Guidelines for prevention of dust explosions during the extraction and processing of sugar
Notes:
The text and illustrations in this publication have been prepared with care. No responsibility can be accepted in the event of errors. The regulations of the competent state agencies and the prevention division of the trade associations shall always ultimately prevail in individual cases.

The dissemination of the guidelines for planning and training purposes is permitted and encouraged.

The guidelines are also available in electronic format.
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1 Introduction

These guidelines has been prepared by a working group set up by BG Rohstoffe und chemische Industrie (BG RCI – the trade association for the raw material and chemical industry), together with representatives from the sugar industry and BG Nahrungsmittel und Gastgewerbe (BGN – the trade association for the food and hospitality industry). They take into account the findings from many sugar dust explosions in Germany and abroad, research on dust explosions and the requirements for explosion-protection measures arising from government and trade association regulations and other recognised codes of practice.

This compilation should aid planners, manufacturers and operators of machines and installations for the sugar industry in assessing the risks of a dust explosion and in selecting appropriate explosion-protection measures.

NB: for the marketing of equipment and protective systems within the meaning of Directive 94/9/EC, a conformity assessment procedure is to be carried out in accordance with the directive. These guidelines provide assistance for assessment, but cannot replace the procedure.

These guidelines cover the explosion hazards of sugar, chip and pellet dust.

These guidelines do not claim to offer simple solutions for all cases in practice. Rather, they are intended to illustrate the system for the assessment of hazards and the estimation of risks and to identify new approaches for protection concepts. Where there is sufficient evidence for valid generalisations regarding the protection measures, this will be taken into account.
2 Fundamental considerations

For the sugar industry, dust-explosion protection is a basic requirement for the safe operation of sugar-manufacturing production plants. Explosion events often have serious consequences for the plants and the employees directly or indirectly concerned. Therefore, special importance must be attached to this aspect of preventive occupational safety. Furthermore, the old adage holds in this area: that shortcomings in the planning phase will have to be made good at a later date, and will require a much larger financial outlay and more human resources. The legal conception of safety at work in Germany also takes account of this knowledge.

Explosion protection is largely regulated in Germany through the following regulations:

The explosion protection ordinance (11th ProdSV) regulates the marketing of equipment, protective systems, components and safety, control and regulating devices for potentially explosive areas and contains quality requirements that must be met by the manufacturer. The legal basis of the Explosion protection ordinance is the Product Safety Act (ProdSG). /401/ 

The industrial safety ordinance (BetrSichV) regulates, inter alia, the provision and use of work equipment, such as equipment and protective systems intended for use in potentially explosive areas and primarily contains regulatory information that must be complied with by the employer and/or operator. The legal basis of the industrial safety ordinance is the occupational safety and health act (ArbSchG). /402/ 

In addition to these: the supplementary provisions on explosion protection in the ordinance on hazardous substances (GefstoffV). /404/

The explosion protection rules – EX-RL, a collection of technical rules for avoiding the dangers from explosive atmospheres with a collection of examples for classification of potentially explosive areas into zones (BGR 104) include, among other things, the following technical regulations for workplace safety:

TRBS 1112 "Maintenance"

TRBS 1112 Part 1 “Explosion hazards arising during and through maintenance work – reviews and protection measures

TRBS 1201 "Inspection of work equipment and plant requiring monitoring"1

TRBS 1201 Part 1 "Inspection of equipment in potentially explosive areas and verification of work stations in potentially explosive areas"

TRBS 1201 Part 3 “Repair of equipment; protective systems; safety, control and regulating devices within the meaning of Directive 94/9/EC – determination of inspection requirement according to Section 14(6) BetrSichV".

TRBS 2152 / TRGS 720 "Dangerous, explosive atmospheres - General"

1 The term "plant requiring monitoring" is a special feature of the legislation of the Federal Republic of Germany.
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TRBS 2152 Part 1 / TRGS 721 "Dangerous, explosive atmospheres - Assessment of the explosion hazard"

TRBS 2152 Part 2 / TRGS 722 “Prevention or limitation of dangerous, explosive atmospheres"

TRBS 2152 Part 3 "Dangerous, explosive atmospheres – Avoidance of ignition of dangerous, explosive atmospheres"

TRBS 2152 Part 4 "Dangerous, explosive atmospheres – Measures for the constructional protection from explosion, which limit the effects of an explosion to a safe level"

TRBS 2153 "Prevention of ignition hazards arising from electrostatic charges"

Further documents such as the technical rules for hazardous substances (German acronym: TRGS), trade association regulations (German acronym: BGR), trade association principles (German acronym: BGG) and trade association information (German acronym: BGI), serve to substantiate the requirements imposed.
3 Prerequisites for a dust explosion

The following conditions must be met for a dust explosion to occur:

- combustible (exothermically oxidisable) dust of sufficient fineness
- sufficient oxygen (generally in the form of atmospheric oxygen present in the air)
- a concentration of dust in air within the explosion limits
- an effective ignition source

All of these requirements must be met at the same time and in the same place.

Then and only then will a dust explosion occur.

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zündquelle</td>
<td>ignition source</td>
</tr>
<tr>
<td>Gemischbildung</td>
<td>mixture formation</td>
</tr>
<tr>
<td>Brennbarer Stoff</td>
<td>combustible material</td>
</tr>
<tr>
<td>(Luft-)Sauerstoff</td>
<td>(atmospheric) oxygen</td>
</tr>
</tbody>
</table>

The impact of an explosion depends mainly on

- the characteristic values of the dust,
- the expansion and turbulence of the dust cloud,
- the technical design of the equipment and
- the existing spatial conditions, such as the dimensions, relief areas, connections to other areas.
4 Definition and classification of zones

4.1 Definitions
Areas in which the occurrence of dangerous, explosive atmospheres can be expected (abbreviation: DEA), are deemed to be "potentially explosive areas". They are divided into zones according to the probability of the presence of explosive atmospheres.

“Normal operation” is the state whereby the equipment or plant and their devices are used or operated within their design parameters.²

Inspection and maintenance and the release of small quantities of flammable substances, e.g. in the case of customary disruptions (such as a bag slipping away from a filling device) may fall within “normal operation”.

Disruptions such as the failure of seals, pumps or flanges or the release of substances as a result of accidents, where this requires, for example repair or shutdown, are not considered to fall within “normal operation”.

Directive 1999/92/EC describes the following zones for dust explosion protection:

Zone 20
“A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequently.”

Note:
The term "frequently" is to be used in the sense of "predominant in terms of time". The unit to be considered here is the actual operating lifetime of the plant. Potentially explosive areas are assigned to Zone 20 if an explosive atmosphere prevails³ for more than 50% of the time during the operational life of the plant in or a plant component. These conditions generally occur only inside containers, aspiration lines, equipment, etc. /103/

Zone 21
“A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.”

Note:
The term "occasionally" is to be used in the sense of "not significantly predominant in terms of time". If the presence of an explosive atmosphere exceeds approximately 30 minutes in duration or if this occurs occasionally, e.g. daily, but less than 50% of the operating life of the plant, then the zone is assigned as a Zone 21. These conditions may arise for example in the event of controlled start-up or shut-down operations, the filling of storage silos or in the interior of screw conveyors.⁴

² TRBS 2152 Section 2.1 (2)
³ Kompendium Explosionsschutz 5.1.2
⁴ Kompendium Explosionsschutz 5.1.4
Zone 22

“A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.”

Note:
There is general consensus among many experts that the term "short period" is a period of about 30 minutes and corresponds to an explosive atmosphere generally not expected in normal operation or only a few times per year.5 These include areas with dust deposits that may form a dangerous, explosive atmosphere when dispersed.6

4.2 Examples of zone classification
Experience has shown that dangerous, explosive atmospheres can be expected in the following, for example:

continuously, for long period or frequently (Zone 20)
- in dust extractors on the raw gas side,
- in powder mills: in the mill itself and in the mills’ auxiliary hoppers,
- in powder-conditioning plants,

occasionally (Zone 21)
- in screening machines,
- in elevators,
- in graded hoppers for fine sugar (<250 μm)
- in powder and dust screws with higher peripheral speeds (v > 1 m/s)

not generally or for a short period only (Zone 22)
- in granulated sugar silos,
- in graded hoppers for coarse sugar (> 250 μm)
- in low-speed powder and dust screws (v < 1 m/s)
- in sugar dryers (granulated sugar)
- in fluidised bed dryers (granulated sugar)

5 Kompendium Explosionsschutz 5.1.3 and IVSS brochure “Gefährdungen durch Explosionen” p.8
6 Kompendium Explosionsschutz 5.1.3
• in areas with significant dust deposits, e.g. in the vicinity of open conveyor belt systems (silo cellar)

In all cases it is important to take account of the special problems caused by deposited dust.

• Deposited dust is a constant source of potential dust clouds. A dust deposit of less than 1 mm thickness, distributed uniformly over the entire floor area is sufficient to completely fill a space of normal height with an explosive dust/air mixture during dispersal. As a result of the first explosion, deposited dust may be dispersed and cause secondary explosions. With regard to the risk assessment, this is particularly important because explosive dust/air mixtures and effective sources of ignition occur in this case at the same time.

• Thicker layers of deposited dust on energy-converting operating resources (e.g. cooling fins of the engine no longer visible) lead to various effects due to the insulating properties of the dust (e.g. temperature increase of the resources in question), which may give rise to effective ignition sources where "dust-free" situations would not.

• Because of sugar’s low melting point, the possibility of the formation of smouldering objects is only very minor.

Notes:

Sugar dust is generated in the production process during the milling of granulated sugar into sugar powder in powder mills, as well as sometimes being generated undesirably, e.g. through abrasion during the transportation of sugar.

The release of dust or an enrichment of this type occurs primarily through separation and sifting processes when moving and handling sugar

• at transfer points on conveyor routes,

• in silos and hoppers when loading and unloading and

• in elevators.

NB:

The above list of examples is not exhaustive and is for guidance only. Consideration is to be given on a case-by-case basis.
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5 Selection of equipment and protective systems

The correct choice of equipment, protective systems, components and safety, control and regulating devices is a prerequisite for the implementation of explosion protection. A permanent prerequisite is that the equipment and protective systems are used as intended.

Directive 94/9/EC of the European Parliament and of the Council concerning equipment and protective systems intended for use in potentially explosive areas regulates the marketing of equipment, protective systems, components and safety, control and regulating devices for potentially explosive areas and contains quality requirements to be met by the manufacturer. In this respect, the manufacturer must comply with the essential health and safety requirements relating to the design and construction contained in Annex II to Directive 94/9/EC.

The Product Safety Act (ProdSG) implements Directive 94/9/EC, along with the 11th ProdSV (explosion protection ordinance).

For more information, please refer to BGN's "Action guidelines regarding machine and plant safety".
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Products (as per 11th ProdSV) | Essential safety requirements | Ex-marking | CE-marking | Declaration of conformity | Manufacturer's declaration | Operating instructions
--- | --- | --- | --- | --- | --- | ---
Equipment | X | X | X | X | | X
Protective systems | X | X | X | X | | X
Safety devices | X | X | X | X | |
Control devices | X | X | X | X | |
Regulating devices | X | X | X | X | | X
Components | | | | | | X

Fig. 1: Formal and technological prerequisites

According to the explosion protection ordinance (11th ProdSV), the equipment and protective systems intended for use in areas with a potential for a dust explosion are assigned to Equipment Group II in the sugar-extracting and processing industry. Depending on the operating conditions (intended use), the equipment is divided into three categories.

<table>
<thead>
<tr>
<th>Usable equipment with marking</th>
<th>Suitable for</th>
<th>In Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>II 1 G</td>
<td>Gas/air mixture or vapour/air mixture or mist</td>
<td>0</td>
</tr>
<tr>
<td>II 1 G or 2 G</td>
<td>Gas/air mixture or vapour/air mixture or mist</td>
<td>1</td>
</tr>
<tr>
<td>II 1 G or 2 G or 3 G</td>
<td>Gas/air mixture or vapour/air mixture or mist</td>
<td>2</td>
</tr>
<tr>
<td>II 1 D</td>
<td>Dust/air mixture</td>
<td>20</td>
</tr>
<tr>
<td>II 1 D or 2 D</td>
<td>Dust/air mixture</td>
<td>21</td>
</tr>
<tr>
<td>II 1 D or 2 D or 3 D</td>
<td>Dust/air mixture</td>
<td>22</td>
</tr>
</tbody>
</table>

Fig. 2: Equipment category assignment – zones
**Category 1D:**

This includes equipment designed such that it can be operated in accordance with the parameters established by the manufacturer and ensuring a very high level of safety. Equipment in this category is intended for use in areas where an explosive atmosphere is present continuously or for long periods or frequently (in the case of dust, this corresponds to Zone 20).

Equipment in this category must itself ensure the required level of safety in the rare instances of the equipment malfunctioning. It exhibits explosion-protection measures such that in the event of the failure of one means of protection, at least one independent second protection measure will guarantee the requisite safety or, in the case of two independent malfunctions occurring, the requisite safety is guaranteed.

**Category 2D:**

This includes equipment designed such that it can be operated in accordance with the parameters established by the manufacturer and ensuring a high degree of safety. Equipment in this category is intended for use in areas where it is expected that an explosive atmosphere occurs occasionally (in the case of dust, this corresponds to Zone 21).

The constructional explosion-protection measures within this Category guarantee the required level of safety, even with frequent equipment malfunctions or error conditions which are normally to be expected.

**Category 3D:**

This includes equipment designed such that it can be operated in accordance with the parameters established by the manufacturer and ensuring a normal degree of safety. Equipment in this category is intended for use in areas where it is not expected that an explosive atmosphere will occur; if it does in fact occur, it will in all probability occur only rarely and for a short period (in the case of dust, this corresponds to Zone 22).

Equipment in this category ensures the requisite degree of safety during normal operation.

In the sugar industry, old equipment is often still used which was originally intended for use in the former Zones 10 and 11 (or in potentially gas-explosive Zones 0, 1 or 2). Such equipment may still be used normally, unless retrofit needs have been identified as part of the risk assessment.⁷ The suitability of the equipment must be substantiated in the explosion protection document.

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⁷ See also “Kriterien zur Weiterverwendung älterer elektrischer Betriebsmittel gemäß Betriebssicherheitsverordnung” by M. Wittler, Bochum (VDI report no. 1873, 2005).
6 Risk assessment

As required by the industrial safety ordinance (BetrSichV), the employer (who in general is also the operator of the plant in which the occurrence of an explosive atmosphere is to be expected) shall conduct a risk assessment for the evaluation of explosion risks, and on the basis of this, determine the protection measures necessary to guarantee the safety of its employees. These requirements must be considered both when planning a new plant and when an existing plant is modified. ⁸

The "query flowchart for detecting and avoiding explosion risks" has proven to be a suitable tool for the assessment of risk in explosion protection." ⁹

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² TRBS 1111
⁹ TRBS 2152, page 9, Figure 1
Thus, the following questions, relating to the interior and the exterior of plants, must be answered in the given order:

**Are flammable substances present, or could they be formed?**

It must be determined by the employer whether sugar dust is present in the operation or whether it could be formed as a result of the operation, e.g. by dust extractors on the raw gas side, or in sugar powder conditioning facilities.

In this respect, the production steps (for example) in which the sugar is subjected to mechanical stress and leads to grain destruction are to be considered. This is often the case in screw conveyors and elevators, in screening machines, at transfer points of belt conveyors and at the outlet openings of hoppers and silos.

**Notes:**

*Detailed information also contained in TRBS 2152 Part 1. /504/*

⇒ If this question be safely answered in the negative, no explosion protection is required; otherwise, the following question must be answered.
Can an explosive atmosphere arise through sufficient distribution of the dust in the air?

Firstly, an estimation of sources and amounts of explosive atmospheres consisting of sugar dust is required.

It is important to check whether the dust is stirred up or can be so finely dispersed that the formation of explosive atmospheres can be expected.

**Notes:**

*Detailed information also contained in TRBS 2152 Part 2. /505/**

→ If this question can be safely answered in the negative, the risk assessment ends here; otherwise, the following question must be answered.

Is the formation of a dangerous, explosive atmosphere possible?

Now it must be checked as to whether the expected amount of explosive atmosphere due to local and operational conditions is hazardous. A dangerous, explosive atmosphere is definitely present when, in the case of ignition, the safety and health of employees and third parties may be impaired. In this case, special protection measures are also required.

Where there is over 10 litres of connected explosive atmosphere, this must always be regarded as a dangerous, explosive atmosphere in a confined space, regardless of the dimensions of that space. Even small amounts can be potentially hazardous if located in close proximity to people. In spaces of less than about 100 m³, amounts smaller than 10 litres may be hazardous. A rough estimate can be made using the rule of thumb that in such spaces, explosive atmosphere amounting to more than one ten thousandth of the room volume may be potentially hazardous, e.g. 8 litres thereof in a room of 80 m³. However, it cannot be concluded from this that the whole room is to be considered a hazardous area. Only that subarea in which an explosive atmosphere might occur is considered a hazardous area. The effects of an explosion can, however, go beyond that subarea, and are to be considered.¹⁰

 Assertions as to the potential risk of an explosive atmosphere outdoors can only be made in individual cases, but are likely to play only a minor role in connection with sugar dust.

→ If this question can be safely answered in the negative, the risk assessment ends here; otherwise, the following question must be answered.

Has the formation of a dangerous, explosive atmosphere been completely prevented by the explosion-protection measures?

The priority is to examine whether the formation of explosive atmospheres may be restricted or prevented by technical measures.

¹⁰ TRBS 2152 Part 1 Section 3.4.1
Dust extraction systems are particularly suitable for removing dust from production and transport routes. However, organisational measures may also be appropriate if implemented consistently.

**Notes:**
Detailed information also contained in TRBS 2152 Part 2 /505/

→ If the above question can be safely answered in the affirmative, the risk assessment ends with this step; otherwise, those areas with dangerous, explosive atmospheres are to be classified into zones (see Section 4).

This zone classification may concern areas outside the plant as well as those inside machines, containers and plant.

With regard to the sugar industry, experience has shown that the following work equipment and areas are often affected (see Sections Fehler! Verweisquelle konnte nicht gefunden werden. and Fehler! Verweisquelle konnte nicht gefunden werden.):

- powder mills / milling equipment;
- conditioning equipment;
- conveyors / elevators;
- dryers;
- dust collectors / separators / filters;
- silos / hoppers;
- detection elements and the piping system (dust removal / aspiration);
- screening machines;
- installation rooms or other facilities, if dust cannot be excluded.

**Is the ignition of dangerous, explosive atmospheres reliably prevented?**

In areas that have been classified into zones, effective ignition sources must be avoided. An effective ignition source is a source of ignition which can cause ignition in the explosive atmosphere under consideration.\textsuperscript{11} This includes the selection of appropriate equipment categories according to Annex 4, para. B BetrSichV (regulation on health and safety) for work equipment, machinery and plant components corresponding to the zones and the measures described in TRBS 2153 Part 3 regarding the avoidance of operational ignition sources, e.g. equipotential bonding, earthing, lightning protection, etc.

\textsuperscript{11} TRBS 2152 Part 3 Section 2
Guidelines for prevention of dust explosions during the extraction and processing of sugar

It is therefore necessary to consider whether effective ignition sources are present and can indeed become effective (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

Notes:
Detailed information also contained in TRBS 2152 Part 3 /506/

If the ignition of dangerous, explosive atmospheres has been reliably prevented, the risk assessment ends here; otherwise further constructional measures are to be taken to limit the effects of an explosion to an acceptable level.

Otherwise, the occurrence of an explosion is considered as possible, such that further technological protection measures are to be taken (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

Notes:
Detailed information also contained in TRBS 2152 Part 4 /507/

Completion of the risk assessment:

The results of the risk assessment and the technical and organisational measures taken are to be documented in the explosion protection document (see Section 9.6), pursuant to the industrial safety ordinance (BetrSichV). /402/
7 Protection measures against dust explosions

In principle, it must first be checked as to whether flammable substances can be replaced or whether the occurrence of explosive atmospheres can be prevented by limiting the concentration of dust or through inerting.

**Note:**

*In the field of sugar and pellet dust, inerting is not a common practice.*

The measure known as "concentration limiting" is particularly important in this respect, because it can prevent – or at least limit – the formation of explosive atmospheres.

Often a suitable combination of measures (both technical and organisational measures) can result in the marked improvement of the risk situation.

Depending on the particular material properties and on the plant and process-specific conditions, is must then be examined as to whether, as a further measure, the avoidance of ignition sources is sufficient or whether the ultimately possible effects of an explosion must be limited to a safe level by means of constructional explosion-protection measures.

Preventative protection measures aim to hinder the occurrence of explosions by removing at least one of the explosion prerequisites (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

<table>
<thead>
<tr>
<th>Protection measures</th>
<th>Parameters to be observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoiding combustible dusts</td>
<td>Combustibility explosive properties</td>
</tr>
<tr>
<td>Concentration limiting</td>
<td>Explosion limits</td>
</tr>
<tr>
<td>Inerting</td>
<td>Limiting oxygen concentration</td>
</tr>
<tr>
<td>Avoiding ignition sources</td>
<td>Smouldering temperature, ignition temperature, exothermic decomposition, spontaneous combustion behaviour, smouldering point, minimum ignition energy, impact sensitivity, electrostatic behaviour</td>
</tr>
</tbody>
</table>

**Constructional protection measures** should minimise the impact of an explosion to an acceptable level. /507/

<table>
<thead>
<tr>
<th>Protection measures</th>
<th>Parameters to be observed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosion-resistance design</td>
<td>Maximum explosion over-pressure</td>
</tr>
<tr>
<td>Explosion relief</td>
<td>Explosion constant and maximum explosion over-pressure</td>
</tr>
<tr>
<td>Explosion suppression</td>
<td>Explosion constant and maximum explosion over-pressure</td>
</tr>
</tbody>
</table>
Fig. 3: Allocation of parameters to protection measures

7.1 Avoidance of explosive atmospheres

It is always desirable for the first measure of preventive explosion protection to be the avoidance of explosive atmospheres. With regard to concentration limiting, it is not only the procedure-related dust inside the equipment which should be noted: the dust deposited in operating rooms also presents a significant potential danger – and is often much more ominous for employees. Even a dust layer of 1 mm thickness on the floor is enough to completely fill a normal sized room with an explosive atmosphere. In practice, there are often numerous other deposition surfaces, such as apparatus surfaces, T-sections, cable trays, conduits, etc.

Where there are existing dust deposits, an initial explosion (even if it is only a so-called “deflagration”) may stir up deposited dust and re-ignite it. This process can be repeated in a chain reaction, such that violent and extended expanding secondary explosions (explosions inside buildings) can result in this way, with devastating effects. Within plant, equipment, silos and hoppers, deposited dust and dust caking must be taken into account, alongside the dust dispersed in the course of operations. Deposited dust and dust caking can be dispersed by vibration or by air movements, thus briefly forming a dangerous, explosive atmosphere.

Measures that prevent or restrict the formation of dangerous, explosive atmospheres:

- Quantity limits in conjunction with ventilation measures;
- Avoiding dust formation by careful handling (conveyors, etc.);
- Avoiding dust release by limiting the drop heights (using telescopic downspouts, etc.);
- Avoiding dust deposition surfaces within systems which transport dust;
- Avoiding dust deposits within dust-removal devices by optimally designing the sensing elements, technically correct routing in terms of the flow, and adequate flow rates;
- Avoidance of dust leaking into the working spaces, though dust-proof construction;
- Avoidance of dust leaking into the working spaces, though technical dust-removal measures (object extraction);
- Avoidance of deposition surfaces in the working spaces (possibly by subsequent bevelling or cladding and applying smooth coats, etc.);
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- Eliminating unavoidable dust by regular cleaning, preferably via suction process, as part of a cleaning plan.

7.2 Avoidance of effective ignition sources
The avoidance of effective ignition sources is another preventive explosion-protection measure. However, it requires detailed knowledge of the properties of the products used, of the plant and of the procedure (see Fig. 9).

Both in TRBS 2152 Part 3, BGR 104 and in DIN EN 1127 1, the 13 types of ignition source are given in detail in terms of their ignition mechanisms, and the possible and/or necessary measures to prevent the respective sources of ignition (see Fig. 8). Those ignition sources given in bold are of particular relevance to the field of dust explosion protection in the sugar industry.

- Hot surfaces (see Section Fehler! Verweisquelle konnte nicht gefunden werden.)
- Flames and hot gases, (incl. hot particles) (see Section Fehler! Verweisquelle konnte nicht gefunden werden.)
- Mechanically generated sparks (see Section Fehler! Verweisquelle konnte nicht gefunden werden.)
- Electrical installations (see Section Fehler! Verweisquelle konnte nicht gefunden werden.)
- Electric currents, cathodic protection
- Static electricity (see Section 7.2.5)
- Lightning \(^{12}\)
- Electromagnetic waves (high frequency range)
- Electromagnetic waves ("optical" frequency range)
- Ionising radiation
- Ultrasound
- Adiabatic compression and shock waves
- Exothermic reaction

7.2.1 Hot surfaces
If explosive atmospheres come into contact with hot surfaces, ignition may result. In this respect, it is not only the hot surface which can act as an ignition source, but also any layer

\(^{12}\) Lightning is seen as a relevant source of ignition. In the presence of a lightning protective system according to engineering rules, it can be excluded as an effective source.
of dust or a flammable solid can be ignited by contact with the hot surface and thus in turn become an ignition source for an explosive atmosphere.

The ignition capability of a heated surface depends on the type and concentration of the substance mixed with air. It increases generally with increasing temperature and with an increasing surface area of the heated body.

Furthermore, the ignition-inducing temperature depends on the size and shape of the heated body, on the concentration gradient at the wall, and (partly) on the wall material.

In addition to easily recognisable hot surfaces, such as lighting equipment, radiators, etc., mechanical processes and machining of materials can also lead to dangerous temperatures.

In addition, machines, devices and equipment which convert mechanical energy into heat (e.g. bearings, support rollers) are to be taken into account. Furthermore, all rotating parts in bearings, shaft bushings, cable glands etc. may become sources of ignition if insufficiently lubricated. In tight housings, moving parts may also lead to frictional processes due to the ingress of foreign bodies or the displacement of axes, which in turn may quickly lead to high surface temperatures (e.g. in elevators).

The temperatures of all surfaces that may come into contact with dust clouds may not exceed two thirds of the minimum temperature in °C of that cloud of dust.

For sugar dust, the minimum ignition temperature is 350°C, this means that a surface temperature of 233°C must not be exceeded.

For sugar dust, a maximum surface temperature of 233°C is deemed adequate where there are small dust deposits (< 5 mm). As the smouldering temperature of sugar dust (420°C) is higher than the minimum ignition temperature (350°C), the lower value from the calculation of the maximum surface temperature is to be adopted where there is a dust cloud.

For pellet dust, the minimum ignition temperature is 420°C, which means that a surface temperature of 280°C must not be exceeded.

For pellet dust, a maximum surface temperature of 195°C is deemed adequate where there are small dust deposits (< 5 mm). This is derived from the smouldering temperature (270°C), minus 75°C.

**Note:**

*With regard to the equipment, protective systems and components of all categories, the following applies: in special cases, the above temperature limits may be exceeded if it is proved that no ignition is expected.*

### 7.2.2 Flames and hot gases, incl. hot particles

Flames occur in connection with the combustion reactions, at temperatures of over 1000°C. Both the flames and the hot reaction products (hot gases; incandescent solid particles in the case of dust flames and/or smoky flames) or other highly heated gases can ignite explosive atmospheres. Flames, even those of very small dimensions, are among the most effective sources of ignition.
Any kind of open flame is fundamentally prohibited in areas where explosive atmospheres may occur.

Welding beads resulting from cutting and welding sparks have a very high surface area, and are also very effective sources of ignition.

Measures to avoid open flames are mainly organisational measures, such as the prohibition of smoking, fire and naked flames in areas at risk of dust explosions, and permit procedures. Thus, burning, welding and grinding work requires written permission, and the establishment of the necessary measures (working and environmental conditions, tool selection) by the responsible supervisor. Welding beads flying off in an uncontrolled manner can bridge very long distances (10 metres or more). Similarly sparks emanating from cutting machines (see Fig. 4) must be evaluated. For such work, it is therefore essential that the job is done in a large area free of dust and, where appropriate, wall and floor openings are covered.

As, after the completion of burning, welding and grinding work, the occurrence of fires cannot be completely excluded, a fire watch is to be set up during and after such work in potentially explosive areas.

7.2.3 Mechanically generated sparks
Grinding, rubbing, or impact processes may cause particles to become detached from solid materials; such particles assume an elevated temperature due to the energy expended during separation. If these particles are from oxidisable substances, e.g. iron or steel, they can go through an oxidation process, while still achieving higher temperatures. These particles (sparks) may possibly ignite an explosive atmosphere.

The penetration of foreign materials, (e.g. pieces of metal) in machinery, equipment and plants must be considered as a possible cause of sparking.

Friction, even between similar ferrous metals and between certain ceramic materials can cause localised heating and sparks similar to grinding sparks. This may also ignite explosive atmospheres.

Impact processes involving rust and light metals (e.g. aluminium and magnesium) and their alloys can trigger a thermite reaction, through which explosive atmospheres may be ignited.

Analysis of events in the industry and results of investigations have shown that at low peripheral speeds (speed <1 m / s) the ignition of explosive atmospheres by mechanically generated sparks is not to be expected.\(^{13}\)

By limiting the relative velocities of moving plant parts to v < 1 m/s and the respective power ratings to P < 4kW, dangerous friction and grinding operations and hence any connected mechanically generated sparks and hot surfaces can be generally avoided.

At higher flow velocities or larger drive capacities, e.g. in elevators, belt misalignment guards and slip monitors are to be provided. If the possible friction and grinding points can be clearly localised, the point of danger can be eliminated with a suitable combination of

\(^{13}\) DIN EN 1127-1 Section 6.4.4
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materials (e.g. a rubbing or grinding part made of thermoplastic material which softens before reaching critical temperatures).

Internal bearings should be avoided. If this is not possible, they should have a temperature monitoring facility.

<table>
<thead>
<tr>
<th>Tools that can cause a single spark at most, e.g. screwdrivers</th>
<th>Tools that can cause a shower of sparks, e.g. angle grinders</th>
<th>All sparking tools, e.g. screwdrivers, grinders</th>
</tr>
</thead>
<tbody>
<tr>
<td>permitted in Zone 22</td>
<td>not permitted in Zones 22 and 21, unless:</td>
<td>not permitted in Zone 20</td>
</tr>
<tr>
<td></td>
<td>• workplace shielded from the zone;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• dust deposits are removed or kept moist (clearance certificate);</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 4: Tools for use in potentially explosive atmospheres

7.2.4 Electrical installations

With electrical equipment, electrical sparks and hot surfaces may occur as sources of ignition. Electrical sparks can be generated in the following cases, for example /604/

- the opening and closing of electrical circuits,
- through loose connections and
- through compensating currents.

Notes:

Safety extra-low voltage (e.g. under 50 V) only offers protection against electric shock and is in no way an explosion-protection measure. Even at lower voltages, sufficient energy can still be generated to ignite an explosive atmosphere.

Electrical installations must be designed, executed, installed and maintained in accordance with the provisions of the BGV A3, those of the BetrSichV and of the relevant VDE regulations.

When using electrical equipment such as engines, switches or connectors, different requirements are to be met depending on the location, and according to the respective zone and, depending on the material properties: /401/

Only operating resources (e.g. level indicators, temperature sensors) which meet the requirements of the respective associated categories may be used in the zones.

For older electrical devices, the conditions for use in Zone 22 are satisfied if the existing conditions for Zone 11 are met. These were laid down in DIN VDE 0165. /699/ The essential requirements are IP 54 protection (for motors with squirrel-cage rotors (except for the terminal box) protection class IP 44 will suffice) and the surface temperature must not exceed two thirds of the ignition temperature or 75°C under the smouldering temperature.
This gives, in the case of sugar, a maximum surface temperature of 233°C. This temperature limit is to be applied to all other hot surfaces.

Where old equipment is replaced, e.g. following a fault, only those devices may be used which meet the requirements of Directive 94/9 / EC.

When using lamps, it should be noted that these must also be protected against mechanical impact, as appropriate.

7.2.5 Static electricity

There are various forms of electrostatic discharges with different ignition capabilities. /508/ Spark discharges, propagating brush discharges and cone discharges are those relevant to sugar dust.

To avoid spark discharges, the most important measure is the electrostatic earthing of all electrically conductive equipment. The bleeder resistance $R_e$ to earth must be $< 10^6 \Omega$. In addition, it is useful to connect all adjacent conductive parts conductively with each other, as far as possible.

Very ignition-effective electrostatic discharge processes are to be expected in practice when electrically conductive plant parts are built in an insulated manner and can become charged up (spark discharges). Examples in this respect are pipe parts insulated with seals or paints in conveying or dust lines, supporting baskets in filters or buckets in elevators, which are not integrated into the earthing concept.

In addition to these spark discharges, an additional ignition-effective discharge form should be mentioned: the propagating brush discharge. This usually occurs where insulating surfaces are deposited with conductive layers and the insulating layer is very highly charged. Experience has shown that the following conditions for propagating brush discharge are required:14

- a strongly charge-generating process is present (this may arise, for example, through pneumatic conveying)
- thickness of the insulating layer $D < 9$ mm,
- breakdown voltage $U_D > 4$ kV and $U_D > 6$ kV with textile fabric, such as for FIBC.

Such conditions may then be satisfied, for example, if the silos are made of metal or concrete, the inner walls have an insulating coating and the sugar is injected tangentially.

Propagating brush discharges frequently occur in internally coated conveyor pipes and in inappropriate delivery hoses.15 In particular, conductive or dissipative delivery hoses with insulating inner coatings (e.g. white core) are unsuitable for the pneumatic transportation of explosive products, such as sugar in general.

Furthermore propagating brush discharges have been observed inside non-conductively-lined jet mills and cyclones.

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Notes:
The insulating effect of conventional product caking is not normally sufficient for the formation of propagating brush discharges.

Propagating brush discharges can be avoided by using solely conductive materials. Non-conductive linings or coatings in conductive plant parts (silos) are in to be avoided in particular in places where very high electrostatic charges are expected.

In an electrostatic sense, sufficiently porous coatings (UD < 4 kV) do not lead to a dangerous discharge.

Another form of discharge that may occur when conveying sugar is the “cone” discharge. This can occur when filling silos and large containers with a high bulk resistivity. Whether or not cone discharges actually occur and what energies they may have is mainly determined by the resistivity and grain size of the bulk material, the flow and the apparatus size.

The extent to which these are actually ignition-effective depends on whether the maximal potential energy of such a discharge exceeds the minimum ignition energy of the dust (measured without inductance in the measuring system). Cone discharges occur along the cone and generally end on the silo wall. The energy of a single cone discharge (W_{CD}) can be estimated using the following formula:

\[ W_{CD} = 5.22 \, D^{3.36} \cdot d^{1.46} \]

The formula is valid for diameters of up to 3 m; "D" for metallic silos is the silo diameter, whilst non-metallic silos, it is twice the diameter, given in "m". The value "d" is the median value of the dust is in "mm". The resulting \( W_{CD} \) value is in "mJ".

For example, a sugar crystal with a median value of 0.35 mm in a steel silo with a diameter of 2 m gives a cone discharge energy 11.5 mJ. This is above the minimum ignition energy of the fine dust content. Ignition can thus not be excluded.

If hazards from static electricity are detected, the following requirements must be met: /508, 701/

Zone 20:
Ignition-effective discharges must be ruled out even in taking into account malfunctions which are merely infrequent.

Zone 21:
Ignition-effective discharges must not occur under normal plant operation, including maintenance and cleaning, or in the case of common malfunctions.
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Zone 22:

Measures other than the earthing of conductive parts are not normally required unless strongly charge-generating processes occur.

*Note:*

*Knowledge in the field to date is that the ignition of explosive sugar dust/air mixtures is not expected through brush discharges. Therefore, conductive filter media are not required from a technical dust-explosion point of view.*

The most important measure is the electrostatic earthing of all electrically conductive plant parts. The bleeder resistance to earth must be $< 10^6 \Omega$. In addition, it is useful to connect all adjacent conductive parts conductively with each other, as far as possible.

Experience has shown that the following conditions for propagating brush discharge are required: \(^{16}\)

- thickness of layer $D < 9$ mm,

- surface charge density $\sigma > 2.5 \cdot 10^{-4}$ C/m\(^2\)

and breakdown voltage $U_D > 4$ kV and $U_D > 6$ kV with textile fabric, such as for FIBC.

Propagating brush discharges have been observed in the interior of non-conductive lined jet mills, cyclones and delivery pipes. They arise only when the non-conductive coating is nonporous.

*Notes:*

*The insulating effect of normal product caking is not sufficient for the formation of such discharges.*

*Propagating brush discharges can be avoided by using solely conductive materials. Non-conductive linings or coatings in conductive equipment parts (silos) are to be avoided in particular in places where very high electrostatic charges are expected.*

7.2.6 **Examples of measures to prevent ignition sources**

When using work equipment and when operating plant in potentially explosive areas, measures to prevent ignition sources are to be taken if the generation of dangerous, explosive atmospheres cannot be excluded.

In areas which are potentially explosive due to dust, the following are to be avoided:

- in Zone 22, in order to prevent the ignition of a dust cloud or a layer of dust: all ignition sources occurring continuously or frequently (e.g. in the course of the normal operation of the work equipment)

- in Zone 21, in order to prevent the ignition of deposited and/or dispersed dust, in addition to the ignition sources mentioned for Zone 22: rarely occurring sources of

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ignition (e.g. due to malfunctions in the work equipment) and

- in Zone 20, in order to prevent the ignition of deposited and/or dispersed dust, in addition to the ignition sources mentioned for Zone 21: very rarely occurring sources of ignition (e.g. due to malfunctions in the work equipment).

Note:
If it is impossible to estimate the probability of a source of ignition becoming effective, the ignition source shall be regarded as permanently effective.

7.2.6.1 Pneumatic conveying systems
Pneumatic conveying systems generally operate when completely closed. Therefore, the only measures to prevent ignition sources required regard those which could possibly occur inside the system. It is only inside the system, depending on the process, that the formation of dangerous, explosive atmospheres needs to be reckoned with.

7.2.6.1.1 Ground-mounted hoisting machine
DEA: possible in transmitting containers, conduit and receiving containers

Measures:

- Electrostatic grounding of all electrically conductive plant parts. The resistance to earth is expected to be $< 10^6 \Omega$.
- In addition, it is useful to connect all adjacent conductive parts conductively with each other, as far as possible (see Section 7.2.5).

7.2.6.1.2 Dense phase conveying
DEA: possible in transmitting containers and receiving containers

Measures:

- see Fehler! Verweisquelle konnte nicht gefunden werden. and 7.2.4

7.2.6.1.3 Plug conveying
DEA: possible in transmitting containers and receiving containers

Measures:

- see Fehler! Verweisquelle konnte nicht gefunden werden. and 7.2.5

7.2.6.2 Mechanical conveying
During the mechanical conveying of crystallised sugar, additional dust is created through the grain destruction.
7.2.6.2.1 Elevators

DEA: In elevators for crystallised sugar, the emergence of such atmospheres is to be expected, e.g. through the trickling of excess sugar and the associated enrichment of the air with floating dust particles. Due to air movement, these dust particles may remain in the air for longer than usual.

The measures described below to prevent ignition sources are to be considered sufficient only if the simultaneous entry of ignition sources can be safely ruled out.

Measures:

- Belt monitoring
- Speed monitoring
- Slip monitoring (often in conjunction with rotational speed monitoring)
- Elevator and shaft made of suitable material combinations
- Plastic, e.g. for webbing, buckets made of conductive material

Notes:

The belt monitoring must ensure that neither the bucket nor the belt hit the housing. Such grinding is usually not an effective ignition source. A greater danger exists in the possible tearing away of a bucket or the cracking of the entire belt and the associated fall with the risk of the formation of sparks.

There are no limit values for the minimum allowable distance to the elevator housing. Setting must be done depending on the technical and organisational facilities on site.

Belt misalignment guards are usually installed in pairs: two each on the drive pulley and the tail pulley.

Material combinations such as stainless steel/stainless steel and stainless steel/carbon combinations are to be classified as not causing effective ignition. Avoid combinations of carbon steel and aluminium.

7.2.6.2.2 Screw conveyor

7.2.6.2.2.1 Screw conveyor for granulated sugar

DEA: is not to be expected if the proportion of fine dust is < 3%

Measures: none

7.2.6.2.2.2 Screw conveyor for sugar powder

DEA: is to be expected

Measures:

- Prevent entry of foreign bodies
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- Speed monitoring at the non-drive side
- External bearings or temperature monitoring of internal bearings
- Limiting the rotation to 1m/s peripheral speed

**Note:**
*Higher peripheral speeds may lead to dangerous, explosive atmospheres being assumed on a permanent basis (-> Zone 20)*

### 7.2.6.2.3 Belt conveyor

DEA: at the transfer points of belt conveyors, a spatially-restricted, explosive atmosphere may be formed where the drop heights are higher and the sugar is not visible.

Measures:

- Electrostatic earthing of all electrically conductive plant parts. The bleeder resistance to earth must be $< 10^6 \Omega$.
- In addition, it is useful to connect all adjacent conductive parts conductively with each other, as far as possible (see Section 7.2.5).

**Notes:**

*In the vicinity of open conveyors, dust deposits are to be removed frequently as part of the cleaning management process.*

*Drop heights should be limited to the strict minimum necessary to prevent the separation of the product. Possible measures to prevent separation processes at greater drop heights include feeders such as slides, chutes etc.*

### 7.2.6.2.4 Flexible intermediate bulk containers (FIBC, “big bags”)

DEA: It is only during rapid filling using sugar out of sight, or using very fine-grained sugar (from dust collectors, sugar powder) that an explosive atmosphere may form in the interior. The area around which the flexible intermediate bulk container is operated must also be considered. 17

**Notes:**

*Electrical discharges may be generated both during filling and during emptying. Other objects or people may be inductively charged by loaded flexible intermediate bulk containers.*

Flexible intermediate bulk containers (FIBC, big bags) are divided into four types (A, B, C and D). 17/508/

Type A can be primarily used only in areas with no explosive atmosphere.

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<table>
<thead>
<tr>
<th>Minimum ignition energy (MIE) of the bulk material</th>
<th>non-potentially explosive area</th>
<th>potentially explosive area (Zone 22)</th>
<th>potentially explosive area (Zone 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIE &gt; 1000 mJ or dust explosion impossible</td>
<td>No restrictions</td>
<td>No restrictions</td>
<td>No restrictions</td>
</tr>
<tr>
<td>1000 mJ ≥ MIE &gt; 3 mJ</td>
<td>B, C, D</td>
<td>B, C, D</td>
<td>B, C, D</td>
</tr>
<tr>
<td>3 mJ ≥ MIE</td>
<td>C, D</td>
<td>C, D</td>
<td>C, D</td>
</tr>
</tbody>
</table>

Fig. 5: Selection of appropriate type of flexible intermediate bulk containers (FIBC)

Commonly used for

DEA: not expected for granulated sugar in general, so Type A is sufficient

DEA: expected for sugar powder and icing sugar due to aspiration; thus Type B is required as a minimum

Measures:

- Use of suitable flexible intermediate bulk container.
- Electrostatic earthing of all electrically conductive plant parts. The bleeder resistance $R_{E}$ to earth must be < $10^6 \Omega$.

**Note:**

If special products, such as fructose or sugar, are also packaged in flexible intermediate bulk containers, their characteristics are to be determined, where appropriate, and considered in the risk assessment.

### 7.3 Constructional explosion protection

If the preventive explosion-protection measures do not provide sufficient protection against dust explosions, i.e. the occurrence of a dangerous atmosphere cannot be prevented, and the avoidance of ignition sources cannot be reliably ensured, then constructional protection measures must be employed. /507/

For the constructional explosion protection, the following measures are recommended:

- explosion-resistant design (see Section Fehler! Verweisquelle konnte nicht gefunden werden.),

optionally in combination with,

- explosion pressure relief or explosion suppression (see Section Fehler! Verweisquelle konnte nicht gefunden werden. and Fehler! Verweisquelle konnte nicht gefunden werden.).
Of particular note is the possible transmission of explosions to other parts of the plant or into operational premises. An explosion transmission can be prevented by the use of suitable

- explosion isolation (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

Constructional explosion protection must be provided, especially in areas and facilities where the operations entail a corresponding probability of the occurrence of explosive dust/air mixtures. The zone classification can serve as a guideline to identifying corresponding hazard areas. With this type of explosion-protection measures, the effects of dust explosions are limited by the fact that the plant in question is designed for the relevant, expected explosion pressure. It is possible to construct the apparatus such that it is either explosion-pressure-resistant or explosion-pressure-shock-resistant.

If the plant is designed suitably for the max. explosion pressure, this also represents the expected explosion pressure. In the event of an explosion, this is exclusively limited to the interior of the plant. The plant will thus withstand the maximum occurring explosion pressure.

If the plant is equipped with an explosion-pressure relief system, then the expected explosion pressure corresponds to the reduced explosion pressure. In the event that an explosion takes place, the pressure will increase up to the reduced explosion pressure at most. Any resulting excess pressure is discharged via the pressure relief device into non-hazardous outdoor areas.

7.3.1 Explosion-resistant design

In terms of explosion-resistant design, a distinction is made between “explosion-pressure-resistant” and “explosion-pressure-shock-resistant” designs. In practice, explosion-pressure-shock-resistant designs are normally deployed. /704/

**Explosion-pressure-resistant design**

Containers, vessels and pipelines are explosion-pressure-resistant if they are designed for the expected explosion pressure and can also withstand without such pressure several times without suffering permanent deformation (see Section 10.1).

*Note:*

*Explosion-pressure-resistant containers, apparatus and pipelines are to be calculated and constructed using the accepted engineering standards for pressure apparatus, e.g. the AD 2000 Code (in Germany). (Containers, apparatus or pipelines built according to national regulations of other countries generally entail different, shorter intervals between inspections.)*

**Explosion-pressure-shock-resistant design**

Explosion-pressure-shock-resistant containers, apparatus and pipelines are to be constructed so that they can withstand the expected explosion pressure without rupturing. Here, however, permanent deformation is permitted (see Section 10.1).
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Note:
For sugar dust, the maximum explosion overpressure is 9 bar (see Figure Fehler! Verweisquelle konnte nicht gefunden werden.). A typical value for the reduced explosion overpressure in application of the explosion pressure-relief protection measure is $p_{\text{red}} = 0.4$ bar.

7.3.2 Explosion pressure relief
In order to prevent the build up a non-permitted high pressure, an explosion pressure relief system relieves containers or apparatus in the event of an explosion via a relief area (e.g. a rupture disc), into an area where there is no expected danger to persons or property.

For the calculation of the required relief area, the explosion characteristics of the combustible dust must first have been determined. For design purposes, the maximum explosion pressure ($p_{\text{max}}$) and the maximum pressure rise explosion constant must be known. Furthermore, the volume and pressure shock resistance (reduced explosion overpressure ($p_{\text{red}}$)) are used in the calculation of the relief area.

Rupture discs, explosion flaps and flameless pressure relief devices are used as pressure relief devices.

Explosion pressure relief, with or without a pressure relief duct, shall be designed such that it takes place in unthreatened areas. In particular, no traffic routes may be located in the effective region around the discharge opening. Furthermore, a sufficient distance must be maintained vis-à-vis adjacent buildings and facilities.

Where discharge openings lead into the open air via discharge ducts, then the reduced explosion pressure will significantly increase, depending on the length of the discharge duct. The length of the discharge duct must therefore be considered in the design phase. /710/

Note:
Explosion relief is a very simple, yet effective constructional explosion-protection measure, which should be included in the plant planning phase as early as possible.

7.3.3 Explosion suppression
In the case of explosion suppression, an incipient explosion is detected by means of pressure detectors or infrared detectors, and contained rapidly thanks to the fast injection of extinguishing agents ($t \leq 5$ ms), such that the explosion cannot fully develop. The explosion suppression of the resulting increase in pressure is limited to the reduced explosion overpressure ($p_{\text{red}}$) for which the vessel is to be correspondingly designed in terms of explosion-pressure shock resistance.

Sodium bicarbonate has been proven to be a suitable extinguishing agent against dust explosions in many areas.

Note:
Because, with the explosion-suppression protection measure, the explosion remains restricted to the interior of the respective apparatus, the "locational independence" is a major advantage of this measure. Even the retrofitting of existing plant is often more feasible than other constructional explosion-protection measures. /705/
7.3.4 Explosion isolation

Generally, with regard to the application of constructional explosion-protection measures, it must always be taken into account as to whether additional measures for technical explosion isolation are required. In general, it can be assumed that constructionally protected plant components are also to be technically isolated regard to the explosion. This is done for example by incorporating

- rotary valves,
- quick-closing sliders, quick-closing flaps
- extinguishing barriers,
- quick-closing valves or
- relief vents.

**Rotary valves** prevent the penetration of the flame front and the shock wave. In the event of an explosion, the valve must be shut down automatically to prevent the discharge of burning or smouldering product.

Where **quick-closing sliders** or **quick-closing flaps** are deployed, an incipient explosion is detected by detectors and a trigger mechanism closes the slider or flap within milliseconds. They are mainly used in pipelines. In this way, the pipe is hermetically sealed so that neither flame nor pressure can pass into the isolation device.

In the case of **extinguishing barriers**, an explosion or a flame front is detected by detectors and the propagating flame is extinguished by an atomised extinguishing agent.

**Note:**

*In contrast to the aforementioned isolation devices, extinguishing barriers do not affect the explosion pressure, such that the pipeline and other equipment behind the barrier must be designed to withstand the expected explosion pressure.*

**Quick-closing valves (explosion protection valves)** automatically and hermetically close the pipe cross section when a given flow velocity is exceeded (explosion pressure waves). The flow triggering closing can optionally also be actively generated by a sensor-controlled pilot flow.

The **relief vent** is the most frequently encountered isolation measure in dust removal systems within the sugar industry. The transmission of the explosion is prevented by a discharge in the deflection point. However, this design means that the explosion transmission cannot always be reliably prevented. In any case, the spreading of the flame front is so disrupted that it can be expected that the start of a new explosion front in the subsequent part of the conduit will merely be slow.

The relief vent can be regarded as adequate isolation measure where it is used to avoid an explosion transmission from a dust filter into the detection areas. The prerequisite is that no hazardous dangerous, explosive atmospheres are expected during operations in the dust extraction pipes. In addition, the piping must be free of dust. This can be achieved by proper flow routing and sufficient flow velocity (> 18 m/s).
Notes:
In the dust extraction lines, dust concentrations are usually well below the lower explosive limit, if the system is operated as per the plant manufacturer’s designs. This requires, among other things, that compliance with the minimum flow rate (> 18 m/s) is operationally controlled and maintained.

Where rotary valves, quick-closing sliders, flaps and valves, and relief vents are serving as isolation devices, these are deemed to be protective systems in accordance with EC Directive 94/9/EC. For these protective devices, proof of suitability is to be provided in the form of an EC-type examination (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

7.3.5 Examples of constructional explosion-protection measures
Solutions for constructional explosion-protection measures for the individual plant components may take the following form.

7.3.5.1 Aspiration lines
Aspiration lines are subjected to different loads in the event of an explosion, depending on where the event is triggered and the direction in which the shock wave with the flame front passes through the system.

Aspiration lines between the relief vent and filters are constructed to be pressure-shock-resistant in accordance with the pressure-shock resistance of the filter. The relief vent for explosion isolation should therefore have at least this resistance.

Notes:
The prerequisite is that no dangerous, explosive atmosphere is evacuated and no dangerous, explosive atmosphere is present in the piping system. Minor sources of ignition such as smoking are organisationally excluded. The relief vent only ensures the piping system against an explosion in the filter. Particularly critical plant such as mills are not evacuated in the same system.

It is recommended that the other aspiration lines, insofar as they act as collecting lines, are pressure-shock-resistant in their design. This is especially true for collecting lines which lead through further fire compartments and, in the event of their destruction, would lead to the explosion spreading into these areas. There is, however, no sense in this in the immediate vicinity of the actual evacuation points, as any incoming pressure wave and flame front would anyway be relieved unchecked into the open.

7.3.5.2 Filters
- Filters are pressure-shock-resistant for a reduced explosion overpressure of, for example, 0.4 bar /704/
- Isolation is realised by means of a puncture-resistant rotary valve in the product discharge
- Isolation is via a relief vent or using extinguishing barriers in the raw air inlet
- Explosion pressure relief directly into the open air or via flameless pressure relief e.g. "Q-Pipe"
alternatively the filter chamber is equipped with an explosion suppression facility. 

/705/ /706/

**Example of a filter system without constructional explosion protection**

If the risk assessment shows that the entry of ignition sources, including those from static electricity, has been eliminated, then constructional explosion-protection measures can be dispensed with. If it cannot be excluded that an ignition source may arise from the downstream system components against the production stream, then isolation is required, e.g. by means of a puncture-resistant rotary valve in the product discharge.

**Notes:**

With regard to silo-conditioning filters (large silos for granulated sugar), the requirements may be lower than those for conveyor-path dust removal, as the air is usually moved in a closed circuit and there is no risk of the inadvertent entry of ignition sources.

Furthermore, measurements have even shown that both in the silo and in the silo-conditioning lines, dangerous, explosive atmospheres rarely occur from the sudden loosening of dust deposits (Zone 22).

### 7.3.5.3 Stationary vacuum system

- Filter housing is constructionally protected, e.g. pressure-resistant or pressure-shock-resistant, with pressure relief for the expected explosion pressure. /704/

- Permanently-installed raw-gas lines are pressure-shock-resistant for the expected explosion pressure.

- Conductive hoses are to be used.

- The raw gas collecting pipe is disconnected prior to entry into the filter housing, e.g. via a quick-closing valve.

- Isolation device in the clean air line, e.g. a Ventex valve.

**Note:**

*Higher demands are placed on the technical execution of a stationary vacuum system for cleaning the building and facility with its many connection possibilities within the building, as compliance with the protection concept “Avoidance of ignition sources” cannot be guaranteed due to the flexible handling of the system by the site staff. The possibility of suctioning effective ignition sources must always be reckoned with.*

### 7.3.5.4 Powder mills

- The mill housing is pressure-resistant to the maximum explosion overpressure. /704/

- The mill’s subsequent reservoir is pressure-shock-resistant to the reduced explosion pressure of e.g. 0.4 bar, and depressurised.

- Inlets and outlets, including air supply to the mill, are technically isolated from any explosion.
Note:
In the grinding chamber of the mill housing there is always the risk that an effective ignition source may be formed (e.g. through pin breakage in a pinned disk mill). Thus an increased risk of explosion is to be expected especially in the case of malfunctions. This aspect is also be taken into account especially for existing plant.
8 Structural measures

- Technical fire-protection isolation by means of splitting the building into fire compartments must be effected. The relevant parties to contact in this respect are the licensing authorities, e.g. building authorities and the property insurer.

- Careful surface configuration is indispensable in preventing dust deposits. This is ensured in particular by avoiding deposition areas. Surfaces with a slope of at least 60° to the horizontal largely prevent deposits. Unavoidable potential deposition areas are to be designed so that deposited dust can be easily removed.

- The relief of pressure from spaces (e.g. powder mill space) is required if other constructional protection measures are not applicable and the protection of persons is ensured in other ways, e.g. by arranging an exclusion area where there are no workstations, and through the adequate resistance of the masonry. /706/

- Lightning protection according to DIN V ENV 61024-1/VDE 0185 is required. The relevant parties to contact in this respect are, for example, the building authorities and the property insurer. /606/

- Building isolation through isolation devices in connecting conveyors, e.g. for belt conveyors, is also required in special cases. The relevant parties to contact in this respect are, for example, the building authorities and the property insurer.

- Devices for earthing machines and systems that allow for the safe dissipation of electrostatic charges are also to be thoroughly planned for. /508/

- The electrical equipment which is part of the installation is to be adapted to the requirements of the environment. The choice of protection classes for the installation must be based on the zone classification scheme if all spaces, e.g. the complete silo cellar, have been identified as having potentially explosive atmospheres. /603/

- Permanently-mounted socket devices such as wall outlets are to be arranged such that the insertion port is downward for the plug (maximum deviation from the perpendicular 30°), and that where no plug is inserted, the outlet is covered by a non-detachable flap so that protection is maintained. The devices must be connectable and detachable when the power is off. /699/
9 Organisational measures

9.1 Identification
The identification of hazardous areas must be done in accordance with ASR A1.3 /515/. The prohibition of unauthorised persons entering hazardous areas is also to be clearly and durably to be indicated in the form of labelling.18 /402/

9.2 Cleaning and maintenance
The absence of dust from operational spaces is of high importance. It is therefore necessary to draw up cleaning schedules prescribing the nature, extent and frequency of cleaning measures and assigning responsibilities.

For removing dust deposits, vacuum procedures should be used where possible (stationary vacuum cleaning system, mobile industrial vacuum cleaners).

<table>
<thead>
<tr>
<th>Type of cleaning measure</th>
<th>Location</th>
<th>Frequency</th>
<th>Person responsible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuuming</td>
<td>Silo floors</td>
<td>After the end of the shift</td>
<td>Mr S</td>
</tr>
<tr>
<td>Mopping</td>
<td>Mill area*)</td>
<td>As required, though at least weekly</td>
<td>Ms W</td>
</tr>
</tbody>
</table>

*) The plant must not be in operation!

Fig. 6: Example cleaning schedule

Notes:
A stationary vacuum cleaning system (see Section Fehler! Verweisquelle konnte nicht gefunden werden.) with many connection options on site in dusty areas, facilitates the efficient and thorough removal of dust deposits even on work platforms which are difficult to access (e.g. access via a ladder). Mobile vacuum cleaning systems often cannot be used on site, to eliminate hidden dust deposits.

Mobile industrial vacuum cleaners must be suitable for use with combustible dusts. The vacuum cleaners must not have their own source of ignition. This condition is satisfied, for example, if the vacuum cleaners meet the requirements of DIN EN 60335-2-69 Annex CC or the old Type B1 requirements.

With regard to maintenance operations, in addition to those required for technical reasons, special activities are to be taken into account which affect

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Guidelines for prevention of dust explosions during the extraction and processing of sugar

- the function of protective systems (such as skew fuses, slip monitors or explosion suppression systems)
- the sealing of dust-laden plant,
- the effectiveness of technical dust-removal systems,
- the absence of friction from the moving parts of the plant,
- the prevention of mechanically generated sparks.

These maintenance operations also to be included in a maintenance plan, analogously to the cleaning measures.

9.3 Repair and inspection

Plant in hazardous areas which constitutes equipment, protective systems or safety, control or regulating devices as defined in Article 1 of Directive 94/9/EC, or include this, are classified as installations in need of monitoring pursuant to Article 1(2) Sentence 1.3 BetrSichV. In order to ensure the permanent maintenance of the protective measures taken for explosion protection, the operator must establish an inspection and monitoring concept. The inspection and monitoring concept must include provisions regarding inspection type, scope, depth of inspection and inspection intervals.

In accordance with BetrSichV, where plant and work equipment requires monitoring, the inspections to be done before commissioning, following repairs and periodic inspections are to be distinct from each other. Further specification in terms of the scope and content of the respective inspections can be found in TRBS 1201, TRBS 1201 Part 1 and/or TRBS 1201 Part 3.

All inspections performed according to the inspection concept shall be documented and the audit logs kept.

An overview of the relevant controls and inspections is given in the following table.

<table>
<thead>
<tr>
<th>Work equipment / plant</th>
<th>Reason for inspection</th>
<th>Aim</th>
<th>Inspected by</th>
<th>BetrSichV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work equipment (general)</td>
<td>Before starting work</td>
<td>Obvious defects</td>
<td>Users; trained personnel</td>
<td>Section 3</td>
</tr>
<tr>
<td>Work equipment under certain conditions</td>
<td>Safety depends on assembly conditions</td>
<td>Proper assembly, safe operation</td>
<td>QP</td>
<td>Section 10(1)</td>
</tr>
<tr>
<td></td>
<td>Operating under influences causing damage, after deadlines</td>
<td>Timely detection of damage, safe operation</td>
<td>QP</td>
<td>Section 10(2)</td>
</tr>
</tbody>
</table>
### Exceptional event

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Timely detection of damage, safe operation</th>
<th>Responsible Person</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following repair work</td>
<td>Safe operation</td>
<td>QP</td>
<td>10(2)</td>
</tr>
</tbody>
</table>

### Plant requiring monitoring

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Timely detection of damage, safe operation</th>
<th>Responsible Person</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to initial commissioning; following a significant modification</td>
<td>Orderly state with respect to assembly, installation, setup conditions and safe functioning</td>
<td>AIB or QP</td>
<td>14(1) and (3)</td>
</tr>
<tr>
<td>After modifications to operation and/or construction</td>
<td>Orderly state with respect to operation</td>
<td>AIB or QP</td>
<td>14(2) and (3)</td>
</tr>
<tr>
<td>Repair of equipment, etc., in accordance with Directive 94/9/EC</td>
<td>Pursuant to the requirements of BetrSichV</td>
<td>AIB, officially recognised QP or manufacturer</td>
<td>14(6)</td>
</tr>
<tr>
<td>Periodically, at least every 3 years</td>
<td>Orderly state with respect to operation</td>
<td>AIB or QP</td>
<td>15(15)</td>
</tr>
</tbody>
</table>

### Explosion-susceptible plant

<table>
<thead>
<tr>
<th>Event Description</th>
<th>Timely detection of damage, safe operation</th>
<th>Responsible Person</th>
<th>Section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Testing of workspaces (concept testing)</td>
<td>QP with particular expertise in explosion protection</td>
<td>Annex 4A, Section 3.8</td>
<td></td>
</tr>
</tbody>
</table>

---

**Fig. 7: Reasons for inspections, aims of inspections, and those responsible**

**Key:**

- QP: qualified person
- AIB: approved inspection body

9.3.1 **Inspection prior to commissioning of plant in need of monitoring**

Once again, a distinction between two inspections must be made.\(^{19}\)

9.3.1.1 **Inspection of the plant (BetrSichV Section 14(1) to (3))**

The plant is to be inspected for orderly state, taking into account the intended mode of operation, by a qualified person or by an approved body, with respect to the assembly, installation, setup conditions and safe functioning. This requirement applies likewise following a significant modification to the plant, or to the extent that the operation or design of the system is affected by a modification.

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\(^{19}\) Taken from: *FSA-Leitfaden Brennereien* (FSA guidance on distilleries)
This involves the inspection of the various plant (machinery) with regard to proper assembly, installation and function.

For new plant, this is followed up before commissioning by a second major inspection. This second inspection is intended to provide information as to whether the plant explosion-protection concept used is coherent and has been fully implemented. This inspection may therefore be carried out only by experts (qualified persons with special knowledge in explosion protection).20

9.3.1.2 Inspection that workspaces are safe from the effects of explosion (concept inspection, BetrSichV Annex 4A Section 3.8)

This inspection consists of the following steps:

- inspection of the factual accuracy of the explosion-protection concept,
- inspection of the specification of the explosion-protection concept in the explosion protection document
- inspection of the implementation of the explosion-protection concept for the specific area.

This step involves the comprehensive inspection of the implementation of all organisational and technical measures.

For this purpose, the following aspects are to be inspected, amongst others:

- comprehensive inspection of the explosion-protection concept in the context of local conditions,
- inspection of the complete description of the explosion-protection concept in the explosion protection document.

The following is also to be inspected:

- the correct implementation of all necessary technical and organisational measures, according to the explosion-protection concept,
- the implementation of the zone plan to ensure that the hazardous areas are as according to the zone plan,
- equipment and protective systems and other work equipment, to determine whether they are appropriate for the areas in which they are to be used, based on their device category,
- the identification of potentially explosive areas.

Notes:

Detailed information also contained in TRBS 1201 Part 1 Section 5

20 Taken from: FSA-Leitfaden Brennereien (FSA guidance on distilleries)
This inspection shall be performed by a qualified person with particular expertise in explosion protection.\textsuperscript{21}

9.3.2 Inspection following commissioning (BetrSichV Section 14(6))
After the repair of equipment, a protective system or a safety, control or regulating device as defined in Directive 94/9/EC in respect of a part required for explosion protection, an inspection by an approved inspection body (AIB) or by a recognised qualified person is to be conducted.

The inspection may also be performed by the manufacturer. The manufacturer shall confirm in this case that the equipment, protective system or safety, control or regulating device meets the requirements of the BetrSichV with regard to the essential explosion protection features.

Further details regarding this inspection can be found in TRBS 1201 Part 3.

9.3.3 Periodic inspections (BetrSichV Section 15(15))
The definition of inspection intervals and the inspection content are performed on the basis of the risk assessment, taking into account the manufacturer’s instructions and the operating conditions. The periodic inspections must be repeated at least every 3 years.

With regard to the inspections pursuant to Section 15(15) BetrSichV, the following must be considered:

- equipment, protective systems and safety, control or regulating devices in accordance with EC Directive 94/9/EC for their orderly state and proper interconnection,
- safety, control or regulating devices: for proper functioning according to the appropriate category,
- interactions of equipment, protective systems, safety, control or regulating devices and their connecting elements – with each other and with other plant components.

Periodic inspections in accordance with Section 15 BetrSichV may be performed by an approved inspection body or by a qualified person.

9.4 Operating instructions, training
Taking into account the risk assessment (see Section Fehler! Verweisquelle konnte nicht gefunden werden.), operating instructions are to be drawn up which regulate the handling of combustible substances and hazardous explosive atmospheres (e.g. sugar, chip and pellet dust).

As part of the initial and refresher courses for persons working in the area (plant operators, service personnel, etc.), training in the following is to be given

- the essential conditions for an explosion (see Section Fehler! Verweisquelle konnte nicht gefunden werden.)

\textsuperscript{21} TRBS 1203
• essential conduct in hazardous areas
• the general ban on smoking in potentially explosive areas,
• the prohibition of the use of open flames and the performance of hot work without a permit (see Section Fehler! Verweisquelle konnte nicht gefunden werden.) and
• the ban on access for unauthorised persons.

*Note:*
The comprehensive training of contract workers, e.g. those working for cleaning companies, must be ensured. /101, 102/

### 9.5 Work clearance

The performance of work in potentially explosive areas is permitted only in accordance with the written instructions of the employer. For dangerous activities, such as welding, cutting and grinding, a work clearance system is to be applied.

Such activities may commence only when the employees undertaking them have a permit from the responsible manager which grants clearance for the work, and the necessary protection measures have been taken (see Section Fehler! Verweisquelle konnte nicht gefunden werden.) /101,102, 510/

An example permit is included in the Annex (see Section Fehler! Verweisquelle konnte nicht gefunden werden.).

### 9.6 Explosion protection document

The employer must draw up an explosion protection document including all measures taken for explosion protection. This document is to be kept constantly up to date. It is to be drawn up before start of construction work, i.e. during the planning phase, and is to be revised if changes, extensions or conversions of the work environment, work equipment or the work process are performed, as a result of events occurring or knowledge acquired.

The document must demonstrate/explain in particular,

• that the explosion risks have been identified and have been subject to evaluation,
• that appropriate measures have been taken in order to achieve the objectives of explosion protection,
• which areas in accordance with Annex 3 of the industrial safety ordinance (BetrSichV) have been classified into zones and
• those places where the minimum requirements set out in the Annex 4 of the industrial safety ordinance (BetrSichV) apply.

Reasonable precautions include, in particular, technical and organisational precautions such as the choice of work equipment for potentially explosive areas, maintenance activities, coordination of safety policies, training and inspections.
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The explosion protection document must contain all information on explosion protection at the site. It is not limited to the dust explosion protection. No particular format is specified by law.

Notes:

The risk assessment done within the scope of the explosion protection document is deemed to be an independent observation, but an extension of the general risk assessment required by the occupational safety and health act and the industrial safety ordinance.

In the explosion protection document, the employer may also refer to existing risk assessments, documents or other equivalent reports have been prepared on the basis of obligations under other legislation. These may include, for example, reports, approval documents, plant lists, registers of hazardous substances, cleaning schedules, records of scheduled tours, test documents, training materials and emergency plans.

Recommendation for structure and content

A possible structure for the explosion protection document can be found in the annex (see Section 9.6).
10 Annex (general)

10.1 Definitions, parameters (for combustible dust)

Employer

State occupational safety and health regulations are generally aimed at the employer. It is responsible for the implementation of the requirements. The term “employer” refers to the managerial staff as line managers, as stated in Section 13 of the occupational safety and health act (ArbSchG), insofar as their area of responsibility is affected by the scope of any regulation or insofar as they have been explicitly entrusted with taking over employer obligations by the employer.

Work equipment

The term “work equipment” is used in this publication as per its use in the industrial safety ordinance. The scope is broad and includes tools, equipment, machinery and plant.

Plants are composed of several functional units interacting with each other, and their safe operation is essentially determined by these interactions.

Plant in need of monitoring is included within this definition, within the meaning of Section 2(7) of the Product Safety Act (ProdSG).

Plant in need of monitoring

Which plant is considered as in need of monitoring within the meaning of BetrSichV is defined in Section 1(2) of the BetrSichV.

Plant in potentially explosive areas is classified as plant requiring monitoring within the sense of Section 1(2) Sentence 1.3 BetrSichV, insofar as it constitutes or contains equipment, protective systems, safety, control or regulating devices as defined in Directive 94/9/EC.

Atmospheric conditions

“Atmospheric conditions” are total pressures of 0.8 bar to 1.1 bar and mixing temperatures of -20°C to +60°C. /503/

The oxygen content must be $O_2 \leq 21 \text{ vol}\%$.

Combustibility

The combustibility of a dust is defined by its class number.
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<table>
<thead>
<tr>
<th>Type of reaction</th>
<th>Class number</th>
<th>Type of dust (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No spreading of fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No scorching</td>
<td>CN 1</td>
<td>Sodium chloride</td>
</tr>
<tr>
<td>Brief scorching and rapid extinction</td>
<td>CN 2</td>
<td>Sugar dust, tartaric acid, casein</td>
</tr>
<tr>
<td>Local combustion or smouldering without spreading</td>
<td>CN 3</td>
<td>Lactose, dextrin</td>
</tr>
<tr>
<td>Spreading of a smouldering fire</td>
<td>CN 4</td>
<td>Tobacco, lignite, peat</td>
</tr>
<tr>
<td>Spreading of an open fire</td>
<td>CN 5</td>
<td>Sulphur, wood, cellulose</td>
</tr>
<tr>
<td>Very violent, explosion-like burning off</td>
<td>CN 6</td>
<td>Gunpowder</td>
</tr>
<tr>
<td>Spreading of fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spreading of a smouldering fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spreading of an open fire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very violent, explosion-like burning off</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Explosion**

A sudden oxidation reaction along with a rise in temperature, pressure, or both simultaneously. /503/

**Explosion limits**

The lower explosive limit (LEL) and upper explosive limit (UEL) are the lower and upper limits of concentration (mole fraction) of a flammable substance in a mixture of gases, vapours, mist and/or dusts in which, following ignition, a flame which is independent of the source of ignition, is just about not able to propagate on its own. /503/

**Explosive atmospheres (EAs)**

An explosive atmosphere is a mixture of air and combustible dusts under atmospheric conditions in which the combustion process is transferred to the entire unburned mixture after ignition. “Atmospheric conditions” means total pressures of 0.8 bar to 1.1 bar and mixing temperatures of -20°C to +60°C. /503/

**Explosion-resistant design**

Plant parts such as tanks, apparatus and piping (aspiration lines), are explosion-resistant if they are built to withstand the expected explosion pressure inside without rupturing. /507/

**Explosion-pressure-resistant design**

Plant parts such as tanks, apparatus and piping (aspiration lines) are explosion-pressure-resistant if they can withstand the expected explosion pressure without becoming permanently deformed. /507/
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**Note:**

*In the design and manufacture process, the calculation and construction requirements for pressure vessels are applied. The expected explosion pressure is used as the calculated pressure.*

**Explosion-pressure-shock-resistant design**

Plant parts such as tanks, apparatus and piping (aspiration lines) are built to withstand the expected explosion pressure without rupturing, though permanent deformations are allowed. /507/

**Note:**

*In the design and manufacture process, the directives issued by the "pressure-vessel working group" (AD leaflets) are analogously used, whereby – under the prerequisite of a high ductility of the materials used – a more pronounced use of the strength of the material is allowable, compared to pressure vessels.*

**Potentially explosive area (PEA)**

A potentially explosive area is an area in which a dangerous, explosive atmosphere may occur. An area in which an explosive atmosphere is not expected in such amounts that special precautions are required is not deemed to be a potentially explosive area. /503/

**Dangerous, explosive atmosphere (DEA)**

A dangerous, explosive atmosphere is an explosive atmosphere that occurs in such amounts (ominous amounts) that special protection measures are required for the maintenance of the protection of the health and safety of employees or third parties. /503/

**Smouldering temperature**

The smouldering temperature is the minimum ignition temperature of a 5-mm-thick dust layer. /503/

**Explosion constant**

This is a parameter specific to dust and inspection procedures which is calculated from the cubic law. It corresponds numerically to the value for the maximum rate of pressure rise in a 1 m³ vessel at the test conditions specified in the VDI 2263-1 guideline. The explosion constant depends in particular on the particle size distribution and the surface structure of the dust. /702/

**Cubic law**

Volume dependence of the maximum rate of pressure rise. /702/

\[(dp/dt)_{max} \cdot V^{1/3} = \text{const.} = \text{explosion constant}\]

Because of the relationship between the volume V and the maximum rate of pressure rise \((dp/dt)_{max}\), data for the maximum rate of pressure rise is not sufficient without the simultaneous specification of volume.
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**Maximum explosion pressure** ($p_{\text{max}}$)

The maximum explosion pressure ($p_{\text{max}}$) is the highest determined explosion that can occur when the fuel proportions are changed. /503/

**Maximum rate of pressure rise** ($\left(\frac{dp}{dt}\right)_{\text{max}}$)

This is the highest rate of pressure rise, as determined under specified test conditions when changing the fuel proportions in a closed vessel, occurring in the event of the explosion of an explosive atmosphere. /503/

**Median**

The value for the average grain size. 50% of the dust grains (by weight) are coarser and 50% are finer than the median value.

**Minimum ignition energy (MIE)**

This is the smallest amount (determined under specified test conditions) of electrical energy stored in a capacitor, which if discharged is sufficient to ignite the most ignitable mixture in an explosive atmosphere. /503/

**Minimum ignition temperature of a dust layer**

This is the temperature (determined under specified test conditions) of a hot surface, whereby the layer of dust is ignited. It is identical to the smouldering temperature for a layer which is 5 mm thick). /503/

**Minimum ignition temperature of a dust cloud (ignition temperature)**

This is the temperature (determined under specified test conditions) of a hot surface, at which the most ignitable mixture of air and dust ignites. /503/

**Limiting oxygen concentration (LOC)**

This is the maximum oxygen concentration (mole fraction) in a mixture of a combustible substance with air and inert gas or dust in which an explosion does not occur, as determined under test conditions. /503/

**Spontaneous ignition of a dust layer**

This is the ignition of dust caused by the fact that the heat output rate of oxidation reaction or decomposition reaction of the dust is greater than the rate of heat loss to the environment. /503/

**Dust**

A finely divided solid of any shape, structure and density below a grain size of about 500 μm.
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Dust explosion classes

Classes into which dusts are classified because of their explosion constants.

<table>
<thead>
<tr>
<th>Dust explosion class</th>
<th>Explosion constant (EC) in bar · m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust 1</td>
<td>0 &lt; EC ≤ 200</td>
</tr>
<tr>
<td>Dust 2</td>
<td>200 &lt; EC ≤ 300</td>
</tr>
<tr>
<td>Dust 3</td>
<td>EC ≥ 300</td>
</tr>
</tbody>
</table>

Dust/air mixture

Dust dispersed into the air. The distinguishing variable is the dust concentration.

Equipment, protective systems, components, safety, control or regulating devices

“Equipment” means machinery, resources, fixed or mobile devices, control parts and pieces of equipment and detection or prevention systems, designed to work alone or in combination for the generation, transmission, storage, measurement, control and conversion of energy for the processing of material, and which have their potential sources of ignition and are capable of causing an explosion.

“Protective systems” are devices, other than components of the equipment defined above, which halt incipient explosions immediately and/or limit the affected range of an explosion and which are marketed as autonomous systems.

“Components” are those parts which are required for the safe operation of equipment and protective systems, but have no autonomous function.

“Safety, control or regulating devices” are devices for use outside potentially explosive areas that are essential to the safe operation of equipment and protective systems.

Normal operation

“Normal operation” is deemed to be the state in which the work equipment or plant and their devices are used or operated within their design parameters. /503/

Notes:

The release of small quantities of combustible substances as a result of inspections and maintenance are generally part of normal operations.

The release (even) of small amounts of combustible materials due to malfunctions, e.g. through the failure of seals, flanges or as a result of accidents, which for example require the repair or shutdown of the plant in whole or in part, is not usually regarded as coming under normal operations.
10.2 Explosion events (with a focus on ignition sources)

From the following diagram it can be seen that in the food and feed industry, including the sugar industry, mechanical ignition sources (at 35%) account for the largest share of explosion events and thus must especially be taken into account.

**Fig. 8: Distribution of identified ignition sources (BIA-Report 11/97)**

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gesamtübersicht</td>
<td>General overview</td>
</tr>
<tr>
<td>Holz</td>
<td>Wood</td>
</tr>
<tr>
<td>Papier</td>
<td>Paper</td>
</tr>
<tr>
<td>Kohle</td>
<td>Coal</td>
</tr>
<tr>
<td>Nahrungs- und Futtermittel</td>
<td>Food and feed</td>
</tr>
<tr>
<td>Kunststoffe</td>
<td>Plastics</td>
</tr>
<tr>
<td>Metalle</td>
<td>Metals</td>
</tr>
<tr>
<td>Sonstige</td>
<td>Others</td>
</tr>
<tr>
<td>Mechanische Zündquellen</td>
<td>Mechanical ignition sources</td>
</tr>
<tr>
<td>Glimmnest</td>
<td>Hot spot</td>
</tr>
<tr>
<td>Elektrostatische Entladung</td>
<td>Electrostatic discharge</td>
</tr>
</tbody>
</table>
10.3 Explosion events (with a focus on the relevant plant section)

From the following diagram it can be seen that in the food and feed industry, including the sugar industry, conveyors/elevators 26.9% account for the largest share of explosion events and thus must especially be taken into account.

Fig. 9: Plant affected according to dust group (BIA-Report 11/97)

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gesamtsübersicht</td>
<td>General overview</td>
</tr>
<tr>
<td>Holz</td>
<td>Wood</td>
</tr>
<tr>
<td>Papier</td>
<td>Paper</td>
</tr>
<tr>
<td>Kohle</td>
<td>Coal</td>
</tr>
<tr>
<td>Nahrungs- und Futtermittel</td>
<td>Food and feed</td>
</tr>
<tr>
<td>Kunststoffe</td>
<td>Plastics</td>
</tr>
<tr>
<td>Metalle</td>
<td>Metals</td>
</tr>
<tr>
<td>Sonstige</td>
<td>Others</td>
</tr>
<tr>
<td>Silos/bunker</td>
<td>Mechanical ignition sources</td>
</tr>
<tr>
<td>Mahlanlagen</td>
<td>Grinding equipment</td>
</tr>
<tr>
<td>Förderanlagen/Elevatoren</td>
<td>Conveyors/elevators</td>
</tr>
</tbody>
</table>
10.4 Explosion isolation in aspiration lines
The following illustration shows explosion isolation using an extinguishing barrier. This is triggered after prior detection (pressure and/or infrared).

**Fig. 10: Extinguishing barriers (automatic flame arrester) (source: IVSS)**

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Löschmittelbehälter</td>
<td>Extinguishing agent container</td>
</tr>
<tr>
<td>Detektor</td>
<td>Detector</td>
</tr>
<tr>
<td>Druck-/Flammenfront</td>
<td>Pressure/flame front</td>
</tr>
<tr>
<td>Löschmittelaustritt</td>
<td>Extinguishing agent outlet</td>
</tr>
</tbody>
</table>
10.5 Pressure variation in the case of explosion suppression

The following figure shows an example of the pressure variation of an explosion with or without the use of explosion suppression.

![Diagram](image)

Fig. 11: Pressure variation in the case of explosion suppression

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosionsdruck</td>
<td>Explosion pressure</td>
</tr>
<tr>
<td>Ansprechdruck des Unterdrückungssystems</td>
<td>Response pressure of the suppression system</td>
</tr>
<tr>
<td>maximaler Explosionsdruck</td>
<td>maximum explosion pressure</td>
</tr>
<tr>
<td>Löschmitteleingabe</td>
<td>Extinguishing agent input</td>
</tr>
<tr>
<td>normaler Explosionsablauf</td>
<td>normal explosion progression</td>
</tr>
<tr>
<td>Ablauf einer unterdrückten Explosion</td>
<td>Progression of a suppressed explosion</td>
</tr>
<tr>
<td>reduzierter Explosionsdruck</td>
<td>reduced explosion pressure</td>
</tr>
</tbody>
</table>

*Explanation of illustration*

1. The ignition of the explosive mixture occurs at p = 0 Bar, t = 0 ms

2. The pressure detectors report the incipient explosion at p = 0.10 bar, t ≈ 35 ms

3. Suppression begins with the addition of the extinguishing agent at p = 0.16 bar, t = 40 ms
4. The explosion is suppressed at 
   $p_{\text{red}} = 0.40 \text{ bar (reduced explosion pressure), } t \approx 60 \text{ ms}$

5. The flame reaction is suppressed
10.6 Quick-closing slider
The following figure shows a quick-closing slider for explosion isolation. This is triggered after prior detection (pressure and/or infrared).

![Quick-closing slider](source: IVSS)

**Fig. 12: Quick-closing slider (source: IVSS)**

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Druckgasflasche</td>
<td>Compressed gas cylinder</td>
</tr>
<tr>
<td>Detektor</td>
<td>Detector</td>
</tr>
<tr>
<td>Druck-/Flammenfront</td>
<td>Pressure/flame front</td>
</tr>
<tr>
<td>Explosionsschutzschlieber</td>
<td>Explosion-protection slider</td>
</tr>
</tbody>
</table>
10.7 **Rotary valve for explosion isolation**

The following figure shows a rotary valve for explosion protection. This is triggered after prior detection (pressure and/or infrared).

![Rotary valve for explosion isolation](image)

**Fig. 13: Rotary valve theory (source: IVSS)**

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spaltweite</td>
<td>Gap width</td>
</tr>
<tr>
<td>Dicke des Stegs (Spaltlänge)</td>
<td>Thickness of bar (gap length)</td>
</tr>
<tr>
<td>Steg</td>
<td>Bar</td>
</tr>
<tr>
<td>Kammer</td>
<td>Chamber</td>
</tr>
<tr>
<td>Gehäuse</td>
<td>Housing</td>
</tr>
</tbody>
</table>
10.8 Relief vents
The figure below shows a relief vent.

Fig. 14: Principle of a relief vent in a manifold

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schutzkorb</td>
<td>Protective guard</td>
</tr>
<tr>
<td>Druckentlastungseinrichtung</td>
<td>Pressure relief device</td>
</tr>
</tbody>
</table>
Guidelines for prevention of dust explosions during the extraction and processing of sugar

<table>
<thead>
<tr>
<th>(z.B. Abdeckplatter oder Berstscheibe)</th>
<th>(e.g. cover plate or rupture disc)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Richtungsumkehr nur für die betriebsmässige Luftströmung</td>
<td>Reversal of direction only for operational airflow</td>
</tr>
<tr>
<td>Explosionsdruckentlastung</td>
<td>Explosion relief</td>
</tr>
</tbody>
</table>

10.9 Explosion-pressure-resistant and explosion-pressure-shock-resistant construction
The following figure shows the difference between the two forms of construction.

Fig. 15: Pressure-resistant and pressure-shock-resistant design of a container (source: IVSS)
Guidelines for prevention of dust explosions during the extraction and processing of sugar

10.10 Permit for work in hazardous areas

Fig. 16 (source: Pfeifer & Langen GmbH & Co. KG)
10.11 Sample template for explosion protection document

**General information**

- Name of company
- Identification of operational areas / work areas
- Scope of the documentation
- Creation date

**Persons responsible and qualified to operate the plant or operational part thereof**

- Plant management
- Head of department
- Person responsible for the permit procedure (e.g. hot work, entering tight containers, etc.)
- Persons qualified for the inspection of equipment in potentially explosive areas
- Details of the nature and number of qualified and trained employees in the respective work areas

**Short description of the constructional and on-site conditions**

- Plans of the buildings and plant
- Building plans
- Layout plans of the relevant operational and plant parts
- Emergency and rescue plans for all levels

**Process description**

- Brief description of the procedural sequence
- Brief description of the relevant activities (such as sampling, controls, etc.)
- Process flow diagrams with information on safety-related components, equipment, protective systems and electrical systems and appliances (e.g. P & I diagrams)

**Description of the substances used**
Guidelines for prevention of dust explosions during the extraction and processing of sugar

- Material data (e.g. grain size distribution, composition, concentration, density, etc.)
- For raw materials: information on processing state, any precleaning or other pretreatment done by the supplier etc.
- Relevant technical explosion parameters
- Quantities/volume flow

Zone classification
- Areas where imminent explosive atmospheres may occur
- On the interior of plant
- In the vicinity of plant
- Zone classification in operational areas or outdoors
- Zone classification on the interior of plant

Risk assessment
- Description of relevant threats
- Hazards during normal operation, including during startup operations and shutdown
- Warnings of disruptions to be expected for operational reasons
- Hazards as a result of maintenance
- Description of the explosion-protection concept
- Preventive measures
- Technical protection measures

Order of priority of protection measures
- Measures to prevent the formation of dangerous, explosive atmospheres
- Avoidance of ignition sources:
  - Measures to prevent the ignition of dangerous, explosive atmospheres
- Constructional explosion protection:
Guidelines for prevention of dust explosions during the extraction and processing of sugar

Measures to limit the effects of an explosion

- Description of requirements for work equipment

**Organisational measures**

- Relevant operating instructions
- Description of the necessary qualifications of employees
- Description of necessary instructions
- Description of the work clearance system
- Coordination between several employers
  - Operating procedures for dealing with temporary workers, contractors, students, trainees, etc.
- Identification of the zoned areas
- Measures to maintain the zone classification
- Cleaning schedules
- Inspections rounds
- Preventive maintenance
- Maintenance concept
- Inspection schedule

**Annexes**

- EC Declarations of Conformity
- Manufacturer’s declaration
- EC type examination certificate
- Evidence of the design of pressure relief areas, suppression systems, etc.
- Evidence of the suitability of relevant electrical installations and equipment
- Sample permit for hot work (welding permit)
- Sample permit for work in confined spaces
Guidelines for prevention of dust explosions during the extraction and processing of sugar

- Relevant operating instructions
- Relevant operating instructions for work equipment
- Documentation of instructions
- Inspection certificates
- Reference list for applicable documents

**Action plan**

- Description of measure
- Details of the person responsible for the implementation
- Specification of the scheduled completion date
10.12 **Summary explosion protection document**

The explosion protection documentation for the .......... factory/area consists of the individual documentation listed below.

<table>
<thead>
<tr>
<th>Single document</th>
<th>Templates</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explosion areas – zone classification</td>
<td>Aggregate list, installation plan</td>
<td>Device</td>
</tr>
<tr>
<td>Risk assessment, including checklists for ignition sources</td>
<td>Checklists on intranet</td>
<td>Device</td>
</tr>
<tr>
<td>Marking of zones</td>
<td>…</td>
<td>On site</td>
</tr>
<tr>
<td>Clearance procedures for work in explosive area</td>
<td>Form on intranet, Device</td>
<td>Control station</td>
</tr>
<tr>
<td>Employee training</td>
<td>PPT on intranet, device</td>
<td>Human resources / foreman’s area / secretary</td>
</tr>
<tr>
<td>Taking into account of explosion-protection measures given in the relevant operating instructions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Documentation of inspections in explosion-protection area</td>
<td>Checklists on intranet</td>
<td>SAP</td>
</tr>
<tr>
<td>Material data (register of hazardous substances)</td>
<td>…</td>
<td>SAP</td>
</tr>
<tr>
<td>Powers/responsibilities</td>
<td>…</td>
<td>Intranet</td>
</tr>
</tbody>
</table>

Approval: Place, date  
Signature of plant manager/operations manager

**Fig. 17: Permit**
11 Annex (sugar dust)

11.1 Combustion and explosion characteristics of sugar dust
Sugar dust is a combustible (exothermically oxidisable) dust, and is explosive when mixed with air if it is sufficiently fine.

The risk of a dust/air mixture exploding is described by combustion and explosion characteristics which depend, among other things, on the fineness (median value) of the dust. It should be noted that there may be deviations in individual cases – both with regard to the upper and lower values. With regard to sugar, not all possibly significant impacting factors are known at this time, other than the grain size, (e.g. crystal-bound water; fine structure of the particle surface depending on the production process).

The following figures show the basic dependencies, using the example of some selected samples of sugar dust. Therefore, the values for the relevant sugar are to be determined in each case.

<table>
<thead>
<tr>
<th>Median (µm)</th>
<th>Minimum ignition energy (mJ) (with inductance in the measuring system)</th>
<th>Minimum ignition energy (mJ) (without inductance in the measuring system)</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>MIE &lt; 5</td>
<td>5 &lt; MIE &lt; 10</td>
</tr>
<tr>
<td>30</td>
<td>MIE &lt; 10</td>
<td>MIE &lt; 10</td>
</tr>
<tr>
<td>36</td>
<td>30 &lt; MIE &lt; 100</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>MIE &gt; 1000</td>
<td>MIE &gt; 100</td>
</tr>
<tr>
<td>275</td>
<td>$10^5 &lt; MIE &lt; 10^6$</td>
<td></td>
</tr>
<tr>
<td>300</td>
<td>MIE &gt; $10^6$</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 18: Essential dependence of the minimum ignition energy of sugar dust for various particle size distributions
Fig. 19: Minimum ignition energy of some gases and dusts

<table>
<thead>
<tr>
<th>German</th>
<th>English</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelletstaub</td>
<td>Pellet dust</td>
</tr>
<tr>
<td>Zuckerstaub</td>
<td>Sugar dust</td>
</tr>
<tr>
<td>Methan</td>
<td>Methane</td>
</tr>
<tr>
<td>Mindestzündenergie</td>
<td>Minimum ignition energy</td>
</tr>
<tr>
<td>Gase</td>
<td>Gases</td>
</tr>
<tr>
<td>selten</td>
<td>rarely</td>
</tr>
<tr>
<td>Stäube</td>
<td>Dust</td>
</tr>
<tr>
<td>Schweissfunken</td>
<td>Welding sparks</td>
</tr>
<tr>
<td>Schleißfunken (Trennschleifer)</td>
<td>Grinding sparks (angle grinder)</td>
</tr>
<tr>
<td>Schlagfunken</td>
<td>Impact sparks</td>
</tr>
<tr>
<td>Gleitstielbüschelentladungen</td>
<td>Propagating brush discharges</td>
</tr>
<tr>
<td>Elektrostatische Funken</td>
<td>Electrostatic sparks</td>
</tr>
</tbody>
</table>
Notes:
As long as there is only a small fraction (≤ 3%) of dust distributed evenly in coarse granulated sugar, and enrichment by segregation is negligible in transport processes, the formation of an explosive atmosphere is relatively unlikely.

The values reported represent only the results of individual studies of the samples. Conclusions about other samples is generally only possible in terms of trends. More information regarding the listed types of sugar dust can be found on the GESTIS-DUST-EX database /802/ (see Section 13.8 Fehler! Verweisquelle konnte nicht gefunden werden.).

<table>
<thead>
<tr>
<th>Median (µm)</th>
<th>LEL (g/m³)</th>
<th>p_max (bar)</th>
<th>Explosion constant (bar m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;25</td>
<td>30</td>
<td>9.1</td>
<td>140</td>
</tr>
<tr>
<td>25</td>
<td>60</td>
<td>9.1</td>
<td>140</td>
</tr>
<tr>
<td>80</td>
<td>60</td>
<td>8.3</td>
<td>135</td>
</tr>
<tr>
<td>300</td>
<td>500</td>
<td>4.0</td>
<td>12</td>
</tr>
<tr>
<td>380</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>790</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1250</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 20:** The essential dependence of the lower explosive limit (LEL), the maximum explosion pressure (p_max) and the explosion constant of sugar dust at different particle sizes

If there are no specific characteristics known for assessing the risk of explosion of actually handled sugar dust, then the values given in Fig. 21 are to be applied. From experience, these values tend towards the “safe side” where normal operating conditions exist (so-called atmospheric conditions).

- Dust explosion class : Dust 1
- Max. explosion overpressure p_max : 9 bar
- Explosion constant : 140 bar m/s
- Lower explosion limit LEL : 30 g/m³
- Minimum ignition temperature of the dust cloud (ignition temperature) : 350 °C (BAM – Oven)
- Minimum ignition temperature of a 5 mm layer of dust (smouldering temperature) : 420 °C
- Combustibility : CN 2
Guidelines for prevention of dust explosions during the extraction and processing of sugar

Minimum ignition energy: < 5 mJ (with inductance)
                      : > 5 mJ/<10 mJ (without inductance)
Melting point        : 169 °C
Limiting oxygen concentration: 9 vol. %

Sugar dust does not tend to produce hotspots, due to its low melting point!

**Fig. 21: Critical combustion and explosion characteristics of dust sugar**

**Notes:**
These figures are mean values: they need to be confirmed by measurements if necessary in each specific case.

A definition of terms is given in Annex Fehler! Verweisquelle konnte nicht gefunden werden..
11.2 Typical zone classification for sugar dust
This zone classification has demonstrated itself to be useful and appropriate in terms of the safety considerations of many plants and operating areas over many years.

Other zone classifications are conceivable in places. However, a detailed risk assessment must be then be done, setting forth in detail the basis of the assumptions and conditions under which this second classification was made. This information must be included in the explosion protection document. /402/

<table>
<thead>
<tr>
<th>Zone classification for plant and operational areas in the sugar sector which are potentially explosive as a result of sugar dust</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant using granulated sugar</strong></td>
<td></td>
</tr>
<tr>
<td>Large silo</td>
<td></td>
</tr>
<tr>
<td>Within close range of the filling jet</td>
<td>21</td>
</tr>
<tr>
<td>Other spaces</td>
<td>22</td>
</tr>
<tr>
<td>Sifter (interior space)</td>
<td>21</td>
</tr>
<tr>
<td>Filter (only internal raw gas side)</td>
<td></td>
</tr>
<tr>
<td>a.) in general, regular cleaning</td>
<td>20</td>
</tr>
<tr>
<td>b.) suctioned cons. &lt; LEL, occasional cleaning</td>
<td>21</td>
</tr>
<tr>
<td>Interior of dust extraction lines (clean gas side with/without concentration monitoring.)</td>
<td>- / 22</td>
</tr>
<tr>
<td>Heart of dust extraction (raw gas)</td>
<td>22</td>
</tr>
<tr>
<td>Elevator (interior)</td>
<td>21</td>
</tr>
<tr>
<td>Drying drum (interior)</td>
<td>22</td>
</tr>
<tr>
<td>Fluidised bed dryer (interior)</td>
<td>22</td>
</tr>
<tr>
<td>Type hopper (interior), receiving silo, receiving container</td>
<td>21</td>
</tr>
<tr>
<td>Pneumatic conveying line</td>
<td></td>
</tr>
<tr>
<td>a.) dense flow conveying</td>
<td>22</td>
</tr>
<tr>
<td>b.) ground-mounted hoisting machine</td>
<td>22</td>
</tr>
<tr>
<td>c.) plug conveying</td>
<td>-</td>
</tr>
<tr>
<td>Loading silo vehicles (tank interior and interior of tube)</td>
<td></td>
</tr>
<tr>
<td>a.) with suction</td>
<td>22</td>
</tr>
<tr>
<td>b.) without suction</td>
<td>21</td>
</tr>
<tr>
<td>Filling of big bags (interior)</td>
<td></td>
</tr>
<tr>
<td>a.) with suction</td>
<td>22</td>
</tr>
<tr>
<td>b.) without suction</td>
<td>21</td>
</tr>
<tr>
<td>Filling of containers (with in-liner) by jet conveyor, with extraction</td>
<td>21</td>
</tr>
</tbody>
</table>
Guidelines for prevention of dust explosions during the extraction and processing of sugar

---

**using sugar powder (median ~ 30µm)**

<table>
<thead>
<tr>
<th>Equipment/Component</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Powder conditioner (with air supply)</td>
<td>20</td>
</tr>
<tr>
<td>Powder mill (mill interior, grinding chamber only)</td>
<td>20</td>
</tr>
<tr>
<td>Powder hopper (interior only)</td>
<td>20</td>
</tr>
<tr>
<td>Powder screw / dust screw with</td>
<td></td>
</tr>
<tr>
<td>a.) slow peripheral speed (v &lt; 1 m/s)</td>
<td>22</td>
</tr>
<tr>
<td>b.) fast peripheral speed (v &gt; 1 m/s)</td>
<td>21</td>
</tr>
<tr>
<td>Pneumatic conveying (pipelines, sending and reception tank) through</td>
<td></td>
</tr>
<tr>
<td>a.) dense phase conveying</td>
<td>21</td>
</tr>
<tr>
<td>b.) ground-mounted hoisting machine</td>
<td>20</td>
</tr>
<tr>
<td>c.) plug conveying</td>
<td>21</td>
</tr>
</tbody>
</table>

**Operational areas**

<table>
<thead>
<tr>
<th>Operational Area</th>
<th>Risk Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>with dust-proof plant without dust deposits</td>
<td>-</td>
</tr>
<tr>
<td>with non-dust-proof plant and dust deposits</td>
<td>22</td>
</tr>
<tr>
<td>Special case: deposits in hazardous quantities can be reliably prevented by regular cleaning!</td>
<td>-</td>
</tr>
</tbody>
</table>
12 Annex (chip and pellet dust)

12.1 Combustion and explosion characteristics of chip and pellet dust

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dust explosion class</td>
<td>Dust 1</td>
</tr>
<tr>
<td>Max. explosion overpressure $p_{\text{max}}$</td>
<td>8.6 bar</td>
</tr>
<tr>
<td>Explosion constant</td>
<td>91 bar m/s</td>
</tr>
<tr>
<td>Lower explosion limit LEL</td>
<td>125 g/m$^3$</td>
</tr>
<tr>
<td>Ignition temperature</td>
<td>420 °C</td>
</tr>
<tr>
<td>Smouldering temperature</td>
<td>270 °C</td>
</tr>
<tr>
<td>Combustibility</td>
<td>CN 4</td>
</tr>
<tr>
<td>Minimum ignition energy (350 μm)</td>
<td>&gt; $10^3$ mJ</td>
</tr>
<tr>
<td>Limiting oxygen concentration</td>
<td>9 vol. %</td>
</tr>
</tbody>
</table>

Note:
These figures are mean values: they need to be confirmed by measurements if necessary in each specific case.

A definition of terms is given in Annex Fehler! Verweisquelle konnte nicht gefunden werden.
12.2 Typical zone classification for chip and pellet dust

This zone classification has demonstrated itself to be useful and appropriate in terms of the safety considerations of many plants and operating areas over many years. The exact environmental conditions must be observed in individual cases.

Other zone classifications are conceivable in places. However, a detailed risk assessment must be then be done, setting forth in detail the basis of the assumptions and conditions under which this second classification was made. This information must be included in the explosion protection document.

<table>
<thead>
<tr>
<th>Zone classification for plant and operational areas in the sugar sector which are potentially explosive as a result of chip and pellet dust</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant</strong></td>
<td></td>
</tr>
<tr>
<td>Fluidised bed/steam dryer (interior)</td>
<td>-</td>
</tr>
<tr>
<td>Chip drying drum (in the discharge area of the interior)</td>
<td>22</td>
</tr>
<tr>
<td>Cyclone (interior) downstream of chip drying drum</td>
<td>22</td>
</tr>
<tr>
<td>Bucket conveyor (elevator) for pulp (interior)</td>
<td>22</td>
</tr>
<tr>
<td>Spreader screw for pulp (interior, upstream of chip hopper)</td>
<td>22</td>
</tr>
<tr>
<td>Pulp hopper (interior, upstream of feed screw)</td>
<td>22</td>
</tr>
<tr>
<td>Feed screw (interior, upstream of press, without addition of molasses before press)</td>
<td>22</td>
</tr>
<tr>
<td>Feed screw (interior, before press, with addition of molasses before press)</td>
<td>-</td>
</tr>
<tr>
<td>Pellet press (press area only)</td>
<td>-</td>
</tr>
<tr>
<td>Slip sieve / tube (downstream of pellet press, upstream of pellet cooler)</td>
<td>22</td>
</tr>
<tr>
<td>Conveyor belt (in discharge area), e.g. sidewall conveyor</td>
<td>22</td>
</tr>
<tr>
<td>Pellet cooler (interior only)</td>
<td>22</td>
</tr>
<tr>
<td>Fan (downstream of pellet cooler, before cyclone)</td>
<td>22</td>
</tr>
<tr>
<td>Cyclone (interior; for dust removal from pellet cooler)</td>
<td>22</td>
</tr>
<tr>
<td>Bucket conveyor (elevator) for pellets (inside the shafts)</td>
<td>22</td>
</tr>
<tr>
<td>Screw conveyor or sidewall conveyor for pellets (for further transport)</td>
<td>22</td>
</tr>
<tr>
<td>Warehouse (bulk storage, with dropping of pellets from the ceiling)</td>
<td>22</td>
</tr>
<tr>
<td>Silo/hopper interior (in the case that pellets are dropped from the silo/hopper cover)</td>
<td>22</td>
</tr>
<tr>
<td>Pellet loading (see section on operating ranges)</td>
<td>22</td>
</tr>
<tr>
<td>Filters for removal of dust from route (only raw gas side of interior)</td>
<td></td>
</tr>
<tr>
<td>a) in general: regular cleaning</td>
<td>20</td>
</tr>
<tr>
<td>b) special case: suctioned cons. &lt; LEL and occasional cleaning.</td>
<td>21</td>
</tr>
<tr>
<td>Heart of dust extraction (sucked Conc. &lt;LEL)</td>
<td>22</td>
</tr>
</tbody>
</table>
### Zone classification for plant and operational areas in the sugar sector which are potentially explosive as a result of chip and pellet dust

<table>
<thead>
<tr>
<th>Pellet dust screw (interior)</th>
<th>Zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>a.) slow peripheral speed (v &lt; 1 \text{ m/s})</td>
<td>22</td>
</tr>
<tr>
<td>b.) fast peripheral speed (v &gt; 1 \text{ m/s})</td>
<td>21</td>
</tr>
</tbody>
</table>

### Operational areas

| with dust-proof plant without dust deposits | - |
| with non-dust-proof plant and dust deposits | 22 |
| Special case: deposits in hazardous quantities can be reliably prevented by regular cleaning! | - |
13 List of references

13.1 Regulations, rules and information from accident insurers

101. BGV A 1 – Berufsgenossenschaftliche Vorschrift
Grundsätze der Prävention

102. BGR A1 – Berufsgenossenschaftliche Regel
Grundsätze der Prävention

103. BGR 104 – Berufsgenossenschaftliche Regel
Explosionsschutz-Regeln (EX-RL)
Sammlung technischer Regeln für das Vermeiden der Gefahren durch explosionsfähige Atmosphäre mit Beispielsammlung

104. BGR 109 – Berufsgenossenschaftliche Regel
Vermeidung der Gefahren von Staubbränden und Staubexplosionen beim Schleifen, Bürsten und Polieren von Aluminium und seinen Legierungen

105. BGR 121 – Berufsgenossenschaftliche Regel
Arbeitsplatzlüftung – Lufttechnische Maßnahmen

107. None

108. BGI 5127 – Berufsgenossenschaftliche Information
Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen
Colour version of TRBS 2153, see /508/

109. BGR 133 – Berufsgenossenschaftliche Regel
Ausrüstung von Arbeitsstätten mit Feuerlöschern - zurückgezogen
See ASR A2.2 "Maßnahem gegen Brände"

110. None

111. None

112. BIA-Report 12/97
Brenn- und Explosionskenngrößen von Stäuben
Berufsgenossenschaftliches Institut für Arbeitssicherheit
December 1997

For more recent information, also see BGIA's GESTIS-Dust-Ex-Database. /802/

113. None
13.2 European Directives

201. Directive 94/9/EC

13.3 Laws

301. Occupational safety and health act (ArbSchG)
Act on the introduction of measures of occupational safety and to improve the safety and health of workers at work

302. Product Safety Act (ProdSG)
Act on making products available on the market

303. Chemicals act (ChemG)
Act on protection against dangerous substances
13.4 Ordinances

401. Ordinance on the marketing of equipment and protective systems for hazardous areas (Explosion protection ordinance – 11th ProdSV) December 1996 and modifications made up until publication of the guideline 1)

402. Ordinance on safety and health in the provision of equipment and its deployment at work, on safety during operation of plant requiring monitoring and the organisation of occupational safety (Industrial safety ordinance – BetrSichV) September 2002 and modifications made up until publication of the guideline 1)

403. Ordinance regarding the workplace (Workplace ordinance – ArbStättV) August 2004 and modifications made up until publication of the guideline 1)

404. Ordinance on protection against hazardous substances (Ordinance on hazardous substances – GefStoffV) December 2010 and modifications made up until publication of the guideline 1)
13.5 Technical regulations

501. TRBS 1203 – Technische Regeln für Betriebssicherheit
Befähigte Personen

501.1 None

502. TRBS 1201 – Technische Regeln für Betriebssicherheit
Prüfung von Arbeitsmitteln und überwachungsbedürftigen Anlagen

502.1 TRBS 1201 Teil 1 – Technische Regeln für Betriebssicherheit
Prüfung von Anlagen in explosionsgefährdeten Bereichen und Überprüfung von
Arbeitsplätzen in explosionsgefährdeten Bereichen

502.2 TRBS 1201 Teil 3 – Technische Regeln für Betriebssicherheit
Instandhaltung an Geräten, Schutzsystemen, Sicherheits-, Kontroll- und
Regelvorrichtungen im Sinne der RL/94/9/EG
Ermittlung der Prüfnotwendigkeit gemäß § 14 Abs. 6 BetrSichV

503. TRBS 2152 – Technische Regeln für Betriebssicherheit
TRGS 720 - Technische Regeln für Gefahrstoffe
Gefährliche explosionsfähige Atmosphäre
Allgemeines

504. TRBS 2152 Teil 1 – Technische Regeln für Betriebssicherheit
TRGS 721 - Technische Regeln für Gefahrstoffe
Gefährliche explosionsfähige Atmosphäre –
Beurteilung der Explosionsgefährdung

505. TRBS 2152 Teil 2 – Technische Regeln für Betriebssicherheit
TRGS 722 - Technische Regeln für Gefahrstoffe
Gefährliche explosionsfähige Atmosphäre –
Vermeidung oder Einschränkung gefährlicher explosionsfähiger Atmosphäre

506. TRBS 2152 Teil 3 – Technische Regeln für Betriebssicherheit
Gefährliche explosionsfähige Atmosphäre –
Vermeidung der Entzündung gefährlicher explosionsfähiger Atmosphäre

507. TRBS 2152 Teil 4 – Technische Regeln für Betriebssicherheit
Gefährliche explosionsfähige Atmosphäre –
Konstruktive Maßnahmen, welche die Auswirkung einer Explosion auf ein
unbedenkliches Maß beschränken (Konstruktiver Explosionsschutz)

508. TRBS 2153 – Technische Regeln für Betriebssicherheit
Vermeidung von Zündgefahren infolge elektrostatischer Aufladungen
Also see colour version /108/

509. None

510. TRBS 1112 Teil 1 – Technische Regeln für Betriebssicherheit
Explosionsgefährdungen bei und durch Instandhaltungsmaßnahmen –
Beurteilung und Schutzmaßnahmen

511. None
Guidelines for prevention of dust explosions during the extraction and processing of sugar

512. TRBS 1111 – Technische Regeln für Betriebssicherheit
Gefährdungsbeurteilung und sicherheitstechnische Bewertung

513. None

514. ASR A2.2 Maßnahmen gegen Brände
515. ASR A1.3 Sicherheits- und Gesundheitsschutzkennzeichnung
599. Glossary of terms to the regulations of the industrial safety ordinance and the ordinance on hazardous substances
### 13.6 Standards

<table>
<thead>
<tr>
<th>No.</th>
<th>Standard</th>
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<tbody>
<tr>
<td>601</td>
<td>DIN EN 1127-1</td>
</tr>
<tr>
<td></td>
<td>Explosive atmospheres</td>
</tr>
<tr>
<td></td>
<td>Explosion prevention and protection</td>
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<tr>
<td></td>
<td>Part 1: Basic concepts and methodology</td>
</tr>
<tr>
<td>602</td>
<td>None</td>
</tr>
<tr>
<td>603</td>
<td>DIN EN 60079-14 / DIN VDE 0165 Part 1</td>
</tr>
<tr>
<td></td>
<td>Explosive atmospheres</td>
</tr>
<tr>
<td></td>
<td>Electrical installations design, selection and erection</td>
</tr>
<tr>
<td>604</td>
<td>None</td>
</tr>
<tr>
<td>605</td>
<td>None</td>
</tr>
<tr>
<td>606</td>
<td>None</td>
</tr>
</tbody>
</table>
13.7 Other texts

701. VDI 2263
Dust fires and dust explosions; Hazards, assessment, protective measures
May 1992

702. VDI 2263 Sheet 1
Dust fires and dust explosions; Hazards, assessment, protective measures; Test methods for the determination of the safety characteristic of dusts
May 1990

703. VDI 2263 Sheet 2
Dust fires and dust explosions; Hazards, assessment, protective measures; Inerting
May 1992

704. VDI 2263 Sheet 3
Dust fires and dust explosions; Hazards, assessment, protective measures; Pressure-shock-resistant vessels and apparatus; Calculation, construction and tests
May 1990

705. VDI 2263 Sheet 4
Dust fires and dust explosions; Hazards, assessment, protective measures; Suppression of dust explosions
April 1992

706. VDI 2263 Sheet 5
Dust fires and dust explosions; Hazards, assessment, protective measures; Explosion protection in fluidized bed dryers
March 2005

706.1 VDI 2263 Sheet 5.1
Dust fires and dust explosions; Hazards, assessment, protective measures; Explosion protection in fluidized bed dryers - Hints and examples of operation for manufacturers and operators
February 2004

707. VDI 2263 Sheet 6
Dust fires and dust explosions; Hazards, assessment, protective measures; Dust fires and explosion protection in dust extracting installations
September 2007

707.1 VDI 2263 Sheet 6.1
Dust fires and dust explosions; Hazards, assessment, protective measures;
Guidelines for prevention of dust explosions during the extraction and processing of sugar

- Dust fires and explosion protection in dust extracting installations; Examples
  October 2009

708. VDI 2263 Sheet 8
Dust fires and dust explosions;
Hazards, assessment, protective measures;
Fire and explosion protection on elevators
December 2008

708.1 VDI 2263 Sheet 8.1
Dust fires and dust explosions;
Hazards, assessment, protective measures;
Fire and explosion protection on elevators - Examples
March 2011

710. VDI 3673 Sheet 1
Pressure venting of dust explosions
November 2002

711. VDE 0105, Part 9
Operation of power installations part 9: supplementary requirements for electrical installations in potentially explosive atmospheres

- 84 -
13.8 Databases and other information sources on the Internet

801. GESTIS-substances-database
www.dguv.de/ifa/de/gestis/stoffdb/index.jsp

802. GESTIS-Dust-Ex-database
Database on the combustion and explosion characteristics of dust
www.dguv.de/ifa/de/gestis/expl/index.jsp

803. BG RCI’s explosion protection portal
www.bgrci.de/exinfode/start/

803. BG RCI’s hazardous material information system
www.gischem.de

804. Federal Environmental Agency – REACH info
www.reach-info.de

805. DMT GmbH
www.dmt.de

806. DEKRA EXAM GmbH
www.dekra-exam.eu

807. Physikalisch-Technische Bundesanstalt
www.ptb.de

808. Federal Institute for Occupational Safety and Health (BAuA)
Technical regulations for occupational safety

809. VdS Schadenverhütung GmbH
(formerly: Verband der deutschen Sachversicherer)
“Schadensverhütungsrichtlinien”
www.vds.de
13.9 Other sources used in preparing the catalogue

<table>
<thead>
<tr>
<th>No.</th>
<th>Author(s)</th>
<th>Title</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>900.</td>
<td>Wirkner-Bott, I., Schumann, St., Stock, M.</td>
<td>Flammen- und Druckwirkung bei Explosionsdruckentlastung</td>
<td>VDI symposium &quot;Sichere Handhabung brennbarer Stäube&quot; Nuremberg 1992</td>
</tr>
<tr>
<td>901.</td>
<td>Siwek, R.</td>
<td>Explosionsdruckentlastung - Novellierung der Richtlinie VDI 3673</td>
<td>VDI symposium &quot;Sichere Handhabung brennbarer Stäube&quot; Nuremberg 1992</td>
</tr>
<tr>
<td>904.</td>
<td>Siwek, R.</td>
<td>Explosionsfeste Bauweise</td>
<td>VDI symposium &quot;Sichere Handhabung brennbarer Stäube&quot; Würzburg, 25./26.05.1994</td>
</tr>
<tr>
<td>905.</td>
<td>Siwek, R.</td>
<td>Explosionsdruckentlastung</td>
<td>VDI symposium &quot;Sichere Handhabung brennbarer Stäube&quot; Würzburg, 25./26.05.1994</td>
</tr>
<tr>
<td>908.</td>
<td>Radandt, S.</td>
<td>Explosionsdruckentlastung von Silos</td>
<td>VDI symposium &quot;Sichere Handhabung brennbarer Stäube&quot; Würzburg, 25./26.05.1994</td>
</tr>
<tr>
<td>909.</td>
<td>Glor, M.; Lütgents, G.</td>
<td>Elektrostatische Zündgefahr beim Einsatz aufladbarer Packmittel für</td>
<td></td>
</tr>
</tbody>
</table>
Guidelines for prevention of dust explosions during the extraction and processing of sugar

Feststoffe
VDI symposium "Sichere Handhabung brennbarer Stäube"
VDI-Berichte 701

910. Wittler, M
Kriterien zur Weiterverwendung älterer elektrischer Arbeitmittel gemäß Betriebssicherheitsverordnung
VDI symposium „Sichere Handhabung brennbarer Stäube”
Nuremberg, 01 – 03.03.2005

911. Siwek, R.; Beck, H.
Explosionsschutz bei Wirbelschichtanlagen und Filteranlagen
VDI-Richtlinien 2263
VDI symposium “Sichere Handhabung brennbarer Stäube”
Nuremberg, 01 – 03.03.2005

912. Wittler, M
Reichen Gehäuseschutzarten wie IP 65 und 54 für den Einsatz in staubexplosionsgefährdeten Bereichen?
VDI symposium "Sichere Handhabung brennbarer Stäube"
Nuremberg, 11 – 13.03.2008

913. Hesener, U.; Hübner, J.
Prüfungen nach Betriebssicherheitsverordnung
VDI symposium “Sichere Handhabung brennbarer Stäube”
Nuremberg, 11 – 13.03.2008

914. Dyrba, B
Kompendium Explosionsschutz
Band 1 Fragen und Antworten
Band 2 Rechtsvorschriften
Main work (03/2015) with supplementary sheets
14 Reference sources

1. Carl Heymanns Verlag KG
   Luxemburger Straße 449
   50939 Cologne
   Tel.: +49 (0) 2 21 9 43 73 ext. 7000
   Fax: +49 (0) 2 21 9 43 73 ext. 7201
   Email: info@wolterskluwer.de
   www.heymanns.de

2. Beuth-Verlag GmbH,
   Burggrafenstraße 6,
   10787 Berlin
   Tel.: +49 (0) 30 26 01 ext. 0
   Fax: (+49 (0) 30 26 01 ext. 12 60
   Email: kundenservice@beuth.de
   www.beuth.de

3. Erich Schmidt Verlag GmbH & Co.
   Genthiner Straße 30 G
   10785 Berlin
   Tel.: +49 (0) 30 25 00 85 ext. 0
   Fax: +49 (0) 30 25 00 851 ext. 305
   Email: esv@esvmedien.de
   www.esv.info

4. VDE-Verlag GmbH
   Bismarckstraße 33
   10625 Berlin
   Tel.: +49 (0) 30 34 80 01 ext. 0
   Fax: +49 (0) 30 34 80 01 ext. 9088
   Email: vertrieb@vde-verlag.de
   www.vde-verlag.de

5. Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAUA)
   Friedrich-Henkel-Weg 1-25
   44149 Dortmund
   Tel.: +49 (0) 231 90 71 ext. 0
   Fax: +49 (0) 231 90 71 ext. 2454
   Email: poststelle@baua.bund.de
   www.baua.de

6. VDI Verlag GmbH
   VDI-Platz 1
   40239 Düsseldorf
   Tel.: +49 (0) 211 6188 ext. 0
   Fax: +49 (0) 211 6188 ext. 112
   Email: info@vdi-nachrichten.com
   www.vdi-verlag.de
7. VdS Schadenverhütung GmbH
Amsterdamer Str. 174
50735 Cologne
Tel.: +49 (0) 221 7766 ext. 0
Fax: +49 (0) 221 7766 ext. 341
Email: info@vds.de
www.vds.de