# Safety Standards

of the

Nuclear Safety Standards Commission (KTA)

**KTA 2103 (2015-11)**

**Explosion Protection in Nuclear Power Plants with Light Water Reactors (General and Case-Specific Requirements)**

(Explosionsschutz in Kernkraftwerken mit Leichtwasserreaktoren – allgemeine und fallbezogene Anforderungen)

The previous version of this safety standard was issued in 2000-06



Editor:
KTA-Geschaeftsstelle
c/o Bundesamt fuer kerntechnische Entsorgungssicherheit (BfE)
Willy-Brandt-Str. 5 • 38226 Salzgitter • Germany
Telephone +49 (0) 30 18333-1621 • Telefax +49 (0) 30 18333-1625

# KTA SAFETY STANDARD

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**KTA-Geschaeftsstelle c/o BfE, Willy-Brandt-Str. 5, 38226 Salzgitter, Germany**

**Comments by the Editor:**

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

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

**Basic Principles**

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

(2) In accordance with SiAnf, Annex 3, protective measures must be provided to counter fires and explosions in a nuclear power plant. Fire protection in Nuclear Power Plants is dealt with in the safety standard series KTA 2101 and is, therefore, not within the scope of the present safety standard.

(3) The present safety standard presumes that the German Industrial Safety Ordinance (BetrSichV) and the Hazardous Substances Ordinance (GefStoffV) together with the associated technical standards (TRBS and TRGS) are observed. Furthermore, it is assumed that the regulations of the German Social Accident Insurance (DGUV), and that standard DIN EN 60079-10-1 as well as other regulations under public law are observed. Detailed information on the zone-classification of potentially explosive areas are contained in the collection of examples of standard DGUV 113-001. Exceptions are admissible in well-founded cases.

(4) To meet the objectives of explosion protection in nuclear power plants with light water reactors, the present safety standard specifies such explosion protection measures that will help to sustain the safety-related tasks of plant components including the structural components under consideration that the precautionary measures under para. (2) are taken. In this context, technical and administrative measures are specified. The extent and quality of these measures as well as the associated inspection effort are dependent on the importance of the explosion protection with regard to achieving the protective goals and radiological safety goals in accordance with SiAnf, Secs. 2.3 and 2.5.

## 1 Scope

(1) This safety standard shall be applied to nuclear power reactors with light-water reactors.

(2) It deals with the protection from explosions and their detrimental effects. It shall be applied under all operation phases for the protection of equipment and structural components, the specified normal function of which serve to

a) safely shut down the reactor and keep it in a shutdown condition,

b) remove the residual heat, and

c) prevent a release of radioactive substances.

Note:

By applying this safety standard, the protection of personnel working in the power plant is ensured (cf. Basic Principles, para. (3)).

(3) This safety standard shall be applied to explosion hazards from substances that are able to generate an explosive atmosphere or other explosive mixtures if these substances can be brought to, or penetrate into, the nuclear power plant site or if they can be created inside or outside of buildings on the nuclear power plant site.

(4) This safety standard does not apply to protective measures against explosion hazards that may occur

a) when handling substances in accordance with SprengG, Sec. 1, para. 1,

b) when releasing ignitable gases or vapors outside of the nuclear power plant site; excepted are the requirements specified in Section 5 of this safety standard regarding the deployment of gas warning equipment,

c) due to hydrogen released during a beyond-design-basis accident, or

d) due to disruptive actions or another interference by third parties that involve explosive materials.

Note:

Details in the context of para. (4) are dealt with in GL SEWD LWR.

## 2 Definitions

(1) Work place

A work place is a local area designated for a specific work procedure even if more than one person is involved.

(2) Atmosphere, explosive

Explosive atmosphere is an explosive mixture under atmospheric conditions admixed with air. Atmospheric conditions are characterized by an overall pressure between 0.8 bar and 1.1 bar and a mixture temperature between - 20 °C and + 60 °C as well as an oxygen content of no more than 20.95 % by volume.

(3) Atmosphere, dangerously explosive

A dangerously explosive atmosphere is an explosive atmosphere that occurs in such an amount (hazardous amount) that special protective measures are needed to maintain the protection of the safety and health of working personnel or other persons.

(4) Area, potentially explosive

A potentially explosive area is an area in which a dangerously explosive atmosphere can occur. An area in which an explosive atmosphere cannot occur in such amounts that special protective measures would be required is not considered to be a potentially explosive area. Regarding the definition of “potentially explosive areas within zones”, cf. GefStoffV and technical standards TRBS 2152, Part 2 / TRGS 722.

(5) Provision of ignitable gases and flammable liquids

The provision of ignitable gases and flammable liquids means making these materials available for the anticipated task (not for longer than 24 hours) at or near the work place in the required amounts.

Note:

Provision in itself does not comprise the actual storage (cf. Definition (18)). Additional information regarding the term “ignitable” can be found in the European regulation EG 1272/2008 (CLP-VO).

(6) Explosion

Explosion is a sudden oxidation reaction or decomposition reaction with an increase of temperature, of pressure or of both.

(7) Explosion protection

Explosion protection comprises all measures taken for the protection from the hazards caused by explosions.

(8) Explosion protection, structural

Structural explosion protection comprises structural measures that limit the effects of an explosion to an extent that they can be considered as harmless (cf. GefStoffV, Sec. 11, and technical standard TRBS 2152, Part 4).

(9) Liquids, flammable

Flammable liquids – for the purpose of the present safety standard – are all liquids with a flash point lower or equal to 100 °C; these include, especially, ignitable, highly ignitable, or extremely ignitable liquids with a flash point lower or equal to 55 °C.

(10) Gases, ignitable

Ignitable gases – for the purpose of the present safety standard – are all gases and gas mixtures that have an explosive range in air near 20 °C and a standard pressure of 1.013 bar and that are marked as Hazard Class 2.2 with hazard warnings H220 or H221 in accordance with EG 1272/2008 (CLP-VO).

(11) Mixture, explosive

An explosive mixture is a mixture of flammable gases, vapors, mists or dusts in which, after ignition has occurred, the combustion process spreads to the entire unburned mixture.

(12) Mixture, dangerously explosive

A dangerously explosive mixture is an explosive mixture that occurs in such an amount (hazardous amount) that special protective measures are needed to maintain the health and safety of working personnel or other persons. Other explosive mixtures – for the purpose of the present safety standard – are all dangerously explosive mixtures that are not categorized as dangerously explosive atmospheres.

(13) Equipment groups and equipment categories

Equipment groups and equipment categories categorize equipment and protective systems relative to their degree of freedom from ignition sources in accordance with 11thProdSV.

(14) Maintenance

Maintenance encompasses the entirety of measures to maintain and restore the required condition as well as to determine and assess the actual condition.

Note:

Maintenance is subdivided into inspection, servicing, and repairs.

(15) Nuclear power plant site

The nuclear power plant site is the tract of land within corresponding boundaries that belongs to the single-unit or multi-unit nuclear power plant.

Note:

The nuclear power plant site – for the purpose of the present safety standard – extends to all facilities inside the outer security area but not to the generally accessible areas such as information center, outdoor switchyard and parking lots.

(16) Storage depots and storage equipment

Storage depots – for the purpose of the present safety standard – are buildings, areas or rooms inside or outside of the buildings that meet specific requirements regarding the protection of working personnel or other persons and that are intended for storing hazardous substances and that meet the requirements in accordance with technical standard TRGS 510. This also includes storage equipment such as containers or cabinets that meet the requirements in accordance with technical standard TRGS 510 as well as safety cabinets in accordance with technical standard TRGS 510, Appendix 3.

(17) Storage facilities

Storage facilities – for the purpose of the present safety standard – are rooms or areas with the exception of gas stations inside or outside of buildings that are intended for storing stationary or transportable containers for flammable, highly flammable or extremely flammable liquids.

(18) Storing

In accordance with GefStoffV, Sec. 2, para. 5, storing means safe keeping for later (self) use as well as for a disposal to others. Storing includes the provision for transport if the transport does not occur within 24 hours after the provision or on the following workday. If this workday is a Saturday, the period expires at the end of the following workday.

(19) Standard state (regarding volume data of gases)

The volume of gases in the standard state is its volume at 1.013 bar and 0 °C.

## 3 General Requirements

### 3.1 Basic Principles of Explosion Protection

(1) In accordance with GefStoffV, the explosion protection shall be ensured by measures ranked as follows:

1. Preventing the formation of dangerously explosive mixtures (cf. technical standard TRBS 2152, Part 2).
2. Avoiding the ignition of dangerously explosive mixtures (avoiding effective ignition sources, cf. technical standard TRBS 2152, Part 3).
3. Incorporating structural design measures for fire protection that limit the effects of an explosion to an extent that they can be considered as harmless (cf. technical standard TRBS 2152, Part 4).

Note:

This ranked procedure is well suited– in conformance with SiAnf, Annex 3, Sec 3.2.9.1 – to achieve the goals laid down in the present safety standard under Basic Principals, para. (4).

(2) The operator of the nuclear power plant shall, in accordance with GefStoffV, Secs. 6 and 11, perform a risk assessment regarding explosion hazards. If, regarding the requirements of GefStoffV, Secs. 6 and 11, the formation of a dangerously explosive atmosphere cannot be ruled out, the necessary protective measures shall be specified in course of a risk assessment in accordance with BetrSichV, Sec. 3, and an explosion protection document shall be crafted. The explosion hazards shall be assessed in accordance with technical standards TRBS 1111 and TRBS 2152 with its Parts /TRGS 720 ff. In the case of other dangerously explosive mixtures, the procedure followed shall be analogous to the one described in GefStoffV, particularly its Appendix 1, No. 1.

Note:

The risk assessment and the explosion protection document may be presented as one document.

(3) Substances that can lead to the formation of an explosive atmosphere or other explosive mixtures may only be stored in storage facilities or storage equipment intended for this purpose. Only limited amounts of these substances may be made available outside of these storage facilities and storage equipment. After completion of the work task with these substances, they shall be returned to the storage facilities or storage equipment without delay.

(4) If, during certain operating conditions of the power plant, functions of the safety systems are not needed or needed only in parts (e.g., during maintenance procedures), deviations from the requirements of the present safety standard are admissible, provided, even in case of an explosion, the respectively needed function of the safety system cannot be inadmissible affected. Maintenance in power plants shall carried out in accordance with technical standards TRBS 1112 and TRBS 1112, Part 1.

(5) The non-availability of equipment and protective systems as well as of safety, surveillance and control devices that deal with explosion protection shall be dealt with by plant-specific measures to be specified and executed with the objective of ensuring the continued protection of the power plant (e.g., during non-availability of air-mixing ventilators in the turbine building, of ventilation systems of battery compartments, or of gas-measurement equipment in the central hydrogen supply facility).

(6) The fire protection dampers and ventilation dampers in potentially explosive areas shall trigger an alarm "NOT OPEN" in the control room area when ventilation is needed for reasons of explosion protection.

### 3.2 Avoiding Effective Ignition Sources

(1) In accordance with technical standard TRBS 2152, Part 3, effective ignition sources shall be avoided in potentially explosive areas and anywhere an explosive atmosphere may possibly develop (e.g., during servicing and repair tasks).

(2) In these areas suitable explosion-protected equipment in accordance with BetrSichV, Sec. 9, para. (4), shall be used. The suitability of explosion-protected equipment shall be certified for their use in dangerously explosive atmospheres and shall be classified by the equipment manufacturer to a specific equipment category.

(3) Furthermore, ignition sources shall be avoided in areas with dangerously explosive atmospheres that may be caused by plant components and activities of personnel. In this context, the guidelines in accordance with technical standard TRBS 2152, Part 3, shall be observed.

(4) Ignition sources shall also be avoided in areas with other dangerously explosive mixtures (e.g., radiolysis gas). Explosion-protected equipment certified for use in dangerously explosive atmospheres and classified by the equipment manufacturer to a specific equipment category need an additional certification if they are to be used in these areas. The suitability of this equipment for use in areas with other dangerously explosive mixtures shall be separately demonstrated.

### 3.3 Combinations of the Explosion Event with Another Event

#### 3.3.1 General requirements

(1) Combinations of an explosion with another event shall be assumed if

a) the events are causally interconnected, or

b) a simultaneity of the events must be assumed based on its probability and the extent of damages.

(2) Combinations of an explosion with another event shall be analyzed exclusively in terms of achieving the goals laid down in Basic Principals, para. (4), of the present safety standard. Associated necessary measures shall be provided.

(3) The following combinations shall be differentiated between:

a) Combination of causally dependent events:

   aa) explosion and a resultant event, and

   ab) an assumed event and a resultant explosion

and

b) Combination of independent events:

   An assumed event and an independent explosion.

#### 3.3.2 Combination of causally dependent events

##### 3.3.2.1 Explosion and a resultant event

The following combinations of an explosion with a resultant event shall be analyzed:

a) Explosion and a resultant fire

   It shall be prevented that a fire caused by a plant-internal explosion can have inadmissibly adverse effects on the respectively needed function of the safety system.

   Explosions shall not cause damages in fire protection equipment to such an extent that the goals laid down in Basic Principals, para. (4), of the present safety standard are endangered.

   Note:

   Fire protection requirements are detailed in safety standard series KTA 2101.

b) Explosion and resultant component failure

   Unless the component is designed against effects from a plant-internal explosion, a component failure caused by the explosion and that could potentially adversely affect the respectively needed function of the safety system shall be analyzed.

##### 3.3.2.2 An assumed event and a resultant explosion

The following combinations of an assumed event with a resultant explosion shall be analyzed:

a) Plant-internal fire and a resultant explosion

   Occurrence of an inadmissible effect on the respectively needed function of the safety system may be ruled out, provided, the requirements specified in the safety standard series KTA 2101 are observed.

b) Component failure and a resultant explosion

   All components shall basically be designed such that, even if they fail, this will not lead to an explosion.

   If an explosion cannot be ruled out, the protection of the respectively needed function of the safety system shall be ensured. In so far as this is not possible due to system-engineering or usage-related requirements, an equivalent protection condition shall be achieved by applying appropriate measures or a combination of these measures.

c) Earthquake and a resultant explosion

   Equipment of the explosion protection and the plant components specified in Sections 3 and 4 shall be designed against the design basis earthquake in accordance with safety standard KTA 2201.1, or it shall be demonstrated that, in case of an explosion, the respectively needed function of the safety system is ensured.

d) Lightning event and a resultant explosion

   A lightning-caused explosion that could have inadmissibly adverse effects on the respectively needed function of the safety system shall be prevented. An inadmissible adverse effect on the respectively needed function of the safety system may be ruled out, provided, the requirements specified in the safety standard KTA 2206 are observed.

e) Protective measures shall be established for events that, independent of power plant operation, create a dangerously explosive atmosphere outside of safety-related buildings (e.g., transportation accidents), thus, preventing ingress of this atmosphere into the buildings.

### 3.3.3 Combinations of independent events

Combinations of independent events shall be assumed whenever the simultaneity of the events is established. The simultaneity of the explosion event with an independent event shall be assumed if this is deemed necessary based on the probability analysis.

Notes:

1. Simultaneity – for the purpose of the present safety standard – also considers long-term events (e.g., high water) and the possibly still effective resultant events from the explosion.
2. A sufficiently small probability of occurrence may be assumed if the event combinations occur with a probability of less than $1x10^{-5}$ per annum.

## 4 Case-Specific Requirements

### 4.1 Storing and Bottling of Flammable Liquids

(1) Flammable liquids may be stored only in storage facilities intended for this purpose that shall meet applicable rules and regulations. When storing flammable liquids with a flash point lower than or equal to 55 °C in transportable containers the regulation in accordance with technical standard TRGS 510 shall be met. When storing them in stationary vessels or tanks the regulation in accordance with technical standard TRGS 509 shall be met. Supplements and additional requirements are specified in the following paragraphs.

(2) Flammable liquids with a flash point lower than or equal to 55 °C shall be stored in a storage depot only up to an amount of 1000 liters and only in vessels with a capacity not larger than 200 liters. It is not admissible to store flammable liquids with a flash point lower than or equal to 55 °C in compartments with equipment of the safety system and in compartments where an explosion could have inadmissibly adverse effects on the respectively needed function of the safety system.

(3) Flammable liquids in containers with a capacity larger than 1 liter may be stored and handled only if the containers fulfill the regulations in accordance with GGVSEB; other containers larger than 1 liter are not admissible without a protective enclosure.

(4) Flammable liquids with a tendency of dangerous self-disintegration (e.g., unstable substances such as two-component epoxy resins or two-component polyurethanes) may only be stored in separate storage facilities outside of the controlled area. It is not admissible to store any flammable liquids that have a tendency for explosive reactions (e.g., nitromethane).

(5) A hazardous substances inventory in accordance with GefStoffV, Sec. 6, shall be available. In this context, all vessels containing flammable liquids with a flash point lower than or equal to 55 °C in amounts larger than 30 liters that are supplied to, and removed from, storage depots shall be documented. In intervals of no more than one year, a written inventory shall be crafted and the appropriate condition of the storage depots and containers – including those outside of storage depots – shall be checked.

(6) Residual quantities of flammable liquids with a flash point lower than or equal to 55 °C that are not needed anymore in a controlled area shall be immediately removed from this controlled area; the removal shall be documented. Flammable liquids with a flash point lower than or equal to 55 °C needed inside a controlled area are admissible only in amounts up to 100 liters and only if stored in a storage depot or compartment for storage equipment in accordance with technical standard TRGS 510. The storage depots or compartments for storage equipment shall be chosen such that in case of fire or an explosion no mutual interaction can occur. Regarding the hazardous substances inventory for these storage depots or compartments for storage equipment, the requirements under para. (5) shall be applied.

(7) Containers for flammable liquids with a flash point lower than or equal to 55 °C may be refilled only in the following suitable areas:

a) bottling stations or emptying stations in accordance with technical standard TRGS 509,

b) storage compartments that are also certified as a bottling or emptying station in accordance with technical standard TRGS 509,

c) laboratory fume hoods designed to be protected against explosions.

### 4.2 Provision and Deployment of Flammable Liquids

(1) The provision and deployment of flammable liquids is subject to the pertinent regulations in accordance with GefStoffV and BetrSichV as well as the associated technical standards TRGS and TRBS. Supplements and additional requirements are specified in the following paragraphs.

Note:

The term deployment comprises all activities associated with processing and any other handling, not however, activities associated with storing and bottling (cf. Section 4.1).

(2) It is not admissible to provide or deploy flammable liquids that have a tendency for explosive reactions (e.g., nitromethane).

(3) In a controlled area and in areas containing equipment of the safety system as well as in areas in which an explosion could have inadmissibly adverse effects on the respectively needed function of the safety system, the provision and deployment of flammable liquids with a flash point lower than or equal to 55 °C and of liquids, the maximum working temperature of which lies over or closely (i.e., up to 5 K for pure substances and up to 15 K for mixtures) under the flash point of the liquid (cf. technical standards TRBS 2152 Part 1 / TRGS 721), shall be limited to the amount necessary for the work task over a period of 24 hours as follows:

a) The amounts provided per work place may not exceed 50 liters and, for simultaneous use, not more than10 liters at this work place; however, the overall amount deployed in a fire-fighting sub-compartment may not exceed 50 liters.

b) Work tasks with such liquids (e.g., surface treatments) shall only be performed in conjunction with the use of a technical ventilation. The effectiveness of the technical ventilation shall be demonstrated by qualified persons, e.g., using gas detectors.

c) The accumulation of a dangerously explosive atmosphere or other dangerously explosive mixtures shall be limited both in space and time by the measures specified under Section 3.1.

d) No pipe lines are admissible that carry such liquids.

(4) Outside of a laboratory, the provision and deployment specified under para. (3) is admissible only if based on a written work order. This work order shall also specify the necessary protective measures (e.g., ventilation, avoidance of ignition sources, deployment of gas detectors). In the case of multiple work places of this kind, they may not endanger each other. After work completion, the residuals of such liquids, including

waste material incorporating such liquids, shall be removed without delay.

(5) Deviating from para. (3), larger amounts may be deployed, provided, a risk assessment specific to the individual case was performed and respective protective measures were specified.

### 4.3 Gas Stations and Mobile Tank Facilities

(1) Stationary gas stations and mobile tank facilities including the associated refilling equipment shall be located more than 30 meters away from the air inlet ducts of the ventilation systems and from the entrances to, and exits from, buildings.

(2) The amount of gasoline stored on the nuclear power plant site shall be limited to 1000 liters. Deviating this requirement, larger amounts may be deployed, provided, a risk assessment specific to the individual case was performed and respective protective measures were specified.

### 4.4 Hydraulic and Lubrication Oils

Note:

Additional requirements for oil supply systems are detailed in safety standard KTA 2101.3.

(1) Oil supply systems shall be constructed and operated such that, in the case of a leakage, the occurrence of explosive mixtures of oil mists, oil vapors and oil solutions of gases with air are prevented or are at least restricted to a level such that the respectively needed function of the safety system cannot be inadmissible affected.

(2) In the case of oil supply systems with an operating overpressure less than or equal to 10 bar, the requirement specified under para. (1) is considered fulfilled if the oil is suited for the intended purpose and if the oil coast-down temperature (i.e., the oil outlet temperature seeping from the component that caused the heating up of the oil) shall not exceed 60 % of the flash point (measured in °C) of the respective oil.

(3) In the case of oil supply systems with an operating overpressure higher than 10 bar, the requirement specified under para. (1) is considered fulfilled if, in addition to the requirements specified under para. (2), the following requirements are also met:

a) In regular intervals to be specified (depending on the individual test results and the accessibility), the oils shall be analyzed with respect to their suitability. The results of these analyses shall be documented in writing.

b) In order to restrict possible leakages (from, e.g., pipes, valves), the use of screw connections and connections with plane flanges shall basically be avoided. In the case of unavoidable connections of this type, the formation of larger oil mist clouds from spray jets shall be prevented by installing shields such as baffle sheets, baffle discs or baffle pipes.

### 4.5 Storing and Bottling of Ignitable Gases

#### 4.5.1 General requirements

(1) The construction and operation of the gas depots and their distribution networks shall meet the requirements in accordance with BetrSichV and GefStoffV. The handling of ignitable gases in stationary and transportable pressure equipment is subject to the European guidelines GL 97/23/EG (PED) and GL 2010/35/EU (TPED) and the revised appendices ADR. Furthermore, the requirements in accordance with technical standards TRGS 407, TRBS 3145/TRGS 725 and TRBS 3146/TRGS 726 shall be met. The storing of ignitable gases in nonstationary pressure equipment shall meet the requirements in accordance with technical standard TRGS 510.

(2) The storage amounts for ignitable gases specified in the present safety standard apply to rooms above ground level; a storage below ground level shall meet the requirements in accordance with technical standard TRGS 510.

(3) Basically, no ignitable gases with a tendency of dangerous self-disintegration or of explosion-like reactions (e.g., the chemically instable gases listed in Table II of DGUV 100-500, Sec. 2.33) are admissible on the nuclear power plant site; the exception is acetylene, provided, it is handled as specified under Section 4.5.2, para. (8) and, for laboratories, as specified under Section 4.6.5.

Note:

Sec. 2.33 of DGUV 100-500 was retracted the end of 2004. Nevertheless, the standard is still available.

(4) Ignitable gases shall basically be stored in a central gas depot in accordance with technical standard TRGS 510 and as specified under Section 4.5.2; exceptions regarding other types of storage are specified under Section 4.5.3.

(5) The central gas depot specified under Section 4.5.2 and the other depots specified under Section 4.5.3 shall not be located in rooms in which an explosion could have inadmissibly adverse effects on the respectively needed function of the safety system.

(6) Gas depots shall not be located in the immediate vicinity of the air inlet ducts of buildings that contain equipment of the safety system.

(7) Gas supply lines shall basically not be led through rooms that contain equipment of the safety system; excepted are necessary feed lines, provided, they are designed such that the respectively needed function of the safety system cannot be inadmissible affected.

#### 4.5.2 Central gas depot

(1) All hydrogen-supply-related transportable pressure equipment shall basically be stored in the central gas depot; exceptions are the emergency supply for generator cooling (cf. Section 4.6.1) and the hydrogen supply for laboratories and workshops (cf. Section 4.5.3).

(2) Transportable pressure equipment may neither be refilled nor repaired inside the central gas depot. These tasks may be performed only in special rooms.

(3) The only ignitable gases that may be stored in the central gas depot are hydrogen, methane, propane and butane as well as acetylene and ignitable forming gases, provided, the following volumetric and other limitations are observed.

(4) The following shall be applied to storing hydrogen in pressure equipment:

Overall, no more than 5000 m³ (standard state) in transportable pressure equipment with an individual capacity of up to 50 liters.

(5) The following shall be applied to the storing of hydrogen in stationary pressure equipment:

a) Of the maximum allowed amount specified under para. (4), a maximum amount of up to 2500 m³ (standard state) may be stored in one or more spatially neighboring stationary pressure equipment.

b) The (stationary) pressure equipment shall be located at a safety distance of 50 meters away from the outer walls of buildings that contain equipment of the safety system and away from such equipment on the outside as well as from the air inlet ducts of the ventilation systems. This safety distance shall be measured from the outside wall of the pressure equipment. The same safety distance applies to the pressure vessel vehicle during the refilling process.

c) Structures with a tamping effect shall be avoided in the immediate vicinity of stationary pressure equipment.

(6) The following shall be applied to the storing of methane:

No more than 500 m³ (standard state) in transportable pressure equipment with an individual capacity of up to 50 liters.

(7) The following shall be applied to the storing of propane and butane:

No more than 220 kg (in pressurized liquid form) in transportable pressure equipment with an individual capacity of up to 30 liters.

(8) The following shall be applied to the storing of acetylene:

No more than 50 transportable pressure equipment with an individual capacity of up to 40 liters per bottle.

(9) The following shall be applied to the storing of ignitable forming gases:

No more than 100 transportable pressure equipment with an individual capacity of up to 50 liters per bottle.

#### **4.5.3** Gas depots for laboratories and workshops

(1) Gas depots may be provided for the ignitable gases in transportable pressure equipment that are needed in laboratories and workshops if this is necessary for operational reasons (e.g., long transportation routes).

(2) The requirements specified under Sections 4.5.1 and 4.5.2 shall be fulfilled.

(3) The maximum admissible number of transportable pressure equipment shall be adapted to cover the number of bottles required for one day plus needed reserves.

### **4.6** Provision and Deployment of Ignitable Gases

#### **4.6.1** Cooling system of the generator

(1) The cooling system of the generator and the associated hydrogen supply facility, aside from fulfilling the general requirements of explosion protection, need to meet the requirements under para. (13) only, if the goals laid down in Basic Principals, para. (4), of the present safety standard are inadmissibly affected.

(2) The design, construction and operation of the hydrogen supply facility including the employed components shall fulfill the requirements in accordance with BetrSichV and technical standards TRBS 2152/TRGS 720 ff as well as DIN EN 60034-3 (VDE 0530 Part 3). Soft solder shall be avoided.

Note:

Additional requirements regarding design, construction and operation of these systems are specified in VGB-S 165.

(3) The pipes and valves used in the hydrogen supply facility shall be suited for the contact with hydrogen and for the expected pressure (at least pressure stage PN 10). Cast iron valves are not admissible. If copper, brass or bronze are used for pipes and connections, any ammonia impurities in the hydrogen shall be prevented. The hydrogen supply pipe line from the central gas depot to the generator hydrogen supply system shall be designed and constructed to permanently be technically leak-proof in accordance with technical standards TRBS 2152, Part 2/ TRGS 722.

Note:

Additional requirements regarding design and construction of these pipe lines are specified in VGB-R 503 M, IGC DOC 15/06E and DGUV 113-001.

(4) No flanges shall normally be mounted in the hydrogen supply line located inside of building structures. If they are unavoidable, it shall be demonstrated that they are permanently technically leak-proof in accordance with technical standards TRBS 2152, Part 2/ TRGS 722. If this demonstration fails, the hazards shall be assessed, and respective measures taken (e.g., flushing by a sufficiently large air flow such that any possibility for the formation of a dangerously explosive atmosphere is prevented).

(5) The hydrogen discharged from the central hydrogen supply facility shall be continuously monitored by a suitable measuring equipment (e.g. a flow meter or a volumetric flow monitor); this discharge is made up of a volume of hydrogen released in an uncontrolled way and of a volume of hydrogen constantly discharged over time in a controlled way.

(6) Regarding functional safety of the hydrogen measurement function, this monitoring equipment shall comply with Safety Integration Level SIL 1 or higher. The evaluation may be performed in accordance with DIN EN 61511-1. Following the principles of that standard, the specified SIL Level may also be attained by deploying redundant service-proved components or SIL-certified components. If deployed in potentially explosive areas, the monitoring equipment shall meet the requirements in accordance with European guideline GL 2014/34/EU.

(7) The following shall be applied to monitoring:

a) Whenever an upper limit value is exceeded, the hydrogen make-up shall automatically be interrupted from outside of the turbine building.

b) The interruption shall trigger an alarm in the control room.

c) The upper limit value set point of the monitoring equipment as specified under item a) shall be created as the sum of the measured controlled release and the maximum admissible uncontrolled leakage amount of the hydrogen make-up volume from the generator and its auxiliary equipment.

d) In accordance with DIN EN 60034-3 (VDE 05030 Part 3), the maximum admissible uncontrolled leakage amount shall be specified as 18 m³ (standard state) in 24 hours.

e) The sum of the measured controlled release of hydrogen volumes shall not exceed 250 liters (standard condition) in one hour.

f) The volume required for filling or refilling hydrogen (e.g., in order to adapt the gas pressure in the generator to changed load conditions) shall not be included when determining whether the limit value specified under item a) has been met.

g) An alarm shall be triggered upon failure of the power supply of the monitoring equipment, and the failure shall be repaired without delay.

(8) Basically, in the vicinity of the generator and its auxiliary equipment, the formation of a dangerously explosive atmosphere (e.g., hydrogen/air mixture) at possible leakage points shall be prevented by flushing with a sufficiently large air flow. In the case of permanently technically sealed plant component, no release or leakage and, thus, no forming of dangerously explosive mixtures need to be assumed.

(9) The ventilation of the individual rooms of the turbine building shall be designed in accordance with DIN EN 60034-3 (VDE 0530, Part 3) observing the therein specified room-volume limits. No closed-off, unventilated hollow spaces are admissible in rooms where a hydrogen leakage can possibly occur.

(10) Electrical equipment shall be so arranged or constructed that, in case of a short circuit, neighboring equipment of the hydrogen supply will not be damaged.

(11) The following shall be applied to the emergency hydrogen supply:

a) In order to ensure the hydrogen supply to the generator, the gas losses of which during normal operation are replenished from the central hydrogen depot, it is admissible to provide a stationary installation in the turbine building for use as an emergency hydrogen supply in case of malfunctions; the necessary pressurized hydrogen cylinders shall be brought into the turbine building only when needed and, then, only temporarily.

b) In the pressurized hydrogen cylinder battery specified under item a), up to eight pressurized hydrogen cylinders with a capacity of 50 liters each may be linked to a single manifold by means of connecting elbows. However, only two of the connected pressurized hydrogen cylinders may be used simultaneously for supplying hydrogen. Free connections shall be isolated by means of high-pressure intermediate valves.

c) Whenever the generator facility is supplied from a pressurized hydrogen cylinder battery, the number of emptied bottles shall be used to check whether or not the uncontrolled release of hydrogen is larger than 18 m³ (standard state) in 24 hours. If this limit value is exceeded, the procedure to be followed shall be in accordance with DIN EN 60034-3 (VDE 0530 Part 3).

d) The replacement of pressurized hydrogen cylinders shall be documented in writing.

(12) The continuous hydrogen supply to reduce the oxygen in the cooling water of the generator windings shall be automatically interrupted outside of the turbine building whenever the amount of hydrogen make-up exceeds the nominal value by 20 %. This nominal value shall be limited to 500 liters per hour (standard state). An exceeding of this nominal value shall trigger an alarm in the control room.

(13) In case of a malfunction, the hydrogen shall rapidly be removed from the generator coolant water by remote controls (the discharge time shall normally be less than 10 min) and shall be safely released to the atmosphere (rapid $H_2$-discharge from generator). The integrity of the turbine building shall not be endangered by possible blast waves from an explosion at the $H_2$-discharge points.

### 4.6.2 Hydrogen for the recombination of oxygen

Note:

Hydrogen is used in a recombiner to reduce the oxygen present in the exhaust gas system and is also used for the gassing of the primary coolant.

(1) Supplying hydrogen to the exhaust gas system and to the primary coolant supply of pressurized and boiling water reactors and to the volume control system of pressurized water reactors shall be carried out in accordance with the pertinent rules and regulations; in particular, BetrSichV and the associated technical standard TRBS 2152 and its parts /TRGS 720 ff shall be fulfilled.

(2) The hydrogen supply lines shall be designed in accordance with DGUV 100-500, Sec. 2.33. The test pressure of the pipe lines shall be equal to 1.5 times the maximum operating pressure.

(3) Flanges shall normally not be built into the hydrogen supply lines. If they are unavoidable, it shall be demonstrated that they are permanently technically leak-proof in accordance with technical standards TRBS 2152, Part 2/ TRGS 722. If this demonstration fails, the hazards shall be assessed, and respective measures taken (e.g., flushing by a sufficiently large air flow such that any possibility for the formation of a dangerously explosive atmosphere is prevented).

(4) The hydrogen discharged from the central gas depot shall be continuously monitored within the hydrogen supply and distribution system by suitable monitoring equipment (e.g., a volumetric flow monitor). Whenever the volumetric flow of hydrogen exceeds its nominal value by 20 %, the supply shall be automatically interrupted outside of the reactor building, outside of the reactor auxiliary building or of the turbine building. However, the volumetric flow shall not be exceeded by more than 300 liters per hour. An exceeding of this aforementioned flow limits shall trigger an alarm in the control room.

(5) Regarding functional safety of the hydrogen measurement function, this monitoring equipment shall comply with Safety Integration Level SIL 1 or higher. The evaluation may be performed in accordance with DIN EN 61511-1. Following the principles of that standard, the specified SIL Level may also be attained by deploying redundant service-proved components or SIL-certified components. If deployed in potentially explosive areas, the monitoring equipment shall meet the requirements in accordance with European guideline GL 2014/34/EU.

### 4.6.3 Counter gases for the monitoring of radioactivity

(1) Gas flow counters used for measuring radioactivity shall be designed in accordance with the pertinent rules and regulations. Supplements and additional requirements are specified in the following paragraphs.

(2) The gas flow counters shall basically be operated with an argon/methane mixture in a volumetric ratio of 90 to 10 or with non-ignitable gas mixtures. Exceptions are admissible in the case of:

a) radioactivity measurements in laboratories,

b) mobile measurement devices, provided, the counter gas volume in each measurement device does not exceed

  ba) 100 liters in the case of gaseous methane (standard state),

  bb) 200 milliliters in the case of liquid propane,

  bc) 200 milliliters in the case of liquid butane.

c) mobile measurement devices for determining the tritium content of the room atmosphere, provided, they are not deployed in rooms with a free volume less than 50 m³ and the volume of the methane in the pressure equipment does not exceed 3 m³ (standard state).

d) stationary measurement devices in which, due to their location and due to the intrinsic volume limitation of the device, an explosion cannot have inadmissibly adverse effects on the respectively needed function of the safety system.

### 4.6.4 Fuel gases for welding, cutting and related work procedures

(1) The work with fuel gases shall be subject to requirements in accordance with DGUV 113-004 and DGUV 100-500, Sec. 2.26, para. 3.8. Supplemental and additional requirements are specified in the following paragraphs.

(2) When working with fuel gases in rooms with safety-related plant components and in rooms in which an explosion could have inadmissibly adverse effects on the respectively needed function of the safety system, only single cylinder units shall normally be used, the number of which shall be kept as low as necessary. Only one burner tool may be attached to a single cylinder unit. The single cylinder units shall be removed from these rooms after completion of the task or in case of a longer interruption of the task (e.g., at night).

(3) In individual cases, autogenous welding in the reactor building is admissible, provided, the corresponding work permit states the location, time and plant condition and no more than five work places are simultaneously in action.

**4.6.5** Ignitable gases and oxidizing agents in laboratories

(1) When working with ignitable gases and oxidizing agents in laboratories, the requirements in accordance with TRGS 526 shall be met. Supplements and additional requirements are specified in the following paragraphs.

Note:

Requirements regarding a fire-protective structural separation are detailed in safety standard KTA 2101.2.

(2) Laboratories shall not be located in rooms from which an explosion could have inadmissibly adverse effects on the respectively needed function of the safety system.

(3) If gases are supplied from the central gas depot specified in Section 4.5.2, the volumetric flow of ignitable gases shall be monitored by measurement equipment. Whenever the volumetric flow of ignitable gases exceeds the specified nominal value by 20 %, the supply shall be automatically interrupted.

(4) Regarding functional safety of the hydrogen measurement function, this monitoring equipment shall comply with Safety Integration Level SIL 1 or higher. The evaluation may be performed in accordance with DIN EN 61511-1. Following the principles of this standard, the specified SIL Level may also be attained by deploying redundant service-proved components or SIL-certified components. If deployed in potentially explosive areas, the monitoring equipment shall meet the requirements in accordance with European guideline GL 2014/34/EU.

**4.7** Stationary Batteries or Battery Facilities

(1) The requirements of safety standard KTA 3703 and DIN EN 50272-2 (VDE 0510-2) shall be applied to the design, construction and operation of stationary batteries or battery facilities. The following additional requirements shall be fulfilled as far as explosion protection is concerned.

(2) In battery facilities – excepted are facilities that exclusively house gastight batteries – an accumulation of dangerously explosive mixtures in the battery rooms shall be prevented by a technical (artificial) ventilation; furthermore, the danger of ignition in the direct vicinity of the hydrogen source of the batteries shall be prevented by technical and administrative measures.

(3) To ensure sufficient air circulation, the function of the air-conditioning and ventilation system shall be monitored by technical or administrative measures. In this context, the air flow shall be monitored, or at least the following measures shall be taken:

a) monitoring the branch-off circuitry for the ventilator motors in the associated switch gear,

b) monitoring the speed of belt driven ventilators at the ventilator side, and

c) periodic function test of the ventilation system.

(4) The permissible interruption time, $t_0$, of the technical (artificial) ventilation of the battery room shall be calculated from equation (4-1):

$$t_0 = \frac{V_r * f}{Q} \qquad (4\text{-}1)$$

where

$t_0$ : (in hours) – permissible interruption time in which, under the assumption of a uniform distribution, the volume fraction of hydrogen in volume, $V_r$, may increase by 0.8 % by volume.

Note:

0.8 % by volume corresponds to one fifth of the lower explosion limit of hydrogen in air.

$V_r$ : (in m³) – air volume of those room sections in which the released hydrogen can mix with air when an interruption of the technical (artificial) ventilation occurs.

Q : (in m³/h) – minimum value of the volumetric air flow, to be calculated in accordance with DIN EN 50272-2 (VDE 0510-2), Sec. 8.2, with a factor s = 5 and under consideration of the amperage, I, of the charging current.

f : numeric value 5 or 1. The numeric value, f, depends on the value of the amperage, I, of the charging current used in calculating the volumetric air flow, Q, as follows:

a) f = 5 if the value of the amperage used is in accordance with DIN EN 50272-2 (VDE 0510-2), Table 1.

b) f = 1 if the amperage used is equal to the actually existing charging current.

(5) Precautions shall be taken to ensure that within the admissible interruption time, $t_0$, as calculated from equation (4-1), the performance of effective alternative measures is possible (e.g., repair of the ventilation, construction and activation of a replacement ventilation, opening of the fire protection dampers and ventilation dampers).

(6) In the case of a charging operation with voltages above the compensating charge voltage, it shall be checked, prior to manual switching at the rectifier unit, that the ventilation system is in operation as required in accordance with KTA 3703. During such charging operation this check shall be repeated in intervals that are equal to the admissible interruption time, $t_0$, as calculated from equation (4-1) for operation at the respective charging current strength.

**4.8** Precaution Against Radiolysis Gas

(1) The possible hazards from an accumulation of radiolysis gas shall be determined within the framework of a risk assessment. This analysis of diverse effects of potential radiolysis gas reactions and of possible countermeasures shall be carried out with the goal of ensuring the necessary protective measures against damages. The risk assessment shall be performed in the following three steps:

a) All plant-specific areas with a potential for inadmissible radiolysis gas accumulations shall be systematically recorded.

b) Each of these recorded areas shall be analyzed regarding the maximum adverse effects that could result from a radiolysis gas reaction (e.g., blast waves, fragments, jet forces, reaction forces).

c) Protective measures shall be specified for each of the recorded areas. The quality requirements for these measures regarding their prevention of radiolysis reactions shall be specified according to the safety levels associated with the potential event. Passive measures shall be given preference over active measures.

(2) The systematic recording of these areas shall normally be carried out on a plant-specific basis. Experience and insight of other operating utilities shall normally be considered. Areas that are endangered with regard to radiolysis accumulations are those areas of systems

a) that during specified normal operation contain reactor coolant steam,

b) that under abnormal operating conditions will carry, or be exposed to, reactor coolant steam,

c) that border unto areas that conduct reactor coolant steam, i.e., that are separated from these areas by closed valves or inside heat exchangers (seepage of radiolysis gas in case of leakages),

d) that are directly connected to reactor coolant steam areas (e.g., feedwater tank, feedwater system, condensate system), especially, those areas where steam condensation can lead to the accumulation of radiolysis gas.

(3) The recorded system areas shall be inspected for "stagnant" media. The accumulation of radiolysis gas can be safely excluded only if turbulent flow prevails.

(4) The radiolysis gas reaction shall be assumed to occur in form of a detonation. A differing assumption is admissible, provided, it is individually certified. Due to the low limit value of the ignition energy, an ignition mechanism or ignition source shall always be assumed to be present. It shall be assumed that the radiolysis reaction will lead to loss of integrity of the component involved. A differing assumption is admissible, provided, an integrity proof is presented. This integrity proof shall take the deflagration-to-detonation transitions (DDT), the pre-compactions and reflected shock waves that may lead to higher peak pressures than the pressure of the detonation itself (Chapman-Jouguet condition) into consideration. This analysis of the maximum adverse effects shall normally encompass the effects on the plant, the systems and bordering components.

(5) Every assumed radiolysis reaction shall be correlated to a specific safety level. The measures for preventing inadmissible radiolysis gas reactions shall be specified dependent on the possible adverse effects. Examples for measures aimed at avoiding, mitigating and preventing radiolysis gas reactions are listed in the (informative) **Appendix A**. These measures may be correlated to graded quality requirements regarding safety against failure. The effectiveness of the measures introduced shall be continuously monitored and checked by inservice inspections (cf. Section 6, para. (8)).

## 4.9 Gaseous Waste Facilities (Gas Treatment Systems)

### 4.9.1 General requirements

Note:
Plant engineering measures and measure regarding monitoring and functional controls are dealt with in safety standard KTA 3605 (Treatment of Radioactively Contaminated Gases in Nuclear Power Plants with Light Water Reactors). Additional associated fire protection measures are dealt with in safety standard KTA 2101.3 (Fire Protection of Mechanical and Electrical Plant Components).

(1) Any of the possible gaseous waste sources specified in safety standard KTA 3605, Tables 3-1 and 3-2, Nos. A and B respectively, can also contain radiolysis gas. The gaseous waste facilities shall be constructed and operated such that the occurrence of explosive mixtures is prevented or at least limited to such degree that, in case of an explosion, the respectively needed function of the safety system cannot be inadmissible affected.

(2) The control equipment shall be constructed to comply with the Safety Integration Level (SIL) that corresponds to the safety significance of the equipment.

(3) Regarding functional safety of the hydrogen measurement function, this monitoring equipment shall comply with Safety Integration Level SIL 1 or higher. The evaluation may be performed in accordance with DIN EN 61511-1. Following the principles of this standard, the specified SIL Level may also be attained by deploying redundant service-proved components or SIL-certified components. If deployed in potentially explosive areas, the monitoring equipment shall meet the requirements in accordance with European guideline GL 2014/34/EU.

### 4.9.2 Boiling water reactors

(1) In case of a boiling water reactor, the radiolysis gases described in Section 4.8 are separated from the water-steam circuit, predominantly, in the condenser and are led to the gas treatment system that is directly connected to the condenser. All other gaseous waste sources with radiolysis gas (e.g., steam injection of stuffing boxes, vapor space of the feedwater tank) shall preferably be injected into the condenser. If gaseous waste sources with radiolysis gas are injected into the exhaust air facility it shall be demonstrated that the exhaust gas is not explosive anymore after being thinned down with the exhaust air.

(2) The throughput volumes of the exhaust gas shall be measured and monitored. If the actual throughput falls below the specified throughput, additional measures shall be taken to prevent the development of an explosive mixture.

### 4.9.3 Pressurized water reactors

In the case of a pressurized water reactor, the primary coolant is gassed with hydrogen; in addition, additional radiolysis gases are created. These gases are removed from the coolant in the primary coolant degasification system, in its treatment and storage systems as well as in the volume control surge tank. Therefore, the named plant components shall be connected to the gas treatment system in order to remove these gases.

## 4.10 Preventing Explosive Hydrogen Mixtures Inside the Containment Vessel

### 4.10.1 General requirements

To prevent a hydrogen explosion or a hydrogen fire inside the containment vessel during specified normal operation (levels of defense 1 and 2 in accordance with SiAnf) as well as in case of events of level of defense 3, a distance of 0.5 % by volume to the lower explosion limit of hydrogen (4.0 % by volume hydrogen in air) shall be maintained at all times. All hydrogen-creating sources shall be considered.

Notes:

1. The requirements to be considered when determining the creation and release of hydrogen in case of a loss-of-coolant accident are detailed in SiAnf, Annex 5, Appendix 1.
2. Measures against hydrogen released during event sequences that exceed design limit values are not within the scope of the present safety standard (e.g., inertisation of the containment vessel, filtered pressure relief).

### 4.10.2 Monitoring the hydrogen concentration in rooms of the containment vessel after a loss-of-coolant accident

(1) Measurement equipment shall be installed that, even under the conditions expected to prevail after a loss-of-coolant accident, a reliable chronological determination of the hydrogen distribution is ensured in the mainly concerned areas of the containment vessel. In this context, the (ambient) conditions in the containment vessel at the measurement points shall be considered (e.g., temperature, pressure, humidity).

(2) Regarding functional safety of the hydrogen measurement function, this monitoring equipment shall comply with Safety Integration Level SIL 1 or higher. The evaluation may be performed in accordance with DIN EN 61511-1. Following the principles of this standard, the specified SIL Level may also be attained by deploying redundant service-proved components or SIL-certified components.

Note:
A gas detector has Safety Integration Level SIL 1 if it is type tested and approved in accordance with DIN EN 50271 (including Section 4.8).

(3) Based on suitable analysis procedures, measurement locations shall be specified and operated that enable a reliable monitoring of the hydrogen concentration.

**4.10.3** Preventing explosive hydrogen concentrations in the containment vessel after a loss-of-coolant accident

(1) The following principles shall be applied to the measures and equipment for preventing explosive hydrogen concentrations in the containment vessel after a loss-of-coolant accident:

a) If the analyses show that hydrogen concentrations in the containment vessel may locally exceed the lower explosion limit, equipment shall be installed by which a sufficient forced mixing in the containment vessel is ensured.

b) If the analysis of the overall hydrogen concentration shows that reaching the explosion limit cannot be prevented over a long period without taking measures for the reduction of hydrogen, the following requirements shall be met:

   ba) The reduction rate of the recombination equipment shall be such that, at all times, the overall hydrogen concentration stays under the explosion limit.

   bb) The recombination equipment shall be designed such that their reliable availability and function are ensured even under the conditions expected to prevail in the containment vessel at the time when operation of this equipment is necessary.

(2) Active measures shall be actuated at the moment the hydrogen concentration reaches 3.5 % by volume. A manual actuation is admissible.

(3) Within the framework of analyzing accident mitigation, it is not admissible to consider flushing the containment vessel (i.e., feeding air into, and releasing air from, the containment vessel) as a measure for reducing the overall hydrogen concentration.

# 5 Protection Against the Penetration of Ignitable Gases and Vapors from the Outside – Deployment of Gas Warning Equipment

Note:

This section deals with the deployment of gas warning equipment as protection against ignitable gases and vapors penetrating from the outside (cf. GL Blast Waves). However, the questions as to when and under what conditions their deployment will become necessary are not dealt with in the present safety standard.

(1) If ignitable gases and vapors set free outside of the nuclear power plant site have to be prevented from penetrating into the buildings via the ventilation system, then measures in accordance with TRBS 2152 Part 2 / TRGS 722 shall be taken. Supplements and additional requirements are specified in the following paragraphs.

(2) A gas warning equipment shall be deployed.

(3) The gas warning equipment shall be chosen in accordance with of TRBS 2152, Part 2 / TRGS 722 Sec. 2.5.1, para. (3), regarding the suitability of its functional measurement capability and functional safety under the expected deployment conditions. The gas warning equipment shall be type tested and approved for the measurement function and the functional safety for each gas to be detected in accordance with European guideline GL 2014/34/EU, Equipment Group II, Category 1 or 2. With regard to functional safety it can, therefore, be assumed that the gas warning equipment (the gas detectors) corresponds to at least Safety Integration Level SIL 1; the classification of the entire gas warning equipment (e.g., due to redundant design, to automatic measures) shall be specified on a plant-specific basis.

Note:

A gas detector has Safety Integration Level SIL 1 if it is type tested and approved in accordance with DIN EN 50271 (including Section 4.8).

(4) The measuring detectors of the gas warning equipment shall be located such that a timely alarming and triggering of switching measures can occur. This means that the measuring detectors shall be located either directly in front of the inlet opening of the air supply duct or at a suitable distance even as far away as the plant site security fence.

(5) The decisive factors regarding the timely alarming and triggering of the switching measures are:

a) the distance of the gas path, $s_G$, between the location of the measuring detector and the location of the first effective isolation device of the ventilation system in the building to be protected,

b) the time span, $t_G$, required by the gas/air mixture to travel along the gas path, $s_G$,

c) the time span, $t_S$, between triggering the gas alarm and isolation of the ventilation system,

d) the adjustment time, $t_x$, i.e., the time span between the occurrence of a sudden change from clean air to test gas or vice versa at the gas detector input and the time when the specified portion, x, of the maximum display is reached for the test gas. The x corresponds to the value of the alarm threshold (% of lower explosion limit (UEG)) specified in para. (7). The adjustment time of the respective measuring component used shall be the one specified by the manufacturer of the gas detector. In case more than one ignitable gas is involved, the safety analysis shall be based on the longest adjustment time.

(6) The sum of time span, $t_S$, and adjustment time, $t_x$, of the gas warning equipment shall be compared to the time span, $t_G$. The following relation shall be fulfilled:

$$t_x + t_S \le t_G \qquad (6\text{-}1)$$

(7) The alarm thresholds of the gas warning equipment shall basically be adjusted to a value between 10 % and 20 % of the lower explosion limit (UEG) of the gas mixture to be expected. With regard to specific applications, these alarm thresholds shall be set, on one hand, to be low enough that, when exceeded, the respective protective measure will early on become effective. On the other hand, the setting shall be high enough to avoid false alarms. If the adjustment time, $t_x$, of the gas warning equipment was certified in a safety report as $t_{30}$ or $t_{40}$, it is admissible to set the alarm thresholds to the values 30 % or 40 % of the lower explosion limit (UEG). In these cases, the value $t_x$ in relation (6-1) shall be replaced by $t_{30}$ or $t_{40}$.

(8) Switching measures that are executed to interrupt the air supply to the building to be protected shall be triggered whenever a gas alarm is triggered from at least two separate measurement detectors.

# 6 Tests and Inspections

Notes:

1. Requirements regarding the quality of testing measures are detailed in safety standard KTA 1401.
2. Requirements regarding the testing manual are detailed in safety standard KTA 1202.

(1) The tests and inspections of work materials and technical measures in potentially explosive areas to be performed prior to commissioning and after modifications requiring testing as well as the inservice inspections shall be carried out in accordance with BetrSichV.

(2) Explosion-protected equipment and protective systems as well as safety, surveillance and control devices in accordance with European guideline GL 2014/34/EU that are intended for use in dangerously explosive atmospheres are systems to be

monitored and to be inspected in accordance with BetrSichV. TRBS 1201, Part 1, shall be observed.

(3) In accordance with BetrSichV, it shall be checked whether the tests and inspections prior to commissioning or after a modification requiring testing must be performed by an Approved Inspection Agency (ZÜS).

(4) Equipment and protective systems as well as safety, surveillance and control devices that are deployed in regions where other explosive mixtures (e.g., radiolysis gas) can occur shall be subjected by the operating utility under its own responsibility to inservice inspections with special regard to their orderly condition. The same applies to repairs.

(5) Commissioning tests and inservice inspections of gas treatment systems shall be performed as specified in safety standard KTA 3605, Tables 6-1 and 6-2.

(6) In addition to the testing requirements in accordance with BetrSichV, the following items shall be tested and inspected in intervals to be specified by the operating utility:

a) the storage depots and provision locations for substances that can generate other dangerously explosive mixtures (e.g., chemical depots with epoxy resins) – to be tested and inspected for their orderly condition,

b) the gas warning equipment in accordance with BGI 518 with explosion protection functions that are located outside of explosion-endangered areas – to be tested, e.g., for compliance with Section 5, and

c) the gas detectors with explosion protection functions that are located outside of explosion-endangered areas (e.g., for monitoring the hydrogen volume flow from the central hydrogen supply facility) – to be tested and inspected for their orderly condition and functional capability.

(7) In individual cases, exceptions to existing legal provisions regarding the construction and operation of facilities requiring tests and inspections subject to ProdSG may be declared by the licensing authorities in accordance with AtG, Sec. 8, para. (3).

(8) Inservice inspections shall be specified that demonstrate the sustained effectiveness of the measures specified in Section 4.8 for the prevention of radiolysis gas reactions (e.g., tests of the catalysts).

## 7 Instructions

All persons handling substances on the nuclear power plant site that can generate an explosive atmosphere or other explosive mixtures or who work, or are present, in potentially explosive areas shall be properly instructed regarding the specific aspects of explosion protection.

Note:

Additional information regarding maintaining the knowledge of the competent persons are detailed in BetrSichV and in TRBS 1203.

## 8 Documentation

The documentation shall contain written reports on:

a) the results of the explosion risk assessments performed for the protection of the function of the safety system (i.e., risk assessment and explosion protection documentation in accordance with BetrSichV and GefStoffV) including the protective measures applied,

b) the results of the tests and inspection specified under Section 6, and

c) the instructions specified under Section 7.

## Appendix A (informative)

### Example Table for Radiolysis Gas Precaution

| Measures | For Avoiding, Mitigating and Preventing Events at the Levels of Defense: |
|---|---|
| Regular manually operated flushings; effectiveness monitoring by continuous temperature measurements that trigger alarms when limits are exceeded or failures occur. | 1 / 2 |
| Catalyst or thermally controlled venting; monitoring the effectiveness by discontinuous measurements is admissible. | 1 / 2 |
| Flushing line with valves; valve interlocks in the open position; valve position check before startup; effectiveness test by measurements during startup. | 1 / 2 |
| Catalyst; effectiveness monitoring by continuous temperature measurements that trigger alarms when limits are exceeded or failures occur. | 3 |
| Operational measurements to prove that an accumulation is prevented by physical effects (e.g., convection, diffusion, gas transport in the condensate); effectiveness monitoring by continuous temperature measurements that trigger alarms when limits are exceeded or failures occur. | 3 |
| Flushing line with valves; valve interlocks in the open position; valve position check before startup; effectiveness test by continuous measurements during operation. | 3 |
| Structural protective measures that reduce the effects to a lower level of defense | 3 |

**Table A-1:** Examples for measures with the objective of avoiding, mitigating and preventing radiolysis gas reactions

Note:

Table 4-1 is an extract of the RSK-Recommendation of July 10, 2003; the recommendation contains additional information and requirements for precautionary measures against radiolysis gas, also with regard to the level of defense 4.

## Appendix B

## Regulations Referred to in the Present Safety Standard

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

| | | |
|---|---|---|
| AtG | | Act on the peaceful utilization of atomic energy and the protection against its hazards (Atomic Energy Act – AtG) of December 23, 1959, revised version of July 15, 1985 (BGBl. I, p. 1565), most recently changed by Article 307 of the Act of August 31, 2015 (BGBl. I 2015, No. 35, p. 1474) |
| ProdSG | | Act on the provision and marketing of products (Product Safety Act – ProdSG), of November 11, 2011 |
| SprengG | | Act on explosive substances (Explosive Substances Act – SprengG) of September 13, 1976 (BGBl. I, p. 2737), revised version made public April 17,1986, most recently changed by the Act July 23, 1998 (BGBl. I, p. 1530) |
| StrlSchV | | Ordinance on the protection from damage by ionizing radiation (Radiological Protection Ordinance – StrlSchV) of July 20, 2001 (BGBl. I, p. 1714; 2002 I, p. 1459), most recently changed by Article 5 of the Act of December 11, 2014 (BGBl. I, p. 2010) |
| BetrSichV | | Ordinance on the safety and health protection when using work materials (Industrial Safety Ordinance – BetrSichV) of February 3, 2015 (BGBl. I, p. 49) |
| GefStoffV | | Ordinance on the protection from Hazardous Substances (Hazardous Substances Ordinance – GefStoffV), of November 26, 2010 (BGBl. I, p. 1643), most recently changed by Article 2 of the Ordinance of February 3, 2015 (BGBl. I, p. 49) |
| GGVSEB | | Ordinance on the transport of dangerous goods by road, rail and inland waterways (GGVSEB), of June 17, 2009 (BGBl. I, p. 1389) most recently changed by Article 1 of the Ordinance of March 4, 2011 (BGBl. I, p. 347) |
| $11^{th}$ProdSV | | Eleventh ordinance regarding the Product Safety Act (Explosion Protection Ordinance – $11^{th}$ ProdSV), Article 21 of the Act on Reforming the Equipment and Product Safety Law of November 8, 2011, (BGBl. I, No. 57, p. 2178) |
| EG 1272/2008 (CLP-VO) | | Regulation (EC) No. 1272/2008 of the European parliament and of the council of December 16, 2008, on classification, labelling and packaging of substances and mixtures (CLP-VO) |
| SiAnf | (2015-03) | Safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B2) |
| SiAnf-Interpretations | (2015-03) | Interpretations of the safety requirements for nuclear power plants of November 22, 2012, revised version of March 3, 2015 (BAnz AT of March 30, 2015 B3) |
| KTA 1202 | (2009-11) | Requirements for the Testing Manual |
| KTA 1401 | (2013-11) | General Requirements Regarding Quality Assurance |
| KTA 2101.1 | (2015-11) | Fire Protection in Nuclear Power Plants; Part 1: Basic Requirements |
| KTA 2101.2 | (2015-11) | Fire Protection in Nuclear Power Plants; Part 2: Fire Protection of Structural Components |
| KTA 2101.3 | (2015-11) | Fire Protection in Nuclear Power Plants;<br>Part 3: Fire Protection of Mechanical and Electrical Plant Components |
| KTA 2206 | (2009-11) | Design of Nuclear Power Plants Against Damaging Effects from Lightning |
| KTA 3605 | (2012-11) | Treatment of Radioactively Contaminated Gases in Nuclear Power Plants with Light Water Reactors |
| KTA 3703 | (2012-11) | Emergency Power Facilities with Batteries and AC/DC Converters in Nuclear Power Plants |
| EG 1272/2008 (CLP-VO) | (2008-12) | Regulation (EC) No. 1272/2008 of the European parliament and of the council of December 16, 2008, on classification, labelling and packaging of substances and mixtures (CLP-VO) |

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| ADR | (2013-01) | Appendix of the publication of the Appendices A and B of the European agreement of September 30, 1957 on the international transportation of dangerous goods by road (ADR) in the version of January 1, 2013 |
| BGL 518 (T023) | (2012-04) | German Social Accident Insurance (DGUV), Trade Union Information: Gas detectors for explosion protection – Deployment and operation |
| DGUV 113-001 (prev.: BGR 104) | (2014-03) | German Social Accident Insurance (DGUV) (previous Trade Union Standard): Explosion protection standards (EX-RL); Collection of technical standards for the prevention of hazards from explosive atmospheres, including collection of examples for the classification of the hazardous areas into zones |
| DGUV 113-004 (prev.: BGR 117-1) | (2008-09) | German Social Accident Insurance (DGUV) (previous Trade Union Standard): Vessels, silos and narrow spaces; Part 1: Working in vessels, silos and narrow spaces |
| DGUV 100-500 (prev.: BGR 500) | (2008-04) | German Social Accident Insurance (DGUV) (previous Trade Union Standard): Operating with work materials |
| IGC DOC 15/06E | (2006) | European Industrial Gases Association AISBL Gaseous hydrogen stations; Revision of Doc 15/96 and Doc 15/05 |
| DIN EN 50271 | (2011-04) | Electrical apparatus for the detection and measurement of combustible gases, toxic gases or oxygen - Requirements and tests for apparatus using software and/or digital technologies; German version prEN 50271:2010 |
| DIN EN 50272-2 (VDE 0510 Part 2) | (2001-12) | Safety requirements for secondary batteries and battery installations - Part 2: Stationary batteries; German version EN 50272-2:2001 |
| DIN EN 60034-3 (VDE 0530 Part 3) | (2009-03) | Rotating electrical machines - Part 3: Specific requirements for synchronous generators driven by steam turbines or combustion gas turbines and for synchronous compensators (IEC 60034-3:2007); German version EN 60034-3:2008 |
| DIN EN 60079-10-1 (VDE 0165) | (2014-11) | Explosive atmospheres - Part 10-1: Classification of areas - Explosive gas atmospheres (IEC 31J/234/CDV:2014); German version FprEN 60079:2014 |
| DIN EN 61511-1 (VDE 0810 Part 1) | (2005-05) | Functional safety - Safely instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and software requirements (IEC 61511-1:2003 + Corrigendum 2004); German version EN 61511-1:2004 |
| GL Blast Waves | (1976-08) | Guideline for the protection of nuclear power plants against pressure waves from chemical reactions by means of the design of nuclear power plants with regard to strength and induced vibrations and by means of the adherence to safety distances; made public by BMI on August 1, 1976 (RS I 4 – 513 145/1 - (GMBl. S. 442)) |
| GL SEWD LWR | (1995-12) | Guideline for the protection of nuclear power plants with light-water reactors against disruptive actions or other interference by third parties (SEWD RL LWR) ; made public by BMU on December 6, 1995 (RS I 3 – 513 13151 - 6/14 VS-nfD) |
| GL 2010/35/EU (TPED) | (2010-06) | Directive 2010/35/EU of the European Parliament and of the Council of June 16, 2010 on transportable pressure equipment (TPED) |
| GL 97/23/EG (PED) | (1997-05) | Directive 97/23/EU of the European Parliament and of the Council of May 29, 1997 on pressure equipment (PED) |
| GL 2014/34/EU | (2014-02) | Directive 2014/34/EU of the European Parliament and of the Council of February 26, 2014 on the harmonisation of the laws of the Member States relating to equipment and protective systems intended for use in potentially explosive atmospheres |
| RSK-Recommendation | (2003-07) | Recommendation of Reactor Safety Commission, 364th RSK Session on July 10,2003: General requirements for measures to prevent inadmissible radiolysis gas reactions |
| TRBS 1111 | (2006-12) | Technical Standards for Operating Safety; Hazard assessment and safety related evaluation (BAnz No. 232a, p. 7, of December 1, 2006) |
| TRBS 1112 | (2010-10) | Technical Standards for Operating Safety; Maintenance (GMBl. 2010, No. 60, p. 1219, of October 14, 2010) |
| TRBS 1112 Part 1 | (2010-05) | Technical Standards for Operating Safety; Risk of an explosion during and from maintenance tasks – Assessment and protective measures (GMBl. 2010, No. 29, p. 615, of May 12, 2010) |

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| TRBS 1201 | (2012-08) | Technical Standards for Operating Safety;<br>Test and examination of work material and of systems to be monitored (BAnz No. 232a, p. 11, of December 9, 2006), the revised version of August 2012 (GMBl. 2012, No. 45, p. 864, of October 17, 2012) |
| TRBS 1201 Part 1 | (2006-09) | Technical Standards for Operating Safety / Technical Standards for Hazardous Substances;<br>Tests and inspections of plants in potentially explosive areas and checking work places in potentially explosive areas, of September 2006 (BAnz No. 232a, p. 20 of December 12, 2006) |
| TRBS 1203 | (2012-04) | Technical Standards for Operating Safety;<br>Competent persons (GMBl. 2010, No. 29, p. 627), the revised version of April 2012 (GMBl. 2012, No. 21, p. 386) |
| TRBS 2152 /<br>TRGS 720 | (2006-03) | Technical Standards for Operating Safety (TRBS)/ Technical Standards for Hazardous Substances (TRGS);<br>Dangerously explosive atmosphere; General requirements, of March 2006 (BAnz No. 103, p. 4, of June 2, 2006) |
| TRBS 2152 Part 1 /<br>TRGS 721 | (2006-03) | Technical Standards for Operating Safety (TRBS)/ Technical Standards for Hazardous Substances (TRGS);<br>Dangerously explosive atmosphere; Assessment of the explosion risk, of March 2006 (BAnz No. 103, p. 8, of June 2, 2006) |
| TRBS 2152 Part 2 /<br>TRGS 722 | (2012-05) | Technical Standards for Operating Safety (TRBS)/ Technical Standards for Hazardous Substances (TRGS);<br>Preventing or limiting dangerously explosive atmosphere, of March 2006 (BAnz No. 103, p. 11, of June 2, 2006), the revised version of May 2012 (GMBl. 2012, No. 22, p. 398) |
| TRBS 2152 Part 3 | (2009-11) | Technical Standards for Operating Safety;<br>Dangerously explosive atmosphere; Preventing the ignition of a dangerously explosive atmosphere, of November 2009 (GMBl. 2009, No. 77, p. 1583) |
| TRBS 2152 Part 4 | (2012-04) | Technical Standards for Operating Safety;<br>Measures of structural explosion protection limiting the effects of an explosion to an extent that they can be considered as harmless – Dangerously explosive atmosphere, of April 2012 (GMBl. 2012, No. 21, p. 387) |
| TRBS 3145 /<br>TRGS 725 | (2013-06) | Technical Standards for Operating Safety / Technical Standards for Hazardous Substances;<br>Transportable compressed-gas containers – filling, storing, plant-internal transport, emptying, of June 2013 (GMBl. 2013, No. 41/42, p. 803) |
| TRBS 3146 /<br>TRGS 726 | (2014-04) | Technical Standards for Operating Safety / Technical Standards for Hazardous Substances;<br>Stationary pressure equipment for gasses, of April 2014 (GMBl. 2014, No. 28/29, p. 606) |
| TRGS 407 | (2013-06) | Technical Standards for Hazardous Substances;<br>Handling of gasses – Risk assessment (GMBl. 2013, No. 41/42, p. 814-844), the revised version of June 2013 (GMBl. 2013, No. 63, p. 1263) |
| TRGS 509 | (2014-09) | Technical Standards for Hazardous Substances;<br>Storing of liquid and solid hazardous substances in stationary containers as well as filling and emptying facilities of transportable containers, of September 2014 (GMBl. 2014, No. 66/67, p. 1346-1400) |
| TRGS 510 | (2013-01) | Technical Standards for Hazardous Substances;<br>Storing hazardous substances in transportable containers, of January 2013 (GMBl. 2013, No. 22, p. 446, of May 15, 2013), in the revised version of November 2014 (GMBl. 2014, No. 65, p. 1346) |
| TRGS 526 | (2008-02) | Technical Association for Generation and Storage of Power and Heat (VGB Power Tech), Standard;<br>Laboratories |
| VGB-S 165 | (2014-07) | Technical Association for Generation and Storage of Power and Heat (VGB Power Tech), Standard;<br>Recommendations for the improvement of H2 safety in hydrogen-cooled generators |
| VGB-R 503 M | (2002-09) | Technical Association for Generation and Storage of Power and Heat (VGB Power Tech);<br>Guideline for the internal piping of the turbine generator |