Collection of Examples

"Dust Explosion Prevention and Protection for Machines and Equipment"

Part 2: Conveyors, transfers and receivers

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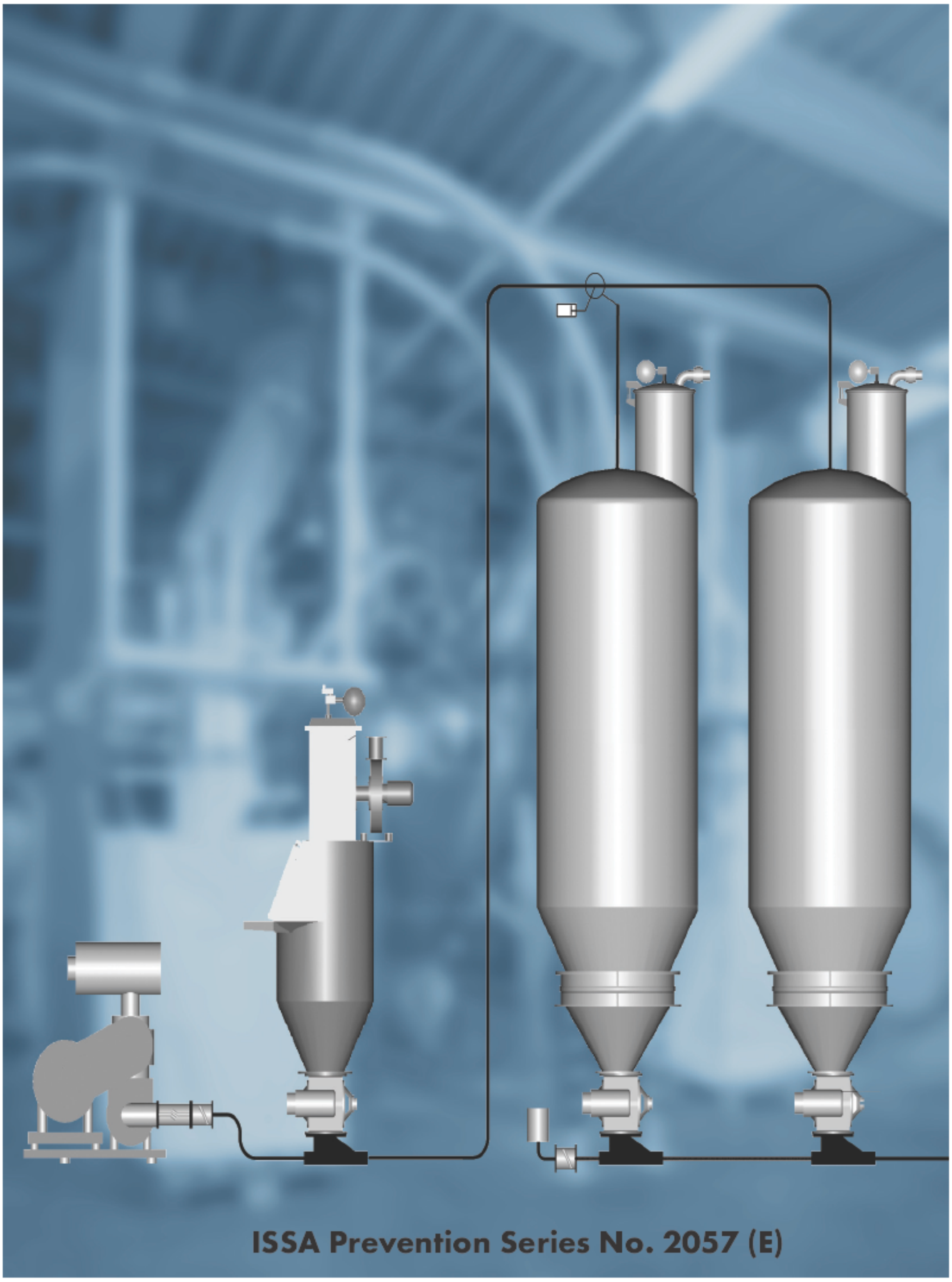

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Section on Machine and System Safety

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Section on Prevention in the Chemical Industry

INTERNATIONAL SOCIAL SECURITY ASSOCIATION

has 336 members (government authorities and public institutions) in 157 countries. The headquarters of the ISSA are at the International Labour Organization in Geneva. Its main goal is the promotion and improvement of SOCIAL SECURITY in all parts of the world.

To improve occupational safety and health in industrial plants, the

ISSA INTERNATIONAL SECTION ON MACHINE AND SYSTEM SAFETY

was established in 1975. It handles matters relating to the safety of machinery plants and systems.

Chair and secretariat:
Berufsgenossenschaft Nahrungsmittel und Gastgewerbe (BGN), 68165 Mannheim, Germany

To promote work safety in plants of the chemical industry, including plastics, explosives, mineral oil and rubber industries, the

ISSA INTERNATIONAL SECTION ON PREVENTION IN THE CHEMICAL INDUSTRY

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Berufsgenossenschaft Rohstoffe und chemische Industrie (BG RCI), 69115 Heidelberg, Germany

Collection of Examples for the Brochure "Dust Explosion Prevention and Protection for Machines and Equipment"

Part 2:

Conveyors
(pneumatic conveying, belt-, chain- and screw conveyors, vibratory feeders, bucket elevators),

transfers and receivers

Compendium for Practicel Use

Published by

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Preface

The International Social Security Association (ISSA) has the target to show and to evaluate supported by the specialized Sections the risks detected in different working fields by means of exchange of experience, publications and symposia and to propose measures which can reduce the risks and so the accidents at work and the occupational diseases to an acceptable degree.

The Bureaus of the Sections “Prevention in the Chemical Industry” and “Machine and System Safety” of the ISSA founded a “working group explosion protection” in order to promote the international exchange of experience between experts and to elaborate common solutions for specific problems. In this way they want to contribute to a high and common state-of-the-art safety in industrialized countries. They are willing to share their knowledge with industrially less developed countries.

The subject “explosion protection” of machines is for examples dealt with in the European Union with two Directives, in the Machinery Directive (2006/42/EC) and in the Explosion Protection Directive ATEX (94/9/EC). In these two Directives the essential requirements (ESR) are fixed. An important requirement of these Directives is to make risk assessments. They are the basis for the use of machines in the enterprises. It is fixed in a further Directive: ATEX 137 (1999/92/EC). Here also a risk assessment is required.

The compendium shall facilitate the responsible persons in the enterprises to assess the explosion risk when selecting and using machines and systems in explosive areas as described in this brochure and to decide on the protective devices in accordance with the risk assessment. The compendium is composed of several parts. The first part deals with mills, crushers, separators and screeners. The present second part deals with conveyors, transfers and receivers.

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Contents

Introductory Remarks

This part is a continuation of the ”Collection of Examples Part 1: Mills, crushers, mixers, separators, screeners” of the brochure ”Dust Explosion Prevention and Protection for Machines and Equipment“.

As described in various ISSA brochures, especially “Dust Explosion Prevention and Protection for Machines and Equipment - Basic Principles” (ISSA, 2004, Mannheim, ISBN 92-843-7129-5), both preventive and protective measures can be applied, as single measures or in combination.

In the following chapters typical dust explosion hazards and possible preventive and protective measures will be discussed for various machinery and installations. In this brochure it is assumed that hybrid mixtures are not present. This means that no flammable gases or vapours with a concentration of more than 20 vol.-% of the lower explosion limit (LEL) are present.

Preventive measures

- Avoidance of explosive atmospheres by e. g.
  - limitation of the concentration
  - inerting
  - use of vacuum
- Avoidance of effective ignition sources

If “Avoidance of effective ignition sources” is applied as the only preventive measure, it should be guaranteed that all relevant effective ignition sources are reliably prevented. Meeting this requirement will become increasingly difficult with decreasing **M**inimum **I**gnition **E**nergy (**MIE**) and increasing complexity of installations and processes. All limit values included in this brochure are to be considered as indicative only. When products with a MIE below 10 mJ are processed, in practice it will be hard to apply “Avoidance of effective ignition sources” as the only preventive measure (see also flow chart in figure 1). In addition it needs to be taken into account that the MIE decreases with increasing temperature. Additional preventive measures “Avoidance of explosive atmospheres” or protective measures then have to be applied. For products with a low MIE ”Phlegmatisation” (partial inerting) could be used as additional measure. Due to the reduction in oxygen concentration the ignition sensitivity of the product is reduced.

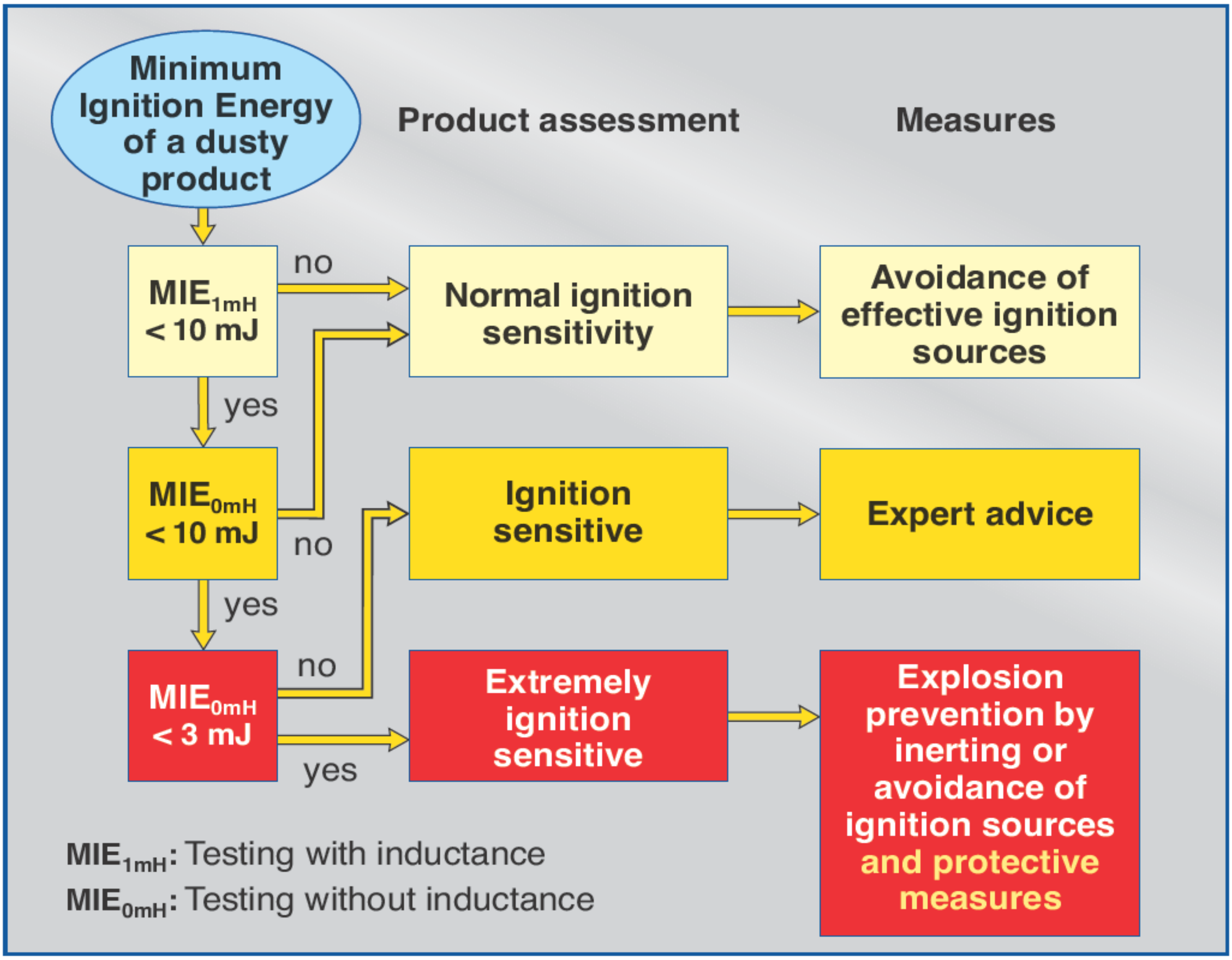


Figure 1: Scheme to estimate protective measures as a function of the MIE of the product involved. In general the MIE is at first tested with an electrical discharge spark somewhat expanded in time (with inductance in the discharge circuitry). If the resulting MIE_{1mH} is found to be below 10 mJ, the test is repeated without inductance in the discharge circuitry (MIE_{0mH}).

Protective measures can also be necessary for products with a MIE above 10 mJ, if not all relevant effective ignition sources are reliably prevented.

Protective measures

- Explosion-resistant design for the expected explosion pressure combined with explosion isolation
- Explosion-resistant design with explosion venting combined with explosion isolation
- Explosion-resistant design with explosion suppression combined with explosion isolation

The adequate choice of measures depends on the details of plant construction and layout, and on the properties of the involved dust or powder. Usually an individual assessment must be made, taking the advantages and disadvantages of the various safety measures, as well as their limits of application, into consideration. Therefore, the explosion risks have to be determined and assessed (for example according the European guideline 1999/92/EC) and appropriate measures have to be applied.

Although the collection of examples in this document indicates a number of possible explosion hazards and protective measures, it is not exhaustive. The illustrations show some typical solutions that have proved effective. For each application, however, the specific boundary conditions need to be taken into account (for example pressure piling in interconnected vessels, forbidding of venting because of toxic materials, exceeding maximum rates of pressure rise when using explosion suppression).

Furthermore, instable chemical products, or products that are sensitive to ignition by impact and hybrid mixtures, need special safety considerations, appropriate to each case.

The equipment and machines that are described hereafter technically have to be in conformity with the current technical state of the art. Especially protective systems such as rotary valves, rupture discs or explosion suppression systems have to be approved for prior to use, e. g. have to be certified in the EC by notified testing institutes. Regular inspection and maintenance is required, in order to prevent risks due to mechanical failures.

The booklet includes several examples for zoning inside the various conveying systems. The user of conveying systems needs to verify if, for his specific application, the examples do apply. The actual zoning depends on many conditions (such as conveying speed, product load, product properties).

The definitions of zones can be found in the ISSA document “Practical Assistance for the Preparation of an Explosion Protection Document” (ISSA, 2006, Mannheim, ISBN 92-843-1167-5) or in the European directive 1999/92/EC.

In these examples it will be indicated which of the 13 potential ignition sources [EN 1127-1] are relevant for the machines.

The potential ignition sources include:

1. **Hot surfaces;**
2. **Flames and hot gases** (including hot particles);
3. **Mechanically generated sparks;**
4. **Electrical apparatus;**
5. Stray electric currents, cathodic corrosion protection;
6. **Static electricity;**
7. Lightning;
8. Radio frequency (RF): electromagnetic waves from 10^4 Hz to $3 \cdot 10^{12}$ Hz (high frequency);
9. Electromagnetic waves from $3 \cdot 10^{11}$ Hz to $3 \cdot 10^{15}$ Hz;
10. Ionizing radiation;
11. Ultrasonics;
12. Adiabatic compression and shock waves;
13. **Exothermic reactions, including self-ignition of dusts.**

From experience it is known that the ignition sources indicated in **bold** are especially relevant.

The following examples explain which ignition sources may arise and how these can be prevented.

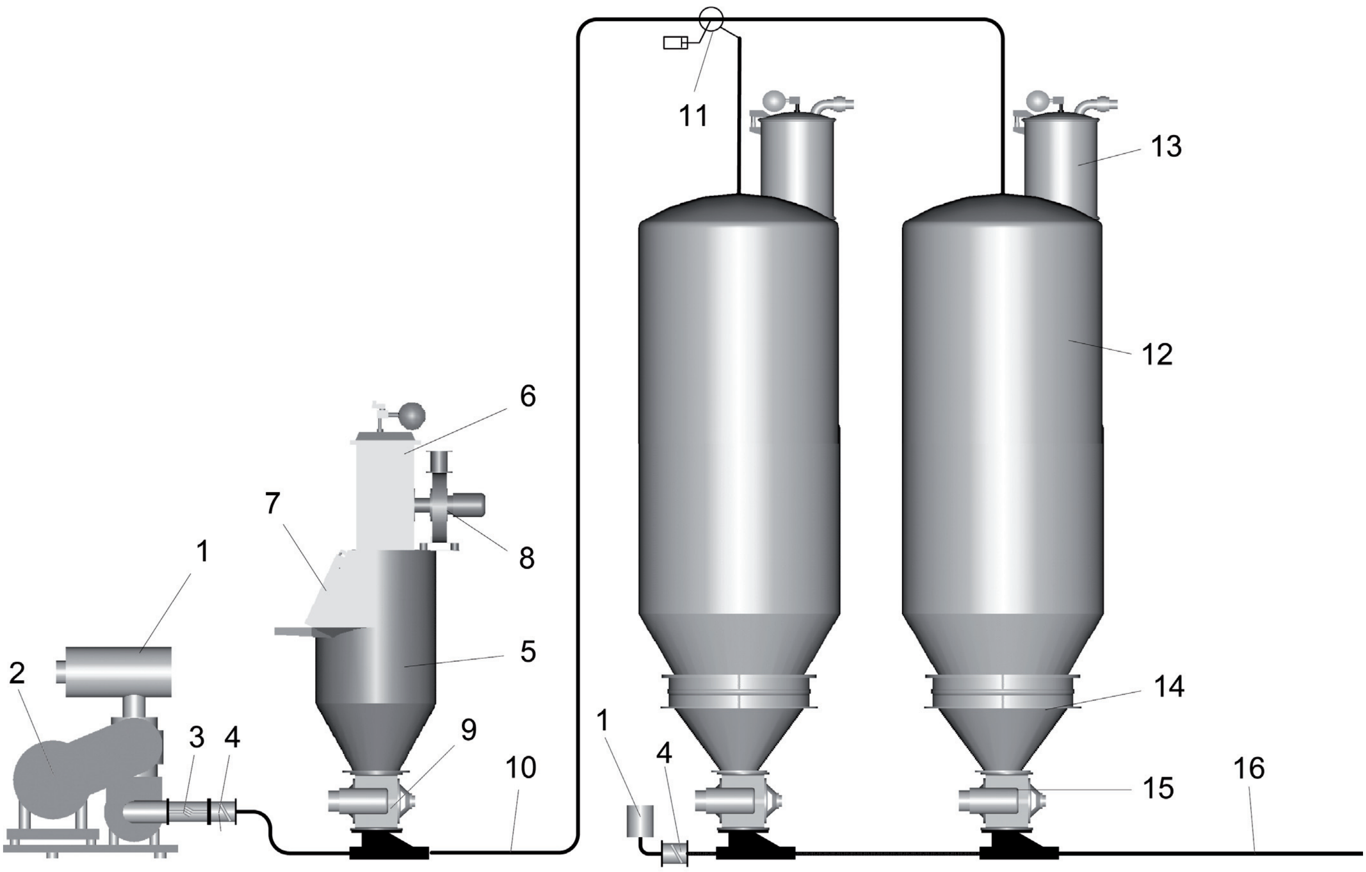
Each ignition source has to be assessed separately to verify if it is effective, in order to determine if effective ignition sources can be excluded during normal operation (including start-up and shut-down), predictable and rare fault conditions.

For some situations protective measures that have proven to be effective will be presented. Typical examples will be given. However, it has to be noted that every plant will differ and therefore measures need to be adapted to the specific situation.

6 Conveyors

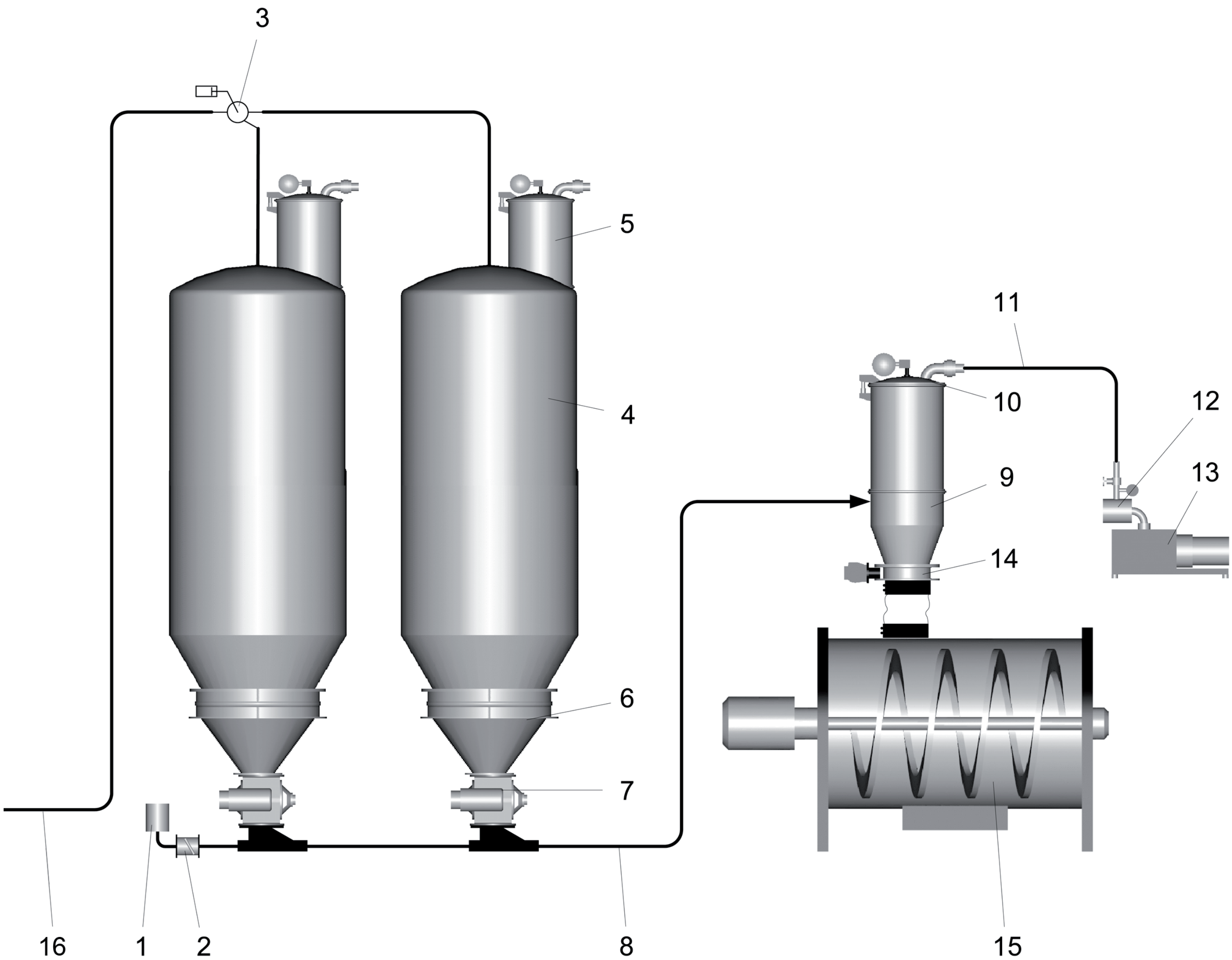
6.1 Pneumatic conveying

In this publication a pneumatic conveying system consists of product intake, product feeder, pressure or vacuum generator, piping and a receiver. A distinction has to be made between pressure (figure 2) and vacuum (figure 3) systems.



1 Air inlet filter
2 Compressor/blower
3 Spark arrestor
4 Non-return valve
5 Product intake hopper
6 Filter for intake hopper
7 Product inlet
8 Extraction fan
9 Rotary feeder
10 Conveying line “pressure”
11 Diverter valve
12 Silo
13 Air vent filter
14 Discharge device
15 Discharge rotary valve
16 Conveying line

Figure 2: Example of a positive pressure pneumatic conveying system



1 Air inlet filter
2 Non-return valve
3 Diverter valve
4 Silo
5 Air vent filter
6 Discharge device
7 Discharge rotary valve
8 Vacuum conveying line
9 Filter receiver
10 Filter
11 Clean air outlet
12 Secondary filter
13 Vacuum pump
14 Butterfly valve
15 Mixer
16 Filling line

Figure 3: Example of a vacuum pneumatic conveying system

Explosive atmosphere in the conveying line

The probability that an explosive dust/air-mixture will arise in the conveying line depends on the type of conveying, such as dilute-phase or dense-phase (moving bed flow or pulsed flow) and product properties: particle size distribution and specific weight of the product involved (see also figures 5 and 6). For coarse products with low fines (< 500 μm) content it can be assumed that no explosive atmospheres will arise in the conveying line. However, it needs to be taken into account that, in the receiver, fines may accumulate and might cause an explosive atmosphere.

During start-up and shut-down explosive atmospheres need to be taken into account. During normal operation, especially with high product loads, experience is that the dust-air mixture is too rich (upper explosion limit is exceeded) to enable ignition by an effective ignition source. Figure 4 gives an example of a dust zoning depending on the type of conveying and product load.

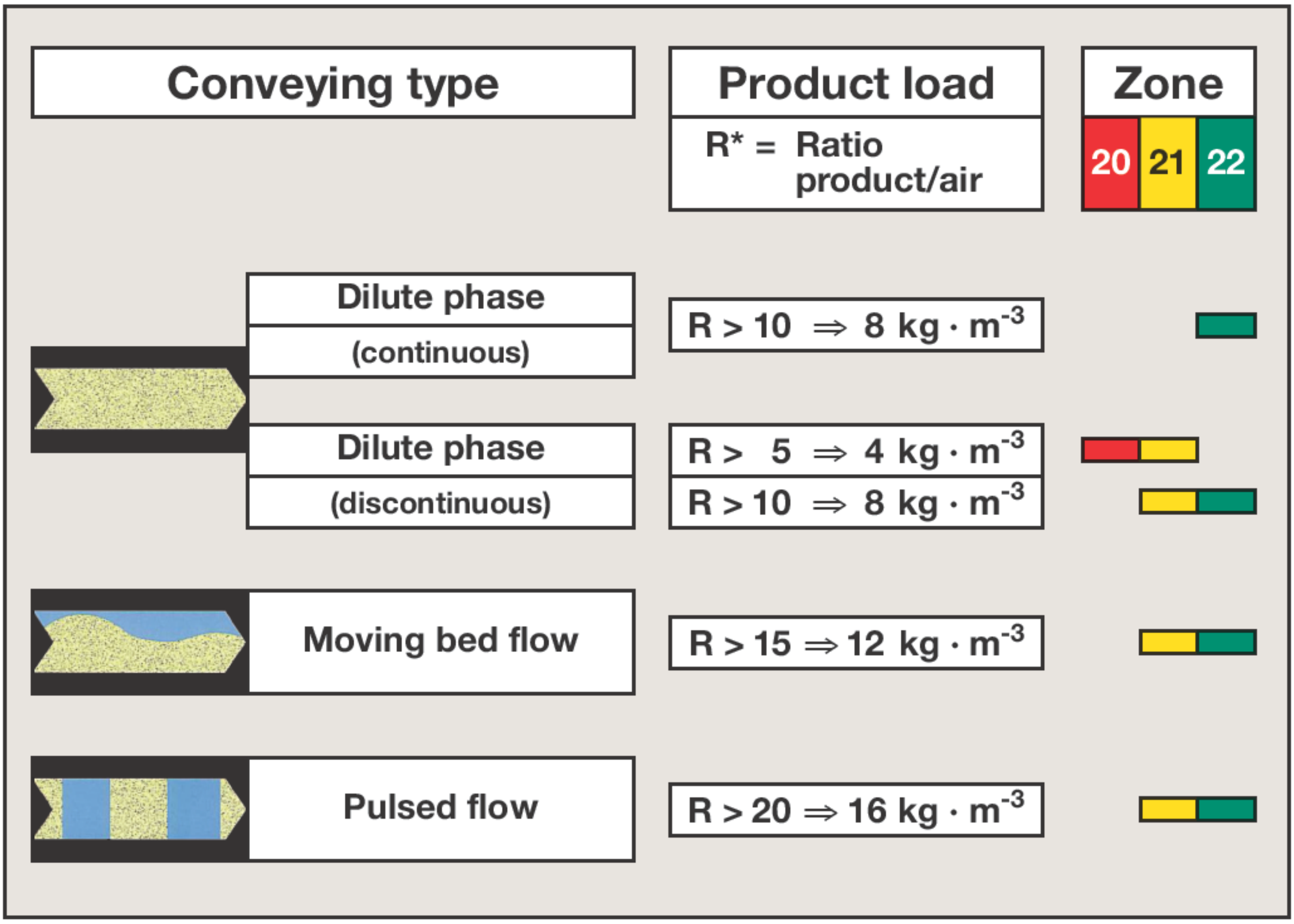


Figure 4: Example of dust zoning in a conveying line with combustible dusts, as a function of the type of conveying, including start/stop. R is the product load factor, expressed in kg product/kg conveying air.

Ignition sources and measures

With pneumatic conveying following ignition sources may arise:

- spark discharges caused by electrostatic charging of conductive piping, flanges, valves or other devices, due to unreliable or unsteady earthing ($R_E < 10^6\ \Omega$);
- propagating brush discharges when a non-conductive coating, with break-down voltage > 4 kV is applied inside conductive piping or receivers;
- propagating brush discharges on non-conductive product deposits, with break-down voltage > 4 kV. Such deposits may arise during conveying of product with low melting temperature, or conveying at increased temperature, due to sintering or melting processes;
- propagating brush discharges on non-conductive piping, with a break-down voltage > 4 kV;
- mechanical sparks and/or hot surfaces in blowers or fans in the product flow;
- effective ignition sources, such as smouldering lumps, that are introduced into the conveying system;
- auto-ignition. From experience it is known that, due to the short residence time in the conveying line, no significant temperature increase of the conveyed product will arise. With products that are very sensitive to elevated temperatures, auto-ignition of deposits may arise;
- elevated conveying air temperatures will increase the ignition sensitivity of the product and hence may cause additional ignition hazards.

Foreign objects in the product flow may cause impact or frictional sparks. In general impact or frictional sparks do not pose an ignition hazard in pneumatic conveying lines.

For most conveying conditions, pneumatic conveying systems pose a small dust explosion hazard. This is due to the unlikely presence of an explosive dust/air-mixture in combination with the reduced ignition sensitivity caused by the high turbulence.

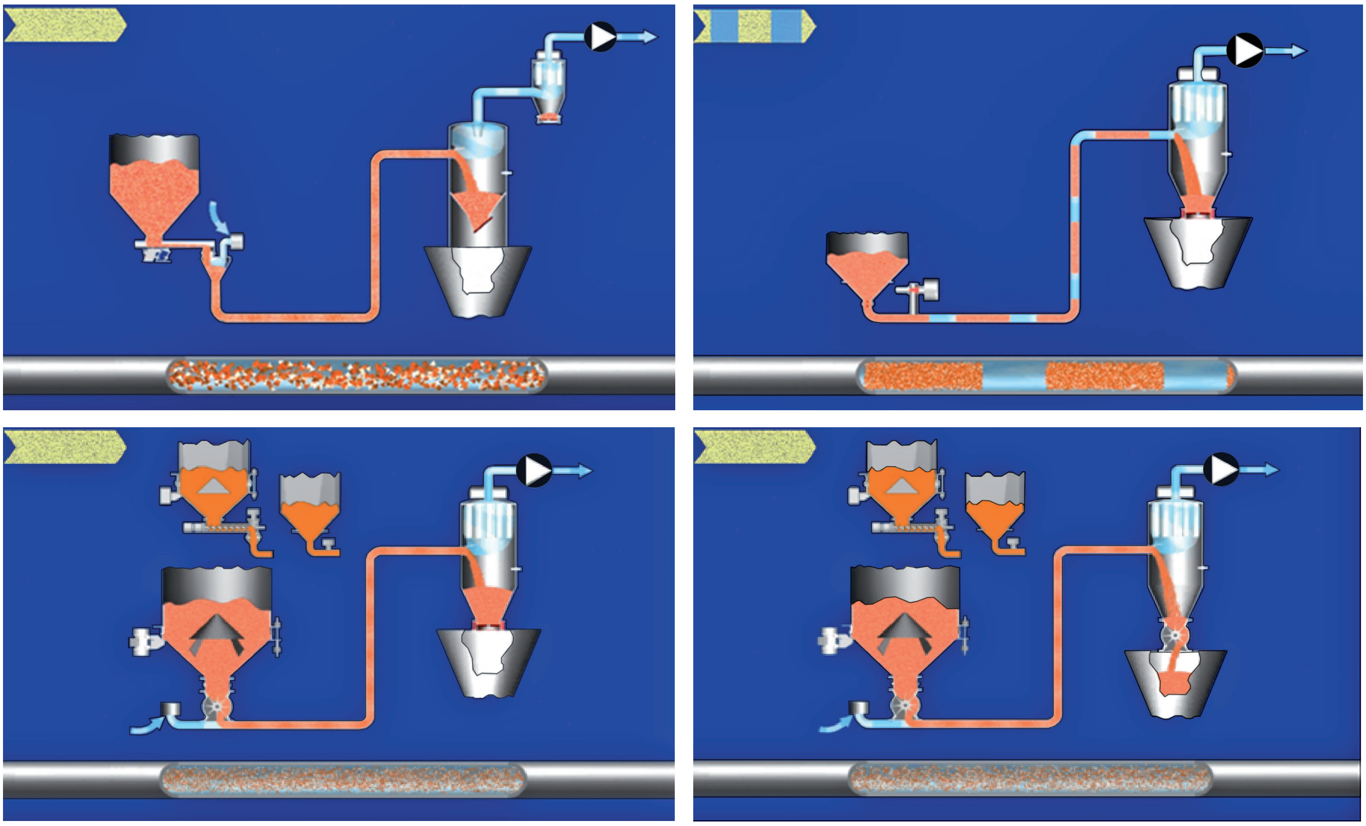


Figure 5: Pneumatic conveying systems (dilute phase and plugged flow) with various product feeders

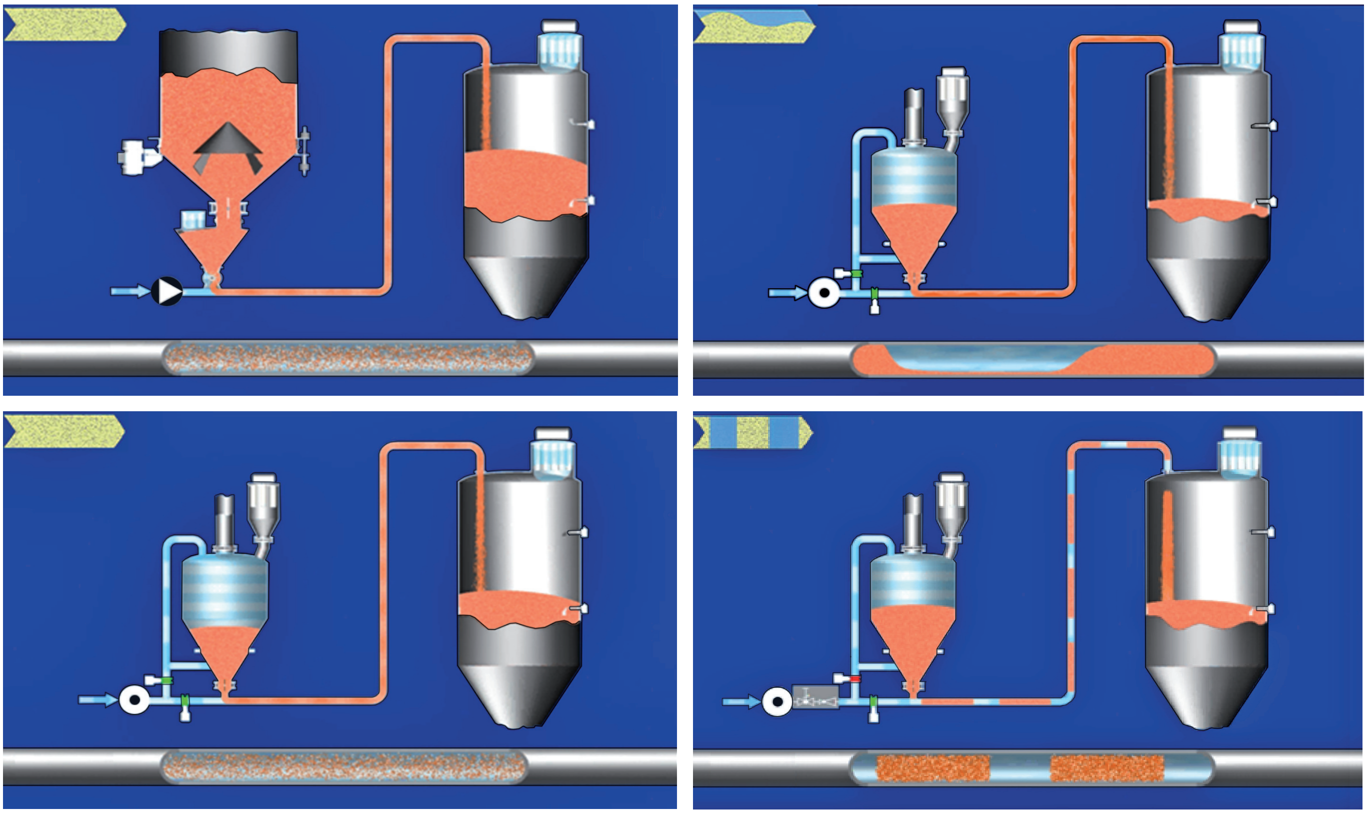


Figure 6: Pneumatic conveying systems (dilute phase, moving bed flow and plugged flow) with various product feeders

Pneumatic conveying lines enable transport of smouldering lumps. From experience it is known that this will not cause an ignition in the conveying line, but it may cause ignition of an explosive dust/air-mixture in downstream process parts. Increased process temperatures may also result in generation of smouldering lumps in downstream equipment.

Pneumatic conveying lines enable explosion propagation. Such propagation is not only possible into the direction of the air flow, but also against the air flow, even with high conveying velocities. The probability of explosion propagation increases with decreasing product load. Therefore start-up, shut-down or feed interruptions are especially critical situations. The reduced explosion pressure has only a minor effect on the probability of explosion propagation. Therefore, even with very low reduced explosion pressures, flame propagation needs to be taken into account. A reduced explosion pressure below 0.3 bar, however, will prevent significant pressure piling in connected equipment.

The probability of explosion propagation decreases with decreasing cross sectional area of the conveying line.

6.2 Mechanical conveyors

6.2.1 Belt conveyors

Belt conveyors can be applied as open or enclosed conveyors. Open belt conveyors will result in a dustier environment. Enclosed belt conveyors create an increased risk of explosion propagation.

Pipe conveyors are also considered as belt conveyors. With pipe conveyors the belt will close itself around the conveyed product. The enclosure is dust tight and enables conveying over several kilometres.

In general explosion hazards with belt conveyors are very small. Experience is that with belt conveyors fire hazards (and therefore fire protection) dominate. Fires, however, provide ignition sources for explosive atmospheres that may arise during transfers or are caused by disturbed dust deposits. In addition: burning parts, and also smouldering lumps, can be conveyed quickly towards interconnected equipment, such as bucket elevators.

Explosive atmospheres

For fine products, or coarse products with large content of fines (e. g. non-cleaned grain), explosive atmospheres may arise occasionally at drop-off or drop-over points (zone 21). Further along the belts explosive atmospheres are unlikely to arise and, if they do, will persist for a short period only (zone 22).

Measures to prevent or reduce explosive atmospheres include:

- reduction of fines content in conveyed product;
- reduction of drop height;
- increased moisture content;
- spraying of liquids that bind dusts;
- effective dust extraction;
- no return of separated dusts on conveyor belts.

Around drop-off or drop-over points dust deposits will arise. Measures to reduce such deposits include:

- reduced belt speed;
- application of conductive belts;
- belt cleaners.

Ignition sources and measures

With belt conveyors the following ignition sources may arise:

- stuck rollers, resulting in overheating due to friction;
- hot surfaces due to stuck bearings;
- hot surfaces due to belt friction or slippage;
- electrostatic discharges due to insufficient earthing of conductive or dissipative parts. Typical examples include metal reinforced belts, metal drums with non-conductive bearings or insulating surfaces.

Measures to prevent effective ignition sources include:

- periodic maintenance/inspection and cleaning (removal of dust deposits) and effective dust extraction at enclosed locations;
- rotation control;
- misalignment control (especially for long belts);
- temperature control, e. g. with a sensor cable (especially for enclosed belt conveyors or other situations with difficult access where stuck rollers might be overlooked);
- detection of smouldering lumps at transfers, in order to prevent transport of such lumps;
- application of conductive or dissipative belts; respecting maximum allowable speeds (IEC 60079-32-1 and EN 12882);
    - as an alternative non-conductive belts may be used, where electrostatic charges are removed with the help of corona discharges (which are not capable of igniting dust-air mixtures);
- application of fire retardant belt conveyors;
- adequate cleaning (remove dust deposits) or effective dust extraction of enclosed areas.

If explosive atmospheres and effective ignition sources cannot be excluded with sufficient certitude, protective measures are required.

Explosion isolation measures might be required to prevent explosion propagation. Possible solutions include chemical or mechanical barriers.

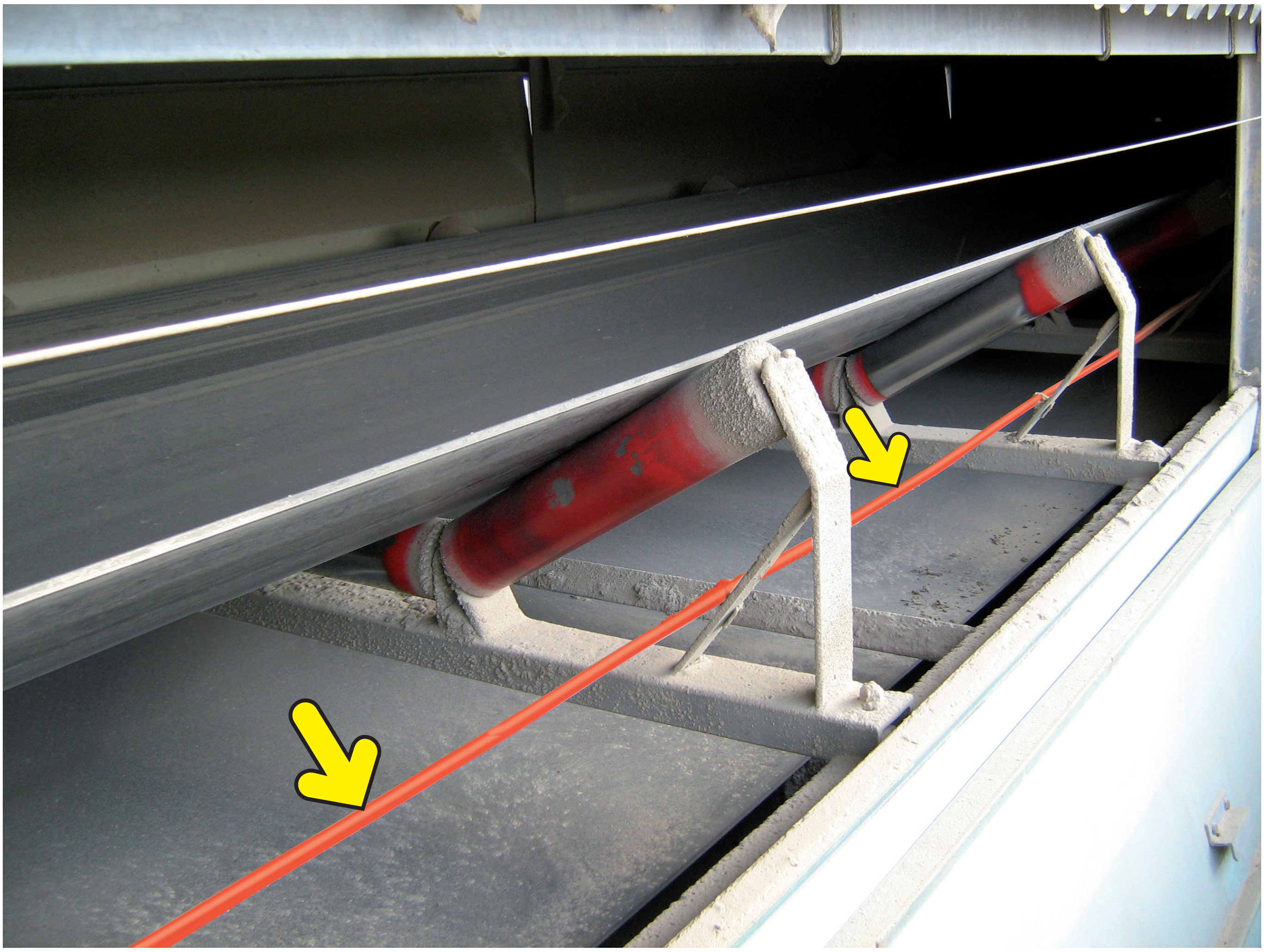


Figure 7: Application of sensor cable (arrows) as temperature control; this will enable early detection of defective rollers. (Source: G.T.H. Getreide Terminal Hamburg GmbH & Co. KG)

6.2.2 Chain conveyors

6.2.2.1 Trough chain conveyors

A trough chain conveyor consists of a drive unit, an endless chain, provided with scrapers, running inside an enclosed trough, and a tensioning unit which enables tensioning or loosening of the chain (figure 8).

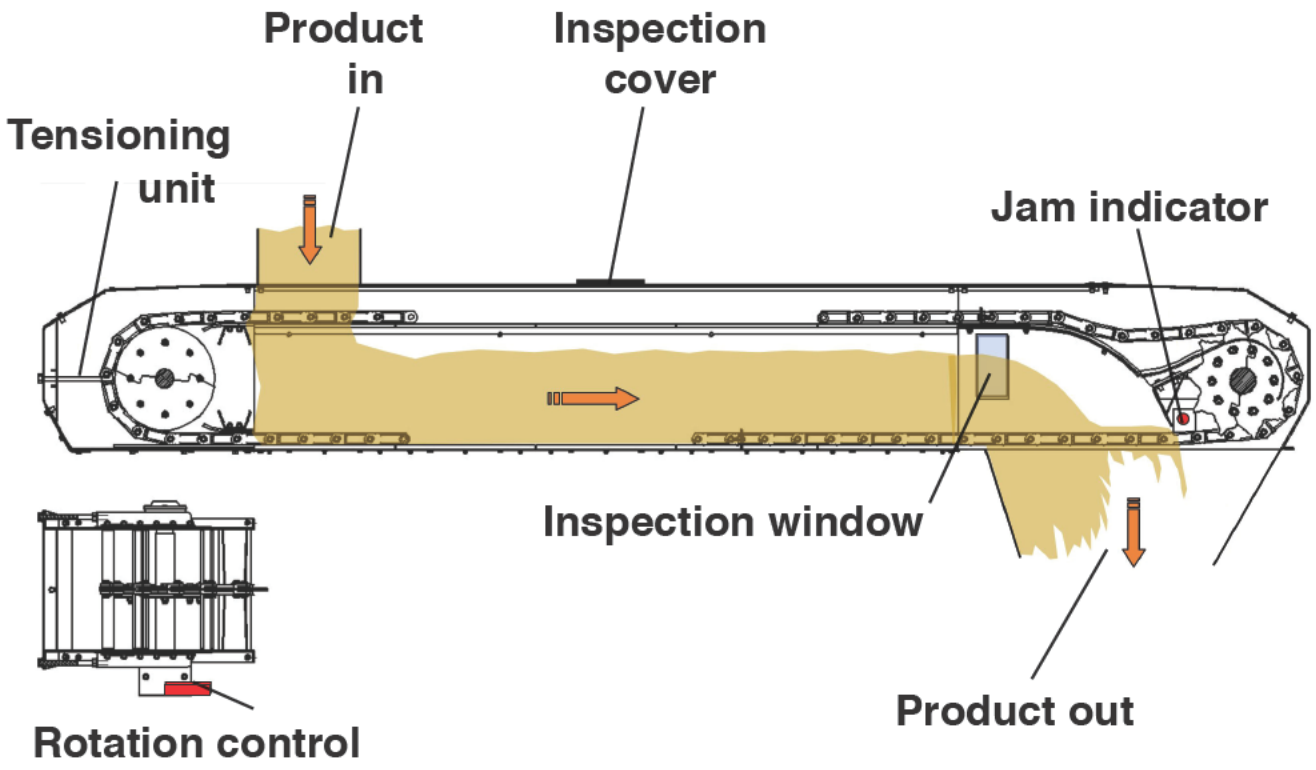


Figure 8: Trough chain conveyor (schematic)

Explosive atmospheres

When dusts or dusty products are conveyed with trough chain conveyors, explosive atmospheres have to be assumed near drop-off or drop-over points. Because of the slow and smooth conveying, inside trough chain conveyors explosive atmospheres are very limited in size.

For fine products or coarse products with large fines content (e. g. non-cleaned grain) explosive atmospheres may arise occasionally at drop-off or drop-over points (zone 21). Apart from these points explosive atmospheres are unlikely to arise and, if they do, will persist for a short period only (zone 22).

However, especially for enclosed designs, explosion propagation from adjacent process parts via the conveyor is possible.

Ignition sources and measures

With trough chain conveyors following ignition sources may arise:

- hot surfaces at drive bearings;
- hot surfaces and mechanical sparks;
- in case of jamming: auto ignition of jammed product due to the energy supplied by the chain conveyor;
- auto ignition of large, long lasting, dust deposits due to insufficient cleaning;
- electrostatic discharges.

Measures to prevent effective ignition sources include:

- use of external bearings or temperature monitoring of bearings;
- limit the conveying velocity to maximum $v = 1\ m \cdot s^{-1}$;
- use of blockage sensor or material blockage flap with sensor;
- periodical cleaning at the discharge valve and removal of (sticky) dust deposits;
- construction from conductive materials;
- adequate earthing and inspection of all conductive and dissipative items; especially for trough chain conveyors with insulating parts or coatings.

6.2.2.2 Pipe chain and aeromechanical conveyors

Pipe chain conveyors consist of a drive unit, tensioning unit and pipe with chain, provided with discs at equal distances. The product, in the spaces in between the discs, is moved along with the help of these discs (figure 9). The chain runs inside a dust tight pipe. The spacing between discs and pipe is very limited. The pipe chain conveyor enables the integration of several in- and outlets. Usually piping and discs (cast, stainless steel or plastic) have round cross sections, but square cross sections do exist. Conveying is possible in horizontal, vertical or sloped directions, up to about 60 m. The capacity is, depending on product and conveyor, up to about 70 $m^3 \cdot h^{-1}$ at a conveying speed up to about 0,4 $m \cdot s^{-1}$.

Figure 9:

Layout of a pipe chain conveyor (schematic)

(Source:
Schrage GmbH Anlagenbau)

Aeromechanical conveyors (figure 10), also named disc-conveyors, are related to pipe chain conveyors. The design is rather similar. However, the spacing between discs and pipe is considerably more. The movement of the discs creates an air flow, causing an underpressure behind the discs. Due to this underpressure product is picked up and fluidised in the air flow.

Discs are in plastic (for example polyurethane), the cable in steel or also in plastic. The capacity is, depending on the design and product, with a speed of about 4 m $\cdot$ s^{-1} up to 50 $m^3 \cdot h^{-1}$.

Figure 10: Use of an aeromechanical conveyor to charge a mobile silo (Source: Gough GmbH Sieb- und Fördertechnik)

Explosive atmospheres

Experience with pipe chain conveyors and aeromechanical conveyors is that, with a full load, there is no explosive atmosphere inside such conveyors: so they have no zone. With a partial load, depending on the product, a zone 22 might be required. Explosive atmospheres may arise at in- and outlets (typical zone 21).

Ignition sources and measures

Ignition sources that may arise in pipe chain conveyors are:

- mechanical sparks, due to introduced foreign objects or metal reinforcement of the discs;
- hot surfaces due to overheated bearings at the drive or return station or hot surfaces due to friction with speeds beyond $1\ m \cdot s^{-1}$;
- electrostatic discharges due to isolated metal pulleys or highly insulating surfaces (internal coating of pipe, plastic discs on metal chains). Charging level decreases with decreasing speed;
- introduced smouldering lumps.

Explosion hazards are, in general, very limited since explosive atmospheres, that may arise at in- and outlets, are typically outside the reach of potential ignition sources.

Measures to prevent effective ignition sources are:

- low speed of moving parts ($v < 1\ m \cdot s^{-1}$), to prevent effective mechanical sparks or hot surfaces;
- low drive power ($W < 4$ kW), to prevent effective mechanical sparks or hot surfaces;
- conductive/dissipative parts that are interconnected and earthed will prevent charging of such conductive/dissipative parts;
- periodical maintenance and cleaning (removal of deposits at in/outlets or return station);
- re-consider use of non-conductive elements when conveying ignition sensitive products with MIE < 10 mJ;
- prevent introduction of foreign objects or smouldering lumps.

If the strength is sufficient, pipe chain conveyors and aeromechanical conveyors may prevent explosion propagation, due to the large number of discs and high product load. However, such conveyors should not be considered as explosion isolation devices which will prevent explosion propagation.

6.2.3 Vibratory feeders

With a vibratory feeder a trough or duct is brought into vibration in such a way that, because of the inertia of the product, this product is transported. The trough can be round or rectangular in shape, the top can be open or closed. Vibratory feeders are used especially for products that are sticky or sensitive to break-up.

A distinction can be made between vibratory feeders operating with a large amplitude but low frequency, and feeders with small amplitudes but large frequencies.

Vibratory feeders are typically applied as dosing units or as pre-classifiers. Figure 11 presents a vibratory feeder with a tubular trough.

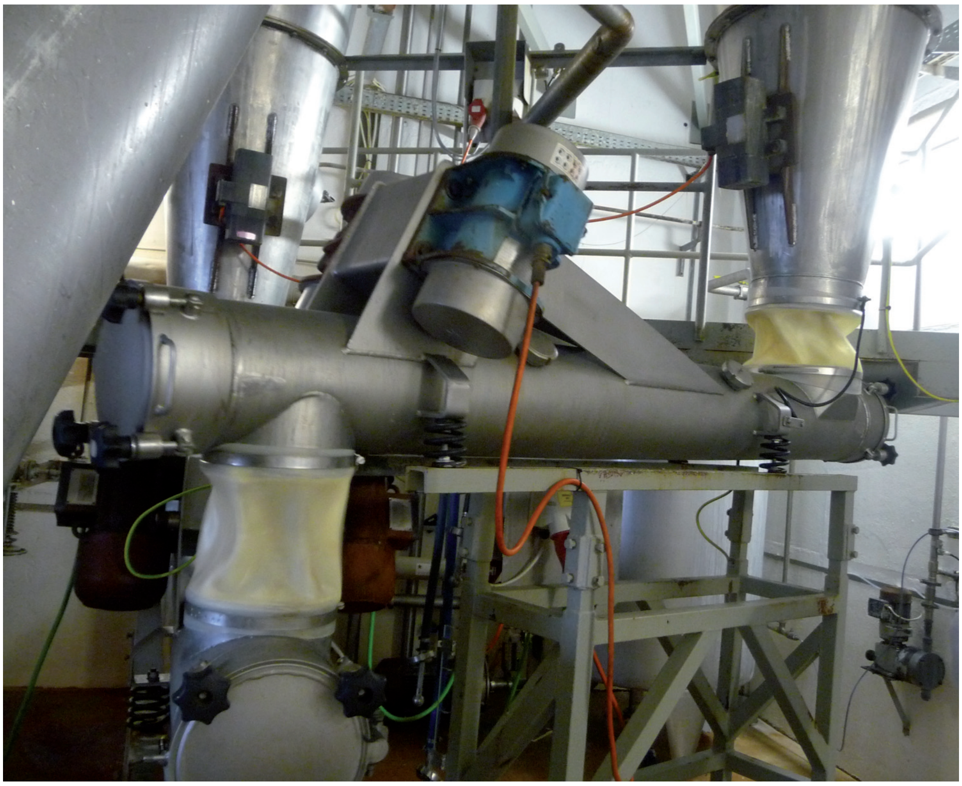


Figure 11:

Vibratory feeder (Source: Molda AG)

Explosive atmospheres

In general explosive atmospheres are not to be expected inside vibratory feeders. However, at in- and outlets explosive atmospheres may arise: zone 21 (occasional presence of explosive atmospheres).

Ignition sources and measures

Apart from introduced ignition sources, only electrostatic discharges should be considered as effective ignition sources.

Hazardous electrostatic discharges can be prevented if all parts are made out of conductive or dissipative materials and earthed.

6.2.4 Screw conveyors

A screw conveyor consists of a screw flight moving inside a housing (figure 12). Typically the drive is connected to the screw, however, the housing can also be driven.

The diameter of the screw ranges from a few millimeters to several meters. Screw conveyors can be executed as duct- or trough screws. Screw conveyors can be applied for horizontal, sloped or vertical conveying. Vertical screw conveyors especially have high circumferential speeds, horizontal screw conveyors usually run at low speeds.

Apart from screw conveyors with fixed screws, there are also flexible screw conveyors with flexible screws or spirals. Initially such flexible screw conveyors were applied for granular products, but now also for powders.

Typical applications are dosing and conveying of products into inerted vessels, in order to limit the entrance of air.

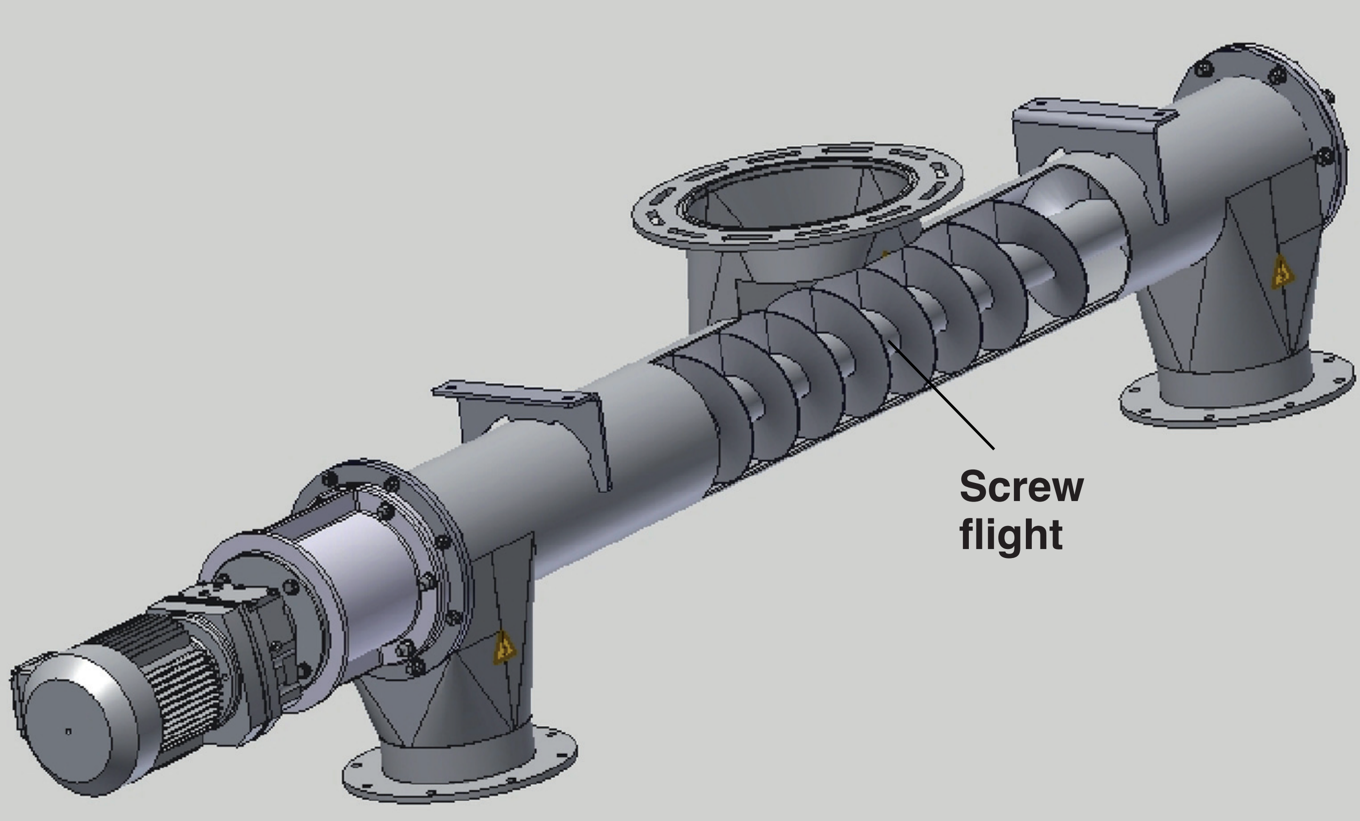


Figure 12: Schematic view of a reversible screw conveyor
(Source: AZO® GmbH + Co. KG)

Explosive atmospheres

Explosive atmospheres inside screw conveyors cannot be excluded, especially not if these run at high speeds (tip speed) ($v > 1\ m \cdot s^{-1}$).

At inlets and outlets explosive atmospheres have to be taken into account. If it is assumed that these arise occasionally, these areas should be considered as a zone 21. For the remaining part of low speed screw conveyors it is to be expected that explosive atmospheres are unlikely to arise and, if they do, will last for a short time only: zone 22. For high speed screw conveyors, explosive atmospheres are more likely to arise (zone 20 or 21).

Ignition sources and measures

The main ignition sources are:

- hot surfaces due to friction, especially with intermediate bearings;
- increased temperature due to product jams;
- electrostatic charging.

Effective ignition sources become more likely with increasing circumferential speeds.

Measures to prevent effective ignition sources are:

- operation at reduced speed. Experience is that with circumferential speeds $v < 1\ m \cdot s^{-1}$ no hazardous friction is to be expected;
- temperature control (e. g. EN 13463 part 6) on intermediate bearings or avoiding the use of intermediate bearings;
- prevent the introduction of foreign objects;
- prevention of hazardous product obstruction, for example by limiting drive power, providing a discharge flap or use of a screw with increasing pitch;
- prevention of hazardous electrostatic charging, typically by using only conductive and earthed parts;
- continuous welding of the screw onto the shaft (no spot welding).

With high speed screw conveyors, for example for vertical conveying, in general the presence of effective ignition sources needs to be assumed. This can be avoided if adequate material combinations are used to prevent hot surfaces. Typical examples are the application of thermoplastic or other non-metallic liners. Non-conductive liners, however, might provoke electrostatic discharges.

Only propagating brush discharges will be able to ignite dust-air mixtures. In general such discharges can be prevented if the thickness of the liner is more than 10 mm.

If explosive atmospheres and effective ignition sources cannot be prevented with sufficient certainty, explosion protective measures are required.

Duct screw conveyors, depending on the design and resistance, might be used as explosion isolation. Trough screw conveyors are, in general, not able to stop explosion propagation.

6.2.5 Elevators

Elevators are used for upward conveying of bulk products (figure 13).

In practice the most used types are:

- bucket elevators
- Z-type bucket elevators (bucket conveyor, pendulum bucket conveyor)
- corrugated sidewall conveyors.

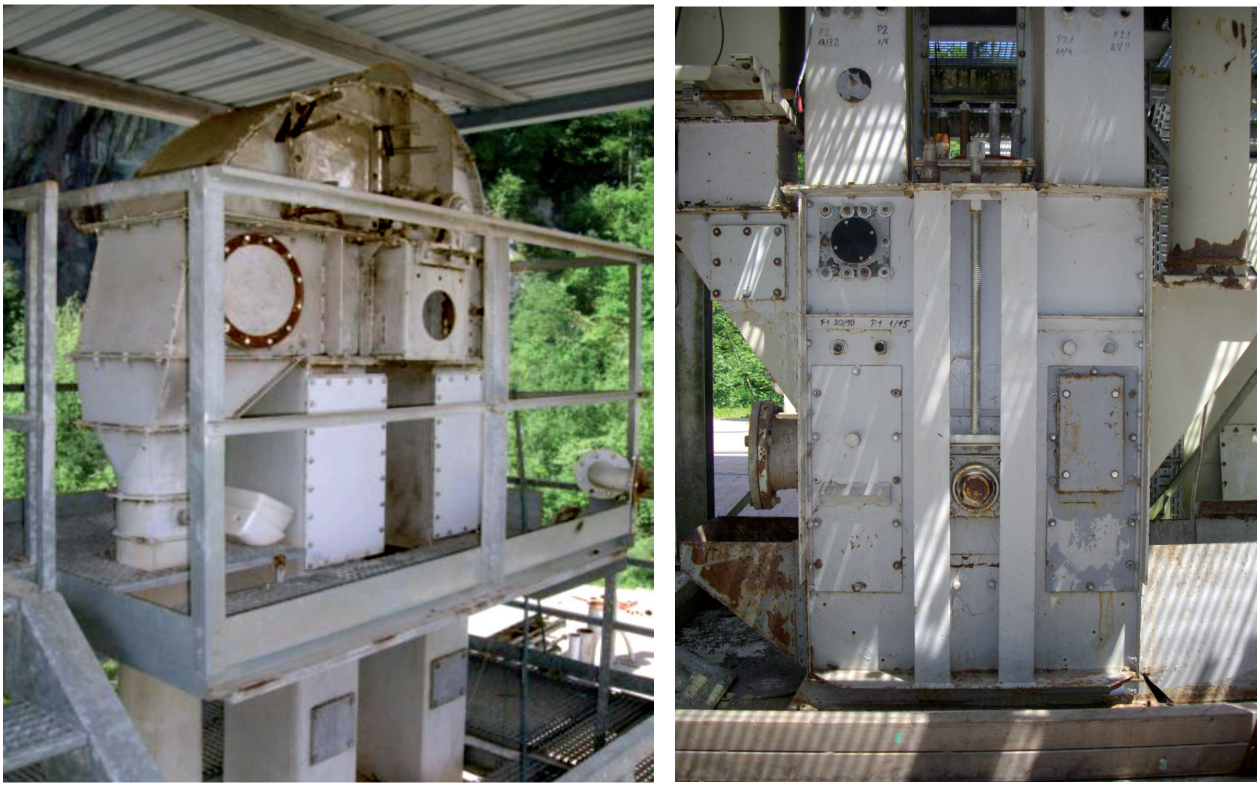


Figure 13: Head (left) and boot of a 15 m high grain bucket elevator (capacity up to 150 t · h^{-1})

(Source: Berufsgenossenschaft Nahrungsmittel und Gastgewerbe (BGN))

Bucket elevators

Bucket elevators are intended for vertical (upwards) conveying of bulk products in buckets. The buckets are connected to a chain or a belt, which runs around either in one vertical leg (single leg bucket elevator) or in two legs (twin leg bucket elevator). The drive is at the head of the bucket elevator via a drum (belt elevator) or a sprocket wheel (chain elevator). The force is therefore transferred via friction (drum) or via a rigid connection (sprocket wheel). Belt elevators are mainly used for lightweight and easy flowing products, whereas chain elevators are mainly used for heavy duty applications. Belt elevators typically run at higher speeds than chain elevators.

Charging of the product occurs in the boot by pouring product into the buckets or scooping product with the buckets. Discharging of the product is at the head and, depending on the speed, by gravity or by centrifugal forces.

Z-type bucket elevators

With Z-type bucket elevators bulk products are conveyed Z-wise: i. e. horizontally, then vertically (or up a slope) and horizontally again. Charging of product is at one (or several) location in the first horizontal part into a bucket belt (buckets that are linked to one another with hinged connections) or into pendulum buckets or pivoting cups (individual buckets on a common belt). Pendulum buckets enable discharging of product into several outlets at the last horizontal part: by tipping the individual buckets at the required outlet.

Corrugated sidewall conveyors

These elevators do not have individual buckets: on the belts individual pockets are created, with corrugated sides (for flexibility). Movement here is also Z-wise: horizontal, vertical (or up a slope) and horizontal again. Charging is into the first horizontal part into the pockets. Discharging is at the end of the last horizontal part (by tipping of the pockets).

Explosive atmospheres

The probability of creating explosive atmospheres inside bucket elevators mainly depends on the properties of the conveyed product. Decisive are the fineness of the product itself or the amount of fines included in the product and the capability to create dust/air mixtures (dustiness of the product).

Especially where the product is charged or discharged, it has to be taken into account that the dust concentration of a flammable dust may exceed the lower explosion limit. Also, accumulation of very fine dust is to be expected in the boot. This very fine dust may be much easier to ignite and cause a much more violent explosion than the "average" dust fraction of the conveyed product.

Depending on the dust content and dustiness of the product, the lower explosion limit may also be exceeded in the rest of the bucket elevator, for example due to disturbed dust deposits. The risk analysis should also take into account running of empty bucket elevator, start/stop situations, malfunctions (e. g. impact of buckets against the casing) and inspections. Especially when the elevator is running empty, explosive dust/air-mixtures may be created due to disturbed dust deposits or dust falling from buckets at return points.

With coarse products, with a low dust content, for example cleaned grain, a zone 21 is recommended. With fine products or products with a large dust content, for example non-cleaned grain, a zone 20 should be assumed.

Ignition sources and measures

The main ignition sources are:

- hot surfaces due to friction involving the belt, buckets or belt drum against the casing;
- slipping of the belt;
- bearings running hot;
- friction and impact due to introduced foreign objects;
- friction and impact due to impact of buckets;
- electrostatic discharges due to insufficient earthing of conductive parts;
- break-up of smouldering lumps at scooping or discharge of product.

Possible measures include prevention of ignition sources or protective measures. Inerting is rarely applied.

Measures to prevent effective ignition sources are:

- installation of rotation control, to control the speed of the lower (undriven) drum (figure 14);
- installation of misalignment detection;
- application of dissipative belts (see IEC 60079-32-1, EN 12882 and chapter 6.2.1, page 17 of this brochure). A belt is dissipative when the surface resistance of both sides of the belt is below $3 \cdot 10^8\ \Omega$. If the belt is constructed from layers of different materials, it can only be considered as dissipative if the volume resistance also does not exceed $10^9\ \Omega$;
- external bearings;
- temperature control of bearings;
- use of plastic buckets;
- in order to prevent propagating brush discharges: do not apply non-conductive coatings or only if the break-down voltage is below 4 kV;
- distance between moving and stationary objects should, according to experience, be beyond 25 mm;
- limitation of speed (if possible).

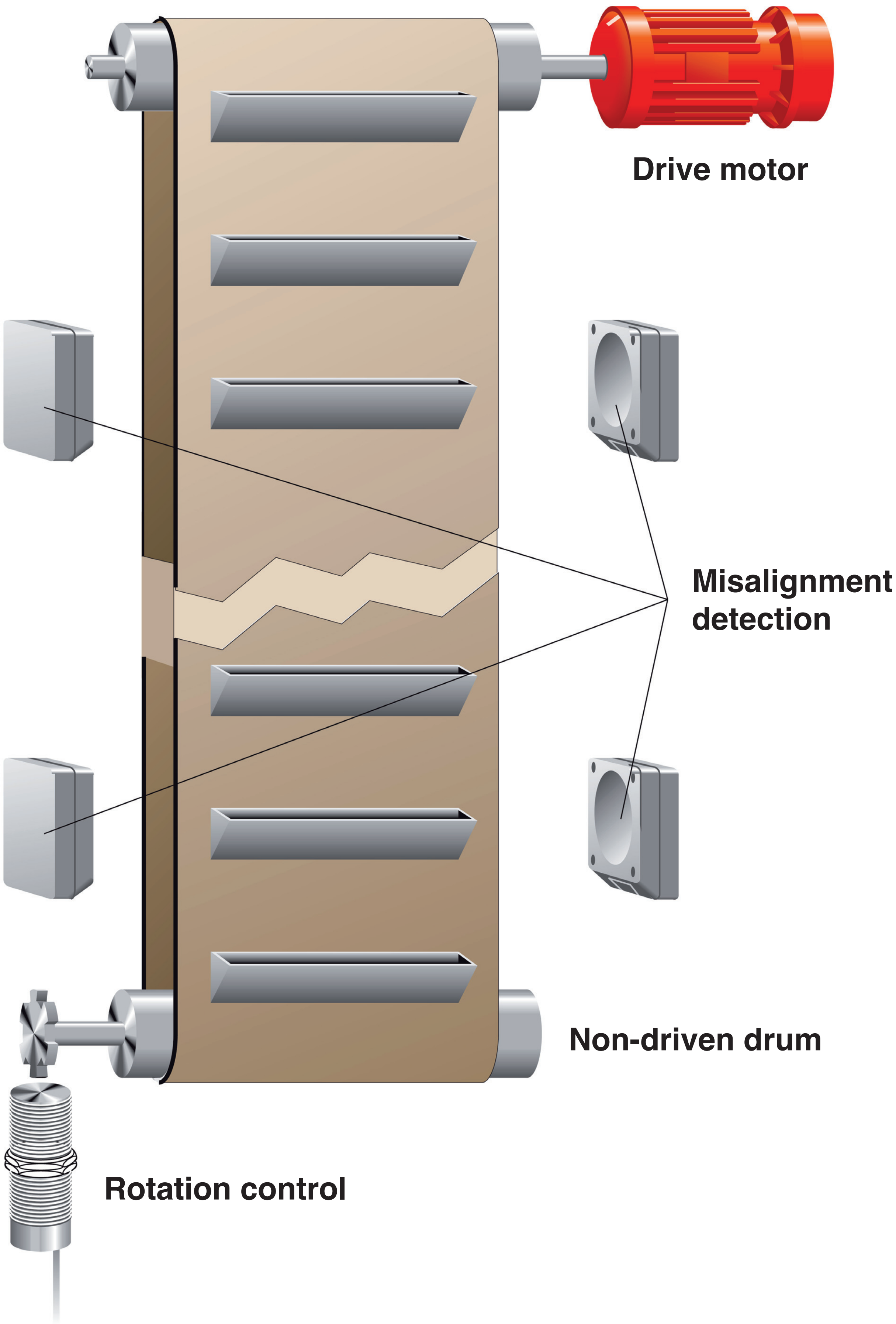


Figure 14:
Schematic view of an elevator with rotation and misalignment control

Determining if measures to prevent ignition sources are sufficient for an elevator depends on various conditions.

The most important are:

- explosion safety characteristics of the conveyed product (minimum ignition temperature (MIE), dustiness, see also ISSA brochure "Determination of the Combustion and Explosion Characteristics of Dusts", ISBN 92-843-7092-2, 1998, Mannheim);
- design and operational conditions of the bucket elevator (speed, material combinations, removal of foreign bodies);
- location (for example outside a building or inside special protected rooms) such that people are never endangered;
- position in the process (for example as reception elevator or positioned behind a dryer, cleaner, sifter).

The following protective measures can be applied:

- explosion resistant design for the maximum explosion pressure;
- explosion resistant design in combination with explosion venting;
- explosion resistant design in combination with explosion suppression.

Since explosive dust/air-mixtures may arise inside elevators, elevators may also enable propagation of fires or explosions. Measures to prevent explosion propagation (application of rotary valves, chemical barriers or product buffers) therefore always need to be considered.

For the design of explosion venting as a protective measure for bucket elevators, figure 15 provides information. As a function of the resistance of the bucket elevator and the K_{St}-value of the dust involved it is indicated where such vents are required (head, boot, both legs) and at which inner distances on the legs.

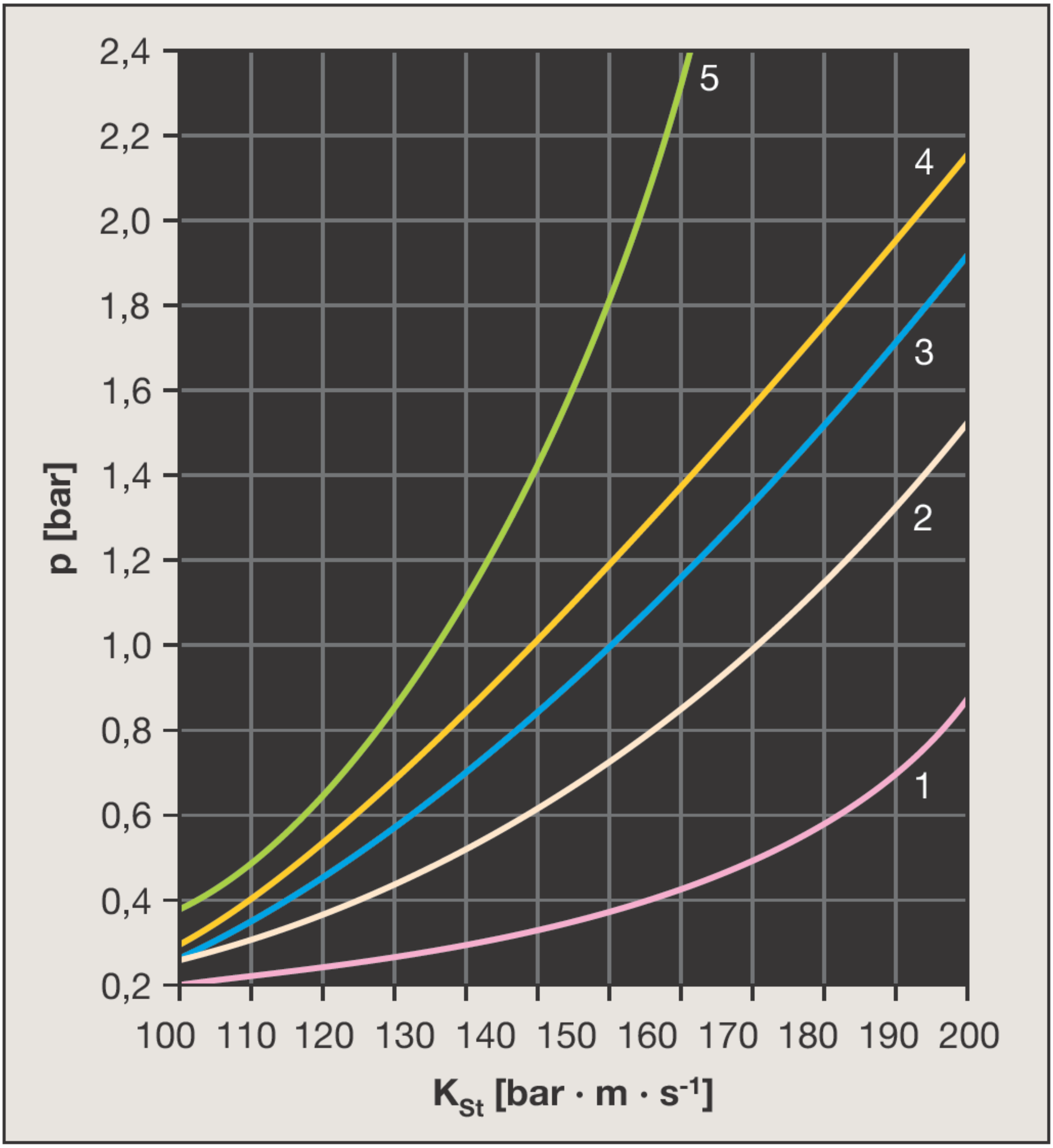


Figure 15: Required resistance of bucket elevators for various K_{St}-values and locations of vents. (1) Head and boot and legs at 3 m distances. (2) Head and boot and legs at 6 m distances. (3) Head and legs at 3 m distances. (4) Head and legs at 6 m distances. (5) Head and legs at 12 m distances or head only if the length of the legs does not exceed 12 m. (Radandt, Roser, Vogl, FSA-Research Report, "Constructional Explosion Protection for Elevators", F05-0701).

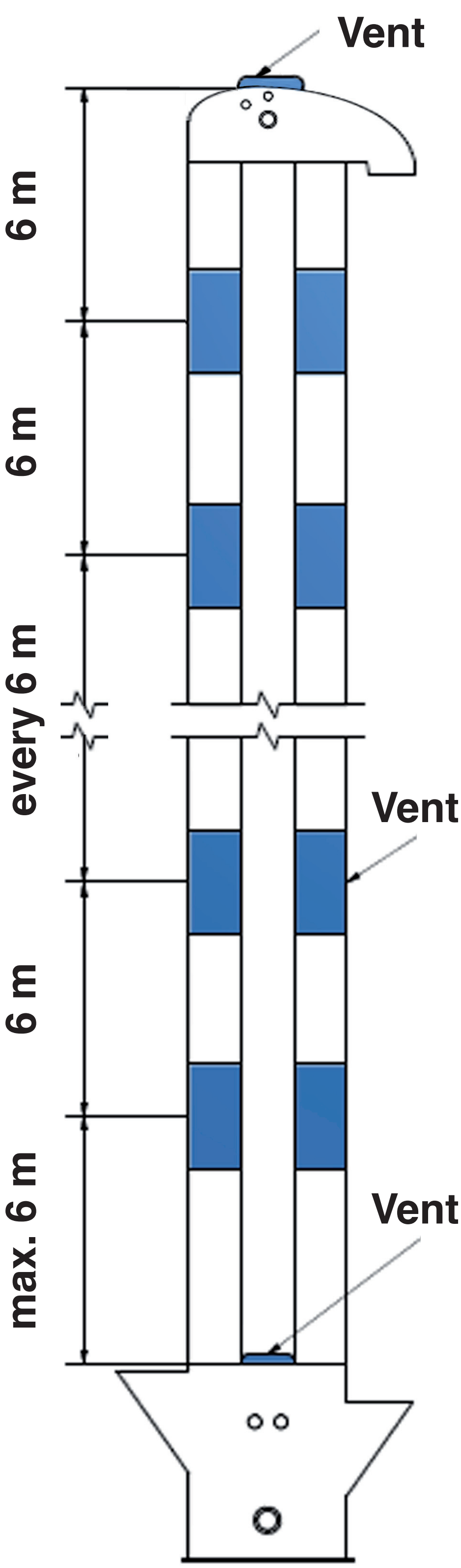
Figure 15 may be used under following conditions:

- ignition inside the elevator (no explosion propagation from interconnected equipment);
- organic dusts;
- maximum explosion pressure of dusts $p_{max} \leq 10$ bar;
- rectangular section of legs;
- free space around buckets < 60 % of leg section;
- bucket distances ≤ 280 mm with $K_{St} \leq 150$ bar · m · s^{-1};
- bucket distances ≤ 140 mm with $K_{St} \leq 210$ bar · m · s^{-1};
- metal buckets;
- vent area of each vent ≥ leg section;
- vent opening pressure $p_{stat} \leq 0.1$ bar;
- venting into open air (no vent ducts);
- efficiency of applied vents: EF = 1;
- no vents located in between elevator legs;
- location of vent on boot in between legs (directing upwards) or, as an alternative, on the side of the boot. If there is insufficient space, the boot vent can also be installed on both the upward and downward leg, just above the boot (maximum distance in between elevator boot and lower edge of vent 0.3 m).

Figure 16 gives an example of a vented bucket elevator designed according to figure 15.

Figure 16:

Schematic view of the locations of the vents on a bucket elevator with a resistance of 0.7 bar, for products with a K_{St}-value of 150 bar · m · s^{-1}



If plastic buckets, instead of metal buckets, are applied, the required resistance should be increased, depending on the K_{St}-value of the conveyed product. This increase is:

20 % for dusts with a K_{St}-value below 100 bar · m · s^{-1};

35 % for dusts with a K_{St}-value in between 100 bar · m · s^{-1} and 150 bar · m · s^{-1};

50 % for dusts with a K_{St}-value in between 150 bar · m · s^{-1} and 200 bar · m · s^{-1}.

If, as an alternative to explosion venting, explosion suppression, in combination with explosion isolation, is applied indicative values are to be found in table 1 for the locations of the chemical barriers on the legs and the required resistance of the bucket elevator. The values are presented as a function of the detection method (pressure or flame). For pressure detection a distinction is also made depending on the range of the activation pressure of the pressure detector.

The recoil forces that arise during the activation of the chemical barriers require an adequate mounting of those barriers and sufficient resistance of the elevator casing. Beyond the location of the chemical barriers, the required resistance of the elevator legs can be reduced from (p_{a1}) to (p_{a2}), see table 1 and figure 17.

Supplier specific deviations from these indicative values are possible, based upon relevant evidence or experience.

Table 1: Indicative values for the required resistance of bucket elevators provided with explosion suppression and the installation distances of chemical barriers (Source: FSA e. V.)

Detection	**Installation distance** [m]	**Minimum required resistance (overpressure)** p_{a1} [bar]	**Minimum required resistance (overpressure)** p_{a2} [bar]	**K_{st}-value** $[bar \cdot m \cdot s^{-1}]$
Pressure detection: Activation pressure (overpressure where the suppression system is activated)				
$80 < p_{act} \leq 110$ mbar	8	1,5	1,2	≤ 150
$30 < p_{act} \leq 80$ mbar	6	1,0	0,7	≤ 150
$p_{act} \leq 30$ mbar	5	0,7	0,4	≤ 150
$80 < p_{act} \leq 110$ mbar	8	0,3	0,2	≤ 100
Flame detection	1,5	0,3	0,2	≤ 150
Flame detection	8	≥ 0,1	≥ 0,1	≤ 100
Flame detection	5	≥ 1,0	≥ 0,5	> 150 ≤ 200

The values can be used under following conditions:

- bucket elevators with rectangular leg sections;
- metal buckets;
- distance between buckets and casing ≤ 70 mm in any direction;
- bucket distances ≤ 280 mm.

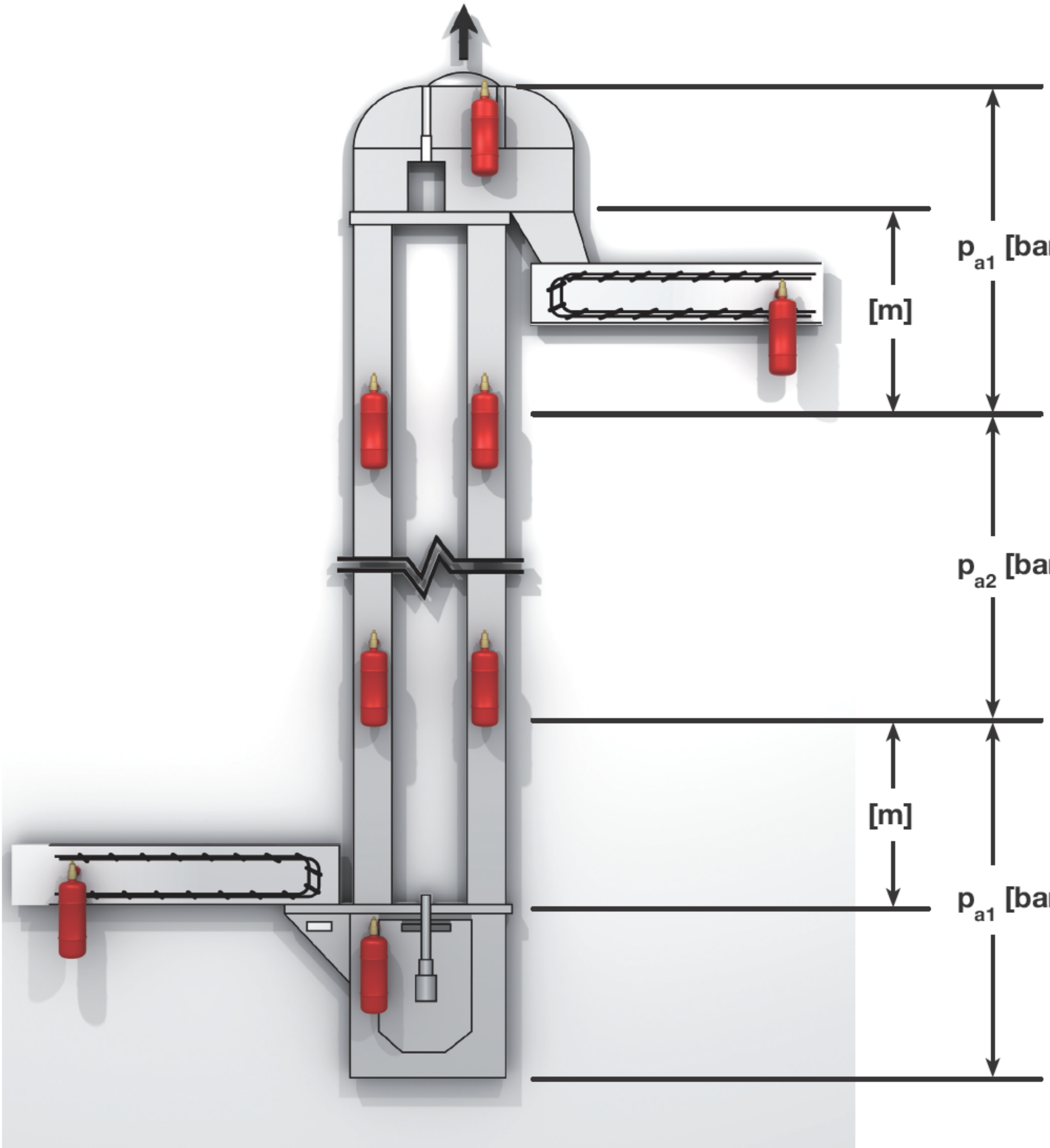


Figure 17: Indicative values for the required resistance of bucket elevators provided with explosion suppression and the installation distances of chemical barriers (table 1)

For optimum reliability of the protective system, a combination of pressure and flame detection is recommended.

7 Transfers and Receivers

An installation often consists of various pieces of equipment, interconnected by conveyors. Therefore, for the risk analysis of conveyors the equipment up- and downstream also needs to be taken into account. Transfers (drop-off and drop-on) facilitate the formation of explosive atmospheres. Ignition sources can be transferred and new ignition sources may arise.

Transfer and receiving equipment may include:

- bag emptying units (FIBC or manual emptied bags);
- filling of hoppers/bins;
- separators at the end of pneumatic conveying (see ”Collection of Examples, Dust Explosion Prevention and Protection for Machines and Equipment, Part 1: Mills, crushers, mixers, seperators, screeners”, ISSA-Prevention Series No. 2057 (E), chapter 4, page 33);
- buffer hoppers/bins on packaging lines;
- buffer hoppers/bins for mixers and mills;
- buffer hoppers/bins for reactors;
- intermediate hoppers/bins between 2 pneumatic conveying lines;
- buffer hoppers/bins for dosing units;
- buffer hoppers/bins between 2 conveying elements.

Examples are given in figures 18 to 22.

Figure 18:
FIBC filling
(Source: AZO® GmbH + Co. KG)

Figure 19:
FIBC emptying
(Source: AZO® GmbH + Co. KG)

Figure 20:

Manual bag emptying unit with dust extraction

(Source: AZO® GmbH + Co. KG)

Figure 21:

Separator at the end of a pneumatic conveying line. From here product is conveyed with a screw conveyor into a stirred vessel.

(Source: AZO® GmbH + Co. KG)

Figure 22: Compensator (arrow) in between magnet separator and sifter
(Source: AZO® GmbH + Co. KG)

Explosive atmospheres

At drop-off or drop-over of fine products and coarse products with large contents of fines (such as uncleaned grain) an explosive atmosphere may arise occasionally (zone 21). In the separator at the end of a pneumatic conveying line, especially for small separators, a zone 20 might be required.

If products are discharged into vessels, containing combustible gases or vapours, hybrid mixtures may arise. These require an adapted risk assessment.

If products are discharged into inerted vessels, it needs to be taken into account that air is entrained in the product flow. This should be considered in the design of the inerting system.

Ignition sources and measures

Remark: in the following analysis of ignition sources it is assumed that neither the conveyed product, not the receiver contains any flammable gas/vapour.

The main ignition sources are:

- introduced ignition sources (for example smouldering lumps);
- electrical equipment (for example level probes);
- electrostatic discharges from the transfer unit or receiver or from the product itself.

Measures to prevent effective ignition sources are:

- measures in the upstream process parts (see ”Collection of Examples, Dust Explosion Prevention and Protection for Machines and Equipment Part 1: Mills, crushers, mixers, seperators, screeners”, ISSA-Prevention Series No. 2057 (E) and chapter 6.1 and 6.2 of this brochure);
- measures at transfers to prevent the introduction of ignition sources (for example spark detectors at product discharge, temperature detection with emergency stop);
- use of electrical equipment that is certified for the application;
- measures to prevent hazardous electrostatic discharges:
  - in order to prevent hazardous electrostatic charging, compensators and flexible connections should be made from conductive or dissipative materials with permanent and reliable earthing connections ($R_E < 10^6\ \Omega$); for short compensators used for gravity transfer of products between two pieces of equipment (short drop, $L/D \leq 2/1$, see figure 22) it is possible to use non-conductive material;
  - in order to prevent propagating brush discharges: do not apply non-conductive coatings, or only use them if the break-down voltage is below 4 kV.

If receivers are conductive and earthed and have no internal non-conductive coatings, hazardous electrostatic discharges from the receivers can be ruled out.

If bulk products are charged to a very high level, cone discharges may arise in the receiver (see “Static Electricity, Ignition hazards and protection measures” ISSA, Heidelberg, 1996, ISBN 92-843-1099-7). Whether these cone discharges are effective ignition sources depends on many factors (diameter of receiver, product particle size distribution and MIE). If the specific resistance of the bulk material is above $10^{10}\ \Omega \cdot m$, cone discharges (arising from the product itself) cannot be excluded, even in case of a conductive, earthed receiver without non-conductive coatings. Below $10^{10}\ \Omega \cdot m$, in a conductive, earthed receiver without non-conductive coatings, no hazardous discharges, arising from the product itself, need to be taken into account.

If prevention of effective ignition sources is insufficient to prevent explosions (for example products with a very low MIE) then protective measures, such as explosion isolation of conveying and aspiration lines, are required to prevent explosion propagation towards other parts of the process. It needs to be taken into account that the surrounding room might suffer from the explosion effects.

Pneumatic conveying into mobile silos (silotainers)

During pneumatic conveying of bulk products into mobile silos (tanker trucks, rail cars or sea containers) these vessels are receivers. As an example the loading of a tanker truck is considered.

The charging unit consists of a hose, which is connected to the tanker truck with the help of a coupling. Air is released from the truck via, for example, a hose towards a separator.

Explosive atmospheres may arise in the free volume of the tanker truck, above the product and, depending on the product, may last over longer periods.

Ignition sources that may arise with this type of tanker truck loading are:

- electrostatic discharges due to insufficient earthing of conductive parts (especially inside the tanker truck);
- electrostatic discharges due to highly insulating surfaces (both inside the tanker truck and inside the hose);
- smouldering lumps that were already present inside the tanker truck (from previous loads), are created inside the tanker truck due to hot surfaces, or are introduced with the product into the tanker truck.

Measures to prevent effective ignition sources are:

- connect the tanker truck (via an earthing control system) to the same potential as the conveying unit;
- prevent product deposits at dispersing devices (cloths, sieves, slotted plates or similar) inside the tanker truck by inspections as well as removal of dust deposits below such dispersing devices;
- prevent deposits due to condensation by the correct choice of temperature (compressor/pressurised air cooler) and application of a condensate dryer, where necessary;
- prevent hot surfaces by the correct choice of temperature (compressor/pressurised air cooler) and sufficient time intervals between two truck loadings, where necessary;
- prevention of effective propagating brush discharges. No insulating layers (for example liners, coatings) with a break-down voltage above 4 kV are allowed inside piping or receivers. The combination of products that can be charged to a very high level and have a low melting point might be dangerous: sintering or melting might result into a dense insulating layer with a break-down voltage above 4 kV;
- choice of adequate hoses.

References

EN 1127-1

Explosive atmospheres - Explosion prevention and protection - Part 1: Basic concepts and methodology

EN 13463-6

Non-electrical equipment for use in potentially explosive atmospheres - Part 6: Protection by control of ignition source ‚b'

IEC/TS 60079-32-1

Explosive atmospheres - Part 32-1: Electrostatic hazards, guidance

EN 12882

Conveyor belts for general purpose use - Electrical and flammability safety requirements

GESTIS-DUST-EX

Database Combustion and explosion characteristics of dusts

http://www.dguv.de/ifa/Gefahrstoffdatenbanken/GESTIS-STAUB-EX/index-2.jsp

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Dust Explosion Prevention and Protection for Machines and Equipment

- Basic Principles (Engl./Ger.) (2004/1998)
- Collection of Examples

  Part 1: Mills, crushers, mixers, separators, screeners
  (Engl./Ger.) (2013/2012)

  Part 2: Conveyors, transfers and receivers
  (Engl./Ger.) (2016/2014)

Explosion Suppression (Engl./Ger./Fr.) (1990)

Determination of the Combustion and Explosion Characteristics of Dusts (Engl./Ger.)(1998/1995)

Practical Assistance for the Preparation of an Explosion Protection Document (Engl./Ger./It.) (2006)

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Safety of Liquified Gas Installations (Propane and Butane)
(Engl./Ger./Fr./It./Span.) (1992)

Static Electricity - Ignition hazards and protection measures
(Engl./Ger./Fr./It.) (1996/1995/2002/1997)

Gas Explosions-Protection against explosions due to mixtures of flammable gases, vapors, or mists with air (Engl./Ger./It.) (2000/1999/2000)

Dust Explosions-Protection against explosions due to flammable dusts
(Engl./Ger./It.) (2003/2002/2003)

Dust Explosion Incidents: Their Causes, Effects and Prevention
(Engl./Ger.) (2005)

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