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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*.

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 equations 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 are met by a particular design and if not, how the design can 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 equations discussed in this International Standard are very useful for quantifying the consequences of design fire scenarios. Such equations are particularly valuable for allowing the practitioner to determine very quickly how a tentative fire-safety design should be modified to meet agreed-upon performance criteria, without having to spend time on detailed numerical calculations until the stage of final design documentation. Examples of areas where algebraic equations 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 compartment fire hazards, such as smoke filling and flashover.

The algebraic equations 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 The requirements in this International Standard govern the application of algebraic equation sets to the calculation of specific characteristics of vent flows.

1.2 This International Standard is an implementation of the general requirements provided in ISO/TR 13387-3 for the case of fire dynamics calculations involving sets of algebraic equations.

1.3 This International Standard is arranged in the form of a template, where specific information relevant to algebraic vent-flow equations 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.

1.4 Examples of sets of algebraic equations meeting all the requirements of this International Standard are provided in separate annexes to this International Standard for each different type of vent-flow scenario. Currently, there is one informative annex containing general information and conservation relationships for vent flows and a second informative annex with specific algebraic equations for calculation of vent-flow characteristics.

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/TR 13387-3, *Fire safety engineering — Part 3: Assessment and verification of mathematical fire models*

ISO 13943, *Fire safety — Vocabulary*

3 Terms and definitions

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

NOTE 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 enclosed space having one or more openings is a complex thermo-physical phenomenon that can be highly transient or nearly steady-state. Vent flows can 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 Scenarios elements (e.g. a two-layer environment, uniform mixture, etc.) to which specific equations apply shall be clearly identified.

4.5 Because different equations describe different vent-flow characteristics (see 4.3) or apply to different scenarios (see 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 General requirements governing documentation can be found in ISO/TR 13387-3.

5.2 The procedure followed in performing calculations shall be described through a set of algebraic equations.

5.3 Each equation shall be presented as a separate subclause containing a phrase that describes the output of the equation, as well as explanatory notes and limitations unique to the equation being presented.

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

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

5.6 Examples shall demonstrate how the equation 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 equation 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 equation 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. For example, the use of a given equation set for vent flows in a zone model can yield results inconsistent with those from another equation set for smoke layers in the zone model, where the vent flow is caused by a smoke layer, leading to errors.

7 Requirements governing input parameters

7.1 Input parameters for the set of algebraic equations shall be identified clearly, such as heat release rate or geometric dimensions.

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

7.3 The valid ranges for input parameters shall be listed as specified in ISO/TR 13387-3.

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 equation set. These data shall have a level of quality (e.g., repeatability, reproducibility) assessed through a documented/standardized procedure [see ISO 5725 (all parts)].

8.2 The domain of applicability of the algebraic equation shall be determined through comparison with the measurement data of 8.1, following the principles of assessment, verification and validation of calculation methods.

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

Annex A
(informative)

General aspects of vent flows

A.1 Terms and definitions used in Annex A

The terms and definitions given in ISO 13943 and the following should 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 elevation

A.1.6
interface position
smoke layer height
elevation of the smoke layer interface relative to a reference elevation, 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 of relatively smoke-free air

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 Symbols and abbreviated terms used in Annex A

A_{vent} area of vent (m^2)

B_{vent} width of vent (m)

C_D flow coefficient (–)

g gravity acceleration ($m \cdot s^{-2}$)

H_l height of lower edge of vent above reference elevation (m)

H_u height of upper edge of vent above reference elevation (m)

max(x_1,x_2) maximum of x_1 and x_2

$\dot{m}_{ij}$ mass flow rate of smoke or air flowing from enclosure i to adjacent space j ($kg \cdot s^{-1}$)

$\dot{m}_{ji}$ mass flow rate of smoke or air flowing from adjacent space j to enclosure i ($kg \cdot s^{-1}$)

$p_i(z)$ pressure in enclosure i at height z above reference elevation (Pa)

$p_j(z)$ pressure in enclosure j at height z above reference elevation (Pa)

v flow velocity ($m \cdot s^{-1}$)

ρ_i density of smoke (or air) in enclosure i ($kg \cdot m^{-3}$)

ρ_j density of smoke (or air) in enclosure j ($kg \cdot m^{-3}$)

$\Delta p_{ij}(z)$ pressure difference between enclosure i and j at height z; that is, $p_i(z)$-$p_j(z)$, (Pa)

z height above reference elevation (m)

A.3 Description of physical phenomena addressed by the equation set

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

A.3.1 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 can 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 enclosure and the adjacent spaces that the vent connects, mass flow rate is calculated by using an orifice flow theory.

The properties of an enclosure, such as smoke layer interface height, temperature and other properties, are calculated from the principle of heat and mass conservation for the smoke layer. The vent flow is then calculated by use of the conservation of heat and mass for flow rates through boundaries. The description of smoke layer properties is given in ISO 16735.

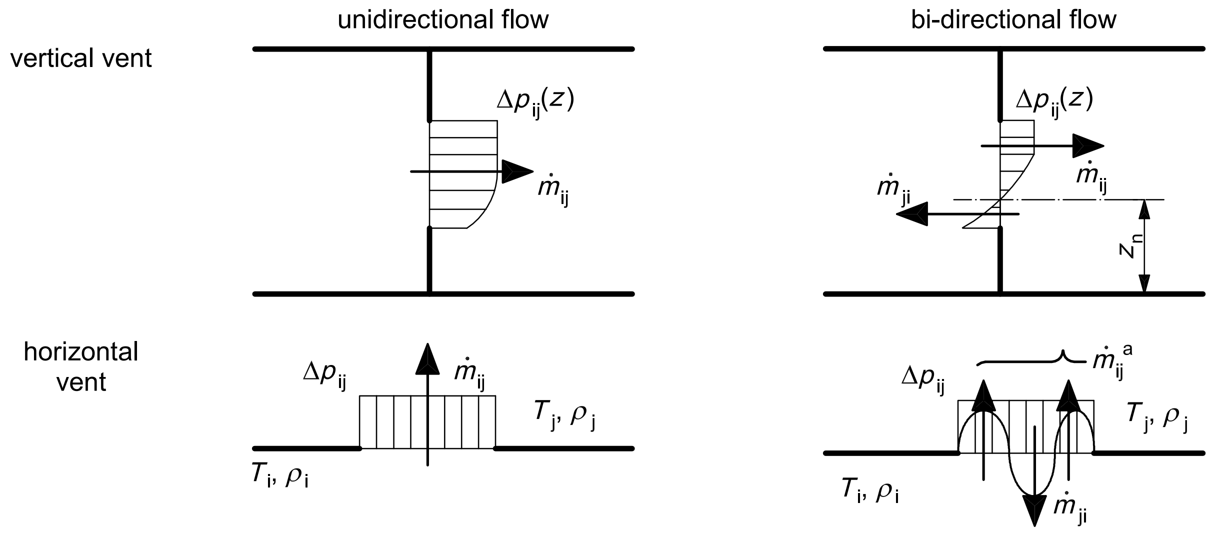
A.3.2 Vent-flow characteristics to be calculated

Equations provide the rate of mass, enthalpy and chemical species flow.

A.4 Equation set documentation

A.4.1 Equation sets

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



a Flow is unstable. No explicit equation is available at present.

Figure A.1 — Conditions of vent-flow calculation