



**Committee of Experts on the Transport of Dangerous Goods
and on the Globally Harmonized System of Classification
and Labelling of Chemicals****Sub-Committee of Experts on the Globally Harmonized
System of Classification and Labelling of Chemicals****Thirty-third session**

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Item 2 (c) of the provisional agenda

Classification criteria and related hazard communication:**Dust explosion hazards****Proposed annex to address dust explosion hazards****Transmitted by the expert from the United States on behalf of the
correspondence group*****Introduction**

1. At the thirty-second session of the Sub-Committee, the correspondence group submitted an informal paper presenting a draft annex addressing dust explosion hazards for its consideration. The Sub-Committee noted the work done by the correspondence group and requested a working paper at the next session. This working paper presents a revised annex – the result of the work by the correspondence group since the thirty-second session. The paper also provides a review of the work performed by the correspondence group identified to address dust explosion hazards in the GHS.

Background

2. At the seventeenth session of the Sub-Committee, the expert from the United States introduced a paper proposing that the hazards presented by dust explosions be included in the GHS (ST/SG/AC.10/C.4/2009/6). The Sub-Committee agreed that work could begin on the topic, including an analysis of existing practices and regulations addressing dust

* In accordance with the programme of work of the Sub-Committee for 2017–2018 approved by the Committee at its eighth session (see ST/SG/AC.10/C.3/100, paragraph 98 and ST/SG/AC.10/44, para. 14).

explosion hazards (ST/SG/AC.10/C.4/34, paragraphs 9 to 13). Over the next biennium, the correspondence group developed and distributed a survey to experts representing member countries and non-governmental organizations.

3. Upon completion of the survey, the correspondence group identified three workstreams to address how dust explosion hazards should be addressed in the GHS (see informal document INF.21, thirty-third session). These workstreams are listed below:

- Workstream 1: review the existing national consensus and reference regulations developed by competent authorities, identify the common pieces of information used to communicate the hazards, and determine how and if this information is to be addressed;
- Workstream 2: ensure that any information proposed to be included in section 9 of the Safety Data Sheet (SDS) is communicated to the informal group on Section 9 of Annex 4;
- Workstream 3: start the discussion and develop an outline or work plan for a separate chapter in the GHS containing more detailed information on the conditions under which a dust explosion hazard could be encountered.

4. Over the next several sessions, the correspondence group worked on issues associated with Workstreams 1 and 2. At its twenty-fourth session, the Sub-Committee adopted the proposals to provide guidance on communication of dust explosion hazards on the SDS in annex 4 to the GHS (see ST/SG/AC.10/C.4/48, paragraph 32).

5. Over the next several sessions, the correspondence group continued work on Workstream 3. At the thirtieth session, the Sub-Committee noted that the correspondence group agreed that work on Workstream 3 should proceed by providing guidance in the form of an annex to the GHS, using a “thought-starter” provided by the expert from Germany. It would include definitions and hazard identification criteria and address risk management options, and would provide guidance for harmonized hazard communication for those competent authorities who might wish to use it (see ST/SG/AC.10/C.4/60, paragraphs 13 to 19).

6. The development of the annex proceeded quickly, resulting in an informal document presenting a draft annex for consideration by the Sub-Committee at the thirty-second session (see INF.23, thirty-second session). At the thirty-second session the Sub-Committee noted the work by the correspondence group and its intent to submit a formal proposal for the thirty-third session (see ST/SG/AC.10/C.4/64, paragraphs 26 and 27).

Overview of dust explosion hazard annex

7. Because of the complexity and severity of the hazards associated with dust explosions, the content and purpose of the annex is slightly different than that of many of the chapters in the GHS. The annex provides guidance on the factors that contribute to a dust explosion hazard and on hazard identification and the need for risk assessment, prevention, mitigation, and communication. Dust hazards may present themselves in two ways - as a hazard present in the supplied form, as well as a hazard that may result from downstream processing.

8. The annex is organized as follows:

- Section 2.2 “Definitions”: Similar to other sections of the GHS, the annex includes a section on definitions. The correspondence group used definitions from recognized international and national sources.

- Section 2.3 “Identification of combustible dust”: A decision flow chart is included so users may more easily understand the factors associated with determining whether a substance, mixture, or solid material should be identified as a combustible dust. Immediately following the flow chart, each of the decision boxes is explained in greater detail.
- Section 2.4 “Factors contributing to a dust explosion”: Various factors that contribute to a dust explosion are discussed in this section.
- Section 2.5 “Other factors impacting the severity of a dust explosion”: The more significant factors that impact the severity of the explosion discussed in this section.
- Section 2.6 “Hazard prevention, risk assessment and mitigation”: Within this section of the annex, two tables are presented to better explain the types of issues that should be considered. The first table presents the principles of explosion protection, and includes both preventive and mitigative measures, as well as the safety characteristics that are most relevant to the measures proposed. The second table uses ignition sources as an example to explain the type of evaluation necessary when considering potential dust explosion protection measures during operations.
- Section 2.7 “Supplemental information for hazard and risk communication”: For those implementing countries who may wish to have a common way to communicate, this section references the Annex 4 guidance which provides suggested statements for specific sections of the SDS. This section also provides additional suggested phrases for communicating the hazard and risk.
- Section 2.8 “References”: The last section of the annex includes a listing of references on test methods and specifically notes a few existing regulations and guidance documents.

Proposal

9. The correspondence group invites the Sub-Committee to consider the recommended annex to the GHS and the consequential amendments as set forth in annexes 1 and 2 of this document.

Annex 1

“Annex 11

GUIDANCE ON OTHER HAZARDS NOT RESULTING IN CLASSIFICATION

A11.1 Introduction

This guidance aims to provide information that facilitates the identification of hazards which do not result in classification, but which may need to be assessed and communicated.

A11.2 Dust explosions

This section provides guidance on the factors that contribute to a dust explosion hazard and on hazard identification and the need for risk assessment, prevention, mitigation, and communication.

A11.2.1 *Scope and applicability*

A11.2.1.1 Any solid substance or mixture, which is combustible, may pose a dust explosion risk when in the form of fine particles in an oxidizing atmosphere such as air. A risk assessment may be needed for many substances, mixtures, or solid materials, not just those classified as flammable solids according to Chapter 2.7. In addition, dusts may be formed (intentionally or unintentionally) during transfer or movement, or in a facility during handling or mechanical processing (e.g., milling, grinding) of substances/mixtures/solid materials (e.g., agricultural commodities, wood products, pharmaceuticals, dyes, coal, metals, plastics). Thus, the possibility of the formation of small particles and their potential accumulation should also be assessed. Where a dust explosion risk is identified, effective preventive and protective measures should be implemented as required by national legislation, regulations, or standards.

A11.2.1.2 This guidance identifies when combustible dusts may be present and thus, when the risk of a dust explosion should be considered. The guidance:

- (a) Gives a flow chart specifying the key steps to identify possible dust explosions;
- (b) Identifies the factors contributing to a dust explosion;
- (c) Sets out principles of hazard and risk management; and
- (d) Indicates where expert knowledge is required.

A11.2.2 *Definitions*

In this section, the following terms, specific to dust explosion hazards and risks, are used:

Combustible dust: Finely divided solid particles of a substance or mixture that are liable to catch fire or explode on ignition when dispersed in air or other oxidizing media;

Combustion: Energy releasing (exothermic) oxidation reaction of (or with) combustible substances/mixtures/solid materials;

Dispersion: Distribution of fine dust particles in the form of a cloud;

Dust deflagration index (K_{st}): A safety characteristic related to the severity of a dust explosion. The larger the value for K_{st} , the more severe the explosion. K_{st} is dust specific and volume independent, and is calculated using the cubic law equation:

$$(d_p/d_t)_{max} \cdot V^{1/3} = const. = K_{st}$$

where:

$(d_p/d_t)_{max}$ = maximum rate of pressure rise

V = volume of testing chamber

Dusts are classified into dust explosion classes according to their K_{st} value:

St 1: $0 < K_{st} \leq 200 \text{ bar m s}^{-1}$

St 2: $200 < K_{st} \leq 300 \text{ bar m s}^{-1}$

St 3: $K_{st} > 300 \text{ bar m s}^{-1}$

The K_{st} value and the maximum explosion pressure are used to design appropriate safety measures (e.g. pressure relief venting).

Explosible dust atmosphere: A dispersion of a combustible dust in air which after ignition results in a self-sustaining flame propagation;

Explosion: Abrupt oxidation or decomposition reaction producing an increase in temperature, pressure, or both simultaneously;†

Limiting oxygen concentration (LOC): maximum oxygen concentration in a mixture of a combustible dust and air and an inert gas, in which an explosion will not occur, determined under specific test conditions;

Maximum explosion pressure: Highest pressure registered in a closed vessel for a dust explosion at optimum concentration;

Minimum Explosible Concentration (MEC)/Lower Explosible Limit (LEL): The minimum concentration of a combustible dust dispersed in air measured in mass unit per volume that will support an explosion;

Minimum ignition energy (MIE): Lowest electrical energy stored in a capacitor, which upon discharge is sufficient to ignite the most sensitive dust/air mixture under specific test conditions;

Minimum ignition temperature (MIT) of a dust cloud: Lowest temperature of a hot surface on which the most ignitable mixture of a dust with air is ignited under specified test conditions;

Particle size: Smallest sieve aperture through which a particle will pass if presented in the most favourable orientation;‡

A11.2.3 Identification of combustible dust

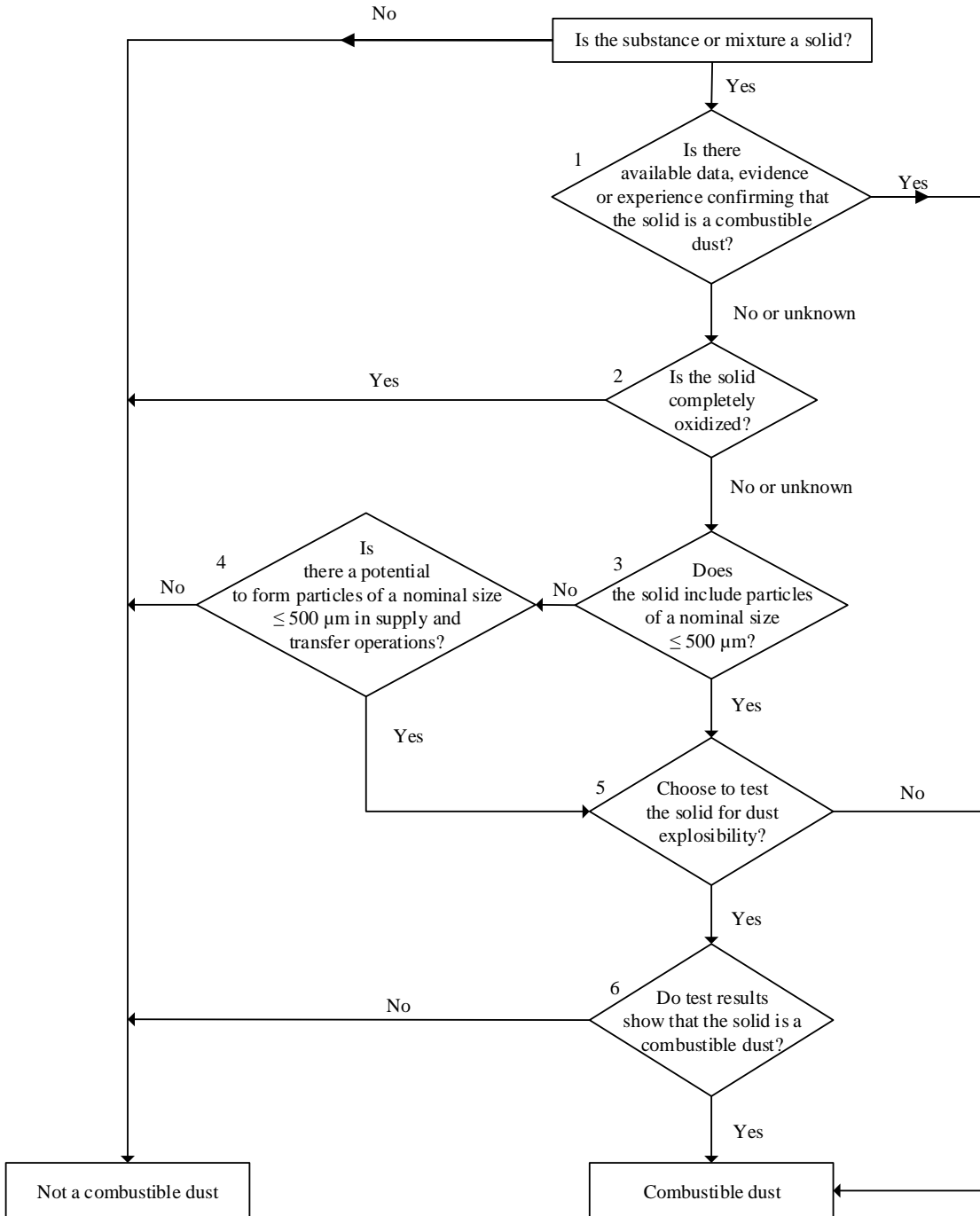
A11.2.3.1 The purpose of this section is to identify whether a combustible dust is present. Figure A11.2.1 presents a flow chart that helps to identify whether a substance or

† Explosions are divided into deflagration and detonation depending on whether they propagate with subsonic velocity (deflagration) or supersonic velocity (detonation). The reaction of a combustible dust which is dispersed in air and ignited normally propagates with subsonic speed, i.e. as a deflagration. Whereas explosive substances ("Explosives"; see Chapter 2.1) have the intrinsic potential for highly energetic decomposition and react in the condensed phase, combustible dusts need to be dispersed in the presence of an oxidizing atmosphere (generally oxygen) to create an explosible dust atmosphere.

‡ For further information on particle size see A11.2.4.1.

mixture is a combustible dust and hence whether the risk of a dust explosion has to be assessed. Section A11.2.3.2 contains a detailed explanation and guidance on the interpretation of each box used in the flow chart.

Figure A11.2.1: Flow chart for decision on combustible dusts



A11.2.3.2 *Explanations to figure A11.2.1*

A11.2.3.2.1 Care has to be taken when using available data, because the behaviour of combustible dusts is very sensitive to conditions such as particle size, moisture content etc.

If the conditions under which available data were generated are not known, or are not applicable to the substance, mixture, or solid material under investigation, the data might not be relevant and a conservative approach is recommended when going through the flow chart.

Box 1: Is there available data, evidence or experience confirming that the solid is a combustible dust?

A11.2.3.2.2 Clear evidence for a combustible dust may be obtained from publicly available incident reports relevant to the substance, mixture, or solid material in question. Similarly, if experience has shown that the substance, mixture, or solid material is combustible in powder form, a dust explosion risk can be assumed. If a substance, mixture, or solid material is not classified as flammable, it may still have the potential to form an explosible dust-air mixture. Specifically any organic or metallic material handled in powder form or from which a powder may be formed in processing, should be assumed to be a combustible dust unless explicit evidence to the contrary is available.

A11.2.3.2.3 The following are examples of available data indicating a combustible dust:

- (a) Classification of the substance or one of the components of the mixture as pyrophoric or flammable solid.
- (b) Availability of relevant information such as MIE, K_{st} values, flammability limits, ignition temperatures.
- (c) Results from screening tests (such as Burning index according to VDI 2263, Hartmann tube according to ISO IEC 80079-20-2).

A11.2.3.2.4 In the absence of data, it is common practice to assume the presence of a combustible dust and to apply appropriate risk management measures (see A11.2.6).

Box 2: Is the solid completely oxidized?

A11.2.3.2.5 When a solid substance or mixture is completely oxidized, e.g. silicon dioxide, further combustion will not occur. Consequently, the solid substance or mixture will not ignite, even if it is exposed to a source of ignition. However, if a solid substance or mixture is not entirely oxidized, combustion of the solid substance or mixture is possible if it is exposed to a source of ignition.

Box 3: Does the solid include particles of a nominal size $\leq 500 \mu\text{m}$?

A11.2.3.2.6 When evaluating materials in relation to box 3, users should consider whether the material includes fine particles which might be released during normal or foreseeable conditions of use.

A11.2.3.2.7 When assessing the particle size with regard to the risk of dust explosions, only the fine particles with a size $\leq 500 \mu\text{m}$ are relevant[§], even if the median particle size of the whole sample is larger than $500 \mu\text{m}$. Hence, only the dust fraction itself, and not the mixture of coarse and fine particles, has to be considered to evaluate the risk of forming explosible dust atmospheres. However, a lower concentration limit for the dust particles in a solid (e.g., by weight percent) that will not lead to such a risk cannot be defined and

[§] Use of \leq aligns with NFPA 652, Standard on the Fundamentals of Combustible Dust. However, this notation implies a precision which this parameter does not have in practice.

therefore also small fractions of fine particles are relevant. For further explanation see A11.2.4.1.

Box 4 Is there a potential to form particles of a nominal size $\leq 500 \mu\text{m}$ in supply and transfer operations?

A11.2.3.2.8 At this stage in the flow chart the solid, as presented, does not include particles smaller than $500 \mu\text{m}$. In that form it is not a combustible dust. However, it is not completely oxidized and fine particles could form during supply and transfer operations. Therefore, such conditions should be critically reviewed in detail, especially with respect to foreseeable effects which may lead to the formation of fine particles, e.g., mechanical stress such as abrasion during transport or transfer operations, or desiccation of moisturized material. If such effects cannot be excluded, expert opinion should be sought. See section A11.2.6.2.1 for considerations related to the generation of fine particles during operations and processing.

Box 5 Choose to test the solid for dust explosibility?

A11.2.3.2.9 If testing for dust explosibility is carried out, it should be done in accordance with recognized and validated testing standards, such as those listed in A11.2.8.1. Where a solid is tested, and the solid as presented does not consist of particles $\leq 500 \mu\text{m}$, it has to be ground for the purposes of testing for dust explosibility.

Box 6 Do test results show that the solid is a combustible dust?

A11.2.3.2.10 Properties such as particle size, chemistry, moisture content, shape, and surface modification (e.g., oxidation, coating, activation, passivation) can influence the explosion behaviour. Standard tests determine whether a dust is actually able to form explosible mixtures with air.

A11.2.4 Factors contributing to a dust explosion

A dust explosion may occur when there is a combustible dust, air or another oxidizing atmosphere, an ignition source, and the concentration of the combustible dust dispersed in air or another oxidizing atmosphere is above the minimum explosible concentration. The relationship between these factors is complex. The following sections give further information on the specific factors that contribute to a dust explosion hazard. In some cases, expert advice may be needed.

A11.2.4.1 Particle characteristics (size and shape)

A11.2.4.1.1 The $500 \mu\text{m}$ size criterion is based on the fact that particles of greater size generally have a surface-to-volume ratio that is too small to pose a deflagration hazard. However, this criterion should be used with care. Flat platelet-shaped particles, flakes, or fibres with lengths that are large compared to their diameter usually do not pass through a $500 \mu\text{m}$ sieve, yet could still pose a deflagration hazard. In addition, many particles accumulate electrostatic charge in handling, causing them to attract each other, forming agglomerates. Often agglomerates behave as if they were larger particles, yet when they are dispersed they can present a significant hazard. In such cases, a conservative approach is recommended and the material should be treated as a combustible dust.

A11.2.4.1.2 The particle size influences the explosion severity as well as the ignition sensitivity. A decrease in particle size tends to lower the MIE and the MIT of a dust cloud while the maximum explosion pressure and K_{St} value will rise.

A11.2.4.1.3 A concentration limit for the fraction of small dust particles in a combustible solid substance or mixture (e.g., by weight percent) that will not lead to a combustible dust hazard cannot be defined because:

- (a) Small amounts of dust are sufficient to form an explosible dust-air mixture. Assuming the lower explosion limit of a combustible dust is 30 g/m³, an amount of 0.3 g dispersed in 10 l of air would be sufficient to form a hazardous explosible dust atmosphere. Therefore, a (combustible) dust cloud with a volume of 10 l has to be considered as hazardous even when unconfined.
- (b) Dust may not be equally distributed in a substance or mixture and may accumulate and/or separate.

A11.2.4.2 *Concentration of combustible dust*

A11.2.4.2.1 A dust explosion may occur if the concentration of combustible dust dispersed in air reaches a minimum value, the (MEC/LEL) **. This value is specific for each dust.

A11.2.4.2.2 The MEC/LEL of many materials have been measured, varying from 10 to about 500 g/m³. For most combustible dusts it may be assumed that 30 g/m³ is the MEC/LEL (it has to be taken into account that 30 g dispersed in 1 m³ of air, resembles a very dense fog).

A11.2.4.3 *Air or other oxidizing atmospheres*

Generally air is the oxidizing agent in dust explosions, however, if combustible dusts are handled in other oxidizing gases or gas mixtures dust explosions may also occur.

A11.2.4.4 *Ignition sources*

A11.2.4.4.1 Dust explosions will occur when an effective ignition source is present in an explosible dust-air mixture (explosible atmosphere). The effectiveness of a potential source of ignition reflects the ability to ignite an explosible atmosphere. It depends not only on the energy of the ignition source, but also on its interaction with the explosible atmosphere.

A11.2.4.4.2 The assessment of ignition sources is a two-step procedure: First, possible ignition sources are identified. In the second step, each possible ignition source is assessed with respect to its ability to ignite the explosive atmosphere. The ignition sources identified as effective in this procedure then require appropriate preventive measures within the explosion protection concept (see A11.2.6.1).

A11.2.4.4.3 Potential sources of ignition include:

- (a) Hot surfaces
- (b) Flames and hot gases
- (c) Mechanically generated sparks

** Although there is an UEL for dusts in air, it is difficult to measure and imprecise. Furthermore, in practice it is not generally possible to consistently maintain a dust-in-air concentration above the UEL; tests in a blender showed dust explosibility even when 75% filled. In consequence, and in contrast to gases and vapours, seeking to maintain safety by operating with dust concentrations above the UEL is not generally a viable approach.

- (d) Electric apparatus
- (e) Stray electric currents and cathodic corrosion protection
- (f) Lightning
- (g) Static electricity
- (h) Radio frequency electromagnetic waves (10^4 Hz - 3×10^{12} Hz)
- (i) Electromagnetic waves (3×10^{11} Hz - 3×10^{15} Hz)
- (j) Ionizing radiation
- (k) Ultrasonics
- (l) Adiabatic compression and shock waves
- (m) Exothermic reactions, including self-ignition of dusts, smouldering/glowing particles or dusts, and thermite reactions (e.g., between aluminium and rusty steel)

A11.2.5 *Other factors impacting the severity of a dust explosion*

In addition to the factors explained in A11.2.4, other conditions also influence how severe a dust explosion can be. The more significant of these are environmental factors and confinement, which are explained below. Since the list of factors presented in this section is not complete, expert advice should be sought as appropriate when assessing the risks in a given situation.

A11.2.5.1 Influence of temperature, pressure, oxygen availability, and humidity

A11.2.5.1.1 Safety relevant data are frequently given under the tacit assumption of atmospheric conditions and are usually valid in the following range (“standard atmospheric conditions”):

- (a) Temperature -20 °C to $+60$ °C;
- (b) Pressure 80 kPa (0.8 bar) to 110 kPa (1.1 bar);
- (c) Air with standard oxygen content (21 % v/v).

A11.2.5.1.2 An increase in temperature may have multiple effects such as a decrease in MEC and MIE, thus increasing the likelihood of a dust explosion.

A11.2.5.1.3 An increase in pressure tends to lower the MIE and the MIT of a dust cloud while the maximum explosion pressure will rise. The effect is increased sensitivity, thus increasing the likelihood and severity of a dust explosion.

A11.2.5.1.4 Higher oxygen content can significantly increase the sensitivity of an explosible atmosphere and the severity of an explosion due to higher explosion pressures. Equally lower oxygen concentration can reduce the risk of an explosion. The LEL may also rise. Such a situation can occur when a process is undertaken under an inert atmosphere.

A11.2.5.1.5 Low or high humidity (of air, gas phase) may influence the occurrence of electrostatic discharges.

A11.2.5.1.6 Therefore, the risk and severity of dust explosions under non-standard atmospheric conditions should be evaluated by expert consideration of the actual process conditions.

A11.2.5.2 *Confinement*

Confinement means the dust is in an enclosed or limited space. A combustible dust (as defined above) can react without confinement or when confined. When confined, the explosion pressure is likely to be higher than when unconfined, as confinement allows pressure to build up, increasing the severity of an explosion. Using suitably sized and located explosion relief allows the burning dust cloud and hot products of a dust explosion to vent to safe places outside the confined area, reducing the potential for the pressure to increase, and so limiting the potential explosion severity. Expert advice may be needed on the possible application and design of explosion relief venting based upon the physical and chemical properties and potential health/physical hazards of the substance, mixture, or solid material.

A11.2.6 *Hazard prevention, risk assessment and mitigation*

A11.2.6.1 *General explosion protection concept for dusts*

A11.2.6.1.1 Table A11.2.1 shows the principles of explosion protection. The table presents both preventive and mitigative measures, and identifies which safety characteristics are most relevant to the measures proposed. For guidance on safety characteristics, refer to Annex 4, Table A4.3.9.3.

A11.2.6.1.2 The first priority should involve preventive measures such as substitution and application of dust-free processes to avoid where possible the presence of combustible dusts, as shown in the column “Avoidance of combustible dusts”.

A11.2.6.1.3 Where the presence of combustible dusts cannot be avoided, measures such as exhaust ventilation should be taken to prevent the concentration of combustible dusts reaching the explosible range; see the column “Avoidance of reaching the explosion range”. Good housekeeping practices are important to prevent the formation of dust clouds or – if that is not achieved – the propagation of pressure waves and fireballs from an initial explosion, e.g. inside equipment or enclosures, dispersing and igniting dust accumulations into a work area. Such secondary explosions can often be more destructive than the primary explosion. A written housekeeping plan with regular inspection for excessive dust levels, including emphasis on priority areas, is strongly recommended. Housekeeping should be conducted concurrently with operations.

A11.2.6.1.4 Where measures cannot be taken to avoid or reduce explosible dust atmospheres, then, ignition sources should be assessed and avoided where possible (see A11.2.4.4 and Table A11.2.2). Ignition sources can include fires and heat caused by the frictional energy of mechanical equipment. Heat or arcing caused by the failure of or the use of improper electrical equipment, such as lighting, motors, and wiring, have also been identified as ignition sources. Improper use of welding and cutting equipment can be a factor. Periodic inspections, lubrication, and adjustment of equipment can be a major tool to prevent ignitions which can lead to explosions. Additional examples of what to consider when evaluating ignition sources are in the column “Avoidance of ignition sources”.

A11.2.6.1.5 Where ignition of an explosible dust atmosphere cannot be excluded, the effects should be mitigated by protective measures. When containment is used as a mechanism to reduce the risk or when the dust is confined, then explosion-proof design or relief venting should be considered. Equipment and buildings with known combustible dusts should be equipped with devices or systems designed to prevent an explosion, minimize its propagation, or limit the damage it causes. Explosion relief venting is one of the most common approaches taken to reduce the explosion pressure. Examples of other mitigating measures are shown in the column “Minimizing effects of a dust explosion”.

A11.2.6.1.6 Section A11.2.8.2 contains a list of regulations and guidance documents on prevention and mitigation of dust explosions, including those discussing explosion prevention systems and the use of deflagration venting.

A11.2.6.1.7 Every facility where there is a potential for dust explosions should have a safety program and an established emergency action plan. A communication system is needed to notify everyone at the plant when there is an emergency and they might be at risk. A central alarm system, page system or horn can be used to signal the need for evacuation. All workers should be trained in the hazards of combustible dust, the risk of explosions, and proper preventive measures.

Table A11.2.1: General concept to prevent and mitigate dust explosions

Prevention		Mitigation
Avoidance or reduction of explosible dust atmospheres	Avoidance of ignition sources	Minimizing effects of a dust explosion
<p><u>Relevant safety characteristics</u></p> <ul style="list-style-type: none"> • <i>Dust explosibility</i> <p>Avoidance of combustible dusts by [examples below]</p> <ul style="list-style-type: none"> • Substitution • Passivation • Application of dust-free processes • ... 	<p>Identification of relevant ignition sources</p> <ul style="list-style-type: none"> • Identification of relevant areas and activities (zoning) • Identification of potential ignition sources • Determination of relevant safety characteristics (see below) 	<p><u>Relevant safety characteristics</u></p> <ul style="list-style-type: none"> • <i>Maximum explosion pressure</i> • <i>Deflagration index (K_{st})</i> <p>Explosion pressure proof design by [examples below]</p> <ul style="list-style-type: none"> • Venting (reduction of explosion pressure) • Explosion resistance • ...
<p><u>Relevant safety characteristics</u></p> <ul style="list-style-type: none"> • <i>Lower explosible limit (LEL)/ Minimum Explosible Concentration (MEC)</i> <p>Avoidance of reaching the explosible range by [examples below]</p> <ul style="list-style-type: none"> • Good house keeping • Exhaust ventilation • Dust reduced procedures • ... 	<p><u>Relevant safety characteristics</u></p> <ul style="list-style-type: none"> • <i>Minimum ignition energy</i> • <i>Minimum ignition temperatures (dust clouds and dust layers)</i> • <i>Self-ignition behaviour</i> <p>Prevention of effective ignition sources by [examples below]</p> <ul style="list-style-type: none"> • Avoidance of open fire or flames • No smoking • Limitation of surface temperatures • Use of approved electrical and mechanical equipment (according to respective zone) • Prevention of electrostatic discharges (e.g., grounding, dissipative materials) • Prevention of mechanical heating or sparks (e.g., temperature monitoring, misalignment monitoring of moving parts, ...) • Spark detection and extinguishing • ... 	<p>Explosion suppression by [examples below]</p> <ul style="list-style-type: none"> • Explosion detection and dispersion of extinguishing media (powder, water, ...) • ...
<p><u>Relevant safety characteristics</u></p> <ul style="list-style-type: none"> • <i>Limiting oxygen concentration (LOC)</i> <p>Oxygen reduction by [examples below]</p> <ul style="list-style-type: none"> • Inerting (N_2, CO_2, argon, flue gas, water vapour, ...) 		<p>Explosion isolation by [examples below]</p> <ul style="list-style-type: none"> • Ignition and flame resistant components (rotary valves, double acting valves, quick acting gate valves, ...) • Extinguishing barriers • ...

A11.2.6.2 *Considerations for dust explosion protection during operations and processing*

A11.2.6.2.1 Processing operations may change the physical form of substances, mixtures, and solid materials such that smaller particles are formed (e.g., sieving, milling, grinding). When substances, mixtures, and solid materials that are not completely oxidized are subjected to such operations, this may result in the formation of combustible dusts. In such cases, the principles of this guidance apply equivalently, and the measures for hazard prevention, risk assessment and mitigation described in A11.2.6.1 should be considered. The responsible party (e.g., manufacturer, employer) at a facility performing processing operations has the best knowledge about the operation that is necessary to conduct an appropriate dust explosion risk assessment and determine the proper measures for hazard prevention and risk mitigation.

A11.2.6.2.2 Table A11.2.2 presents potential ignition sources that may be present during operations and that should be considered. The table uses ignition sources as an example when evaluating potential dust explosion protection measures during operations. Expert advice may be needed to develop and apply appropriate preventive and mitigative measures.

Table A11.2.2: Potential ignition sources during operations

Type of ignition source [see A11.2.4.4.3]	Facility management	Storage	Transfer-operations		Formulation and packaging				Reaction and downstream processing				
	Construction work, repair, maintenance		Conveying (solids)	Pumping (liquids)	Other transfer operations	Mixing (no reaction)	Sieving/milling/grinding	Formulation operations	Packaging	Reaction	Off-gas handling / scrubbing	Work-up (phase separation; crystallization; filtration, isolation)	Distillation
Hot surfaces	Caused by friction of moving parts at bearings, shaft seals, etc.				Heated equipment, pipes, heat exchangers								
Flames and hot gases	Hot work: welding, cutting, etc.	Generally not relevant						Possible formation of hot gases	Generally not relevant				
Mechanically generated sparks	Sparks generated by use of tools (e.g., hammering, drilling, grinding)		Sparks generated due to grinding, friction or impact (frequently caused by mechanical failures or entrainment of foreign parts into moving equipment or machinery)				Generally not relevant			Sparks generated due to grinding, friction or impact			
Electric apparatus	Machines, process control technology installations, motors, switches, cables, lighting												
Stray electric currents and cathodic corrosion protection	Stray currents, e.g., from welding or faulty equipment	Relevant in some cases, e. g.: backflow to electricity generation plants, train tracks, vicinity of electric system with high current											
Lightning	Relevant in some cases, e. g.: thunderstorm even with invisible lightning bolts, activities near lightning protection systems												
Static electricity	Generally not relevant	Relevant in some cases	Frequently generated by flow or separation processes										
Radio frequency electromagnetic waves		Relevant in some cases, e. g.: radio transmitting station, high frequency generators for heating, curing, welding, cutting											
Electromagnetic waves		Relevant in some cases, e. g.: insolation, powerful light source, laser radiation											
Ionizing radiation		Relevant in some cases, e. g.: X-ray machine, radioactive materials											
Ultrasonics		Relevant in some cases, e. g.: ultrasound scanner, ultrasonic testing, sonic driller											
Adiabatic compression and shock waves	Generally not relevant		Compression of gases, rapidly shutting valves when conveying / pumping material		Generally not relevant			Relevant in some cases, e. g.: relaxation of high-pressure gases in pipelines, hammer blow					
Exothermic reactions	Generally not relevant	Pyrophoric and self-heating substances	Transfer of smouldering nests into other areas		Pyrophoric and self-heating substances			Strongly exothermic reaction	Self-heating and ignition of charcoal absorbers	Activated catalysts or residues	Possible decomposition of residue	Self-ignition of dust layers (esp. spray drying)	

A11.2.7 Supplemental information for hazard and risk communication

A11.2.7.1 As explained in Chapter 1.4, paragraph 1.4.6.3, there are many communication elements which have not been standardized in the harmonized system. Some of these clearly need to be communicated to the downstream user. Competent authorities may require additional information, or suppliers may choose to add supplementary information on their own initiative. Each party producing or distributing a product that is determined to be hazardous, including if it becomes hazardous during downstream processing, should create and provide their downstream user with appropriate information, in the form of a Safety Data Sheet (SDS) or another format as appropriate, to alert the user to the hazards and risks.

A11.2.7.2 For substances, mixtures, or solid materials, sections 2, 5, 7, and 9 of the SDS, at a minimum, should provide information on combustible dusts. Annex 4 in the GHS provides further guidance on each section of the SDS. For example, section 2 (A4.3.2) addresses hazards that do not result in classification; section 5 (A4.3.5) covers requirements for fighting a fire; section 7 (A4.3.7) provides guidance on safe handling practices and section 9 (A4.3.9) describes the physical and chemical properties of a substance, mixture, or solid material.

A11.2.7.3 To communicate combustible dust hazards, and thus a potential risk of dust explosions under the approach described in this annex in a standardized manner, competent authorities may require the use of the following phrases on labels, SDSs and/or in operating instructions or may leave the choice to the manufacturer or supplier:

- (a) In the case where a substance or mixture is identified as a combustible dust according to Figure A11.2.1: “May form explosible dust-air mixture if dispersed”, or
- (b) In the case where a substance, mixture, or solid material is to be further processed in such a manner that the processing creates a combustible dust according to A11.2.6.2.1, in combination with Figure A11.2.1: “May form explosible dust-air mixture if small particles are generated during further processing, handling, or by other means.”
- (c) In addition, the phrase “Warning” may be used in conjunction with items (a) or (b).

A11.2.8 References**A11.2.8.1 Test methods**

Recognized and scientifically validated testing methods and standards, such as those listed below, should be used when evaluating dust explosibility.

International standards

ISO/IEC 80079-20-2, "Explosive atmospheres - Part 20-2: Material characteristics – Combustible dusts test methods"

National standards

ASTM E1226, “Standard Test Method for Explosibility of Dust Clouds”

VDI* 2263-1, "Dust Fires and Dust Explosions; Hazards – Assessment – Protective Measures; Test Methods for the Determination of the Safety Characteristics of Dusts"

A11.2.8.2 *Regulations and guidance on prevention and mitigation*

There are a number of documents available providing guidance on preventive and mitigation measures to minimize or eliminate dust explosions. A partial list is provided below. The use of country-specific documents, including those addressing specific hazards and risks associated with materials such as wood, coal, sulfur, combustible metals, and agricultural and food, is encouraged where available.

- (a) Directive 1999/92/EC of the European Parliament and of the Council (ATEX), Annex 1
- (b) U.S. OSHA's Combustible Dust Directive (Combustible Dust National Emphasis Program)
- (c) Health and Safety Executive, UK, HSG 103, Safe Handling of Combustible Dusts: Precautions Against Explosions
- (d) U.S. National Fire Protection Association (NFPA)

NFPA 652: Standard on the Fundamentals of Combustible Dust

NFPA 654: Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing, and Handling of Combustible Particulate Solids

NFPA 68: Standard on Explosion Protection by Deflagration Venting

NFPA 69: Standard on Explosion Prevention Systems"

* VDI stands for "Verein Deutscher Ingenieure"

Annex 2

Consequential amendments to Annex 4 of the GHS

Section A4.3.2.3

Replace the last sentence (“The statement “May form explosible dust-air mixture if dispersed” is appropriate in the case of a dust explosion hazard.”) with the following:

“To communicate combustible dust hazards, and thus a potential risk of dust explosions under the approach described in Annex 11 in a standardized manner, competent authorities may allow the use of the phrases identified in A11.2.7.3 on labels, SDSs and/or in operating instructions or may leave the choice to the manufacturer or supplier.”
