UDC 697.9

JET MOMENTUM FLUX:
DETERMINATION BASED ON THE WEIGHING OF AIR ISSUING FROM A SUPPLY DEVICE

Key words: Ventilation, air supply device, test method

1 SCOPE OF METHOD

The scope of this method is to provide a relatively simple method for measuring the kinematic momentum flux of a jet issuing from a commercial supply device. The method is based on measuring the reaction force when blowing the jet towards a balance. This method can also be used for determining the kinematic momentum flux as a function of the distance from the supply device.

2 FIELD OF APPLICATION

The method can be used to record the momentum flux from the following classes of terminal devices (ISO 5219).

Class 1: Nozzles, grilles and registers.

Class 3: Linear grilles, slots and linear diffusers.

3 REFERENCES

CEN/TC 156/WG4 N86, Draft Standard. Air terminal Devices, Aerodynamics Testing and Rating for Mixed Flow Application, Revised ISO 5219, EUROPEAN STANDARD – DRAFT 1992-11-04.

Taghi Karimipanah, Turbulent Jets in Confined Spaced – Application in Mixing Ventilation, PhD Thesis, Centre for Built Environment, Royal Institute of Technology, Gävle, Sweden, 1996.

International Standard, ISO 5167-1980, Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross-section conduits running full.

4 DEFINITIONS

A	Area of impingement plate ($A = L \times W$)	$[m^2]$
A_f	Free area of supply device	$[m^2]$
dA	Area differential	$[m^2]$
F	Flow force ($F = M + pA$)	[N]
g	Acceleration due to gravity	$[m/s^2]$
h	Impingement height	[m]
L	Length of impingement plate	[m]
M	Kinematic momentum flux ($M \equiv \int \rho \overline{U^2} dA$)	[N]
$M(0)$	Jet exit momentum	[N]
m	Weight reading	[kg]
$\tilde{\tilde{m}}$	Estimated weight reading (Relation (7))	[kg]
p	Mean pressure relative to the ambient	[Pa]
q	Volumetric flow rate	$[m^3/s]$
R	Reaction force	[N]
U	Instantaneous axial velocity	$[m^2]$
$\bar{u}$	Mean value of axial velocity	[m/s]
u'	Fluctuating part of axial velocity ($u' = (U - \bar{u})$)	[m/s]
V_r	Radial velocity component	[m/s]
V_{out}	Velocity component of air flowing out from a control volume	[m/s]
W	Width of impingement plate	[m]
x	Coordinate in axial direction	[m]
θ	Entrainment angle	[radian]
ρ	Density of air	$[kg/m^3]$

In terms of the mean velocity and the fluctuating part of the velocity field the kinematic momentum flux is expressed as

$$M = \int (\bar{u}^2 + \overline{u'^2}) dA \tag{1}$$

Published by Nordtest
Tekniikantie 12
FIN–02150 Espoo
Finland

Phone: + 358 9 455 4600
Fax: + 358 9 455 4272
E-mail: nordtest@nordtest.org
Internet: www.nordtest.org

ISSN: 0283–7226
Project: 1240-95

5 SAMPLING

6 METHOD OF TEST

6.1 Principle

Figure 1 shows the principle. The jet from the supply device is blown towards a plate. At the plate the flow is directed horizontally outwards. Due to entrainment of air into the jet there is an inflow across the sides (a–c) and (b–d) of the control volume.

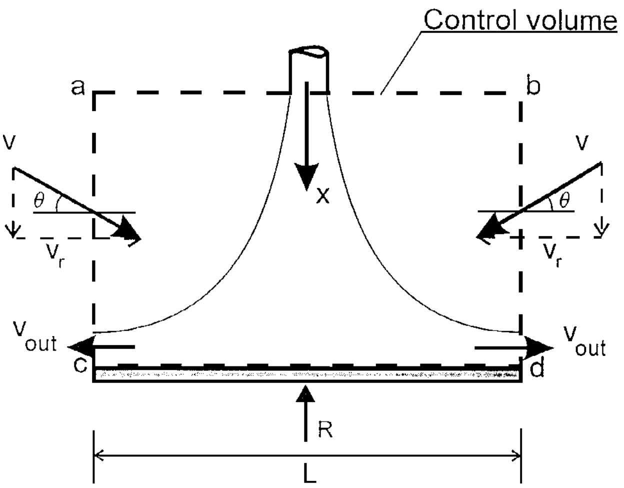

Figure 1. Principle for determination of the flow force by recording the reaction force R.

The change in flow force, F, in the x-direction between the stations (a–b) and (c–d) is due to the inflow of axial momentum across the sides.

$$F_{c-d} - F_{a-b} = 2(L + W)\int_0^h \rho \overline{V_r(x)}^2 \tan\theta(x)dx \quad (2)$$

The reaction force is equal to the force exerted by the pressure on the plate

$$R = p_{c-d} A \quad (3)$$

This gives the momentum balance after using the expression for the flow force

$$R - M(0) - p_{a-b}A = 2(L + W)\int_0^h \rho \overline{V_r(x)}^2 \tan\theta(x)dx \quad (4)$$

If at the top of the control volume the pressure is equal to the pressure in the quiescent ambient, p_{a-b} = 0, and the inflow across the sides is horizontal (θ = 0) the the reaction force is equal to the kinematic momentum flux at the inlet.

$$R = M(0) \quad (5)$$

6.2 Apparatus

- Fan (blower)
- Device for measuring the flow rate, e.g., an orifice plate, see ISO standard.
- Supply terminal
- Weighing system
- Support for the supply device
- Impingement plate
- Smoke visualisation device.

An example of an experimental set up is shown in Fig. 2.

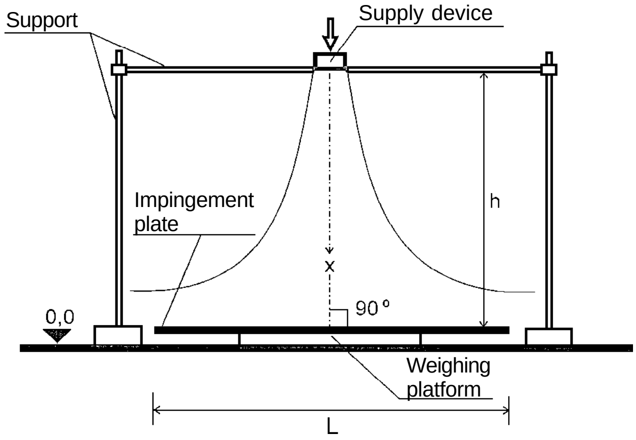

Figure 2. Test facility configuration.

6.3 Preparation

The free area, A_f, of the supply device is noted. The support is firmly clamped to the ground in order to avoid vibrations. The weighing platform is placed horizontally on the floor. With a plummet a check is made that the centre of the weighing platform is directly below the centre of the supply device. On the weighing platform a plate (impingement plate) is placed. The plate should be fabricated of a stiff material. Before the fan is started, the weight of the impingement plate is determined.

The fan is connected to the supply device. The flow rate shall be recorded with an orifice plate or a flow meter of similar accuracy.

The jet is directed towards the centre of the impingement plate and perpendicular to the impingement plate. Smoke visualisation is used to check that the width of the jet is less than the length, L, and the width, W, of the plate.

6.4 Procedure

The following steps are required for each flow rate of interest

- The impingement height, h, is selected. The shortest distance required is about $5\sqrt{A_f}$. From there on the distance is increased by intervals equal to about $2\sqrt{A_f}$.
- The measuring time should be long enough to obtain a stable mean value. Usually about 200 sec is sufficient.
- The mean weight, m, is noted.
- The reaction force, R, is calculated as

$$R = gm \quad (6)$$

- The procedure is repeated for other impingement heights.
- The recorded reaction forces are plotted in a graph as a function of the impingement height, see Fig. 3.
- The kinematic momentum flux of the jet is defined as the maximum value of the reaction force.

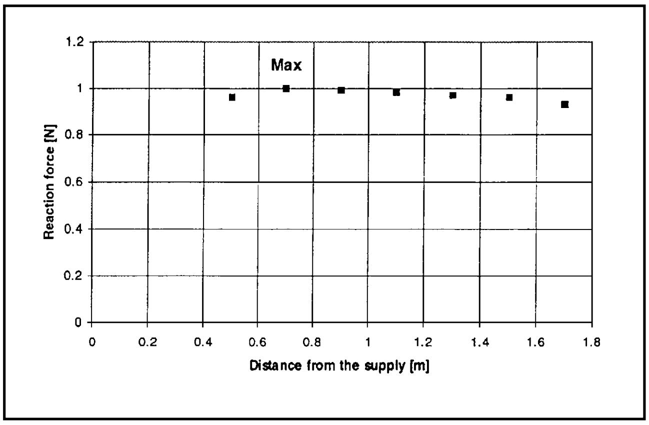

Figure 3. Typical plot for determination of momentum flux.

6.5 Expression of results

The measured results are expressed in SI-units as Newton [N].

6.6 Accuracy

The uncertainty can be divided into the following groups:

Accuracy of the weighing system

This accuracy can be controlled by selecting a weighing system with a suitable range and accuracy. The expected magnitude of the weight reading can be assessed by using the relation

$$\tilde{\tilde{m}} = \frac{\rho}{g}\left(\frac{q}{A_f}\right)^2 \qquad (7)$$

By selecting a suitable weighing system the uncertainty caused by the weighing system can be as low as 2% and therefore negligible compared to other errors.

Errors depending on the method

Lack of proper alignment of the weighing platform and the supply device, e.g. the weighing platform is not horizontal and/or the jet is not blown perpendicular towards the plate.

Disturbances in the ambient air

The total uncertainty is estimated to be: read value ± ca. 10%.

6.7 Test report

The test report shall include the following information, if relevant:

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organisation or the person who ordered the test
d) Purpose of the test
e) Method of sampling and other circumstances (date and person responsible for sampling)
f) Name and address of manufacturer or supplier of the tested object
g) Name or other identification marks of the tested object
h) Description of the test object
i) Date of supply of the test object
j) Date of the test
k) Test method
l) Conditioning of the test speciments, environmental data during the test (temperature, pressure, RH, etc.)
m) Identification of the test equipment and instruments used
n) Any deviation from the test method
o) Test results (use SI units)
p) Inaccuracy or uncertainty of the test result
q) Date and signature.