Ch.6
VENTILATION SYSTEMS

Ventilation – a means of changing the air in an enclosed space to:

- Provide fresh air for respiration – approx. 0·1 to 0·2 l/s per person.
- Preserve the correct level of oxygen in the air – approx. 21%.
- Control carbon dioxide content to no more than 0.1%. Concentrations above 2% are unacceptable as carbon dioxide is poisonous to humans and can be fatal.
- Control moisture – relative humidity of 30% to 70% is acceptable.
- Remove excess heat from machinery, people, lighting, etc.
- Dispose of odours, smoke, dust and other atmospheric contaminants.
- Relieve stagnation and provide a sense of freshness – air movement of 0·15 to 0·5m/s is adequate.

VENTILATION SYSTEMS (cont...)

Measures for control:

- Health and Safety at Work, etc. Act.
- The Factories Act.
- Offices, Shops and Railway Premises Act.
- Building Regulations, Approved Document F – Ventilation.
- BS 5925: Code of practice for ventilation principles and designing for natural ventilation.

Room/building/accommodation	Air changes per hour
Assembly/entrance halls	3–6
Bathrooms (public)	6*
Boiler plant rooms	10–30†
Canteens	8–12
Cinema/theatre	6–10
Classrooms	3–4
Dance halls	10–12
Dining hall/restaurants	10–15
Domestic habitable rooms	approx. 1*
Factories/garages/industrial units	6–10
Factories – fabric processing	10–20
Factories (open plan/spacious)	1–4
Factories with unhealthy fumes	20–30
Foundries	10–15
Hospital wards	6–10
Hospital operating theatres	10–20
Kitchens (commercial)	20–60*
Laboratories	6–12
Laundries	10–15
Lavatories (public)	6–12*
Libraries	2–4
Lobbies/corridors	3–4
Offices	2–6
Smoking rooms	10–15
Warehousing	1–2

Ventilation of dwellings

Habitable rooms – rapid or purge ventilation should be capable of producing four air changes per hour for each room, plus a whole building ventilation rate of not less than:

Bedrooms	1	2	3	4	5
Ventilation rate (l/s)*	13	17	21	25	29

* Add 4 l/s per person where occupancy is greater than 2 persons per main bedroom and greater than 1 person in other bedrooms.
* The minimum acceptable rate for any dwelling is 0.3 l/s per m^2 total internal floor area.

Kitchen, utility room, bathroom and sanitary accommodation – local ventilation by intermittent or continuous mechanical means, i.e. an extract fan capable of achieving the following minimum rates (l/s):

Room	Intermittent**	Continuous (high)	Continuous (low)
Kitchen	30 (adjacent to hob), or 60 (elsewhere)	13	Total extract for all rooms, not less than the whole building ventilation rate.
Utility room	30	8	
Bathroom	15	8	
Sanitary accommodation	6	6	

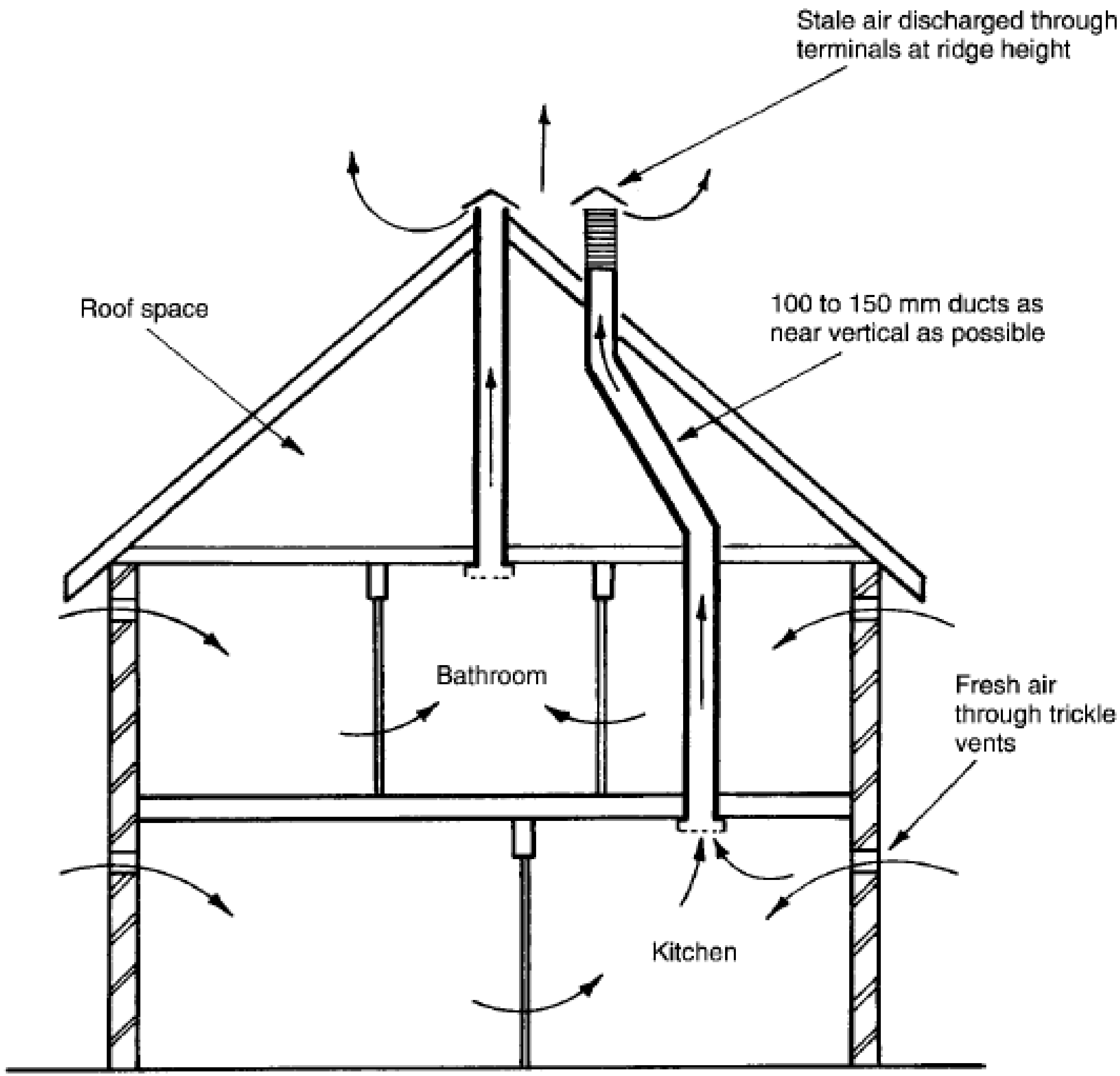
** 15min. overrun where fitted to an internal room. 10mm ventilation gap under door.

Natural Ventilation – Passive Stack Ventilation (PSV)

PSV consists of vertical or near vertical ducts of 100 to 150 mm diameter, extending from grilles set at ceiling level to terminals above the ridge of a roof. Systems can be applied to kitchens, bathrooms, utility rooms and sometimes sanitary accommodation, in buildings up to four storeys requiring up to three stacks/ducts.

PSV

PSV is energy efficient and environmentally friendly with no running costs. It works by combining stack effect with air movement and wind passing over the roof. It is self-regulating, responding to a temperature differential when internal and external temperatures vary.

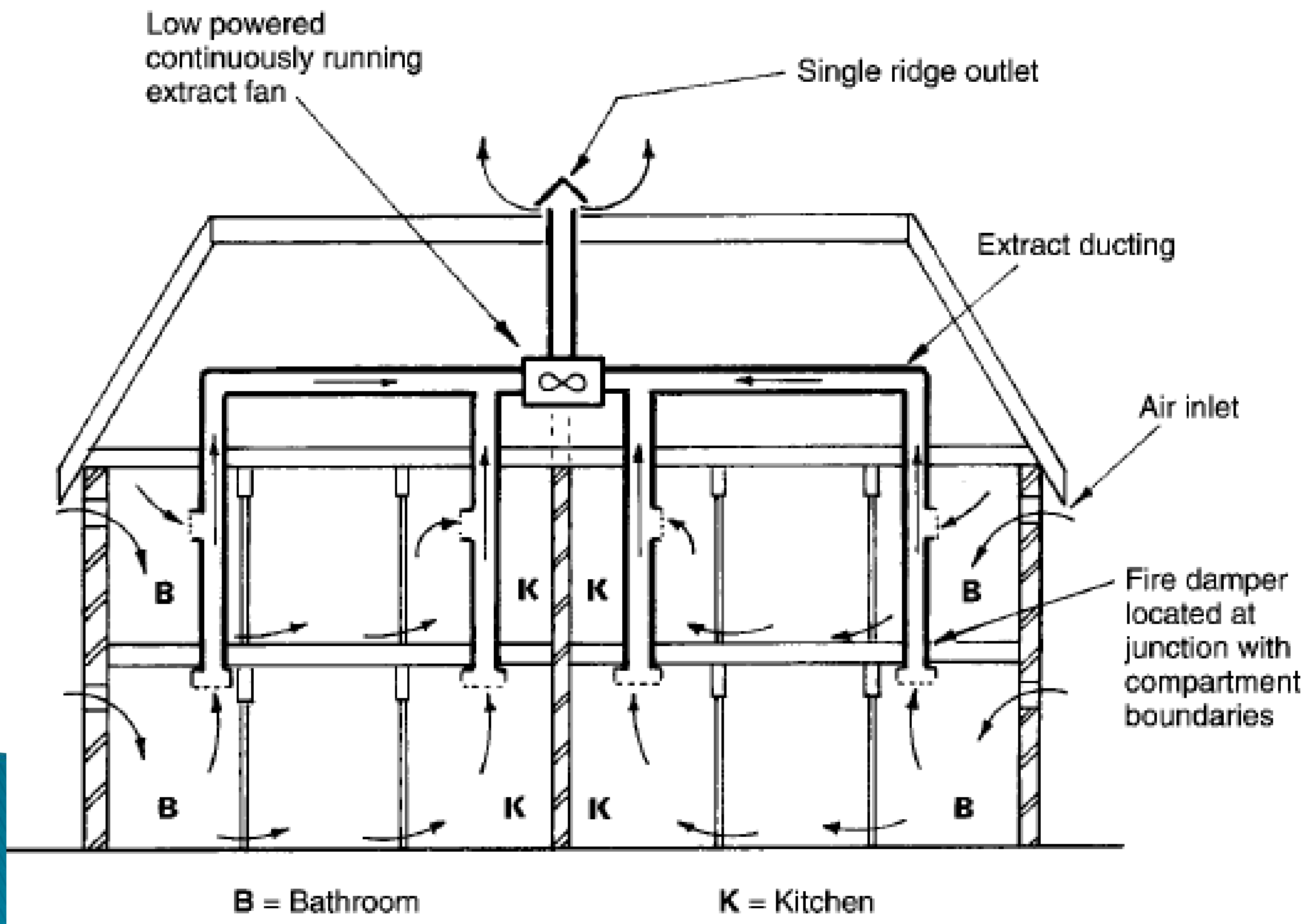


PSV to a dwelling house

Mechanically Assisted Ventilation Systems (MAVS)

MAVS may be applied to dwellings and commercial premises where PSV is considered inadequate or impractical. This may be because the number of individual ducts would be excessive, i.e. too space consuming and obtrusive with several roof terminals. A low powered (40 W) silent running fan is normally located within the roof structure. It runs continuously and may be boosted by manual control when the level

of cooking or bathing [redacted] sensors can also be used to automatically increase air flow.



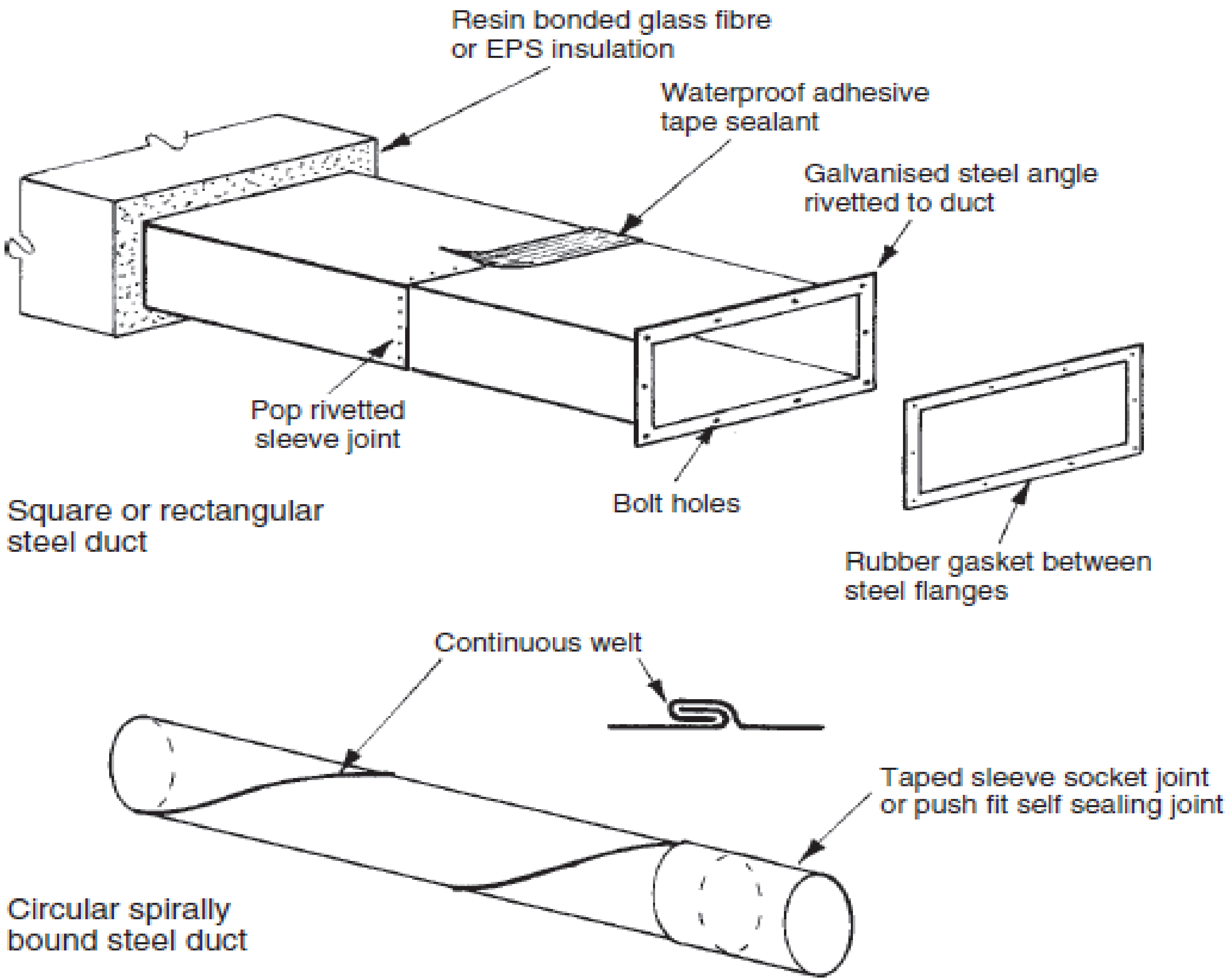
MAVS in a group of flats

Ducting – Profile

Profile : generally circular, square or rectangular but may be oval.

For efficient distribution of air, the uniformity of circular ducting is preferred for the following reasons:

- less opportunity for turbulence
- less resistance to friction
- inherent rigidity
- lower heat losses or gains
- sound transfer generally less
- less potential for air leakage


Resin bonded glass fibre
or EPS insulation
Waterproof adhesive
tape sealant
Galvanised steel angle
rivetted to duct
Pop rivetted
sleeve joint
Bolt holes
Square or rectangular
steel duct
Rubber gasket between
steel flanges
Continuous welt
Taped sleeve socket joint
or push fit self sealing joint
Circular spirally
bound steel duct

Ducting – Materials

Galvanized sheet steel is the most common material used for ventilation and air conditioning ducting. Factory prefabricated sections are site jointed by bolted steel angle flanges with a rubber sealing gasket, the rigid angles can also function as suspended bracket fixings.

Sleeve jointing with pop-rivets and tape sealant is also used with smaller profile sections. In addition to galvanized steel, aluminum may be used in smaller profiles or externally in non-corrosive atmospheres. Copper or stainless steel is used where the ducting forms a feature, e.g. a cooker hood.

extensions. Plastic materials have limitations where performance in fire is a consideration.

Material	Sheet/wall thickness (mm)	Situation	Application
Galvanised steel	0·6	Low velocity < 10 m/s	Universal
		Low pressure < 500 Pa	..
	0·8	Velocity > 10 m/s	..
		Pressure > 500 Pa	..
Aluminium or copper	0·8	Low velocity	Features
Stainless steel	As galvanized steel		Features
UPVC	3·0	Low velocity	Domestic
Polypropylene	3·0	Low velocity	Domestic
Resin bonded glass fibre	3·0	Low velocity	Warm air heating

Low Velocity Air Flow in Ducts

Simple ducted air systems, typical of those serving internal WCs and bathrooms, operate at relatively low air velocity with little frictional resistance or pressure drop. In these situations the relationship between air flow and duct diameter can be expressed as:

$$Q = 6{\cdot}3 \times 10^{-7} \times \sqrt{d^5 \times h \div L}$$

where: Q = air flow rate in m^3/sec.

d = duct diameter in mm.

h = pressure drop in mm water gauge.

L = length of duct in metres.

To determine duct diameter from design input data, the formula is represented:

$$d = 305 \times \sqrt[5]{Q^2 \times L \div h}$$

E.g. A 10m long ventilation duct is required to provide air at 0·10 m^3/sec at a pressure drop of 0·15mm wg.

$$0{\cdot}15 \text{ mm} = 1{\cdot}5 \text{ pascals (Pa) (over 10 m of ducting)}$$
$$= 0{\cdot}015 \text{ mm per m. or } 0{\cdot}15 \text{ Pa per m.}$$

$$d = 305 \times \sqrt[5]{(0{\cdot}10)^2 \times 10 \div 0{\cdot}15}$$

$$d = 305 \times \sqrt[5]{0{\cdot}6667}$$

$$d = 305 \times 0{\cdot}922 = 281 \text{ mm diameter.}$$

To check that the calculated diameter of 281mm correlates with the given flow rate (Q) of 0·10 m^3/sec:

$$Q = 6{\cdot}3 \times 10^{-7} \times \sqrt{d^5 \times h \div L}$$

$$Q = 6{\cdot}3 \times 10^{-7} \times \sqrt{(281)^5 \times 0{\cdot}15 \div 10}$$

$$Q = 6{\cdot}3 \times 10^{-7} \times 162110$$

$$Q = 0{\cdot}102 \text{ m}^3\text{/sec}$$

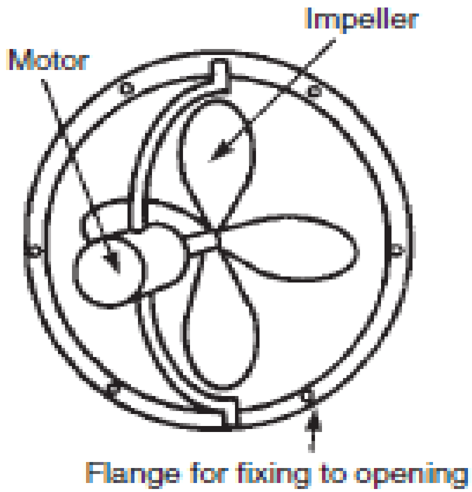
Types of Fan

Propeller fan † does not create much air pressure and has limited effect in ductwork. Ideal for use at air openings in windows and walls.

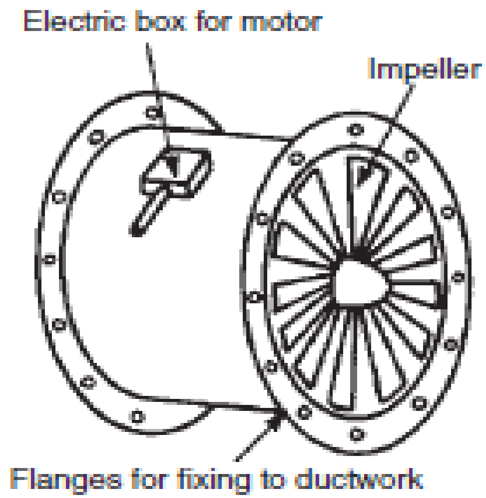
Axial flow fan † can develop high pressure and is used for moving air through long sections of ductwork. The fan is integral with the run of ducting and does not require a base.

Bifurcated axial flow fan † used for moving hot gases, e.g. flue gases, and greasy air from commercial cooker hoods.

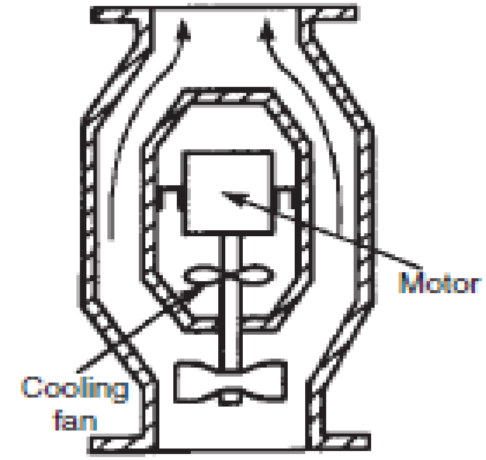
Centrifugal fan † can produce [redacted] has the capacity for large volumes of air.



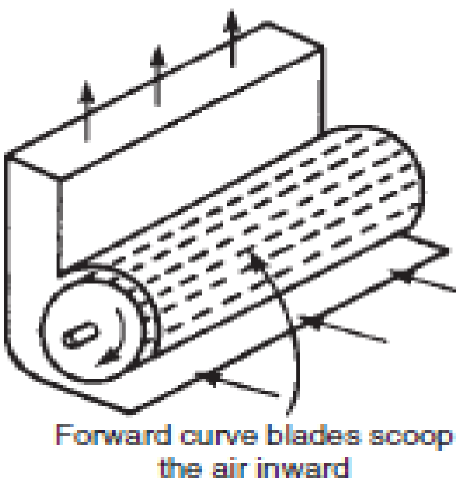
Propeller fan



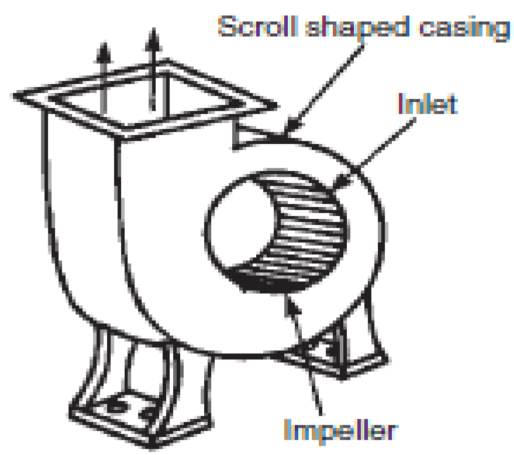
Axial flow fan



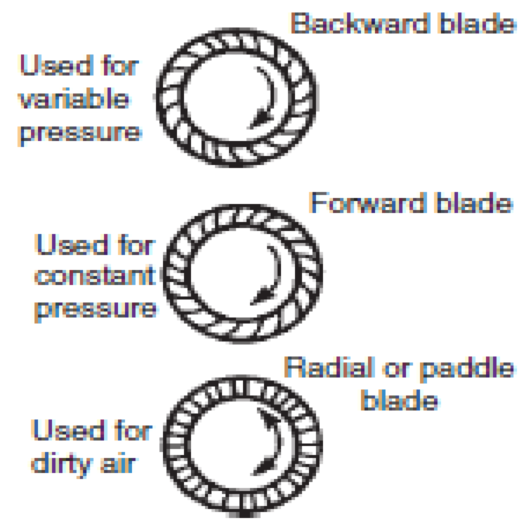
Bifurcated axial
flow fan



Cross-flow fan



Centrifugal fan



Types of impeller used
with centrifugal fans

Ventilation Design – Air Velocity

Air velocity within a room or workplace should be between 0.15 and 0.50 m/s, depending on the amount of activity. Sedentary tasks such as desk work will fall into the range of 0.15 to 0.30 m/s, whilst more active assembly work, shop work and manufacturing, between 0.30 and 0.50 m/s. These figures are designed to provide a feeling of freshness,

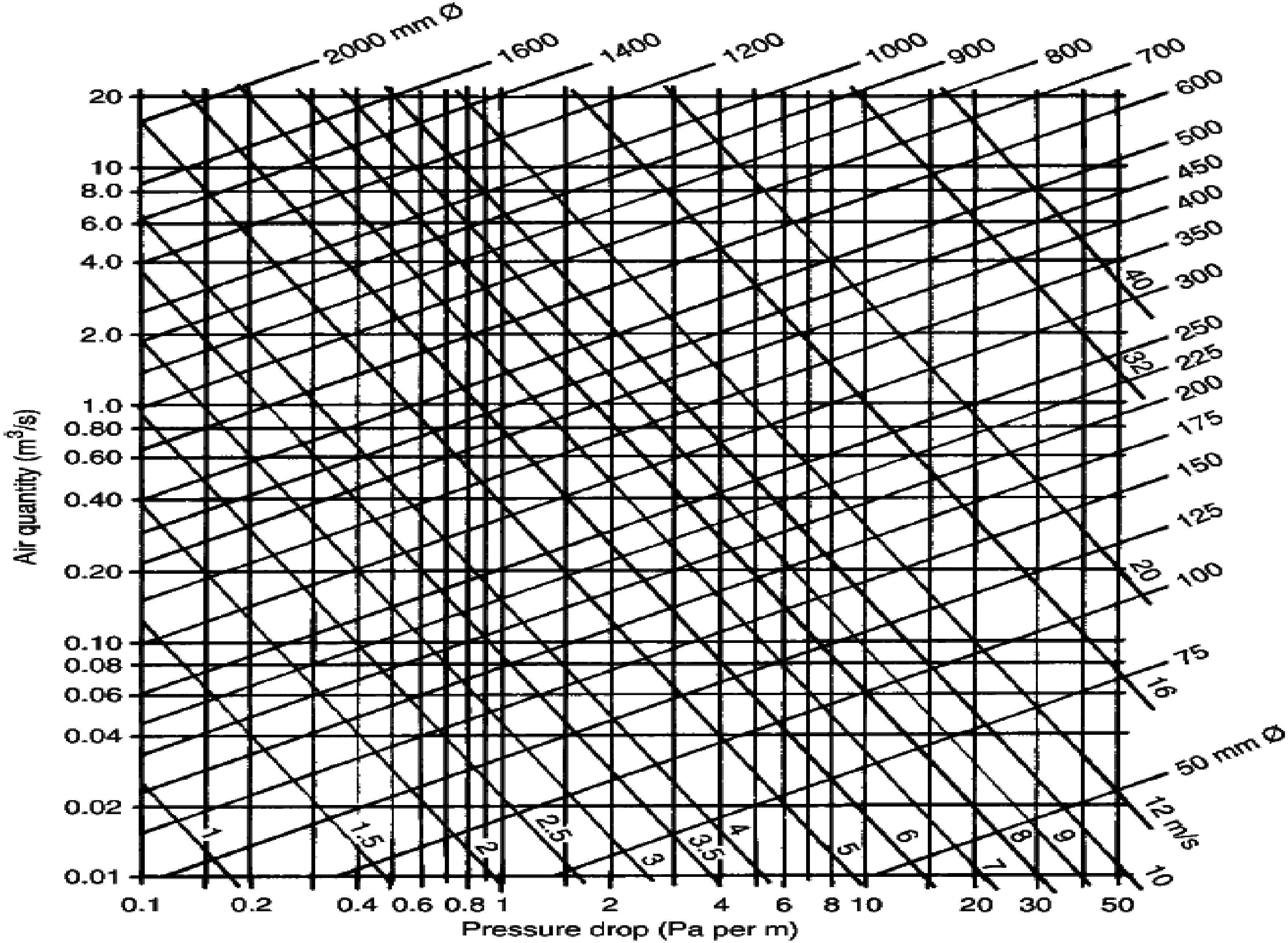
to relieve stagnation without noise distraction from air movement

equipment.

Situation	Ducted air velocity (m/s)
Very quiet, e.g. sound studio, library, study, operating theatres	1·5–2·5
Fairly quiet, e.g. private office, habitable room, hospital ward	2·5–4·0
Less quiet, e.g. shops, restaurant, classroom, general office	4·0–5·5
Non-critical, e.g. gyms, warehouse, factory, department store	5·5–7·5

Ventilation Design – Duct Sizing Chart

Estimation of duct size and fan rating can be achieved by simple calculations and application to design charts. The example below is a graphical representation of the quantity of air (m 3 /s), friction or pressure reduction (N/m 2 per m) or (Pa per m) and air velocity (m/s) in circular ductwork.



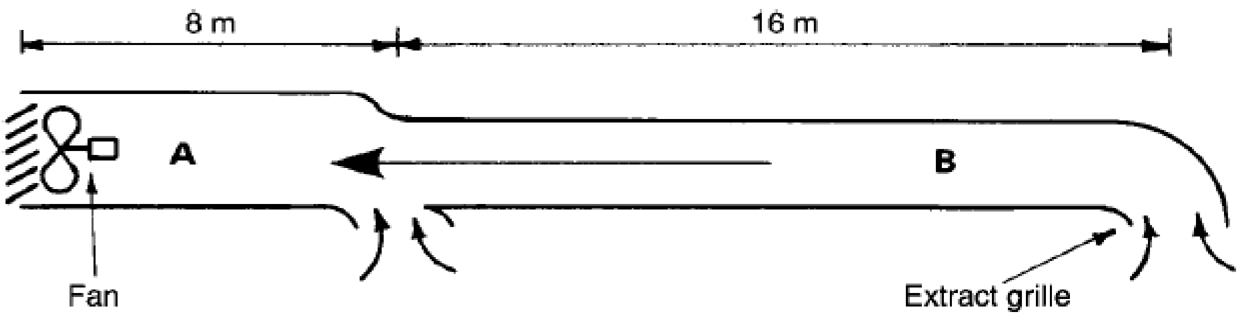
General air flow data for circular ducts

For mechanical supply and extract systems, the air volume flow rate or quantity of air can be calculated from the following formula:

$$Q(m^3/s) = \frac{\text{Room volume} \times \text{Air changes per hour}}{\text{Time in seconds}}$$

Air changes per hour can be obtained from appropriate legislative standards for the situation or the guidance given on pages 198 and 199.

E.g.



Room volume = 1800 m^3, requiring six air changes per hour

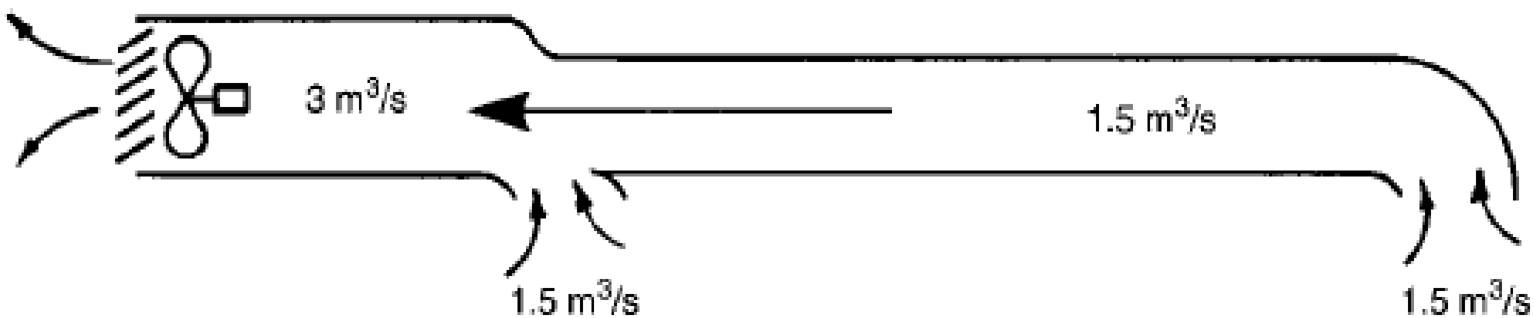
The ducted extract air system shown is a simple straight run, with duct A effectively 8m long and duct B effectively 16m long. Where additional bends, tees, offsets and other resistances to air flow occur, a nominal percentage increase should be added to the actual duct length. Some design manuals include 'k' factors for these deviations and an example is shown on pages 228 and 229.

For the example given:

$$Q = \frac{1800 \times 6}{3600} = 3m^3/s$$

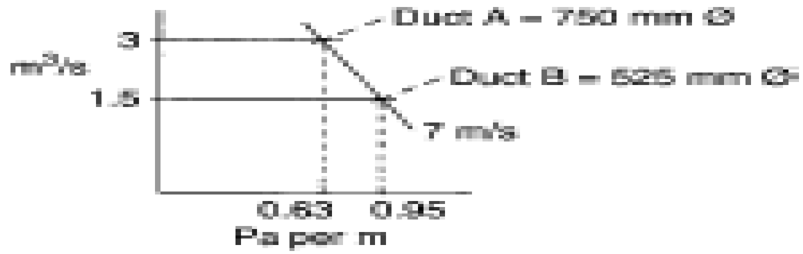
EXAMPLE (CONT….

Disposition of extract grilles and room function will determine the quantity of air removed through each grille and associated duct. In this example the grilles are taken to be equally disposed, therefore each extracts 1·5m^3/s. Duct A therefore must have capacity for 3m^3/s and duct B, 1·5m^3/s.

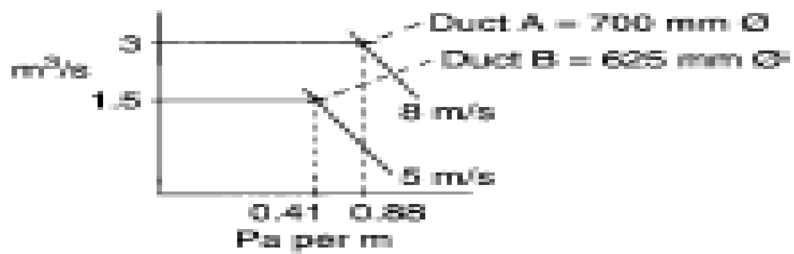


There are several methods which may be used to establish ventilation duct sizes, each having its own priority. The following shows three of the more popular, as applied to the design chart on page 221.

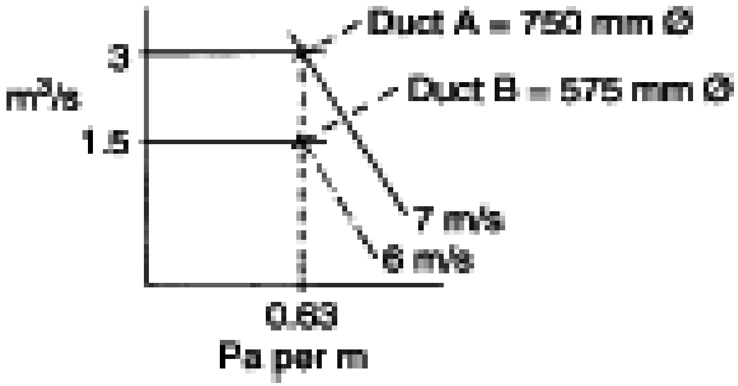
- Equal velocity – applied mainly to simple systems where the same air velocity is used throughout. For example, selected velocity is 7m/s (see page 220), therefore the design chart indicates:



- Velocity reduction – air velocity is selected for the main section of ductwork and reduced for each branch. For example, selected air velocities for ducts A and B are 8m/s and 5m/s respectively:



- Equal friction/constant pressure drop – air velocity is selected for the main section of ductwork. From this, the friction is determined and the same figure applied to all other sections. For example, selected air velocity through duct A is 7m/s:



Using the example on page 222 with the equal velocity method of duct sizing shown on page 223, the fan will be required to extract 3 m^3 of air per second at a pressure of:

Duct (A) = 8 m × 0·63 Pa per m = 5·04 Pa
Duct (B) = 16 m × 0·95 Pa per m = 15·20 Pa
20·24 Pa (i.e. 20·25)

System pressure loss is calculated from: $k = P/Q^2$

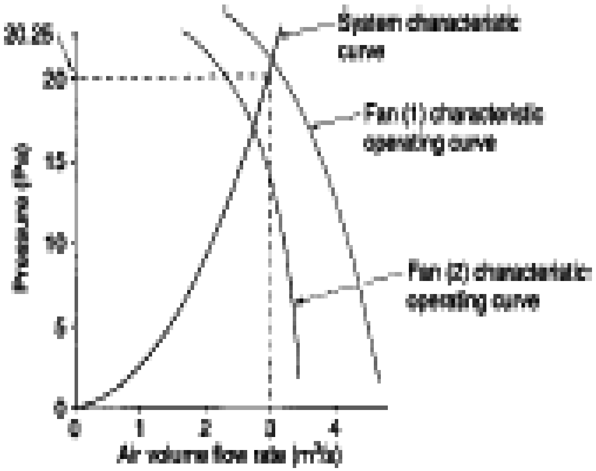
where: k = pressure loss coefficient
P = pressure loss (Pa)
Q = air volume flow rate (m^3/s)

Therefore: $k = 20{\cdot}25/3^2 = 2{\cdot}25$

Using this coefficient, the system characteristic curve may be drawn between the operating air volume flow rate of $3m^3/s$ down to a nominal low operating figure of, say, $0{\cdot}5m^3/s$. By substituting figures in this range in the above transposed formula, $P = k \times Q^2$ we have:

$P = 2{\cdot}25 \times (0{\cdot}5)^2 = 0{\cdot}56$ Pa	[$0{\cdot}5m^3/s$ @ 0·56 Pa]
$P = 2{\cdot}25 \times (1{\cdot}0)^2 = 2{\cdot}25$ Pa	[$1{\cdot}0m^3/s$ @ 2·25 Pa]
$P = 2{\cdot}25 \times (1{\cdot}5)^2 = 5{\cdot}06$ Pa	[$1{\cdot}5m^3/s$ @ 5·06 Pa]
$P = 2{\cdot}25 \times (2{\cdot}0)^2 = 9{\cdot}00$ Pa	[$2{\cdot}0m^3/s$ @ 9·00 Pa]
$P = 2{\cdot}25 \times (2{\cdot}5)^2 = 14{\cdot}06$ Pa	[$2{\cdot}5m^3/s$ @ 14·06 Pa]
$P = 2{\cdot}25 \times (3{\cdot}0)^2 = 20{\cdot}25$ Pa	[$3{\cdot}0m^3/s$ @ 20·25 Pa]

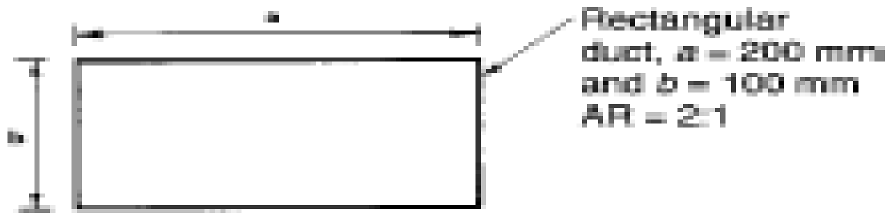
Plotting these figures graphically against fan manufacturers data will provide an indication of the most suitable fan for the situation:



Select fan (1), as with variable settings this would adequately cover the system design characteristics.

Some ventilation design manuals limit data presentation to circular profile ductwork only. It is often more convenient for manufacturers and installers if square or rectangular ductwork can be used. This is particularly apparent where a high aspect ratio profile will allow ducting to be accommodated in depth restricted spaces such as suspended ceilings and raised floors.

Aspect ratio:



The numerical relationship between dimension a to b. Square = 1:1.

Conversion of circular ductwork to square or rectangular (or vice versa) using the equal velocity of flow formula:

$$d = \frac{2ab}{a + b}$$

where: d = duct diameter

a = longest dimension of rectangular duct

b = shortest dimension of rectangular duct.

E.g. a 400mm diameter duct to be converted to a rectangular profile of aspect ratio 3:1.

$$a = 3b$$

Substituting in the above formula:

$$400 = \frac{2 \times 3b \times b}{3b + b} = \frac{6b^2}{4b} = \frac{6b}{4}$$

Therefore:

$$b = \frac{4 \times 400}{6} = 267 \text{ mm}$$

$$a = 3b = 800 \text{ mm}$$

For equal volume of flow and pressure drop there are two possible formulae:

1. $$d = 1{\cdot}265 \times \left|\frac{(a \times b)^3}{a + b}\right|^{0{\cdot}2}$$

2. $$d = \left|\frac{32(a \times b)^3}{\pi^2(a + b)}\right|^{0{\cdot}2}$$

Notes: 0.2 represents the 5th root of data in brackets.
Formulae assume identical coefficient of friction occurs between circular and rectangular ducts, i.e. same material used.

E.g. circular duct of 400 mm diameter to be converted to rectangular having an aspect ratio of 3:1. Therefore, $a = 3b$.

Substituting in formula 1:

$$400 = 1{\cdot}265 \times \left|\frac{(3b \times b)^3}{3b + b}\right|^{0{\cdot}2}$$

$$400 = 1{\cdot}265 \times \left|\frac{(3b^2)^3}{4b}\right|^{0{\cdot}2}$$

From this, $b = 216$ mm
$a = 3b = 648$ mm

Substituting in formula 2:

$$400 = \left|\frac{32(3 \times b^2)^3}{\pi^2(3b + b)}\right|^{0{\cdot}2}$$