
Fire safety engineering — Requirements governing algebraic equations — Ceiling jet flows

Ingénierie de la sécurité incendie — Exigences régissant les équations algébriques — Écoulements en jet sous plafond

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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 16736 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

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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 can 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 performance criteria agreed-upon, without having to spend time on detailed numerical calculations until the stage of final design documentation. In this respect, the equations for ceiling jet flows can be used for estimating the response time of fire detectors and the first activated sprinklers, as well as the time for damage to some structural elements (e.g., plastic roof- or sky-lights).

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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.

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Fire safety engineering — Requirements governing algebraic equations — Ceiling jet flows

1 Scope

1.1 The requirements in this International Standard govern the application of explicit algebraic equation sets to the calculation of specific characteristics of ceiling jet 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 explicit algebraic equations.

1.3 This International Standard is arranged in the form of a template, where specific information relevant to algebraic ceiling jet flows 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 ceiling jet flow. Currently, there is one informative annex containing algebraic equations for quasi-steady state, axisymmetric ceiling jet flows.

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 Annex A for the terms and definitions specific to that annex.

4 Requirements governing description of physical phenomena

4.1 General types of source fires, flow boundary (including symmetry) conditions and other scenario elements to which the analysis is applicable shall be described with the aid of diagrams.

4.2 Ceiling jet flow characteristics to be calculated and their useful ranges shall be clearly identified, including those characteristics inferred by association with calculated quantities (e.g., the association of smoke concentration with excess gas temperature based on the analogy between energy and mass conservation) and those associated with radiant heat transfer to targets remote from the ceiling jet flow, if applicable.

4.3 Regions of the ceiling jet flow (whether or not in the plume turning region, degree of fire-source influence, etc.) to which specific equations apply shall be clearly identified.

4.4 Because different algebraic equations describe different ceiling jet flow characteristics (see 4.2) or apply to different ceiling jet flow regions (see 4.3), 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 to be followed in performing calculations shall be described through a set of algebraic equations.

5.3 Each equation shall be presented in a separate subclause containing a phrase that describes the function of the equation, 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 ceiling jet flows in a zone model can yield different results from another equation set for plume flows in the zone model, where the plume and ceiling jet zones connect, leading to errors.

7 Requirements governing input parameters

7.1 Input parameters for the set of algebraic equations shall be described.

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 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 equations 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 equations to the specific scenarios given in Clause 4 shall be identified, for example, the assumption that flaming combustion is not present in the ceiling jet flow.

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Annex A (informative)

Equations for quasi-steady state, axisymmetric ceiling jet flows

A.1 Terms and definitions used in Annex A

The terms and definitions given in ISO 13943 and the following apply.

A.1.1

axisymmetric

mean motion and properties, such as mean temperature rise, are symmetric with respect to a vertical centreline

A.1.2

built environment

any building, structure or transportation vehicle

EXAMPLE Structures other than buildings include tunnels, bridges, offshore platforms and mines.

A.1.3

ceiling

highest elevation boundary of the enclosed space in any built environment, such as a room in a building or a cabin in a vehicle

A.1.4

ceiling jet

gas motion in a layer beneath the surface of a ceiling, driven by the buoyancy of hot gases from fire plume impingement on the ceiling

A.1.5

characteristic depth of ceiling jet temperature profile

depth below the ceiling surface, at a given radius, r , at which the mean temperature rise above ambient in the ceiling jet flow becomes a factor of e^{-1} times the maximum mean temperature rise at that radius

A.1.6

characteristic depth of ceiling jet velocity profile

depth below the ceiling surface, at a given radius, r , at which the mean gas velocity in the ceiling jet flow becomes a factor of e^{-1} times the maximum mean gas velocity at that radius

A.1.7

combustion efficiency factor

ratio of the heat of combustion measured under specific fire test conditions to the net heat of combustion

A.1.8

convective fraction

ratio of the convective heat release rate to the heat release rate

A.1.9

convective heat flux

rate of heat transfer per unit area of a target surface due to the motion of a gas, such as the ceiling jet flow

A.1.10

convective heat release rate

component of the heat release rate carried upward by the fire plume motion

NOTE Above the mean flame height, this component is considered invariant with height.

A.1.11**fire plume**

upward turbulent fluid motion generated by a source of buoyancy that exists by virtue of combustion and often includes a lower flaming region

A.1.12**fire plume turning region**

flow area in which there is a transition from a plume flow to a ceiling jet flow, defined by a ratio of radial distance to effective ceiling height, $H - z_v$, equal to 0,15 to 0,2

A.1.13**fire source diameter**

effective diameter of the fire source, equal to the actual diameter for a circular source or the diameter of a circle having an area equal to the plan area of a non-circular source

A.1.14**flame**

luminous region of fire plume associated with combustion

A.1.15**fuel mass burning rate**

mass generation rate of fuel vapours

A.1.16**heat release rate**

rate at which heat is actually being released by a source of combustion (such as the fire source)

A.1.17**jet flame**

flame that is dominated by momentum, rather than buoyancy, forces

A.1.18**mean flame height**

time-average height of flames above the base of a fire, defined as the elevation where the probability of finding flames is 50 %

A.1.19**mean gas velocity**

time-average gas velocity in the ceiling jet flow at a given radial distance, r

A.1.20**mean temperature rise**

time-average gas temperature increase above the ambient temperature value in the ceiling jet flow, at a given radial distance, r

A.1.21**net heat of combustion**

amount of heat generated per unit mass lost by a material when exposed to specific fire test conditions

A.1.22**quasi-steady state**

assumption that the full effects of heat release rate changes at the fire source are felt everywhere in the flow field immediately

A.1.23**radiant energy release factor**

ratio of the combustion heat released in a fire as thermal radiation to the net heat of combustion