TECHNICAL REPORT

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Fire safety engineering —

Part 7:
Detection, activation and suppression

Ingénierie de la sécurité contre l'incendie —

Partie 7: Détection, activation et suppression

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Contents

International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet iso@iso.ch

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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.

The main task of ISO technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard (“state of the art“, for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 13387-7, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 4, *Fire safety engineering*.

It is one of eight parts which outlines important aspects which need to be considered in making a fundamental approach to the provision of fire safety in buildings. The approach ignores any constraints which might apply as a consequence of regulations or codes; following the approach will not, therefore, necessarily mean compliance with national regulations.

ISO/TR 13387 consists of the following parts, under the general title *Fire safety engineering*:

- *Part 1: Application of fire performance concepts to design objectives*
- *Part 2: Design fire scenarios and design fires*
- *Part 3: Assessment and verification of mathematical fire models*
- *Part 4: Initiation and development of fire and generation of fire effluents*
- *Part 5: Movement of fire effluents*
- *Part 6: Structural response and fire spread beyond the enclosure of origin*
- *Part 7: Detection, activation and suppression*
- *Part 8: Life safety — Occupant behaviour, location and condition*

Annexes A to C of this part of ISO 13387 are for information only.

Introduction

There are many important active measures that can be implemented to warn occupants and building management about the existence of a fire, to change or modify the normal progress of a fire so that safety and loss reduction criteria can be satisfied. These active protection measures, which constitute subsystem 4 in the fire safety engineering design process, are described and discussed in detail in this document.

Subsystem 4 provides guidance on the use of engineering methods for evaluation of the time to detect smoke or flames by a wide range of commercial devices, including the time required for heat sensitive elements in suppression or other control devices to respond to the gas-flow generated by an incipient or growing fire. To accomplish this, subsystem 4 draws on subsystems 1 to 3 for characterizing the size of the fire as well as the temperature, species concentration and gas velocity fields generated by the design fire, as described further in clause 5. Subsystem 4 also draws on a description of sensor locations and characteristics from building design parameters as well as information available from ISO/TC 21 (*Equipment for fire protection and fire fighting*) standards on fire detection and alarm systems.

Once detection has occurred, the subsystem also provides guidance on how to evaluate the time required to activate the desired response to a fire, such as an alarm, a smoke damper or a specified flow of extinguishing agent from typical distribution devices. To accomplish this, subsystem 4 draws on information from the vendors and manufacturers of detection and suppression systems. The hydraulic design of suppression agent piping systems is considered to be part of the activation process of bringing agent to the stage of interacting with the fire.

The effect of various suppression strategies on the fire heat release rate is evaluated in subsystem 4 by reference to installation guidelines, information obtained from ISO/TC 21 standards on fixed fire extinguishing systems and the use of engineering judgement in the application of these guidelines and standards to design-fire scenarios. Once a suppression strategy (usually in terms of a required agent flow rate) is assumed, there is considerable feedback required between subsystem 4 and subsystem 2 to determine the resultant fire environment, as described in clause 5. Typically, the success of a strategy is judged from expected maximum gas or material temperatures, radiant heat to target locations, effluent/species concentrations and/or the total amount of suppression agent required compared to design objectives.

The main discussion of how engineering methods are used to evaluate or calculate the important subsystem 4 outputs is carried out in clause 6, which is subdivided into subclauses on detection time, activation time and effect of suppression strategies. Each of these subclauses contains a discussion of fire safety engineering design, the important physical and chemical processes to be considered, evaluation methods for specific classes of devices as well as an explicit list of required input parameters needed to perform an engineering analysis and the outputs from such an analysis.

Clause 7 is a discussion of the engineering methods available to evaluate detection, activation and suppression design options. The engineering method selected to solve the design problem should be assessed and verified using the principles documented in ISO/TR 13387-3, *Assessment and verification of mathematical fire models*. Special care should be taken when using input data published in the literature since this information and/or data may be related to specific test conditions and/or specific commercial products; the application of information and/or data under different conditions may result in significant errors.

Further information and background material together with specific literature references that support the discussion in the preceding clauses with details of the fundamental approach to fire safety engineering is available from the sources listed in the bibliography.

Fire safety engineering —

Part 7:
Detection, activation and suppression

1 Scope

This part of ISO 13387 is intended to provide guidance to designers, regulators and fire-safety professionals on the fundamental engineering methods that should be included in design guides and reference manuals for the prediction of:

a) times to detect fire events, based on the design-fire environment and properties and/or location of automatic detection devices;

b) times to activate automatic alarm systems and automatic systems designed to control fire growth or to control the effects of fire, based on system design parameters;

c) the effectiveness of activated automatic suppression systems in limiting the potential consequences of a fire, based on key system characteristics.

NOTE The effect of human intervention on detection, activation or suppression is considered beyond the scope of this document.

This part of ISO 13387 is not itself a design guide or reference manual but can be used as a resource by national organizations in the preparation of such documents. This report also provides a framework for critically reviewing the suitability of engineering methods, whether hand calculations or predictive computer models or correlations based on empirical data, to predict detection, activation and the effect of fire suppression systems. Note that the term “engineering method” used in this document refers to any of the preceding techniques.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO/TR 13387. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO/TR 13387 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 3009:1976, *Fire-resistance tests — Glazed elements*.

ISO 6182-1:—[1], *Fire protection — Automatic sprinkler systems — Part 1: Requirements and test methods for sprinklers*.

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[1] To be published. (Replaces ISO 6182-1:1993).

ISO/TR 13387-1, *Fire safety engineering — Part 1: Application of fire performance concepts to design objectives.*

ISO/TR 13387-2, *Fire safety engineering — Part 2: Design fire scenarios and design fires.*

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

ISO/TR 13387-4, *Fire safety engineering — Part 4: Initiation and development of fire and generation of fire effluents.*

ISO/TR 13387-5, *Fire safety engineering — Part 5: Movement of fire effluents.*

ISO/TR 13387-6, *Fire safety engineering — Part 6: Structural response and fire spread beyond the enclosure of origin.*

ISO/TR 13387-8, *Fire safety engineering — Part 8: Life safety — Occupant behaviour, location and condition.*

ISO 13943, *Fire safety — Vocabulary*.

3 Terms and definitions

For the purposes of this part of ISO/TR 13387, the definitions given in ISO 13943, ISO/TR 13387-1 and the following apply.

3.1
activation time
time interval from response by a sensing device until the suppression system, smoke control system, alarm system or other fire safety system is fully operational

3.2
ADD
measured volumetric flow rate of water per unit area from ESFR sprinklers that is delivered near the base of a fire plume for a specific fire heat release rate

3.3
agent outlet
point in fixed extinguishing system at which a sprinkler, suppression or control device is located

3.4
control-mode sprinkler
sprinkler (for example, conventional or spray type) that limits fire propagation through wetting/soaking of uninvolved fuel

3.5
conventional sprinkler
sprinkler type which projects 40 % to 60 % of the total water flow initially downward

3.6
design density
sprinkler application rate in the absence of a fire

3.7
detection time
time interval from ignition of a fire until its detection by an automatic or manual system

3.8
engineering judgement
process exercised by a professional who is qualified, because of training, experience and recognized skills, to complement, supplement, accept or reject elements of a quantitative analysis

3.9
fire extinguishment
process by which agents eliminate all flaming combustion

3.10
HRR
heat release rate

3.11
method
abbreviation for one of the recommended engineering methods used to predict detection and activation times and the effect of fire suppression or fire control systems, whether by hand calculation, predictive computer models or empirical correlations

3.12
prewetting
process by which water from sprinkler sprays gradually, soaks or wets fuel surrounding the fuel region actively involved in fire, leading to a reduction in fire propagation

3.13
RDD
volumetric flow rate of water per unit area, applied uniformly to the top surface of a fuel array, needed to cause fire HRR to decay rapidly to a sufficiently low level

3.14
smoke management
the use of compartmentation and buoyancy effects, in addition to flow control, dilution and pressurization, to re-direct smoke

3.15
spray sprinkler
sprinkler type which projects 80 % to 100 % of the total water flow initially downward

3.16
sprinkler activation area
total horizontal area over which sprinklers are designed to operate

3.17
sprinkler application rate
volumetric water flow rate applied per unit surface area from operating sprinklers (also called “sprinkler density” or “discharge density” for horizontal surfaces or, more generally, “surface density”)

3.18
suppression-mode sprinkler
sprinkler (for example, ESFR type) that delivers water directly to burning fuel surfaces, thereby reducing the fire HRR

3.19
suppression system
a system designed for active stabilization, reduction or elimination of fire propagation and heat/smoke release

3.20
water mist protection system
array of devices designed for fire extinguishment through the use of multiple water sprays

4 Symbols and abbreviated terms

4.1 Symbols

C	Conductivity factor, expressed in $(\mathrm{m/s})^{1/2}$
d_{gn}	Geometric number-mean diameter of particles, expressed in mm
K	Light extinction coefficient in smoke/effluent species, expressed in m^{-1}
N	Number concentration of particles, expressed in m^{-3}
T_{e}	Temperature of detector sensing element, expressed in K
T_{ea}	Nominal operating temperature of detector, expressed in K
T_{g}	Actual gas temperature in test section of tunnel or near detector during fire, expressed in K
T_{u}	Ambient air temperature during testing, expressed in K
t_{R}	Response time of detector, expressed in s
u	Actual gas velocity in test section of tunnel or near the detector during fire, expressed in m/s
σ_{g}	Geometric standard deviation of particle diameter, expressed in mm

4.2 Abbreviated terms

ADD	Actual delivered density, expressed in mm/s
CFD	Computational fluid dynamics
ESFR	Early suppression fast response (suppression-mode sprinkler type)
HRR	Heat release rate, expressed in kW
IR	Infra-red
RDD	Required delivered density, expressed in mm/s
RTI	Response time index, expressed in $(\mathrm{m \cdot s})^{1/2}$
UV	Ultra-violet

5 Subsystem 4 of the total design system

5.1 General discussion

This clause describes the procedure by which this document is to be used together with other parts of ISO 13387.

5.2 Explanation and illustrations

To aid in the use of this document in a comprehensive fire safety design process, the information herein can be considered to be part of a detection, activation and suppression subsystem 4 within the total fire safety design system (see Figure 1). The first layer of the design system contains a set of global information, which contains data either transferred among various subsystems or employed to make engineering decisions. These data include three types of global information, which are described more fully in ISO/TR 13387-1:

a) prescribed and/or estimated parameters, consisting of
   1) building parameters (includes location and/or specifications for all fire-related systems);
   2) occupant parameters;
   3) fire loads;
   4) fire scenarios;
   5) environmental parameters;

b) intervention effects, consisting of
   1) alarm activation;
   2) heat and smoke control activation;
   3) suppression activation;
   4) fire brigade intervention;

c) simulation dynamics profiles versus time, consisting of
   1) size of fire and/or smoke;
   2) thermal profile;
   3) pressure and/or velocity profile;
   4) effluent/species profile;
   5) occupant condition;
   6) occupant location;
   7) building condition;
   8) contents condition.

The next layer of the design system consists of a set of evaluations, which in the case of subsystem 4, includes three types of analysis results providing

a) detection time;

b) activation time;

c) performance of suppression systems.

Each of these three types of evaluations is discussed in detail in the three parts of clause 6.

The final layer of the design system consists of processes that include

a) convective heat detection;

b) effluent/species detection;

c) radiant energy detection;

d) agent flow in suppression systems;

e) interactions between suppression systems and fires;

f) interactions between smoke control and suppression systems.

These six different processes, plus other related processes, are part of calculation procedures that generate the three types of evaluations required by subsystem 4 for use by the other subsystems in the total fire safety design system.

5.3 Information flow

To perform one of the three types of evaluations (detection, activation or suppression), a fire safety engineering practitioner must make use of global information data as input parameters for the detailed process calculations. These calculations allow the time for response of alarm, smoke and/or heat control and active suppression devices to be output for use by life safety (and in the future, property, culture and environmental protection) subsystems. In addition to outputting response times, the process calculations in this subsystem also evaluate the success of strategies for active suppression of fire by providing empirical information on required flow rates of suppression agents to reduce or eliminate flaming combustion. With information on the potential success of suppression strategies, the fire growth, smoke movement and life safety subsystems can more readily evaluate the net effect on the fire environment and on people. Finally, the process layer of design subsystem 4 can determine the detailed characteristics of suppression agent delivery, thus allowing alternative, predictive field model calculations to be performed in the fire growth and/or smoke movement subsystems.

ISO TC 92/SC 4 FIRE SAFETY ENGINEERING BUS SYSTEM

Subsystem 4 (SS4) — Detection, activation and suppression

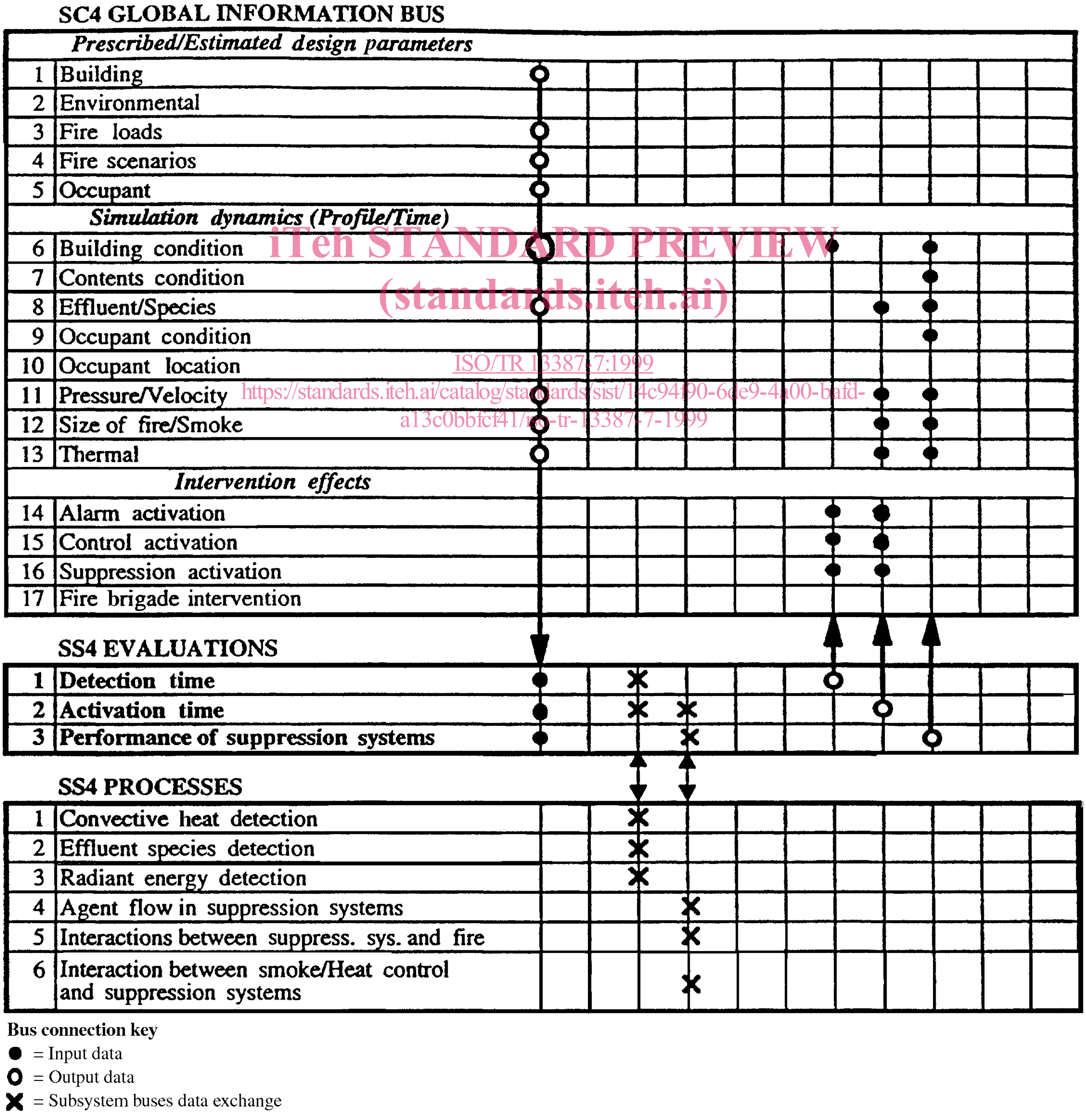

Figure 1 — Illustration of the global information, evaluation and process buses for SS4.

6 Subsystem 4 evaluations

This clause discusses in detail the primary engineering evaluations related to fire detection times (see 6.1), activation times (see 6.2) of alarms and heat and/or smoke control measures and the effectiveness of suppression and other systems (see 6.3) for actively reducing fire consequences. The evaluation of operating characteristics of fire suppression and control systems (for example, flow capacities, nozzle performance, exhaust capacities and other parameters typically obtained from vendors) is discussed as part of the evaluation of activation times in 6.2 since system operating characteristics actually determine the time required for these systems to begin to interact with the design fire. In 6.3, the system operating characteristics (for example, agent flow rates from nozzles) required for successful fire suppression are evaluated. These requirements must be met by system performance during activation, as calculated in 6.2.

Associated with each key subsystem output, recommended engineering methods for predicting unit physical and chemical processes are discussed and all input information required by such methods is identified. Guidance on locating unit process input data is also provided, along with available literature references. Areas for which a lack of knowledge and/or input data are known to exist are addressed.

6.1 Detection time

6.1.1 Role in fire safety engineering design

Because the response time of detectors plays such an important role in fire safety, the selection of the proper detector type and detector location for application to each type of occupancy must be consistent with clearly established design objectives. Descriptions of the three major detector types, thermal, effluent/species (which includes obscuration and/or optical beam detectors) and radiant emission, along with references to recommended design documents, are discussed in the following clauses. This information should be used to match particular design objectives (for example, resistance to non-fire related alarms, shortest possible detection time or compatibility with the building and/or contents environment) to the detector selection and location process. In very general terms (see references [10], [11] and [19] in the bibliography for additional information), thermal point or line detectors are best suited to situations where cost and reliability are overriding factors, for example, to trigger water flow in automatic sprinkler systems or where there are large numbers of locations to be monitored or where there is a high particle count (for example, fine dust or droplets, fumes, insects, etc.) that can cause other detector types to alarm without a fire. Effluent/species detectors are generally best suited when high sensitivity is needed to give the shortest possible detection time, for example, when life safety or sensitive contents is the overriding concern.

Point detectors, whether thermal or effluent and/or species, often depend on fire-induced convective flows to transport heat or smoke up to ceiling level in a plume and then radially outward in a ceiling-jet. This natural buoyant motion, especially in the earliest stages of fire growth, may often:

a) bypass detectors improperly located outside of the plume or ceiling-jet flows (see reference [45] for information on ceiling-jet thickness);

b) require significant transport times;

c) be disrupted by HVAC vent system flows; and

d) be disrupted by ambient stratification of the air in the building, as discussed in 6.1.2.4 of subsystem 2 and in reference [19], pp. 4-15.

All of these phenomena can lead to significant detection delays. Radiant emission detectors and tubing networks of sampling effluent/species detectors are often best suited for situations where such delays would result in detection times that are inconsistent with design objectives (for example, very early detection of small fires).

Detection systems that are not properly designed because of incorrect detector type or location can result in large numbers of alarms to non-fire signals, or “false alarms” being produced, especially when hundreds or thousands of smoke detectors at a single location (for example, a hospital) can produce several false alarms per day. In some instances false alarms can outnumber “real” alarms by ratios in excess of 20:1. Large numbers of false alarms can lead to situations in which the alarm is ignored by many or all of the occupants or in which all detectors are disabled. Careful location of detectors coupled with the correct choice of detector type and/or the use of detectors (see 6.1.6) which incorporate multi-criteria detection, for example, can result in significantly fewer false alarms. With correct design, false alarm to fire ratios can be reduced to 3:1 or fewer. The importance of the ongoing maintenance of fire detection and alarm systems as a means of minimizing false alarms should also not be overlooked.

The task of determining the response of detectors to a design fire that properly tests whether design objectives have been achieved is complicated by the fact that most occupancies (except some single-family residential units) contain detectors that are interconnected with a central control system. This central system can have a range of capabilities from activation of an alarm when any detector in the network responds all the way to sophisticated programmable or learned decisions as to the proper alarm level based on analysis of the history of previous ambient conditions. With such sophisticated systems, which can be just one component of a much larger building automation system, the calculation of “detection time” depends not only on information discussed in 6.1 but also on activation times associated with the complete control system. Just as non-fire signals can be minimized by careful location and selection of individual detectors, false alarms produced by a centralized detection system can be minimized by selection of the proper logic and/or computer algorithms, by a higher level of integrity for detection functions than for other building functions and by careful design to eliminate electrical interference, system faults and even malicious action by occupants or employees. Detection subsystems within a building automation system must have directly measurable performance and reliability that is suitable for an emergency system.

There are several reviews of engineering methods for evaluating the response of fire detectors in a variety of design situations. For example, reference [25] contains a comprehensive literature review, reference [10] contains excellent background information while references [11] and [36] describe specific predictive techniques and engineering methods. The selection and installation of detectors should be consistent with national standards, such as the codes in reference [2].

6.1.2 Thermal (point or line-type) detectors

6.1.2.1 Processes considered in evaluating system designs

The response of a thermal detector can be modelled by calculating the heat transfer taking place by convection between the gas and the detector, by conduction through the detector body to the mounting structure and by radiation to/from the surroundings. During the initial stage of fire growth, while temperatures and flame heights are relatively low, the effect of radiant heat transfer may be less important than convection. When the sensitive element is thermally isolated sufficiently from the remainder of the detector or when fire growth is rapid, conductive heat loss may also be less important than convection. However, as maximum flame thickness increases and flames surround the detector element, radiant heat transfer may no longer be negligible. Finally, conduction may not be negligible compared to convection for slowly growing fires. See reference [2] for engineering guidance on the evaluation of thermal detector performance and response time.

6.1.2.1.1 Methods to evaluate response of fixed temperature detectors to heat transfer

A fixed temperature detector is a device which responds when its sensitive element is heated to a temperature exceeding a predetermined level, called the activation temperature or device temperature rating. For point type detectors, by treating the sensitive element as a mass distinct from the rest of the detector, it is shown in reference [30] that element temperature depends on:

a) thermal properties of the element (mass, specific heat, surface area);

b) convective heat transfer coefficient with the fire environment;

c) conductive heat losses through connections to the rest of the detector or device.

As shown in reference [30] and annex B, a parameter called “response time index” (RTI), can be measured that characterizes both the thermal properties of the element and the heat transfer coefficient for the local fire environment. Similarly, a “conductivity factor” (C) can be measured that characterizes the heat loss from the sensitive element in conjunction with the RTI (see annex B). The RTI is really just a measure of the thermal time constant of the sensitive element for a given flow velocity. Both these parameters, which take values specific to the detector of concern, allow the detector response time to be determined from a knowledge of mean gas velocity and temperature near the detector. See reference [19] for information on the engineering evaluation of fixed temperature detector performance and response time.

Point type thermal detectors are normally tested, classified and installed consistent with national standards and regulatory guidelines. Activation temperatures are chosen so as to be compatible with the normal ambient temperature of the installation. Standard sensitivity tests on point type thermal detectors using a constant gas velocity and prescribed gas temperatures yield detector response time, which with the equations in annex B, can be used to estimate detector RTI (C factors tend to be insignificant for detectors). Alternatively, recommended spacing for detectors in national standards can be converted to equivalent values of RTI for engineering evaluation. For example, annex B of reference [2] contains tables where RTI values are listed explicitly along with recommended spacing.

One common point type, fixed temperature detector is the sensitive element (for example, glass bulb or fusible link) in an automatic sprinkler, which responds when the element is heated to its activation temperature, or temperature rating. The operation time of such sprinkler elements can be determined in the same manner as for a fixed temperature heat detector (see ISO 6182-1 for recommended sensitivity and temperature rating ranges and references [12] and [48] for engineering design methods). However, once the first sprinkler operates, prediction of the operation of subsequent sprinklers for purposes of engineering design becomes very difficult due to significant changes in gas temperature and velocity caused by:

a) energy absorption by sprinkler droplets due to sensible heating and evaporation;

b) momentum addition to the flow field due to the thrust force of the spray;

c) water vapour addition to the flow due to evaporation (a minor effect).

All of these effects can, in principle, be resolved by field modelling, as noted in 7.3.2.

Fixed temperature detectors may also be of the line type. Line detectors can sense a fire within a highly obstructed enclosure where it may not be practical to find suitable, discrete locations for point detectors. Such enclosures may occur within complex mechanical or electronic equipment. Line detectors can be activated by the melting of plastic insulation separating conductive wires (requiring replacement of the line segment after activation), by changes in the resistivity of a rugged, thermistor type of cable, by changes in the air pressure of a pneumatic conduit or by changes in the cladding reflectivity of fibre-optic cable. Intelligent monitors of such detectors can determine the location of the fire along the line element.

6.1.2.1.2 Methods to evaluate response of rate of rise detectors to heat transfer

A rate-of-rise detector is a device which responds when the temperature rises at a rate exceeding a predetermined amount. The approach is to assume a single response time index (RTI) and a conductivity factor (C) for the sensitive element (see annex B), then the temperature variation history of the sensitive element can be calculated in the same manner as described in 6.1.2.1.1. The response time can then be determined as the time at which the rate of rise of the calculated temperature exceeds that needed for operation.

A similar approach may also be taken with line-type detectors, using representative values for RTI and conductivity factor (C) and average values for the gas temperature and velocity.

See annex B of reference [2] and reference [19] for information on the engineering evaluation of the performance and response time of rate-of-rise thermal detectors.

6.1.2.2 Required input information and/or data

The required input information and/or data are as follows.

a) Size of fire and/or smoke:

The flame position, or the distance and the direction relative to the detector must be known to assess the effect of radiant heat transfer. For the purposes of this evaluation, design fire data appropriate for the occupancy should be used.