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MELBOURNE AND METROPOLITAN TRAMWAYS BOARD

ENGINEERING DEPARTMENT

PLANNING BRANCH.

SOME THOUGHTS ON THE VENTILATION OF TRAMWAY SUBWAYS.

AUGUST 1966.

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INTRODUCTION.

It is of importance from the point of view of public appeal that atmospheric conditions within tramway tunnels are controlled within such limits as to be at all times more comfortable than the conditions prevailing at street level. They should not be marred by excess temperature, draughts, stagnant pockets of air or unpleasant odours.

This ideal may on occasions be difficult to achieve as Melbourne enjoys a mild and generally pleasant though somewhat variable climate with a mean average temperature of 58.8°F. - refer diagram No. 1.

As a result the average temperature differential below the acceptable maximum in the tunnel which would be available for the removal of excess heat by air circulation would be of the order of 10 to 15°F.

However a detailed study of specific schemes may be necessary to decide whether adequate and satisfactory ventilation may be achieved by natural convection aided by vehicle movement or whether assisted ventilation may also be necessary and to what extent.

Overseas practice in the past appears to be to provide additional ventilation only after it has been proved necessary - in some cases a considerable time after.

2. FACTORS TO BE CONSIDERED.

2.1. Dust removal.

The problem of dust created during construction would be the concern of the construction organization and should present no unusual problems.

Dust will however be produced though perhaps on a minor scale during operation due to sanding for adhesion while accelerating and braking, the drying of mud brought in on peoples footwear, and sweeping.

It is not anticipated that the dust problem would require special treatment.

2.2. Exhaust fumes.

If internal combustion fuel engines are not permitted within the tunnels this problem should be negligible even though the air at street level is to some extent polluted by motor vehicles.

A compressed air line through the length of the tunnel for the convenience of maintenance personnel may warrant further consideration.

2.3. Unpleasant odours.

These may arise from sewer gas, town gas, fumes from paints or other surface treatment chemicals, and sometimes from damp earth. Another source of objectional odours would be due to the breakdown of equipment such as a hot axle box or burnt electrical insulation.

The elimination of some of these may require a considerable movement of air.

2.4. Humidity.

This would be minor. It could result from damp tunnel walls, on days when the air drawn in from outside is both warm and of high humidity. The solution of course is to ensure that the walls are dry and that there is adequate air circulation.

2.5. Stagnant air pockets.

It is considered that the movement of vehicles through the tunnel will create such air movement that the problem of stagnant pockets of air is unlikely to arise. On the other hand the clearance between the vehicles and the tunnel walls at present under consideration should not result in excessive draughts.

2.8. **Temperature.**

This is the criterion for the design of the ventilation. The governing factor will be passenger comfort - and the aim should be to ensure that the tunnels are pleasantly warm in winter and also pleasantly cool in summer.

The upper limit should be somewhere in the 70-75°F range depending on humidity.

Refer table 1 also diagram No. 1.

TABLE 1

A.S.H.R.A.E.* COMFORT TABLE

AIR MOVEMENT 15 TO 25 FT. PER MIN.
90% APPROVAL.

RELATIVE HUMIDITY %	50	60	70	80	90	100
Comfort Temperature Range Winter °F	68½ 74½	67½ 73½	67 72½	66½ 71½	66 70½	65½ 69½
Summer °F	74½ 78	73½ 77	72½ 76	71½ 74½	70½ 73½	69½ 72½

*American Society of Heating, Refrigerating and Air Conditioning Engineers.

3. **TUNNEL HEAT RELEASE.**

The entire electrical energy consumption of underground trams will appear as heat, and apart from the energy losses in external substations and feeders this heat will be released within the tunnels. Its only means of escape will be into the tunnel walls and surrounding earth and in the air that is blown out or is sucked out of the tunnels.

The following quotation which refers to the London Tubes is taken from the book "Rails Through The Clay". "The primary purpose of the ventilation system on tube railways is to remove heat, and it has been estimated that 30% of the heat released when coal is burnt at Lots Road is eventually emitted in the tube tunnels from motors, resistances and brakes. Heat from passengers' bodies adds a little more. The subsoil surrounding tube tunnels has been gradually warming up ever since the lines were opened" The London Tubes were at about 73°F in 1963.

At present Swanston Street is traversed by over 1,000 trams per day in each direction and the power consumed per tram mile is 3.27 kwhr. These trams carry about 90,000 passengers. If it is assumed that

(i) 10 people release 1 kilowatt of heat - refer appendix No. 1 and diagram No. 2

(ii) the average tram load is 22 people i.e. the trams enter empty and leave with 45 people or vice versa

(iii) the average speed is 12 m.p.h.

then the heat release by the passengers per tram mile is therefore

$$= \frac{22}{10} \times \frac{1}{12} \text{ kwhr. per mile}$$

$$= 0.18 \text{ kwhr. per mile.}$$

Hence 1,000 trams will release about 3,500 kwhr. per mile of single tunnel which is equivalent to an average heat release spread over the 24 hours of about 150 kw. per mile of tunnel.

If however the service is doubled by coupling in pairs and both the rate of acceleration and top speed are increased this heat release could be increased up to the order of 450 kw. per mile, which would be equivalent to a 1 kw. radiator every 12 feet radiating continuously.

4. VENTILATION REQUIREMENT.

If the average outside air temperature is assumed to be 59°F and that air is heated 15°F so that it is exhausted at 74°F, then the air changes may be determined as follows.

Volume of tunnel per mile (16 ft. internal diameter)	=	1,100,000 cft.
Assume air density is 12 cft. per lb.		
Mass of air in a mile of tunnel	=	92,000 lb.
If the specific heat is 0.23BTU/°F/lb. and the temperature rise is 15°F		
Heat input to air per mile of tunnel	=	320,000 B.T.U.
(Since 1 kwhr. = 3413 B.T.U.)	=	93 kwhr.
For present service with an average heat release of 150 kw. per mile		
Number of air changes required per hour	=	1.6
If heat release increases to 450 kw. per mile number of air changes required per hour	=	4.8

It is of interest to note that fans on the London Tubes are capable of giving about 3 air changes per hour, and to this must be added air changes due to trains and natural convection through openings.

5. METHODS OF VENTILATION.

5.1. Piston action of vehicles.

If the vehicles operate through separate tunnels which are connected at stations then if each tram acted as an airtight piston there would be one complete air change between the tunnel beginning (or end) and the first station for each tram. In practice though, leakage past vehicles would be large, the volume of air swept in and out would be more than adequate at the first station.

There would be a similar air interchange with the first and second stations, but of course the mean air temperature circulated between these stations would be higher and thus the second station would be warmer.

It is therefore reasonable to assume for a comparatively short tunnel with 3 or 4 stations and the "up" and "down" tunnels are separated between stations,, ventilation by the tram is likely to prove adequate.

Passageways and various underground rooms may however require special ventilation.

It does not necessarily follow however during prolonged periods of extreme weather conditions that conditions in the tunnel though perhaps remaining more comfortable than at street level may not also become unpleasant despite the equalizing effect of the temperature of the tunnel walls.

5.2. Ventilation by convection.

This is based on the simple principle that "warm air rises". The basic problem here is that the air movement depends on the temperature difference between the atmosphere in the tunnel and that outside.

While it may be utilized to provide considerable air movement averaged over considerable periods, refer diagram No. 2, there may be periods of several days however during heat waves when it would be ineffective.

A technical problem would be to provide the necessary outlets of sufficient cross section area to handle the required volumes of air. Locations for such ventilation shafts and towers would be difficult to obtain within the Central City Business Area.

A strong prevailing wind in the line of a tunnel of some length too would cause a considerable flow of air along its entire length, but it would be both variable and unpredictable, and could cause discomfort to people waiting at the first station.

5.3. Forced ventilation.

This is of course the most reliable method and by using fans the desired air flow may be achieved directly to where it would be most effective. This would be most desirable in regions where people are waiting for the trams. Duct sizes may be reduced to the economic minimum taking into consideration the additional cost of operation due to the increased velocity of air flow.

The ideal would be to draw the air from well above street level away from dust and motorcar exhaust fumes and blow it into the tunnels. Thus the tunnels would be pressurised forcing the air to escape along tramway tunnels, passenger access tunnels, and selected shafts through gratings at street level or convection towers.

6. AIR CONDITIONING.

This is likely to be required only for specialized applications such as offices, shops and chambers housing special equipment. It is not likely to have any appreciable influence on the preliminary design of underground tramways.

ESTIMATES OF ENERGY METABOLISM (M) OF VARIOUS TYPES OF ACTIVITY.

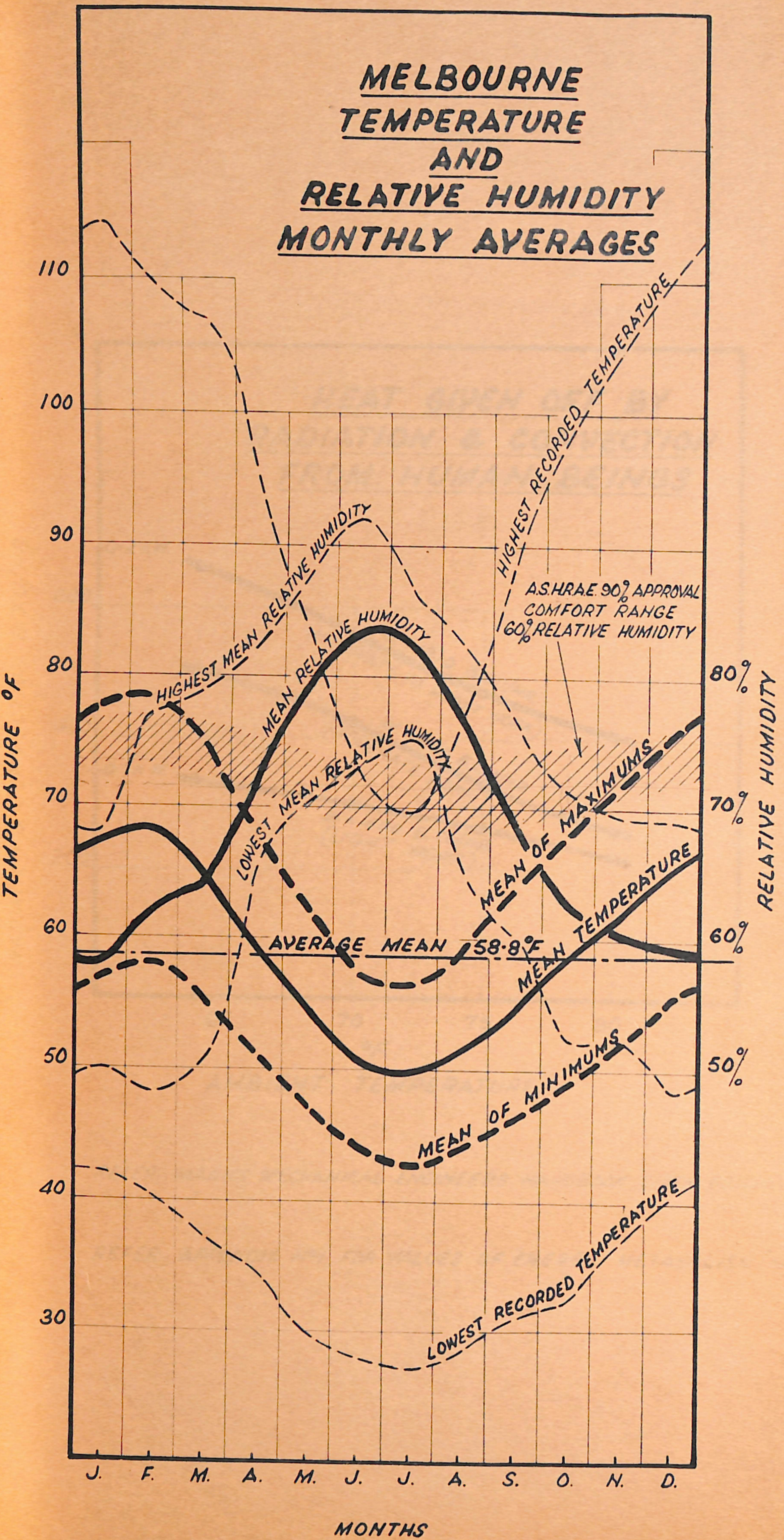
REFER A.S.H.R.A.E. GUIDE AND DATA BOOK 1963.

VALUES APPLY TO A 154LB. MAN AND DO NOT INCLUDE REST PAUSES.

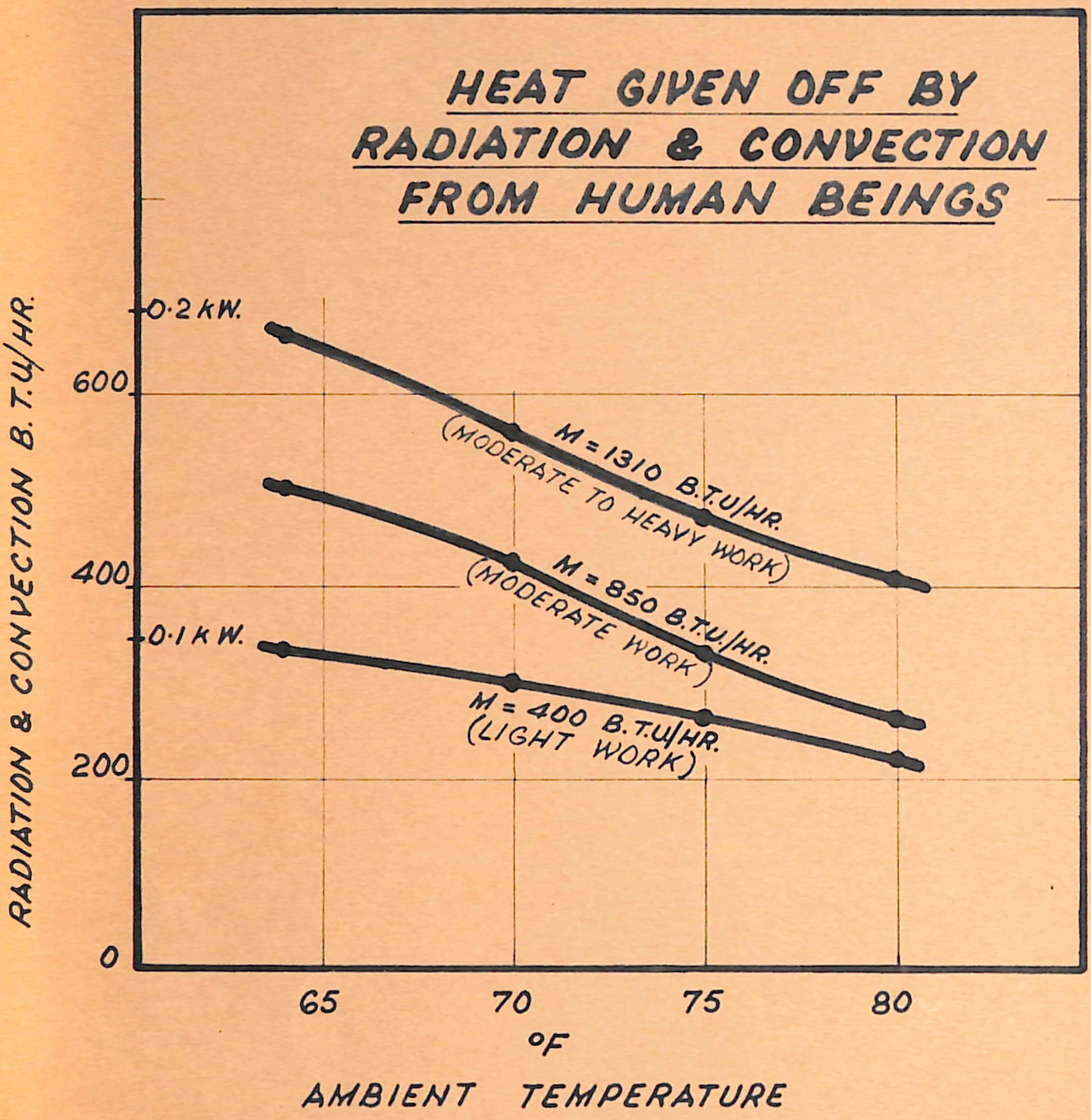
KIND OF WORK	ACTIVITY	M B.T.U./HR
	Sleeping.	250
	Sitting quietly.	400
Light work	Sitting, moderate arm and trunk movements.	(450 (550
	Sitting, moderate arm and leg movements (e.g. driving a car in traffic)	(550 (650
	Standing, light work at machine or bench, mostly arms.	(550 (650
Moderate work	Sitting, heavy leg and arm movements.	(650 (800
	Standing, light work at machine or bench, some walking about.	(650 (750
	Standing, moderate work at machine or bench, some walking about.	(750 (1000
	Walking about with moderate lifting or pushing.	(1000 (1400
Heavy work	Intermittent heavy lifting, pushing or pulling (e.g. pick and shovel work).	(1500 (2000
	Hardest sustained work.	(2000 (2400

Note - One kilowatt = 3413 b.t.u./hr.

Note - Refer diagram No. 2 for heat loss due to convection and radiation.



REFER COMMONWEALTH YEAR BOOK No. 51 – 1965.



REFER MARKS MECHANICAL ENGINEERS HANDBOOK SIXTH EDITION.

REFER APPENDIX No. 1 FOR VALUES OF ENERGY METABOLISM (M)