. Naturally enough, if the surface is tilted so much that it is in shadow, I is zero, since the angles of incidence of the radiation will be 90°.

Equation (3) can be written in a more general but less informative manner.

$$I\,\delta = I \cos i \qquad (4)$$

where 'i' is the angle of incidence of the ray on the surface. This is true of all surfaces, but it must be borne in mind that the angle of incidence is between the incident ray and the normal to the surface. It is not the glancing angle.

Intensity of direct solar radiation with a clear sky

Inclination and orientation of surface		Sun altitude (degrees)											
		5°	10°	15°	20°	25°	30°	35°	40°	50°	60°	70°	80°
		Intensity of direct solar radiation with a clear sky (for place 0–300 m above sea level (W/m^2)											
1 Normal to sun		210	388	524	620	688	740	782	814	860	893	912	920
2 Horizontal roof		18	67	136	212	290	370	450	523	660	773	857	907
3 Vertical wall: orientation from sun in degrees (wall solar azimuth angle)	0°	210	382	506	584	624	642	640	624	553	447	312	160
	10°	207	376	498	575	615	632	630	615	545	440	307	158
	20°	197	360	475	550	586	603	602	586	520	420	293	150
	30°	182	330	438	506	540	556	555	540	480	387	270	140
	40°	160	293	388	447	478	492	490	478	424	342	240	123
	45°	148	270	358	413	440	454	453	440	390	316	220	113
	50°	135	246	325	375	400	413	412	400	355	287	200	103
	55°	120	220	290	335	358	368	368	358	317	256	180	92
	60°	105	190	253	292	312	210	320	312	277	224	156	80
	65°	90	160	214	247	264	270	270	264	234	190	132	68
	70°	72	130	173	200	213	220	220	213	190	153	107	55
	75°	54	100	130	150	160	166	166	160	143	116	80	40
	80°	36	66	88	100	108	110	110	108	96	78	54	28

With unusual shaped buildings, the calculation of heat loads is a lengthy process.

Air flow in the conservatory

The intent is to use the openable vents for natural ventilation to control air flow through the building, the flow being created by the wind, stack effect, cooling effect of the sprays and the internal conditions. The formulae used for the calculation of the air flow and openable vent area come from the ASHRAE books.

The air flow required at time of peak cooling load is given by (1985 Fundamentals, page 22.6)[3]

$$Q = \frac{H}{(cf1)\,Cp\,\rho\ \ (Ti\text{-}To)} = \frac{H}{(cf2)\,(Ti\text{-}To)}$$

where
Q = air flow removed, m^3/h
H = heat removed, W
Cp = specific heat of air at constant pressure, 1 kJ/kg.K

ρ = density of standard air, 1.2 kg/m^3
Ti-To = average indoor-outdoor temperature difference, K
cf1 = conversion factor, 0.28
cf2 = conversion factor, 0.34

The factors that affect ventilation wind forces include average speed, prevailing wind direction, seasonal and daily variation in speed and direction and local obstructions.

Having a required air flow and knowing a reasonable wind speed value for summer (winds are stronger in winter, usually), the free area of ventilation openings can be calculated from

$$A = \frac{Q}{(cf)\,Cv.v}$$

where

A = free area of inlet openings, m^2
Q = air flow, m^3/h
v = effectiveness of openings (Cv is assumed to be 0.50 to 0.60 for perpendicular winds and 0.25 to 0.35 for diagonal winds)
cf = conversion factor, 3600

In the case for Adelaide, the area was calculated at 140m^2, to be provided at both high and low level. The final building design gave 20 percent more area at the bottom, which will slightly improve the air flow.

It is envisaged that the ventilation damper operators will not be idle for too long as they respond to external winds.

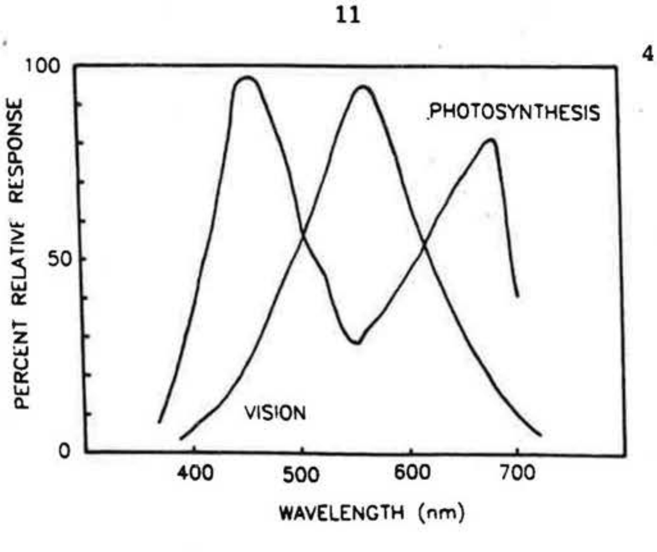
Light in the conservatory

In natural conditions, plants grow in the light environment of their locality and changes to this, despite the maintenance of temperature, humidity, and the time for which they are lit, will see alterations to their growing pattern, size, colour. It may even be sufficient to distress them to the point of collapse.

As only 1 per cent of the radiation falling on a plant is used in photosynthesis, the quality of this light is important.

In a tropical forest, the upper storey trees tolerate the full sun. Beneath this canopy it is dim, and the plants there are of a different class. For many the light that filters through the leaves of the top cover is sufficient for their healthy growth. It is equally important for many that they have a regular period of darkness.

Both plant and animal systems have evolved to use a narrow band of radiation between about 350 nm and 750 nm (see diagram). Due to the absorption characteristics of chlorophyll, plants utilise blue and red wavelengths most effectively, whereas human vision is stimulated maximally by green light.



Action spectra for photosynthesis and vision. Plant utilise blue and red light most effectively. Human vision is stimulated maximally by green light.

Water treatment

The mains water offers the cheapest and reliable source of water for a botanic garden. In some areas, however, there are inclusions, mostly natural but some deliberately added, which are not desirable in the long term interests of a botanic display. For the Adelaide water supply the salts level is high and fluoride is added to put some bite into it.

	Average	Range	
		Min	Max
Corductivity (μS)	792	499	1320
Dissolved Salts Calculated	399	269	696
Calcium (Ca)	28	22	36
Magnesium (Mg)	20	13	31
Chloride (Cl)	155	84	325
Fluoride (F)	0.92	0.33	1.12
ph Units	7.4	7.0	7.9
Colour (HU)	3	1	16

This quality of water is satisfactory for garden watering where seasonal rains come to the aid of plants and soil. In an enclosed conservatory this could be done from stored rainwater, but it is usually insufficient in quantity. The Botanic Gardens required water of better quality than the mains supply.

From the services viewpoint, this requirement had implications in that to allow the use of the high pressure fogging sprays (two systems were under consideration using either 4200 or 7000 kPa), metal pipes and not UPVC were necessary. Also, we wished to use copper and not stainless steel for economy and ease of fabrication.

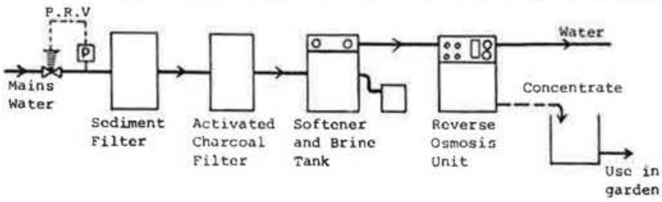
The headache was the removal of the fluoride, added to Adelaide water at 1 ppm as an acid.

This would not come out of solution in time as would the chlorine, or by the use of an activated carbon filter. The fluoride if deposited on the leaves has, in time, a deleterious affect on the photosynthesis process.

After discussion with a water treatment firm and the Botanic Gardens, a compromise was reached whereby water containing 60-80 ppm TDS and 0.02 ppm fluoride would be accepted. The selected system achieved a lower ppm. The combination of equipment chosen to do this is, in order of flow:

- a sediment filter (necessary in Adelaide) (chlorine attacks the membranes in the reverse osmosis system)
- an activated carbon filter to remove the chlorine
- a water softener (for calcium and magnesium removal)
- a reverse osmosis unit

This combination produced an output of 10,000 L per day. The waste water from the process is collected, pumped to a tank and then used for external ground watering.



These systems function best when operated continuously, and this will be done, except for times in the winter rain season when it can be shut down completely and rain used.

A de-ioniser system was considered but abandoned because of the handling of hydrochloric acid and caustic soda; the need to use treated water to regenerate the anion and cation resins; the need to neutralise before being able to release the drain and the aggresive property of the treated water with respect to copper pipe. This should not be taken as a criticism of de-ioniser systems which find application in many processes.

Water systems

Fogging system

For the fogging system, a high degree of filtration is required because of the small size of the nozzle orifice. The water treatment system does this.

As the water will be sprayed into the conservatory when visitors and staff are there, it was considered prudent to filter the water immediately before delivery to the pumps to strain out the Legionella pneumophila bacteria. At the time of the commencing the design, a Legionella outbreak occurred in Adelaide.

In discussions with the SA Health Commission, two schemes were proposed.

(a) a hollow fibre filter that could filter to below half the size of the Legionella bacteria.

(b) an ultraviolet filter to kill the bacteria.

The first was initially considered but finally the economics of the second won it acceptance.

Rain and pool systems

A pool is included in the landscaping display for aesthetic and aural reasons. The audible part is that it is the catchment for a small 'rain' system that will aid in the maintenance of the relative humidity and give some background noise which most people find pleasant in otherwise quiet surroundings. The water for this system is heated in a small plate heat exchanger to 22°C.

There is a general rain system provided by nozzles at the top of the structure, running off a line below the arch beam. This is for occasional use by the staff to wash-down the plants, and this water supply is also heated.

In winter this will use rainwater to help flush the soil.

Irrigation system

Water from the storage tanks is made available via a pressure pump to an in-ground irrigation system. This system is time controlled. The water for this will also be heated when necessary to provide water at about 20°C.

Storage of water

Most conservatories catch, store and use as much rain water as possible. Even in Hamburg where they get acid rain (ph of 4.9 has been recorded), they catch, treat and store rain water.

The problem is that the rain fall is not predictable and storage space is limited. There may be a heavy fall of rain most of which may have to be discharged because the tanks are full. In cities such as Adelaide, even if it was possible to store all the rain that fell on the conservatory, this would be insufficient for a year's water usage. The water usage rate was based on water used in the old palm house which had been recorded by the staff. The initial proposal was to match a tropical rainfall of 1250 mm.

The tanks to be used are to be the rectangular fibreglass type. They are suitable for rainwater and the storage of the treated water. They provided an inert, economical enclosure for the water.

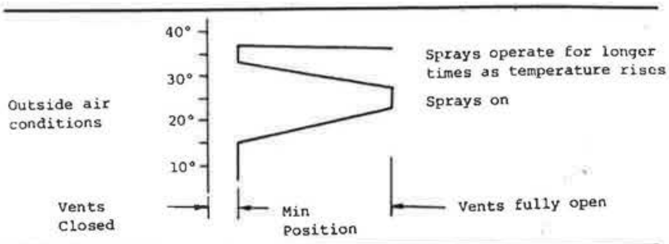
Costs restraints do not allow the automatic control of tank selection and usage, but provisions are to be made in the piping so that the installation of the necessary sensors and control valves can be fitted at a later date.

So the principle is to build as much storage as possible and reduce the operating costs to produce treated water.

Weather control system

The weather control system used in commercial glasshouses is simple and gives good results. An aspirated thermostat and humistat suspended in the growing area, generally about 2.0-2.5m above the ground controls the sprays, openable vents and heating. A control function sketch for such a system is shown below.

For the conservatory the need was seen to not only provide an environmental control system for the interior, but one that would record system operation for use as a reference in discussion with other botanic gardens on general operation and maintenance. It would also assist in teaching students interested in botany.



The control system monitors conditions external to the building, including temperature, relative humidity, sunlight level, wind speed and direction and the presence of rain.

Internally the system has twelve electronic temperature/relative humidity sensors located around the conservatory, at both low and high level. A sensor also records the carbon dioxide level and the light level is also monitored.

It is the internal sensors that will control the openable vents, which can be controlled in zones, the spray operation on an east-west zoning and the heating, again in twelve zones. With experience gained in operating the system, it is anticipated that the number of zones may be able to be reduced to eight.

There are commercial computer based systems available in the UK, West Germany and the USA suitable for such a conservatory. Simpler systems for greenhouses, as described above, are more widely available. The system to be installed in Adelaide is a 'local product', based on an IBM PC and sensors from various controls suppliers. The preparation of the softwear will be a joint effort between the contractor and the consultant, with the consultant initially operating and monitoring the system for the Botanic Gardens.

The functions the control system operates are:

(a) pneumatically operated louvre banks at high and low level, controlled in zones (see diagram). The louvres are driven by double-acting pneumatic operators selected for external operation.

(b) fogging sprays on an on/off variable time basis, zoned east and west to suit the north-south orientation of the building and the fact that at times half the glass (east or west) will be in shade.

(c) heating by hot water, using both perimeter convection heating piping and heated air supply from four fans.

Not controlled by this system is the pool flow and pool rain system which will be continuous except for maintenance.

The system will close the top sets of louvres to half open when rain is sensed. The lower sets will continue to operate to maintain the internal conditions.

The division of the heating load between the convection piping and the air was an arbitrary one. After consideration the convection system capacity was set to match the glass conduction and the air to heat the minimum ventilation figure and the heat loss to infiltration (assumed at 0.5 change/hour). This gave a piping system in keeping with those seen in overseas conservatories using this dual heating system.

The air heating system outlets will ensure warm air reaches the top of the building and with the heating from the convection pipes in the centre of the building (beneath a raised walkway) will combine to stop a cold downdraft from the high glass and infiltration through the top louvres.

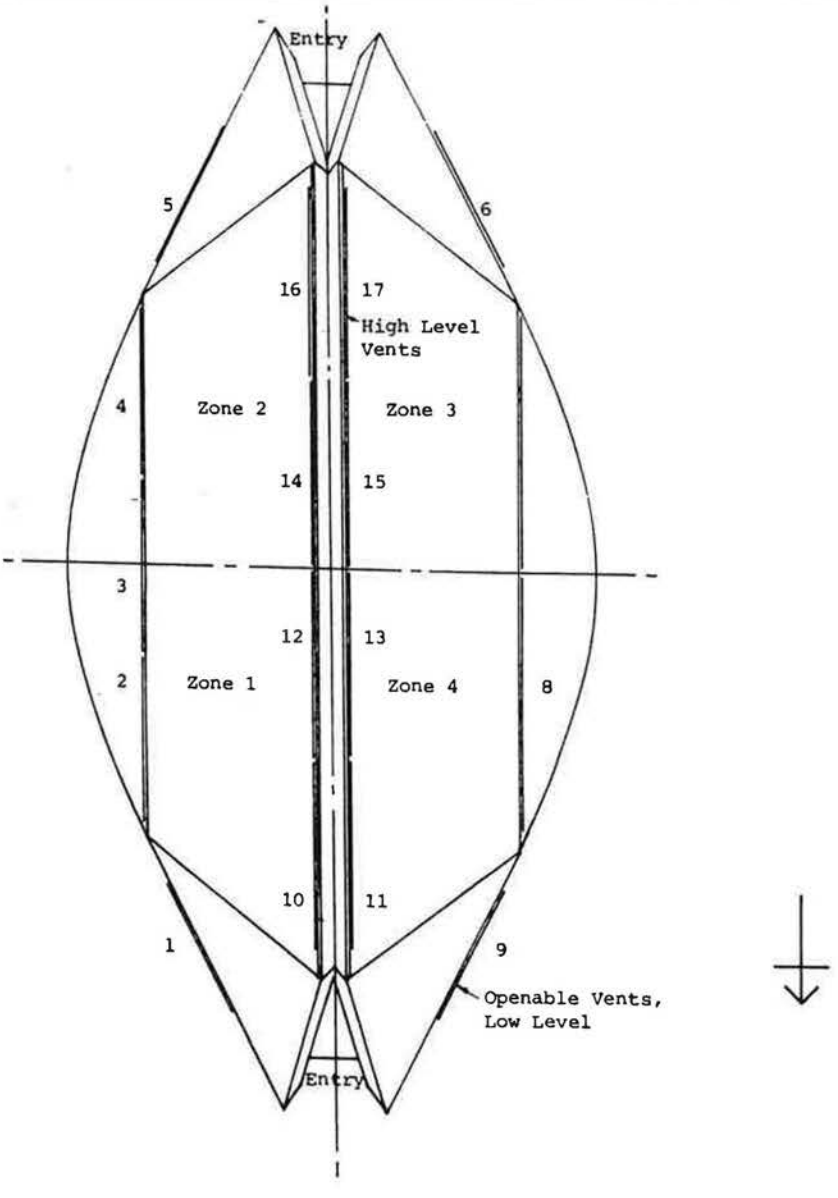
In the winter, it is envisaged that the louvres will be closed for most of the day, and certainly at night.

There will be condensation on the interior of the glass and this is designed to run down and into condensation drains in the glazing system. Condensation will run rather than drip, on surfaces angled at greater than 26° to the horizontal. A value of 25 ml of water per minute per m^2 was used as a worst case flow for the drain channel design. This condensation on winter nights is expected to severely retard radiation heat losses to the night sky.

The control system will also monitor equipment operation and will be connected to a watching service for out-of-hours attention to plant failure or the movement of the internal conditions outside the prescribed limits for that period. The com-

BOTANIC GARDENS OF ADELAIDE

CONTROL SYSTEMS



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puter is to be located remote to the site, as no space was available within the equipment rooms.

Soil warming

Have you had your root zone warmed today? No? — well don't be disappointed — neither will the plants at the conservatory.

Soil is known to have good thermal properties and with the air above it being maintained at a warm temperature, root zone warming (RZW to the initiated) will not be required. RZW is used in some commercial applications for crops such as tomatoes, but has not been shown of benefit in conservatories.

The soil temperature follows that of the air and even at approximately 300 mm follows the pattern of the daily average temperature for that time of year but delayed by about one month. This applies down to 2m.

When visiting the University of Hamburg conservatory, the effect this warming can have in some areas was noted. Here the air (heated in winter) is distributed through a concrete in-ground duct around the perimeter. The duct has slot outlets in the top blowing air up the vertical glass face. This duct was warming the soil inside the conservatory and improved growth was resulting in the area alongside it. The duct also provided a barrier to the very low soil temperatures outside in winter.

Why a fogging system?

With the vast majority of tropical conservatories utilising evaporative cooling systems, why change? The natural environment of the tropical forest is one of calm with only light winds. The 45-60 air changes per hour that would be used with an evaporative cooler were considered as not entirely compatible with this. The very large ducts would be both costly in themselves and physically large, sufficient to be an architectural design problem. The operating costs were also considered. Using 45 air changes per hour the total air flow would be 391.25 m^3/s. The energy required to move this would be 125 kW and a total annual energy consumption value of 736,600 kWh.

In comparison the fogging spray pumps, filters, air compressor to operate the openable vents and the fans to operate in the winter for the heating will use 219,500 kWh — 35 per cent of the evaporative cooler system. The energy conservation achieved is of great value to the client body and is a benefit of being aware of systems used here and elsewhere in the world.

In America, one commercial grower in Texas with four green houses using 'pad and fan' systems changed to a fogging spray system. He operated his vents manually. His power consumption was reduced by 80 per cent and his crops improved in quantity and quality. A similar result was seen in California, and in Utah 2.43 hectares of roses were also benefiting from a fogging spray installation.

The spray, injected as water particles of 10 micron size evaporates in the air. This particle size is that of a naturally occurring fog, and has been used in 'fog sculptures'. If the spray is held on and the air is still a fog can be produced. In operation it will be absorbed into the air taking the latent heat of evaporation from the radiation entering through the glass. The combination of the air movement due to the stack effect up the inside of the glass and the cooling effect of the evaporation of the moisture will create the desired low air movement within the conservatory.

It is expected that at times a plume of moist air will be visible, streaming from the upper vents — sure to get letters complaining of wastage of energy.

Maintenance

Part of the environmental control system operation will be the maintenance of the filters, pumps and sprays. With the spray nozzles on branch pipes on the underside of the sloping trusses, this posed a problem.

A scheme to service these from a travelling gondola that ran along the arch beam was discarded due to cost. This envisaged the gondola carrying a one-man maintenance cage to a truss and then having this cage travel down and up the truss, operated by a winch on the gondola.

A simple scheme was finally selected using a trolley to travel up and down the UC section bottom chord of the trusses with a chair supported from a trolley, the trolley being hauled by a portable winch at the bottom end of the truss. The winch, trolley and chair are moved from truss to truss as required. The winch is electric and is fed from a wall outlet (adjacent each pair of trusses).

For the exterior, a glass cleaning unit based on the use of 'Swirl-on' from the top of the building.

A maintenance programme for the mechanical plant will be prepared and operated by mechanical contractors as the Botanic Gardens do not employ the necessary specialist tradespeople.

Conclusions

The system as described is expected to find increasing use in the commercial plant propagation and growing field in Australia, as it is in the USA. A number of spraying systems already exist here, some having been introduced as cooling systems for poultry laying batteries.

The economy of operation offered by these systems and the general improvement in plant condition and growth are the major benefits offered by such systems.

The choice of spraying system, extent of openable vent and the control of these systems will ensure competition in this industry and, no doubt, further design investigation or products and design methods.

It is possible that a later paper can be given on the actual operation of the Adelaide system.

Acknowledgements

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3. ASHRAE Fundamentals, 1985 edition (S.I. units).
4. Loveys, B. R.: 'Light Quality and Plant Growth', presented at the 29th IES National Convention 1983. ■

NEW PRODUCTS

New range of compressed air dryers

The UK based Domnick Hunter company which is a world leader in products that provide high quality compressed air has just released two new ranges in their Pneudri family of desiccant compressed air dryers.

The two new ranges — Pneudri Mini and Pneudri Midi are designed to achieve dry compressed air in any industrial application. They complement the large capacity Pneudri maxi range for large volume industrial applications which was introduced several years ago.

The two new ranges — Pneudri Mini and Pneudri Midi.

Filtermation Pty Ltd of Thomastown, Vic. is the sole Australian distributor of the Domnick Hunter range of filtration equipment and has now added all three models in the Pneudri series to their product range.

The Pneudri Mini and Midi compressed air dryers are designed as modular, self contained dryers which can be mounted simply into any compressed air installation with pre- and after-filtration. They employ a well proven drying principle to remove water vapour and are compact, self contained units requiring no interconnecting pipework. Their performance is unaffected by cold ambient conditions which can adversely affect other types of dryers. They are also compatible with the Domnick Hunter Oil-X range of compressed air filters which also ensure delivered air quality by particulate, oil mist and oil vapour removal.

The performance flow rates of the Pneudri Mini range commences at 1.4 litres per second and the Pneudri Midi range at 9.5 1/s (100-100kPa gauge).

Filtermation Pty Ltd provides a high degree of technical suport for specialist compressed air applications and also offers comprehensive technical literature on all three Pneudri dryer ranges. For more information please contact: Filtermation Pty Ltd, 1 Longview Court, Thomastown 3074. Telephone (03) 4658822.

Flowhood air balance systems

Flowhood air balance systems are available in either the analog mechanical model CFM-83, or the new digital electronic models, the CFM-85 and the backpressure compensating CFM-85BP. The new electronic meters are easy to use, more shock resistant and faster reading than previous models. All Flowhood units are complete with the capture hood assembly, selected top sizes and a meter calibrated for air flow measurement only.

The Models 8420 and CFM-86BP Airdata Multimeters may be used as hand-held portable meters for velocity, pressure or temperature, or when used with a flowhood air capture hood kit, may be used to obtain direct air flow readings. Features include, memory, recall, average, and sum to 99 readings. The Model 8420 provides maximum capability with local and standard air density corrected readings displayed in English or metric units. The Model CFM-86BP is a simplified version and provides local density corrected readings in English units only. Please note that the airdata Multimeter kits may be purchased with, or without a flowhood capture hood kit.

For further information please contact: John Dawson, Instrument Supply Company, 177 Payneham Road, St Peters, SA 5069. Telephone: (08) 363 1460 Fax: (08) 363 1953 telex: AA89725.

Flowhood air balance system.