SIST

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**Preprečevanje in eksplozijska zaščita korčnih elevatorjev pred požarom in eksplozijo**

Fire and explosion prevention and protection for bucket elevators

Brand- und Explosionsschutz für Becherwerke

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



**Ta slovenski standard je istoveten z: CEN/TR 16829:2016+AC:2019**



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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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# Contents

# European foreword

This document (CEN/TR 16829:2016+AC:2019) 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 shall not be held responsible for identifying any or all such patent rights.

This document includes Corrigendum 1 issued by CEN on 24 April 2019.

The start and finish of text introduced or altered by corrigendum is indicated in the text by tags AC〉 〈AC.

## 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.



[AC> EN 1127-1 <AC], *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 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.

[AC) NOTE (AC] 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.



[AC⟩ NOTE External explosive atmospheres can also influence the atmosphere in the elevator. ⟨AC]

[AC⟩ For example the following situations can exist: ⟨AC]

| 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).<br>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).<br>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.<br>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<br>• Friction between elevator belt and drive pulley due to slippage<br>• Friction of loose parts in bucket elevator (loose bucket, lost parts of pulley lagging etc.) with moving parts<br>• Damage to bearings and gear units |

| **Potential ignition source** | **Possible causes** |
|---|---|
| Mechanical sparks | • Mechanical sparks (metal) buckets colliding with casing wall (due to insufficient belt tension, defective belt, loose buckets) or with discharge chute<br>• Misalignment of pulley |
| Electrical equipment | • Electrical equipment and motors<br>• Inadequate earthing and/or equipotential bonding |
| Electrostatics | • Electrostatic charging due to separation processes between belt and drive pulleys<br>• Electrostatic charging of buckets due to electrostatic induction<br>• 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<br>• Introduction of glowing nests<br>• Welding, grinding, cutting operations<br>• Damage to the casing due to external mechanical action |
| Flames and hot gases including hot particles | • Introduction of glowing nests<br>• Propagation of fire or explosion from connected installations or from outside |
| Mechanical sparks | • Introduction of foreign material<br>• 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.