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Australian Standard[®]

**Measurement of fluid flow in
closed conduits**

Part 0: Vocabulary and symbols

This Australian Standard was prepared by Committee CE/24, Measurement of Water Flow in Open Channels and Closed Conduits. It was approved on behalf of the Council of Standards Australia on 3 August 1993 and published on 20 December 1993.

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closed conduits**

Part 0: Vocabulary and symbols

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PREFACE

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This Standard is one of a series, to be published progressively, which deals with methods of measurement of fluid flow in closed conduits. The following Parts were published concurrently with this Part:

AS

2360 Measurement of fluid flow in closed circuits

2360.0 Part 0: Vocabulary and symbols (*this Standard*)

2360.1.1 Part 1.1: Pressure differential methods—Measurement using orifice plates, nozzles or Venturi tubes—Conduits with diameters from 50 mm to 1200 mm

2360.1.2 Part 1.2: Pressure differential methods—Measurement using orifice plates or nozzles—Conduits with diameters less than 50 mm

2360.1.3 Part 1.3: Pressure differential methods—Measurement using orifice plates, nozzles or Venturi tubes—Guide to the use of methods specified in Parts 1.1 and 1.2

2360.1.4 Part 1.4: Pressure differential methods—Measurement using orifice plates, nozzles or Venturi tubes—Guide to the effect of departure from the conditions specified in Part 1.1

2360.1.5 Part 1.5: Pressure differential methods—Measurement using orifice plates, nozzles or Venturi tubes—Pulsating flow, in particular sinusoidal or square wave intermittent periodic–type fluctuations

2360.6.1 Part 6.1: Volumetric methods—By mass

2360.6.2 Part 6.2: Volumetric methods—By volume

2360.7.1 Part 7.1: Assessment of uncertainty in the calibration and use of flow measurement devices—Linear calibration relationships

2360.7.2 Part 7.2: Assessment of uncertainty in the calibration and use of flow measurement devices—Non–linear calibration relationships

At the date of publication of this Part the following Parts, with the numbers of the parent international Standards in parenthesis, had not been published:

Pressure differential methods—Measurement using orifice plates, nozzles or Venturi tubes—Connections for pressure signal transmissions between primary and secondary elements (ISO 2186)

Pitot static tube methods—Measurement of velocity at a point of the cross–section of a conduit (ISO 7145)

Pitot static tube methods—Measurement using Pitot–static tubes (ISO 3966)

Pitot static tube methods—Measurement in swirling or asymmetric flow conditions using ISO 3966 or ISO 3354 (ISO 7194)

Current meters method—Measurement of clean water in full conduits and under regular flow conditions using current meters (ISO 3354)

Non-radioactive tracer methods—Review of alternative methods (ISO 2975.1)

Non-radioactive tracer methods—Measurement using constant rate injection (ISO 2975.2)

Non-radioactive tracer methods—Measurement using transit time (ISO 2975.6)

Weighing methods—Verification of static type (ISO 9368.1)

Weighing methods—Verification of dynamic type (ISO 9368.2, not published)

When published, the details for the above unpublished Australian Standards will be listed in the Catalogue of Australian Standards and Other Products.

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<i>Reference to International Standard</i>		<i>Australian Standard</i>	
ISO		AS	
772	Liquid flow measurement in open channels—Vocabulary and symbols	3778	Measurement of water flow in open channels
		3778.1	Part 1: Vocabulary and symbols
5167	Measurement of fluid flow by means of pressure differential devices	2360	Measurement of fluid flow in closed conduits
5167.1	Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full	2360.1.1	Part 1.1: Pressure differential methods—Measurement using orifice plates, nozzles, or Venturi tubes—Conduits with diameters from 50 mm to 1200 mm
5168	Measurement of fluid flow—Evaluation of uncertainties	3778	Measurement of water flow in open channels
		3778.2.4	Part 2.4: General—Estimation of uncertainty of a flow-rate measurement

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Measurement of fluid flow in closed conduits

Part 0: Vocabulary and symbols

1 Scope

This International Standard defines the terms to be used in the field of measurement of fluid flow in closed conduits, and gives the corresponding symbols.

It has been found necessary to exclude terms which come under the following categories:

- a) terms which are self-evident;
- b) terms which do not apply specifically to this field, in particular those referring more specifically to flow in open channels (see ISO 772);
- c) terms referring to very specific methods of measurement which cannot be the subject of standardization.

2 Symbols

Reference number	Quantity	Symbol ¹⁾	Dimensions ²⁾	Corresponding SI unit
4.10	Cross-sectional area of the conduit, for the operating conditions	A	L^2	m^2
10.3	Concentration of the tracer	C	ML^{-3} ⁴⁾	kg/m^3
7.17	Discharge coefficient	C	$4)$	
8.2	Critical flow function	C_c	$4)$	
8.3	Real gas critical flow coefficient	C_r	$4)$	
4.16	Velocity of sound	c	LT^{-1}	m/s
4.31	Specific heat capacity at constant pressure	c_p	$L^2T^{-2}\Theta^{-1}$	$J/kg.K$
4.31	Specific heat capacity at constant volume	c_v	$L^2T^{-2}\Theta^{-1}$	$J/kg.K$
7.16	Diameter, depending on the operating conditions, — of the circular cross-section of the conduit — of the measuring conduit upstream of an orifice plate or nozzle — of the inlet cylinder of a classical Venturi tube	D	L	m
4.9	Hydraulic diameter	D_h	L	m
7.16	Orifice diameter or throat of	d	L	m
7.17	primary element, for the operating conditions or diameter of the head of a Pitot tube			
7.16	Velocity of approach factor	E	$4)$	
	Relative uncertainty	E	$4)$	
	Absolute uncertainty	e	$4)$	
4.17	Frequency	f	T^{-1}	s^{-1}
	Acceleration due to gravity	g	LT^{-2}	m/s^2
4.19	Equivalent uniform roughness	k	L	m
4.15	Length	l	L	m
4.33	Molar mass of fluid	M	M	kg/mol
5.9	Population mean	m	$5)$	
4.16	Mach number	Ma	$4)$	
5.9	Population size	N	$5)$	
10.4	Dilution ratio [rate]	N	$4)$	
5.5.1	Sample size	n	$4)$	
4.11.1	Absolute static pressure of the fluid	p	$ML^{-1}T^{-2}$	Pa
4.20	Differential pressure	Δp	$ML^{-1}T^{-2}$	Pa
4.1.1	Mass flow-rate	$q_m, (q)$	MT^{-1}	kg/s
4.1.2	Volume flow-rate	$q_v, (Q)$	L^3T^{-1}	m^3/s
4.33	Molar gas constant	R	$ML^2T^{-2}\Theta^{-1}$	$J/(mol.K)$
	Radius	R	L	m
5.2	Test result	R	$4)$	
4.18	Arithmetical mean deviation of the (roughness) profile	R_a	L	m
4.9	Hydraulic radius	R_h	L	m
4.15	Reynolds number		$4)$	
	— referred to D	Re_D		
	— referred to d	Re_d	$4)$	
4.17	Strouhal number	Sr	$4)$	
5.9	Experimental standard deviation	s	$5)$	
5.22	Standard error of estimate	s_R	$5)$	
	Fluid absolute temperature	T	Θ	K

Reference number	Quantity	Symbol ¹⁾	Dimensions ²⁾	Corresponding SI unit
5.25	Student's t distribution	t	⁴⁾	
5.26	Uncertainty	U	⁴⁾	
4.7	Mean axial fluid velocity	U	LT^{-1}	m/s
5.26.1	Random uncertainty	U_r	⁴⁾	
5.26.2	Systematic uncertainty	U_s	⁴⁾	
Figure 2	Upper and lower limits of a non-symmetrical uncertainty	U^+, U^-	⁴⁾	
4.21	Friction velocity	u^*	LT^{-1}	m/s
4.17	Local velocity of the fluid	v	LT^{-1}	m/s
4.8	Non-dimensional [relative] velocity	v^*	⁴⁾	
	Component of the local velocity parallel to the pipe axis	v_x	LT^{-1}	m/s
5.11	Weight of measurement	w_i	⁴⁾	
7.15	Acoustic ratio	X	⁴⁾	
7.13	Differential pressure ratio	x	⁴⁾	
5.1	Average value (of a variable x)	$\bar{x}$	⁴⁾	
5.11.1	Arithmetic weighted mean; weighted average	$\bar{x}_w$	⁴⁾	
9.1	Index of asymmetry	γ	⁴⁾	
	Distance from a measurement point to the wall	y	L	m
	Non-dimensional distance from a measurement point to the wall	y^*	⁴⁾	
4.33	Compressibility factor	Z	⁴⁾	
7.18	Flow coefficient	α	⁴⁾	
4.10	Kinetic energy coefficient	α	⁴⁾	
7.4	Diameter ratio	β	⁴⁾	
4.31	Ratio of the specific heat capacities	γ	⁴⁾	
7.19	Expansibility [expansion] factor	ε	⁴⁾	
	Fluid temperature, in degrees Celsius	θ	Θ	°C
4.6	Angle between the local velocity vector and the conduit axis	θ		rad
5.2	Sensitivity [influence] coefficient	θ_x	⁴⁾	
4.32	Isentropic exponent	κ	⁴⁾	
4.20	Universal head loss coefficient	λ	⁴⁾	
	Dynamic viscosity of the fluid	μ (or/ou η)	$ML^{-1}T^{-1}$	Pa.s
4.15	Kinematic viscosity of the fluid	ν	L^2T^{-1}	m ² /s
5.7	Number of degrees of freedom	ν	⁴⁾	
4.32	Density of the fluid	ρ	ML^{-3}	kg/m ³
7.14	Pressure ratio	τ	⁴⁾	
4.21	Wall shear stress	τ_o	$ML^{-1}T^{-2}$	Pa
	Included angle of the divergent	ϕ		rad
	Angle between the local velocity vector and the axis of the metering device	ϕ		rad
¹⁾ Symbols shown in parentheses are non-preferred. ²⁾ M = mass, L = length, T = time, Θ = temperature. ³⁾ The concentration can also be expressed as a dimensionless quantity. ⁴⁾ Dimensionless quantity. ⁵⁾ The dimension of this parameter is the dimension of the quantity to which it relates.				

3 Subscripts

Meaning	Symbol
Upstream	1
Downstream	2
Effective	e
Maximum	max
Minimum	min
Nominal	n
Residual	R
Random	r
At constant entropy	S
Systematic	s
Transition	t

4 General terms in fluid mechanics

4.1 flow-rate: Quotient of the quantity of fluid passing through the cross-section of a conduit and the time taken for this quantity to pass through this section.

4.1.1 mass flow-rate, q_m : Flow-rate in which the quantity of fluid is expressed as a mass.

4.1.2 volume flow-rate, q_v : Flow-rate in which the quantity of fluid is expressed as a volume.

4.2 mean flow-rate: Mean value of flow-rate over a period of time.

4.3 velocity distribution: Pattern of the axial vectors of the local fluid velocities over a cross-section of a conduit.

4.3.1 fully developed velocity distribution: Velocity distribution that, once attained, does not vary from one cross-section of a fluid flow to another. It is generally attained at the end of a sufficiently long straight length of conduit.

4.3.2 regular velocity distribution: Distribution of velocities which sufficiently approaches a fully developed velocity distribution to permit an accurate measurement of the flow-rate to be made.

4.4 flow profile: Graphic representation of the velocity distribution.

4.5 swirling flow: Flow which has axial and circumferential velocity components.

4.6 swirl angle, θ : Angle between the local velocity vector at a particular point of the cross-section and the conduit axis. The swirl angle varies over the cross-section.

4.7 mean axial fluid velocity, U : Ratio of the volume flow-rate (the integral over a cross-section of the conduit of the axial components of the local fluid velocity) to the area of the measurement cross-section.

4.8 non-dimensional [relative] velocity, v^* : Ratio of the flow velocity at a given point to a reference velocity measured at the same time which may be the velocity at a particular point (for example the centre-line velocity) or the mean axial fluid velocity.

4.9 hydraulic diameter, D_h : Four times the quotient wetted cross-sectional area and the wetted perimeter.

NOTES

1 For a circular cross-section conduit running full, the hydraulic diameter is equal to the internal diameter of the conduit.

2 **Hydraulic radius, R_h ,** is also used; it is equal to the quotient of the wetted cross-sectional area and the wetted perimeter ($D_h = 4R_h$).

4.10 kinetic energy coefficient, α : Coefficient defined by the formula

$$\alpha = \frac{1}{A} \int \int_A \left(\frac{v}{U} \right)^3 dA$$

where

dA is an element of the cross-sectional area;

A is the cross-sectional area of the flow.

(In most practical installations, α varies between 1 and 1.2 approximately.)

4.11 static pressure: Pressure which would be measured by a pin-point observer travelling with a particle of the fluid.

4.11.1 absolute static pressure of the fluid, p : Static pressure of a fluid measured with reference to a perfect vacuum.

4.11.2 gauge pressure: Difference between the absolute static pressure of a fluid and the atmospheric pressure at the place and time of the measurement.

4.12 Dynamic pressure

4.12.1 dynamic pressure of a fluid element: For an elemental fluid streamline, the increase in pressure above the static pressure which would result from the complete isentropic transformation of the kinetic energy of the fluid into pressure energy. It is equal to $\frac{1}{2}\rho v^2$ if the fluid is incompressible.

4.12.2 mean dynamic pressure in a cross-section: Ratio of the power of the fluid flowing through the cross-section in the form of kinetic energy to the volume flow-rate. It can be expressed as $\alpha \times \frac{1}{2}\rho U^2$ if the fluid is incompressible.

4.13 total pressure: Sum of the gauge pressure and the dynamic pressure.

NOTE — For an element of fluid at rest, the gauge pressure and the total pressure have the same numerical value.

4.14 stagnation pressure: Pressure which characterizes the state of the energy of a fluid when its kinetic energy is completely transformed into pressure energy. It is equal to the sum of the absolute static pressure and the dynamic pressure.

NOTE — For an element of fluid at rest, the absolute static pressure and the stagnation pressure have the same numerical value.

4.15 Reynolds number, Re : Dimensionless parameter expressing the ratio between the inertia and viscous forces. It is given by the formula

$$Re = \frac{Ul}{\nu}$$

where

U is the mean axial fluid velocity across a defined area;

l is a characteristic dimension of the system in which the flow occurs;

ν is the kinematic viscosity of the fluid.

NOTE — When specifying a Reynolds number, the characteristic dimension on which it has been based should be indicated for example, the diameter of the conduit, the diameter of the orifice of a differential pressure device, the diameter of a Pitot tube head, etc.).

4.16 Mach number, Ma : Ratio of the mean axial fluid velocity to the velocity of sound in the fluid at the considered temperature and pressure. It is given by the formula

$$Ma = \frac{U}{c}$$

4.17 Strouhal number, Sr : Dimensionless parameter relating the vortex shedding frequency f generated by a body having a characteristic dimension l to the fluid velocity v . It is given by the formula

$$Sr = \frac{fl}{v}$$

4.18 arithmetical mean deviation of the (roughness) profile, R_a : Arithmetic mean of the absolute values of the profile departures within the sampling length. It has the dimensions of length.

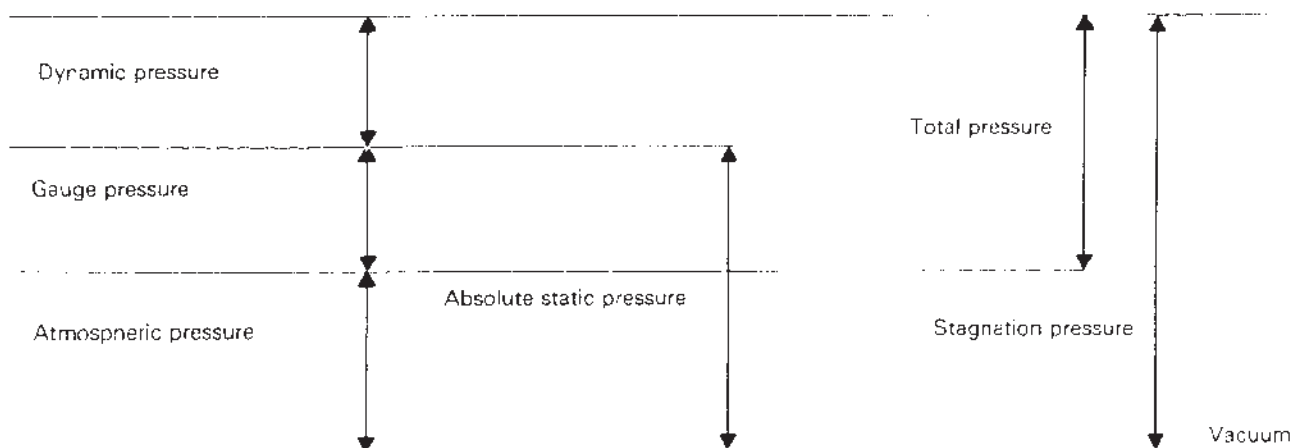


Figure 1 — Diagram illustrating the terms relating to pressure

4.19 equivalent uniform roughness, k : Diameter of closely-packed spherical particles lining the inner surface of a conduit that would give the same pressure loss per unit length as the actual surface of a conduit of equivalent diameter.

4.20 universal head loss coefficient, λ : Ratio of the pressure loss of a flow, along a length of conduit equal to the hydraulic diameter, to the dynamic pressure calculated from the mean axial fluid velocity. It is given by the formula

$$\Delta p = \lambda \frac{l}{D_h} \times \frac{1}{2} \rho U^2$$

4.21 friction velocity, u^* : Square root of the quotient of the wall shear stress τ_w and the density of the flowing fluid, i.e.

$$u^* = \sqrt{\frac{\tau_w}{\rho}} = U \sqrt{\frac{\lambda}{8}}$$

4.22 steady flow: Flow in which parameters such as velocity, pressure, density and temperature do not vary sufficiently with time to affect the required accuracy of measurement.

NOTE — The steady flows observed in conduits are in practice flows in which these parameters vary in time about mean values independent of time; these are actually "mean steady flows".

4.23 pulsating flow of mean constant flow-rate: Flow in which the flow-rate in a measuring section is a function of time but has a constant mean value when averaged over a sufficiently long period of time.

NOTE — Two types of pulsating flow are found, i.e.

- periodic pulsating flow;
- randomly fluctuating flow.

4.24 unsteady flow: Flow, which may be laminar or turbulent, in which parameters such as velocity, pressure, density and temperature fluctuate with time.

NOTE — The time interval being considered has to be sufficiently long that the random components of the turbulent flow itself may be ignored.

4.25 laminar flow: Flow under conditions where the forces due to viscosity are predominant in comparison with the forces due to inertia.

NOTE — Laminar flow may be unsteady but is completely free from turbulent mixing. Poiseuille flow is an example of steady laminar flow in a circular conduit.

4.26 turbulent flow: Flow under conditions where the forces due to inertia are predominant in comparison with the forces due to viscosity.

NOTE — Turbulent flow is a flow in which irregular (random) velocity fluctuations in time and space are superimposed on the mean flow.

4.27 fully rough turbulent flow: Flow in a conduit of a given relative roughness which occurs when the universal coefficient for head loss λ is independent of the Reynolds number Re .

4.28 transition flow: Flow intermediate between laminar flow and turbulent flow.

NOTE — As a guide, the Reynolds number for the transition flow of a newtonian fluid, when referred to the conduit diameter, is generally between a lower limit of 2 000 and an upper limit which varies between 7 000 and 12 000 depending on the conduit roughness and other factors.

4.29 Coanda effect: Effect which occurs when a jet of fluid adheres to a nearby solid surface.

4.30 Doppler effect: Apparent change in the frequency of a radiation due to relative motion between a primary or secondary source and the observer.

4.31 ratio of the specific heat capacities, γ : Ratio of the specific heat capacity at constant pressure to the specific heat capacity at constant volume:

$$\gamma = \frac{c_p}{c_v}$$

It varies in general whenever the gas temperature and/or pressure vary.

4.32 isentropic exponent, κ : Ratio of the relative variation in pressure to the corresponding relative variation in density under elementary reversible adiabatic (isentropic) transformation conditions:

$$\kappa = \frac{\rho}{p} \left(\frac{\partial p}{\partial \rho} \right)_s$$

For an ideal gas, the isentropic exponent is equal to the ratio of the specific heat capacities, this ratio being considered as constant in the chosen integration interval.

NOTE — The subscript S means "at constant entropy".

4.33 compressibility factor, Z : Correction factor expressing numerically the deviation from the ideal gas law of the behaviour of a real gas at given pressure and temperature conditions. It is defined by the formula

$$Z = \frac{pM}{\rho RT}$$

where R , the molar gas constant, equals 8,314 3 J/(mol.K).

5 Uncertainties

The definitions given in this clause are based on those from appropriate statistics standards but on occasions the full rigorous statistical definitions are not given in view of the practical interpretation of these definitions. In no case will the definitions given lead to errors in the formulae used. For further details, see ISO 3534 and the *International vocabulary of basic and general terms in metrology* (BIPM/IEC/ISO/OIML).

5.1 average value, $\bar{x}$: Arithmetic mean of n readings of the quantity x . The average value $\bar{x}$ is calculated using the following formula:

$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

5.2 sensitivity [influence] coefficient, θ_x : Ratio of the change in a result R to the change in an input parameter x :

$$\theta_x = \frac{\Delta R}{\Delta x}$$

In relative terms this becomes

$$\theta = \frac{\Delta R / R}{\Delta x / x}$$

5.3 frequency distribution: Relationship between the measured values of a variable and their frequencies of occurrence.

5.4 population: Totality of items under consideration.

5.5 sample: One or more items taken from a population and intended to provide information on the population, and possibly to serve as a basis for a decision on the population or on the process which produced it.

5.5.1 sample size, n : Number of items which are to be included in the sample.

5.6 true value: Value which characterizes a quantity perfectly defined in the conditions which exist when that quantity is considered.

It is an ideal value which could only be achieved if all causes of measurement error were eliminated.

5.7 number of degrees of freedom, ν : In general, the number of observations minus the number of parameters.

NOTE — For example, the standard deviation is said to have $(n - 1)$ degrees of freedom because for the estimation of the mean it is necessary to use one degree of freedom.

5.8 deviation: Difference between the value of a quantity and a standard or reference value.

NOTE — Particularly in statistics, the reference value is frequently the arithmetic mean of a series of measurements.

5.9 experimental standard deviation, s : For a series of n measurements of the same measurand, the parameter characterizing the dispersion of the results and given by the formula

$$s = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}}$$

where

x_i is the result of the i th measurement;

$\bar{x}$ is the arithmetic mean of the n results considered.

NOTES

1 The experimental standard deviation should not be confused with the population standard deviation σ of a population of size N and of mean m , given by the formula

$$\sigma = \sqrt{\frac{\sum_{i=1}^N (x_i - m)^2}{N}}$$

2 If the series of n measurements is considered to be a sample of a population, s is an estimate of the population standard deviation.

5.9.1 experimental standard deviation of the mean, $s(\bar{x})$: Estimate of the standard deviation of the arithmetic mean $\bar{x}$ with respect to the mean m of the overall population. It is given by the formula

$$s(\bar{x}) = \frac{s(x)}{\sqrt{n}}$$

5.9.2 residual standard deviation, s_R

See 5.22, standard error of estimate.

5.10 experimental variance, s^2 : A measure of the scatter or spread of a distribution. It is estimated by calculating the sum of the squares of deviations of measurements about the mean, divided by the number of degrees of freedom:

$$s^2 = \frac{\sum_{i=1}^n (x_i - \bar{x})^2}{n - 1}$$

5.10.1 residual variance, s_R^2 : The square of the residual standard deviation.

5.11 weight of measurement, w_i : Number which expresses the degree of confidence in the result of a measurement of a certain quantity in comparison with the result of another measurement of the same quantity.

5.11.1 arithmetic weighted mean, $\bar{x}_w$; weighted average, $\bar{x}_w$: Sum of the products of each value and its weight (which can be positive or zero) of measurement divided by the sum of the weights of measurement. It is given by the formula

$$\bar{x}_w = \frac{\sum_{i=1}^n w_i x_i}{\sum_{i=1}^n w_i}$$

5.12 calibration: The set of operations which establish, under specified conditions, the relationship between values indicated by a measuring device and the corresponding known values obtained using a measuring standard suitable for the flow-rates being measured.

5.12.1 calibration hierarchy

5.12.1.1 traceability: Property of a result of a measurement whereby it can be related to appropriate standards, generally international or national standards, through an unbroken chain of comparisons.

5.13 normal distribution; Laplace-Gauss distribution: Probability distribution of a continuous random variable x such that the probability density is

$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} \exp \left[-\frac{1}{2} \left(\frac{x - m}{\sigma} \right)^2 \right]$$

NOTE — m is the arithmetic mean and σ is the standard deviation of the normal distribution.

5.14 method of least squares: Technique used to compute the coefficients of the equation when a particular form of equation is chosen for fitting a curve to data. The principle of the method of least squares is the minimization of the sum of squares of deviations of the data from the curve.

5.15 regression: Process of quantifying the dependence of one variable on one or more other variables. Regression is a procedure for determining the unknown constants of a proposed model in such a manner that predictions from the model are as close as possible to the data in some way. Often "as close as possible" is taken to mean that the sum of squares of the deviations is a minimum. Many of the available computer programs suitable for curve fitting have the word "regression" in the title. For the purposes of this International Standard, regression and least squares may be regarded as synonyms.

5.16 (absolute) error of measurement: The result of a measurement minus the (conventional) true value of the measurand.

NOTES

- 1 The term relates equally to
 - the indication,
 - the uncorrected result,
 - the corrected result.
- 2 The known parts of the error of measurement may be compensated by applying appropriate corrections. The error of the corrected result can only be characterized by an uncertainty.
- 3 "Absolute error", which has a sign, should not be confused with **absolute value of an error** which is the modulus of an error.

5.17 outlier: An observed value which appears to be inconsistent with the remainder of the set of data.

5.18 spurious errors: Errors which invalidate a measurement. They generally have a single cause such as the incorrect recording of one or more significant digits or the malfunction of instruments.

5.19 random error: Component of the error of measurement which, in the course of a number of measurements of the same measurand, varies in an unpredictable way.

NOTE - It is not possible to correct for random error.

5.20 systematic error: Component of the error of measurement which, in the course of a number of measurements of the same measurand, remains constant or varies in a predictable way.

NOTES

- 1 Systematic errors and their causes may be known or unknown.
- 2 The known part of a systematic error is not to be included in the uncertainty budget to the instrument which is calibrated (it should, as a bias error, be subtracted beforehand).

5.21 elemental error: Random or systematic error associated with a single source or process in a chain of sources or processes.