PD CEN/TR 16829:2016

BSI Standards Publication

Fire and explosion prevention and protection for bucket elevators

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National foreword

This Published Document is the UK implementation of CEN/TR 16829:2016.

Earlier guidance on protection of bucket elevators from internal dust explosions was based on large scale experimental work carried out by the Health and Safety Laboratory and was published in the I Chem E guide to dust explosions. Since then many bucket elevators have been fitted with explosion protection based on this advice, as a result the number of explosions in bucket elevators has reduced in recent years. This seems likely to be the consequence of improved controls over ignition sources in the elevators, as described in this TR.

The UK committee cannot see a justification for retrofitting older elevators built to I Chem E guidelines in order to meet the venting advice in this TR. Moreover, provided the details of an installation closely follow that used in the HSL research, a bucket elevator fitted with vents according to the I Chem E guide, and other features as described in this TR, then it should meet the requirements of DSEAR, and the reasonably practical precautions required by the HSW Act. The Approved Code of Practice and further guidance on the Regulations can be found in HSE publication L138.

The UK participation in its preparation was entrusted to Technical Committee EXL/23/1, Flame arresters.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Fire and explosion prevention and protection for bucket elevators

Prévention et protection contre l'incendie et l'explosion des élévateurs à godets

Brand- und Explosionsschutz für Becherwerke

This Technical Report was approved by CEN on 13 July 2015. It has been drawn up by the Technical Committee CEN/TC 305.

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European foreword

This document (CEN/TR 16829:2016) has been prepared by Technical Committee CEN/TC 305 “Potentially explosive atmospheres – Explosion prevention and protection”, the secretariat of which is held by DIN.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

1 Scope

This European Technical Report applies to bucket elevators that may handle combustible products capable of producing potentially explosive atmospheres of dust or powder inside the bucket elevator during its operation. The precautions to control ignition sources will also be relevant where the product in the bucket elevator creates a fire risk but not an explosion risk.

For the purposes of this report, a bucket elevator is defined as an item of bulk material handling equipment that carries material in powder form or as coarse products such as whole grain, wood chips or flakes, in a vertical direction by means of a continuous movement of open containers.

This Technical Report specifies the principles of and guidance for fire and explosion prevention and explosion protection for bucket elevators.

Prevention is based on the avoidance of effective ignition sources, either by the elimination of ignition sources or the detection of ignition sources.

Explosion protection is based on the application of explosion venting, explosion suppression or explosion containment and explosion isolation rules specifically adapted for bucket elevators. These specific rules may be based on agreed test methods.

This European Technical Report does not apply to products that do not require atmospheric oxygen for combustion.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1127-1:2011, *Explosive atmospheres — Explosion prevention and protection — Part 1: Basic concepts and methodology*

EN 13237, *Potentially explosive atmospheres — Terms and definitions for equipment and protective systems intended for use in potentially explosive atmospheres*

EN 13463-1, *Non-electrical equipment for use in potentially explosive atmospheres — Part 1: Basic method and requirements*

EN 13463-5, *Non-electrical equipment intended for use in potentially explosive atmospheres — Part 5: Protection by constructional safety 'c'*

EN 13463-6, *Non-electrical equipment for use in potentially explosive atmospheres — Part 6: Protection by control of ignition source 'b'*

EN 14373, *Explosion suppression systems*

EN 14460, *Explosion resistant equipment*

EN 14797, *Explosion venting devices*

EN 14491, *Dust explosion venting protective systems*

EN 15089, *Explosion isolation systems*

EN 60079-10-2, *Explosive atmospheres — Part 10-2: Classification of areas — Combustible dust atmospheres*

EN ISO 12100, *Safety of machinery — General principles for design — Risk assessment and risk reduction (ISO 12100)*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

IEC/TS 60079-32-1, *Explosive atmospheres — Part 32-1: Electrostatic hazards, Guidance*

VDI 2263-1, *Dust fires and dust explosions; hazards, assessment, protective measures; test methods for the determination of the safety characteristic of dusts*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 13237, EN 15089 and the following apply.

Note 1 to entry: The zones for the classification of hazardous areas are defined in Directive 1999/92/EC.

3.1
volume
3.1.1
bucket elevator leg volume
internal volume of pipe section connecting head to the boot

3.1.2
bucket elevator head volume
internal volume above the leg connection, including outlet section and excluding the volume of the pulley

Note 1 to entry: Attached chutes are not included.

3.1.3
bucket elevator boot volume
internal volume below the leg connection, including inlet section and excluding the volume of the pulley

3.2
vent spacing
distance between vents measured from centre to centre

3.3
bucket spacing
distance between buckets measured from centre to centre

3.4
combustible dust
finely divided solid particles, 500 µm or less in nominal size, which may be suspended in air, may settle out of the atmosphere under their own weight, which can burn or glow in air, and may form explosive mixtures with air at atmospheric pressure and normal temperatures

4 Bucket elevators

4.1 General

Bucket elevators are described as bulk materials handling equipment, conveying material in a vertical direction by means of a continuous movement of open containers. A bucket elevator consists of three main parts: the boot where the material enters the equipment, the leg or legs where the material is transported upwards and the head where the material is discharged. The most common type of bucket elevators generally use open containers fixed to a moving belt or chains. In case of a single leg bucket elevator the belt moves upwards and returns in the same leg. In a twin-leg bucket elevator the returning of the belt occurs in a second leg.

Bucket elevators require special attention since they have been involved in dust explosions and they have many potential ignition sources. The most common ignition sources are due to mechanical problems, for example due to friction between the belt and the casing, heating up of mechanical rotating parts on elevator head and boot, impact of damaged buckets or foreign objects. These mechanical problems may also create explosive atmospheres: impact or vibrations will cause dust deposits in the legs to fall down and create an explosive atmosphere. Therefore if, during normal operation, there is no explosive dust-air mixture present inside a bucket elevator, mechanical problems are still likely to cause an explosion.

NOTE Maintenance related ignition sources like hot work are also very common.

Even if an ignition source does not cause an explosion it may result in a fire and spread quickly because the leg of a bucket elevator acts as a chimney.

Fire and explosion protection of bucket elevators requires special attention. A bucket elevator might be considered as two volumes (head and boot) between which there are one or two long ducts (the legs). The information (see EN 14491) for flame accelerations inside a long duct, however, cannot be applied. The buckets do affect flame acceleration: especially metal buckets which will cool the flame (and reduce flame acceleration). But the buckets also form repeated obstacles which cause increased turbulence and hence promote flame accelerations. Plastic buckets may become part of the fuel for a fire.

4.2 Bucket elevator types

There are many types of bucket elevators. Casing types include twin leg, single leg, and “Z” type. The buckets can be attached to either a belt or a chain and can be made from metal or plastic.

Typical examples of the different types of bucket elevators are included in Annex A.

The Technical Report will focus on vertical bucket elevators. Z type bucket elevators operate at low velocities and thus reduced dust generation and risk of ignition. Measures can be reduced in this case and will not be dealt with in the following.

5 Fire and explosion hazards

5.1 General

A fire or explosion inside a bucket elevator is a large hazard due to the flame and/or pressure effects to the surroundings which may lead to damage to the bucket elevator itself and can lead to damage to the connected equipment, surroundings of the equipment and to personnel.

Consequences of ignition can be a smouldering fire, fire with flames, explosion and a propagating explosion. Following a dust explosion a fire is likely to continue inside or outside the bucket elevator.

If an explosion occurs inside a bucket elevator, it will tend to accelerate, because of the large L/D ratio. Without adequate protection this may cause failure of the bucket elevator and endanger the surroundings: adjacent equipment, buildings and personnel.

When no precautions are included to prevent fire propagation, a highly hazardous situation can occur where a fire or explosion may spread to adjacent sections of the installation, such as silo cells. With explosion propagation, increased turbulence, pre-compression and jet ignition may trigger very violent secondary explosions in these installations.

For a fire or an explosion to occur the following conditions must coincide:

— combustible dust is either deposited or whirled up within the explosion limits;

— sufficient presence of oxygen;

— an effective ignition source.

In bucket elevators the explosion hazard depends very strongly on the bulk material conveyed. In particular the fine fraction of the bulk material with particle sizes less than 500 µm and the dustiness (how easy a dust cloud is formed) play a decisive role here.

If a bulk material contains relevant fractions of dust, an explosion hazard is to be assumed.

Even in the case of low dust concentrations, in time dust can adhere to the bucket elevator casing forming layers inside the bucket elevator that can be a few mm thick. The adhered dust layers are not in themselves explosive mixtures but do form a continuous potential for an explosive mixture: e.g. due to a malfunction of a bucket elevator (belt misalignment) the casing may start vibrating and the adhered dust could become whirled-up and dispersed as an explosive dust cloud.

5.2 Explosion hazards

5.2.1 Presence of explosive atmospheres

The possibility of formation of an explosive atmosphere is very dependent on the product involved and operational conditions either running full or empty.

NOTE External explosive atmospheres can also influence the atmosphere in the elevator. For example the following situations can exist:

Example A	Example B
The bucket elevator is conveying a combustible product with an average particle size smaller than 500 µm or a dusty product containing a considerable amount of fines (here fines are defined as particles less than 100 µm). This implies that during **normal operation** dust clouds may arise frequently inside the bucket elevator and are likely to be above the lower explosion limit (LEL). For this situation it is assumed that a potential explosive atmosphere is frequently present.	The bucket elevator is conveying a coarse product (typically > 1 000 microns) with a very limited amount of fines. For this situation it is assumed that a potential explosive atmosphere is likely to occur occasionally during normal operation.

The process conditions and specific product properties like moisture content, friability, granulometry, flow characteristics and impurities will influence the occurrence of explosive atmospheres A or B.

In both situations dust can stick to the inner surfaces of the bucket elevator. Such dust deposits can pose a fire hazard depending on the burning characteristics. In time these dust layers may accumulate sufficient quantity of material to form an explosive atmosphere should they become dispersed by the action of vibration, shaking etc. For most situations a layer with a thickness of 0,1 mm is sufficient to create a potential explosive atmosphere. Since vibrations and other mechanical movements can be expected, those dust layers can be disturbed to create a potential explosive atmosphere.

Only for a specific application, where it can be proven that no hazardous dust deposits will be created, a zone 22 situation could be considered.

Note that inside a bucket elevator transporting a coarse granular product, due to friction of the product granules, dust may be formed.

Typical examples are given in Annex F

5.2.2 Presence of potential ignition sources

5.2.2.1 General

A list of ignition sources can be found in EN 1127-1. An ignition hazard assessment should be carried out by the manufacturer according to EN 13463-1.

This will identify the equipment related ignition sources able to ignite an explosive atmosphere (potential ignition sources) and the effective ignition sources depending on the frequency of occurrence i.e. in normal operation, expected malfunction or rare malfunction.

There are also ignition sources related to other influences:

— Ignition sources introduced from connected equipment have to be considered by the end user. Typical examples are hot, glowing and burning product, embers, explosion from connected equipment etc.

— External ignition sources due to smoking, maintenance, welding, cutting etc. (hot work) have to be considered by the end user. These should be prevented by organizational measures.

— Ignition sources that may arise from the product conveyed should be taken into account: e.g. by self-heating in deposits inside the bucket elevator.

Note that outside a bucket elevator, ignition sources can also be created by the bucket elevator as an assembly: especially due to the presence of electrical equipment, drive systems and bearings. If the bucket elevator is intended to be used in a potential explosive atmosphere the manufacturer has to consider these ignition sources too and follow the standards EN 13463 series for non-electrical and EN 60079 series for electrical equipment.

5.2.2.2 Equipment related ignition sources

Table 1 summarises the typical **equipment related potential ignition sources** that can be created **inside** a bucket elevator.

Table 1 — Equipment related potential ignition sources

Potential ignition source	Possible causes
Hot surfaces	• Friction of bucket elevator belt against elevator casing wall due to misalignment • Friction between elevator belt and drive pulley due to slippage • Friction of loose parts in bucket elevator (loose bucket, lost parts of pulley lagging etc.) with moving parts • Damage to bearings and gear units
Mechanical sparks	• Mechanical sparks (metal) buckets colliding with casing wall (due to insufficient belt tension, defective belt, loose buckets) or with discharge chute • Misalignment of pulley

Potential ignition source	Possible causes
Electrical equipment	• Electrical equipment and motors • Inadequate earthing and/or equipotential bonding
Electrostatics	• Electrostatic charging due to separation processes between belt and drive pulleys • Electrostatic charging of buckets due to electrostatic induction • Electrostatic charging of any other non-earthed conductive installation components

5.2.2.3 Ignition sources introduced or acting from outside

Bucket elevators being part of an installation configuration have interfaces which should also be taken into account. This means that ignition sources that may be introduced into the bucket elevators should be considered in addition to the equipment related ignition sources.

A summary of the typical potential ignition sources introduced or acting from outside is shown in Table 2.

Table 2 — Potential ignition sources introduced or acting from outside

Potential ignition source	Possible causes
Hot surfaces	• Introduction of foreign material • Introduction of glowing nests • Welding, grinding, cutting operations • Damage to the casing due to external mechanical action
Flames and hot gases including hot particles	• Introduction of glowing nests • Propagation of fire or explosion from connected installations or from outside
Mechanical sparks	• Introduction of foreign material • Damage to the casing due to external mechanical action
Lightning	• Lightning protection inadequate

5.2.2.4 Ignition sources arising from the product itself

There are also ignition sources possible arising from the product itself. Therefore one should check whether self-ignition or exothermal decomposition are to be expected due to the characteristics of the bulk material.

Such exothermal reactions should be assumed to occur particularly in installations operating at elevated temperatures and in which large coherent dust accumulations form either intentionally (storage, intermediate storage, etc.) or unintentionally (deposits, cakings).

In the case of organic products (such as grain), an excessive moisture content may furthermore pose the risk of self-ignition due to microbiological processes (Maillard reaction).

In bucket elevators, large product accumulations may occur in the boot and in horizontal infeed and outfeed sections. It should be taken into account here that the self-ignition or degradation temperature, which is characteristic of the self-heating behaviour of any dust, will decrease as the volume and layer thickness increase. Glowing nests and smouldering fires having formed by self-ignition may become ignition sources for dust explosions when deposits are whirled up.

Particularly with some organic bulk materials, there is the additional danger of smouldering before self-ignition, which can release combustible gases such as carbon monoxide with wood (formation of hybrid mixtures).

Self-ignition and exothermal decomposition require the dust heap to be exposed to elevated temperatures for a sufficient time; the specific induction time, i.e. the time between the beginning of storage and the ignition of a particular dust heap should be reached for this to occur.

NOTE If there is a suspect of burning material in the product upstream of the bucket elevator, the product should be discharged into the open air and not through the bucket elevator.

5.2.3 Effect of ignition: smouldering product, fire, explosion, propagation of explosion

After ignition it will depend upon the presence of dust deposits or explosive clouds whether smouldering product, fire or an explosion will occur. In most cases ignition arises in the head or the boot (due to the high probability of ignition sources at these locations).

If ***smouldering products*** are formed they may be transported further into the downstream process (i.e. a silo) and may become an additional hazard.

In the case of ***fire***, apart from fire damage to the bucket elevator, there also may be damage due to transport of burning product via the de-dusting system and the bucket elevator outlet, which may lead to fire or explosion downstream.

In the case of an ***explosion***, the dust explosion characteristics in combination with the bucket elevator design (protection of bucket elevator, strength of bucket elevator) will determine the actual explosion course. An explosion may **propagate** to connected equipment leading to secondary explosions and/or fires. If the pressure exceeds the strength of the bucket elevator, failure of the casing will occur and flame jets and fire balls are formed which may cause secondary explosions and/or fire especially in dusty environments.

5.2.4 Risk assessment

The likelihood of explosive atmospheres, presence of ignition sources and actual ignition will determine the likelihood of a fire or an explosion. The location of the bucket elevator and the presence of adequate protective systems will determine the consequences of a fire or an explosion.

The need to take additional preventive and/or protective measures will strongly depend on the situation: is ignition likely or not, can the effects be tolerated or not, are the risks acceptable or not?

The user normally selects a bucket elevator based upon the category (related to internal zone) and then shall perform a risk assessment based upon the local circumstances. Such a risk analysis shall include the probability that ignition sources enter from outside (see 6.3.2.2) but also the potential consequences of an explosion. Depending upon the acceptability of risks, in addition to preventative measures (based upon category of the bucket elevator) explosion protection measures may be needed.

5.3 Fire hazards

In addition to the explosion hazard addressed in this report, combustible products and combustible construction materials inside bucket elevators (e.g. belt, buckets) can also present a fire hazard that has to be considered.

The vertical orientation and enclosed construction are favourable factors in terms of fire spread and unfavourable for controlling a fire. A fire developing in a bucket elevator, where combustible dust is present, can lead to a dust explosion or flash fire. A dust explosion often results in an ensuing fire, even when explosion mitigation techniques are used.

For assessing the fire hazard in bucket elevators, the combustion characteristics of the following must be known: combustible materials used (such as the belts and buckets), of the material to be conveyed and of the dust occurring primarily during transport. For assessing the dust, the combustion class (BZ), the glowing temperature and the self-ignition characteristics of the dust can be used. Ignition sources can be introduced from outside (such as glowing nests, hot particles) or may be generated inside the bucket elevator (e.g. hot bearings, buckets scraping, return or drive pulley heating up due to slippage). Furthermore, deposits of material conveyed must be checked for possible self-ignition processes or exothermal degradations.

The combustion class *BZ* (see VDI 2263-1, an EN standard is in preparation) characterises the combustion behaviour of deposited bulk material/dust and will at least allow a rough estimation as to whether deposited dust will ignite or whether ignited dust will allow glowing combustion or flaming combustion to develop. Furthermore, it must be noted that burning dust is to be considered an ignition source in itself.

In the combustion classification an attempt is made to ignite a defined dust heap by a hot wire or flame. The results will lead to classification of the dust into the following Combustion Classes:

— *BZ* 1 no ignition;

— *BZ* 2 brief ignition, rapid extinction;

— *BZ* 3 localised combustion or glowing;

— *BZ* 4 spreading of glowing combustion;

— *BZ* 5 spreading of flaming combustion;

— *BZ* 6 explosion-like combustion.

No fire protection measures are required as a matter of principle where non-combustible dusts or dusts of combustion class *BZ* 1 are handled and provided that no other combustible materials (such as belts and buckets including materials to be conveyed) are present.

With dusts of combustion classes *BZ* 2 or *BZ* 3 in the presence of non-combustible belts and buckets, or dusts of combustion class *BZ* 1 in the presence of combustible equipment installed in the bucket elevator, fire precautions are usually sufficient.

For combustion class *BZ* 4 a case by case evaluation of the fire protection and damage control measures is recommended, based on the presence of combustible equipment in the bucket elevator and the speed of propagation in the burning test.

For dusts of combustion class *BZ* 5, both fire precautions and measures for damage control in the event of fire should be considered irrespective of the presence of any further combustible materials.

Due to the high mass burning rate, dusts with a combustion class *BZ* 6 call for an individual assessment, which is not within the scope of this document.

6 Fire and explosion prevention and protection of bucket elevators

6.1 General

Fire and explosion protection is to be based upon the following basic measures:

— prevent deposits of combustible materials and explosive mixtures;

— prevent ignition sources.

If prevention is not sufficient additional measures shall be taken, such as fire fighting (extinguishing) and/or explosion protection (explosion containment, explosion venting, explosion suppression in combination with explosion isolating measures).

6.2 Fire prevention and protection

6.2.1 Fire prevention

The use of combustible construction materials will increase the fire hazard. From the fire hazard perspective, bucket elevator components like the enclosure, the buckets and the belt should be non-combustible and/or not supporting or propagating combustion. These are e.g. materials classified as A1, A2 or B according to EN 13501-1 (see EN 13478).

When not in service, combustible products should not be stored in bucket elevators.

All ignition sources, that are controlled in order to prevent dust explosions, will also prevent fires. Therefore, for ignition source control measures see 6.3.2.

6.2.2 Fire protection

Manual fire fighting

Manual firefighting by plant personnel should not be relied on to control and extinguish a bucket elevator fire, unless the fire is detected in its early stages. Besides fire and explosion hazard for plant personnel, smoke will develop, hindering firefighting efforts due to poor visibility. In particular, plastic construction materials produce large amounts of toxic, black smoke when involved in a fire.

Automatic fire protection

Fire protection in a building by means of automatic sprinklers will not control a fire inside a bucket elevator because ceiling sprinklers will not be activated and if sprinklers are activated, the inside of the bucket elevator is shielded from sprinkler water. Fire protection by means of automatic sprinklers inside the bucket elevator will ensure control of the fire to prevent fire spread inside the bucket elevator and will limit the overall consequences of a fire.

If a risk assessment has shown that fire protection for bucket elevators is required, this can be done as follows.

1) Provide automatic sprinkler protection at the top of the vertical bucket elevator leg where the enclosure is non-combustible. If the enclosure is constructed from combustible materials, provide additional automatic sprinkler protection along the leg (i.e. treat it as a vertical shaft with combustible sides).

2) Design the automatic sprinklers to deliver a minimum end sprinkler pressure of 1 bar, using sprinklers with a K factor of 115 (14 mm) or greater. Temperature rating of the sprinklers should be 70 °C. Sprinklers with a temperature rating of 100 °C may be used in locations where the ambient temperature is in excess of 43 °C. For locations prone to extremely cold and freezing conditions, use dry-pipe sprinkler systems with a temperature rating of 140 °C.

3) Connect the automatic sprinkler system to an adequate and reliable water supply.

4) The bucket elevator driving mechanism should be interlocked to shut down automatically on sprinkler water flow or fire detection if continuing operation could spread fire to other areas. This is especially important when a bucket elevator is installed inside a building and runs through a fire wall or floor (fire compartment) but also when different building floors are protected by means of automatic sprinkler systems. This is because fire spread to other areas will overtax the sprinkler system. Penetrations in fire rated walls and floors should be properly sealed or protected.

Manual shutdown is acceptable where all of the following are provided:

i) The area is constantly attended during conveyor operation or fire detection is provided.

ii) There are documented shutdown procedures for the conveyor system, and operators have been trained in shutdown procedures.

iii) Controls are easily accessible in a fire situation involving the conveyor.

iv) Other protection is adequate.

v) For the design of the bucket elevator, take into account the mass of filled buckets and accumulation of water in the bucket elevator. Drainage of water should be considered.

6.3 Explosion prevention and protection

6.3.1 Prevention of explosive atmospheres

When conveying combustible bulk materials with a fine-fraction grain size smaller than 500 µm, potentially explosive atmospheres can occur inside bucket elevators. This holds, in particular, for very fine bulk materials and bulk materials with a high dust content.

Explosive dust and explosive atmospheres can be expected to accumulate particularly at charging, transfer and discharging stations. The avoidance of explosive atmospheres **cannot**, therefore, be the sole precaution in most cases.

By taking appropriate measures, however, it is nevertheless possible to reduce the likelihood of occurrence, and the extent of the explosive atmosphere **inside the bucket elevator**. Such appropriate measures can include:

— dust removal systems at charging, transfer and discharging stations where the material to be conveyed has a low dust content;

— conveying speeds as low as practical;

— avoidance of surfaces where deposits can form;

— avoidance of material conveyed being returned;

— removal of dust deposits by means of appropriate discharge systems;

— binding of dust using, e.g. water, oils (high boiling point, no volatile constituents);

— periodic cleaning.

Regarding the environment of the bucket elevator, in many cases, dust is released into the area around the bucket elevator due to leaks, particularly at charging, transfer and discharging stations as well as openings (inspection doors) of the bucket elevator. This may result in considerable dust deposits, particularly in the release areas, but also on external surfaces. The extension of dust deposits can be reduced by periodic cleaning.

Summarising, prevention of explosive atmospheres inside bucket elevators is not really feasible when dealing with dusty products or with products containing dust. Dedusting systems can reduce the dust concentration locally but are unlikely to prevent explosive atmospheres throughout the bucket elevator. Inerting is one option for preventing the formation of an explosive atmosphere inside the bucket elevator.

6.3.2 Prevention of ignition sources

6.3.2.1 Equipment related ignition sources

The equipment related ignition sources are listed in Table 1.

If these ignition sources are to be considered effective ignition sources on account of the characteristics of the material to be conveyed (e.g. minimum ignition energy, minimum ignition temperatures), they will have to be assessed in terms of their likelihood of occurrence.

The manufacturer of a bucket elevator to be used for conveying flammable products shall carry out an ignition hazard assessment and based upon this analysis will indicate in which category the internal part of the bucket elevator will fall. The manufacturer puts this bucket elevator on the market with this category indication and the limits of use in relation to the products involved and equipment parameters (speed, temperature etc.). An example of such an analysis (according to EN 13463-1) is given in Annex D.

The likelihood of occurrence of potential ignition sources can be reduced by technical measures, such as selection of appropriate bearings and appropriate materials, and by organisational measures (e.g. maintenance).

To reduce the likelihood of these ignition sources occurring, measures to control ignition sources may also be required, e.g. misalignment, slip monitors and temperature detection on bearings.

With slip monitoring, the speed of the return pulley is compared with the drive pulley in order to detect belt slippage. The aim is to prevent overheating due to friction.

NOTE 1 during start-up initially there will be some friction, which needs to be taken into account in the design of the slip monitoring, for example an alarm delay of maximum 10 s during start-up.

The misalignment monitor checks the lateral movement of the belt towards the casing, preventing the generation of hot surfaces and of sparks due to friction between buckets, belt and casing.

NOTE 2 If the bucket elevator is intended for use in a potentially explosive atmosphere, it is also the responsibility of the manufacturer to prevent the bucket elevator from creating an ignition source in the surrounding atmosphere. In that situation, apart from an internal ignition source analysis, an external ignition hazard analysis is also required.

Table 3 shows the recommendations for all bucket elevators that will transport explosive dusty products.

Table 3 — Recommendations for all bucket elevators

No	Requirement	Information
1	General	All bucket elevators within the scope of this document should comply with the requirements contained in EN 13463–1 unless stated otherwise in this document.
2	Ignition hazard assessment	**Normal operating conditions**: Normal operating conditions should be considered to occur in situations where the bucket elevator performs its intended use within its design parameters. This includes conditions during start up and shut down. (See also EN ISO 12100.) For the purposes of bucket elevators made according to this document, failures (such as a breakdown of bearings, slip, misalignment or releases of substances caused by accidents) which involve repair or shut-down are not considered to be part of normal operation.

No	Requirement	Information
		Expected malfunction: An expected malfunction should be considered to be a failure or a fault in a bucket elevator that normally occurs in practice. In addition, an expected malfunction should be considered to occur when a bucket elevator or its components do not perform their intended functions. For the purposes of bucket elevators made according to this document this can happen for a variety of reasons, including: • Malfunction of bearing and/or seal • Slip of belt on pulley due to overload, stray object causing obstruction, belt tension problems, belt/pulley wear, too warm product or environment leading to belt elongation etc. • Misalignment of belt due to overload etc. • Misalignment of pulley due to bearing malfunction or failure of pulley/shaft connection. • Loss of buckets or fixation elements due to wear or vibration leading to obstruction of belt and pulley. • Loss of pulley friction elements due to wear or vibration leading to obstruction of belt and pulley • Choking of bucket elevator
		Rare malfunction: A rare malfunction is a type of malfunction which is known to happen but only in rare instances. An example of a rare malfunction is sudden breakage of a belt or chain. Two independent expected malfunctions which, separately, would not create an ignition hazard but which, in combination, do create an ignition hazard, are regarded as a single rare malfunction. As an example, misalignment of belt with failure of misalignment detector.
3	Assignment to equipment categories	Depending on the outcome of the ignition hazard assessment the manufacturer can indicate the internal and external category of the bucket elevator.
4	Temperature limits	These are the temperatures of the environment in which the bucket elevator can be located and the admissible temperatures of the product being conveyed.
5	Mechanical design criteria	The strength of the bucket elevator in relation to internal over-pressure should be given but also wall thickness and construction details in relation to stability of the bucket elevator and to wear and corrosion. Preferably the casing should to be manufactured from non-combustible material.
6	Speed	Typically 1 to 4 m/s, keep as low as practical.
7	Material combinations	Prevent combinations of light metal and carbon steel.

No	Requirement	Information
8	Pulleys	Crowned drive and return pulley design and if cover is required then use antistatic flame retardant material. If pulley is assembled out of several parts then measures should be taken to ensure integrity is maintained.
9	Belt and chain: material and construction.	Use dissipative material (surface resistance on both sides < 3 × 108 Ohm, according to IEC/TS 60079–32–1). Use fire retardant material. Adequate joint construction to prevent premature failure. Chains are to be selected to ensure acceptable low corrosion and wear.
10	Bucket: material and construction	Dissipative/ conductive bucket material, according to IEC/TS 60079–32–1. is required for use with MIE values of less than 1 mJ, Attachment of buckets to belt - use self-locking nuts. The fixings are to be selected to ensure acceptable low corrosion and wear.
11	Linings	Where linings are necessary for wear resistance they should have a maximum break-down voltage of 4 kV and a maintenance check program to ensure a minimum thickness of at least 8 mm to prevent propagating brush discharges.
12	Earthing and bonding	All conductive fixed and moving parts should be earthed and bonded to limit ground resistances to < 106 Ohm (for metal items having fixed metal earthing a ground resistance of < 10 Ohm should usually be achieved).
13	Electrical equipment	Equipment category inside and outside the bucket elevator should be appropriately selected depending upon the hazardous area.
14	Prevention of deposits	Prevent horizontal ledges and surfaces. The boot part should be designed such that easy cleaning is possible.
15	Clearing between moving parts and casing	> 25 mm, depending upon height and capacity. Specific situations (such as strong wind load) may require additional clearances or controls.
16	Shaft seals	Seals should be safe in accordance with EN 13463–5
17	Bearings	Preferably located outside the casing in accordance with EN 13463–5
18	Belt tension system	Measures should be taken to ensure integrity is maintained in accordance with EN 13463–5.
19	Power transmission systems, clutches and couplings	Equipment outside the bucket elevator should be appropriately selected depending upon the hazardous area.
20	Brakes and braking systems	Anti-runback system is recommended for bucket elevators > 10 m high and with capacity of > 10 m^3/hour.
21	Pulley-shaft attachment head pulley and boot pulley	Head: key or welded and tapered locking device Boot: key or tapered locking device

Table 4 — Additional recommendations for bucket elevators to become internally category 2

No	Requirement	Information
1	Slip detection device	Monitor the speed of drive and boot pulley: at difference of > 10 % activate alarm and stop bucket elevator.
2	Misalignment detection device	Monitor the horizontal belt movement. Should the distance to casing becomes too small for a maximum period of 5 s activate alarm and stop bucket elevator. If misalignment is detected by temperature detection device on friction plates alarm and stop should occur without time delay.
3	Bearing temperature detection	Monitor the bearing temperature. Should the bearing temperature increase significantly above the temperature in normal operation activate alarm and stop bucket elevator.

NOTE 3 It might be recommended to define a pre-alarm level which does not stop a bucket elevator. The pre-alarm level can be used for e.g. for preventative maintenance or to achieve a controlled shutdown of the plant.

The systems for the control of ignition sources should comply to IPL 1 according to EN 13463-6.
Additional requirements for bucket elevators to become internally category 1

Because of the complexity of the mechanical systems in bucket elevators it is not possible to give general precautions for category 1 equipment. An individual risk assessment taking rare malfunctions into account has to be executed.

For category 1 bucket elevators measures are also required to prevent transport of ignition sources from the bucket elevator into connected equipment. If it is concluded from the risk analysis that such potential ignition sources are acceptable, these measures are not required, but the bucket elevator cannot become category 1 equipment at its boundaries.

If ignition sources cannot be prevented during rare malfunctions, explosion effect mitigating measures are to be installed in addition to category 2 requirements. For more details on design see 6.3.3. The explosion isolation measures shall prevent explosion propagation to interconnected equipment.

6.3.2.2 Ignition sources introduced or acting from outside

Apart from the equipment-inherent ignition sources, one shall take into account that ignition sources introduced from outside may also become effective depending on the installation configuration and operating conditions.

The entry of foreign material and glowing nests is to be considered first. The occurrence of such ignition sources depends significantly on the location of the bucket elevator within the overall installation and, thus, on the upstream processes. Hence, foreign material is more likely to be introduced into a receiving bucket elevator than into a bucket elevator exclusively used for conveying cleaned bulk material.

Also process malfunctions (such as blockage of the outlet) could result into ignition in the bucket elevator.

Table 5 shows the typical ignition sources that are not created directly by the bucket elevator itself and measures to prevent that the ignition sources become effective.

Table 5 — Measures to prevent ignition sources introduced or acting from outside to be become effective

Ignition sources	Measures to prevent that the ignition sources become effective
Hot surface	technical measures: • to prevent foreign bodies entering, e.g. cleaning of material to be conveyed (such as a separator), safety grid and/or magnetic separator in the inlet chute • to prevent blockage at outlet, e.g. level detector in outlet chute **and** organisational measures: permit-to-work system, maintenance
Flames and hot gases (including hot particles)	• Hot particle detection in feeding installations with elimination of sparks and hot particles • Explosion isolation
Mechanical sparks	technical measures: • to prevent foreign bodies entering, e.g. cleaning of material to be conveyed (such as a separator), safety grid and/or magnetic separator in the inlet chute • to prevent blockage at outlet, e.g. level detector in outlet chute **and** organisational measures: permit-to-work system, maintenance
Lightning strike	Appropriate design of lightning protection system (see EN 62305)

Control of ignition sources introduced from outside should be given in user instructions.

Additional protective measures:

Depending upon the dust explosion risk assessment for the process where the bucket elevator is integrated, additional explosion effect mitigating measures may be required.

6.3.2.3 Ignition sources arising from the bulk material

Self-ignition can be avoided by short storage times of the product, by cleaning of the product and by reducing and controlling the product moisture content (usually less than 16 % for self-ignition due to micro-biological processes at ambient temperature).

The process temperatures must be kept below the (volume dependent) self-ignition temperature of the bulk material.

The most important organisational measure to prevent self-ignition inside the bucket elevator is the periodic cleaning of the bucket elevator boot to remove product deposits. Self-cleaning bucket elevators might be considered.

Additional protective measures:

Depending upon the dust explosion risk assessment for the process where the bucket elevator is integrated, additional explosion effect mitigating measures may be required.

6.3.3 Protective measures

Designing explosion protection implies limiting the consequences of an accidental explosion to such an extent that the explosion resistance of the bucket elevator is not exceeded. Explosion protection methods include explosion suppression and explosion venting. The bucket elevator can also be designed to withstand the maximum expected explosion pressure (explosion resistant construction). These methods shall be used in combination with explosion isolation.

In case of an explosion in the bucket elevator, the bucket elevator and the relevant process parts shall have their electrical power automatically switched off.

Venting design guidance is given in Annex B.

Suppression design guidance is given in Annex C.

Explosion resistant design shall be either for p_{max} or for p_{red} when venting or suppression is applied. For the design requirements refer to EN 14460.

To avoid explosions initiated in the bucket elevator from running into interconnected process items, explosion isolation is required. In general explosion isolation is required on the inlet and outlet of the bucket elevator, de-dusting lines and other connecting lines, unless it is concluded differently from the risk analysis.

Passive isolation techniques include but are not limited to:

— rotary valves (according to EN 15089);

— explosion diverters (dedusting lines only) (according to EN 16020);

— product chokes with proven effectiveness.

Active isolation techniques include but are not limited to:

— extinguishing barriers (according to EN 15089);

— fast-acting valves (according to EN 15089).

7 Information for use

7.1 General

In addition to the information of EN 13463-1 the following additional information shall be supplied:

a) information on the intended use such as limitations on the product to be conveyed and process conditions;

b) if inerting is applied appropriate information on the leakage rates e.g. tightness of flange and inspection door seals etc.;

c) In case of an explosion in the bucket elevator, the bucket elevator and the relevant process parts shall have their electrical power automatically switched off.

d) **Shipping instructions**. In some cases this shall include recommendations on special lifting arrangements designed to minimise equipment distortion.

e) **Storage instructions**. Special instructions associated with equipment storage.

f) **Erection and commissioning manual**. The manual should at least cover the specific information to ensure the adequate installation and functioning of all preventive and protective measures and systems as defined in 6.2.

g) **Operation and maintenance manual**. The manual shall at least cover the following where appropriate:

1) explosion pressure resistance rating of the bucket elevator casing;

2) maintenance required for the preventive and protection systems as defined in 6.2;

3) Information about checks and actions after an explosion or fire event;

4) Specific warnings. Users should consider the risks of fire and explosion that starts elsewhere in a building or process. It may be necessary to stop conveying systems automatically in this case, and fit explosion isolation devices. Where a bucket elevator will be fitted with explosion vents, user instruction should contain advice on the additional dangers these vents may create, and refer to the advice in EN 14491.

h) **Foreign materials**. The bucket elevator manufacturer shall inform the user of any limitations with regard to the ingress of foreign materials e.g. bolts or stones.

i) **Routine inspections, service and cleaning**. The operation and maintenance manual shall inform the user that the ignition minimising properties of bucket elevators and bucket elevator accessories can only be retained if routine inspections, services and cleaning are carried out. The manual shall at least address the following:

1) it shall request that the intervals between routine inspections shall be chosen to take the specific operating conditions into account. For example, the time between inspection may need to be reduced if the bucket elevator is exposed to abrasive dust and corrosive atmospheres. Unexpected noise, temperatures and vibrations should especially be taken into account. Due to the appearance of noticeable problems the bucket elevator shall be taken out of service and inspected;

2) it shall contain a list of recommended spare parts together with the necessary service information and recommended intervals of (visual) inspection;

3) it shall inform that special care shall be devoted to wear and tear of components such as bearings, belts, etc. Correct tension in a belt drive shall be checked, to avoid slippage;

4) it shall request that elevator buckets shall be inspected for damage which could compromise bucket/casing clearances;

5) it shall request that, where the bucket elevator has different categories inside and out, seals forming part of the casing shall be inspected for damage, and replaced if necessary;

6) it shall request that installed monitoring devices (such as bearing temperature, misalignment detectors, slippage control, monitoring systems or similar devices) shall be checked regularly, thereby allowing to do this in accordance with a user's plan if this has shown the need for more frequent checks;

7) it shall request regular cleaning operations at appropriate intervals in all applications, where dust may be expected to form layers on surfaces of the bucket elevator proper and its components.

7.2 Markings

The marking shall be in accordance to EN 13463-1.

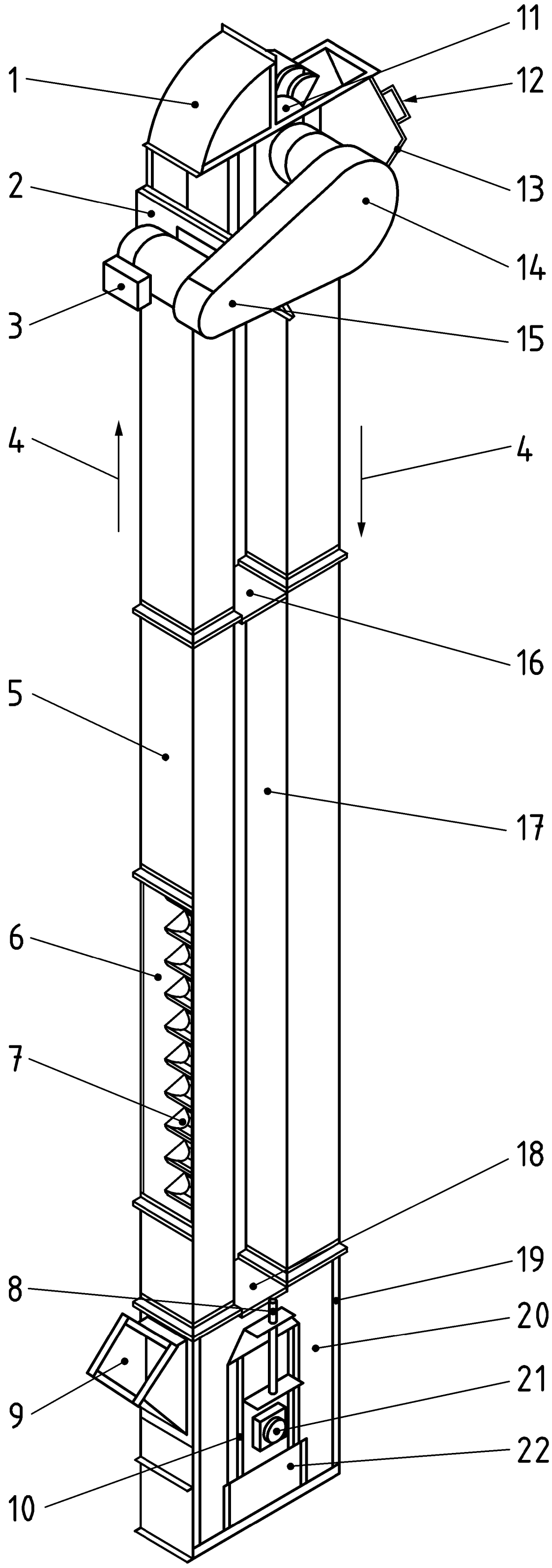
An example of a nameplate is shown in Annex E.

Annex A
(informative)

Examples/types of bucket elevators

A.1 Twin leg bucket elevator

A bucket elevator in which the head and boot are connected by 2 legs – one houses the belt and buckets travelling towards the head, full of product, referred to as the ‘up leg’. The other leg houses the belt and empty buckets travelling back towards the boot, known as the ‘down leg’. See Figure A.1.



Key

1 curved head housing

2 pressed steel motor mounts

3 drive motor

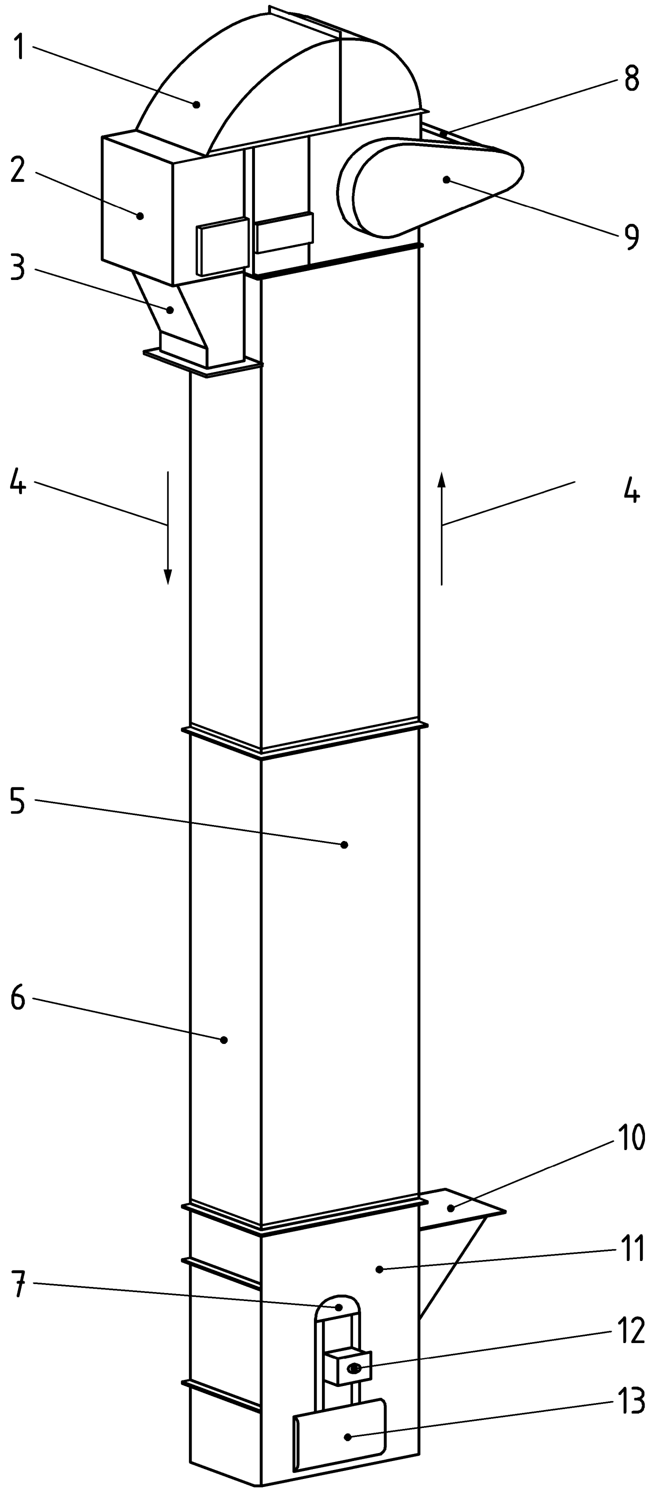
4 direction of travel

5 removable cover for inspection
6 pressed steel buckets (stainless steel & plastic options)
7 synthetic rubber reinforced belt
8 belt tensioning device
9 angled Inlet
10 (not shown) Fabricated crowned steel boot pulley (Coned pulley optional)
11 fully crowned steel head pulley (optional lagged to prevent belt slip)
12 head access panel
13 outlet (angled or vertical)
14 shaft mount speed reducer
15 fully enclosed drive belt system
16 leg joining plate
17 pressed steel leg
18 boot top access cover
19 back inlet (optional)
20 pressed steel boot casing
21 flanged bearings and caps
22 boot side access cover (both sides)

Figure A.1 — General view of twin leg, belt and bucket elevator

A.2 Single leg bucket elevator

A bucket elevator in which the head and boot are connected by one leg that contains the belt and buckets. See Figure A.2.



Key

1 curved head housing
2 head access panel
3 outlet (angled or vertical)
4 direction of travel
5 pressed steel leg
6 removable cover for inspection
7 belt tensioning device

8 drive motor
9 fully enclosed drive belt system
10 angled Inlet
11 pressed steel boot
12 flanged bearings and caps
13 boot side access cover (both sides)

Figure A.2 — General view of single leg, belt and bucket elevator

A.3 Belt and bucket elevator

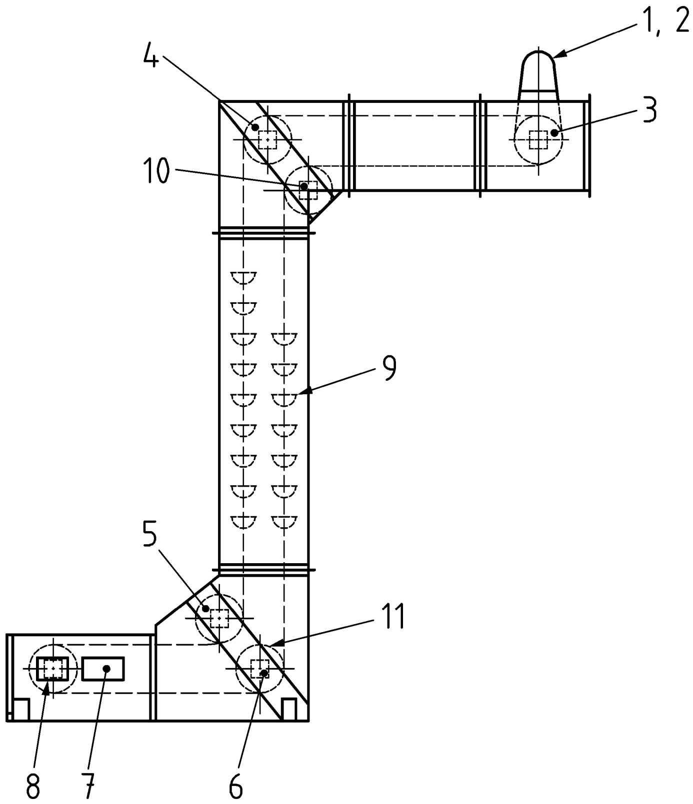
The buckets are attached to a flexible continuous belt that runs around a pulley at both the head and the boot of the bucket elevator.

A.4 Chain and bucket elevator

The buckets are attached to a continuous chain or chains that run around sprockets at the head and boot of the bucket elevator.

A.5 Z-type bucket elevators

Z-type bucket elevators are a type of chain and bucket elevators that run at slow speed and are normally not used for conveying combustible dust. See Figure A.3.



Key

1	geared motor	5	flange bearing	9	bucket
2	drive chain	6	take-up bearing	10	flange bearing
3	flange bearing	7	tension slide	11	sprocket
4	anti-run back bearing	8	flange bearing		

Figure A.3 — Z-type bucket elevator

A.6 Buckets

Buckets are generally open top containers made from mild steel, stainless steel or plastic. Bottomless buckets are also used and the product is then conveyed in a continuous column 'en-masse'.

A.7 Materials of construction

Bucket elevators are generally made from mild, stainless steel or aluminium fabrications. However there are still some older bucket elevators in operation made from wood.

A.8 Belt speed

Bucket elevators will generally run between 1 m/s and 4 m/s. They are usually fitted with an anti run back device (back stop) to prevent blockages if the bucket elevator stops when the up leg is still full of product.

Annex B
(informative)

Guidance on explosion venting

B.1 General

The following guidance is based on the reports given in the bibliography (Holbrow et al., Roser et al.).

Explosion venting of bucket elevators is designed to prevent internal explosion pressures exceeding the strength of the bucket elevator construction. The maximum explosion pressure allowed inside the bucket elevator is the reduced explosion pressure, p_{red}.

The following conditions are necessary for application of this part of the technical report.

Explosion venting devices shall be positioned so that the effectiveness of the venting process is not impeded. Personnel and nearby plant shall not be at risk from the venting action.

Vent openings shall have an area equal to or greater than the internal cross-sectional area of the bucket elevator leg(s).

The minimum vent area for the head and the boot shall be equal to the internal cross sectional area of the leg.

Venting devices shall comply with EN 14797. The static activation overpressure of the explosion venting device, p_{stat}, shall not exceed 0,1 bar.

Guidance for the design of explosion venting is given for dusts with p_{max} < 10 bar and K_{St}-values up to 200 bar m s^{-1}.

Only bucket elevators with rectangular cross sections (up to 0,5 m^2 for twin leg and 2 m^2 for single leg elevators) have been tested so far. Circular legs and larger cross sections require additional considerations. The guidance given below might not represent these cases.

B.2 Guidance for venting of twin leg bucket elevators

The guidance given is valid under the following conditions:

— bucket spacing < 280 mm;

— rectangular cross section of the bucket elevator legs;

— free area in relation to the cross section area (CSA) of the bucket elevator legs < 60 %;

— venting area ≥ cross section area (CSA) of the bucket elevator leg. Both bucket elevator legs are vented;

— required vent height ≥ 1,5 × bucket spacing;

— static activation overpressure p_{stat} ≤ 0,1 bar;

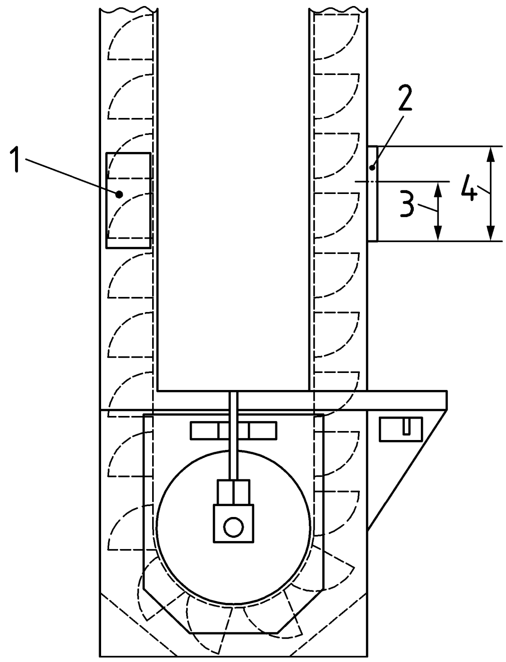
— metal or plastic buckets (see B.4);

— maximum internal cross sectional area of one leg is 0,5 m^2.

These rules apply to vents positioned on one side of the bucket elevator leg. It may be necessary to position vents on two sides of the leg. The total effective area of these two vents should equal at least the area of the single vent they replace; that is, the cross sectional area of the leg.

Where there is a requirement to put a vent on the boot and it is not possible to install it on the boot, the vent shall be put on both legs as close as possible to the boot. The distance between the lower edge of the vent and the top of the boot must not exceed 0,5 times the vent spacing or within 3 m of the boot whichever is the smaller value. The same criterion applies to the head, when it is not practical to vent the head.

Ensure that the venting process is not impeded by the belt. This can e.g. be achieved by positioning the vents in a face normal to the belt. Figure B.1 shows the vent locations permitted in the legs relative to the belt or chain.



Key

1 explosion venting device located on the leg plane at right angles to the belt or chain

2 explosion venting device located on the leg plane opposite to the belt or chain

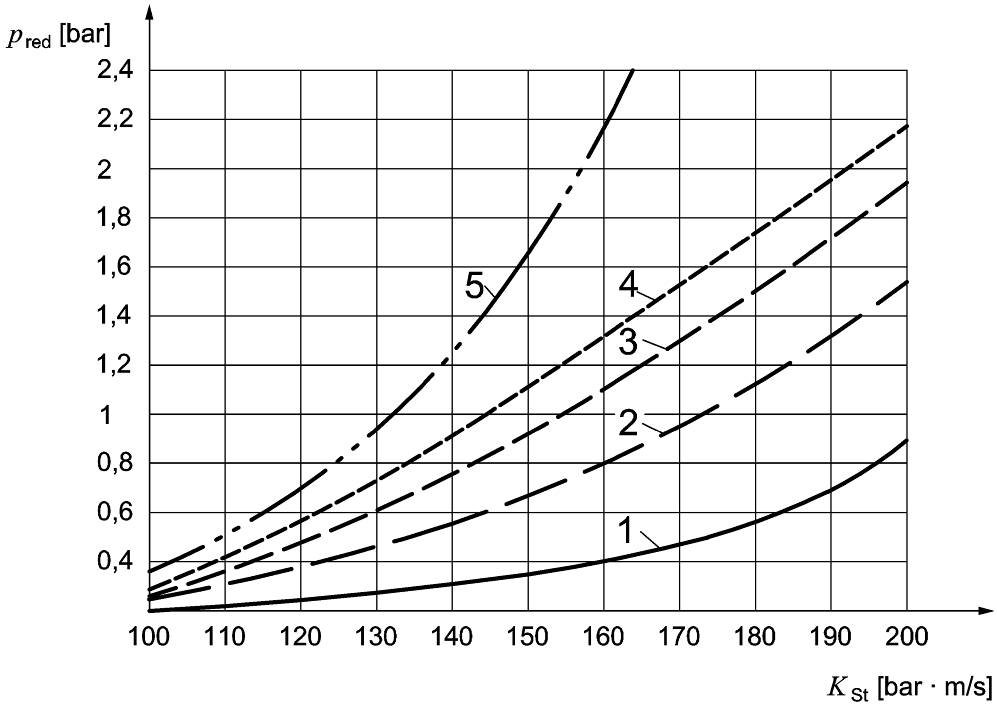
3 bucket spacing

4 required venting area ≥ CSA; required vent height ≥ 1,5 × bucket spacing

Figure B.1 — Vent locations on bucket elevator legs

The bucket elevator should be designed for the reduced explosion pressure, taking into account the weakening due to the vents and the reaction forces arising during the venting process. The reaction forces can be calculated using the formula in EN 14491. The length of the vented flame can be calculated from the formula in EN 14491 taking the volume as the volume between two subsequent vents. The external pressure effects close to the vent can be calculated from the formula in EN 14491 taking the volume as the volume between two subsequent vents. On larger distances from the vent the effects of multiple vents need to be taken into account. As a conservative approximation the external overpressure from the various vents at a certain location the pressures can be added together.

Figure B.2 shows the required pressure resistance for various K_{St} values and vent configurations.



Key

X K_{St} [bar · m/s]

Y p_{red} [bar]

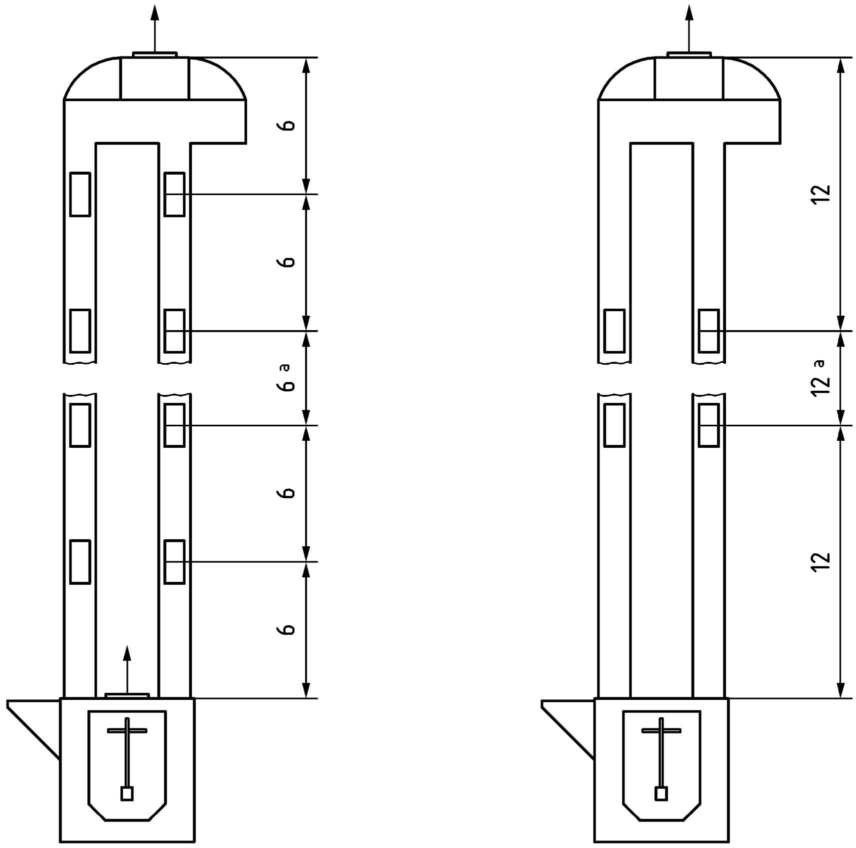
Figure B.2 — The required pressure resistance for various K_{st} values and vent configurations (see Table B.1)

The curves are represented by following formula:

$$p_{\text{red}} = \exp\left(a \cdot K_{\text{st}}^{\text{c}} + b\right)$$

Table B.1 — Vent configuration

Curve No.	Vent configuration (installation distance)	coefficient a	coefficient b	exponent c
1	head + boot + legs (3 m distance)	$3,292 \cdot 10^{-6}$	−1,957	2,5
2	head + boot + legs (6 m distance)	0,438	−5,761	0,5
3	head + legs (3 m distance)	−67,98	5,467	−0,5
4	head + legs (6 m distance)	−401,6	2,78	−1
5	head + legs (12m distance) or only head with max. length of the legs 12 m	0,673	−7,74	0,5



Key

a iterative distance

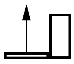
 venting device

Figure B.3 — Maximum installation distance of the vents on the example of vent configuration (2) and (5) (see Figure B.2)

B.3 Guidance for venting of single leg bucket elevators

The guidance given is valid under the following conditions:

— Bucket spacing < 450 mm.

— Rectangular cross section of the bucket elevator leg.

— Free area in relation to the cross section area of the bucket elevator legs < 75 %.

— Venting area ≥ cross section area of the bucket elevator leg.

— Static activation overpressure p_{stat} ≤ 0,1 bar.

— Metal or plastic buckets (see note below on effect of plastic buckets).

— Maximum internal cross sectional area of the leg is 2,0 m^2.

The following guidance is given:

— As a minimum requirement, vents shall be fitted to the head and the boot or as close as possible to the head and as close as possible to the boot.

— For dusts with K_{St} values of 100 bar m/s or less, vents installed in the head and boot of the bucket elevator, with none on the legs, will limit the reduced explosion pressure to 0,5 bar.

— For dusts with a K_{St} value of 80 bar m/s, a vent spacing of 20 m will limit the reduced explosion pressure to 0,25 bar.

— For 3 m vent spacing use twin leg graph (Figure B.2).

— For 6 m vent spacing with vent opening pressure (P_{stat}) of 0,05 bar use twin leg graph (see Figure B.2) with P_{stat} of 0,1 bar.

— For 6 m vent spacing with vent opening pressure (P_{stat}) of 0,1 bar use twin leg graph (see Figure B.2) with P_{stat} of 0,1 bar and double the bucket elevator strength.

B.4 Increased bucket elevator strength for plastic buckets

Plastic buckets will enhance explosion pressures. Increased bucket elevator strength is required to withstand the higher pressures, as given in next table.

K_{St} [bar·m·s^{-1}]	**Increase of bucket elevator strength**
< 100	20 %
100 to 150	35 %
> 150 to 200	50 %

B.5 Containment without venting

It should be noted that in this paper no guidance is given for the maximum expected explosion overpressure. Flame acceleration of dusts with $K_{St} \geq 150$ bar m s^{-1} through the elongated elevator legs can result in high explosion pressure peaks.

For bulk materials with fine dust fractions of $p_{max} \leq 9$ bar and $K_{St} \leq 100$ bar m/s, pressure relief may not be required regardless of the length of the elevator, provided that it can withstand explosion pressures of $p \geq 1$ bar overpressure. This applies under the following conditions:

— location of the ignition source inside the elevator (no flame jet ignition from connected equipment);

— organic dusts;

— rectangular cross-section of the bucket elevator legs;

— free area in relation to the cross-section area of the bucket elevator legs < 60 %;

— metal buckets;

— bucket spacing ≤ 280 mm;

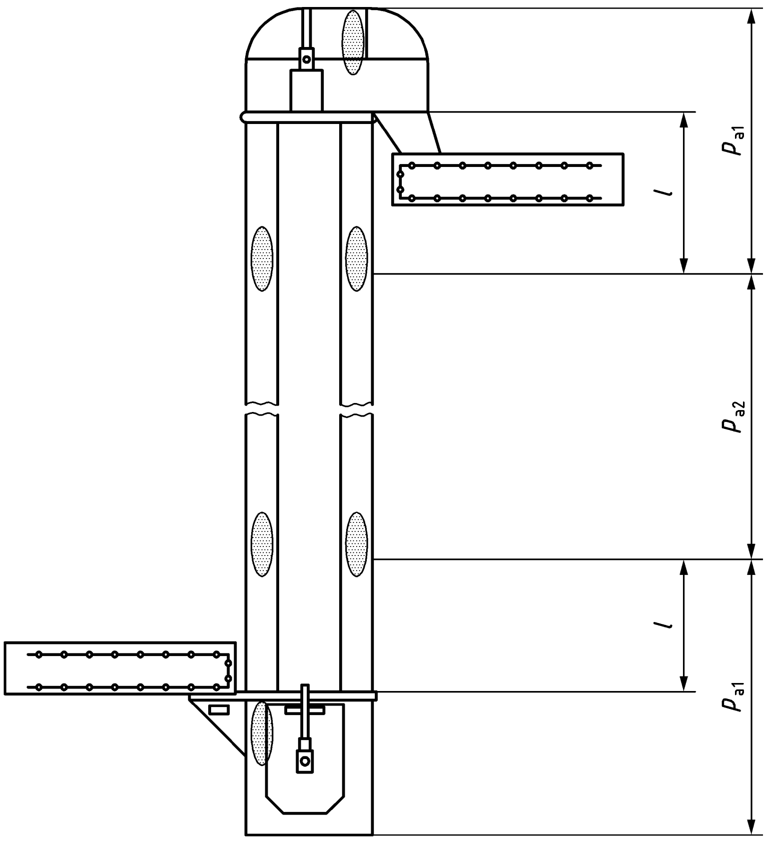
— maximum internal cross sectional area of one leg is 0,5 m^2.

Annex C
(informative)

Guidance on explosion suppression

This guidance is based on explosion suppression tests carried out in a twin leg bucket elevator as described in the "Research Project G-05-0801" (2011) by M. Roser, A. Vogl, S. Radandt and is considered state of the art knowledge. Other protection schemes and manufacturer specific deviations are possible from the indicative results given in this Annex C. The protective system as well as the application guide shall be in accordance with the requirements of EN 14373 and EN 15089.

One suppressor was installed at the bucket elevator boot and one at the head. Additional extinguishing barriers were located in each leg of the bucket elevator (see Figure C.1). The pressure sensors as well as the flame sensors of the detection system were installed at or close to the bucket elevator head and boot.



Key

p_{a1} minimum explosion resistance

p_{a2} minimum explosion resistance

l installation distance

Figure C.1 — Schematic of bucket elevator with explosion suppression system

For installation distances l of barriers and required explosion resistance p_a see Table C.1.

To stop explosion propagation from the head or boot along the legs, extinguishing barriers are used. The experimental investigations have shown that without such barriers, flame propagation can readily occur from the bucket elevator boot or from the bucket elevator head into the bucket elevator legs even when the explosion overpressure is still quite low (20 to 60 mbar). Therefore, if pressure sensors are applied, the barriers need to be installed at rather large distances from the head and boot in order to stop explosion propagation. The consequence of such a large distance is that the reduced explosion pressure will be high. Flame detectors enable extinguishing barriers at short distances and result in lower reduced explosion pressures. If the explosion starts in the legs the best method of detection is by pressure sensors. Therefore optimum protection will be reached with a combination of pressure and flame sensors.

In Table C.1 indicative results of the recommended explosion resistance and the necessary installation distance of the extinguishing barriers are shown for ignition in the head or the boot. The influence of the type of the detection system (pressure sensors or flame sensors) and of settings of the detection system (in case of pressure sensors) is given. The activation pressure p_{act} represents the explosion overpressure just in the moment at which the suppressors will be activated.

Table C.1 — Information on the recommended explosion resistance of a twin leg bucket elevator and the necessary installation distance of the extinguishing barriers in the up and downleg (see Figure C.1)

Detection	**Installation distance** l [m]	**Minimum explosion resistance** p_{a1} [barg]	**Minimum explosion resistance** p_{a2} [barg]
Pressure detection system: $p_{act} \leq 110$ mbarg	8	1,5	1,2
Pressure detection system: $p_{act} \leq 80$ mbarg	6	1,0	0,7
Pressure detection system: $p_{act} \leq 30$ mbarg	5	0,7	0,4
Flame detection system	1,5	0,3	0,2

The information given in Table C.1 is valid under the following conditions:

— maximum explosion overpressure of the dust: $p_{max} \leq 9$ bar;

— K_{St}-value: $K_{St} \leq 150$ bar·m·s^{-1};

— twin leg bucket elevator with rectangular legs;

— metal buckets;

— maximum distance between bucket and casing: ≤ 70 mm;

— maximum bucket distance: ≤ 280 mm;

— Suppressant: sodium bicarbonate or ammonium phosphate.

If the K_{St}-value of the dust is $K_{St} \leq 100$ bar·m·s^{-1} and a pressure detection system is used with pact ≤ 110 mbarg in combination with an installation distance of the extinguishing barriers of 8 m, a minimum pressure resistance p_{a1} = 0,3 bar and p_{a2} = 0,2 bar is required. If a flame detection system is used a pressure resistance of $p_{a1} = p_{a2} \geq 0,1$ bar is sufficient.

In case of dust with $150 < K_{St} \leq 200$ bar·m·s^{-1} a flame detection system in combination with an installation distance of the extinguishing barriers of 5 m and a pressure resistance of $p_{a1} \geq 1{,}0$ bar and $p_{a2} \geq 0{,}5$ bar is required.

The amount of suppressant required depends on the volume of the bucket elevator head and boot and of the cross section area of the bucket elevator legs. It must be taken from the application guide of the manufacturer of the protective system.

Annex D
(informative)

Example of an ignition hazard assessment

D.1 Intended use

The equipment is a bucket elevator designed for use in places where a source of release of flammable materials gives rise to a zone 22 potentially explosive atmosphere inside a building.

Inside the bucket elevator a zone 20 is present.

The bucket elevator is driven by an electric motor that has been certified by a notified body as category 2 electrical equipment and is suitable for the potentially explosive atmosphere surrounding it.

D.2 Construction

It is designed for vertically conveyed combustible powder. The ignition sensitivity of the powder has been assumed to be very high and therefore all potential ignition sources have been taken into account. Depending on the ignition sensitivity of the actual powder conveyed by a bucket elevator some ignition sources might not be relevant.

The bucket elevator contains two pulleys fixed on their axle which is rotating in two bearings each. The bearings are mounted directly on the housing. The head pulley is driven by an electric motor via a gear box and rubber coupling. At this spot also a non-return mechanism is installed to prevent back-running of the bucket elevator. The boot pulley axle can be manually adjusted to keep the belt under tension. The belt is flame retardant and antistatic. Both surfaces pulleys are roughed to enhance grip on the belt. The bucket elevator is built out of carbon steel with carbon steel buckets. The velocity of the bucket elevator is 2 m/s. There are no exposed light metal or plastic parts. The drive pulley has a weight of 60 kg.

The bucket elevator is equipped with a slip detection device by monitoring the number or revolutions. When too low the motor is stopped. The motor has a power of 10 kW.

D.3 Ignition hazard assessments

An ignition hazard assessment according to EN 13463-1 has been carried out for the following components of this bucket elevator:

— pulleys (see Table D.1);

— bearings (see Table D.2);

— axles (see Table D.3);

— belt (see Table D.4);

— buckets (see Table D.5);

For ancillary equipment such as coupling, gear box, brake and electric motor the ignition hazard-assessment shall be carried out according to the relevant standard.

For the outside (zone 22) no potential ignition sources are to be expected during normal operation.

For the inside (zone 20 conditions) one should take into account that in addition to foreseeable malfunctions, rare malfunctions may also lead to potential ignition sources, mainly leading to heat generation and mechanical sparks:

— Plugging of bucket elevator due to overfilling will lead to slip and heat formation. When the slip detection fails this can lead to ignition.

— Failure of tension adjustment leading to slipping belt. When the slip detection fails this can lead to ignition.

— Misalignment of belt leading to mechanical friction of belt and buckets to casing: heat formation and ignition.

— Break of belt will lead to mechanical friction: heat formation and ignition.

— Failure of the axle.

— Failure of one the bearings: heat formation on the bearing but also potential dislocation of the axle and pulley.

— Failure of fixation of a pulley on its axle.

— Failure of the coupling.

For each component the ignition hazard assessment is illustrated as an example.

Table D.1 — Ignition hazards for the pulleys

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
1	Electrical sparks	/				X								X		
2	Hot surfaces on electrical equipment	/				X								X		
3	Electrostatic discharges	Sparking of pulley to casing due to loss of bonding of pulley. Sparking of metal bucket fixeners on belt to pulley			X		Charging by belt and or charged product in combinatio n with loss of bonding	• Antistatic belt • Pulley is bonded to axle by metallic contact and axle is bonded to casing via bearings	IEC/TS 600 79–32–1 and Instruction manual EN 13463–1 and EN 13463–5, protection type c					X	1	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
4	Mechanical sparks	Pulley fixation on axle fails leading to axial movement of pulley. Axle is moving axially (bearing failure). Failure of axle Failure of belt Slipping of belt due to overfilling of bucket elevator, too high product temperatures, greasy substances in product, failure of belt tightening, wear of belt, failure of belt, wear of pulley gripping surface		X			Potential spark energy is 120 Nm and thus higher than 20 Nm as given in EN 13463–1	• Pulley is permanently fixed on axle. Failure is considered as rare malfunction. • Slip detection device will stop drive in case of head pulley failure and in case of other slipping of belt. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident. • Belt is maintained well.	Instruction manual EN 13463–1 and EN 13463–5, protection type c. EN 13463–6, protection type b				X		2	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
5	Hot surfaces due to friction and rubbing	Pulley fixation on axle fails leading to axial movement of pulley. Axle is moving axially (bearing failure). Failure of axle Failure of belt			X		Temperatures are expected to be higher than ignition temperatures of considered products.	• Pulley is permanently fixed on axle. Failure is considered as rare malfunction. • Slip detection device will stop drive in case of head pulley failure. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident. • Belt failure is seen as rare incident	Instruction manual EN 13463–1 and EN 13463–5, protection type c. EN 13463–6, protection type b	Test report about bearing temperature show that temperatures will not be higher than 40 °C.			X		2	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
		Slipping of belt due to overfilling of bucket elevator, too high product temperatures, greasy substances in product, failure of belt tightening, wear of belt, failure of belt, wear of pulley gripping surface.		X			Temperatures are expected to be higher than ignition temperatures of considered products.	• Overfilling is to be prevented as are too high product temperatures. • Belt must be replaced in time. • Maintenance of belt pulley. • Belt is out of flame retardant material in this way preventing outbreak of fire. • Slip detection will stop drive.	Instruction manual EN 13463–1 and EN 13463–5, protection type c.				X		2	
6	Chemical reactions	/				X								X		
7	Open flames and hot gases	/				X								X		

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
8	Lightning	Inside a building				X								X		
9	Stray electrical currents and cathodic corrosion protection	/				X								X		
10	Ultrasonics	/				X								X		
11	Electromagnetic waves	/				X								X		
12	High frequent radiation	/				X								X		
13	Ionising radiation	/				X								X		
14	Adiabatic compression	/				X								X		
Resulting equipment category including all existing ignition hazards:													2			

Table D.2 — Ignition hazard assessment for the axles

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
1	Electrical sparks	/				X								X		
2	Hot surfaces on electrical equipment	/				X								X		
3	Electrostatic discharges	Sparking of axle to casing due to loss of bonding of axle.			X		Charging by belt and or charged product in combinatio n with loss of bonding.	Axle is bonded to casing via bearings.	IEC/TS 6007 9–32–1 and Instruction manual EN 13463–1 and EN 13463–5, protection type c					X	1	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
4	Mechanical sparks	• Failure of axle • Failure of bearings			X		Potential spark energy is 120 Nm and thus higher than 20 Nm as given in EN 13463–1.	• Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident.	Instruction manual EN 13463–1 and EN 3463–5, protection type c.					X	1	

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
5	Hot surfaces due to friction and rubbing	• Failure of axle • Failure of bearings			X		Temperatures are expected to be higher than ignition temperatures of considered products.	• Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident.	Instruction manual EN 13463–1 and EN 13463–5 protection type c	Test report about bearing temperatures how that temperatures will not be higher than 40 °C.			X		2	
6	Chemical reactions	/				X								X		
7	Open flames and hot gases	/				X								X		

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
8	Lightning	Inside a building				**X**								**X**		
9	Stray electrical currents and cathodic corrosion protection	/				**X**								**X**		
10	Ultrasonics	/				**X**								**X**		
11	Electromagnetic waves	/				**X**								**X**		
12	High frequent radiation	/				**X**								**X**		
13	Ionising radiation	/				**X**								**X**		
14	Adiabatic compression	/				**X**								**X**		
Resulting equipment category including all existing ignition hazards:														**1**		

Table D.3 — Ignition hazard assessment for the bearings

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
1	Electrical sparks	/				X								X		
2	Hot surfaces on electrical equipment	/				X								X		
3	Electrostatic discharges					X										
4	Mechanical sparks					X										

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
5	Hot surfaces due to friction and rubbing	• Damaged elements i.e. due to internal sparks by electrostatic charging or stray currents • Ingress of dust or water • Loss of lubrication • To high axial forces causes damage to bearings			**X**		Temperatures are expected to be higher than ignition temperatures of considered products.	• Measures to prevent spark over and stray currents: earthing and bonding of all conductive elements. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C).	Instruction manual EN 13463–1 and EN 13463–5, protection type c.	Test report about bearing temperature show that temperatures will not be higher than 40 °C.				**X**	1	

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
6	Chemical reactions	/				**X**								**X**		
7	Open flames and hot gases	/				**X**								**X**		
8	Lightning	Inside a building				**X**								**X**		
9	Stray electrical currents and cathodic corrosion protection					**X**								**X**		
10	Ultrasonics	/				**X**								**X**		
11	Electromagneti c waves	/				**X**								**X**		
12	High frequent radiation	/				**X**								**X**		
13	Ionising radiation	/				**X**								**X**		

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
14	Adiabatic compression	/				X								X		
Resulting equipment category including all existing ignition hazards:															1	

Table D.4 — Ignition hazard assessment for the belt

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
1	Electrical sparks	/				X								X		
2	Hot surfaces on electrical equipment	/				X								X		
3	Electrostatic discharges	Discharges from belt due to static charging during use: Spark (from bucket fixeners to pulley), corona, brush and propagating brush discharges.	X				Spark discharges may become hazardous in case of low MIE dusts Corona and brush discharges are no hazards for dust. Propagating brush discharge is a potential hazard.	The use of an antistatic belt	IEC/TS 600 79–32–1 and Instruction manual					X	1	

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
4	Mechanical sparks	Buckets are fixed on belt by metal fasteners that then may cause sparks with pulley at slip or breakage of belt. Slip on pulley due to overfilling of bucket elevator, too high product temperatures, failure of belt tightening, wear of belt, wear of pulley gripping surface.		**X**			Potential spark energy is 120 Nm and thus higher than 20 Nm as given in EN 13463–1.	• Slip detection device will stop drive in case of slipping	Instruction manual EN 13463–6, protection type b				**X**		2	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
5	Hot surfaces due to friction and rubbing	Belt slips on pulley due to overfilling of bucket elevator, too high product temperatures, failure of belt tightening, wear of belt, wear of pulley gripping surface. Belt gets misaligned and starts grinding on the casing (caused by failing of pulley fixation leading to axial movement of pulley, axle is moving axially due to bearing failure, failure of axle, pulleys are not lined out well)		X			Temperatures are expected to be higher than ignition temperatures of considered products	• Pulley is permanently fixed on axle. Failure is considered as rare malfunction. • Slip detection device will stop drive at slip. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. • The maximal bearing temperature is determined under the most adverse conditions 30 °C). • Failure of axle is seen as rare incident.	Instruction manual EN 13463–1 and EN 13463–5, protection type c.				X		2	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
6	Chemical reactions	/				X			EN 13463–6, protection type b					X		
7	Open flames and hot gases	Due to slipping and grinding on the casing		X			Due to friction belt gets so hot it starts burning	Slip detection stops drive Flame retardant belt	Instruction manual EN 13463–6, protection type b					X	1	
8	Lightning	Inside a building				X								X		
9	Stray electrical currents and cathodic corrosion protection	/				X								X		
10	Ultrasonics	/				X								X		

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
11	Electromagn etic waves	/				X								X		
12	High frequent radiation	/				X								X		
13	Ionising radiation	/				X								X		
14	Adiabatic compression	/				X								X		
														Resulting equipment category including all existing ignition hazards:	3	

Table D.5 — Ignition hazard assessment for the buckets

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
1	Electrical sparks	/				X								X		
2	Hot surfaces on electrical equipment	/				X								X		
3	Electrostatic discharges	Discharges from buckets due to static charging during use.	X				Spark discharges may become hazardous in case of low MIE dusts.	The use of an antistatic belt	IEC/TS 60079–32–1 and Instruction manual.					X	1	
		Bucket get loose from belt		X			Spark discharges may become hazardous in case of low MIE dusts.	Buckets are fixed permanently	Instruction manual				X		2	

	1		2					3			4					
	Ignition hazard		**Assessment of the frequency of occurrence without application of an additional measure**					**Measures applied to prevent the ignition source to become effective**			**Frequency of occurrence including measures applied**					
	a	**b**	**a**	**b**	**c**	**d**	**e**	**a**	**b**	**c**	**a**	**b**	**c**	**d**	**e**	**f**
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
4	Mechanical sparks	Buckets hit the casing: Breakage of belt. Belt gets misaligned and starts grinding on the casing (caused by failing of pulley fixation leading to axial movement of pulley, axle is moving axially due to bearing failure, failure of axle, pulleys are not lined out well)		**X**			Potential spark energy is 120 Nm and thus higher than 20 Nm as given in EN 13463–1.	• Pulley is permanently fixed on axle. Failure is considered as rare malfunction. • Slip detection device will stop drive at slip. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident	Instruction manual EN 13463–1 and EN 13463–5, protection type c. EN 13463–6, protection type b	Test report about bearin g tempe rature show that tempe rature s will not be higher than 40 °C		**X**			3	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	**Potential ignition source**	**Description/ basic cause**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Reasons for assessment**	**Description of the measures applied**	**Basis**	**Technical documentation**	**During normal operation**	**During foreseeable malfunction**	**During rare malfunction**	**Not to be considered**	**Resulting equipment category in respect of this ignition hazard**	**Necessary restrictions**
5	Hot surfaces due to friction and rubbing	Buckets are grinding the casing due to: Breakage of belt. Belt gets misaligned and starts grinding on the casing (caused by failing of pulley fixation leading to axial movement of pulley, axle is moving axially due to bearing failure, failure of axle, pulleys are not lined out well).		X			Temperatures are expected to be higher than ignition temperatures of considered products.	• Pulley is permanently fixed on axle. Failure is considered as rare malfunction. • Slip detection device will stop drive at slip. • Bearings are calculated according to ISO 281 for a specified lifetime. A malfunction is generally agreed as a rare incident under these conditions. The maximal bearing temperature is determined under the most adverse conditions (30 °C). • Failure of axle is seen as rare incident.	Instruction manual E 13463–1 and EN 13463–5, protection type c. EN 13463–6, protection type b				X		2	

	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
6	Chemical reactions	/				X								X		
7	Open flames and hot gases	/				X								X		
8	Lightning	Inside a building				X								X		
9	Stray electrical currents and cathodic corrosion protection	/				X								X		
10	Ultrasonics	/				X								X		
11	Electromagnetic waves	/				X								X		
12	High frequent radiation	/				X								X		

Nr.	1		2					3			4					
	Ignition hazard		Assessment of the frequency of occurrence without application of an additional measure					Measures applied to prevent the ignition source to become effective			Frequency of occurrence including measures applied					
	a	b	a	b	c	d	e	a	b	c	a	b	c	d	e	f
Nr.	Potential ignition source	Description/ basic cause	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Reasons for assessment	Description of the measures applied	Basis	Technical documentation	During normal operation	During foreseeable malfunction	During rare malfunction	Not to be considered	Resulting equipment category in respect of this ignition hazard	Necessary restrictions
13	Ionising radiation	/				X								X		
14	Adiabatic compression	/				X								X		
	Resulting equipment category including all existing ignition hazards:														3	

Annex E
(informative)

Example of a nameplate

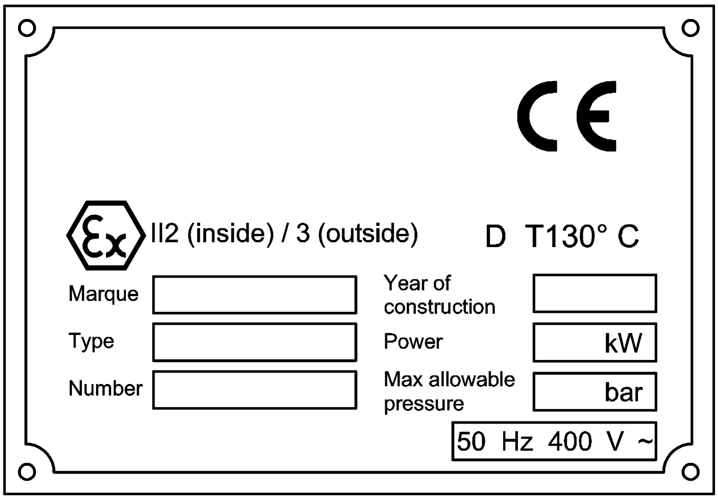


Figure E.1 — Example of a name Ex CE plate

Annex F
(informative)

Guidance for assessing the probability of generating explosive atmospheres

The following typical examples can be used as guidance:

1. Grain

Grain (such as wheat, barley, corn) that has not been cleaned may be rather dusty and should be considered to as example A. Only after thorough cleaning, such as with an aspirator, example B can be assumed.

Remarks:

1) Cleaning with the help of an aspirator means that fines are removed from grain in free fall by a strong counter airflow. Dust extraction on a bucket elevator or on the inlet chute may reduce the dust concentration to a certain extent, but cannot be considered as cleaning.

2) Depending on the origin of the product it may contain different fines content and consequently the fines content may vary in time. For the purpose of this analysis it is recommended to assume worst-case condition.

3) In some agricultural products, part of the dust may be non-combustible (e.g. soil).

2. Oil seeds

Products like soya beans and sunflower seed are rather fatty and therefore the seeds produce hardly any dust. However, for soya beans it is known that the hulls are not fatty and unless the product is thoroughly cleaned, may result in serious dust clouds, similar to example A. For sunflower seed the hulls are more fibrous and will hardly result in any dust: similar to example B.

3. Pellets

Pellets typically consist of fines, mixed with a binder and pressed. The probability that dust is created mainly depends on the binder that is used:

— When water is applied (which is common with wood pellets) the pellets break up easily and dust is to be expected as in example A.

— When oils or fats are applied (which is common for feed), hardly any dust formation is to be expected: as in example B.

4. Sugar

Dry refined sugar is a very friable material. Any manipulations with this type of sugar (such as screw conveyors, discharge operations) will increase the amount of dust. Therefore, in general bucket elevators conveying dry refined sugar should be considered similar to example A. Only when the process conditions are such that dust is unlikely, similar to example B may be assumed; as a typical example: the first bucket elevator transporting the fresh sugar from the dryer.

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