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Fire safety engineering — Requirements governing algebraic equations — Vent flows

Ingénierie de la sécurité incendie — Exigences régissant les équations algébriques — Écoulements au travers d'une ouverture

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16737 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

This second edition cancels and replaces the first edition (ISO 16737:2006), which has been technically revised.

Introduction

This International Standard is intended to be used by fire safety practitioners who employ fire safety engineering calculation methods. Examples include fire safety engineers; authorities having jurisdiction, such as territorial authority officials; fire service personnel; code enforcers; and code developers. It is expected that users of this International Standard are appropriately qualified and competent in the field of fire safety engineering. It is particularly important that users understand the parameters within which particular methodologies may be used.

Algebraic formulas conforming to the requirements of this International Standard are used with other engineering calculation methods during fire safety design. Such design is preceded by the establishment of a context, including the fire safety goals and objectives to be met, as well as performance criteria when a tentative fire safety design is subject to specified design fire scenarios. Engineering calculation methods are used to determine if these performance criteria will be met by a particular design and if not, how the design must be modified.

The subjects of engineering calculations include the fire-safe design of entirely new built environments, such as buildings, ships or vehicles as well as the assessment of the fire safety of existing built environments.

The algebraic formulas discussed in this International Standard are very useful for quantifying the consequences of design fire scenarios. Such formulas are particularly valuable for allowing the practitioner to determine very quickly how a tentative fire safety design should be modified to meet performance criteria, without having to spend time on detailed numerical calculations until the stage of final design documentation. Examples of areas where algebraic formulas have been applicable include determination of heat transfer, both convective and radiant, from fire plumes, prediction of ceiling jet flow properties governing detector response times, calculation of smoke transport through vent openings and analysis of enclosure fire hazards such as smoke filling and flashover.

The algebraic formulas discussed in this International Standard are essential for checking the results of comprehensive numerical models that calculate fire growth and its consequences.

Fire safety engineering — Requirements governing algebraic equations — Vent flows

1 Scope

1.1 This International Standard specifies requirements for the application of algebraic formula set for the calculation of specific characteristics of vent flows.

1.2 This International Standard is an implementation of the general high-level requirements for the case of fire dynamics calculations involving sets of algebraic formulas.

1.3 This International Standard is arranged in the form of a template, where specific information relevant to algebraic vent flow formulas is provided to satisfy the following types of general requirements:

a) description of physical phenomena addressed by the calculation method;

b) documentation of the calculation procedure and its scientific basis;

c) limitations of the calculation method;

d) input parameters for the calculation method;

e) domain of applicability of the calculation method.

NOTE Examples of sets of algebraic formulae meeting all the requirements of this International Standard will be provided in separate annexes for each different type of vent flow scenario. Currently, there are two informative annexes containing general information on vent flows and specific algebraic formulas for practical engineering calculations.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 13943, *Fire safety — Vocabulary*

ISO 16730, *Fire safety engineering — Assessment, verification and validation of calculation methods*

ISO 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13943 apply. See each annex for the terms and definitions specific to that annex.

4 Requirements governing description of physical phenomena

4.1 The buoyant flow through a vent resulting from a source fire in an enclosure having one or more openings is a complex thermo-physical phenomenon that can be highly transient or nearly steady-state. Vent flows may contain regions involved in flaming combustion and regions where there is no combustion taking place. In addition to buoyancy, vent flows can be influenced by dynamic forces due to external wind or mechanical fans.

4.2 General types of flow boundary conditions and other scenario elements to which the analysis is applicable shall be described with the aid of diagrams.

4.3 Vent flow characteristics to be calculated and their useful ranges shall be clearly identified, including those characteristics inferred by association with calculated quantities.

4.4 Scenario elements (e.g. two-layer environments, uniform mixture, etc.) to which specific formulas apply shall be clearly identified.

4.5 Because different formulas describe different vent flow characteristics (4.3) or apply to different scenarios (4.4), it shall be shown that if there is more than one method to calculate a given quantity, the result is independent of the method used.

5 Requirements governing documentation

5.1 The procedure to be followed in performing calculations shall be described through a set of algebraic formulas.

5.2 Each formula shall be presented in a separate clause containing a phrase that describes the output of the formula, as well as explanatory notes and limitations unique to the formula being presented.

5.3 Each variable in the formula set shall be clearly defined, along with appropriate SI units, although formula versions with dimensionless coefficients are preferred.

5.4 The scientific basis for the formula set shall be provided through reference to recognized handbooks, the peer-reviewed scientific literature or through derivations, as appropriate.

5.5 Examples shall demonstrate how the formula set is evaluated using values for all input parameters consistent with the requirements in Clause 4.

6 Requirements governing limitations

6.1 Quantitative limits on direct application of the algebraic formula set to calculate output parameters, consistent with the scenarios described in Clause 4, shall be provided.

6.2 Cautions on the use of the algebraic formula set within a more general calculation method shall be provided, which shall include checks of consistency with the other relations used in the calculation method and the numerical procedures employed.

7 Requirements governing input parameters

7.1 Input parameters for the set of algebraic formulas shall be identified clearly, such as layer temperature, pressure and geometric dimensions.

7.2 Sources of data for input parameters shall be identified or provided explicitly within the standard.

7.3 The valid ranges for input parameters shall be listed as specified in ISO 16730.

8 Requirements governing domain of applicability

8.1 One or more collections of measurement data shall be identified to establish the domain of applicability of the formula set. These data shall have a level of quality (e.g. repeatability, reproducibility – see ISO 5725) assessed through a documented/standardized procedure).

8.2 The domain of applicability of the algebraic formulas shall be determined through comparison with the measurement data of 8.1.

8.3 Potential sources of error that limit the set of algebraic formulas to the specific scenarios given in Clause 4 shall be identified, for example, the assumption of one or more uniform gas layers in an enclosed space.

Annex A
(informative)

General aspects of vent flows

A.1 Terms and definitions used in this annex

For the purposes of this document, the terms and definitions given in ISO 13943 and the following apply.

A.1.1

boundary

surface that defines the extent of an enclosure

A.1.2

datum

elevation used as the reference elevation for evaluation of hydrostatic pressure profiles

A.1.3

enclosure

room, space or volume that is bounded by surfaces

A.1.4

flow coefficient

empirical efficiency factor that accounts for the difference between the actual and the theoretical flow rate through a vent

A.1.5

hydrostatic pressure

atmospheric pressure gradient associated with height

A.1.6

interface position

smoke layer height

elevation of the smoke layer interface relative to datum, typically the elevation of the lowest boundary of the enclosure

A.1.7

neutral plane height

elevation at which the pressure inside an enclosure is the same as the pressure outside the enclosure

A.1.8

pressure difference

difference between the pressure inside an enclosure and outside the enclosure at a specified elevation

A.1.9

smoke

airborne stream of solid and liquid particulates and gases evolved when a material undergoes pyrolysis or combustion, together with the quantity of air that is entrained or otherwise mixed into the stream

A.1.10

smoke layer

hot upper layer

hot gas layer

relatively homogeneous volume of smoke that forms and accumulates beneath the boundary having the highest elevation in an enclosure as a result of a fire

A.1.11

smoke layer interface

horizontal plane separating the smoke layer from the lower layer

A.1.12

vent

opening in an enclosure boundary through which air and smoke can flow as a result of naturally or mechanically induced forces

A.1.13

vent flow

flows of smoke or air through a vent in an enclosure boundary

A.2 Description of physical phenomena addressed by the formula set

A.2.1 Scope

This annex is intended to document the general methods that can be used to calculate mass flow rate through a vent. The formula set is based on orifice flow theory.

A.2.2 General description of calculation method

The calculation methods permit calculation of flows through vents in enclosure boundaries arising from pressure differences that develop between an enclosure and adjacent spaces as a result of temperature differences between the enclosure and the adjacent spaces. Pressure differences may also result from fire gas expansion, mechanical ventilation, wind or other forces acting on the enclosure boundaries and vents, but these forces are not addressed in this International Standard. Given a pressure difference across a vent and the temperatures of the enclosures that the vent connects, mass flow rate is calculated by using orifice flow theory.

The properties of an enclosure, such as smoke layer interface height, temperature, and other properties are calculated by the principle of heat and mass conservation for the smoke layer as described in ISO 16735.

A.2.3 Vent flow characteristics to be calculated

Formulas provide the mass flow rate, enthalpy and chemical species flow rate.

A.3 Symbols and abbreviated terms used in this annex

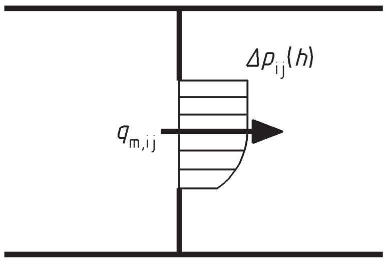
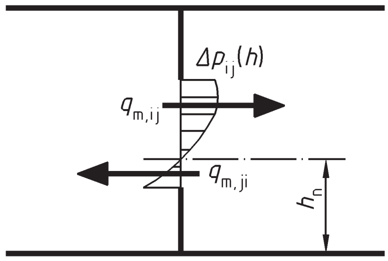
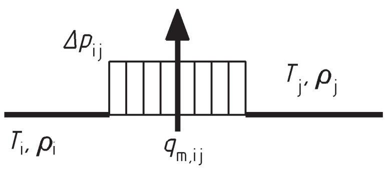
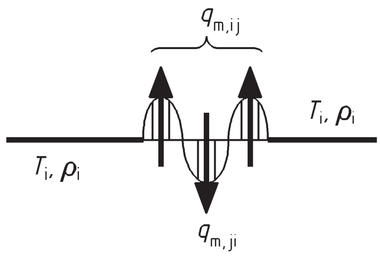
A	area of vent (m^2)
B	width of vent (m)
C_D	flow coefficient (–)
g	gravity acceleration ($m\ s^{-2}$)
h_l	height of lower edge of vent above datum (m)
h_u	height of upper edge of vent above datum (m)
$\max(x_1, x_2)$	maximum of x_1 and x_2
$q_{m,ij}$	mass flow rate flowing out from enclosure i into enclosure j ($kg\ s^{-1}$)
$q_{m,ji}$	mass flow rate flowing out from enclosure j into enclosure i ($kg\ s^{-1}$)
$p_i(h)$	pressure in enclosure i at height h above datum (Pa)
$p_j(h)$	pressure in enclosure j at height h above datum (Pa)
T	temperature (K)
T_0	reference temperature (K)
v	flow velocity ($m\ s^{-1}$)
ρ_i	gas density of smoke (or air) in enclosure i ($kg\ m^{-3}$)
ρ_j	gas density of smoke (or air) in enclosure j ($kg\ m^{-3}$)
ρ_0	gas density of smoke (or air) at reference temperature ($kg\ m^{-3}$)
$\Delta p_{ij}(h)$	pressure difference between enclosure i and j at height h; that is, $p_i(h)$ - $p_j(h)$, (Pa)
ξ	height used as integration variable (m)

A.4 Formula-set documentation

A.4.1 List of formula sets

The velocity of flow through vents is calculated according to orifice flow theory based on application of the Bernoulli equation. Methods to calculate vent flows are developed for the conditions shown in Table A.1. For the case of vertical and horizontal vents, flow may be uni-directional or bi-directional. For horizontal vents, bi-directional flow takes place only for special cases when the pressure difference is small. Explicit formulas presented here are applicable to flow through vertical vents and uni-directional flow through horizontal vents.

Table A.1 — Conditions of vent flow calculation

	uni-directional flow	bi-directional flow
vertical vent		
horizontal vent		 Flow is unstable. No explicit formula is available at present.

A.4.2 Orifice flow — Uniform pressure distribution over vent area

When pressure difference is created by some actions such as external wind or mechanical fans, the flow through the vent is given by:

$$q_{\mathrm{m,ij}} = C_{\mathrm{D}} A \sqrt{2 \rho_{\mathrm{i}} \Delta p_{\mathrm{ij}}} \quad \text{(A.1)}$$

where $\Delta p_{ij} = p_i - p_j$ and the assumption is made that the pressure difference across the vent is uniform over the entire vent area as shown in Figure A.1: