Technical Specification

ISO/TS 23782

First edition
2024-07

Requirements for large-scale test methods to represent fire threats to people in different fire scenarios

Exigences relatives aux méthodes d'essai à grande échelle pour représenter les dangers dus au feu pour les personnes dans différents scénarios d'incendie

Reference number
ISO/TS 23782:2024(en)

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Foreword

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This document was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 3, *Fire threat to people and environment.*

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A number of small-scale test methods are used to measure smoke and toxic fire effluent components (particulates and gases). They have been reviewed by ISO/TC 92/SC 3 in terms of their usefulness with respect to the measurement of toxicity and toxic product yields. However, proper assessment of smoke and fire threat is usually not a scalable phenomenon, so data from small-scale tests only reflect a limited degree of real fire scenarios. In this context, large-scale test methods with a wider range of applicability and better relationships to combustion conditions in real-scale fires are currently under consideration.

Various standardized large-scale tests are currently used to measure the reaction-to-fire properties of materials and products. The main purpose of such tests is to measure local effects such as the rate and extent of flame spread across surfaces and rates of heat release from the defined heat sources. Although apparatus used for these purposes (such as the ISO 9705-1 room corner test) may potentially be modified to address some toxic fire hazard scenarios, they generally have limited applicability to the measurement of hazardous conditions in real-scale fires in multi-enclosure buildings. Limitations include:

— limitation of fire scenarios reproduced and their relevance compared to real fires;

— use of a single, small enclosure;

— use of propane gas as a primary fire source (which itself produces fire effluents interacting with those from the fuel of interest);

— ventilation and plume dispersion characteristics poorly related to those in real-scale multi-enclosure fires.

This document gives the requirements and guidelines for large-scale test methods to represent fire threats to people in fire scenarios for application in fire effluent hazard assessment.

Requirements for large-scale test methods to represent fire threats to people in different fire scenarios

WARNING — In order for suitable precautions to be taken to safeguard health, the attention of all concerned in fire tests is drawn to the possibility that toxic or harmful gases can be evolved during combustion of test specimens. The test procedures involve high temperatures and combustion processes from ignition to a fully developed room fire. Therefore, hazards can exist for burns, ignition of extraneous objects or clothing. The operators should use protective clothing, helmets, face-shields and equipment for avoiding exposure to toxic gases. Means of extinguishing a fully developed fire should be available.

1 Scope

This document specifies requirements for the determination of methods and fire scenarios for fire threat assessment as a basis for designing and constructing large-scale fire tests. It covers different generic design requirements for large-scale fire test rigs to simulate the real fire scenarios of interest.

This document addresses fire threats to people under acute exposure to fire effluents according to the evaluation of tenability conditions. It does not address any chronic effects of that exposure on susceptible populations and firefighters.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 13571, *Life-threatening components of fire — Guidelines for the estimation of time to compromised tenability in fires*

ISO 19701, *Methods for sampling and analysis of fire effluents*

ISO 19702, *Guidance for sampling and analysis of toxic gases and vapours in fire effluents using Fourier Transform Infrared (FTIR) spectroscopy*

ISO 14934-1, *Fire tests — Calibration and use of heat flux meters — Part 1: General principles*

ISO 14934-2, *Fire tests — Calibration and use of heat flux meters — Part 2: Primary calibration methods*

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

4 General principles

4.1 Compromised tenability

One of the main purposes of a large-scale fire test is to estimate the time to the compromised tenability of the environment in a well-defined fire scenario with respect to potential victims. Potential hazards depend on various factors, but in general relate the exposure of occupants in any fire scenario to fire effluents, such as smoke, toxic gases and heat. Important factors are therefore the time-concentration profiles for the major toxic products, optical density of the smoke, and temperature of the gases being inhaled by the occupants. Algorithms have been developed in ISO 13571 to use these input data to predict time to impact on exposed subjects in terms of compromised tenability in any specific scenarios.

The data obtained from a large-scale test conducted in accordance with this document can be used as input for these algorithms. ISO/TR 13571-2 gives examples of tenability calculation based on data from large-scale fire tests or principles of fire safety engineering. Sampling and analysis of fire effluents are conducted according to ISO 19701 and ISO 19702, while the fire stages and their characteristics are described in ISO 19706.

The time to compromised tenability is the shortest of four distinct times estimated by considering asphyxiant fire gases, irritant fire gases, heat, and visual obscuration due to smoke. Even in the same fire test rig, the predominant threat to the occupant can differ from one fire scenario to the other, from time to time and from location to location. The appropriate tenable level should therefore be determined considering the final goal of the estimation.

4.2 Fire profile

For the purpose of this document, it is important to obtain profiles of gas concentrations over time. These profiles in a fire scenario depend on:

— the fire growth curve in terms of the mass-loss rate (kg/s) of the fuel, which in turn is related to ventilation conditions and the volume (kg/m^3) into which it is dispersed with time;

— the yields of toxic smoke and heat in the fire, for example, kg of CO per kg of material burned;

— the mass vectors of emissions, for example kg/s of CO released.

These aspects are affected by many features of the specific fire scenario, one of which is the ventilation conditions. As such, the fire profile should be characterized in terms of the following minimum range of parameters, measured at the breathing zone of a potential victim or along the potential victim pathway during escape.

a) Combustion-related parameter:

   1) mass loss of material divided by the volume of air into which the material is dispersed (mass-loss concentration).

b) Toxicity-related parameters:

   1) carbon monoxide concentration;

   2) hydrogen cyanide concentration;

   3) carbon dioxide concentration;

   4) oxygen concentration;

   5) acid gas concentrations (HF, HCl, HBr, SO2, and NOx);

6) total organic concentration, and as far as possible organic product profile, particularly oxidized organic species (i.e. acrolein and formaldehyde).

c) Heat-related parameters:

1) incident radiant heat flux to subject;

2) air temperature.

d) Visibility-related parameter:

1) smoke optical density (or particulate concentration).

Fire classification and typical characteristics are given in Annex A.

5 Significance and use

5.1 Application of large-scale test

When designing a large-scale fire test, it is necessary to ensure that the conditions of the formation and dispersal of the effluent plume are representative of the real fire scenario of interest. The concentration-time profile should be comparable to that predicted in the real-scale scenario. Alternatively, an appropriate calculation can be applied to the measured data to enable real conditions to be predicted. It is particularly important in this context that the emission and dispersion of fire effluents be calculated from the measured data and that the combustion conditions be similar to those predicted for the real fire scenario of interest. The emission pattern can then be used as input for any calculations used to extrapolate from large-scale to real-scale. The emission pattern can also be used as a reference scenario for validation of data obtained from small-scale toxicity and smoke tests.

It should be noted that the place where the toxicants are generated and the place where the people are exposed to the toxicants can differ. In some cases, it is the same enclosure, but in other cases, it is not the same enclose, e.g. a hallway connected to the enclosure where the fire actually occurred.

The main purpose of this document is to provide the basic requirements for a potential large-scale test to represent a real fire scenario. Large-scale tests have two applications:

a) tests that enable a product to be burned in a realistic end-use configuration and in an enclosure environment providing combustion conditions and a fire effluent plume similar to that predicted in different kinds of real fire scenarios (enabling measurements of concentration-time profiles and calculation of toxic product yields with time);

b) tests that enable a relatively large mass of material (or composite) to be burned in a large-scale enclosure environment under closely defined combustion conditions for comparison with data from small-scale toxicity tests (i.e. as a reference scenario for small-scale validation).

The test result can be utilized for various purposes, such as computational fluid dynamics (CFD) model validation and fire investigation, etc.

5.2 Fire test scenario

The fire scenario in a large-scale test should be carefully designed to represent the fire threats to people that would be encountered in the real fire scenario. A real fire scenario of interest may be selected considering fire statistics, in particular the most frequent fire cases or those with a severe consequence. A detailed description of the real fire scenario includes:

— a description of the facility in which the fire occurs, including the occupancy type (i.e. residences, hospitals, office buildings and schools), its geometry and topology, potential escape routes and places of refuge, and any installed fire mitigation devices (suppression system, etc.);

— the combustible products potentially involved in the fire;

— a description of the specific fire incident, comprising an ignition event (type and location), the involvement of one or more combustible products at various rates of fire growth and heat and smoke production, various stages of fire development (ISO 19706), and the eventual extent of the fire;

— the safety provisions that affect the progression of the fire, e.g. compartmentation,[3] smoke control, fire suppression;[4]

— the people occupying the facility at the time of the fire, including the types of people normally in the facility, their ages, their physical capabilities, their sensitivities to smoke and heat, and their location histories relative to the fire.

Selecting or defining a suitable fire scenario is the starting point for assessing fire threats to people for generating the necessary data output from the large-scale test. This enables a determination of a suitable test rig and instrument requirements. Experience is used to define instrument placement.

5.3 Suitable test rig

Conventional and standardized large-scale fire test rigs consist of one small, medium or large size enclosure with or without a door (see ISO 9705-1, ISO 13784 series, ISO 24473, for example). One of these enclosures may be used in the test with some modifications, i.e. window, corridor for occupants and adjacent room connected to the fire room.

From the description of the real fire scenarios and combustion conditions it is possible to identify a range of hazard scenarios faced by building occupants depending on the fire conditions and their location relative to the fire enclosure. These will have implications on the experimental designs required to reproduce representative conditions, and thus also on the characteristics of test rigs needed. The following general hazard scenarios are identified, although it is possible to envisage many other specific variants.

a) Small smouldering or flaming fire developing in a small and fully-enclosed room, with the subject inside the room of fire origin (e.g. lounge or bedroom in a dwelling, hotel room).

b) As in a), but with a fire room door opening onto a fully-enclosed space (such as a hallway or dwelling interior volume). Exposed subjects may be in the fire enclosure or in an enclosure remote from the fire.

c) As in a) or b), but a window is partly open to the exterior.

d) As in a) or b), but one or more large exterior vents are open.

e) Flaming fire in a fully-enclosed space with a relatively low ceiling but a large floor area (such as a supermarket or store).

f) Flaming fire as in e), but with exterior vents.

g) Flaming fire in a large space with a large floor area and high ceiling (or smoke venting or extraction).

Examples of some suitable test rigs are provided in Annex B.

6 Suitable test rig design

6.1 General

The dimensions of the test rig have an impact on the outcome of the test. The relative position of the different elements (ignition system, burning item, ventilation, sensors) will have an impact on the development of the fire, combustion, efficiency, ventilation, etc. In addition to the content of the test, specific details that lead to a specific fire scenario and temporal evolution of heat release rate, temperature and hence toxicants release, are important.