
Fans for general purposes

Part 1. Methods of testing performance

Ventilateurs d'usage général

Partie 1. Méthodes pour les essais de performance

Vielzweck-Lüfter

Teil 1. Methoden für Leistungsprüfungen

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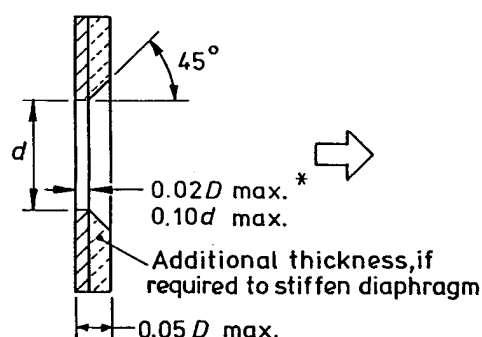
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to BS 848 : Part 1 : 1980

Fans for general purposes
Part 1. Methods of testing performance

Corrections

AMD 5495
July 1987

Figure 17. Orifice plates and assemblies
Delete figure 17(d) and substitute the following.



*The thickness shall not exceed either of these limits.

AMD 5495
July 1987

Figure 18. Flow coefficients of in-duct orifices with D and $D/2$ taps

Delete figure 18 and substitute the new figure 18 attached.

NOTE. In the figure, ' Re_d ' has been amended to read ' Re_D '.

AMD 5495
July 1987

Clause 28.3 Calculations

In line 2 of the right hand column of text, delete

$$q_m = \frac{\pi D_6^2}{4} \sqrt{2\rho_u \Delta p_{\text{eff}}}$$

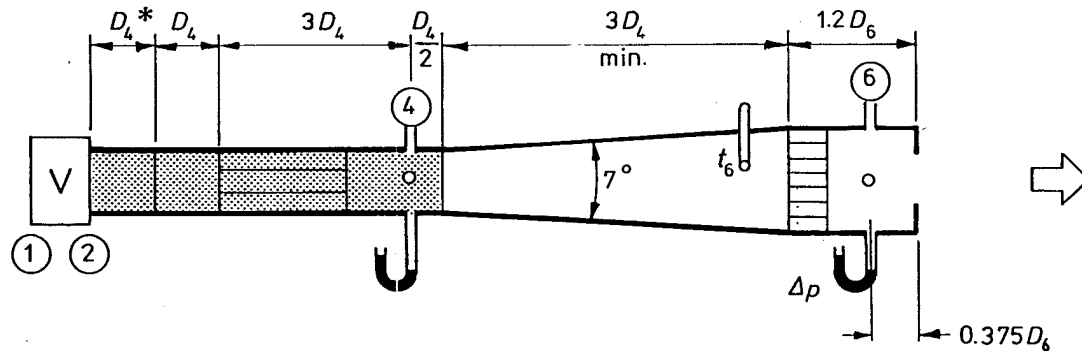
and substitute

$$q_m = \alpha \frac{\pi D_6^2}{4} \sqrt{2\rho_u \Delta p_{\text{eff}}}$$

AMD 5495
July 1987

Figure 27. Standardized airways for free inlet, ducted outlet, type B installations

Delete figure 27(b) and substitute the following.

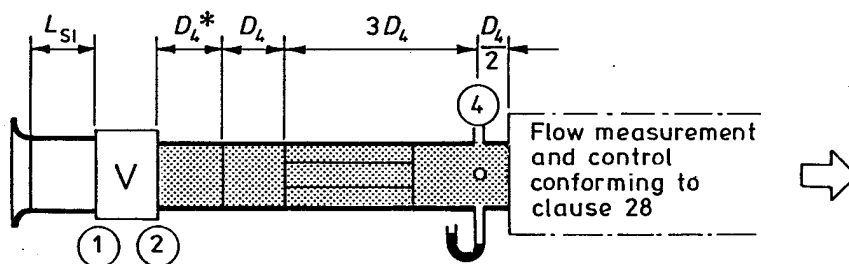


AMD 5495
July 1987

Figure 29. Standardized airways for ducted inlet, ducted outlet, type D installations

Delete figure 29(d) and substitute the following.

Ducted inlet simulation
section conforming
to 24.5



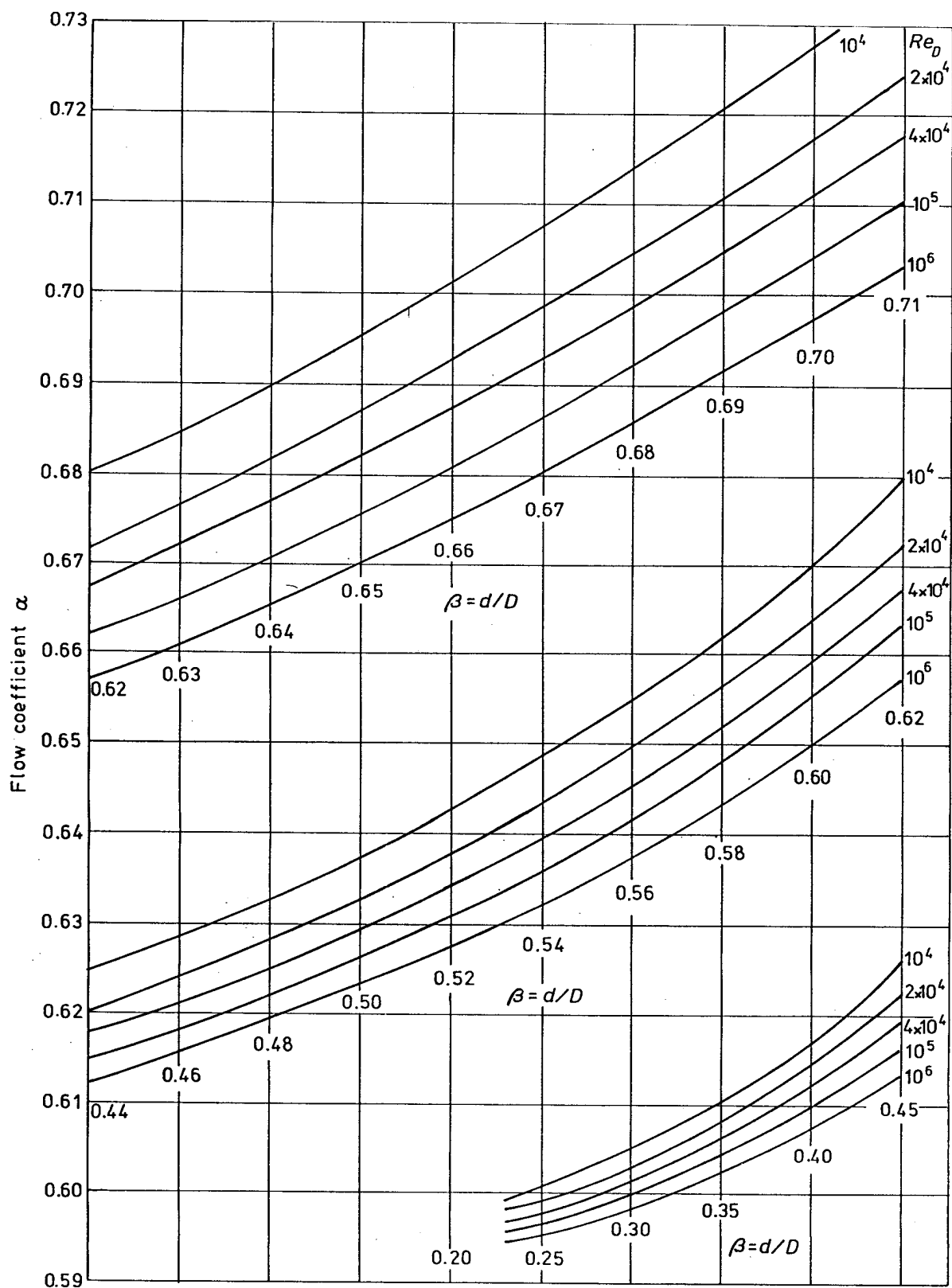


Figure 18. Flow coefficients of in-duct orifices with D and $D/2$ taps

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Fans for general purposes
Part 1. Methods of testing performance
(Reprinted, incorporating Amendment No. 1)

NOTE 1. This amendment corrects an omission in the reprinted text of BS 848 : Part 1.

NOTE 2. A rule in the margin indicates the correction of textual errors in BS 848 : Part 1.

Correction

AMD 7330
November 1992

Clause 30.3 Calculations

Insert the following as the sixth row in the second column of equations.

$$p_{t2} = p_{s4} + (1 + \zeta_{24}) p_{d4} \quad (\text{see figure 24})'$$

9211

MCE/17

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Foreword

This standard has been prepared under the direction of the Mechanical Engineering Standards Committee and reflects current practices and developments in the fan industry.

The need to revise BS 848 : Part 1 : 1963 has been evident for some time. The original intention had been to await the completion by the International Organization for Standardization (ISO) of a new international standard on air performance test methods of industrial fans, but this is still some way off. This revision has therefore been issued taking into account the degree of agreement which has been reached in the international committees.

It has been demonstrated that the current codes for fan performance testing established in different countries do not always lead to the same results. The differences depend chiefly on the flow pattern at the fan outlet and, while often minor can be of substantial significance. To meet this situation there is general agreement that it is essential that all standardized test airways for fans to be used with ducts have portions in common adjacent to the fan inlet and/or outlet sufficient to ensure consistent determination of fan pressure, irrespective of the permissible variations in the methods of flow measurement and control.

It is considered that sufficient international agreement (backed by an experimental programme) has now been reached on the design of these common parts to justify their inclusion in the methods of test with standardized airways for this revision. Fan performances determined in accordance with these methods are expected to agree, within the limits of uncertainty of measurement, with the performances determined under the international standard when completed. The use in the 1963 edition of an outlet duct simulation section two diameters in length, whilst valid for the combination of a fan and a short outlet duct, is not permissible for type B or type D standardized airway tests for which it is essential that the simulation section reproduces the common part incorporating a standardized flow straightener.

Since the connection of a duct to a fan outlet and/or inlet modifies its performance it has been agreed in ISO that four standard installation types should be recognized. These are type A with free inlet and outlet, type B with free inlet and ducted outlet, type C with ducted inlet and free outlet and type D with ducted inlet and outlet. A fan adaptable to more than one installation type will have more than one standardized performance characteristic accordingly.

Test methods 4 and 9 of the 1963 edition of BS 848 : Part 1, which were recognized as being of lower accuracy, have been excluded. The other standardized airway methods have been redesigned to meet type A, B, C or D requirements and to provide alternative methods of flow measurement by venturi nozzle, conical inlet, orifice plate or pitot-static tube traverse. Very large fans cannot always be tested with standardized airways, in which case they may be tested according to the site testing rules. For testing on site, methods of flow measurement by pitot-static tube or anemometer traverse have been revised and extended to cover additional geometric shapes of cross section.

SI units are used throughout this standard. A table of conversion factors is included as appendix E.

The compressibility factor k_p is now based on polytropic rather than isentropic compression. This is in order to bring British practice into agreement with that of the international majority. The standard conversion rules for fan speed and air conditions are limited to cases where the change in k_p does not exceed 0.01. A modified set of conversion rules is given in appendix C which may be used over a wider range of k_p subject to agreement based on the experimental evaluation of an index which may vary from one fan type to another.

A new treatment is given for the estimation of the uncertainty of performance determination in a particular test. Instrumental uncertainties representative of good practice are specified and lead to uncertainties in standardized airway tests of about $\pm 2\%$ in inlet volume flow and power input, and in fan total pressure when the proportion of fan dynamic pressure is moderate, combining to give $\pm 3.5\%$ uncertainty in efficiency. The greater difficulties of site testing may cause a rise to $\pm 3\%$ to 4% uncertainty of flow measurement. Performance tolerances to include deviations in fan manufacture have been excluded from this standard, but some recommendations have been included in appendix A.

A complete statement of fan performance should include the appropriate fan sound power level. Test methods for determining this quantity is given in Part 2 of this standard.

The use of Y is now obligatory when the mean air velocity is 35 m/s or more; at 35 m/s the error in the density calculated would reach 0.2 % if uncorrected.

British Standard

Fans for general purposes

Part 1. Methods of testing performance

Section one. General

1. Scope

This British Standard deals with the determination of the performance of fans of all types except those designed solely for air circulation, e.g. ceiling fans and table fans.

Fans are classified for the purposes of this standard according to the installation type or types for which they are intended. There are four standard installation types:

- type A: free inlet, free outlet;
- type B: free inlet, ducted outlet;
- type C: ducted inlet, free outlet;
- type D: ducted inlet, ducted outlet.

Methods of measurement and calculation for the flow rates, fan pressures and fan efficiencies defined as performance ratings are specified in section one. Compressibility effects are covered up to a maximum pressure ratio of 1.3.

Methods of test for the determination of the corresponding standard performance ratings are described in section two.

Recommendations for the determination of volume flow rate and fan pressure under site conditions are given in section three.

Estimates of uncertainty of measurement are provided and rules for the conversion within specified limits of test results for changes of speed, gas handled and, in the case of model tests, size.

2. References

The titles of standards publications referred to in this standard are listed on the inside back cover.

3. Definitions

For the purposes of this British Standard the following definitions apply.

3.1 air. An abbreviation for the expression 'air or other gas' except when referred to as 'atmospheric air'.

3.2 standard air. Atmospheric air having a density of exactly 1.2 kg/m^3 .

NOTE. Atmospheric air at a temperature of 16°C , a pressure of $100\,000 \text{ Pa}$ and a relative humidity of 65 % has a density of 1.2 kg/m^3 , but these conditions are not part of the definition.

3.3 absolute pressure. That pressure, measured from absolute zero, which is exerted at a point at rest relative to the air around it.

3.4 atmospheric pressure. The absolute pressure of the free atmosphere in the test enclosure.

3.5 static pressure at a point. The absolute pressure at the point minus the reference atmospheric pressure.

NOTE. In accordance with this definition, static pressure may be positive or negative.

3.6 dynamic pressure at a point. The rise in static pressure which occurs when air moving with the specified velocity at the point is brought to rest without loss of mechanical energy, i.e. at constant entropy. (Formerly known as velocity pressure.)

NOTE. Dynamic pressure is always positive.

3.7 total pressure at a point. The sum of the static pressure and the dynamic pressure at the point.

NOTE. According to the sign and magnitude of the static pressure, total pressure may be positive or negative.

3.8 mass flow at a section. The mass of air which passes through the specified airway cross section per unit of time.

NOTE. The mass flow will be the same at all cross sections within the fan and airway system, apart from leakage.

3.9 volume flow at a section. The mass flow at the specified airway cross section divided by the average air density at that section.

3.10 average velocity at a section. The volume flow at the specified airway cross section divided by the cross-sectional area.

NOTE. This is the average component of the air velocity normal to that section, swirl components being excluded.

3.11 average static pressure at a section. The static pressure averaged over the area of the specified airway cross section.

NOTE. In this standard, sections for pressure measurement are so located that the static pressure will be approximately constant over the section. It is, therefore, unnecessary to weight readings for local mass flow.

3.12 effective dynamic pressure at a section. The dynamic pressure calculated from the average velocity and the average density at the specified airway cross section.

NOTE. The effective dynamic pressure will be less than the average of the dynamic pressures across the section because it excludes from consideration that part of the dynamic energy flux which is due only to departures from uniform, axial velocity distribution.

3.13 effective total pressure at a section. The sum of the average static pressure and the effective dynamic pressure at the specified airway cross section.

NOTE. The effective total pressure will, in general, be less than the average of the total pressures across the section because it excludes from consideration that part of the dynamic energy flux which is due only to departures from uniform, axial, velocity distribution.

3.14 inlet density. The fluid density at the fan inlet calculated from the effective total pressure and total temperature at the fan inlet.

3.15 total temperature. The temperature resulting if the moving air is brought to rest adiabatically.

3.16 fan outlet area. The gross area at the outlet section of the fan without deductions for motors, fairings or other obstructions.

3.17 fan dynamic pressure. The effective dynamic pressure at the fan outlet calculated from the mass flow, the average air density at the outlet and the fan outlet area. A conventional quantity representative of the dynamic component of the fan output.

3.18 fan total pressure. A conventional quantity representative of the fan pressure when the dynamic contribution to its output is included.

For a fan with free outlet for a type A or C installation: the fan static pressure plus the fan dynamic pressure.

For a fan with ducted outlet: the effective total pressure at the fan outlet minus the effective total pressure at the fan inlet, each being determined in accordance with the requirements of this standard for a type B or type D installation.

NOTE. This definition does not relate to the fan alone. The test methods of section two determine fan total pressure for standardized installation types A, B, C and D; the four values thus obtained for a given fan are not necessarily the same, and it is essential that the installation type of the test is stated. Site installations do not often conform closely to one of the standardized airway configurations, and the fan total pressure derived from a site test is only strictly applicable to that site installation.

3.19 fan static pressure. A conventional quantity representative of the fan pressure when the dynamic contribution to its output is excluded. (See note to 3.18.)

For a fan with free outlet: the average static pressure at the fan outlet minus the effective total pressure at the fan inlet, each being determined in accordance with the requirements of this standard for a type A or type C installation.

For a fan with ducted outlet for a type B or type D installation: the fan total pressure minus the fan dynamic pressure.

3.20 mass flow. The average value of the fluid mass passing through the fan per unit of time. When the fan is not gas-tight it is taken as the mass flow either through the fan inlet or through the fan outlet as appropriate to the application.

3.21 inlet volume flow. The mass flow divided by the inlet density.

3.22 pressure ratio. For a fan with free outlet: the ratio of the absolute pressure at the fan outlet to the absolute total pressure at the fan inlet.

For a fan with ducted outlet: the ratio of the absolute total pressure at the fan outlet to the absolute total pressure at the fan inlet.

3.23 compressibility coefficient. The ratio of the mechanical work done by the fan on the air to the work that would be done on an incompressible fluid with the same mass flow, inlet density and pressure ratio. The work done is derived from the impeller power on the assumption of polytropic compression with no heat transfer through the fan casing.

3.24 air power (total). A conventional power output which, for a fan with ducted outlet, is the product of the inlet volume flow, the compressibility coefficient and the fan total pressure, or, for a fan with free outlet, is the air power (static) plus the kinetic energy flux at the fan outlet.

3.25 air power (static). A conventional power output which, for a fan with free outlet, is the product of the inlet volume flow, the compressibility coefficient and the fan static pressure, or, for a fan with ducted outlet, the air power (total) less the kinetic energy flux at the fan outlet.

3.26 impeller power. The mechanical power supplied to the fan impeller.

3.27 fan shaft power. The mechanical power supplied to the fan shaft.

3.28 motor input power. The electrical power supplied at the terminals of an electric motor drive.

NOTE. With other forms of drive it is not usual to express the input to the prime mover in terms of power.

3.29 rotational speed. The number of revolutions of the fan impeller per unit of time.

3.30 tip speed. The peripheral velocity of the impeller blade tips.

3.31 fan total efficiency. The air power (total) divided by the impeller power.

3.32 fan static efficiency. The air power (static) divided by the impeller power.

3.33 fan total efficiency (shaft power). The air power (total) divided by the shaft power.

- 3.34 fan static efficiency (shaft power).** The air power (static) divided by the shaft power.
- 3.35 overall total efficiency.** The air power (total) divided by the motor input power for a fan and motor combination.
- 3.36 overall static efficiency.** The air power (static) divided by the motor input power for a fan and motor combination.
- 3.37 fan.** A rotary machine which maintains a continuous flow of air at a pressure ratio not normally exceeding 1.3.
- 3.38 impeller.** The rotating part of a fan which, by means of its blades, transfers energy to the air.
- 3.39 casing.** Those stationary parts of a fan which direct the flow of air from the fan inlet opening(s) to the fan outlet opening(s).
- 3.40 duct.** An airway in which the air velocity is comparable with that at the fan inlet or outlet.
- 3.41 chamber.** An airway in which the air velocity is small compared with that at the fan inlet or outlet.
- 3.42 transition piece.** An airway along which there is a gradual change of cross-sectional area and/or shape.
- 3.43 test enclosure.** A room, or other space protected from draught, in which the fan and test airways are situated.
- 3.44 Reynolds number.** A non-dimensional parameter which defines the state of development of a flow and is used as a scaling parameter. It is the product of the local velocity, the local density and a relevant scale length (e.g. duct diameter, or blade chord) divided by the dynamic viscosity.
- 3.45 Mach number.** A non-dimensional parameter equal to the ratio of a specified velocity to the velocity of sound in the gas at a specified location.

4. Symbols and units

4.1 Symbols. For the purposes of this British Standard the following symbols and units apply.

Symbol	Term	Unit
p	Absolute pressure at a point	Pa
p_x	Average absolute pressure at an airway section 'x'	Pa
p_s	Static pressure at a point	Pa
p_{sx}	Average static pressure at an airway section 'x'	Pa
p_d	Dynamic pressure at a point	Pa
p_{dx}	Effective dynamic pressure at an airway section 'x'	Pa
p_t	Total pressure at a point	Pa
p_{tx}	Effective total pressure at an airway section 'x'	Pa
p_{tF}	Fan total pressure	Pa
p_{dF}	Fan dynamic pressure	Pa
p_{sF}	Fan static pressure	Pa
Δp	Differential pressure across a flow measurement device	Pa
Δp_j	Differential pressure at point j in a pitot-static traverse	Pa
Δp_{eff}	Effective differential pressure at the section traversed	Pa
p_u	Absolute pressure upstream of a flow measurement device	Pa
p_{fxy}	Loss of pressure due to friction between airway sections 'x' and 'y'	Pa
p_a	Atmospheric pressure in test enclosure	Pa
p_v	Partial pressure of water vapour	Pa
p'_{sat}	Saturation pressure of water vapour at wet bulb temperature	Pa
t	Temperature	°C
t_a	Dry-bulb temperature in test enclosure	°C
t_w	Wet-bulb temperature in test enclosure	°C
t_x	Average temperature at an airway section 'x'	°C
ρ_a	Density of air in test enclosure	kg/m ³
ρ_x	Average density at an airway section 'x'	kg/m ³
ρ_i	Inlet density	kg/m ³
q_m	Mass flow	kg/s
q_v	Inlet volume flow	m ³ /s
r	Pressure ratio	—
r_{pd}	Pressure ratio of a flow measurement device	—

Symbol	Term	Unit
P_{tF}	Air power (total)	W
P_{sF}	Air power (static)	W
P_R	Impeller power	W
P_A	Fan shaft power	W
P_B	Bearing power loss	W
P_M	Motor output power	W
P_E	Motor input power	W
Re_d, Re_D	Reynolds number $\frac{vd\rho}{\mu}$ or $\frac{vD\rho}{\mu}$	—
η_t	Fan total efficiency	—
η_s	Fan static efficiency	—
η_{tA}	Fan total efficiency (shaft power)	—
η_{sA}	Fan static efficiency (shaft power)	—
η_{tE}	Overall total efficiency	—
η_{sE}	Overall static efficiency	—
v	Velocity of air at a point	m/s
v_x	Average velocity of air at an airway section 'x'	m/s
n	Rotational speed (in revolutions per second)	r/s
a	Diameter of wall pressure tapping hole	mm
a_n	Average radial dimension of annular section	m
c	Core diameter	m
D	Diameter of airway	m
D_o	Downstream duct diameter	m
D_R	Impeller tip diameter	m
$\bar{D}$	Mean diameter of section	m
d	Diameter of orifice or nozzle throat	m
d_i	Diameter of total pressure hole in pitot-static tube	mm
d_t	Diameter of head of pitot-static tube	mm
E	Inlet diameter at the entry or larger side of rectangular opening of fan powered exhaust ventilators	m
L	Length of airway	m
L_{T2}	Length of transitional airway	m
L_{s1}	Length of transitional section	m
l	Length of cell of square or hexagonal cross section	m
w	Width of cell of square or hexagonal cross section	m
$b \times h$	Dimensions of a rectangular airway	m
A_x	Cross-sectional area of airway at a section 'x'	m ²
Ma	Mach number = $\sqrt{\frac{\rho v^2}{\gamma p}}$	—
R	Gas constant = $\frac{p}{\rho (273 + t)}$	J/(kg K)
γ	Isentropic exponent, equal to the ratio of specific heats for a perfect gas*	—
c_p	Specific heat at constant pressure* = $\frac{\gamma R}{\gamma - 1}$	J/(kg K)
μ	Dynamic viscosity	Pa s
ν	Kinematic viscosity = $\frac{\mu}{\rho}$	m ² /s
k_p	Compressibility coefficient	—

*For atmospheric air it may be taken that:

$$c_p = 1000 \text{ J/(kg K)}$$

$$\gamma = 1.40$$

Symbol	Term	Unit
α	Flow coefficient	—
β	Ratio of orifice or nozzle diameter to airway diameter	—
ϵ	Expansibility factor	—
λ	Darcy friction factor	—
ζ	Conventional friction loss coefficient	—
D_h	Hydraulic diameter = $\frac{4 \times \text{area of cross section}}{\text{perimeter of cross section}}$	m
D_e	Equivalent diameter = $\sqrt{\frac{4 \times \text{area of cross section}}{\pi}}$	m
m	Number of straight traverse lines	—
k	Number of measuring points	—
S	Ratio of percentage change in fan total pressure to percentage change in volume flow	—
K_d	Ratio of fan dynamic pressure to fan total pressure	—
U	Peripheral speed	m/s
Y	Correction factor (see 13.4)	—
Z	Constant used to define compressibility coefficient	—
q	Index used in conversion rules for compressible flow	—
g	Acceleration due to gravity	m/s ²
H	Altitude at barometer minus altitude at fan	m
x	Measured or calculated quantity	—
e_x	Uncertainty of x	—

4.2 Subscripts. The following subscripts identify the locations specified for particular measurements, air conditions and calculated quantities.

Subscript	Location
a	the ambient atmosphere in the test enclosure
1	the test fan inlet
2	the test fan outlet
3	the pressure measurement section in an inlet side airway
4	the pressure measurement section in an outlet side airway
5	the inlet side throat or downstream tapping for Δp
6	the outlet side upstream tapping for Δp and p_u
7	the inlet side upstream tapping for Δp and p_u
8	the outlet side throat or downstream tapping for Δp
c	the centre point of the test section
d	the air downstream of a flow measurement device
i	air having the total pressure and total temperature at fan inlet
u	the reference air conditions upstream of a flow measurement device
xy	the airway length from plane x to plane y

4.3 Multiples and sub-multiples. It is recommended that the following should be the only multiples and sub-multiples of the SI units used in fan technology:

Pressure	kilopascal	1 kPa = 10 ³ Pa
Barometric pressure	millibar	1 mbar = 100 Pa
Volume flow	litre per second	1 litre/s = 10 ⁻³ m ³ /s
Power	kilowatt	1 kW = 10 ³ W
Efficiency	per cent	% = 100 x ratio
Rotational speed	revolutions per minute	60 r/min = 1 r/s
Dimensions	millimetre	1 mm = 10 ⁻³ m
	micrometre	1 μ m = 10 ⁻⁶ m

5. Instrumentation for measurement of pressure

5.1 Barometers. The atmospheric pressure in the test enclosure shall be determined with an uncertainty not exceeding $\pm 0.3\%$. Barometers of the direct reading mercury column type should be read to the nearest 100 Pa (1 millibar) or to the nearest 1 mm of mercury. They should be calibrated and corrections applied to the readings as specified in BS 2520. Correction may be unnecessary if the scale is preset for the regional value of g (within $\pm 0.01 \text{ m/s}^2$) and for room temperature (within $\pm 10^\circ\text{C}$).

Barometers of the aneroid or pressure transducer type may be used provided they have a calibrated accuracy of $\pm 200 \text{ Pa}$ and the calibration is checked at the time of test.

The barometer should preferably be located in the test enclosure. If elsewhere in the locality a correction, $\rho_a g H \text{ Pa}$, should be added for any difference in altitude exceeding 10 m,

where

H is the altitude at barometer minus altitude at fan (m);

g is the acceleration due to gravity (9.8 m/s^2).

5.2 Manometers. Manometers for the measurement of pressure difference shall have an uncertainty under conditions of steady pressure, and after applying any calibration corrections (including that for any temperature difference from calibration temperature), not exceeding $\pm 1\%$ of the significant pressure or 1.5 Pa, whichever is the greater.

The significant pressure should be taken as the fan total pressure at rated duty or the pressure difference when measuring rated volume flow according to the manometer function. Rated duty will normally be the point of best efficiency on the fan characteristic.

The manometers will normally be of the vertical or inclined liquid column type, but pressure transducers with indicating or recording instrumentation are acceptable, subject to the same accuracy and calibration requirements.

Calibration should be at a series of steady pressures, taken both in rising and falling sequence to check for any difference.

of $\pm 0.25\%$ or 0.5 Pa, whichever is the greater.

5.3 Damping of manometers. Rapid fluctuations of manometer readings should be limited by damping so that it is possible to estimate the average reading within $\pm 1.0\%$ of the significant pressure. The damping may be in the air connections leading to the manometer or in the liquid circuit of the instrument. It should be linear, and of a type which ensures equal resistance to movement in either direction. The damping should not be so heavy that it prevents the proper indication of slower changes. If these occur a sufficient number of readings should be taken to determine an average within $\pm 1.0\%$ of the significant pressure.

5.4 Checking of manometers. Liquid column manometers should be checked in their test location to confirm their calibration near the significant pressure. Inclined tube instruments should be frequently checked for level and rechecked for calibration if disturbed. The zero reading of all manometers shall be checked before and after each series of readings without disturbing the instrument.

6. Determination of average static pressure in an airway

6.1 Methods of measurement. A differential manometer complying with the recommendations of 5.2 to 5.4 shall be used, with one side connected either to wall tapplings, or to the static pressure connections of a set of pitot-static tubes in the plane of pressure measurement.

To determine the average static pressure in this plane the other side of the manometer shall be open to the atmospheric pressure in the test enclosure.

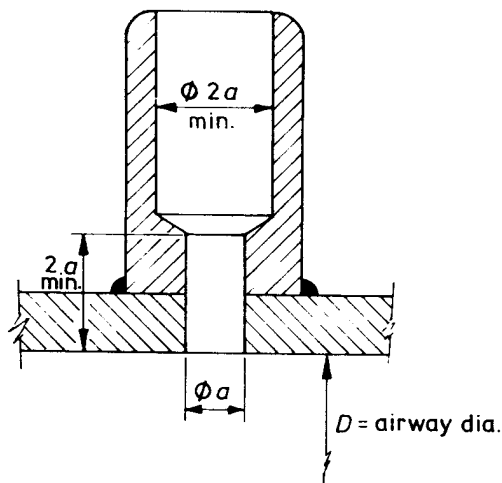
To determine the pressure difference between planes of pressure measurement on opposite sides of the fan, either or both sides of the manometer may be connected between sets of tapping connections arranged as recommended in 6.4.

6.2 Use of wall tapplings. At each of the sections for pressure measurement in the standardized airways specified in section two the average static pressure shall be taken to be the average of the static pressures at four wall tapplings constructed in accordance with this clause. The same method may be used at the planes selected for pressure measurement on site in accordance with clause 36, provided it can be shown that the flow in the plane is reasonably uniform, free from swirl, and free from flow separation.

6.3 Construction of tapplings. Each tapping takes the form of a hole through the wall of the airway conforming to the dimensional limits shown in figure 1. Additional limits are specified in clauses 20, 21 and 22 for the tapplings used in flow measurement devices. It is essential that the hole is carefully produced so that the bore is normal to and flush with the inside surface of the airway, and that all internal protrusions are removed. Rounding of the edge of the hole up to a maximum of $0.1a$ is permissible.

Special care is required when the velocity in the airway is comparable with that at the fan inlet and outlet. In these cases the tapping should be situated in a section of the airway that is free from joints or other irregularities for a distance of D upstream, $D/2$ downstream, and $D/4$ in the plane of the tapplings, D being the airway diameter. In very large airways it may not be practicable to meet this condition. In such cases the pitot-static tube method described in 6.6 may be used.

6.4 Position and connections. In the case of a cylindrical airway the four tapplings should be equally spaced around the circumference. In the case of a rectangular airway they should be at the centres of the four sides. Four similar tapplings may be connected to a single manometer but, to avoid averaging error, it is recommended that they should be connected in pairs by two equal lengths of tubing as shown in figure 2. The mid-points of these should be connected by a third tube, and the manometer connected at the mid-point of this.



NOTE. a to be not less than 1.5 mm nor greater than 10 mm and not greater than $0.1D$.

Figure 1. Construction of wall pressure tapplings

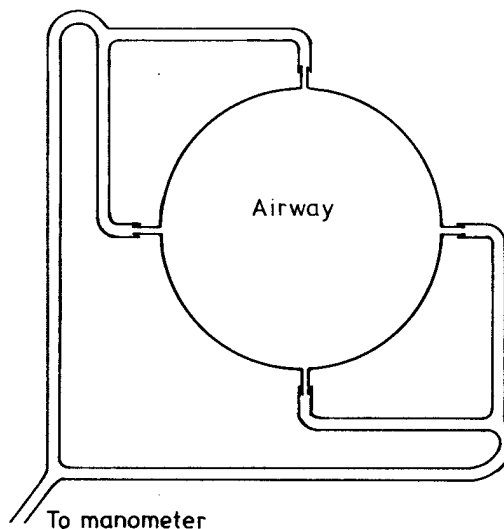


Figure 2. Tapping connections to obtain average static pressure

6.5 Checks for compliance. Care shall be taken to ensure that all tubing and connections are free from blockage and leakage.

Before the commencement of any series of observations the pressure at the four side tapplings should be individually measured at a flow rate towards the maximum of the series. If any one of the four readings lies outside a range equal to 2 % of the significant pressure, the tapplings and manometer connections should be examined for defects, and if none are found the flow should be examined for uniformity.

NOTE. By the significant pressure is meant the pressure across the nozzle or orifice at rated flow in the case of flow measurement, or the rated fan pressure in the case of pressure measurement.

6.6 Use of pitot-static tube. At the appropriate pressure measurement plane in a circular airway, a minimum of four points should be selected equally and symmetrically spaced around the axis at approximately one-eighth of the airway diameter from the wall or, in the case of a rectangular airway, one-eighth of the duct width from the centre of each wall. Under steady flow conditions, a static pressure reading should be taken at each point and the average calculated. Alternatively, if desired, the static pressure connections of four separate pitot-static tubes may be connected together to give a single average reading in the manner described in 6.4.

7. Measurement of temperature

7.1 Thermometers. Instruments for the measurement of temperature shall have an accuracy of $\pm 0.5^\circ\text{C}$ after the application of any calibration correction. The corrected test reading should be recorded to the nearest 0.5°C .

7.2 Thermometer location. Temperature measurements taken inside an airway shall be made with the sensing element directly in the airstream located on a horizontal diameter, one third of the airway diameter or 100 mm from the wall, whichever is the lesser. Instruments should be withdrawn from the airstream when performance readings are taken, unless it is demonstrated that their presence does not affect the determination of performance.

7.3 Humidity. The dry bulb and wet bulb temperatures in the test enclosure should be measured at a point where they can record the condition of the air entering the test airway. The instruments should be shielded against radiation from heated surfaces.

The wet bulb thermometer should be located in an air stream of velocity of at least 3 m/s. The sleeving should be clean, in good contact with the bulb, and kept wetted with pure water.

7.4 Influence of air velocity. The uncertainty of temperature measurement will increase if the temperature sensing element is placed in an airstream of velocity exceeding 35 m/s with atmospheric air (0.1 Mach number) (see 13.3).

8. Determination of density

8.1 Density of the air in the test enclosure. The density of the air in the test enclosure (in kg/m^3) is given by the following expression:

$$\rho_a = \frac{3.484 (p_a - 0.378 p_v)}{1000 (273 + t_a)}$$

However, when testing with standardized airways, the effect of water vapour is usually negligible. At temperatures below 23°C the following simplified expression may be used with an uncertainty not exceeding $\pm 0.5\%$.

$$\rho_a = \frac{3.468 p_a}{1000 (273 + t_a)}$$

This latter expression may also be used under site conditions when the moisture content of the air is less than 1.5 % by mass.

8.2 Average density of the air in an airway section. The average density of the air in an airway section x , where the average static pressure is p_{sx} , and the average air temperature in $^{\circ}\text{C}$ is t_x , may be obtained from the following expression:

$$\rho_x = \rho_a \left(\frac{p_a + p_{sx}}{p_a} \right) \left(\frac{273 + t_a}{273 + t_x} \right) (1 + Y)$$

8.3 Determination of vapour pressure. The vapour pressure (in Pa) may be obtained from the following expression:

$$p_v = p'_{\text{sat}} - p_a A (t_a - t_w)$$

where

p'_{sat} is the saturation vapour pressure at the wet bulb temperature t_w ;

t_a is the dry bulb temperature;

$A = 6.66 \times 10^{-4} \text{ }^{\circ}\text{C}^{-1}$ when t_w is between 0°C and 150°C ;

$A = 5.94 \times 10^{-4} \text{ }^{\circ}\text{C}^{-1}$ when t_w is less than 0°C .

Table 1 lists values of saturated vapour pressure (p'_{sat}) in 0.5°C increments of water or ice in contact with air over the temperature range -4.0°C to 49.5°C .

Table 1. Saturation vapour pressures

Wet-bulb temperature t_w	Saturation vapour pressure p'_{sat}	Wet-bulb temperature t_w	Saturation vapour pressure p'_{sat}	Wet-bulb temperature t_w	Saturation vapour pressure p'_{sat}
$^{\circ}\text{C}$	Pa	$^{\circ}\text{C}$	Pa	$^{\circ}\text{C}$	Pa
-4	437	14	1598	32	4754
-3.5	456	14.5	1650	32.5	4890
-3	476	15	1704	33	5029
-2.5	496	15.5	1760	33.5	5172
-2	517	16	1817	34	5319
-1.5	539	16.5	1876	34.5	5468
-1	562	17	1936	35	5622
-0.5	584	17.5	1999	35.5	5779
0	611	18	2063	36	5940
0.5	633	18.5	2128	36.5	6106
1	657	19	2196	37	6274
1.5	681	19.5	2266	37.5	6447
2	706	20	2337	38	6624
2.5	731	20.5	2410	38.5	6806
3	758	21	2486	39	6991
3.5	785	21.5	2563	39.5	7181
4	813	22	2643	40	7375
4.5	842	22.5	2724	40.5	7576
5	872	23	2808	41	7778
5.5	903	23.5	2894	41.5	7988
6	935	24	2983	42	8199
6.5	967	24.5	3073	42.5	8419
7	1001	25	3166	43	8640
7.5	1036	25.5	3262	43.5	8870
8	1072	26	3360	44	9100
8.5	1109	26.5	3461	44.5	9341
9	1147	27	3564	45	9582
9.5	1188	27.5	3670	45.5	9835
10	1227	28	3779	46	10089
10.5	1269	28.5	3890	46.5	10350
11	1312	29	4005	47	10616
11.5	1356	29.5	4122	47.5	10888
12	1402	30	4242	48	11166
12.5	1449	30.5	4365	48.5	11450
13	1497	31	4492	49	11740
13.5	1546	31.5	4621	49.5	12035

9. Measurement of rotational speed

9.1 Fan shaft speed. The fan shaft speed shall be measured at regular intervals throughout the period of test for each test point so as to ensure the determination of average speed during each such period with an uncertainty not exceeding $\pm 0.5\%$. No device used should significantly affect the speed of the fan under test or its performance.

9.2 Examples of acceptable methods

9.2.1 Digital counter measuring the revolutions for a measured time interval. The number of impulses counted shall be not less than 1000 during the measured time interval. The timing device shall be actuated automatically by the starting and stopping of the counter and shall not be in error by more than 0.25% of the time needed to count the total number of impulses.

9.2.2 Revolution counter. This shall be free from slip and timed over a period of not less than 60 s per operation.

9.2.3 Direct indicating mechanical or electrical tachometer. This shall be free from slip and calibrated before and after use. The smallest division on the scale of such an instrument should represent not more than 0.25% of the measured speed.

9.2.4 Stroboscopic methods. These shall be calibrated against a rotating standard before and after use unless fed by or checked against a source whose frequency is known or measured within $\pm 0.25\%$.

9.2.5 Frequency meter. When the fan is direct driven by a synchronous or induction motor, by measurement of the supply frequency and in the latter case, also counting the slip frequency. The frequency meter shall have an uncertainty of not more than 0.5% (i.e. accuracy class index of 0.5 in accordance with BS 89). Alternatively, a digital instrument of lower class index, i.e. smaller uncertainty, is permissible. The device used for indicating slip frequency shall be used in such a manner as to permit direct counting with an uncertainty not exceeding $\pm 0.25\%$ of the shaft speed.

10. Determination of power input

10.1 Measurement accuracy. The power input to the fan over the specified performance range should be determined by a method, including the averaging of a sufficient number of readings at each test point, which achieves a result with an uncertainty not exceeding $\pm 2.0\%$.

10.2 Fan shaft power. When the power to be determined is the input to the fan shaft, acceptable methods include the following.

10.2.1 Reaction dynamometer. The torque is measured by means of a cradle or torque-table type dynamometer for which torque-arm and weight calibration data are available.

10.2.2 Torsion meter. The torque is measured by means of a torsion meter having an uncertainty not exceeding 1.0% of the torque to be measured and for which static calibration data are available.

10.2.3 Summation of losses. The power output of an electric motor for direct drive is deduced from its electrical power input by the summation of losses method specified in BS 4999 : Part 33. For this purpose, measurements of voltage, current, speed and, in the case of a.c. motors, watts input and slip of induction motors shall be made for each test point and the no-load losses of the motor when uncoupled from the fan shall be measured.

10.2.4 Calibrated motor. The power output of an electric motor for direct drive is determined from an efficiency calibration acceptable to both manufacturer and purchaser. The motor should be run on load for a sufficient time to ensure that it is running at its normal working temperature. The electrical supply should be within the statutory limits, i.e. $\pm 6\%$ voltage, $\pm 1\%$ frequency.

10.3 Electrical instruments. The electrical power input to the motor during the fan tests described in 10.2.3 or 10.2.4 shall be measured by one of the following methods:

- (a) for a.c. motors by the two wattmeter method or by an integrating wattmeter;
- (b) for d.c. motors by measurement of the input voltage and current.

For standardized airway tests the instruments used for these measurements shall be of class index 0.5 in accordance with BS 89 to which calibration corrections are applied or, alternatively, of class index 0.2 for which calibration corrections are unnecessary.

10.4 Impeller power. To determine the power input to the fan impeller it is necessary, unless the impeller is mounted directly on the motor shaft, to deduct from the fan shaft power an allowance for bearing losses and for the losses in any flexible coupling. This may be determined by running a further test at the same speed with the impeller removed from the shaft and measuring the torque losses due to bearing friction. If considered necessary the fan impeller may be substituted by an equivalent weight (having negligible aerodynamic loss) to provide similar bearing loadings.

10.5 Transmission systems. For tests with standardized airways the interposition of a transmission system between the fan and the point of power measurement should be avoided unless it is of a type in which the transmission losses under the specified working conditions can be reliably determined, or the specified power input is required to include those losses.

NOTE. For requirements for power measurement on site see clause 37.

11. Measurement of dimensions and determination of areas

11.1 Flow measurement devices. The dimensions of nozzles, orifices and airways used for flow measurement shall conform to the tolerances specified in the appropriate clauses covering their use.

11.2 Tolerance on dimensions

11.2.1 Specified airway component lengths shall be measured after manufacture and shall conform to the requirements of the test method within a tolerance of $-1\% + 10\%$ except where otherwise stated.

11.2.2 Specified airway component diameters shall be measured after manufacture and shall conform to the requirements of the test method within a tolerance of $\pm 1\%$ except where otherwise stated.

11.3 Determination of cross-sectional area

11.3.1 Dimensional measurements. Sufficient dimensional measurements shall be taken across the reference planes of airways to determine cross-sectional areas within $\pm 0.5\%$ in standardized airways and other well-defined regular sections.

NOTE. It is recognized that this accuracy is not always obtainable on site.

11.3.2 Circular sections. For circular sections the mean diameter of the section is taken as being equal to the arithmetic mean of the measured values on at least three diameters of the measuring section. The diameters shall be so positioned that they are at equal angles within the cross section. If the difference in linear measurement between two adjacent diameters is more than 1% , the number of measured diameters shall be doubled. The area of the circular section shall be taken as follows:

$$\frac{\pi \bar{D}^2}{4}$$

where

$\bar{D}$ is the arithmetic mean of the measured diameters.

11.3.3 Rectangular sections. The width and height of a rectangular section shall be measured along the lines defined for traversing in figure 32 and if the difference between two adjacent widths or heights is more than 2% then the number of measurements in that direction shall be doubled. The average width of the section shall be taken as the arithmetic mean of all the widths measured and the average height of the section shall be taken as the arithmetic mean of all the heights measured. The cross-sectional area of the section shall be taken as being the average width multiplied by the average height.

11.3.4 Annular sections. The radial dimension of the annular section shall be measured on at least four equally spaced radii and if the length of the adjacent lines varies by more than 1% then the number of measurements along equally spaced radii shall be doubled. The average width a_n of the annular section shall be taken as the arithmetic mean of the measurements made. The internal or core diameter c shall be measured either:

(a) directly across four equally spaced diameters with the arithmetic mean of the measurements being taken as the mean diameter, or

(b) indirectly, by measuring the circumference of the core and dividing this by π to give the diameter.

The cross-sectional area of the annular section is then taken as follows:

$$\pi (c + a_n) a_n$$

where

c is the core diameter;

a_n is the average radial dimension of annular section.

11.3.5 Other forms of cross section. The cross-sectional area of other forms of airway may be determined by splitting the cross section into regular geometric forms and taking measurements of the boundaries of the geometric forms so determined. The number of measurements will depend on the forms involved but the same degree of accuracy should be sought as has been specified for regular sections. The areas of the separate shapes shall be calculated and either added to give the total cross-sectional area or used individually to determine flow rates in individual subsections.

11.3.6 Alternative methods. Other methods of determining cross-sectional area may be permitted by agreement between the manufacturer and the purchaser. For example, in the case of a circular duct by measuring the outer perimeter of a circular duct and allowing for wall thickness.

12. Determination of flow rate

12.1 General. The measurement of flow rate may be carried out in accordance with BS 1042 : Part 1 or Part 2A, and any flow rate measurement obtained in this way will conform to the requirements of this standard. It is not normally practical to measure the flow rate in accordance with BS 1042 : Part 1 or Part 2A when testing fans, largely because of the limitations which these standards impose on the lengths of straight pipe required upstream of the flow metering plane. This standard therefore specifies modifications of these flow metering methods which are appropriate for fan testing purposes, and in each case the associated uncertainty of measurement is given.

The flow shall be effectively swirl free. Provisions to ensure that this condition is met are included in the methods of test. Two basic flow metering methods are permissible under these relaxed conditions: i.e. the use of an in-line flowmeter or a traversing method.

12.2 In-line flowmeters (standard primary devices)

12.2.1 The flowmeters which may be used are the venturi nozzle, the orifice plate and the conical inlet. The first two may be used at the inlet to or outlet from an airway as well as between two sections of an airway. The conical inlet may only be used at the inlet to an airway, drawing air from free space. The requirements for these instruments and for the simplified installations in which they may be used are given in clauses 20 to 22.

12.2.2 The general expression for the mass flow rate through an in-line differential pressure flowmeter is as follows:

$$q_m = \alpha \epsilon \frac{\pi d^2}{4} \sqrt{2 \rho_u \Delta p}$$

where

q_m is the mass flow rate (kg/s);

d is the throat diameter (m);

ρ_u is the upstream density (kg/m³);

Δp is the pressure difference (Pa);

α is the flow coefficient;

ϵ is the expansibility factor.

For a given device, ϵ is a function of the pressure ratio and α is a function of the Reynolds number. Values for these coefficients are given in clauses 20 to 22 and in figures 14, 16, 18, 19, 20, 21 and 22.

12.2.3 The pressure difference across an in-line flowmeter shall be measured with an uncertainty not exceeding $\pm 1.4\%$ of the observed value.

12.2.4 The uncertainty of the flow rate measurement is given in 16.4.2.

The values for the uncertainties of the coefficient associated with each flow metering element are given in clauses 20 to 22. It shall always be possible to reduce the uncertainties associated with any in-line flowmeter installation conforming to these relaxed conditions by calibrating the installation against an improved or calibrated standard device in accordance with BS 1042 : Part 1.

12.2.5 In order to facilitate the selection of type and size of flowmeter the losses associated with each type are given in figure 3. Approximate values for the pressure difference (expressed as a multiple of the dynamic pressure in the downstream airway), which will be registered across each device are also shown.

12.2.6 The venturi nozzle is the preferred device because of its relatively low pressure loss and its lower sensitivity to disturbances in the approaching airflow. The orifice plate in particular incurs higher pressure losses and an auxiliary booster fan is required if the fan characteristic is to be extended to maximum volume flow. For tests at one or more pre-set points on a fan characteristic, an orifice plate can, simultaneously with the flow measurement, provide the control pressure drop, and this can be a useful property.

12.2.7 In-line flowmeters are normally used for tests in a laboratory; they may, however, be used for site tests, provided the installation meets the appropriate requirements specified in clauses 20 to 22.

12.3 Traverse methods. The local velocity should be measured at a number of positions across a duct and the individual velocity values combined using an integration technique, to yield an estimate of the mean velocity in the duct. Measurement of the cross-sectional area of the duct in the traverse plane then allows the calculation of the flow rate.

In standardized airways, a pitot-static tube conforming to the requirements of BS 1042 : Part 2A (see figure 4) shall be used. For site tests any pitot-static tube conforming to ISO 3966 or a vane anemometer may be used.

Location of measuring positions and methods of measurement for standardized airways and site tests are given respectively in clause 23 and clauses 34 and 35.

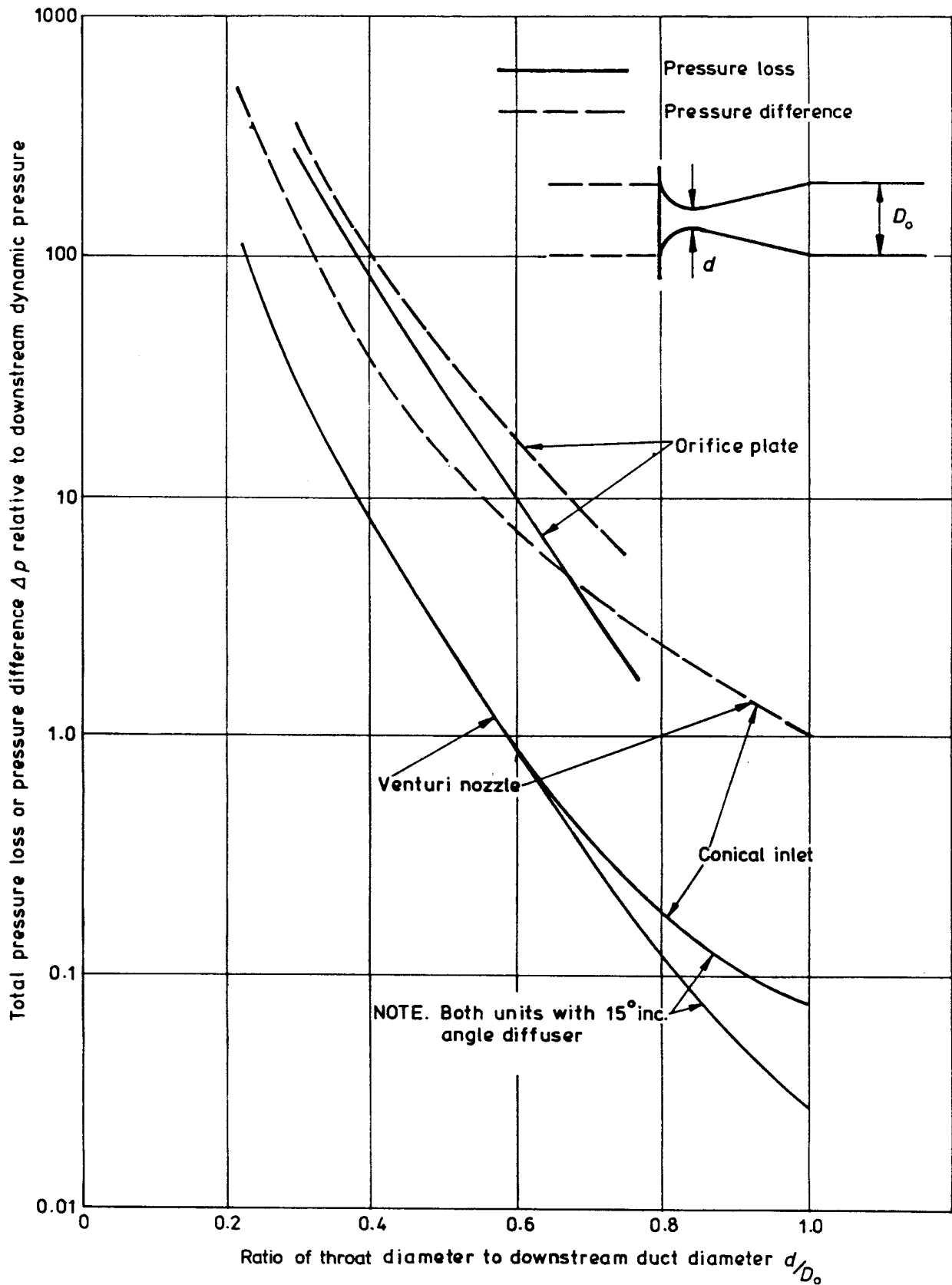
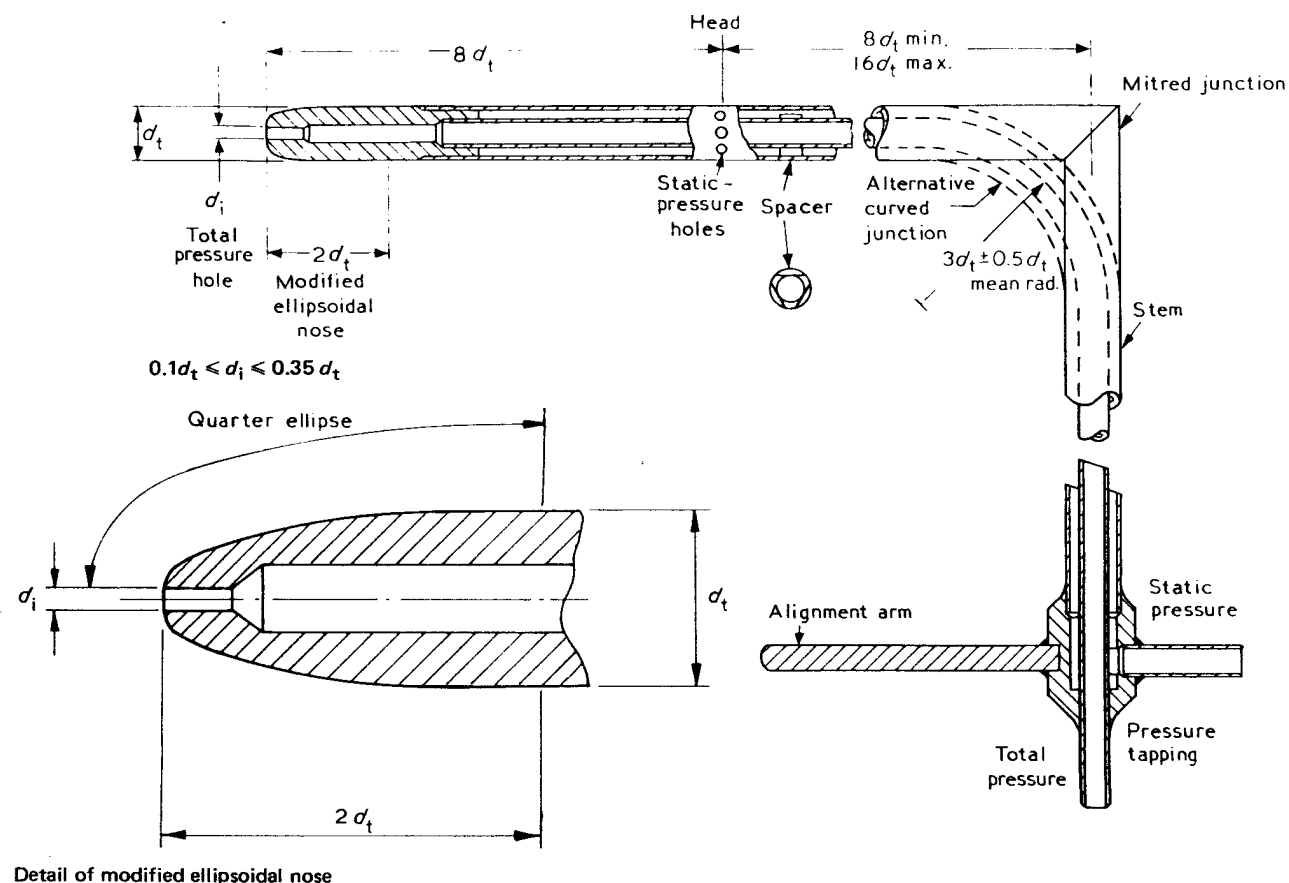


Figure 3. Pressure loss and pressure difference of standard primary devices



Detail of modified ellipsoidal nose

Figure 4. NPL modified ellipsoidal-nosed standard pitot-static tube

13. Calculation of the results of a test

13.1 General. Specific instructions for the determination of fan performance from the measurements at a single test point are given in section two or section three according to the particular method of test adopted. Some of the assumptions and approximations made to simplify this procedure are explained in this clause, together with their limitations.

13.2 Units. The units used throughout these calculations should be the SI units given in 4.1. The results will then also be in these units, viz. pressures in pascals, Pa; power in watts, W; volume flows in cubic metres per second, m³/s.

13.3 Temperature

13.3.1 In this standard t_x is taken as the total temperature of the air at section x, rather than the true (static) temperature, which is slightly lower at high air velocities, and not readily measurable. Total temperatures are obtained from the assumptions stated in clauses 27, 28, 29 and 30 and their use in the expressions minimizes the systematic error arising from the neglect of Mach number corrections. Corresponding assumptions should be made in site tests.

13.3.2 The behaviour of air in the test airways specified in this standard may be taken as adiabatic provided the air is taken from the ambient atmosphere and there is no deliberate injection of heat or mechanical energy except at the fan under test. The total temperature at all sections up to the fan inlet will then be constant and equal to the static temperature of the test enclosure or ambient atmosphere, t_a :

$$t_1 = t_3 = t_a$$

13.3.3 The total temperature at the fan outlet t_2 , and downstream as far as t_4 at the plane of pressure measurement, will be increased above t_1 by an amount dependent on the impeller input power P_R , the mass flow q_m and the specific heat of the air at constant pressure, c_p :

$$t_2 = t_4 = t_1 + \frac{P_R}{c_p q_m}$$

NOTE 1. In the above expression c_p can be taken as 1000 J/(kg K) when atmospheric air is the working fluid.

NOTE 2. P_R should be replaced by the electric input power P_E when the impeller is driven by a motor wholly immersed in the airstream.

NOTE 3. t_2 and t_4 need not be calculated for low pressure fans within the limits specified in 13.8.

13.3.4 When the above conditions do not apply the temperature shall be measured by a thermometer inserted into the airway in accordance with 7.2 at a point where the velocity does not exceed 35 m/s provided this is reasonably close to the relevant section.

13.4 Dynamic pressure and fan dynamic pressure

13.4.1 In any duct or chamber section x with area A_x and mass flow q_m at which the average static pressure p_{sx} is measured and the total temperature t_x determined in accordance with 13.3, the effective dynamic pressure p_{dx} , the effective total pressure p_{tx} and the air density ρ_x are given by the following expressions:

$$p_{dx} = \frac{q_m^2}{2\rho_x A_x^2}; \quad p_{tx} = p_{sx} + p_{dx}; \quad \rho_x = \rho_a \left(\frac{p_a + p_{sx}}{p_a} \right) \left(\frac{273 + t_a}{273 + t_x} \right) (1 + Y).$$

ρ_a is the density of the air in the test enclosure or ambient atmosphere derived from the atmospheric pressure p_a and temperature t_a in accordance with 8.1.

$(1 + Y)$ is a correction factor taking into account the difference between the total temperature t_x and the static temperature at section x , where Y is given by the following expression:

$$Y = \left(\frac{\gamma - 1}{2\gamma} \right) \left(\frac{q_m^2}{A_x^2} \right) \frac{R (273 + t_x)}{(p_a + p_{sx})^2} \\ = \left(\frac{v_x}{760} \right)^2 \text{ approximately in atmospheric air.}$$

13.4.2 For a type A or C fan installation with free outlet and fan outlet area A_2 (as specified in 18.5), the fan dynamic pressure p_{dF} is given by the following expression, ρ_2 being defined as in 13.4.1 in terms of t_2 (defined in 13.3.3) and p_{s2} .

$$p_{dF} = \frac{q_m^2}{2\rho_2 A_2^2}$$

13.4.3 For a type B or D fan installation with ducted outlet, p_{s2} cannot be measured directly. At the section of pressure measurement 4, downstream of the fan, p_{s4} is measured and t_4 taken as equal to t_2 as given in 13.3.3. ρ_2 is then taken as equal to ρ_4 , which is calculated from the expression in 13.4.1, and the fan dynamic pressure is given by:

$$p_{dF} = \frac{q_m^2}{2\rho_4 A_2^2}$$

13.4.4 These expressions may be used without significant systematic error at any velocity likely to be present in fan test airways. Correction factor Y may be taken as zero without such error exceeding 0.25 % of p_{dx} provided v_x does not exceed 35 m/s in atmospheric air (0.1 Mach number generally).

13.5 Fan static pressure and fan total pressure

13.5.1 Determination. The determination of these quantities depends upon the classification of the fan by installation type (see clause 17) and they are defined as follows.

For a type A or C installation with free outlet (see note):

$$\begin{aligned} \text{fan static pressure} \quad p_{sF} &= p_{s2} - p_{t1} \\ \text{fan total pressure} \quad p_{tF} &= p_{sF} + p_{dF} \end{aligned}$$

For a type B or D fan installation with ducted outlet (see note):

$$\begin{aligned} \text{fan total pressure} \quad p_{tF} &= p_{t2} - p_{t1} \\ \text{fan static pressure} \quad p_{sF} &= p_{tF} - p_{dF} \end{aligned}$$

Thus, for a free outlet fan, p_{sF} is directly defined in terms of p_{s2} , while, for a ducted outlet fan, p_{tF} is directly defined in terms of p_{t2} . In certain cases of free outlet fans (see 18.5) p_{dF} and the corresponding value of p_{tF} may be difficult to define, and are regarded as nominal.

NOTE. In some European specifications quantities equivalent to p_{sF} for a free outlet fan or to p_{tF} for a ducted outlet fan are both referred to as 'fan pressure', but are related to installation type.

13.5.2 Calculation. The pressures p_{t1} , p_{t2} and p_{s2} cannot be measured directly at the fan inlet or outlet, but are derived from measurements of static pressure upstream of the inlet, p_{s3} , or downstream of the outlet, p_{s4} . The calculations depend on the methods of measurement and on the classification of the fan by installation type as described in 13.5.3 to 13.5.6.

13.5.3 Determination of p_{s2} for a type A or C free outlet installation. When the air is discharged directly from the fan outlet into the test enclosure or ambient atmosphere with reference absolute pressure p_a , p_{s2} is taken as equal to p_{s4} , and is zero since the pressure measurement section 4 is located where the air velocity is negligible.

When the fan discharges directly into a chamber forming part of a site installation, and p_{s4} is the static pressure in the chamber measured in accordance with the requirements of 33.2.3, p_{s2} is taken as equal to p_{s4} .

13.5.4 Determination of p_{t2} for a type B or D ducted outlet installation. When p_{s4} is measured as specified in section two or section three in a duct on the outlet side of the fan:

$$p_{t2} = p_{t4} + p_{f24} = p_{s4} + p_{d4} (1 + \zeta_{24})$$

The allowance for duct friction between the fan outlet and the pressure measurement section 4 is $p_{f24} = \zeta_{24} p_{d4}$. For a standardized airway test ζ_{24} is specified in 24.6 (see figure 24). On site p_{f24} is obtained from the best available evidence, supplemented by the friction allowance given in appendix D.

13.5.5 Determination of p_{t1} for a type A or B free inlet installation. When the fan extracts air directly from the test enclosure or ambient atmosphere with reference absolute pressure p_a , p_{t1} is taken as equal to p_{t3} and p_{s3} and is zero since the pressure measurement section 3 is located where the air velocity is negligible.

When the fan extracts air directly from an inlet side chamber as described in clause 26:

$$p_{t1} = p_{t3} = p_{s3} + p_{d3}$$

NOTE. p_{s3} , p_{t3} and p_{t1} are normally negative.

When the fan extracts directly from a chamber forming part of a site installation, and p_{s3} is the static pressure in the chamber measured in accordance with 33.2.3, $p_{t1} = p_{t3} = p_{s3} + p_{d3}$, p_{d3} being determined (if significant) in accordance with 36.2.4.

When the fan is mounted on a partition separating two large spaces and thus forms a type A installation, $p_{sF} = (p_{s2} - p_{t1})$ is taken as the static pressure difference between the two spaces.

13.5.6 Determination of p_{t1} for a type C or D ducted inlet installation. When p_{s3} is measured as specified in section two or section three in a duct or chamber on the inlet side of the fan:

$$p_{t1} = p_{t3} - p_{f31} = p_{s3} + p_{d3} - \xi_{31} p_{d1}$$

NOTE. p_{s3} , p_{t3} and p_{t1} are normally negative.

The allowance for duct friction between pressure measurement section 3 and the fan inlet is $\xi_{31} p_{d1}$ for all standardized airways specified in section two, p_{d1} being the dynamic pressure in the airway section having the same size and shape as the fan inlet, and ξ_{31} being given in 24.6(b). In calculating the friction allowance it is sufficient in this case to take $\rho_1 = \rho_3$. On site p_{f31} is obtained from the best available evidence, supplemented by the friction allowance given in appendix D.

13.6 Inlet volume flow. The methods of flow measurement in this standard lead to a determination of the mass flow q_m . In the absence of leakage (but see 3.20 and 26.6.2) q_m will be constant throughout the airway system, and the inlet volume flow q_v can be expressed as follows:

$$q_v = \frac{q_m}{\rho_i}$$

where

$$\rho_i = \rho_a \left(\frac{p_a + p_{t1}}{p_a} \right) \left(\frac{273 + t_a}{273 + t_1} \right)$$

p_{t1} is determined as described in 13.5 for the relevant installation type. t_1 is determined as described in 13.3.2 or 13.3.4 as appropriate.

ρ_i , the inlet density, is a conventional value so that q_v is the volume flow of free air before acceleration towards the fan inlet. When the fan extracts air directly from the test enclosure or ambient atmosphere, $\rho_i = \rho_a$ since $p_{t1} = 0$ (13.5.5) and $t_1 = t_a$ (13.3.2).

13.7 Fan efficiencies (compressible flow)

13.7.1 When the air density and volume flow change significantly as the air passes through the fan, the air power is calculated on the assumption of a polytropic evolution from the density and pressure at fan inlet to those at fan outlet. The compressibility coefficient k_p is a function of the pressure ratio r and a constant Z expressed as follows:

$$k_p = \frac{Z \log_{10} r}{\log_{10} (1 + Z(r - 1))}$$

The constant Z is calculated for the appropriate type of fan installation as described in 13.7.2 and 13.7.3 and k_p may then be estimated from figure 5.

13.7.2 For a type A or C fan installation with free outlet, the pressure ratio r and the constant Z are given by the following expressions:

$$r = \frac{p_a + p_{s2}}{p_a + p_{t1}} = 1 + \frac{p_{sF}}{p_a + p_{t1}}; \quad Z = \frac{(\gamma - 1) \rho_i p_R}{\gamma q_m p_{sF}} = \frac{p_R}{3.5 q_v p_{sF}} \text{ for atmospheric air.}$$

The total and static air power are given by the following expressions:

$$\text{air power (static)} = k_p q_v p_{sF}; \quad \text{air power (total)} = k_p q_v p_{sF} + \frac{q_m p_{dF}}{\rho_2}.$$

13.7.3 For a type B or D fan installation with ducted outlet, the pressure ratio r and the constant Z are given by the following expressions:

$$r = \frac{p_a + p_{t2}}{p_a + p_{t1}} = 1 + \frac{p_{tF}}{p_a + p_{t1}}; \quad Z = \frac{(\gamma - 1) \rho_i p_R}{\gamma q_m p_{tF}} = \frac{p_R}{3.5 q_v p_{tF}} \text{ for atmospheric air.}$$

The total and static air power are given by the following expressions:

$$\text{air power (total)} = k_p q_v p_{tF}; \quad \text{air power (static)} = k_p q_v p_{tF} - \frac{q_m p_{dF}}{\rho_2}.$$