Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

KTA 2101.2 (2015-11)

Fire Protection in Nuclear Power Plants
Part 2: Fire Protection of Civil Structures

(Brandschutz in Kernkraftwerken
Teil 2: Brandschutz an baulichen Anlagen)

The previous version of this safety standard was issued in 2000-12

If there is any doubt regarding the information contained in this translation, the German wording shall apply.

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KTA SAFETY STANDARD

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Comments by the Editor:

Taking into account the meaning and usage of auxiliary verbs in the German language, in this translation the following agreements are effective:

shall	indicates a mandatory requirement,
shall basically	is used in the case of mandatory requirements to which specific exceptions (and only those!) are permitted. It is a requirement of the KTA that these exceptions - other than those in the case of **shall normally** - are specified in the text of the safety standard,
shall normally	indicates a requirement to which exceptions are allowed. However, exceptions used shall be substantiated during the licensing procedure,
should	indicates a recommendation or an example of good practice,
may	indicates an acceptable or permissible method within the scope of the present safety standard.

Basic Principles

(1) The safety standards of the Nuclear Safety Standards Commission (KTA) have the task of specifying those safety-related requirements which shall be met with regard to precautions to be taken in accordance with the state of science and technology against damage arising from the construction and operation of the plant (Sec. 7, para. (2), subpara. (3) Atomic Energy Act - AtG) in order to attain the protective goals specified in AtG and the Radiological Protection Ordinance (StrlSchV) and further detailed in the Safety Requirements for Nuclear Power Plants (SiAnf) and the SiAnf-Interpretations.

(2) The Safety Requirements for Nuclear Power Plants (SiAnf), Appendix 3 "Internal and external events as well as external hazards", states among others that protective measures against fires inside the nuclear power plant must be provided. The basic requirements regarding fire protection measures are detailed in the safety standard KTA 2101.1. The fire protection of civil structures (also called "building structures" or "structural components") is detailed in the present safety standard and the fire protection of mechanical and electrical components in safety standard KTA 2101.3. All three parts of the safety standard series KTA 2101 must be considered in the planning and execution of fire protection measures.

Note:

The additionally relevant safety standards of the KTA are specified in safety standard KTA 2101.1.

(3) The present safety standard is prepared based on the assumption that the building codes, fire protection laws and fire protection regulations of the individual German states (Länder), the German Workplace Ordinance, the German Accident Prevention Regulations (UVV) of the trade unions and other public law regulations are complied with. If the specifics of the nuclear power plant require deviations from laws, ordinances or other public law regulations or from the German Accident Prevention Regulations, then, in each individual case, the particular procedures specified in these regulations regarding deviations and exemptions must be followed.

1 Scope

This safety standard applies to nuclear power plants with light water reactors.

Note:

Further scope-related specifications are detailed in safety standard KTA 2101.1.

2 Definitions

Notes:

(1) Applicable definitions are specified in safety standard KTA 2101.1.

(2) In specifying requirements for the structural material classes as well as for the fire resistance time, the present safety standard uses the terminology introduced by the building inspectorate (cf. DIBt-BRL "List of Building Regulations").

3 Design of Structural Fire Protection Measures

3.1 Certification Procedure

(1) It shall be proven that the structural fire protection measures will withstand the fire effects determined in accordance with safety standard KTA 2101.1, Sec. 3.2.3, without losing their fire protection function (e.g., stability, room isolation).

Note:

A simplified procedure specific to nuclear power plants that is used for determining the required fire resistance time of structural fire protection measures is presented in the informative Appendix A. The fire resistance classes for the intended structural elements can be deduced from these fire resistance times.

(2) In case the requirements specific to nuclear power plants go beyond requirements specified by the building inspectorate, the respective proofs may be provided analytically, experimentally, by analogy or by plausibility considerations.

(3) In the case of an analytical proof it is permissible to use simplified analysis procedures.

Note:

Analysis procedures are specified, e.g., in the fire protection sections of the Eurocodes that comply with the building inspectorate regulations.

(4) Experimental proofs shall be presented for special structural elements that, in addition to requirements regarding fire resistance, must also fulfill requirements specific to nuclear power plants.

(5) Any analogy consideration shall be based on referential results of experimental or analytical proofs that were performed for comparable constructions (e.g., type of construction, building materials, dimensions) and for comparable loadings (e.g., temperature effects, operational loading, additional loading regarding design basis accidents).

(6) Plausibility considerations may be presented to prove that structural measures designed for other load cases can also be considered for ensuring safety in the event of fire.

3.2 Fire Events under Consideration of Additional Requirements and of Combinations with Other Events

(1) If additional design requirements as specified in safety standard KTA 2101.1, Sec. 3.4.1 para. (4), must be considered (e.g., regarding radiation protection, gas leak tightness, lower temperature increases on the far side of the fire) then the determination of the fire resistance of the components shall be based also on these requirements. The proof guidelines and proof criteria established by the building inspectorate shall be applied analogously under consideration of the above requirements. It is admissible to use the certification procedures specified under Section 3.1 in these cases.

(2) Structural fire protection measures, the function of which must be ensured for the event combinations specified in safety standard KTA 2101.1, Sec. 3.3, shall be designed accordingly.

(3) Those structural fire protection measures, the fire protection function of which must be ensured even after an earthquake, shall be designed for the earthquake effects determined as specified in KTA 2201.1, provided that the intensity of the design-basis earthquake is higher than VI (EMS-98 - European Macroseismic Scale). The proofs regarding fire and earthquake may be performed independently of each other.

4 Location and Accessibility of Buildings

4.1 General Requirements

(1) Buildings shall be arranged taking operational and, additionally, the following requirements into consideration:

a) the fire protective physical separation by the distances between buildings,

b) the rapid and safe rescue of persons in the event of fire, and

c) the access points for the firefighting missions.

(2) The requirements in accordance with DIN 14090 shall basically be applied and additionally those specified under Sections 4.2 through 4.5.

4.2 Access Roads

(1) All surface areas on the plant site that are used for vehicular traffic shall basically be designed at least as a fire department staging area in accordance with DIN 14090. Exceptions are admissible in the case of remote vehicular surface areas (e.g., parking lots), provided, they are is insignificant regarding accessing buildings or plant components. In case they have a reduced load-carrying capacity they shall be marked accordingly.

(2) Buildings with safety-related systems and plant components shall basically be accessible via two independent access roads that are at least 6 meters wide. Exceptions are admissible in the case of access roads to remote buildings that have a low fire load density (e.g., auxiliary service water pump building).

(3) In the case of plant-engineering related bottlenecks, the width of the access roads may be reduced to a minimum of 3.5 meters. However, the length of such bottlenecks shall be limited to a maximum of 40 meters.

4.3 Access Points

It can happen that access points dedicated to rescue and firefighting missions are locked for security reasons. It is, therefore, mandatory that these doors can be opened from the outside and can be arrested in the open position. The same applies to plant-internal access points of enclosed building areas.

Note:

Requirements regarding the blocking of entry points are detailed in Section 7.1.

4.4 Fire Department Staging Areas

The fire department staging areas in accordance with DIN 14090 may be part of the width of access roads, provided, a width of at least 5 meters next to the staging area remains available for the access road.

4.5 Free Movement Areas

(1) Regarding rescue and danger aversion missions, a free movement area of at least 7 meters by 40 meters shall be assigned in front of each of the necessary access points of the buildings. The distance between the free movement area and the respective access points shall normally not exceed 25 meters.

(2) The free movement areas in accordance with DIN 14 090 may be part of the width of access roads, provided, a width of at least 3 meters next to the free movement area remains available for the access road.

(3) Walk ways or other similar surfaces bordered by curb stones may be integrated up to a width of 2 meters into the free movement area.

5 Fire Compartments and Firefighting Sub-Compartments

5.1 Fire Compartments

If system-technological or usage-related requirements make it necessary for the size of a fire compartment to exceed the size basically specified by building regulations, the required fire protection shall be ensured by compensatory measures (e.g., by creating firefighting sub-compartments (also called “firefighting sections”) as specified under Section 5.2, by additional plant-engineering related fire protection measures, or by a combination of these measures).

Note:

This applies, e.g., to the reactor building and to the turbine building of boiling water reactors.

5.2 Firefighting Sub-Compartments

(1) The following areas shall be designed as firefighting sub-compartments:

a) rooms for electronic data processing equipment and their conduit rooms,

b) rooms for switch gear and their conduit rooms,

c) rooms for electronic equipment and their conduit rooms,

d) rooms for emergency power generation systems and their fuel depots, and for redundancies of the emergency power supply systems,

e) rooms for redundant safety-related systems and plant components,

f) rooms with storage vessels and facilities for lubrication oil, turbine oil and other combustible fluids,

g) cable ducts and cable wells, insofar as they are not part of a room,

h) cable floors,

i) pool for new fuel assemblies,

j) rooms for transformers with combustible fluids inside of buildings,

k) rooms for the external oil supply (e.g., oil storage vessels including their auxiliary equipment). In the case of boiling water reactors, this room shall be located outside of the control rod drive room.

l) rooms in which more than 3 m^3 of activated charcoal are stored,

m) rooms for fuel oil storage tanks,

n) rooms for the conditioning of combustible waste material including the respective storage rooms.

(2) In addition, the following areas shall normally be constructed as firefighting sub-compartments:

a) rooms for the fuel oil day tanks,

b) storage rooms for closed containers for combustible radioactive substances,

c) rooms in which up to 3 m^3 of activated charcoal are stored.

(3) Walk-in pipe or cable ducts that are longer than 50 meters shall basically be subdivided into, as far as possible, equal-length firefighting sub-compartments. If the ducts do not contain any combustible materials or if they are equipped with a stationary fire extinguishing system, then a subdivision is required only if a duct is longer than 100 meters. When creating the subdivisions, personnel protection shall be taken into consideration.

(4) The control room together with its functional areas and the associated cable floor shall be constructed to be at least one firefighting sub-compartment. The document area and the personnel rest area shall be separated from the control room by fire resistant building elements out of non-combustible building materials. Any other rooms directly accessible from the control room shall normally be separated by fire retardant building elements out of non-combustible building

materials. The doors into the control room shall normally be constructed to be smokeproof.

(5) The emergency control center including annex room and the associated cable floor shall be constructed as at least one firefighting sub-compartment to be at least fire resistant and constructed out of non-combustible building materials.

5.3 Measures Regarding Neighboring Buildings and Building Corners

5.3.1 Neighboring buildings

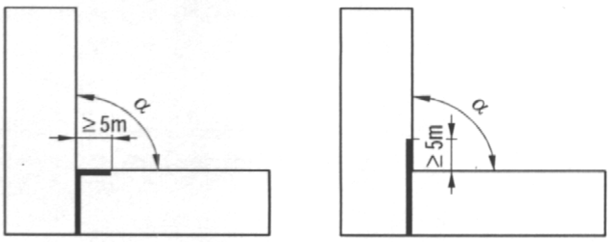
If the distance between buildings is smaller than 5 meters, at least one of the opposing external walls shall be designed as a fire wall.

Note:

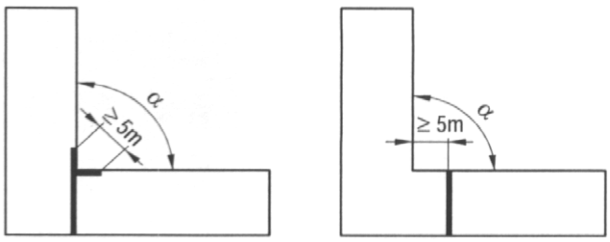
Requirements applying to fire walls are specified in the DIBt-BRL “List of Building Regulations”.

5.3.2 Building corners

If building components that meet under an angle, α, smaller than or equal to 120 degrees must be separated by a fire wall, the building corner shall be designed as shown in **Figure 5-1.**



The fire wall at the inside corner shall be extended in either of the two directions to a length ≥ 5 meters.



The fire wall shall be extended in both directions.

The fire wall shall be located at a distance of ≥ 5 meters away from the inside corner.

Figure 5-1: Building corners

5.3.3 Roofs of lower buildings or building components

(1) Roof levels or roofs of lower building components or of neighboring lower buildings that are closer than 5 meters from external walls of larger building parts or buildings shall basically be designed to be at least fire resistant and constructed out of non-combustible building materials. This requirement is fulfilled in the case of those roofs, the load-carrying roof shell of which are constructed out of mineral building materials (e.g., concrete).

(2) The measures under para. (1) are not required if the neighboring external wall of the higher building is constructed as a fire wall.

6 Structural Elements Enclosing Fire Compartments and Firefighting Sub-Compartments

6.1 Structural Elements Enclosing Fire Compartments

(1) All structural elements for enclosing fire compartments – including their supports and bracing structures – shall be designed to be at least fire resistant and constructed out of non-combustible building materials

(2) Walls that enclose fire compartments toward adjacent buildings or building parts shall basically be designed as continuous fire walls. If the functional and operational use of the building so requires, it is admissible to use overlapping instead of continuous fire walls, provided, the fire walls are designed to be at least fire resistant and constructed out of non-combustible building materials. These walls shall be constructed together with basically hermetically closed ceilings having at least the same fire resistance. If system-technology necessitates openings in these ceilings, these openings shall be locked shut as if they were openings in fire walls.

(3) If operating activities in a fire compartment lead to an increased fire risk (e.g., higher fire load densities, difficult accessibility) or if the fire compartment serves as protection for equipment of the safety system, the structural elements specified under paras. (1) and (2) may be required to have a higher fire resistance capability. Proof of these measures shall be performed as specified under Section 3.

6.2 Structural Elements Enclosing Firefighting Sub-Compartments

(1) The walls and ceilings that separate firefighting sub-compartments – including their support structures and bracing structures – shall basically be designed to be fire resistant and constructed out of non-combustible building materials. Higher fire resistance classes may be required, and lower fire resistance classes may be admissible. Higher requirements would apply if they are necessary

a) due to an increased fire risk (e.g., higher fire load densities, difficult accessibility), or

b) for the protection of equipment of the safety system.

Lower requirements regarding the fire resistance require individual proofs.

(2) Walls shall basically meet the requirements of fire walls regarding impact resistance. Exceptions are admissible, e.g., for rooms that are directly accessible from the control room as well as for the separating elements of room areas without safety-related equipment.

6.3 Closing Elements for Openings in Enclosing Structural Elements of Fire Compartments and Firefighting Sub-Compartments

6.3.1 General requirements

(1) Closing elements of openings in enclosing structural elements of fire compartments include, e.g.,

a) fire protection closing elements (fire protection doors and gates),

b) windows,

c) fire dampers,

d) fire shields of cables,

e) fire shields of pipes, and

f) joint sealants.

Note:

Requirements for the fire shields of cable penetrations in the reactor containment vessel are detailed in safety standard KTA 3403, Sec. 4.7.

(2) The fire resistance time of the closing elements of openings shall basically be the same as the required fire resistance time of the enclosing structural elements. Exceptions are admissible for firefighting sub-compartments, provided, a proof is presented as specified under Section 3.1.

(3) Insofar as the closing elements of openings must, in addition to fire protection, meet requirements regarding

a) radiation protection,

b) leak tightness,

c) mechanical stability with respect to external events and plant-internal design basis accidents, or

d) plant security,

and which, therefore, might lead to a reduction of the fire resistance capability of a structural element, then the fire protection shall be ensured by other equivalent measures.

(4) The function of the fire shields of pipe penetrations shall be demonstrated both for the fire event and for the loading under specified normal operation.

6.3.2 Special requirements regarding earthquakes

In the case of cable penetrations, the fire protection functions of which, as specified in Section 3.2 para. (3), must be demonstrated to be ensured even after an earthquake, the relative deformation of the fire shield of the cable in direction of the cable penetration caused by the dynamic earthquake loading shall be limited by constructional means (e.g. fixed-point placement) to such a level that the fire resistance time of the fire shield is not inadmissibly reduced.

6.4 Measures to Counter Fire Flashover Between External Structural Elements

6.4.1 External walls

(1) External walls shall consist of non-combustible building materials. This also applies to barrage structures, the outer-wall glazing and cladding including their mounting elements and insulating materials, however, not to the sealants, protective coatings, flashings and sun protection devices.

(2) External walls including their openings shall be designed to be fire resistant if any fire loads (e.g., combustible materials regularly stored or placed on the plant site outside of buildings) are not stored or placed at a sufficient distance away from the buildings.

Note:

Sufficient distances are specified under Section 6.4.3 as well as, e.g., in TRGS 510.

6.4.2 Roofs

(1) The support structure of the roofs and the roof insulation shall consist of non-combustible building materials.

(2) Roof openings belonging to different fire compartments or firefighting sub-compartments shall be no closer to each other than 5 meters if these openings are unprotected from a standpoint of fire protection.

6.4.3 Structural fire protection measures for open-air transformers

(1) The distance between open-air transformers shall basically be as specified in DIN EN 61936-1. Otherwise, the open-air transformers shall be separated by walls that are designed as specified in accordance with DIN EN 61936-1.

(3) Adjacent open-air transformers filled with more than 1000 liters of combustible isolating fluids that are closer to each other than specified in accordance with DIN EN 61936-1 shall be protected from each other by walls that are fire resistant and constructed of non-flammable structural materials and that are dimensioned in accordance with DIN EN 61936-1, however, with the minimum dimensions as follows:

Height: extending beyond the top edge of the transformer vessel including the expansion vessel – at least 1.0 meters

Depth: extending forward and, in the case of a freestanding installation, also to the back – at least 1.5 meters

(3) Building walls that border on open-air transformers filled with combustible isolating fluids shall be designed as fire walls if the distance to the transformers is less than specified in accordance with DIN EN 61936-1.

(4) These walls shall extend, vertically, at least 5 meters above the height of the top edge of the transformer vessel including the expansion vessel or up to an equivalent ceiling above the transformer and, horizontally, at least to a length of 5 meters beyond either side of the transformer outer dimension.

6.5 Encapsulation

6.5.1 Encapsulations with sustained functional integrity

All structural elements serving as encapsulation with sustained functional integrity shall – including their supports and bracing structures – have a sufficient fire resistance capability. They shall normally be designed to be at least fire resistant and constructed out of non-combustible building materials.

Note:

A typical encapsulation with sustained functional integrity is, e.g., a channel made from calcium-silicate slabs with a defined fire resistance time that has the approval of the building inspectorate.

6.5.2 Encapsulations without sustained functional integrity

The suitability of encapsulations without a defined fire resistance time shall be proven by the procedures specified under Section 3.1 (e.g., plausibility proof).

Note:

An encapsulation without sustained functional integrity is, e.g., a sheet metal channel without a defined fire resistance time.

7 Rescue Routes

7.1 General Requirements

(1) For reasons of security, doors along rescue routes may be blocked for a limited time. For these cases, the possibilities for rescuing and firefighting missions shall be regulated on a plant-specific basis.

(2) These doors shall carry a sign warning of the possible blocking and indicating the plant-specific regulations.

7.2 Necessary Staircases

(1) The walls and ceilings of the necessary staircases shall be designed to be at least fire resistant and constructed out of non-combustible building materials.

(2) Closing elements of openings from the necessary staircases to adjacent rooms shall basically be designed to be fire resistant and smoke proof. A lower fire resistance class or non-smokeproof doors are admissible for those closing elements of openings to rooms with an area not exceeding

200 m² and with a low fire risk. In these exceptional cases, the closing elements shall be constructed to be at least fire retardant, leak tight and self-closing.

(3) Basically, no requirements are specified regarding fire resistance and smoke leakage for openings in necessary staircases that lead to the outside. Where the necessary staircases are located in front of the external wall of buildings, an angle is created to the outside wall. In this case the distance to unprotected openings shall be equal to the safety distance specified under Section 5.3.2.

(4) Supporting structural elements of stairs shall be designed to be fire resistant.

7.3 Airlock Antechambers

(1) The walls and ceilings of airlock antechambers as well as closing elements of openings in these civil structures shall basically be constructed to be fire resistant and constructed out of non-combustible building materials

(2) In well-founded cases (e.g., due to a low fire risk), lower fire resistance times are admissible for closing elements of openings.

(3) Doors and dampers shall be constructed to be self-closing and doors, additionally, to be smokeproof.

8 Ventilation Systems, Heat and Smoke Removal Equipment

8.1 General Requirements

(1) In the case that fire dampers are installed in ventilation systems that, in accordance with safety standard KTA 3601, must be leak tight, these fire dampers shall not have inadmissible adverse effects on the leak tightness of the system.

(2) Leak tight ventilation systems with fire protection requirements shall be designed such that the recurrent leakage tests in accordance with safety standard KTA 3601 can be performed. These tests shall not have any lasting adverse effects on fire protection.

8.2 Requirements for Ventilation Systems

(1) Pipes, adapter fittings, ducts and channels of ventilation conduits shall basically be designed to be constructed of non-combustible materials. In case corrosive gasses (e.g. from battery rooms and laboratories) need to be removed, exceptions are permissible, provided, the structural materials used are at least flame retardant.

(2) In case ventilation facilities have the combined function of operational ventilation and heat and smoke removal, then the requirements regarding the temperature and pressure resistance for the individual structural elements of the ventilation systems shall be specified under consideration of the mixture temperature that can occur in the ventilation ducts. The suitability of the ventilation system regarding heat and smoke removal shall be demonstrated.

(3) If ventilation ducts of the required system for ventilating the control room lead through other fire compartments or fire-fighting sub-compartments, they shall be constructed to be at least fire resistant.

8.3 Equipment for Heat and Smoke Removal

Smoke removal conduits and smoke removal dampers shall be designed in accordance with DIN 18232-5. The design shall basically be based on the temperature class F600. Deviations are admissible, provided, it is proven that

a) the smoke will cool off along the smoke removal conduits, or

b) lower temperatures are expected inside the fire compartment or area.

8.4 Ventilation Measures for the Necessary Staircases

(1) The necessary staircase shall basically be equipped with openings for smoke removal. If this is impossible for plant-engineering related reasons, powered systems shall be provided that counteract the penetration of smoke into the necessary staircases or that can remove possibly penetrated smoke from the necessary staircases. Regarding the reactor containment vessel, the special plant-engineering related features shall be taken into consideration.

(2) The inlet and exhaust ducts of the powered systems, as far as they are routed outside of the necessary staircases, shall be constructed to be as fire resistant as the respective fire-endangered building.

(3) Any powered smoke removal from other areas shall not direct smoke into the necessary staircase and airlock antechambers.

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Appendix A (informative)

Simplified Validation Procedure for Determining the Required Fire Resistance Time of Structural Fire Protection Measures

A 1 Basic Data for the Validation Procedure

The simplified validation procedure described in the following may be used for determining the fire resistance time of structure-related fire protection measures (also refer to [1] and [2]).

It shall be observed that this validation procedure may not be intermixed with other analytical procedures.

Basic data for this validation procedure are room-specific lists identifying their geometry, the mass and calorific values of the contained combustible materials, as well as the ventilation conditions caused by openings that, in the event of fire, may regularly or irregularly be in the open position, or the ventilation conditions caused by a forced ventilation with a specified volume flow rate.

Specifically, the following input parameters are required:

a) room area, A [m²],

b) room height, H [m],

c) sum of natural ventilation openings, A_V [m²],

d) input air flow rate of forced ventilation, $\dot{V}_{zu}$ [m³/h],

e) masses, M_i in kg, of the unprotected combustible materials (e.g., oil, cables) as well as their calorific values, H_{ui} in kWh/kg,

f) masses, M_j in kg, of combustible materials protected against ignition by being enclosed in containments, closed systems or other enclosures (e.g., intumescent coating in the case of cables).

The criterion for the expected fire loading of structural elements in the natural course of a fire event is the fire duration, $t_ä$, that is equivalent to the standard fire loading (uniform-temperature-time-curve) in accordance with DIN 4102-2; the fire duration, $t_ä$, is determined following the procedure described in DIN 18230-1 as dependent on a theoretical fire load density, q_R.

A 2 Theoretical Fire Load Density, q_R

The theoretical fire load density, q_R in kWh/m², is calculated from the individual masses, M_i, the calorific values, H_{ui}, and the combustion efficiencies, χ_i, of the unprotected combustible materials as well as from the corresponding values M_j, H_{uj} and χ_i of the protected combustible materials and, if applicable, considering the energy losses, ΔQ_W, caused by heat sinks.

$$q_R = (Q_u + Q_g - \Delta Q_W) / A \quad \text{(A 2-1)}$$

where

Q_u : sum of unprotected fire loads, [kWh],
$$Q_u = \Sigma (M_i \times H_{ui} \times \chi_i) \quad \text{(A 2-2)}$$

Q_g : sum of protected fire loads, [kWh],
$$Q_g = \Sigma (M_j \times H_{uj} \times \chi_j \times \psi_j) \quad \text{(A 2-3)}$$

ΔQ_W : sum of energy losses, [kWh], caused by heat sinks as specified under Section A 4

Applicable values for the average combustion efficiencies, χ_i, of combustible materials are listed in **Table A 2-1**. Specific combustion efficiencies listed in [3] may be used in individual cases.

State	Average Combustion Efficiency χ
gaseous	1.0
fluid	0.9
solid	0.8

Table A 2-1: Applicable simplified combustion efficiencies

The combustible materials that are protected by containing them in closed systems or other enclosures may be reduced by applying combination coefficients, ψ_j. The following values may be assumed without detailed validation

$$\psi_j = 0.8 \quad \text{(A 2-4)}$$

for the largest individual protected fire load

$$\psi_j = 0.55 \quad \text{(A 2-5)}$$

for other protected fire loads

The consideration of energy losses caused by heat sinks is an iterative procedure. The initial step is to assume that $\Delta Q_W = 0$; the further analytical procedure is presented in Section A 4.

A 3 Equivalent Fire Duration, $t_ä$

Under consideration of the actual room height, H, and ventilation conditions inside the fire compartment or area, the equivalent fire duration, $t_ä$ [min], is determined as dependent on the theoretical fire load density, q_R, from equations (A 2-1) through (A 2-3) as follows:

$$t_ä = t_{ä,0} \times f_H \times f_{Av} \quad \text{(A 3-1)}$$

where

$t_{ä,0}$: basic value of the equivalent fire duration [min] for a most unfavorable ventilation and a room height H_{ref} = 2.5 meters

f_H : correction factor for other room heights, H

f_{Av} : correction factor for the actual ventilation conditions

Note:

The correction factor, f_{Av}, shall be determined for planned and unplanned ventilation conditions.

The basic value for $t_{ä,0}$ can be extracted from the value diagrams of **Figure A 3-1** or **Figure A 3-2** (same content with different plotting scales).

The value diagrams of **Figure A 3-1** and **Figure A 3-2** distinguish between the following cases:

a) uniformly distributed fire load:
fire extends over the entire room,

b) non-uniformly distributed fire load:
fire is limited to a larger partial area of the room,

c) point-source fire load:
entire fire load is on fire in a localized area.

In case of a non-uniformly distributed fire load, the higher equivalent fire duration shown in **Figure A 3-1** and **Figure A 3-2** is applicable only for those areas where a non-uniformly distributed fire load or a point-source fire load is expected. For other areas, the equivalent fire duration of a uniformly distributed fire load shall be applied.

The correction factor, f_H, for a room height other than the reference room height, H_{ref}, shall be calculated using equation (A 3-2):

$$f_H \left[\frac{H_{ref}}{H}\right]^{0.3} \wedge \qquad \text{(A 3-2)}$$

The correction factor, f_{Av}, for the actual ventilation condition can be read out from **Figure A 3-3** as dependent on the relative effective overall surface area of the openings, $A_{V,eff}/A$:

$$f_{Av} = f(A_{V,eff} / A) \qquad \text{(A 3-3)}$$

where

$$A_{V,eff} = A_V + \dot{V}_{zu}/2200,\ [m^2] \qquad \text{(A 3-4)}$$

A_V : overall surface area, [m²] of the vertical openings in the enclosing walls

$\dot{V}_{zu}$: supplied volumetric air rate, [m³/h] in the case of an available forced ventilation

Without further considerations, this procedure is applicable only for a relative effective overall surface area of the openings, $A_{V,eff}/A$, up to 3 %.

A 4 Consideration of Heat Sinks

The influence on the expected fire effects of the energy losses to available heat sinks inside the fire compartment or area, such as

a) structural concrete elements in addition to the enclosing structural elements (e.g., partition walls, support columns), Q_B,

b) structural steel elements (e.g., bearing and support structures, shells), Q_S,

c) large-volume vessels for fluids, Q_F,

may be taken into consideration as the overall energy loss, ΔQ_W, in equation (A 2-1). In this context,

$$\Delta Q_W = \Sigma\, Q_{W,i} \qquad \text{(A 4-1)}$$

where

$Q_{W,i} = Q_B$, Q_S or Q_F , [kWh]

The energy losses, $Q_{W,i}$ may generally be determined as follows:

$$Q_{W,i} = M_W \times c_{p,W} \times (\overline{T}_{SW} - T_O) / (3.6 \times 10^6) \qquad \text{(A 4-2)}$$

where

M_W : mass, [kg], of the component

$c_{p,W}$: specific heat capacity, [J/(kg×K)], of the component

$\overline{T}_{SW}$: calorific mean temperature, [°C], of the component

T_O : operating temperature, [°C], of the component

The calorific mean temperature, $\overline{T}_{SW}$, can be extracted from **Figure A 4-1** dependent on the previously calculated (without heat sinks) equivalent fire duration, $t_ä$, (without heat sinks) and on the flock parameter, σ_W

$$\sigma_W = \left(\frac{\alpha_W}{\rho_W \times c_{p,W}}\right) \times \left(\frac{A_W}{V_W}\right) \qquad [s^{-1}] \qquad \text{(A 4-3)}$$

where

A_W: fire-affected surface area, [m²], of the structural element

V_W: volume [m³] of the structural element

A_W/V_W: profile factor, [m⁻¹], (analogous to A_m/V in accordance with DIN EN 1993-1-2)

α_W: heat transfer coefficient. [W/(m²×K)]

ρ_W: density, [kg/m³], of the structural element

$c_{p,W}$: specific heat capacity, [J/(kg×K)], of the structural element

The thermal characteristics of the materials to be considered can be extracted from **Table A 4-1.**

Material	α_W W/(m²×K)	ρ_W kg/m³	$c_{p,W}$ J/(kg×K)
concrete	20	2200	879
steel	20	7850	600
water	–	1000	4182
oil	–	910	1880

Table A 4-1: Thermal characteristics of different materials

Instead of extracting the calorific mean temperature from **Figure A 4-1**, this parameter may be determined by applying equation (A 4-4)

$$\overline{T}_{SW} = T_g\left[1 - \exp\left(-s_w \times 60 \times t_ä\right)\right] \qquad \text{(A 4-4)}$$

where

σ_W : flock parameter, [s⁻¹], calculated from equation (A 4-3)

$t_ä$: equivalent fire duration, [min], determined in the initial step without ΔQ_W

T_g : hot-gas temperature, [°C], of the standardized fire after a fire duration of $t_ä$

$$T_g = RT + 345 \times \log(8 \times t_ä + 1) \qquad \text{(A 4-5)}$$

where

RT : room temperature, [°C], at the start of the fire

The calculation of energy losses, Q_F, to vessels filled with fluids is based on the weighted mean values of the density, $\overline{\rho}_F$, and of the specific heat capacity $\overline{c}_{p,F}$:

$$\overline{\rho}_F = \mu_{BE} \times \rho_{BE} + \mu_{FL} \times \rho_{FL} \qquad \text{(A 4-6)}$$

$$\overline{c}_{p,F} = \mu_{BE} \times c_{p,BE} + \mu_{FL} \times c_{p,FL} \qquad \text{(A 4-7)}$$

where

$c_{p,BE}$: specific heat capacity, [J/(kg×K)], of the vessel wall

$c_{p,FL}$: specific heat capacity, [J/(kg×K)], of the fluid

ρ_{BE}: density, [kg/m³], of the vessel wall

ρ_{FL} : density, [kg/m³], of the contained fluid

$$\mu_{BE} = \frac{M_{BE}}{M_{ges}}; \quad \mu_{FL} = \frac{M_{FL}}{M_{ges}} \qquad \text{(A 4-8)}$$

where

$$M_{BE} = A_F \times d_{BE} \times \rho_{BE} \qquad \text{(A 4-9)}$$

$$M_{FL} = V_F \times \rho_{FL} \times h/100 \qquad \text{(A 4-10)}$$

$$M_{ges} = M_{BE} + M_{FL} \qquad \text{(A 4-11)}$$

and the vessel parameters are

A_F: surface area, [m²],

d_{BE}: wall thickness, [m],

V_F: volume, [m³],

h: average filling, [%],

A 5 Required Fire Resistance Time, erf t_f

The required fire resistance time, erf t_f in minutes, of the structure-related fire protection measures is determined by multiplying the equivalent fire duration, $t_ä$, with the safety factor, γ:

$$\text{erf } t_f = \gamma \times t_ä \qquad \text{(A 5-1)}$$

The safety factor, γ, shall be extracted from **Table A 5-1** under consideration of the significance of the structural elements to be dimensioned, of the provided fire protection measures and of the basic ventilation conditions.

Fire Fighting Category	Ventilation	Safety Factor, γ, for Fire Safety Class		
		SKb 3	SKb 2	SKb 1
A	p	1.45	1.10	0.70
	u	0.85	0.50	0.50
B	p	1.35	1.00	0.60
	u	0.80	0.50	0.50
C	p	1.10	1.00	0.50
	u	0.50	0.50	0.50
D	p	0.75	0.50	0.50
	u	0.50	0.50	0.50
p : planned u : unplanned				

Table A 5-1: Safety factor, γ, for the design of structure-related fire protection measures in nuclear power plants

With respect to the effectiveness of firefighting missions, the following four categories are differentiated between:

a) Category A: manual firefighting missions after on-site clarification of the situation; action begins more than 10 min after occurrence of the fire.

b) Category B: manual firefighting missions by on-site personnel; action begins less than 10 min after occurrence of the fire.

c) Category C: stationary fire extinguishing system, manually triggered; action begins less than 10 min after occurrence of the fire.

d) Category D: stationary fire extinguishing system; automatically triggered or manually triggered on site or triggered in the control room immediately after the fire alarm; action begins less than 2 min after occurrence of the fire.

With respect to ventilation, it shall be differentiated between planned (p) and unplanned (u) ventilation conditions. In case of the planned ventilation,

a) all openings (including doors) that stand open in the event of fire,

b) the leakage openings in the enclosing structural elements, and

c) the available forced ventilation that would continue to be in operation in the event of fire

are considered.

In case of the unplanned ventilation,

a) open doors that, regularly, would be closed in the event of fire, or

b) continued operation of a forced ventilation that, regularly, would be shut down, and additionally,

c) leakage openings specified above under planned ventilation.

are considered.

Notes:

(1) The forced ventilation mentioned under planned ventilation also comprises such forced ventilation, the shutdown or isolation of which in the event of fire is not specified unambiguously, e.g., in the plant-internal fire protection regulation.

(2) An unplanned forced ventilation may, if applicable, be the fire-related failure of, or unplanned air release from, compressed air systems in the fire compartment or area.

Regarding the design of structural elements, they shall be correlated to one of the following three fire safety classes, SKb 1 through SKb 3:

a) SKb 1: subordinate structural elements with fire resistance requirements, e.g., parts of the secondary support structure,

b) SKb 2: closing elements of openings, or fire shields of cable or pipe penetrations through separating structural elements,

c) SKb 3: structural elements separating fire compartments or firefighting sub-compartments (e.g., also physical separations of redundancies) or that support separating structural elements, as well as all structural elements of the major support structure.

Note:

The structural elements are correlated to the fire safety classes in accordance with MIndBauRL and DIN 18230-1 which present additional details. Particularly in existing power plants, a downgrading by one fire safety class (e.g., SKb 3 to Skb 2) is admissible, provided, the required safety level is ensured by other means (e.g., additional organizational fire protection measures).

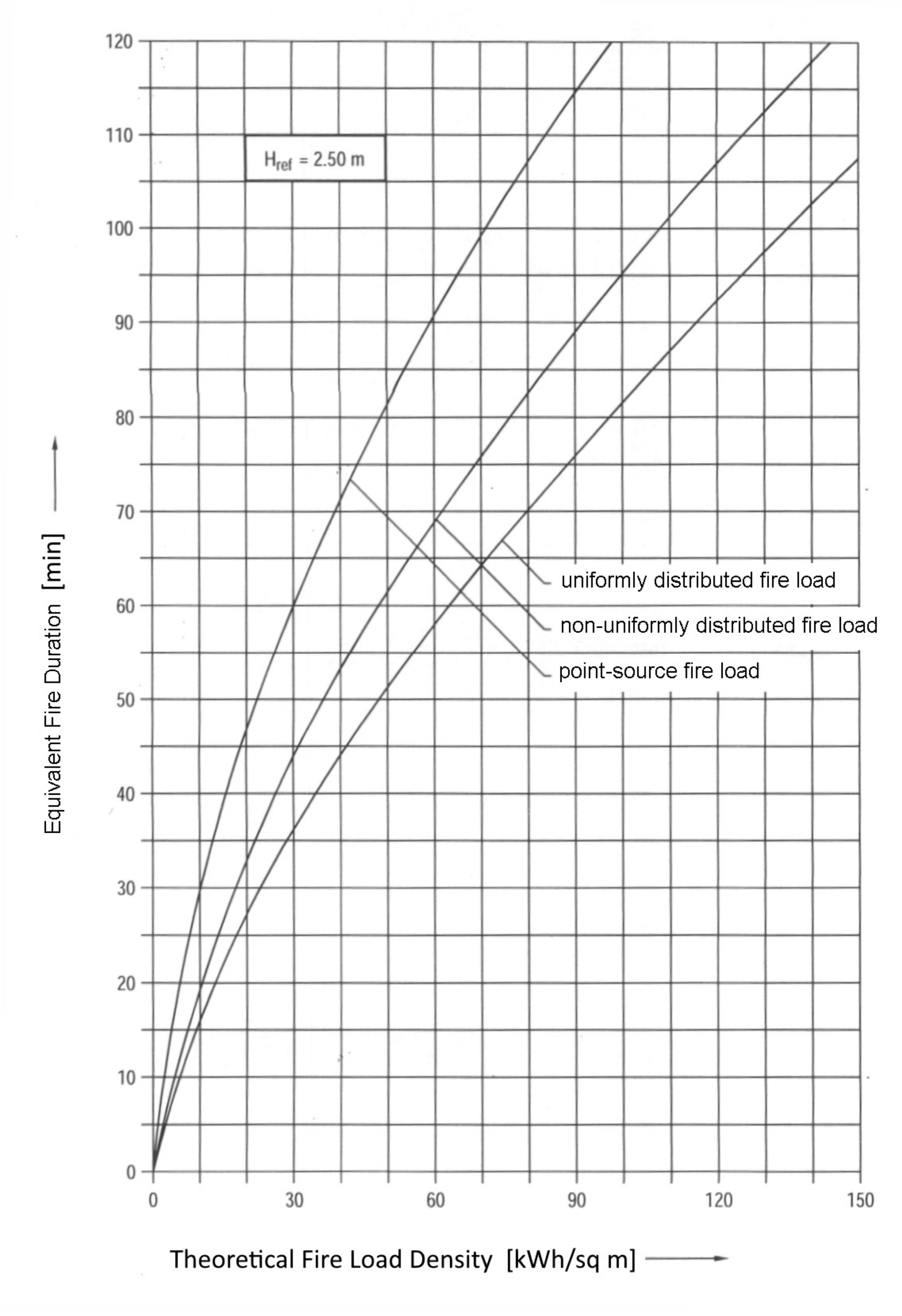

Figure A 3-1: Basic equivalent fire duration, $t_{ä,0}$, as a function of the theoretical fire load density, q_R

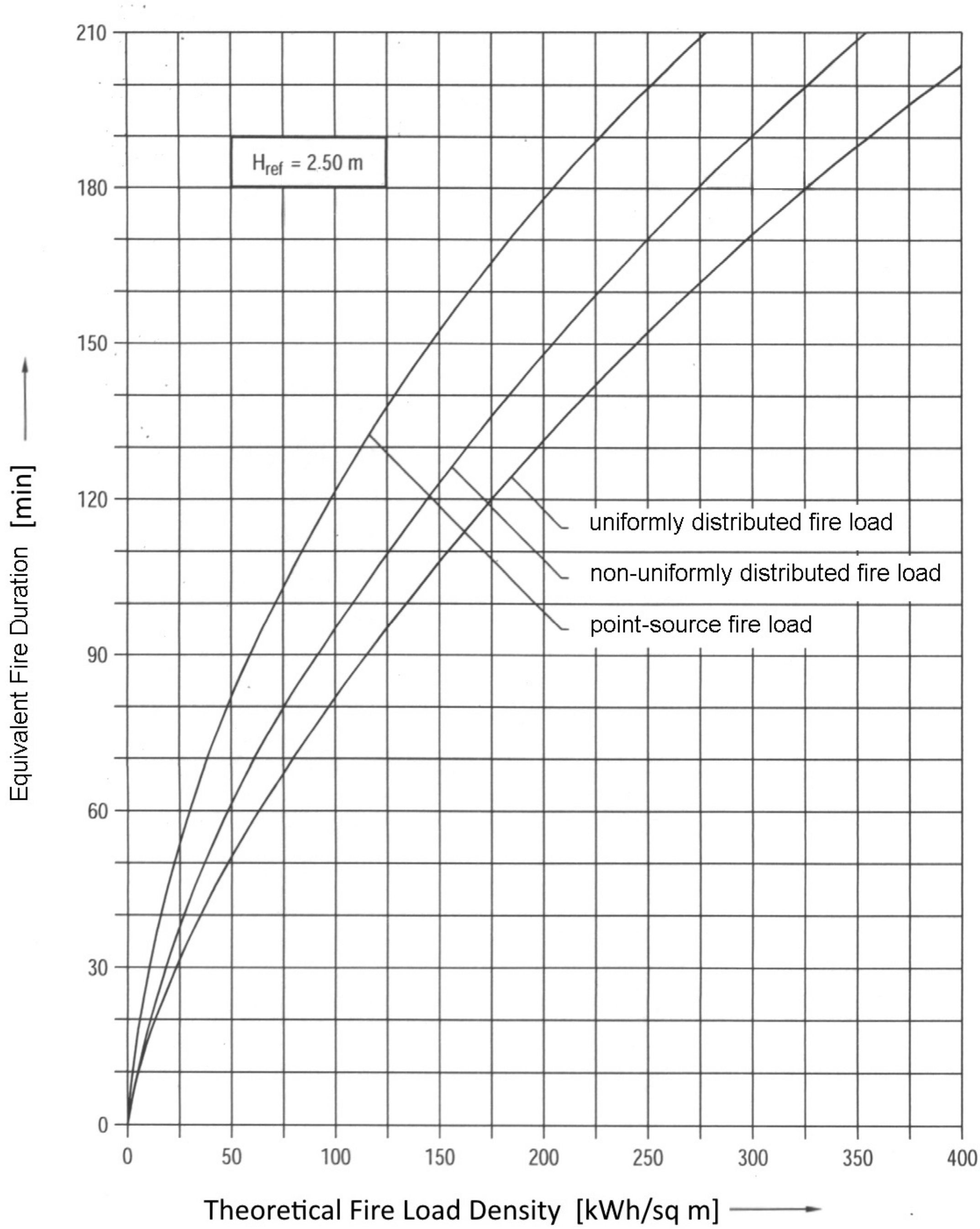

Figure A 3-2: Basic equivalent fire duration, $t_{ä,0}$, as a function of the theoretical fire load density, q_R

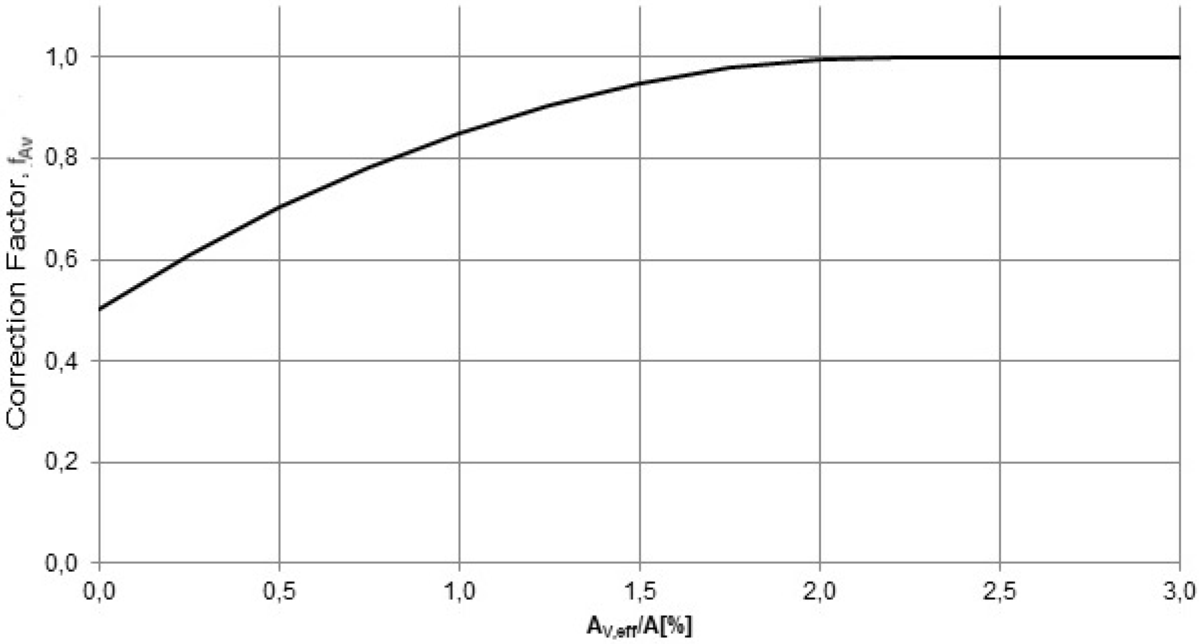

Figure A 3-3: Correction factor, f_{Av}, as a function of the relative effective overall surface of the openings, $A_{V,eff}/A$

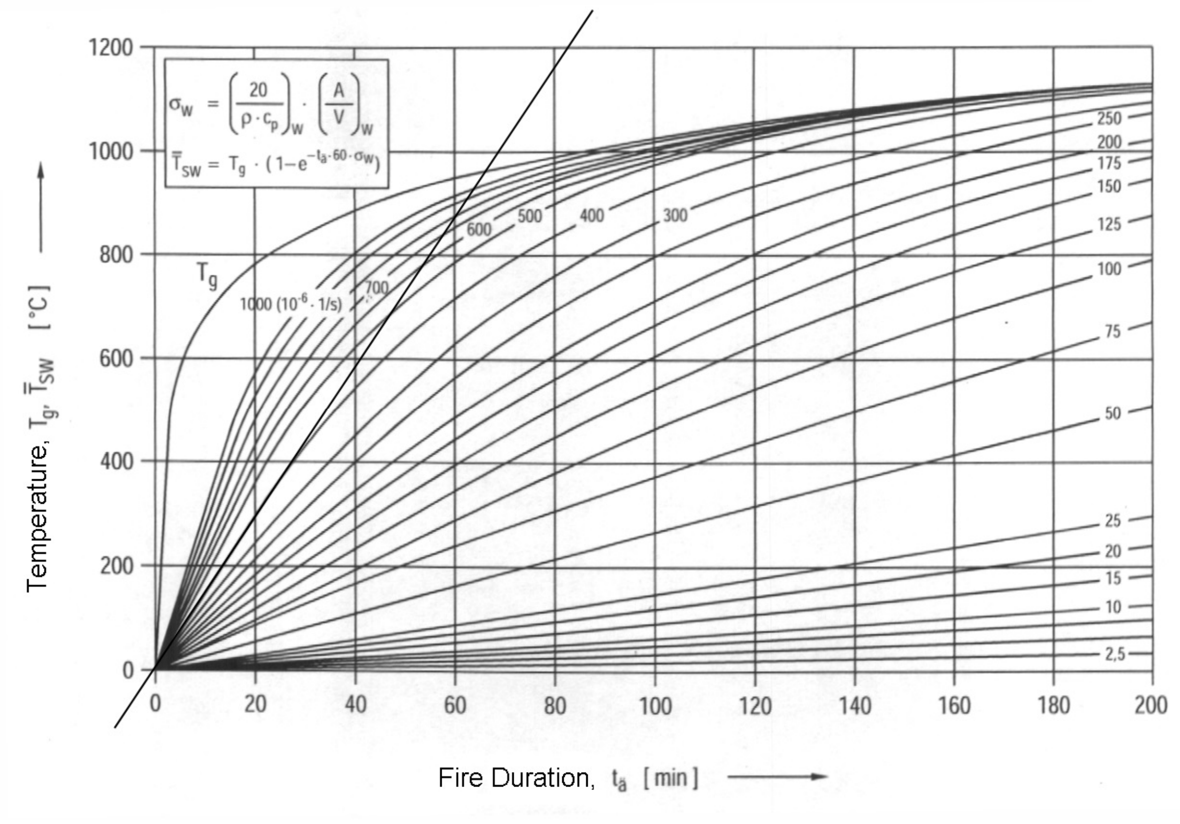

Figure A 4-1: Calorific mean temperature, $\overline{T}_{SW}$, as a function of fire duration, $t_ä$ and flock parameter σ_W

Literature

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Appendix B

Regulations Referred to in the Present Safety Standard

(Regulations referred to in the present safety standard are valid only in the versions cited below. Regulations which are referred to within these regulations are valid only in the version that was valid when the latter regulations were established or issued.)

AtG		Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act – AtG) of December 23, 1959, revised version of July 15, 1985 (BGBl. I, p. 1565), most recently changed by Article 307 of the Act of August 31, 2015 (BGBl. I 2015, No. 35, p. 1474)
StrlSchV		Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I, p. 1714; 2002 I, p. 1459), most recently changed by Article 5 of the Act of December 11, 2014 (BGBl. I, p. 2010)
SiAnf	(2015-03)	Safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B2)
SiAnf Interpretations	(2015-03)	Interpretations of the safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B3)
KTA 2101.1	(2015-11)	Fire Protection in Nuclear Power Plants; Part 1: Basic requirements
KTA 2101.3	(2015-11)	Fire Protection in Nuclear Power Plants; Part 3: Fire Protection of Mechanical and Electrical Plant Components
KTA 2201.1	(2011-11)	Design of Nuclear Power Plants Against Seismic Events; Part 1: Principles
KTA 3403	(2010-11)	Cable Penetrations Through the Reactor Containment Vessel
KTA 3601	(2005-11)	Ventilation Systems in Nuclear Power Plants
DIN 4102-2	(1977-09)	Fire Behavior of Building Materials and Building Components; Building Components; Definitions, Requirements and Tests
DIN 14090	(2003-05)	Areas for the fire brigade on premises
DIN 18230-1	(2010-09)	Structural Fire Protection in Industrial Buildings - Part 1: Analytically Required Fire Resistance Time
DIN 18232-5	(2012-11)	Smoke and heat control installations - Part 5: Powered smoke exhaust systems; requirements, design
DIN EN 1993-1-2	(2010-12)	Eurocode 3: Design of steel structures - Part 1-2: General rules - Structural fire design; German version EN 1993-1-2:2005 + AC:2009
DIN EN 61936-1, VDE 0101-1	(2014-12)	Power installations exceeding 1 kV a.c. - Part 1: Common rules (IEC 61936-1:2010, modified + Cor.:2011 + A1:2014); German version EN 61936-1:2010 + AC:2011 + AC:2013 + A1:2014
MIndBauRL	(2014-07)	Exemplary guideline for the structural fire protection in industrial buildings (*Muster-Industriebaurichtlinie - MindBauRL*)
TRGS 510	(2013-01)	Technical standards for hazardous materials (TRGS): Storage of hazardous material in mobile vessels