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**Federal Ministry for the Environment,  
Nature Conservation, Building and Nuclear Safety**

**Publication  
of a Technical Rule of the Commission  
on Process Safety  
(TRAS 320 – 'Precautions and Measures  
against the Hazard Sources Wind, Snow Loads and Ice Loads')**

**Of 15 June 2015**

A technical rule elaborated by the Commission on Process Safety, 'Precautions and Measures against the Hazard Sources Wind, Snow Loads and Ice Loads' (TRAS 320), is published hereinafter.

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Bonn, 15 June 2015

Federal Ministry for the Environment,  
Nature Conservation, Building and Nuclear Safety

For the Ministry

## Technical Rule on Installation Safety:

Precautions and Measures against the  
Hazard Sources Wind, Snow Loads and  
Ice Loads

TRAS 320

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## Preamble

Technical Rules on Installation Safety (TRASs) set out regulations on and information about safety technology that are consistent with the state of the art of safety technology within the meaning of Article 2(5) of the Major Accidents Ordinance (12th BImSchV). Requirements concerning the operation and characteristics of such installations that result from other regulatory instruments and are intended to fulfil other protection aims remain unaffected.

Technical Rules on Installation Safety are drawn up pursuant to Article 51a of the Federal Immission Control Act (BImSchG) by the Commission on Process Safety (KAS) with consideration being given to the regulations in place concerning other protection aims. Where necessary, they are adjusted to reflect the state of the art of safety technology. They are proposed to the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and may be published by the Ministry in the *Bundesanzeiger* following consultation with the supreme Land authorities responsible for Installation Safety. Reference may be made to Technical Rules on Installation Safety in legislation or administrative regulations.

## 1 Foundations – Requirements laid down in the Major Accidents Ordinance (StörfallV)

The present Technical Rule on Installation Safety examines three environmental hazard sources: wind, snow loads and ice loads.

As a matter of principle, construction works are designed to withstand the wind loads detailed in DIN EN 1991-1-4 (December 2010, previously DIN 1055-4) and the snow loads detailed in DIN EN 1991-1-3 (December 2010) (previously DIN 1055-5 (July 2005), which covered snow loads and ice loads). Safety-relevant technical installations of the kind that are subject to the Major Accidents Ordinance are not explicitly mentioned in the standards discussed above. These installations have a higher hazard potential on account of the hazardous substances that are present in them. Particular examination, precautions and measures to guarantee safety are therefore necessary. These installations, including structures and enclosures, therefore need to be designed with particular allowances being made for the static and dynamic loads to which they are exposed. Both requirements are dealt with by the present Technical Rule on Installation Safety.

According to Article 3(1) of the Major Accidents Ordinance (StörfallV), the operator of an establishment within the scope of this Ordinance has to take the precautions required in keeping with the nature and extent of the possible hazards in order to prevent major accidents. In the fulfilment of this obligation, pursuant to Article 3(2) of the Major Accidents Ordinance, consideration is also to be given to environmental hazard sources unless they are reasonably to be excluded as causes of major accidents.

Hazard sources that are reasonably to be excluded may give rise to ‘accidents despite precautions’, whose occurrence is not to be prevented, but against the effects of which additional precautionary measures are to be taken to keep these effects as small as

possible (Article 3(3) Major Accidents Ordinance), irrespective of the precautions to prevent major accidents taken under Article 3(1) of the Major Accidents Ordinance.

Such hazard sources may include, e.g.,

1. the failure of precautions taken under Article 3(1) of the Major Accidents Ordinance,
2. wind, snow loads and ice loads above a reasonably to be presumed intensity or return period (cf. section 13 below).

This means that, in particular when there is a danger of substances being released or equipment intended to prevent major accidents being disrupted due to reasonably to be excluded hazard sources, additional measures are to be taken in order to keep the adverse effects on humans, the environment and property as small as possible.

As environmental hazard sources pursuant to Article 3 of the Major Accidents Ordinance, wind, snow loads and ice loads may act on installations subject to the Major Accidents Ordinance or safety-relevant parts of installations and parts of construction works in which installations are located. Furthermore, unsecured or inadequately secured objects or parts of installations may be carried away by wind or impact on and, consequently, threaten safety-relevant installations or parts of installations. Large, localised fluctuations in air pressure and pressure fluctuations triggered by suction or pressure as a consequence of the action of gusts on outlets may trigger and/or alter flows of substances within installations. The present Technical Rule on Installation Safety provides guidance concerning the scale of the hazard in each case and the measures to be taken.

The general level of knowledge about natural hazard sources such as wind, snow loads and ice loads has developed further against the background of climate change. To date, however, the meteorological data on changes in wind velocities, snow loads and ice loads in Germany have not allowed a clear trend to be identified. Although model calculations give reason to presume there will be an increase in the damage caused by winter storms and thunderstorms in future due to climate change, they do not permit definite inferences to be drawn concerning any increases in wind velocities, peak winds, snow loads and ice loads to be assumed as a consequence of climate change.

There are records of tornadoes being observed in Germany that date back to the 9th century, and since 1950 for the whole territory of the old Länder. However, only a limited amount is known about the precise numbers of tornadoes and their intensity in each case; no tornado hazard map is available for Germany.

For the reasons that have been stated above, no proposals are put forward in the present Technical Rule on Installation Safety for climate change to be taken into consideration in the form of a climate change factor for wind (including tornadoes), snow loads and ice loads analogous to the climate change factor proposed in TRAS 310.

The German Strategy for Adaptation to Climate Change (DAS) states that, at establishments where hazardous substances are present in large quantities and could be released if extreme events occur, the safety requirements in place hitherto and the approach to safety management are to be reviewed and, where necessary, adapted so that they are consistent with the latest advances in knowledge about safety technology and the findings reached when hazards are assessed pursuant to the Major Accidents Ordinance.<sup>1</sup>

Operators of establishments have to pay attention to changes in hazard maps (the wind map published in DIN EN 1991-1-4/NA,<sup>2</sup> the DWD gust map,<sup>3</sup> the snow load map published in DIN EN 1991-1-3/NA<sup>4</sup> and the ice load map published in DIN 1055-5).<sup>5</sup> If new conclusions are drawn from these maps concerning actions caused by wind, snow loads and ice loads, attention is to be paid to these findings when major accident prevention concepts (Article 8(3) Major Accidents Ordinance) and safety reports (Article 9(5) Major Accidents Ordinance) are being updated.

With regard to the procurement of information about threats caused by environmental hazard sources, the operators of establishments have an *obligation to gather information*, i.e. an obligation to compile information that is already available elsewhere or held by the operator.<sup>6</sup> *Obligations to ascertain new information* exist to a limited extent in relation to the 'extended' obligations (Articles 9-12 Major Accidents Ordinance). Significant sources of information are cited in the present Technical Rule, and the guidance and explanatory notes on it.<sup>7</sup>

Measured against the yardstick of proportionality, the operator has to give consideration to the following sources when information is gathered and evaluated, as well as when it is determined what information is (spatially) relevant to the concrete establishment and/or the site on which the installation is located:

1. information already available to the operator,
2. information known to the authorities and
3. information known to the general public.

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<sup>1</sup> *German Strategy for Adaptation to Climate Change adopted by the German federal cabinet on 17th December 2008*, [http://www.bmub.bund.de/en/service/publications/downloads/details/artikel/german-strategy-for-adaptation-to-climate-change-summary-1/?tx\\_ttnews\[backPid\]=216](http://www.bmub.bund.de/en/service/publications/downloads/details/artikel/german-strategy-for-adaptation-to-climate-change-summary-1/?tx_ttnews[backPid]=216).

<sup>2</sup> DIN EN 1991-1-4/NA: National Annex – Nationally determined parameters - Eurocode 1: Actions on Structures – Part 1-4: General actions – wind actions (December 2010).

<sup>3</sup> Gisela Augter, Marita Roos: *Berechnung von Sturmintensitäten für Deutschland*, Berichte des Deutschen Wetterdienstes 236, Offenbach am Main, 2011.

<sup>4</sup> DIN EN 1991-1-3/NA: National Annex – Nationally determined parameters - Eurocode 1: Actions on structures – Part 1-3: General actions – Snow loads (December 2010).

<sup>5</sup> DIN 1055-5: Actions on structures – Part 5: Snowloads and ice loads (July 2005).

<sup>6</sup> Schulte, M.; Kloos, J.: *Abgrenzung der Behördenpflichten gegen Betreiberpflichten gemäß Bundes-Immissionsschutzgesetz und Störfall-Verordnung in Bezug auf umgebungsbedingte Gefahrenquellen*, Dresden, 2010 (see <http://www.kas-bmu.de>).

<sup>7</sup> See: [http://www.kas-bmu.de/publikationen/tras\\_pub.htm](http://www.kas-bmu.de/publikationen/tras_pub.htm).

The obligations to gather and ascertain information extend to information about the possible consequences of climate change; the operator has to pay attention to this information in the context of the obligations placed upon it under Article 3(1) of the Major Accidents Ordinance.

## 2 Scope

The present Technical Rule on Installation Safety applies to establishments covered by Article 3(5a) of the Federal Immission Control Act that fall within the scope of the Major Accidents Ordinance. Its requirements apply, in particular, to construction works, including buildings and structures, whose failure could lead to a major accident. It is recommended, however, that the present Technical Rule on Installation Safety also be applied to other installations<sup>8</sup> that require licencing under the Federal Immission Control Act if there is a comparable danger of hazardous substances being released, including substances that are dangerous to the environment.<sup>9</sup> Here too, construction works and their structures are to be examined accordingly at the same time.

Since construction law and immission control law apply independently of each other, attention is to be paid, where necessary, to further-reaching requirements under construction law.

The present Technical Rule on Installation Safety is addressed, in particular, to

1. operators,
2. authorities and
3. assessors/safety experts

who have to make, order or appraise precautions against environmental hazard sources to which sites are exposed and that are triggered by wind, snow loads and ice loads.

The present Technical Rule on Installation Safety applies for hazard sources that result from

1. wind, including gusts, peak winds, wind-excited vibrations and tornadoes,
2. the creation of wind-induced projectiles, and the effects of ground-level and air-borne projectiles,
3. snow loads and
4. ice loads.

Reference is made to the fact that, in addition to snow loads and ice loads, cold can trigger further hazard sources, e.g. the freezing of substances in pipes and safety

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<sup>8</sup> The term 'establishment' is used below if requirements imposed by the Major Accidents Ordinance only apply to establishments. Otherwise, the word 'site' is used if requirements are to be applied to establishments and it is recommended they be applied to installations that require licencing.

<sup>9</sup> Analogous to substances covered by Article 2 of the Major Accidents Ordinance.

valves, the failure of measurement and control equipment, etc. These hazard sources are not dealt with by the present Technical Rule on Installation Safety.

For the reasons discussed in section 1, although tornadoes are described as a hazard source in the present Technical Rule on Installation Safety, no guidance can be provided concerning protection aims and protection concepts. However, tornadoes are to be taken into consideration at the same time when 'major accidents despite precautions' are examined (section 13) and measures to mitigate their effects are determined.

Frequently, the hazard sources precipitation and flooding are connected directly with extreme wind events as well. Operators are also to pay attention to these hazard sources pursuant to Article 3(3) of the Major Accidents Ordinance. TRAS 310 is to be drawn upon for this purpose.

### **3 Definitions<sup>10</sup>**

Particular attention is to be paid to the following definitions when the present Technical Rule on Installation Safety is applied. Guidance on the definition of other terms used in the present Technical Rule on Installation Safety can be found in the 'guidance and explanatory notes' to the present Technical Rule on Installation Safety, the BMUB's Guide to the Enforcement of the Major Accidents Ordinance and the background documents published by the Commission on Process Safety.

#### **3.1 Hazard source**

A hazard source (hazard root) is the origin of a hazard that may give rise to destructive actions. When onsite hazard sources are being examined, hypothetically possible states and events are relevant, e.g. the failure of parts of installations that may lead to the disruption of normal operation and therefore give rise to a hazard. A hazard source is to be equated with a 'possible hazard root'. It does not inevitably lead to the disruption of normal operation (see section 3.9 below) or major accidents.

#### **3.2 Environmental hazard sources**

Environmental hazard sources are influences that may affect a site from beyond its boundaries and result in the functioning of safety-relevant parts of an installation or establishment being impaired.<sup>11</sup>

#### **3.3 Hazard source analysis**

Hazard source analysis within the meaning of the present Technical Rule on Installation Safety is the first step in a comprehensive process in which hazard sources and their causes are identified. Hazard source analysis determines hazard sources without assessing or appraising them. Environmental hazard sources are examined

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<sup>10</sup> Cf. the DWD's weather lexicon: <http://www.dwd.de/lexikon>.

<sup>11</sup> Cf. Commission on Process Safety: *Richtwerte für sicherheitsrelevante Anlagenteile (SRA) und sicherheitsrelevante Teile eines Betriebsbereiches (SRB) (KAS-1)*, Bonn, 2006, <http://www.kas-bmu.de/publikationen/kas/KAS1.pdf>.

during the hazard source analysis undertaken within the framework laid down by the present Technical Rule on Installation Safety in order to ascertain whether they could affect a site.

### 3.4 Analysis of hazards and threats

Within the meaning of the present Technical Rule on Installation Safety, the analysis of hazards and threats involves studying the actions of environmental hazard sources on a site. The safety-relevant parts of installations are identified and the preconditions for the occurrence of major accidents determined.

### 3.5 Wind

For the purposes of the present Technical Rule on Installation Safety, the various types of wind are divided into the following two categories:

1. Wind events, perceived by an observer at ground level as straight-line air movements. They include synoptic storms (low-pressure storms), thunderstorms and gravity winds. They are referred to collectively below with the term 'storms'.
2. Tornadoes, i.e. vortexes of air rotating within small areas with contact to the surface of the Earth. Tornadoes display high tangential velocities and lower translation velocities. They are associated with pressure fluctuations, as well as vertical acceleration.

Various wind phenomena are summarised with their characteristic features in **Table 1**. These wind phenomena are distinguished not only by the velocities of their peak winds, but also by the size of the areas they affect and their duration. A low-pressure storm affects the greatest area and lasts the longest, while tornadoes affect only relatively small areas and are of relatively short duration.

With the phenomena detailed in **Table 1** as its point of departure, DIN EN 1991-1-4 gives consideration to various actions on installations or parts of installations, e.g. cladding units. A horizontal flow of air is assumed in the model on which it is based. Force F1 tornadoes (cf. **Table 2**) are not covered by DIN EN 1991-1-4 because their aerodynamics are different from those of other types of wind (see below). Nonetheless, at a maximum of 183 km/h, they still fall within the range of velocities reached by low-pressure storms, so that the horizontal wind pressures they generate are covered indirectly by DIN EN 1991-1-4.

**Table 1:** Characteristics of various wind phenomena

Phenomenon	Velocity	Width	Development
Water spout	50–100 km/h*	A few metres	Caused by warm air at ground level; mostly only over extensive areas of water
Thunderstorm	70–110 km/h	Several km	Caused by differences in the density of air layers
Foehn storm (downslope winds – local wind systems)	Up to 130 km/h Up to 150 km/h in certain Alpine valleys	Several km	Caused by warm, dry downslope wind on mountain slopes
Low-pressure storm	Up to 180 km/h	1,000–2,000 km	Caused by pressure differences between colliding masses of air
Tornado	Fujita force F1: Up to 183 km/h*	F1: 20–100 m	Caused by the collision of dry-cold and moist-warm air, and the formation of a rotating, vertical column of air

\* Tangential velocity

### 3.5.1 Extreme wind

Wind of extreme force, above 118 km/h, of the kind that may occur during particular extreme weather events.<sup>12</sup>

### 3.5.2 Wind velocity

Wind velocity is measured using anemometers and given *as a mean over ten minutes*. Wind velocity may be estimated using the Beaufort scale, in which case it is given as a 'wind force'.

### 3.5.3 Gust

A gust is generally defined as a powerful burst of wind that is often associated with a sudden change of wind direction. More precisely, a gust occurs if the measured 10-minute mean wind velocity is exceeded by at least 5.0 m/s for a number of seconds (*20 seconds at most, three seconds at least*).

### 3.5.4 Peak wind

A peak wind is defined as the *greatest wind velocity* measured during gusts over a particular period of time.

### 3.5.5 Tornado

A tornado is a column of air in contact with the ground that rotates around a more or less vertical axis and is found under what is referred to as a cumulonimbus cloud. This form of cloud is also known as a thundercloud and extends to an altitude of several kilometres.

A tornado may develop if there are major differences of temperature between layers of air, air rises or is pushed upward and the water vapour it contains condenses into drop-

<sup>12</sup> Cf. *Lexikon der Geographie*: <http://www.wissenschaft-online.de/abo/lexikon/geogr/7603>.

lets (forming a thundercloud). The condensation heat released when this happens and, additionally, a strong vertical wind shear (increase in radial wind velocity and, in some cases, changes in wind direction with altitude) generate a rotating funnel of rising wind. This may reach a diameter of up to one kilometre, while wind velocities of several hundred kilometres an hour may occur. A tornado devastates a strip several hundred metres wide along its track (damage (Asgard's) path).

'Tornadoes' are also known by other names, e.g.: 'wind spout' (tornado over land), 'water spout' (tornado over the sea or a large inland lake).

Tornadoes are classified, among other things, using the Fujita Scale, which is shown in **Table 2**. Since the wind velocities given in **Table 2** frequently cannot be measured, tornadoes are often rated depending on the damage they cause to the fabric of buildings.

**Table 2:** Fujita Scale with rating by typical damage

Fujita Scale				
F Scale	Rating	Velocity in m/s at $v_{\max}$	Velocity in km/h at $v_{\max}$	Typical damage
F0	Weak (= Beaufort 8)	17.5–32.5	63–117	Light objects are swirled around, individual roof tiles and branches are torn down
F1	Weak	32.8–50.8	118–183	Parts of roofs are peeled off, mobile homes and trailers are overturned, strong branches are broken off, individual trees are uprooted
F2	Strong	51.1–70.5	184–254	Whole roofs are ripped off, severe damage to light buildings, major damage to vehicles, stable trees are toppled or broken.
F3	Strong	70.8–92.8	255–334	Light buildings are overwhelmingly destroyed, collapse of individual buildings, heavy vehicles are overturned, extremely severe damage to woody plants with extensive loss of branches
F4	Violent	93–117	335–421	Devastating damage to substantial buildings, widespread collapse of buildings, road vehicles are thrown long distances, trees are debarked by objects flying about
F5	Violent	> 117	> 421	Substantial buildings overwhelmingly damaged beyond repair, incredible damage, heavy objects such as road vehicles fly hundreds of metres through the air, total debarking of tree trunks that remain standing, rootstocks of felled trees are torn out of the ground

On average, approximately four tornadoes a year with an intensity greater than F1 (weak) occur in Germany. These are locally limited events that affect areas of a few square kilometres.

### **3.6 Snow load**

Snow load is one of the climatically induced, variable actions on installations and parts of installations. It is influenced by the geographical location and the shape of the object under examination. Depending on its characteristics and age, weights between 1.0 kN/m<sup>3</sup> and 5.0 kN/m<sup>3</sup> may be assumed when snow is lying. In the relevant standards,<sup>13</sup> snow loads are converted into reference values used to determine the safety of structures. The reference values specified in these standards correspond to the 98% fractiles of the annual maximums and therefore a mean return period of 50 years.

#### **3.6.1 Exceptional snow load**

An 'exceptional snow load' is defined as an exceptional impact pursuant to section 1.5.3.5 of DIN EN 1990 (December 2010) caused by snow loads. When structures are planned, therefore, the partial factors associated with impacts caused by exceptional snow loads in the context of an exceptional combination of impacts may be reduced, and combination factors for other forms of load taken into consideration to a reduced extent. Furthermore, when exceptional snow loads act on a structure, its complete failure must be excluded; however, localised damage to structures (for instance due to plastic deformation) is permissible. After an exceptional snow load has acted on a structure, a review of its integrity is therefore required before the installation is operated further.

#### **3.6.2 Extreme snow load**

An 'extreme snow load' is defined as the greatest snow load at a location documented in regionally available records.

### **3.7 Ice load**

Ice load is defined as the additional static (weight) and dynamic (air resistance) loads imposed on parts of installations by freezing rain or hard rime, i.e. a deposit of super-cooled fog droplets on surfaces. Parts of installations in upland areas are particularly threatened by frozen fog deposits. The formation of ice in this way is greatly encouraged by strong winds and high levels of liquid water in fog. In lowland areas, by contrast, ice formation usually occurs during freezing rain. Ice loads are therefore found not only on horizontal surfaces, but may act on structures in combination with wind loads and cause vibrations when this happens.

### **3.8 Wind-induced projectile**

The terms 'wind-induced projectile' and 'wind-induced projectile impact' are used in the present Technical Rule on Installation Safety. If parts of installations or objects are detached or lifted by the wind and carried through the air, they are referred to as 'airborne projectiles'. If objects are slid or rolled along the ground by the wind, they are referred to as 'ground-level projectiles'. Collapsing parts of installations, trees, etc. are referred to as other 'wind-induced projectiles'.

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<sup>13</sup> DIN EN 1991-1-3 and DIN EN 1991-1-3/NA.

### **3.9 Disruption to normal operation caused by wind, snow loads and ice loads**

Where the occurrence of not reasonably to be excluded gusts, peak winds, snow loads, ice loads and secondary hazard sources, such as wind-induced projectiles, pressure fluctuations or vibrations, leads to the design loads of safety-relevant parts of installations<sup>14</sup> being exceeded, normal operation has been disrupted.

Disruption to normal operation of this kind is encountered, in particular, in the following situations:

1. When the stability and/or integrity of safety-relevant parts of sites and installations where particular substances are present is immediately threatened.
2. When the functioning of safety-relevant parts of sites and installations is threatened.
3. When safety-relevant operating procedures or work processes cannot be carried out or only carried out under more difficult conditions, e.g. due to restrictions on the accessibility of parts of sites and installations.

### **3.10 Protection concept**

Within the meaning of the present Technical Rule on Installation Safety, a protection concept addresses the development of suitable precautions to prevent major accidents and measures to mitigate the effects of major accidents caused by the actuation of environmental hazard sources.

### **3.11 Installation-specific protection aims**

Within the meaning of the present Technical Rule on Installation Safety, installation-specific protection aims give concrete form to the legal protection aims laid down for sites in order to preserve human health, the environment and property from the adverse consequences of a release, fire or explosion involving hazardous substances that is caused by the actuation of an environmental hazard source. Where installations require licencing under the Federal Immission Control Act, it must be guaranteed, pursuant to Article 5(1) of the Federal Immission Control Act, that

1. harmful effects on the environment and other hazards, significant disadvantages and significant nuisances to the public and the neighbourhood cannot arise;
2. precautionary action is taken against harmful effects on the environment and other hazards, significant disadvantages and significant nuisances, in particular measures consistent with the state of the art.

As far as establishments are concerned, it must be guaranteed that the characteristics and operation of an establishment's installations are consistent with the state of the art of safety technology.

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<sup>14</sup> See: Commission on Process Safety: *Richtwerte für sicherheitsrelevante Anlagenteile (SRA) und sicherheitsrelevante Teile eines Betriebsbereiches (SRB) (KAS-1)*, Bonn, 2006, <http://www.kas-bmu.de/publikationen/kas/KAS1.pdf>.

### 3.12 Precondition for the occurrence of a major accident

A precondition for the occurrence of a major accident is defined as the moment/status in the event chain subsequent to the commencement of disruption at/during which the preconditions for the occurrence of a major accident are fulfilled. Within the meaning of the present Technical Rule on Installation Safety, for example, snow loads and ice loads on a tank with hazardous substances that exceed its design loads are to be regarded, as a rule, as disruption to normal operation as long as there is no danger of, e.g., a substance being released. A precondition for the occurrence of a major accident first arises if the (increasing) snow load or ice load exceeds the design load of the tank or the static equilibrium of the tank's construction to such an extent that this could lead to a serious hazard or damage to property covered by section I No. 4 of part 1 of Annex VI to the Major Accidents Ordinance.

## 4 Systematic approach and structure of the present Technical Rule on Installation Safety

The operator's obligations within the meaning of the Major Accidents Ordinance may be fulfilled with regard to the hazard sources examined in the present Technical Rule on Installation Safety by taking the following four steps:

1. **hazard source analysis,** which involves scrutinising what hazard sources could affect the site,
2. **analysis of hazards and threats,** which involves scrutinising whether major accidents could occur as a result of actions on safety-relevant parts of installations,
3. **drafting of a protection concept,** which involves specifying precautions to prevent major accidents,
4. **examination of 'major accidents despite precautions'** which leads, in particular, to the specification of measures to mitigate the effects of major accidents.

The point of departure for the systematic approach taken (cf. **Figure 1**) is a hazard source analysis that involves the determination of possible hazard sources. Initially, in a simplified hazard source analysis, only events that are possible (not reasonably to be excluded) in the region are identified in qualitative terms at the location (incl. the establishment). In a detailed hazard source analysis, quantitative information is drawn upon in order to determine possible hazard sources with greater precision.

The next step is to identify the safety-relevant parts of the establishment and its installations that are threatened.

Depending on their safety-relevance and the possible effects of a major accident, installation-specific protection aims are to be specified, and a protection concept elaborated with which these aims are to be achieved. Once this has been done, the effectiveness of the protection concept is to be scrutinised and the concept is to be documented. Where necessary, further adjustments are to be made to the protection concept.

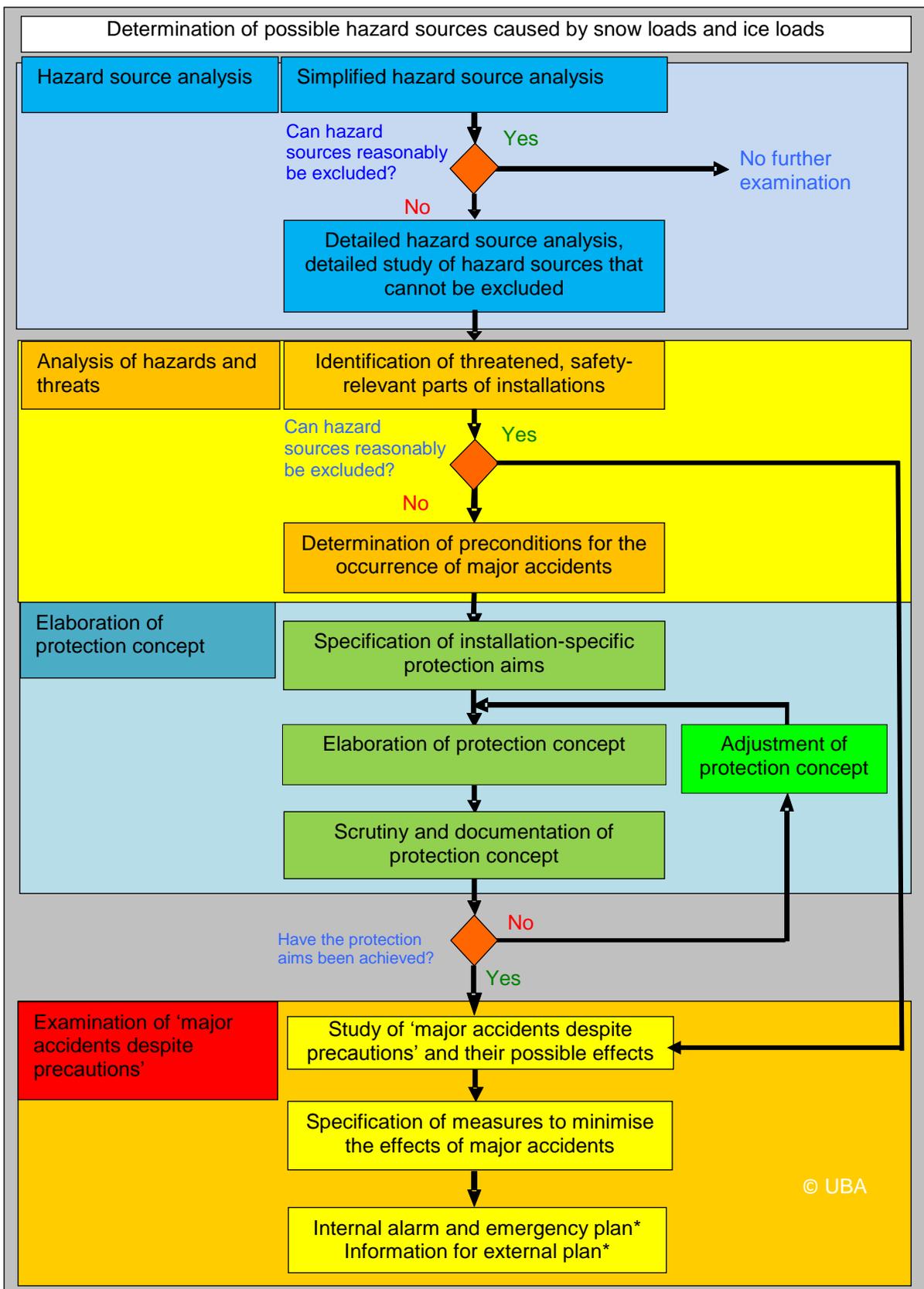
Subsequently, hazard sources that are reasonably to be excluded ('major accidents despite precautions') are studied. It may not be possible to prevent the occurrence of such accidents but, irrespective of the precautions taken to prevent major accidents under Article 3(1) of the Major Accidents Ordinance, additional measures are to be taken to mitigate their effects and so keep those effects as small as possible (Article 3(3) Major Accidents Ordinance). Measures to mitigate the effects of major accidents are to be incorporated into the protection concept.

Where unacceptable risks remain, in particular due to inadequate precautions for the prevention of major accidents, more extensive precautions and measures are to be developed in order to reduce these risks to an accepted degree.

The above does not apply to hazard sources that are so improbable as to be beyond human experience and incalculable. No installation-specific precautions and measures are to be taken against exceptional major accidents of this kind.

Suitable consideration is also to be given to the results obtained from the examination of 'major accidents despite precautions' discussed above when plans are made for emergencies, onsite alarm and emergency plans are amended, information is communicated for the purposes of external alarm and emergency planning, and information is passed on concerning the siting of new activities (pursuant to No. 5 of Article 9(1) Major Accidents Ordinance).

Hazard source analyses, and analyses of hazards and threats are to be taken into consideration in concepts for the prevention of major accidents, and are to be included in safety reports together with the studies of 'major accidents despite precautions' discussed above.



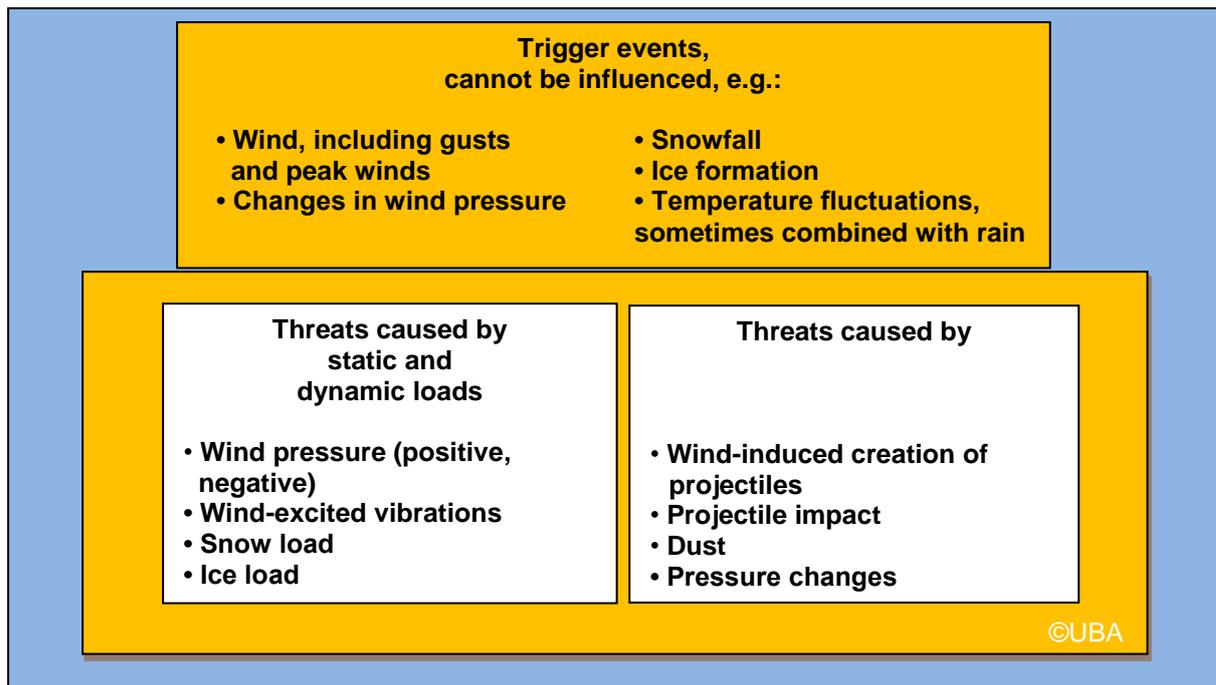
**Figure 1:** Flow chart for the optimisation of the protection concept (\* where required pursuant to Article 10 Major Accidents Ordinance)

## 5 Description of hazard sources

Events connected with the environmental hazard sources dealt with in the present Technical Rule on Installation Safety are categorised as follows:

1. trigger events, such as wind, snowfall, freezing fog or frozen rain, that cannot be influenced by measures and
2. possible consequent events, e.g. wind pressure, snow loads, ice loads or wind-induced projectiles.

The systematic categorisation of various events is set out in **Figure 2**.



**Figure 2:** Systematic categorisation of hazard sources triggered by wind, snow loads and ice loads

### 5.1 Hazard sources caused by static and dynamic loads

In view of the higher hazard potential posed by the hazardous substances that are present in them, safety-relevant parts of installations and establishments are to be designed to withstand wind, snow loads and ice loads.

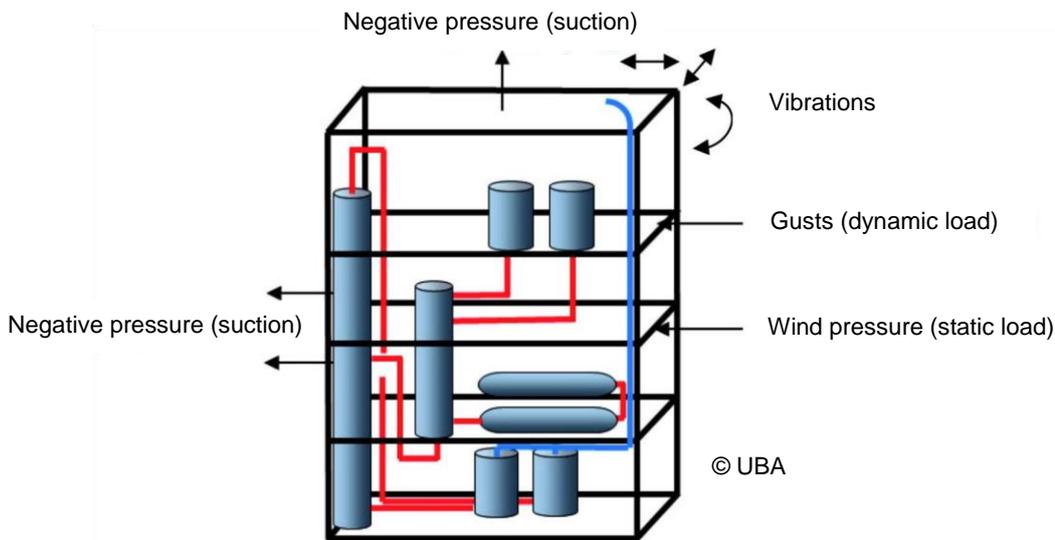
#### 5.1.1 Hazard sources caused by wind loads

Wind, in particular in the form of gusts and peak winds, exerts pressure on installations and parts of installations, e.g. enclosures, that is referred to as wind pressure. This is positive on the windward side (pressure), and negative on side walls, roof surfaces and the leeward side (suction and pressure from inside a construction work due to the penetration of wind). In addition to this, wind, in particular gusts and peak winds, may excite objects to vibrate.

Tornadoes are characterised by their high rotation velocity, in addition to which there is also the velocity at which they move forward (translation velocity). Furthermore, strong,

upward air currents are generated, which may also lead to negative pressures that produce vertical forces. The characteristics of a tornado therefore differ significantly from those of the wind types covered by DIN EN 1991-1-4 with their horizontal air currents.

An overview of the various potential threats caused by wind is shown in **Figure 3**.



**Figure 3:** Potential threats caused by wind loads

In summary, a threat caused by these loads may be triggered by

1. wind pressure on the windward wall,
2. suction on the walls parallel to the wind, the roof and the leeward wall,
3. vibrations.

### 5.1.2 Hazard sources caused by vibrations

A flow of air may excite significant vibrations in parts of installations.

The periodic shedding of eddies, what are known as Kármán vortex streets, may make parts of an installation vibrate. Relevant vibrations occur at the critical wind velocity at which the eddy shedding frequency is equal to an eigenfrequency of the part of the installation in question.

Other types of vibrations may also occur, such as the fluttering of flat parts of an installation or the interference galloping<sup>15</sup> of cylindrical parts in close proximity to one another.

In all these cases, the part of the installation that vibrates frequently fails due to material fatigue after a certain number of stress cycles.

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<sup>15</sup> An aeroelastic phenomenon that may occur when a fluid flows around narrowly spaced cylindrical bodies.

Finally, a sequence of gusts will also give rise to vibrations in the direction of the wind that are usually compensated for when static calculations are carried out by applying an appropriate multiplication factor for the gust wind load.

### **5.1.3 Hazard sources caused by snow loads and ice loads**

Snow loads act primarily on the horizontal and sloping roofs of enclosures, installations and parts of installations. Snow may be transformed dramatically if there are temperature changes due to thawing and freezing, and take on a higher weight density. During periods of thaw, rain trapped in snow may greatly increase the weight of the snow.

Ice loads may form as a consequence of frozen rain or hard rime, a deposit of fog droplets (primarily on the windward side of objects), and therefore also accumulate on other surfaces. Apart from enclosures, other parts of installations, such as pipes, cable trays, platforms, gantries and tanks, may be partially or wholly affected by these loads.

## **5.2 Hazard sources caused by wind-induced projectiles, air pressure changes and pressure fluctuations**

### **5.2.1 Hazard sources caused by wind-induced projectiles**

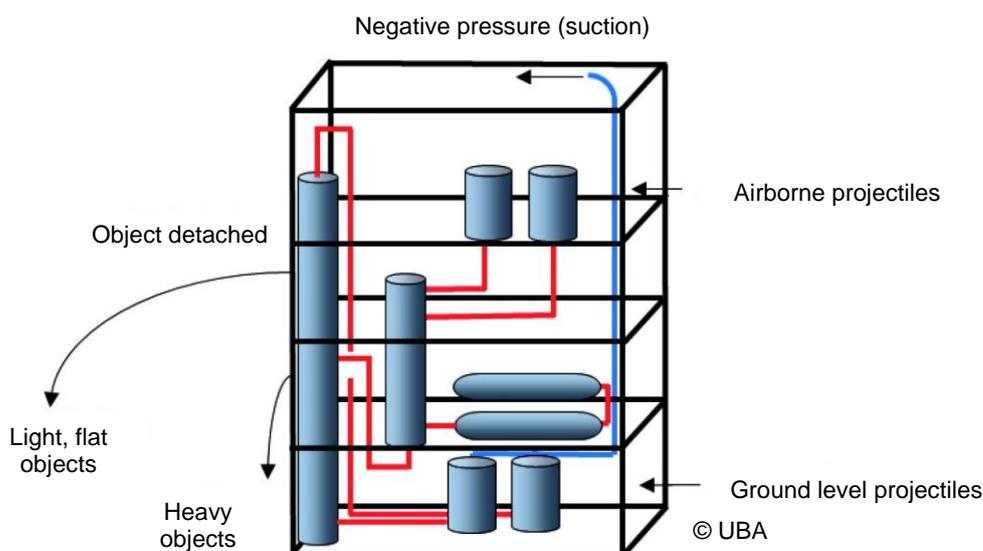
Gusts and peak winds may detach inadequately secured, safety-relevant parts of installations and, by causing their loss, threaten the safety of installations and establishments (Case 1: Loss of safety-relevant parts of installations).

Loose parts from the areas around installations or parts that have been detached from installations may impact on safety-relevant parts of installations and impair their functioning or integrity. Trees may be uprooted and impact on neighbouring parts of installations (Case 2: Damage to safety-relevant parts of installations).

When there are horizontally moving winds, the trajectory of an object that has been detached is determined by a vertical speed vector and a horizontal speed vector. Accordingly, high-density objects and/or compact parts fall almost vertically to the ground, while flat objects with low densities may be carried away by the wind (airborne projectiles). Apart from the object's properties and the wind velocity, the length of its trajectory is determined by the height at which it was originally located.

Further to this, heavy objects may be moved across the ground (sliding or rolling) and impact on other parts of installations at ground level (ground-level projectiles).

The detachment of parts of installations and the threats caused by wind-induced projectiles are summarised in for horizontally acting streams of air.



**Figure 4:** Potential threats caused by the detachment of objects, wind-induced projectiles and negative pressure due to suction

### 5.2.2 Hazard sources caused by air pressure changes and pressure variations

Air pressure changes, pressure and suction during windy conditions, gusts and peak winds in particular, may bring about deformations in containers with flexible skins (e.g. inflatable gas holders at biogas plants). Gusts and peak winds may act on emissions sources and, by giving rise to pressure or suction, cause pressure changes in connected parts of installations. Pressure fluctuations of this kind may trigger and/or alter flows of substances in installations, e.g. in waste gas or ventilation systems. It is therefore also to be appraised whether, in view of the characteristics and operation of the installations in question, changes in air pressure and pressure fluctuations caused by inflowing air could be safety-relevant in any way.

## 6 Simplified hazard source analysis

While flooding may reasonably be excluded as a hazard source for particular regions as early as the 'simplified hazard source analysis', this is not possible for wind, snow loads and ice loads. However, the scale of the threat differs from one region to another. In consequence, hazard maps have been drawn up<sup>16</sup> (although not for tornadoes) that form the foundations for a detailed hazard source analysis.

The appraisal of the hazards caused by tornadoes in Germany is difficult. Unlike in the USA or Switzerland, no validated hazard map for tornadoes has been drawn up for Germany to date so that no grading of regional hazard levels analogous to the wind, snow load and ice load zone maps is available to the operator of an installation. However, this does not mean there is no risk of tornadoes in Germany and this risk therefore does not have to be examined.

<sup>16</sup> Cf. DIN EN 1991-1-3/NA, DIN EN 1991-1-4/NA and DIN 1055-5.

Nonetheless, the frequency with which an establishment could be hit by a tornado is far below the frequency taken as the basis for the analysis of wind, snow loads and ice loads as hazard sources (100-year return period). This means the occurrence of tornadoes is reasonably to be excluded. Although tornadoes are described as a hazard source in the present Technical Rule on Installation Safety, no further guidance is therefore to be given for installation-specific protection aims and protection concepts. However, possible actions of tornadoes should be taken into consideration by examining more extensive event scenarios, as well as the measures derived from them both to mitigate the effects of major accidents, and in the context of alarm and emergency planning (cf. section 13).

Nor is it possible, as a matter of principle, to reasonably exclude 'wind-induced projectiles', and this hazard source must be subjected to a detailed hazard source analysis.

As far as pressure changes and fluctuations are concerned, it is to be scrutinised whether, in view of the characteristics and operation of the installations in question, a change in air pressure and pressure fluctuations caused by inflowing air could be safety-relevant in any way. If this is not the case, it is possible to do without a detailed hazard source analysis.

## **7 Detailed hazard source analysis**

A detailed hazard source analysis is required for situations in which it is not possible to reasonably exclude hazard sources. Since the failure of safety-relevant parts of installations within the scope of the Major Accidents Ordinance may give rise to a major accident, a 100-year event is taken as the basis – in part by analogy to TRAS 310 – for hazard sources that are not reasonably to be excluded. As the essential foundations for this approach, reference is made in the present Technical Rule on Installation Safety to the DIN EN standards developed for the relevant hazard sources (see below) and DIN 1055-5 for ice loads. These include hazard maps for natural events (cf. the national annexes to the DIN EN standards). They are based on statistical evaluations of past events. In these documents, the characteristic parameters of each hazard source are given for 50-year events. In line with the approach taken in the DIN EN standards, within the scope of the present Technical Rule on Installation Safety the values for loads are 'adjusted' to correlate to a 100-year return period not by altering these parameters, but by increasing the partial factor for the actions in question at installations with higher hazard potential, as already provided for in DIN EN 1990.

### **7.1 Static and dynamic loads**

#### **7.1.1 Relationship to standards and reliability classes**

The foundations for hazard source analyses are, in particular, DIN EN 1991-1-4 for wind, DIN EN 1991-1-3 for snow loads (in each case in combination with the relevant national annexes) and DIN 1055-5 for ice loads. Due to the grave consequences of any failure of safety-relevant parts of an installation or site, they are to be designated in reliability class RC 3 and consequences class CC 3 in accordance with the provisions set out in Annex B to DIN EN 1990 and DIN EN 1990/NA (December 2010), e.g. like places of assembly. It follows from this designation that the partial factor for these ac-

tions is to be increased by applying the factor  $K_{FI} = 1.1$  (see also section 1.3.1 of Annex A to DIN EN 1990/NA). This raises the protection aim of the standards from a 50-year event to a 100-year event. (For further discussion of this point, see section 10 below.)

Installations and parts of installations with this designation, in particular structures, are to be reviewed in the course of the hazard source analysis for wind, snow loads and ice loads (see section 10 below).

Where the hazard potential is particularly high, it is to be scrutinised when installation-specific protection aims are being specified whether there is a need for the application of further-reaching partial factors (as set out in to the note to Table B2 of Annex B to DIN EN 1990).

Furthermore, attention is to be paid to the fact that, apart from the obligation to take precautions for major accidents on the basis of obligations to ensure liability for premises, any threat to people due to, e.g., the failure of structures or projectiles must be excluded.

#### 7.1.2 **Wind loads**

Account is taken of the requirements of the present Technical Rule on Installation Safety by increasing the partial factor, as explained above, which is done by applying the multiplication factor  $K_{FI} = 1.1$ , i.e. the partial factor is increased from 1.5 to 1.65 (for further details, see section 10 below).

#### 7.1.3 **Snow loads and ice loads**

Pursuant to Annex D to DIN EN 1991-1-3, in order to meet the requirements of the present Technical Rule on Installation Safety, an increase by approx. 10% may be calculated using the Gumbel probability distribution posited as a basis for the relevant formula. Account is taken of the rise in the return period by increasing the partial factor, which is multiplied by the factor  $K_{FI} = 1.1$ , i.e. from 1.5 to 1.65 (for further details, see section 10 below).

Accidental snow loads are to be taken into consideration as exceptional actions covered by DIN EN 1990. Where the competent authority has specified reference values for this purpose, pursuant to part 4.3 of DIN EN 1991-1-3/NA, use is to be made of these reference values. Where no reference values of this kind have been specified by the competent authority (as may be the case, in particular, away from the North German Plain), use is to be made of data on extreme snow loads that have been recorded in the region.

When the load assumptions for the European Standard concept were revised, there was no revision of the load assumptions for ice loads (caused by frozen rain and hard rime). Ice loads are not given consideration in DIN EN 1991-1-3. As far as such loads are concerned, DIN 1055-5, with its informative Annex A, reflected the state of the art. When the Eurocodes were introduced, this part was dropped without being replaced so that no detailed data on ice loads are to be found (any longer) in the construction standards. Of course, this does not mean that these loads do not exist. Since ice loads are to be examined in the hazard source analysis, DIN 1055-5 should continue to be

used as a source of information for this purpose, with attention being paid to the remarks made above, until such time as the DIN EN standard has been amended to cover ice loads.

## **7.2 Consideration of climate change**

When a hazard source analysis is carried out, consideration is to be given to the anticipated consequences of climate change, even though it is in their nature for them to be affected by uncertainties. It is to be assumed that the changes in the climate that have already occurred are having an influence on the intensity and frequency with which at least some of the hazard sources discussed above are actuated.

However, no adequate information is available with regard to changes to the hazard sources wind, snow loads and ice loads that are being driven by climate change (cf. section 1 above). For this reason, no climate change factors may be given for the loads discussed above at present.<sup>17</sup>

## **7.3 Wind-induced projectiles**

If installations or parts of installations do not withstand the static or dynamic loads described above, they may collapse or overturn, or projectiles may be detached and created ('internal creation of projectiles'). The same applies for installations that may neighbour the site. Similar processes also affect features that are not construction works, e.g. trees ('external creation of projectiles').

As experience with wind-induced projectiles has shown, the possible hazard sources may be summarised as follows:

### **7.3.1 Loss of safety-relevant parts of installations**

The loss of parts of installations may be safety-relevant in itself.

### **7.3.2 Damage to safety-relevant parts of installations**

As a matter of principle, safety-relevant parts of installations may be threatened by wind-induced projectiles (cf. section 5.2.1). Where only their collapse or overturning is relevant, the area threatened is mostly easy to identify. As far as airborne projectiles are concerned, the threat depends on the projectile's path, the impact conditions and the material of the potentially affected safety-relevant part of the installation. It is possible to estimate trajectories and the consequences of an impact for idealised 'model projectiles'.

Gust velocities that lie above 1.1 times the velocities detailed in DIN EN 1991-1-4 are reasonably to be excluded as causes for the creation and movement of projectiles.

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<sup>17</sup> As at June 2015.

## 8 Determination of threatened, safety-relevant parts of establishments and installations

The safety-relevant parts of the establishments and installations in question are

1. installations and parts of installations where particular substances and volumes are present,
2. installations and parts of installations with particular functions

(see also KAS-1<sup>18</sup> and the BMUB's Guide to the Enforcement of the Major Accidents Ordinance).

Threatened installations and parts of installations within the meaning of the present Technical Rule on Installation Safety are safety-relevant installations and parts of installations in which a hazard and/or threat may arise due to a major accident (hazard and/or threat on the site or for the surrounding area) when the environmental hazard sources in question (i.e. threats from the surrounding area) are actuated. The specific installations and parts of installations to be protected are therefore dependent on the kind of hazard source and its presumed intensity.

In so far as safety reports have been drawn up for existing establishments, safety-relevant installations and parts of installations have already had to be determined for this purpose. The installations and parts of installations determined are to be reviewed if, the hazard source in question could act on more than one installation where the same substance or group of substances, pursuant to Annex I of the Major Accidents Ordinance, is present.

**Not all safety-relevant parts of a site and its installations are threatened by the hazard sources dealt with in the present Technical Rule on Installation Safety. The expert delimitation of threatened parts of sites and installations is therefore accorded a high degree of significance. Corresponding guidance is given below in order to ensure that the delimitation undertaken here is meaningful.**

### 8.1 Hazard sources caused by static and dynamic loads

#### 8.1.1 Wind loads

On the basis of the safety-relevant parts of installations already determined pursuant to KAS-1,<sup>19</sup> those parts of establishments and installations are to be determined that are threatened by wind loads (gusts or vibrations).

Attention is to be paid to the following guidance on the identification of the parts in question:

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<sup>18</sup> Commission on Process Safety: *Richtwerte für sicherheitsrelevante Anlagenteile (SRA) und sicherheitsrelevante Teile eines Betriebsbereiches (SRB)* (KAS-1), Bonn, 2006, <http://www.kas-bmu.de/publikationen/kas/KAS1.pdf>.

<sup>19</sup> Cf. Commission on Process Safety: *Richtwerte für sicherheitsrelevante Anlagenteile (SRA) und sicherheitsrelevante Teile eines Betriebsbereiches (SRB)* (KAS-1), Bonn, 2006, <http://www.kas-bmu.de/publikationen/kas/KAS1.pdf>.

1. The threat to safety-relevant parts of installations in construction works that have been constructed in accordance with DIN EN 1990 to meet the requirements of RC 3 may be categorised as low. Where the hazard potential is particularly high, it is to be scrutinised whether there is a need to apply further-reaching partial factors (cf. the note to Table B2 of Annex B to DIN EN 1990).
2. If construction works have not been constructed in accordance with DIN EN 1990 to meet the requirements of RC 3 or if they are light buildings, any threat to parts of installations accommodated in them is to be scrutinised.
3. Any threat to safety-relevant parts of installations that are located completely underground is to be excluded.
4. Safety-relevant parts of installations that are located outdoors without enclosures are potentially threatened.

#### 8.1.2 Snow loads and ice loads

As a matter of principle, snow loads and ice loads may affect all parts of installations that are located outdoors. Particular attention is to be paid to areas and/or parts of installations below the higher parts of installations on account of snowdrifts, snow slips or accumulations of snow.

The operator should use a site plan to categorise the parts of installations affected to a particular degree in terms of the level of threat to which they are exposed.

The following restrictions may be taken into consideration when the affected parts of installations are being selected:

1. If the temperature of the building and/or shell of the installation is permanently higher than 0 °C on account of internal processes, it is possible to do without a detailed examination.
2. If the parts of an installation have been designed and/or reviewed pursuant to the current standard, DIN EN 1990, with consideration being given to the high reliability class RC 3, the level of hazard may be categorised as low.

#### 8.2 Hazard sources caused by wind-induced projectiles: determination of threatened installations and parts of installations

Every installation operator must prevent it from being possible for parts of buildings or installations to be detached as a result of gusts or peak winds and become airborne projectiles. This obligation also covers trees/branches on the site. It serves, firstly, to protect people as required by the obligation to ensure liability for premises, and for the purposes of occupational health and safety. Secondly, within the scope of the Major Accidents Ordinance, safety-relevant parts of installations are also to be protected, irrespective of whether there is a direct threat to people at the same time.

'Wind-induced projectiles' should therefore be studied systematically as a hazard source. To this end, an approach is set out below that has proved its worth in the context of building management. Other, equivalent approaches may also be applied. This systematic approach is based on the following elements:

1. Regular reviews tailored to the installation's status and hazard potential
2. Assessment of the shortcomings found and specification of effective measures
3. Implementation of measures within the prescribed time frame  
Where necessary, compensatory measures to secure threatened areas
4. Where necessary, adjustment of the frequency with which reviews are carried out

When reviews are conducted (Step 1), potential sources for wind-induced projectiles are to be determined, preferably by means of on-the-spot checks. Apart from possible on-site projectile sources, consideration is also to be given to the area immediately around the site (e.g. trees on the edge of the compound, nearby installations and infrastructure facilities).

For example, the following are to be examined as potential projectile sources:

- a) Parts of installations that are not firmly secured (e.g. parts of gantries, sheet-metal cladding units).
- b) Non-built features, e.g. trees that could fall over in gusts or peak winds and impact on safety-relevant parts of installations.
- c) Open storage areas, e.g. with containers, spare parts, barrels, etc. that could be carried away by wind.

To begin with, it is to be scrutinised whether the potential projectiles identified include parts of installations whose loss would be safety-relevant.

Subsequently, it is to be scrutinised whether, in view of the distances from safety-relevant parts of installations at which projectiles could be created and the kinds of projectiles that could be created, actions on parts of safety-relevant installations that would disrupt their functioning could not reasonably be excluded either.

Possible measures to prevent the creation of wind-induced projectiles (Steps 2-4) are described in section 11 below. If a threat to safety-relevant parts of installations from wind-induced projectiles is, nevertheless, not excluded, it may be presumed that, where they consist of solid, ductile material, e.g. many pressure vessels, or are protected by solid walls, e.g. made of reinforced concrete, safety-relevant installations or parts of installations are, as a general rule, not threatened by wind events that are not to be excluded under the present Technical Rule on Installation Safety. By contrast, if safety-relevant installations or parts of installations are less robust and resistant to mechanical damage, and are not protected in other ways (e.g. enclosures), a threat is not to be excluded.

## **9 Determination of the preconditions for the occurrence of major accidents**

Not every actuation of a hazard source that acts on the installations and parts of installations, such as structures, that are relevant pursuant to section 8 above and identified within the meaning of the present Technical Rule on Installation Safety will actually give rise to a serious hazard. When the preconditions for the occurrence of major accidents

are determined, it is therefore to be scrutinised in relation to the individual safety-relevant parts of installations and safety-relevant parts of a site whether, given the presumed types of hazard sources and the intensity with which the hazard sources in question would be actuated in the specific instance, a major accident could really occur or whether there would only be disruption to the operation. To this end, it is to be studied how the actuation of the hazard source could affect the safety-relevant parts of the installations and the site threatened in each particular case.

The following procedure is proposed for the further delimitation of the parts of sites and installations that are threatened within the meaning of the present Technical Rule on Installation Safety:

1. determination of the effects on threatened parts of installations where particular substances and volumes are present,
2. determination of the effects on threatened parts of installations with particular functions (within installations),
3. determination of the effects on threatened installations where particular substances and volumes are present,
4. determination of the effects on threatened installations with particular functions inside and outside the establishment,
5. determination of the effects on the site.

At the latest when it comes to the final step, the consequences of the simultaneous action of hazard sources on all the site's installations and parts of installations, and their interactions (when an action on an installation/part of an installation triggers a major accident in another installation/part of an installation) are to be examined.

Examples of scenarios for the determination of the preconditions for major accidents:

1. Extreme wind:
  - a) overturning and rolling of unsecured barrels and tanks,
  - b) detachment of tanks or containers from their anchorings with damage to the connecting pipes (change of position),
  - c) pipe rupture caused by vibrations,
  - d) damage to floating roofs caused by wind-induced vibrations,
  - e) change of pressure and pressure fluctuations in waste gas systems,
  - f) damage to buildings and/or parts of buildings,
  - g) breakdown of the supply of inputs,
  - h) breakdown of communications links.

2. Extreme snow loads and ice loads:
  - a) collapse of roofs or parts of buildings,
  - b) interruption of supply lines on and off the site, e.g.
    - i. power supply,
    - ii. process control engineering,
    - iii. pipes for means of production,
    - iv. other safety equipment, e.g. communications equipment,
    - v. formation of ice on pipes and pumps.
3. Wind-induced projectiles:
  - a) puncturing of tanks, containers or reaction vessels for hazardous substances made of thin-walled materials and/or materials that are insufficiently mechanically robust (e.g. plastic sheeting or glass),
  - b) rupture of pipes,
  - c) damage to pumps, valves, and measurement and control equipment,
  - d) constraints on the functioning, or breakdown, of parts, of installations and supply facilities on and off the site, e.g.
    - i. power supply,
    - ii. process control engineering,
    - iii. pipes for means of production,
    - iv. other safety-related equipment, e.g. communications equipment.

## 10 Specification of installation-specific protection aims

Installation-specific protection aims are to be drafted on the basis of what is known about possible hazard sources (section 7 above, 'Detailed hazard source analysis') and the hazards and/or threats they make possible (section 9 above, 'Determination of the preconditions for the occurrence of major accidents').

Requirements for the drafting of protection aims:

1. The design of safety-relevant parts of installations, safety-relevant parts of a site and construction works in which safety-relevant installations or parts of installations are operated in accordance with DIN EN 1990 to meet the requirements of reliability class RC 3, which corresponds to a design to withstand a 100-year event. Where the hazard potential is particularly high, it is to be scrutinised whether there is a need for the application of further-reaching partial factors (cf. the note to Table B2 of Annex B to DIN EN 1990).
2. The monitoring of the planning and construction of **new**, safety-relevant parts of installations, safety-relevant parts of a site and construction works in which safety-relevant installations are operated to meet the requirements of the design

supervision level DSL 2 and the inspection level IL 2 defined in DIN EN 1990/NA. Where the hazard potential is particularly high,<sup>20</sup> it is to be scrutinised whether there is a need for the application of DSL 3 and/or IL 3 design supervision and inspection measures. This requirement does not apply to existing installations and parts of installations because the monitoring of planning and construction activities in accordance with DSL 3 or DSL 2 and IL 3 or IL 2 is only feasible retrospectively to a certain extent, if at all.

3. Design of safety-relevant parts of installations, safety-relevant parts of a site and construction works in which safety-relevant installations are operated to withstand the gusts, peak winds and vibrations detailed in DIN EN 1991-1-4/NA and meet the more stringent requirements imposed by indent 1 above.
4. Design of safety-relevant parts of installations, safety-relevant parts of a site and construction works in which safety-relevant installations are operated to withstand the snow loads detailed in DIN EN 1991-1-3/NA and meet the more stringent requirements imposed by indent 1 above and, in addition to this, to withstand exceptional snow loads on the basis of reference values specified for this purpose by the authorities or, if such reference values are not available, extreme snow loads that have occurred in the region previously.
5. Design of safety-relevant parts of installations, safety-relevant parts of a site and construction works in which safety-relevant installations are operated to withstand the ice loads detailed in DIN 1055-5 and satisfy the more stringent requirements imposed by indent 1 above.
6. Monitoring of parts of construction works that are safety-relevant or in which safety-relevant parts of installations are operated in accordance with *VDI Guideline 6200*.<sup>21</sup>
7. Steps to secure safety-relevant parts of installations and safety-relevant parts of a site, and prevent the creation of projectiles (loss of parts of installations).
8. Protection of safety-relevant parts of installations and safety-relevant parts of a site against projectile impact (damage to parts of installations caused by airborne, ground-level and other projectiles).

The following applies to existing installations and parts of installations, i.e. for which a licence was issued prior to the publication of the present Technical Rule on Installation Safety:

- a) Evidence is to be provided that the requirements discussed above (indents 1, 3, 4 and 5 above, in particular design to withstand 100-year events) are satisfied. The Commission on Process Safety considers it appropriate for this to be done within a period of five years following the publication of the present Technical Rule on Installation Safety. This evidence is to be provided in relation to the actions

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<sup>20</sup> E.g., if the part of the installation itself reaches or exceeds the quantitative thresholds set in Column 5 of the table in Annex I to the Major Accidents Ordinance.

<sup>21</sup> *VDI Guideline 6200: Structural safety of Buildings: Regular inspections* (February 2010).

detailed in DIN EN 1991 and DIN 1055-5 for ice loads with the application of the factor  $K_{FI} = 1.1$  (in order to allow for 100-year events) (as required for RC 3 pursuant to DIN EN 1990). Methodologically, however, the calculations may also be carried out in compliance with the standards that applied at the time when a license was last issued.

- b) With regard to installations due to undergo alterations that will have significant effects on structural safety (e.g. corresponding changes of use, changes to the main load-bearing construction, including integral stiffening systems, etc.), it is necessary for the evidence to be provided in accordance with currently valid standards.
- c) When alterations are made that are significant under the Federal Immission Control Act and do not significantly affect structural safety, if at all (e.g., do not involve alterations to the main load-bearing construction, including integral stiffening systems), the provision of the evidence stipulated by indent a) above is not required additionally.
- d) Situations may arise in which the evidence stipulated by indent a) above cannot be provided for older installations, in particular because
  - i. the person appointed to scrutinise the matter does not find sufficient documents or
  - ii. the original calculations are based on older standards and/or other technical building regulations that are not suitable for this scrutiny (section 3(3) of *VDI Guideline 6200*).

In these cases, an initial inspection under *VDI Guideline 6200* (see, in particular, section 6, 'Existing structures') or an at least equivalent procedure is to be conducted by a particularly expert individual in accordance with section 11 of *VDI Guideline 6200*. In particular, when this is done, it is to be scrutinised whether the load tolerances given by the standards used for the original design are still practicable (e.g. inspection of load-bearing parts of installations to ascertain their integrity) and fulfil the protection aim set in indent a) above. If this is the case, the operator has to take organisational safety measures so that the permissible imposed loads are complied with on the site, with the consequence that the load tolerances continue to be maintained. The practicability of load tolerances must also be dealt with by regular inspections and targeted inspections following incidents in which structures have been exposed to particular loads (e.g. high snow loads, hurricanes).

If the load tolerances discussed above are no longer practicable, the inspector has to inform the operator without delay about the necessary consequences (section 10.1.3 of *VDI Guideline 6200*).

- e) If the evidence required by indent a) above cannot be provided – even by an inspection pursuant to indent d) above –, an upgrade (adaptation to the state of the art of safety technology) must be carried out (cf. section 10.2.1 of *VDI Guideline 6200*). The Commission on Process Safety considers it appropriate for this to be

done within a period of ten years following the publication of the present Technical Rule on Installation Safety.

## **11 Elaboration of protection concepts**

Protection concepts are to be developed on the basis of the hazard sources that are not reasonably to be excluded, the hazards and/or threats that are identified and the protection aims. When protection concepts are elaborated, attention is to be paid to the requirement laid down in Article 3(4) of the Major Accidents Ordinance that they be consistent with the state of the art of safety technology.

When a protection concept is elaborated, the following points are of contributory significance alongside the intensity of an event:

1. the speed with which the event occurs,
2. the advance warning time (e.g. weather forecast) and
3. the parties' capacity to take effective action during the event.

This relates, in particular, to organisational measures, e.g. the relocation of hazardous substances to safe facilities, steps taken to secure loose parts of installations, additional protection for parts of installations or the timely shut-down of installations or parts of installations.

The main protective technical measures that may be taken into consideration when a protection concept is elaborated are construction measures:

1. Construction measures against extreme winds include, e.g.
  - a) the design of safety-relevant installations and parts of installations to withstand the wind loads detailed in DIN EN 1991-1-4 and so meet the requirements of reliability class RC 3,
  - b) corresponding application to non-built features,
  - c) enclosures for threatened parts of installations,
  - d) steps to secure parts of installations that represent potential on-site sources for the creation of projectiles, debris, e.g. chimneys, ventilation filters, etc.,
  - e) completely underground configuration of safety-relevant installations or parts of installations, where this is compatible with the requirements of monitoring, maintenance and water pollution control.
2. Construction measures against wind-excited vibrations include, e.g.,
  - a) aerodynamic measures to disrupt the flow forces that trigger vibrations,
  - b) structural measures such as vibration dampers, guy cables, frequency detuning systems.

3. Construction and organisational measures against snow loads and ice loads include, e.g.,
  - a) the design of safety-relevant installations and parts of installations to withstand the snow loads and ice loads detailed in DIN EN 1991-1-3 and/or DIN 1055-5 subject to the application of reliability class RC 3 and consideration of accidental loads,
  - b) corresponding application to non-built features,
  - c) to supplement these measures, the measurement of snow loads with sensors, with roofs being cleared once a particular load is reached (organisational measure).
4. Measures against projectiles include, e.g.,
  - a) regular awareness-raising and instruction for employees concerning the possible consequences of projectiles and their obligations to prevent projectiles being created,
  - b) inspection of the site compound, with particular attention being paid to potential sources for the creation of projectiles; inspections to be carried out regularly and when storm warnings are received,
  - c) assessment of shortcomings that are found and determination of effective measures if safety cannot be guaranteed until the next inspection. These include, e.g., the following measures:
    - i. replacement of the fastenings for inadequately secured parts of installations,
    - ii. installation of additional load-bearing and/or stabilising structures, where necessary,
    - iii. installation of debris nets to protect against parts of facades that fall down,
    - iv. additional fencing off of threatened areas, where necessary,
    - v. installation of crash barriers,
    - vi. steps to secure or remove trees if safety-relevant parts of installations are located in the area that would be affected and might be hit if the trees fell over.

These measures are to be taken in order to ensure that the creation of projectiles is reasonably to be excluded as the cause of a major accident.

- d) Implementation of measures within the prescribed period of time or compensatory measures to bridge over the period until the implementation of measures. These compensatory measures include, e.g.,
  - i. the reduction of the floor load until additional load-bearing elements are installed,
  - ii. steps to secure trees against falling over using firmly anchored cables.

Under certain circumstances, it may be necessary to adjust the frequency with which inspections are carried out in order to keep an eye on the development of damage over time and, where necessary, be able to take the requisite measures promptly as well.

## **12 Scrutiny of protection concepts**

The protection concept developed pursuant to Section 11 is to be reviewed to ascertain whether the protection aims have been achieved. When this is done, consideration is to be given to the intensity of the environmental hazard sources, and the probabilities of failure for the precautions and risk-reduction measures that have been chosen.

This study is used to provide evidence that the operator's obligations pursuant to the Major Accidents Ordinance and the Federal Immission Control Act are being fulfilled.

If the precautions and measures chosen are found not to be sufficient, the protection concept in question is to be revised in order to incorporate further precautions against major accidents.

If the precautions are sufficient, the steps taken to date, in particular the protection aims, protection concepts and their scrutiny, are to be documented, with attention being paid to the relevant requirements of the Major Accidents Ordinance and the Federal Immission Control Act.

## **13 Determination of scenarios pursuant to Article 3(3) of the Major Accidents Ordinance ('major accidents despite precautions') and scenarios for alarm and emergency planning**

These scenarios are determined in order to identify

1. the measures required to keep the effects of major accidents that are reasonably to be excluded as small as possible pursuant to Article 3(3) and Article 5(1) of the Major Accidents Ordinance ('major accidents despite precautions'), and point 2 of section 9.2.6.2.3 of the BMUB's Guide to the Enforcement of the Major Accidents Ordinance),
2. the information required for the elaboration of internal alarm and emergency plans (pursuant to Article 10 Major Accidents Ordinance), and
3. the information required for the drafting of external alarm and emergency plans (pursuant to point 4 of Article 9(1) Major Accidents Ordinance and point 3 of section 9.2.6.2.3 of the BMUB's Guide to the Enforcement of the Major Accidents Ordinance).

Hazard sources that are reasonably to be excluded and could give rise to 'major accidents despite precautions' may include, e.g.,

1. the failure of precautions taken under Article 3(1) of the Major Accidents Ordinance,
2. extreme winds above a reasonably to be presumed intensity and tornadoes of forces up to and including F4 that, by their nature, are not reasonably to be presumed,

3. snow loads and ice loads above a reasonably to be presumed intensity.

This means that, in particular where a substance is released due to hazard sources that are reasonably to be excluded, additional measures are to be taken in order to keep the harmful effects on humans, the environment and property as small as possible.

However, hazard sources that are reasonably to be excluded may also be so improbable as to be beyond human experience and incalculable. No installation-specific precautions are to be taken against exceptional major accidents of these kinds. This applies, e.g., for force F5 tornadoes of which, as far as is known at present, no definite evidence has been provided to date in Germany. Under these conditions, their consideration would not be expedient when the effects of major accidents are being examined.

As a matter of principle, the hazard sources examined in the present Technical Rule on Installation Safety may lead to the secure containment of hazardous substances no longer being guaranteed. In consequence, as a minimum, the release of the largest coherent mass of a hazardous substance within the meaning of the Major Accidents Ordinance is to be assumed, irrespective of its cause.

Alternatively, the operator may, e.g., be guided by:

- a) historic events,
- b) the maximum peak winds that have occurred (in so far as it is possible for them to be determined).

In particular, attention is to be paid to the following points when scenarios are set out:

1. Environmental hazard sources, e.g. tornadoes, extreme winds and snow loads, are extensive events and may therefore act on several parts of an installation simultaneously, causing disruption.
2. In consequence, it is to be scrutinised whether more than the largest coherent mass could be released (e.g. failure of several tanks).
3. It is to be assumed that the feasibility of the measures to mitigate the effects of major accidents provided for to date where environmental hazard sources arise will be limited in certain circumstances (if it is not possible to go outdoors, access routes are blocked, etc.).
4. In addition to this, it is to be assumed that the availability of external personnel will be limited.
5. Furthermore, the extent to which disruption may trigger further disruption at a different installation or different part of the same installation is to be scrutinised.

## **14 Specification of measures to mitigate the effects of major accidents**

According to Article 3(3) of the Major Accidents Ordinance, in order to fulfil its obligations, the operator has to take precautionary measures to keep the effects of major accidents as small as possible. Suitable technical and organisational measures are set

out in the following sections. When technical measures are taken to mitigate the effects of major accidents, two fundamental options are to be distinguished:

1. Measures that take effect immediately at the affected site, installation or part of an installation (e.g. oil depots, pipes) in order to minimise the release of hazardous substances,
2. Measures that take effect around the affected site in order to prevent and/or mitigate the dispersion of substances.

Whether, and to what extent, the external, environmental hazard sources examined in the present Technical Rule on Installation Safety permit measures to be taken to prevent the dispersion of contaminants in the first place must be scrutinised systematically in the individual case. When wind events occur, it may be impossible for people to go outdoors because this would be life-threatening. The icing of internal roads may also be regarded as a hazard source. If these roads ice up and, as a result, there is a danger of vehicles not being able to drive on them safely and potentially colliding with safety-relevant parts of installations, this hazard source is to be excluded, e.g. by means of ice-clearance measures.

Apart from the site that is affected, the area immediately around the establishment may also be affected and the hazard source may last for a long time. This is to be taken into consideration in the alarm and emergency plan (see section 16.2).

It is to be scrutinised whether protection concepts previously developed in the safety report cover the scenarios for the release of substances, fire and explosion in any event, and whether the measures to mitigate the effects of major accidents provided for here, where necessary, are sufficient.

It is possible to mention the following as examples of specific guidance on measures to mitigate the effects of major accidents within the scope of the present Technical Rule on Installation Safety:

1. Safety equipment and protective precautions:
  - a) buffer areas,
  - b) protective walls or embankments,
  - c) quick-closing mechanisms.
2. Consideration of the threats caused by wind, snow loads and ice loads in the site's alarm and emergency organisation.
3. Consideration of the threats caused by wind, snow loads and ice loads in the deliberations conducted by the authorities responsible for preventing hazards and the emergency services when a major accident occurs (Article 5(2) Major Accidents Ordinance).

## **15 Planning for emergencies, amendment of site alarm and emergency plans, communication of information for external alarm and emergency planning**

### **15.1 Planning for emergencies**

Pursuant to Article 8(3) of the Major Accidents Ordinance, in the cases covered by points 1 to 3 of Article 7(2) of the Major Accidents Ordinance, the operator has to review and, where necessary, update the concept for the prevention of major accidents, including the safety management system on which this concept is based, as well as the procedures for its implementation. In consequence, this provision also relates to the planning for emergencies required by section (3)(e) of Annex III to the Major Accidents Ordinance. The results of the above steps are to be taken into consideration when the concept is updated.

### **15.2 Amendment of site alarm and emergency plans**

Under Article 10 of the Major Accidents Ordinance, the operator of an establishment that is subject to extended obligations has to draw up an alarm and emergency plan and, under Article 10(4) of the Major Accidents Ordinance, test, review and update that plan. Establishments with standard obligations may also be obliged to draw up plans of this kind in accordance with an order issued in the individual case (Article 1(2) in conjunction with Article 6(4) Major Accidents Ordinance).

When the alarm and emergency plan is drawn up, consideration is also to be given to equipment that is not located on the site compound and is not part of the site, e.g. overhead cables, masts with communications equipment, but where the loss of its functionality as a consequence of wind loads could affect the site as an external hazard source. Infrastructure facilities such as roads and railway tracks are also to be examined so that consideration can be given to their functions in the alarm and emergency plan as well.

It is to be taken into consideration that disruption of this kind may last for a long period of time. This applies, above all, for extensive low-pressure storms, as well as heavy snow loads and ice loads, which may restrict the use of, or even completely block, the infrastructure around the affected site. Such disruption includes:

#### **1. Destruction of overhead power lines off-site**

Overhead power lines may be destroyed, firstly, by storms/tornadoes and, secondly, by icy precipitation in combination with strong winds. When this happens, either the masts are directly snapped by the wind load or, if there is heavy frozen rain, the power lines are loaded beyond their critical load by clinging ice. This may give rise to localised or even extensive power cuts. As a matter of principle, disruption to supplies of power and other energies should not lead to major accidents. In the scenario described here, countermeasures may be initiated primarily by ensuring there is an independent power supply to the safety-relevant parts of installations. In an emergency, it is to be ensured by the site operator that sufficient fuel is available for stand-by generators in these situations as well.

## 2. Blockage of access routes to a site

The access routes to a site may be disrupted for a protracted period by snow, periods of below-zero temperatures, fallen trees or scattered projectiles. The clearance of roads and paths may be disrupted and no longer possible as a result of protracted and exceptionally heavy snowfall. In addition to this, there is the danger of waterways used for the delivery of shipments freezing over as a result of protracted periods of below-zero temperatures. Hazards may be prevented by the storage of sufficient safety-relevant inputs, as well as forward-looking planning and observation of the weather situation. If the period when the site could be cut off is not foreseeable, its emergency plan must allow threatened processes to be shut down gradually in order to prevent threats caused by a lack of safety-relevant inputs.

Depending on the kind of meteorological event, meteorological service providers are able to warn of extreme events with various advance warning times and levels of reliability. The operator has to assess whether information of this kind is available for its alarm and emergency planning, and to stipulate in the site alarm and emergency plan how such information is to flow from the meteorological service provider and what measures are taken by whom as of which thresholds. As a rule, alarm and emergency planning for hazards caused by extreme winds, snow loads and ice loads is to be incorporated into an overall internal alarm and emergency plan as an integral component. In individual cases, however, it may also be worthwhile to draw up a separate internal alarm and emergency plan, e.g. purely for extreme meteorological events. This separate plan may, however, only be a subdivision of the main alarm and emergency plan. Its integration into the overall alarm and emergency plan is required in this context because significant aspects of consequent processes, such as substance releases that result from extreme wind events, must be consistent with the organisational and operational procedures laid down in the overall alarm and emergency plan.

### **15.3 Communication of information for external alarm and emergency planning**

Operators of establishments with extended obligations have to communicate the information required for the drawing up of external alarm and emergency plans to the competent authorities (point 2 of Article 10(1) Major Accidents Ordinance).

With regard to the hazard sources examined in the present Technical Rule on Installation Safety, the data on 'major accidents despite precautions' (cf. sections 13 and 14 above), in particular, are to be reviewed and, where necessary, amended. Any potential threat outside the establishment caused by airborne projectiles would also have to be communicated.

## **16 Documentation**

The steps taken to date and their results, in particular the installation-specific protection aims, protection concepts and their scrutiny, are to be documented. At establishments with extended obligations, this has to be done in the safety report and, where necessary, the site alarm and emergency plan.

## **17 Fulfilment of further obligations under the Major Accidents Ordinance**

### **17.1 Requirements with regard to maintenance**

According to points 1 and 2 of Article 6(1) of the Major Accidents Ordinance, in order to fulfil its obligations, the operator has to inspect the construction and operation of the safety-relevant parts of installations, and constantly monitor and regularly service the installations in the establishment from a safety point of view.

In addition to this, maintenance and repair work is to be carried out in accordance with the state of the art. Reference is made to section 3.2 of Annex 1 to the BMUB's Guide to the Enforcement of the Major Accidents Ordinance.

The obligation to maintain installations and parts of installations extends to precautions to prevent major accidents caused by environmental hazard sources and measures to mitigate the effects of major accidents.

### **17.2 Information and training for personnel**

Training for personnel covers both the steps required to fulfil obligations under the Major Accidents Ordinance, e.g. to prevent major accidents and mitigate their effects, and steps to ensure the personnel's own safety when environmental hazard sources examined in the present Technical Rule on Installation Safety are actuated.

Personnel are to be given training on the types, possible intensity and frequency of environmental hazard sources that are not reasonably to be excluded, and the action required if they are actuated. It is to be specified in the instructions who is to ascertain an acute hazard or threat has arisen, how personnel are to be informed about the situation, and who has to take what action to prevent major accidents or mitigate the effects of major accidents and ensure the safety of personnel. This applies for all personnel in the establishment, i.e. including employees who work in parts of the establishment that are not safety-relevant.

Exercises are also to be carried out (at least every three years pursuant to Article 10(4) of the Major Accidents Ordinance) as part of periodically to be conducted training courses in order to convey instructions to personnel, e.g. to practise the evacuation of parts of an establishment. When this is done, the organisation, the preparation and the processes for the implementation of measures are to be scrutinised, and instructions and training courses are to be improved, where necessary.

### **17.3 Advice for responsible authorities and emergency services when a major accident occurs**

According to Article 5(2) of the Major Accidents Ordinance, in order to fulfil its obligations, the operator of an installation has to provide the authorities responsible for responding to emergencies and the emergency services with immediate, comprehensive and expert advice. Reference is made to section 2.3 of Annex I to the BMUB's Guide to the Enforcement of the Major Accidents Ordinance. Expert advice presupposes that the information provided is consistent with the latest developments in scientific knowledge.

With regard to environmental hazard sources, this advice is not only to be provided to the authorities responsible for the implementation of the Major Accidents Ordinance, but to all authorities and emergency services responsible for, or involved in, measures to prevent hazard sources being actuated or to mitigate the consequences if they are actuated.

## Abbreviations:

12th BIm-SchV	Twelfth Ordinance on the Implementation of the Federal Immission Control Act – Major Accidents Ordinance
BImSchG	Federal Immission Control Act – Act on the Prevention of Harmful Effects on the Environment Caused by Air Pollution, Noise, Vibration and Similar Phenomena
BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CC 3	Consequences class (for the failure of a structure) defined in Annex B to DIN EN 1990 with the description: High consequences for loss of human life, or economic, social or environmental consequences very great
cf.	Latin: <i>confer</i> , 'compare'
DAS	German Strategy for Adaptation to Climate Change
DIN	German Institute for Standardisation
DIN EN	DIN standard based on a European standard
DIN EN/NA	German National Annex to a DIN EN standard
DSL 2	Design supervision level (DSL) for the planning (of structures) according to DIN EN 1990/NA DSL 2: Extended supervision: Checking performed by an accredited inspection agency, inspecting engineer or expert engineer for construction organisationally independent from the party that has prepared the design (third party checking)
DWD	Deutscher Wetterdienst, German Meteorological Service
e.g.	Latin: <i>exempli gratia</i> , 'for example'
F0, F1, F2, F3, F4, F5	Force of a tornado on the Fujita Scale
i.e.	Latin: <i>id est</i> , 'that is'
IL 2	Inspection level (IL) for construction activities and use according to DIN EN 1990/NA IL 2: Extended inspection: Inspection of construction activities by an independent and accredited third party agency, inspecting engineer or expert engineer for construction (third party inspection)
IPCC	Intergovernmental Panel on Climate Change
KAS	German Commission on Process Safety
KAS-1	<i>Richtwerte für sicherheitsrelevante Anlagenteile (SRA) und sicherheitsrelevante Teile eines Betriebsbereiches (SRB)</i> , Commission on Process Safety, Bonn, 2006
$K_{FI}$	Factor used to differentiate the reliability of structures pursuant to Annex B to DIN EN 1990
kN/m <sup>3</sup>	Kilonewtons per cubic metre
RC 3	Reliability class for structures defined in Annex B to DIN EN 1990, corresponds to Consequences Class CC 3
StörfallV	Major Accidents Ordinance – Twelfth Ordinance on the Implementation of the Federal Immission Control Act
TRAS	Technical Rule on Installation Safety
UBA	German Federal Environment Agency
$v_{max}$	Maximum velocity