SLOVENSKI STANDARD
SIST CR 14378:2002

01-maj-2002

Prezraļ evanje stavb ï Kanali ï Eksperimentalno doloļ evanje tlaļ nih padcev kanalskih komponent

Ventilation for buildings - Experimental determination of mechanical energy loss coefficients of air handling components

Ta slovenski standard je istoveten z: CR 14378:2002

ICS:

91.140.30	Prezraļ evalni in klimatski sistemi	Ventilation and air-conditioning

SIST CR 14378:2002 **en**

CEN REPORT

RAPPORT CEN

CEN BERICHT

CR 14378

January 2002

ICS

English version

Ventilation for buildings - Experimental determination of mechanical energy loss coefficients of air handling components

This CEN Report was approved by CEN on 10 November 2001. It has been drawn up by the Technical Committee CEN/TC 156.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Ref. No. CR 14378:2002 E

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Foreword

This Technical Report has been prepared by Technical Committee CEN/TC 156, 'Ventilation for buildings', the secretariat of which is held by BSI.

This report should be considered with a series of standards for ductwork used for ventilation and air conditioning of buildings for human occupancy.

The position of this report in the field of mechanical building services is shown in Figure 1.

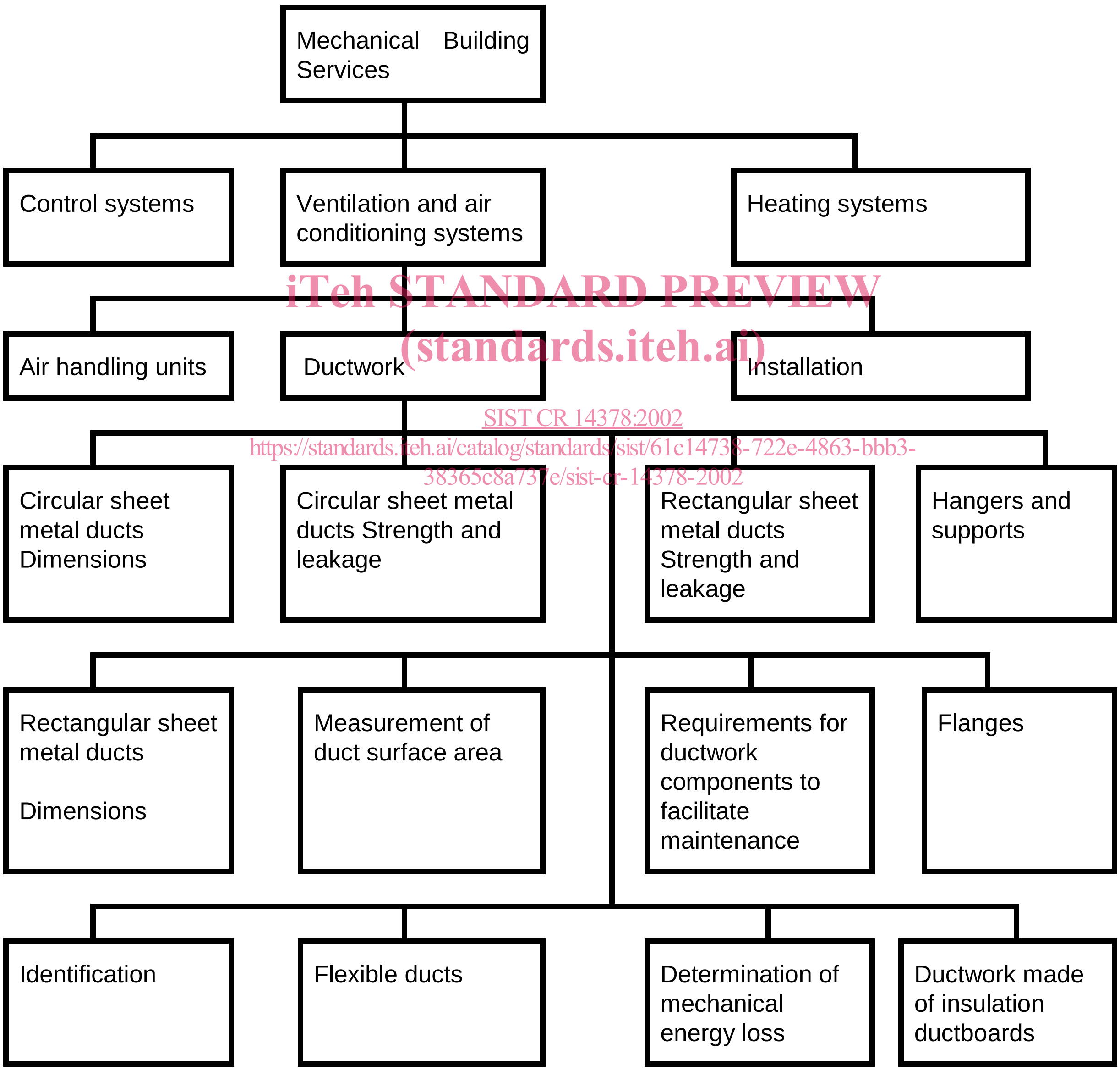


Figure 1 - Position of CR 14378 in the field of mechanical building services

1 Scope

This Technical Report specifies unified test procedures and conditions for the experimental determination of mechanical energy loss coefficients for ductwork components such as ducts, bends, diffusors, converging junctions and diverging junctions.

2 Normative references

This Technical Report incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references the subsequent amendments to or revisions of any of these publications apply to this Technical Report only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

CR 12792 Ventilation for buildings . Symbols, units and terminology

ISO 5221 Air flow measurement in an air handling duct.

3 Terms and definitions

For the purposes of this report, the terms and definitions and symbols are principally in accordance with CEN Technical Report CR 12792.

4 Test method

4.1 Principle

In principle it is possible to give a definition of energy loss produced by a component of air distribution systems.

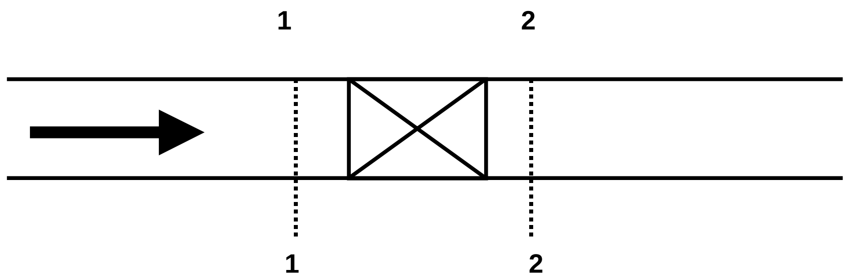


Figure 2 - Diagrammatic representation of energy flow

The mechanical energy loss in the flow within a typical component, as represented in Figure 2, is equal to the difference between the energy entering the component through section I and the energy leaving the component through section 2.

By applying the generalized Bernoulli formula which takes into account the fact that the air is compressible, therefore its density varies through the component, and that it is a real fluid, the velocity distribution in a section being non-uniform, the energy loss per unit mass (J/kg) is expressed by:

$$[\Delta y]_1^2 = \frac{p_1 - p_2}{p_{12}} + \alpha_{A1}\frac{v_{m1}^{\ 2}}{2} - \alpha_{A12}\frac{v_{m2}^{\ 2}}{2} + g(Z_1 - Z_2) \qquad (1)$$

where

Δy is the energy loss per unit mass

pis the absolute pressure

V_m is the mean flow velocity

Z is the altitude

ρ_{12} is the fluid density

g is the free fall acceleration

α_A is the kinetic energy factor

The kinetic energy factor α_A can be determined by Pitot-tube exploration in the cross section under consideration. The density ρ_{12} depends on the flow variation through the component.

In practice the presence of an air handling component in a duct system modifies the flow structure upstream and downstream of the component. For this reason the practical determination of the mechanical energy losses is generally made on the test installation as shown in Figure 3.

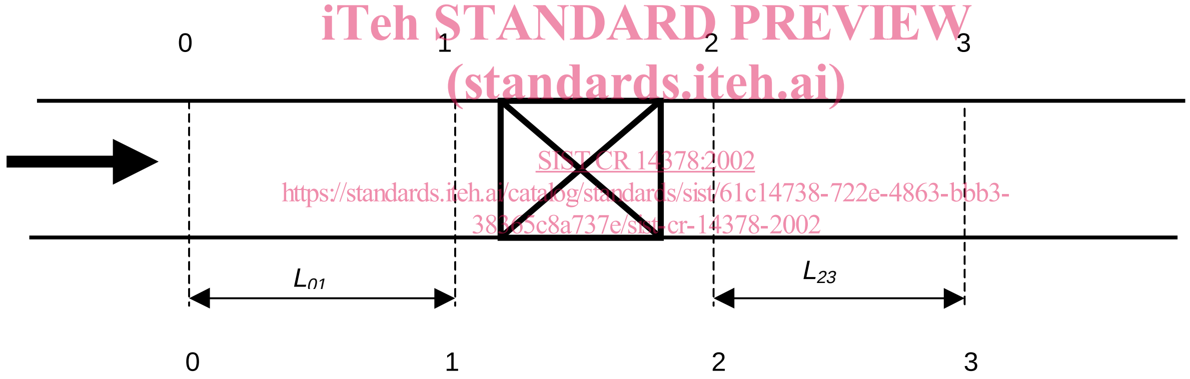


Figure 3 - Diagrammatic representation of the test installation

A straight duct of the length L_{01} is installed upstream of the component and a straight duct of the length L_{23} downstream. The measurement sections (0 upstream and 3 downstream) are consequently distant from the component. From the test values obtained in these sections the characteristics of flow are calculated for the sections I and 2 and then used in the generalized Bernoulli formula to obtain the mechanical energy loss.

The choice of lengths L_{01} and L_{23} and the assumptions concerning the flow through these duct sections can cause differences in the final results. Therefore an agreement on the choice of lengths shall be established before the start of the experimental work.

There is no intrinsic value of energy loss coefficient for an air handling component. For each upstream flow condition a different value will be found. Consequently the use of a long straight duct upstream of the component is just one of many possible conditions. However the different lengths of this duct and different entry conditions can produce variations in the flow pattern.

Therefore, it is important to specify in detail all characteristics of the installation upstream of the component. The upstream straight duct shall have a length equal to 200 and a specified perforated plate at the entrance. The measuring section shall be located at a distance 5D from the component.

The downstream flow pattern is dependent on the component under test. Usually a very long straight duct is used and the measuring section is a distance away in order to allow for the correct measurement. The energy loss of the ducting shall be taken into account in the calculation of the energy loss coefficient of the component under test. For the same length of straight duct this energy loss may be very different depending on the flow pattern (essentially in the presence or in the absence of swirl).

As the actual loss is not known the conventional energy loss corresponding to the fully established flow without swirl is normally used.

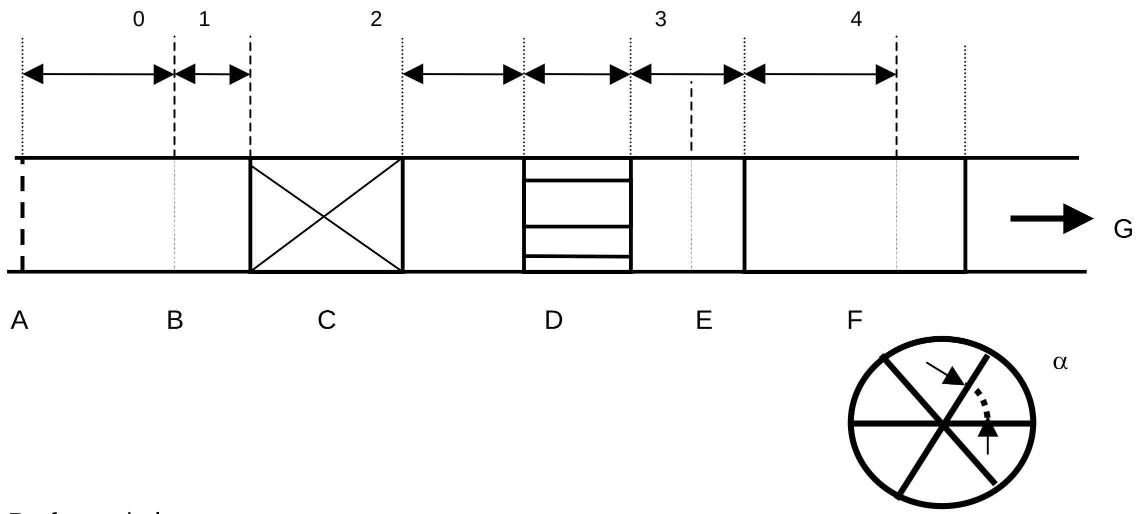
A specified flow straightener (as used for fan performance testing specified in ISO 5221) instead of a very long duct, (it can be as long as 40*D)* shall be installed immediately downstream of the component under test. The correct measurement of the pressure is then possible where the loss in the straightener and associated ducting is taken into account conventionally.

An important advantage of this method is the elimination of the necessity to measure the kinetic energy factor α_A in the upstream section as well as in the downstream section. It is assumed that α_A is equal to one. If a particular component produces a very strong swirling flow with an irregular velocity distribution, the energy loss in the straightener will be far greater than the conventional value used for the calculation. The energy loss coefficient of the component under test will appear higher.

These characteristics are presented in this way because in practice the rotational energy in fluid flow will be lost anyway and this loss is produced by the component (though not jn the component itself). It will be noted that in the usual method (a long straight duct downstream) this assumption is also applied but the measurement is more difficult and the scatter of results obtained in different laboratories can be important.

4.2 Test installation

The standard test installation is shown in Figure 4.



A Perforated plate
B Upstream measuring section
C Component under test
D Flow straightener “ETOILE’
E Downstream measuring section
F Complementary measuring
G Flow rate control and measurement

Figure 4 - Standard test installation

The following specification shall be used:

a) Duct diameter: Equal to the diameter of the component under test

b) Perforated plate at the inlet:

- diameter of holes: 5 mm
- distance between axes : 7,5 mm
- free area/total area: 0,40

c) Duct roughness: Smooth metal duct

d) Flow straightener "ETOILE" in accordance with the drawing

- Length: 20 (tolerance 1%)
- Thickness: < 0,0070
- Angle: $\alpha = 45\,° \pm 5\,°$

4.3 Rectangular and other non-circular ducts and components

For ducts and components with non-circular cross sections (essentially rectangular and oval) the notion of a hydraulic diameter shall be introduced. The hydraulic diameter is calculated as four times the cross section divided by the perimeter.

For a rectangular cross section with sides a and b, therefore, the hydraulic diameter D_h is given by:

$$D_h = \frac{4ab}{2(a+b)} = \frac{2ab}{(a+b)} \tag{2}$$

The standard test installation shall be made with upstream and downstream ducts of the same cross section as the component under test; using D_h instead of D for the circular duct, all calculations will use the same formulae.

As an alternative solution a test installation with circular ducts may be used. The component under test shall be connected to the upstream and downstream ducts using a transition with the following specification:

- the cross section area of the circular duct shall be equal to the cross section area of the component with a tolerance of ± 10 %,
- The length of the transition shall be equal to one diameter of the circular duct,
- For the calculation of the energy loss coefficient under test, the energy loss in the transition shall be considered equal to the loss in a straight duct having the same length.

4.4 Measurements

The following quantities shall be measured:

a) Atmospheric pressure p_a, Pa

b) Air temperature θ °C, [$T = 273{,}15 + \theta$ K]

c) Air humidity from both dry and wet bulb or dew point temperature

d) Static pressure in the section 0 (mean value of four individual readings), p_{s0} Pa

e) Static pressure in the section 3 (mean value of four individual readings), p_{s3} Pa

f) Differential pressure between the section 0 and 3, p_{s03} Pa

g) Static pressure in the section 4 (mean value of four individual readings), p_{s4} Pa

h) Mass flow rate (by an appropriate standardized method as given in Annex B), q_m kg/s

4.5 Calculation method

4.5.1 The calculation method is given in 4.5.2 to 4.5.9

4.5.2 The absolute pressures are calculated for the sections 0 and 3 as follows:

$$p_0 = p_a - p_{s0} \quad (3)$$

$$p_3 = p_a - p_{s3} \quad (4)$$

4.5.3 The mean air density (which is assumed to be constant throughout the test installation) is calculated from:

$$\rho = \frac{p_m}{287T} \bullet f \quad (5)$$

where

$$p_m = \frac{p_0 + p_3}{2} \quad (6)$$

and the humidity factor f is given by:

$$f = 1 - 0{,}378 \bullet \frac{p_v}{p_m} \quad (7)$$

where p_v is the partial vapour pressure

4.5.4 The Reynolds number is calculated from:

$$\mathrm{Re} = \frac{4q_m}{\pi \mu D} \quad (8)$$

where the dynamic viscosity μ is given by:

$$\mu = (17{,}1 + 0{,}048 \cdot \theta)10^{-6} \quad (9)$$

4.5.5 The mean air velocity is calculated from the following:

$$v = \frac{4q_m}{\rho D^2 \pi} \quad (10)$$

4.5.6 The pressures in sections I and 2 are calculated from the following:

$$p_1 = p_0 - \zeta_{01} \bullet \frac{\rho v^2}{2} \quad (11)$$

$$p_2 = p_3 - \zeta_{23} \bullet \frac{\rho v^2}{2} \qquad (12)$$

where

$$\zeta_{01} = 5\left(0{,}005 + 0{,}42\,\mathrm{Re}^{-0{,}30}\right) \qquad (13)$$

and

$$\zeta_{23} = 0{,}95\ \mathrm{Re}^{-0{,}12} + 3\left(0{,}005 + 0{,}42\,\mathrm{Re}^{-0{,}30}\right) \qquad (14)$$

Values of ζ_{01} and ζ_{23} for some Reynolds numbers are given in Table 1.

Table1 — Values of ζ_{01} and ζ_{23} for some Reynolds numbers

Re	ζ_{01}	ζ_{23}
50000	0,11	0,32
100 000	0,09	0,29
200 000	0,08	0,27
400000	0,07	0,24

4.5.7 The differential pressure between sections I and 2 shall then be calculated as follows:

$$p_1 - p_2 = \Delta p_{03} - (\zeta_{01} + \zeta_{23}) \bullet \rho \frac{v^2}{2} \qquad (15)$$

4.5.8 The mechanical energy loss per unit mass is given by:

$$[\Delta y]_1^2 = \frac{p_1 - p_2}{2} \qquad (16)$$

4.5.9 The energy loss coefficient for the component tested is then given by:

$$\zeta = \frac{p_1 - p_2}{\frac{\rho v^2}{2}} \qquad (17)$$

4.6 Calculation of uncertainties

The uncertainties of the test results are determined by consideration of the formula used for calculating the energy loss coefficient of a component:

$$\zeta = \frac{p_1 - p_2}{\rho \frac{v^2}{2}} \qquad (18)$$

In practice the value of p_1-p_2 is not measured directly and is calculated from the measured differential pressure Δp_{03} by:

$$p_1 - p_2 = \Delta p_{03} - (\zeta_{01} + \zeta_{23}) \bullet \rho \frac{v^2}{2} \qquad (19)$$

The energy loss coefficient is therefore given by: