

Australian Standard™

**Atmospheric heating of vessels
containing fluids— Estimation of
maximum temperature**



This Australian Standard was prepared by Committee ME/1, Pressure Equipment. It was approved on behalf of the Council of Standards Australia on 30 November 1999 and published on 3 April 2000.

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Australasian Institute of Engineer Surveyors
Australian Aluminium Council
Australian Building Codes Board
Australian Chamber of Commerce and Industry
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STANDARDS AUSTRALIA

RECONFIRMATION
OF
AS 2872—2000
**Atmospheric heating of vessels containing fluids—Estimation of maximum
temperature**

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NOTES

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PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee ME/1, Pressure Equipment to supersede AS 2872 — 1988.

This Standard is the result of a consensus among representatives on the Joint Committee to produce it as an Australian Standard. Consensus means general agreement by all interested parties. Consensus includes an attempt to remove all objections and implies much more than the concept of a simple majority, but not necessarily unanimity. It is consistent with this meaning that a member may be included in the Committee list and yet not in full agreement with all clauses of this Standard.

Changes since the last edition include the following:

- (a) Inclusion of properties of the refrigerant R134a.
- (b) The addition of Appendix C which provides the theoretical background for the method given in this Standard.
- (c) Inclusion of Appendix D which provides a sample of calculation of thermodynamic properties for refrigerant R404A.

The atmospheric data presented is believed to be conservatively realistic, but provision has been made for departure from the data where, for a particular location, more accurate historical data are available.

This method of estimation should be an aid to investigators concerned with —

- (i) the prediction of maximum temperatures and pressures in vessels;
- (ii) estimation of ullage requirements;
- (iii) assessment of maintenance requirements; and
- (iv) writing of application Standards.

Acknowledgment is gratefully made of the considerable assistance provided by Orica Engineering Pty Ltd (formerly ICI Australia Engineering Pty Ltd), which included technical investigation and the development of the data and calculation methods presented in the Standard.

The terms 'normative' and 'informative' have been used in this Standard to define the application of the appendix to which they apply. A 'normative' appendix is an integral part of a Standard, whereas an 'informative' appendix is only for information and guidance.

CONTENTS

	<i>Page</i>
1 SCOPE	4
2 NOTATION AND CALCULATION PARAMETERS	4
3 METEOROLOGICAL DATA	6
4 CALCULATION OF TEMPERATURES	6
5 VAPOUR PRESSURE	6
 APPENDICES	
A PROPERTIES OF FLUIDS	13
B SAMPLE CALCULATIONS AND CALCULATION SHEET	22
C THEORETICAL BACKGROUND TO THE METHOD GIVEN IN THIS STANDARD	25
D SAMPLE CALCULATION OF THERMODYNAMIC PROPERTIES FOR REFRIGERANT R404A	33

STANDARDS AUSTRALIA

Australian Standard

**Atmospheric heating of vessels containing fluids —
Estimation of maximum temperature**

1 SCOPE This Standard sets out a method for calculating temperatures and the corresponding vapour pressures of fluids in vessels subject to atmospheric heating in the hottest month of the year in various locations around Australia. It is primarily intended for compressed liquefied gases stored in steel containers, and is equally applicable to stationary as well as transport vessels. Because the method is quite general it may also be used for permanent gases and liquids, provided that the liquids are not too viscous (upper limit approximately 1 Pa.s). It may also be used for above-ground pipelines.

Some characteristic properties of a number of fluids are shown graphically in Appendix A.

NOTES:

- 1 Sample calculations are shown in Appendix B.
- 2 The theoretical background for the method given in this Standard is given in Appendix C.

2 NOTATION AND CALCULATION PARAMETERS For the purpose of this Standard, the following notation applies:

- A = total surface area, in square metres
- A_s = daily mean projected area exposed to sun, in square metres
= 0 if vessel is shaded or under cover
- a = absorptivity of surface
 - = 0.15 for aluminium
 - = 0.25 for clean white painted surface
 - = 0.25 for slightly dirty aluminium surface
 - = 0.30 for slightly dirty white painted surface
 - = 0.35 for dirty white painted surface but which is still recognizably white
 - = 0.40 for stainless steel clean surface
 - = 0.45 for slightly dirty stainless steel surface
 - = 0.45–0.60 for coloured surfaces (see manufacturer's data)
 - = 0.75 for heavily rusted surface
 - = 0.95 for matt black surface

NOTE: For painted surfaces that are dusty or degraded, use an intermediate value between the relevant value above and 0.75 (heavily rusted surface).

$$b = \frac{a}{h} \left(\frac{A_s}{A} \right), \text{ in square metre kelvins per watt}$$

where

$$\left(\frac{A_s}{A} \right) = 0.25 \text{ for spheres}$$

= value determined from Figure 2 for cylinders

- c = isochoric (constant volume) heat capacity of vessel contents per unit volume evaluated at mean temperature T , in joules per cubic metre kelvin
- = c' when vessel is nearly full
 = c'' when vessel is nearly empty
 = c_v/v for permanent gases and liquids
 = c_p/v for vented (atmospheric) vessels
- c' = isochoric heat capacity of boiling saturated liquid per unit volume, in joules per cubic metre kelvin (see Appendix A)
- c'' = isochoric heat capacity of condensing saturated vapour per unit volume, in joules per cubic metre kelvin (see Appendix A)
- c_v = isochoric specific heat capacity of vessel contents, in joules per kilogram kelvin
- c_p = isobaric specific heat capacity of vessel contents, in joules per kilogram kelvin
- c_t = specific heat of vessel material, in joules per kilogram kelvin
 = 900 J/kg.K for aluminium
 = 462 J/kg.K for steel
- D = diameter of vessel, in metres
- d = thickness of insulation layer, in metres
- F = parameter from Figure 1
- h = outside surface heat transfer coefficient, in watts per square metre kelvin
- $h = h_c + h_r$
- h_c = convective heat transfer coefficient, in watts per square metre kelvin
 = $5 + 4(v^{0.8})$ where v is velocity of air, in metres per second
 For stationary surface $h_c = 5 \text{ W/m}^2\text{.K}$
- h_r = radiation heat transfer coefficient, in watts per square metre kelvin
 = 1.0 for aluminium and stainless steel surfaces
 = 4.0 for painted surfaces
- m_t = mass of empty vessel without insulation, in kilograms
- p_v = vapour pressure (absolute), in megapascals (see Appendix A)
- R = mean daily total global radiation for hottest month, in megajoules per day square metre (see Clause 3 and Figure 3)

- r = fractional increase in global radiation due to reflection from surroundings.
Typical values are:
 = 0 for grassed areas
 = 0.1 for gravelled areas
 = 0.2 for clean concreted areas
 = 0.3 for reflection from two adjacent walls and paved areas. (Note that in this latter case, the global radiation may be reduced due to shadows for part of the day).
- t_A = mean monthly air temperature for hottest month, in degrees Celsius (see Clause 3 and Figure 4)
- t_{Amax} = maximum air temperature, in degrees Celsius (see Clause 3 and Figure 5)
- t_F = mean temperature of fluid during hottest month, in degrees Celsius (see Clause 4)
- t_{Fmax} = maximum fluid temperature for appropriate condition in Table 1, in degrees Celsius (see Clause 4)
- V = effective fluid volume of vessel for calculation purposes, in cubic metres (see Table 1)
- v = specific volume of contents, in cubic metres per kilogram
- λ = conductivity of insulation material, in watts per metre kelvin
- τ = time constant, in seconds
- $$= \left(\frac{cV + m_i c_i}{A} \right) \left(\frac{1}{h} + \frac{d}{\lambda} \right)$$

3 METEOROLOGICAL DATA Figures 3, 4 and 5 contain meteorological data based on general information available with some minor local effects occasionally disregarded. Where reliable local data for periods not less than 10 years exist, such data should be used where it differs significantly from the data in Figures 3, 4 and 5.

NOTE: The data in Figures 3, 4 and 5 are believed to be applicable to an expected return period of 20 years.

4 CALCULATION OF TEMPERATURES

4.1 Mean fluid temperature during hottest month (t_F) The mean temperature of fluid during hottest month may be calculated as follows:

$$t_F = t_A + \frac{(1 + r)Rb}{0.0864} \quad \dots 4.1$$

4.2 Maximum fluid temperature (t_{Fmax}) The fluid temperature for the calculation conditions given in Table 1 may be calculated using the effective fluid volume specified in the table for the relevant condition and the following equation:

$$t_{Fmax} = t_F + F[900(1 + r)b + t_{Amax} - t_F] \quad \dots 4.2$$

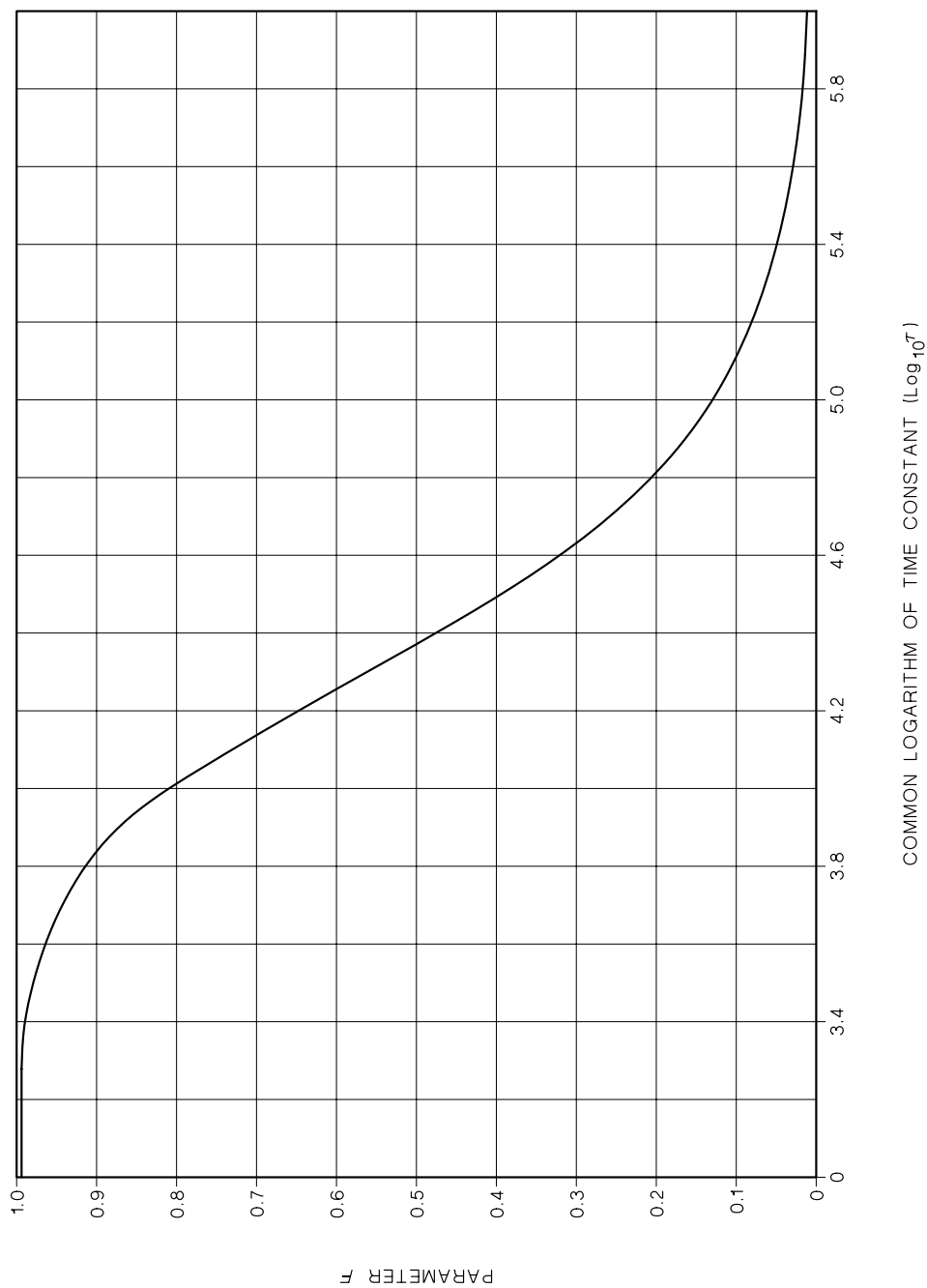
5 VAPOUR PRESSURE The vapour pressure equivalent to the temperature T_{Fmax} calculated from Clause 4.2 may be determined from any source that gives characteristic properties of the relevant gas. Temperature/vapour pressure curves for some gases are given in Appendix A.

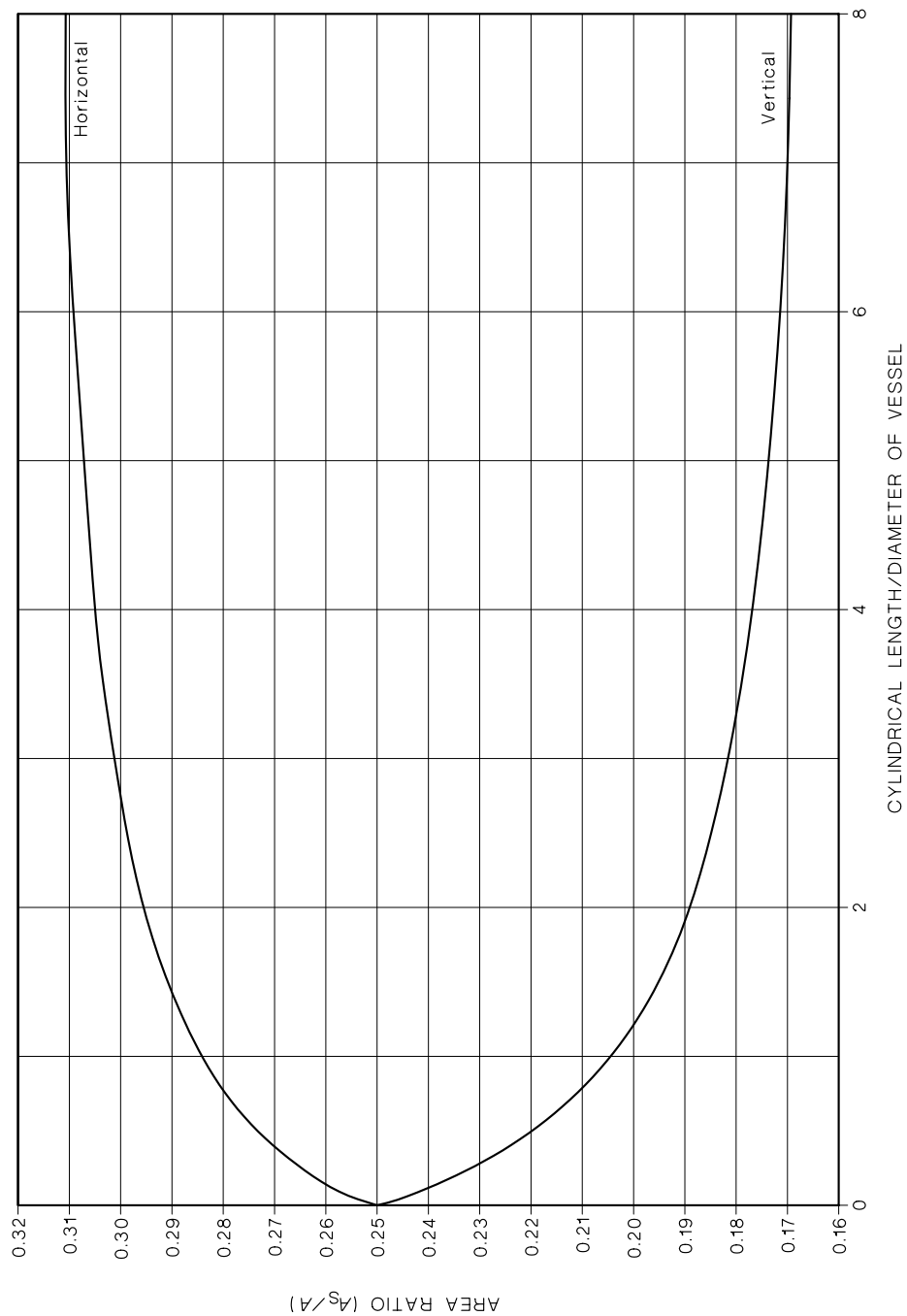
TABLE 1
CALCULATION CONDITIONS AND EFFECTIVE FLUID VOLUME

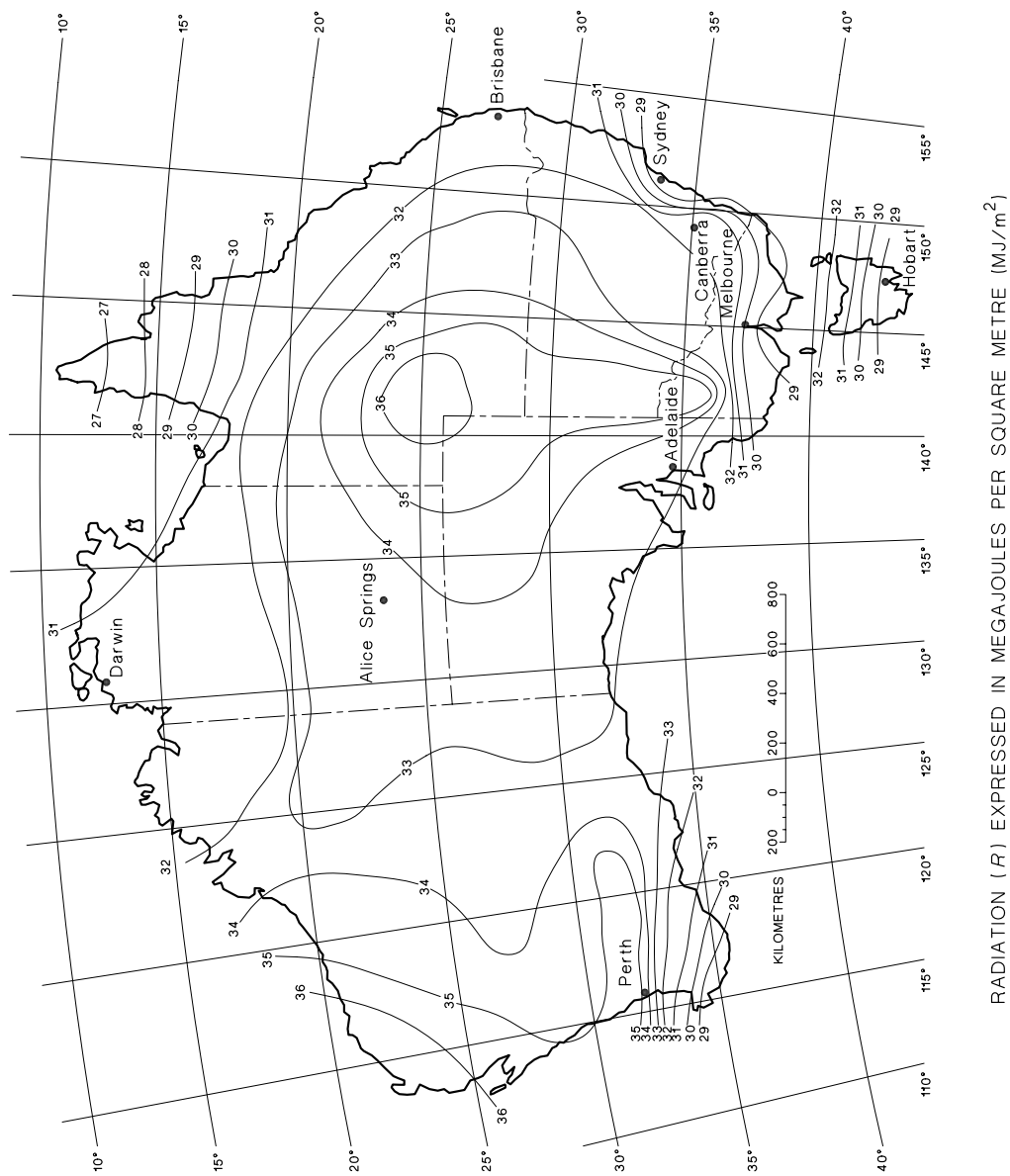
Calculation condition			Maximum fluid temperature (t_{Fmax}) to be calculated	Effective fluid volume (V) for calculations
No	Applicability	Liquid level in vessel		
1	Liquids and liquefied gases	Nearly full	Temperature for determining ullage (Note 1)	Vessel volume
2(a)	Liquefied gases	Nearly empty (Note 2(a))	Temperature governing vapour pressure	Vessel volume
2(b)		Nearly full (Note 2(b))		Lesser of— (i) vessel volume, and (ii) $0.1AD^{1/4}$
3	Permanent gases	—	Temperature of gas (Note 3)	Vessel volume

NOTES:

- 1 This temperature is the maximum bulk liquid temperature; it is relevant in calculating volumetric expansion of liquid and hence for determining ullage.
- 2 For liquefied gases:
 - (a) Except for large vessels, this condition will produce the higher temperature governing vapour pressure.
 - (b) Under this condition, the bulk liquid temperature is lower than the temperature of the heated top layer of liquid. This vapour pressure is determined by the temperature of the top layer of liquid.
- 3 This temperature is the maximum in a permanent gas.

COMMON LOGARITHM OF TIME CONSTANT ($\text{Log}_{10}T$)FIGURE 1 VALUES FOR PARAMETER F

FIGURE 2 RATIO A_s/A FOR CYLINDRICAL VESSELS WITH CONVEX HEMISPHERICAL ENDS



RADIATION (H) EXPRESSED IN MEGAJOULES PER SQUARE METRE (MJ/m^2)

FIGURE 3 MEAN DAILY TOTAL GLOBAL RADIATION FOR HOTTEST MONTH