INTERNATIONAL STANDARD

ISO 16735

First edition
2006-11-15

Fire safety engineering — Requirements governing algebraic equations — Smoke layers

Ingénierie de la sécurité incendie — Exigences régissant les équations algébriques — Couches de fumée

Reference number
ISO 16735:2006(E)

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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 16735 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 use fire safety engineering calculation methods. Examples include fire safety engineers; authorities having jurisdiction, such as territorial authority officials; fire service personnel; code enforcers; 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 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 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 transport and flashover. With respect to smoke layers, algebraic equations are often used to estimate the time for smoke to fill a given fraction of a compartment, as well as the temperature and concentrations within the smoke layer.

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 — Smoke layers

1 Scope

1.1 The requirements given in this International Standard govern the application of algebraic equation sets to the calculation of specific characteristics of smoke layers generated by fires.

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 smoke layer 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 for each different type of smoke layer scenario. Annex A contains general information and conservation requirements for smoke layers and Annex B contains specific algebraic equations for calculation of smoke layer 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 5725 (all parts), *Accuracy (trueness and precision) of measurement methods and results*

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

ISO 13943, *Fire safety — Vocabulary*

ISO 16734:2006, *Fire safety engineering — Requirements governing algebraic equations — Fire plumes*

ISO 16737, *Fire safety engineering — Requirements governing algebraic equations — Vent flows*

3 Terms and definitions

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

4 Requirements governing description of physical phenomena

4.1 The buoyant smoke layer resulting from a source fire in an enclosed space is a complex thermo-physical phenomenon that can be highly transient or nearly steady-state. Smoke layers may contain regions involved in flaming combustion and regions where there is no combustion taking place. In addition to buoyancy, smoke layers can be influenced by dynamic forces due to mechanical fans.

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

4.3 Smoke layer 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 heat exposure to objects and occupants by the smoke layer, if applicable.

4.4 Physical phenomena (e.g., simple smoke filling, mechanical smoke exhaust, etc.) to which specific equations apply shall be clearly identified.

4.5 Because different equations describe different smoke layer 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 General requirements governing documentation can be found in ISO 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 clause 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 recognised 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 given 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 used.

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 (see ISO 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).

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.

Annex A
(informative)

General aspect of smoke layers

A.1 Terms and definitions

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

A.1.1
boundary
surface that defines the extent of an enclosure

A.1.2
enclosure
room, space or volume that is bounded by surfaces

A.1.3
fire plume
upward turbulent fluid motion generated by a source of buoyancy that exists by virtue of combustion and often includes an initial flaming region

A.1.4
flame
luminous region of fire plume associated with combustion

A.1.5
heat release rate
rate at which heat is being released by a source of combustion (such as the fire source)

A.1.6
interface position
elevation of the smoke layer interface relative to a reference elevation, typically the lowest boundary of the enclosure

NOTE Also referred to as the smoke layer height.

A.1.7
quasi-steady state
assumption that the full effects of heat release rate changes at the fire source are felt everywhere in the immediate flow field

A.1.8
smoke
airborne 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 mass

A.1.9
smoke 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

NOTE Also referred to as the hot upper layer and the hot gas layer.

A.1.10
smoke layer interface
horizontal plane separating the smoke layer from the lower, smoke-free layer

A.1.11
vent
opening in an enclosure boundary through which air and smoke can flow as a result of naturally- or mechanically-induced forces

A.1.12
vent flow
flow of smoke or air through a vent in an enclosure boundary

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

A.2.1 General description of calculation method

This annex is intended to describe the methods that can be used to calculate interface positions, average temperatures and average concentrations of specific chemical species of smoke layers that form beneath boundaries during fires in enclosures. These calculation methods are based on the principles of mass, species and energy conservation as applied to the smoke layer as a thermodynamic control volume.

Smoke is accumulated in the upper part of an enclosure as a result of burning. It is assumed that smoke forms a layer of fairly uniform temperature and species concentration. Based on the principles of mass, species and energy conservation applied to the smoke layer, average values of temperature, smoke concentration and interface positions are calculated. Descriptions of fire plumes and vent flows are given in ISO 16734 and ISO 16737, respectively.

A.2.2 Smoke layer characteristics to be calculated

Equations provide average smoke layer temperature, species concentration and interface position.

A.3 Equation-set documentation

A.3.1 General

As shown in Figure A.1, a smoke layer is generated over a fire source in an enclosure. The conservation of mass, heat and specific chemical species are given in A.3.2 to A.3.4.

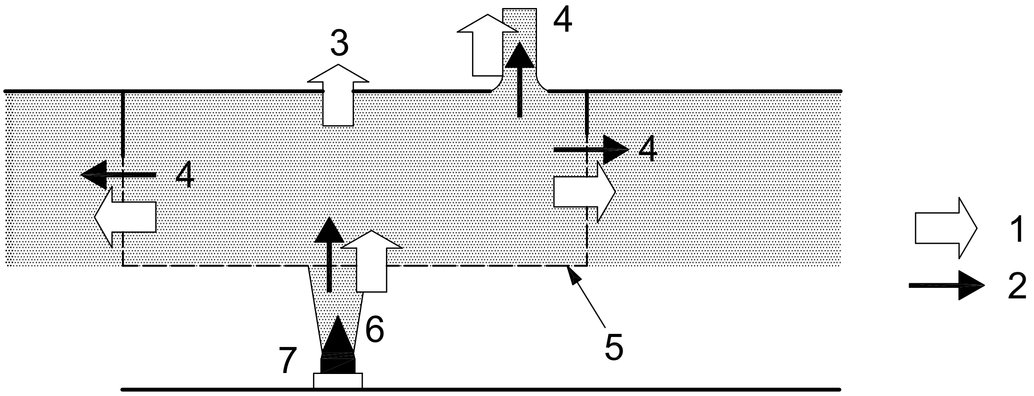
A.3.2 Mass conservation

Conservation of mass in the smoke layer shall be considered over an appropriately chosen control volume as shown in Figure A.1 by broken lines. The mass flow rate incoming across each interface (negative for outgoing flow) of the control volume shall be equal to the rate of mass accumulation of the smoke layer. Plume flow, vent flows and other flows shall be considered where necessary.

A.3.3 Energy conservation

Conservation of energy in the smoke layer shall be considered in a similar way to mass conservation. The energy flow rate incoming across the layer interface (negative for outgoing flow) shall be equal to the rate of energy accumulation in the smoke layer. In addition to plume and vent flows, radiation losses and heat absorption by the enclosure boundary shall be considered appropriately.

NOTE When it is difficult to determine the radiation heat loss from the flame, the energy flow rate can be approximated by heat release rate as will be applied in Annex B.



Key

1 heat flow
2 mass flow
3 wall heat absorption
4 vent flow
5 control volume
6 plume flow
7 fire source

Figure A.1 — General heat and mass conservation of smoke layer in an enclosure with a fire source

A.3.4 Conservation of specific chemical species

Mass conservation of specific chemical species shall be considered in a similar way to total mass conservation. In addition, if a gas phase chemical reaction takes place in the smoke layer, the reaction rate shall be considered appropriately.

A.3.5 Mass flow rate of fire plume across interface

The mass flow rate of the fire plume at the interface (bottom surface of smoke layer) shall be given as a function of the heat release rate of the fire and the vertical distance between the base of the fire source and the layer interface. An example of a set of explicit equations for this plume characteristic is given by ISO 16734.

A.3.6 Mass flowrate of smoke through vent

The mass flowrate through a vent is given as a function of the temperature of the smoke layer and that of the adjacent compartment, pressure differences between the layer and the adjacent compartment, vent width and vent height. An example of a set of equations for this vent characteristic is given in ISO 16737.

A.3.7 Equation of state

Smoke temperature and density are correlated by the equation of state. Typically, smoke is approximated by an ideal gas whose properties are identical with air.

