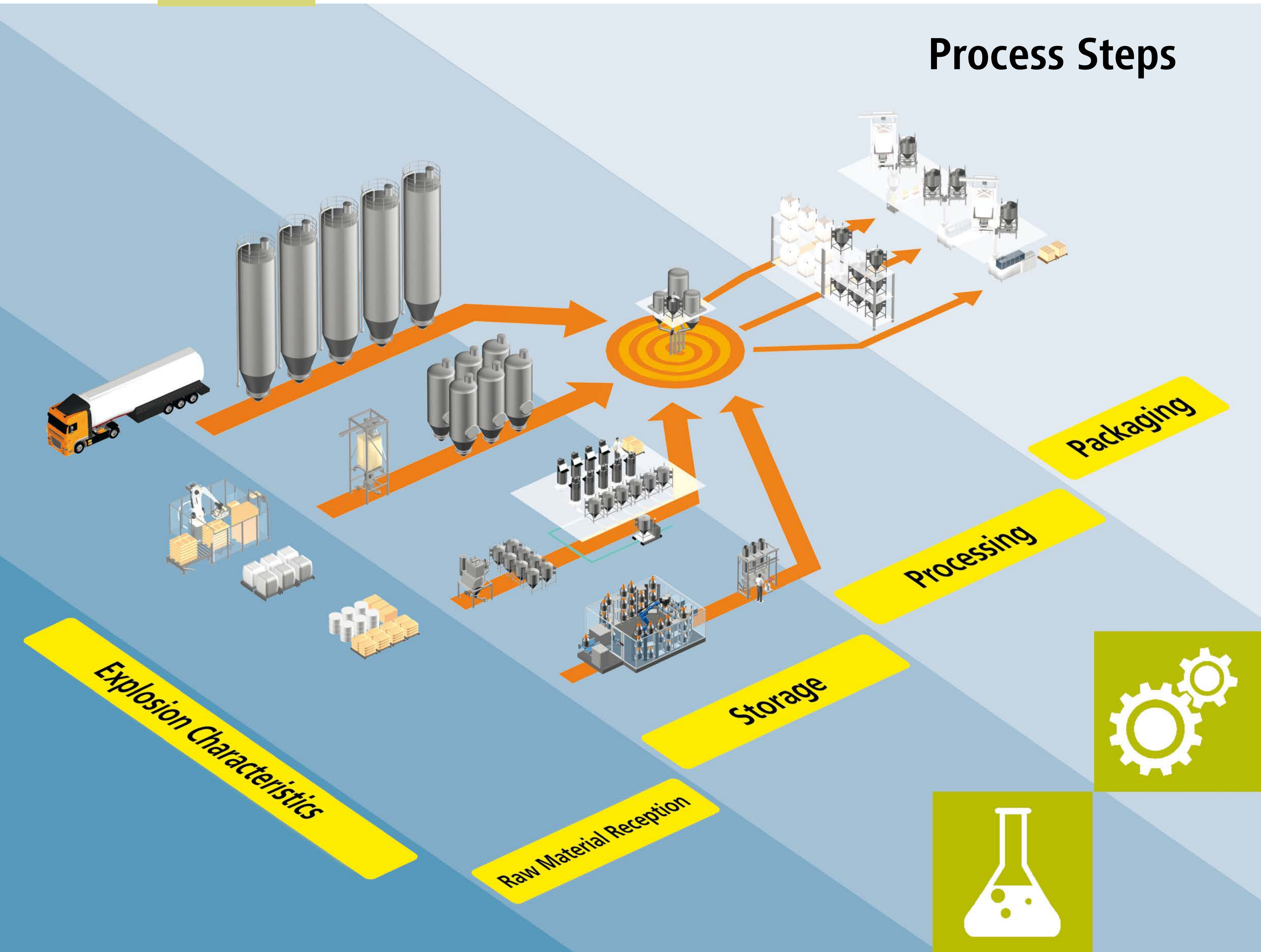
issa INTERNATIONAL SOCIAL SECURITY ASSOCIATION
Section on Prevention in the Chemical Industry
Section on Machine and System Safety

Explosion Safety of Bulk Material Plants

Module: Raw Material Reception

4/2025



Published by

ISSA Section on
Machine and System Safety

Dynamostraße 7–11
68165 Mannheim
Germany
Phone: +49 (0)621 4456-2213
www.safe-machines-at-work.org
E-mail: info@ivss.org

ISSA Section on Prevention
in the Chemical Industry

Kurfürsten-Anlage 62
69115 Heidelberg
Germany
Phone: +49 (0)6221 5108-11002
ww1.issa.int/de/prevention-chemistry
E-mail: issa.chemistry@bgrci.de

Edition 04/2025
ISBN 978-92-843-4137-5

Download of the brochures:
https://safe-machines-at-work.org/explosion-protection
https://ww1.issa.int/de/prevention-chemistry/publications

Explosion Safety of Bulk Material Plants

Module: Raw Material Reception

Legal regulations refer to both the employer and the entrepreneur. The two terms are not completely identical because entrepreneurs do not necessarily have employees. In the context of the present topic, this does not result in any relevant differences, so that these terms are used synonymously.

To facilitate readability, the forms chosen for personal designations (e.g. employer, entrepreneur) apply to both genders in this brochure.

Content

Foreword

The use of complex systems/equipment requires a suitable risk assessment for each individual explosion risk.

For these ISSA-brochures “Explosion Safety of Bulk Material Plant” a modular structure has been developed which makes it easier to divide the explosion risk assessment for a plant into smaller units, so-called “modules”. In addition to a clear layout, this enables a targeted and process-oriented approach. This allows individual assessments of machines from the ISSA example collections “Dust Explosion Protection for Machines and Equipment” Part 1 and Part 2 and of processes/modules from this series of ISSA brochures to be used and linked together at the end for the overall plant risk assessment.

Individual process steps or machines can be better evaluated. In the end, only the individual interfaces need to be considered to obtain the overall concept of the risk assessment.

Thomas Köhler
President of the Section on
Prevention in the Chemical Industry

Jürgen Schulin
President of the Section on
Machine and System Safety

1 Introduction

In the raw material reception process step, combustible, dust-explosive products are received either packed or in bulk.

It is assumed that the raw material does not contain any flammable solvents and that there are no flammable gases and vapors to be considered in this area.

The module consists of:
- Raw material reception
- Storage of packed products
- Emptying of containers
- Reception of bulk material
- Conveying bulk material towards storage2

2 Process description

2.1 Raw material reception

Product identification and quality control are essential for raw material reception.

Product identification
In the case of product identification, the deliveries are checked based on the relevant documents, e.g.
- is it the right product,
- in the right quantity,
- does the packaging comply with the required specifications (e.g. packed in FIBCs of type B or C).

Quality control
The quality of the products should be checked against the requirements. Depending on the requirements, this kind of check may include, e.g.
- particle size and fines content,
- moisture content,
- foreign objects or impurities (e.g. sand, stones, metal),
- product temperature and presence of smoldering nests, for products prone to spontaneous combustion.

To enable raw material reception, involved operators should be adequately trained and have received the correct information about the shipment, including quality control requirements. It is also important to provide the resources or equipment necessary for quality control. Typical equipment is:
- sampler,
- sieves for particle size analysis,
- dry balance (moisture analyzer),
- infrared camera for thermally sensitive products.

2.2 Storage of packed products

Packed product can be received, e.g., in bags, cardboard boxes, drums, metal containers or FIBCs.

Packed products are usually stored in the original package. If the package remains closed, there is usually no hazardous area (zone) to be defined in the storage room. A precondition is adequate housekeeping and organizational measures to clean-up deposits from damaged packaging immediately.

2.3 Emptying of packages

Packed products are typically fed directly into the process. Different emptying stations can be used for this purpose.

Manual emptying stations
Such emptying stations are typically used for bag emptying into a receiving bin (bag emptying station). Bags are cut open and emptied manually. Empty bags are disposed of in containers/bins.
- Bag emptying stations have a coarse mesh grate to prevent the whole bag from entering the process. However, the grate is not suitable to prevent the entry of smaller objects, such as knives or keys.
- Emptying stations usually have an extraction system with integrated filter or a connection to a central exhaust system.
- Feed stations equipped with hinged lid automatically start an extraction fan when the lid is opened. As soon as the bag has been emptied and the lid closed, the extraction fan is automatically stopped and filter elements are cleaned, e.g. by pulse cleaning.

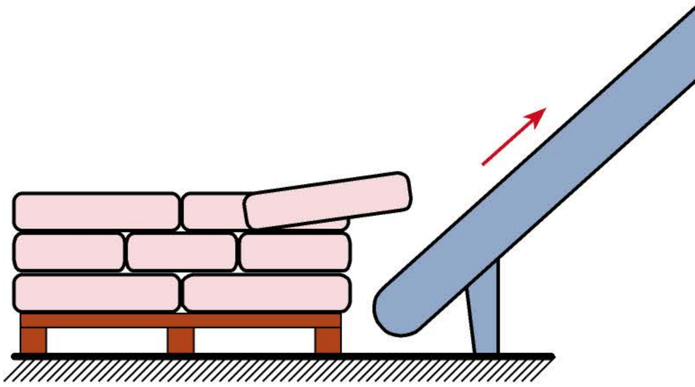
Figure 2:
Bag emptying stations with integrated filters
(Figure: AZO GmbH + Co. KG)

Figure 1:
Bag emptying station with connection to a central exhaust system
(Figure: AZO GmbH + Co. KG)

Product is usually discharged from the receiving hopper via a rotary valve

- into a pneumatic conveying line,
- into a screw conveyor (or a chain or belt conveyor).
- directly into a process vessel (e.g. a mixer).

Such feeding stations are also used for manual tipping of buckets, small containers or boxes.



Automatic bag emptying station

BIn automatic bag emptying systems, the bags are fed manually or with the help of a robot onto a short belt conveyor, which transports them into the actual emptying station.

- The bags cut open by rotating knives and sieved. Most of the product falls through the sieve into the receiving hopper below.
- At the other end of the sieve, the remains of the packaging, together with some product residues, enter a compacting device (bag compactor).
- The compacted bags are disposed in closed containers.

Automatic bag emptying systems are typically equipped with integrated filters. As with manual feed stations, product is usually discharged via a rotary valve, enabling further transport into the process.

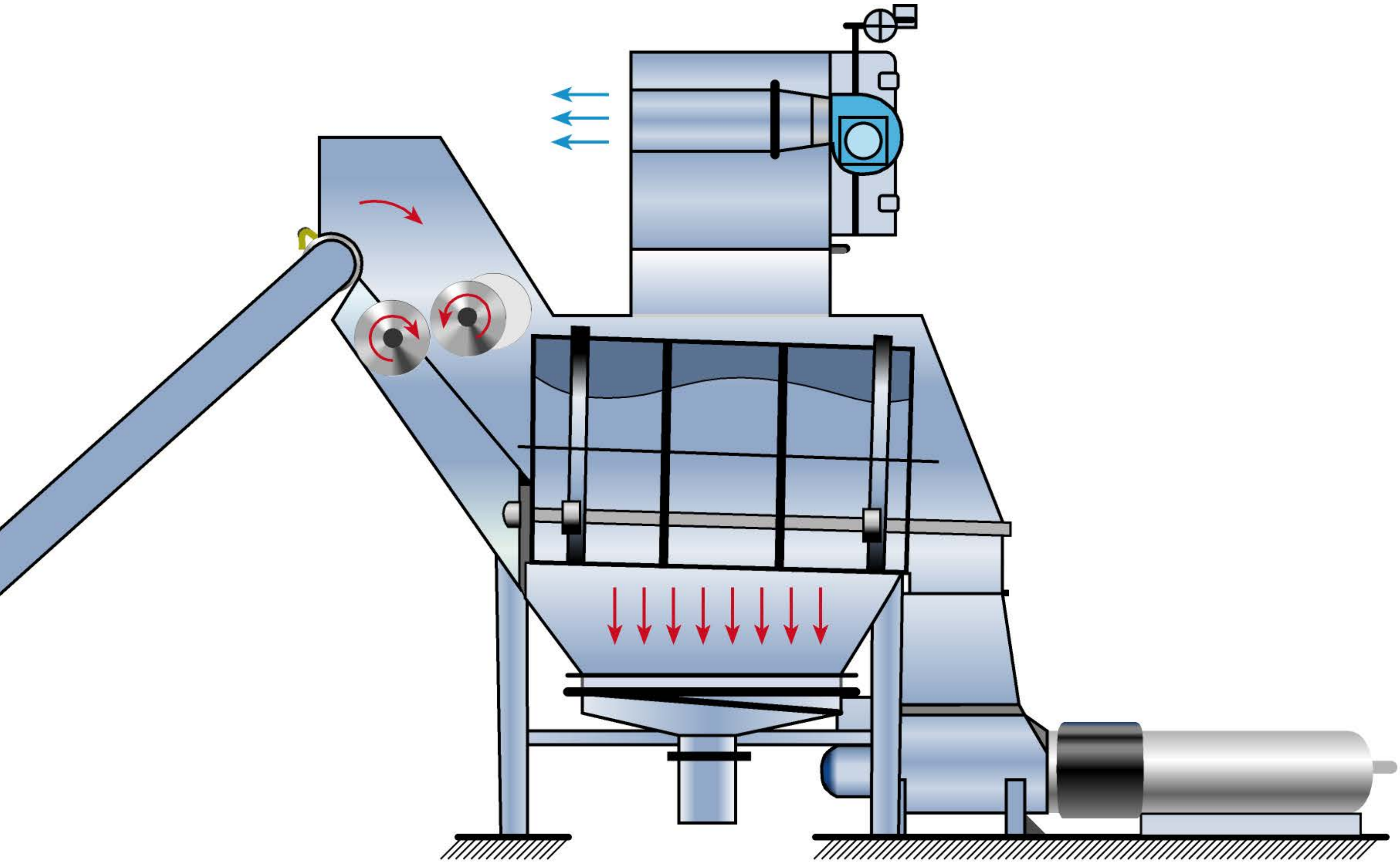


Figure 3:
Automatic bag emptying station (Figure: Telschig GmbH, product range CEMATIC®)

Emptying FIBCs by gravity
The FIBC is suspended above a (large) receiver and the discharge is connected to the receiver in a dust-tight way. The discharge is opened and the contents of the FIBC are discharged into the receiver. The receiver is extracted during the discharge.

Metered emptying of FIBCs
A metering device (e.g. rotary valve, vane valve, intermittent valve, or metering screw) is applied between the FIBC and the receiver. When the FIBC is opened, the product flows in a controlled way into the receiver. Similar equipment is used for emptying drums and containers.

Removal of foreign matter
Depending on the product and the intended use, the emptying of the different receivers may include other devices:

- **Sieves**
  Foreign objects and lumps are removed and either discarded or sent towards a crusher (lump breaker) or a mill to be returned into the process afterwards.
- **Permanent magnets**
  For removing ferromagnetic metal parts.
- **Metal detectors**
  In the product stream, in combination with ejection devices.

Figure 4: Emptying station for FIBCs
(Image: AZO GmbH + Co. KG)

2.4 Bulk material reception

Bulk materials may arrive by truck, road tanker, train or ship.

Road tanker or truck unloading is usually:

- With a blower, which may be integrated in the road tanker. With this blower the tanker is pressurized and the product is conveyed pneumatically into the receiver.
- By gravity discharge into a bulk gutter.
- By tipping or by gravity (typically trucks with sea containers) via a sluice into a pneumatic conveying line (pressure or vacuum).

Unloading of (railroad) wagons (Fig. 5) is done:

- by gravity into a bulk receiver.
- With a suction pipe.

1 Wagon with flat floor
2 Silo wagon with gravity unloading
3 Discharge bucket with opening/closing device
4 Chain conveyor
5 Bucket elevator
6 Bag dumping on the ramp
7 Bag dumping sideways on the ramp

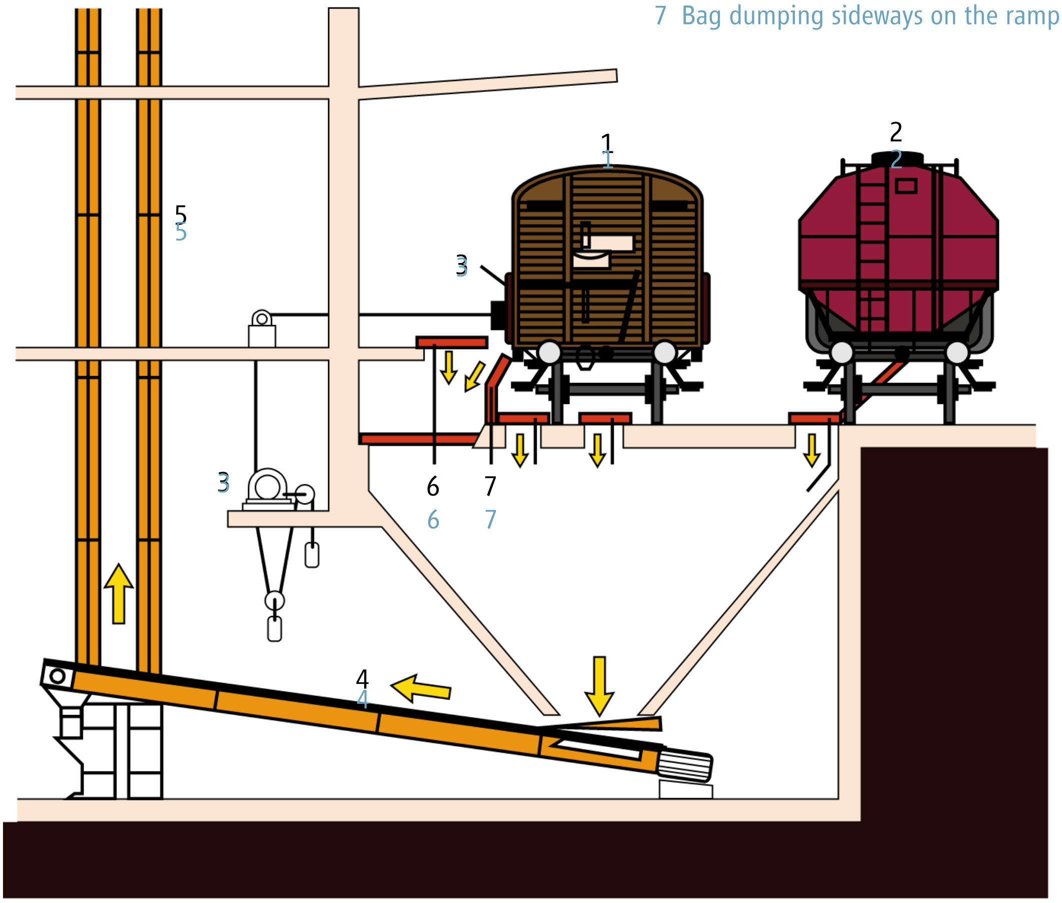
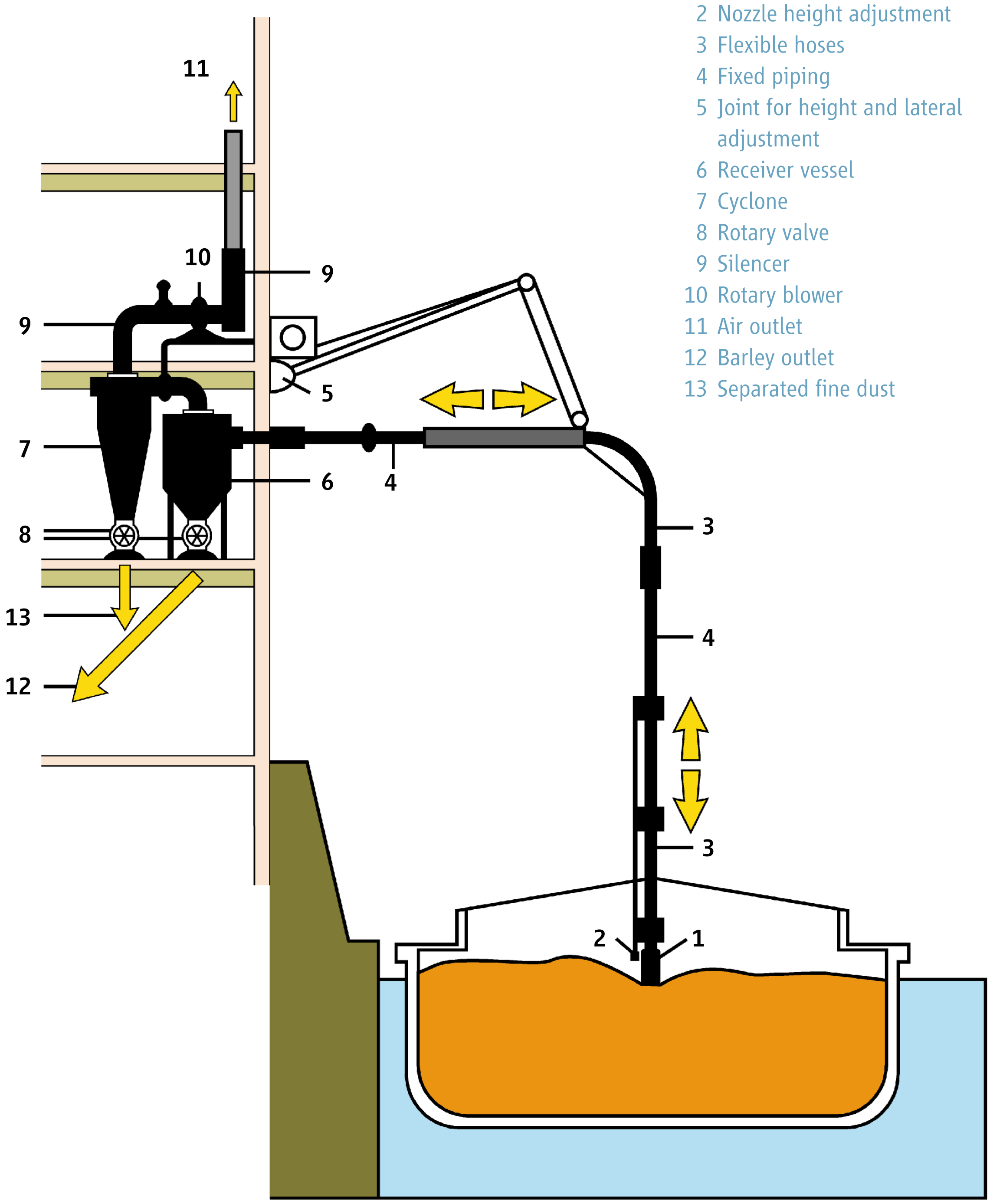


Figure 5:
Schematic view of unloading wagons



1 Suction nozzle
2 Nozzle height adjustment
3 Flexible hoses
4 Fixed piping
5 Joint for height and lateral adjustment
6 Receiver vessel
7 Cyclone
8 Rotary valve
9 Silencer
10 Rotary blower
11 Air outlet
12 Barley outlet
13 Separated fine dust

Figure 6:
Schematic view of ship unloading (barley reception)

3 Safety characteristics

Ship unloading (Fig. 6) is typically done by using
- a suction pipe. Product is transported to receiver vessel by vacuum conveying.
- an unloading crane into an (open top) receiver vessel.

For both types of unloading, wheel loaders/clearing vehicles are usually in the ship to ensure total unloading of the ship at all times.

2.5 Bulk material conveying from receiver to storage

From the bulk gutter or receiver, product is transported towards the bucket elevator by belt, screw, or chain conveyors. The elevator discharges the product onto other belt or chain conveyors, feeding into the silo. For feeding into bulk warehouses, belt or chain conveyors are commonly used instead of bucket elevators. See "Example collection – Dust explosion prevention for machines and equipment – Part 2, Conveyors, transfers and receivers, ISSA example collection no. 2057, ISBN 978-92-843-8185-2"

The product properties (including characteristics) must be known. For a general description of examples of safety characteristics of dusts, please refer to the module "Explosion safety characteristics of dusts".

The following properties (characteristics) are particularly important for the raw material acceptance process step:
- To set requirements for electrical and non-electrical equipment: Minimum ignition temperature of both the dust cloud (MIT) and a 5 mm dust layer ignition temperature and conductivity of the product.
- To check for potential smoldering of the product: LIT, burning behaviour (burning class BZ), but also specific properties regarding self-ignition behavior. In addition, information regarding the possible effects of contamination on auto-ignition is important.
- To assess the sensitivity of the product to electrostatic discharges and mechanical ignition sources: MIT and especially minimum ignition energy (MIE).
- To assess the possibility of charging of the product: conductivity of the product.

4 Risk analysis

4.1 Explosion risks in raw material reception

Dust clouds may be generated during discharge of raw materials. In the presence of an effective ignition source, there is often no hazardous pressure built-up in open air (outside buildings), but only the formation of flames, e.g. with:

- Unloading of bins (bags, cartons, containers, barrels, etc.).
- Gravity unloading of FIBCs.
- Tipping of trucks or railroad wagons.
- Emptying of ships with unloading cranes.

Depending on the situation, flame formation may

- Endanger persons.
- Result into intensified flames when dust deposits in the discharge area are blown up.
- Flame propagation into (enclosed) receivers, which might explode.

4.2 Zoning

General

The probability for the occurrence of explosive atmospheres depends very much on the particle size and fines content of the involved products, the moisture content and the ability to create dust clouds.

Regarding particle size, it should be noted that:

- Products which, according to their specification, contain virtually no fine material may result in products with higher dust contents during handling (e.g. conveying) because of break-up or abrasion.
- In case of coarse products, discharged by gravity, larger particles tend to settle down quickly, whereas fines remain in suspension. In this way, especially at high drop heights, dense dust clouds may arise in time, even if fines content is very low. Using a slide can significantly reduce such dust clouds.

At high product moisture levels, products tend to become sticky. This makes dust formation less likely. Whether moist products nevertheless tend to cause dust and might tend to spontaneous combustion should be clarified in advance.

Presence of explosive dust/air mixtures within plant and equipment		
Typical examples of zones in the raw material receiving process step		
Description	Remarks	Zone
Manual emptying station (below the grating), automatic bag emptying machine, emptying of FIBCs (bulk materials in free fall)	for powder	20 / 21
	for granular or moist powders	21
	for products with low (combustible) fines content	22
Metered discharge of FIBCs	for products with low (combustible) fines content	21 22
Trucks, wagons, containers, unloading by gravity	for well flowing products with low (combustible) fines content	21 22
Road tankers		22
Ship, unloading by crane	Limited dust development below the gripper and around clearing vehicles/ wheel loaders	22
Ship, unloading by suction pipe	Dust formation due to clearing vehicles/wheel loaders	22

Inside plant components

For zoning within screw conveyors, belt conveyors, chain conveyors and bucket elevators, as well as pneumatic conveying systems: See "Collection of Examples – Dust Explosion Prevention and Protection for Machines and Equipment – Part 2, Conveyors, Transfers and Receivers, ISSA Collection of Examples No. 2057, ISBN 978-92-843-8185-2"

Outside equipment

Gravity unloading of trucks/wagons as well as ship unloading by crane, is usually applied for coarse products with limited fines content. Fines/dusts are usually discharged immediately into a pneumatic conveying system. Nevertheless, dust clouds must be considered even with coarse products. If bulk gutters are installed inside enclosed area, explosive dust/air mixtures may arise immediately and hazardous dust deposits may arise in time, which may lead to dust clouds. Therefore, zone 22 or even zone 21 is to be assumed.

When unloading coarse products with fines via a a chute, zone 21 or 22 can be assumed. The extent of zones outside equipment depends very much on the presence of an extraction system. Suitable extraction can essentially limit the extent of the zone to the open product flow.

Suitable extraction means that a sufficiently large air flow is generated that prevents dust cloud formation outside equipment or at least strongly limits the size of such cloud. An often-used solution for truck and wagon unloading is an extraction system at the bulk gutter or through an extraction wall. In case of dusty products and suitable extraction walls, the zone can be limited to the area between the chute and the extraction wall.

Insufficient housekeeping can result in dust deposits which can create an explosive atmosphere due to dispersion.

Figure 7:
Example of open discharge without (A) resp. with extraction (B) (Fig: Prof. Siegfried Radandt)

Figure 8:
Examples of open discharge with exhaust walls (Fig: Prof. Siegfried Radandt)

4.3 List of potential ignition sources

The following table summarizes all ignition sources and indicates whether these are possible for the raw material reception and, if so, whether these are capable to ignite the dust cloud involved. Important: Ignition sources caused by the usual conveying equipment (bucket elevators, screw conveyors, belt conveyors or chain conveyors) are not considered here, but in the Collection of Examples – Dust Explosion Prevention and Protection for Machines and Equipment – Part 2, Conveyors, Transfers and Receivers. ISSA "Collection of Examples" No. 2057, ISBN No., 978-92-843-8185-2.

No.	Type	possible	incendive
1	Hot surfaces	Yes, through truck or clearing vehicle/wheel loader, e.g. by exhaust gas system	Yes
2	Flames and hot gases (including hot particles)	Yes, through smoldering nests in the product	Yes
3	Mechanically generated sparks	Yes, from (truck) blower	Yes, depending on minimum ignition energy and MIT; depending on BZ value smoldering fires can also occur.
4	Electrical equipment	Yes	Yes
5	Stray currents, cathodic corrosion protection	Yes, during electrical welding and due to poor grounding of direct current systems	Yes
6	Electrostatic discharges		
6 a	Corona discharges	Yes	No, energy too low for dust
6 b	Brush discharges	Yes	No, according to the current state of the art (for dust)
6 c	Propagating brush discharges	Yes, in flexibles (pneumatic conveying lines) and FIBCs	Yes
6 d	Cone discharges	Yes, in receiving silos	Yes, see "Storage" module
6 e	Spark discharges	Yes, in case of insufficient or non-existent grounding	Yes
7	Lightning strike	Yes	Yes
8	Electromagnetic waves in the frequency range from 10^{4} Hz to $3*10^{11}$ Hz (high frequency)	No	
9	Electromagnetic waves in the frequency range from $3*10^{11}$ Hz to $3*10^{15}$ Hz	No	
10	Ionizing radiation	No	
11	Ultrasound	No	
12	Adiabatic compression and shock waves	No	
13	Exothermic reactions including spontaneous combustion of dusts	Yes	Yes

Consequently, the following ignition sources must be taken into account:

1 Hot surfaces due to truck or clearing vehicle/ wheel loader
2 Flames and hot gases due to smoldering nests in the product
3 Mechanically generated sparks by (truck) blowers
4 Electrical equipment
5 Stray currents during electrical welding and poor grounding of DC systems
6 c Propagating brush discharges in hoses, expansion joints and FIBCs
6 e Spark discharges in case of insufficient or non-existent grounding
7 Lightning strike
13 Exothermic reactions including spontaneous ignition of dusts

4.4 Risk assessment

Dust explosion hazards are hardly expected during the reception, handling, and storage of closed packages. However, dust explosion hazards can occur when packages are damaged, opened and emptied into the process.

Remark: Storage of paper bags or cartons increases the fire load and can cause explosions in fires if dusty product is released.

Explosion protective measures (such as venting) are not possible for manual emptying stations. Since operators are endangered, explosion risks must be reduced by preventive measures:

- The likelihood of dust clouds can be reduced, but not completely eliminated, by adequate extraction.
- Inerting to avoid explosive atmospheres is not possible. Therefore, the preventive concept "Avoiding effective ignition sources" must be applied.

Therefore, manual emptying stations should generally not be used for extremely ignition-sensitive dusts with a minimum ignition energy < 1 mJ .

For automatic bag emptying machines, usually only preventive measures or explosion suppression are applied. The addition of inert gas to reduce the oxygen concentration (see "Characteristics" module) to increase the minimum ignition energy might be considered. It must be considered that inert gas can escape into the environment via the open inlet opening and become a hazard for personnel.

Also when FIBCs are emptied by gravity into receivers, explosion protection is not possible, and inerting is only possible to a limited extent. Rapid emptying promotes the formation of dust clouds and high charges both on the FIBC and discharged product. Therefore, metered discharge should be preferred for dust-explosive products. Metered discharge limits both the formation of dust clouds and electrostatic charging. Explosion protection (or inerting) of the receiver is possible.

During emptying FIBCs into receivers, the displaced air must be extracted by means of adequate suction to avoid dusty surroundings.

A typical problem with bulk materials is the possible presence of smoldering nests. During emptying, these can break open or glow up and become effective ignition sources. These hazards must be taken into account when designing equipment to receive bulk materials that are prone to smoldering (e.g., wood pellets).

Explosion protection and inerting are also not possible when unloading bulk materials from trucks, railwagons or ships by tipping or with unloading cranes. Explosive mixtures cannot be completely avoided by extraction. Consequently, the preventive measure "Avoiding effective ignition sources" must be applied.

Unloading of bulk materials by means of pneumatic conveying (blowers for road tankers, suction pipes for wagons and ships) rarely lead to the formation of explosive mixtures in the delivery vehicle/ship being unloaded.

- Within road tankers, smoldering nests (due to overheated conveying air and deposits or already present in the product) can lead to smolder gas formation and subsequent explosions. Therefore, blowers with downstream air coolers (air temperature should not exceed approx. 80 °C) and spark prevention should be used. If the road tanker does not meet these requirements, the operator must provide an appropriate blower.
- In case of suction transport (as used in ships or wagons), there is usually no explosion hazard to be considered during unloading.

During pneumatic conveying, the formation of explosive mixtures in the receiver cannot be ruled out, which may require suitable explosion prevention and protection measures (see "Storage" module).

4.5 Required preventive and protective measures

4.5.1 Preventive measures to avoid explosive atmospheres and effective ignition sources

Avoiding explosive atmospheres

- Installation of targeted exhaust systems, such as an exhaust wall at the receiving chute. Experience shows here that using suitable systems explosive dust clouds are substantially limited (explosive atmospheres become unlikely) but local deposits can still occur.
- Avoid surfaces where dust can accumulate, e.g. cable trays.
- Adequate housekeeping.

Avoiding effective ignition sources:

1. **Hot surfaces due to truck or clearing vehicle/ wheel loader**
   - For trucks, ensure that the explosive atmosphere is kept away from areas where ignition sources due to hot surfaces may arise (e.g. engine, catalytic converter, exhaust system). This hazard can usually be avoided by sufficient waiting time before unloading is started.
   - Clearing vehicles/wheel loaders in ships must be suitable for zone 22.
   - Regular inspection and cleaning of hot surfaces where dust can accumulate, such as in the engine compartment.
2. **Flames and hot gases due to smoldering nests in the product**
   In case of ship unloading, it is difficult to avoid (rain) water entering the product during the unloading process. If such unloading operations are used for materials that tend to smolder when wetted (e.g. wood pellets), strict procedures are required: No unloading while it is raining as well as measures to prevent rainwater from entering the product.

Figure 9:
Charred product from the engine compartment of a wheel loader (Figure: Prof. Siegfried Radandt)

In case of gravity unloading of trucks, wagons or crane unloading of ships, it must be considered that foreign bodies or impurities (metal, stones, smolder nests) may arrive with the product. Therefore, receiving gutters or receiving bins should be equipped with cascade grates that prevent the entry of large or rod-shaped objects that can block the conveying equipment and lead to overheating. Alternatively, it might make sense in specific cases to install heavy objects and/or metal separators.

Figure 10:
Cascade grate to prevent the entry of large or rod-shaped objects (Figure: Prof. Siegfried Radandt)

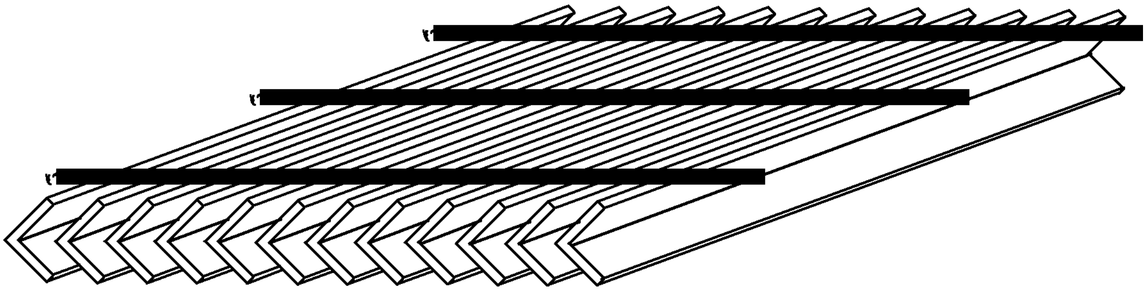


Figure 11:
Schematic view of a cascade grate

Smoldering product can be detected in chutes (free fall) by optical detectors and be removed from the process. Similarly, smoldering fires can be detected with special smoldering nest detectors.

3 Mechanically generated sparks by (truck) blowers

Blowers with downstream air cooler (air temperature should not exceed approx. 80 °C) and spark prevention must be used. If the silo vehicle does not meet these requirements, the operator must provide an adequate compressor.

4 Electrical equipment

As a rule, only equipment that is approved for the defined zones and is maintained accordingly may be used.

5 Stray currents at electrical welding and bad grounding of DC systems

Safe grounding must be ensured by suitable organizational measures.

6 Electrostatic discharges

6a Propagating brush discharges in hoses, compensators and FIBCs

Selection of suitable hoses, compensators and FIBCs according to the requirements of IEC/TS 60079-32-1 and TRGS 727.

It is recommended to provide suitable hoses and prohibit the use of other hoses.

6b Spark discharges in the event of insufficient or non-existent grounding

To avoid dangerous spark discharges, all conductive parts must always be suitably grounded (leakage resistance less than 10^6 Ω).

Vehicles/ships:

- Trucks and road tankers must be grounded before starting the unloading process (see ISSA brochure "Electrostatic").
- Separate grounding of rail cars or ships is not necessary.
- Grounding of wheel loaders/clearing vehicles, e.g. by sliding contacts, is required in the presence of gas explosive atmospheres (e.g. extracted oil seeds).

7 Lightning strike

Adequate lightning protection must be provided.

13 Exothermic reactions including self-ignition of dusts

For products that tend to self-ignition or smoldering when sparks settle in deposits (burning class BZ > 2), the potential presence of smoldering nests in the incoming product must be considered.

4.5.2 Explosion protection

Explosion protective measures are normally difficult to implement on the plant components of the raw material reception.

Dust clouds can be formed when discharging products. When these are ignited by an effective ignition source, there is hardly hazardous pressure built-up in open air (outside buildings), but only formation of flame jets or fire balls, e.g. in case of:
- Emptying of containers (bags, cardboard boxes, containers, barrels, etc.)
- Emptying FIBCs by means of gravity
- Tipping of trucks and railroad wagons
- Unloading ships with an unloading crane

Flame formation can have serious consequences:
- Endanger operators.
- Intensify flames formation due to dispersed dust deposits in the discharge area.
- Flame propagation into enclosed receivers where explosions can be initiated.

The following explosion protective measures can be considered for receivers.
- Pressure-resistant or pressure shock resistant design for the maximum explosion overpressure P_{max} (possible for smaller silos)
- Pressure shock resistant design for the reduced explosion overpressure p_{red} in conjunction with explosion venting (if necessary flameless venting)
- Pressure shock resistant design for the reduced explosion overpressure p_{red} in combination with explosion suppression (possible for smaller silos)

Decisive conditions for the design of protective measures are:
- **Plant configuration**
  Receiver volume and height-to-diameter ratio, ducting lengths and diameters, type of conveying equipment, etc.
- **Process conditions**
  Dust distributions, volume flows, process temperatures, process pressures, flow velocities etc.
- **Ambient conditions**
  Temperatures, humidity (e.g. condensation)
- **Product features**
  (safety-related product parameters)

In addition to the above-mentioned protective measures, explosion isolation measures are necessary if the propagation of an explosion from one part of the plant to another must be prevented. These can be subdivided into passive and active systems.
- **Passive systems** act automatically without the need for a control unit. The device is closed by the pressure wave generated by the explosion. Each system requires a minimum pressure to close.
- Known **passive systems** are the explosion diverter and the passive explosion protection valve. However, the rotary valve also can be counted among the passive elements. It must be automatically stopped immediately in the event of an explosion. Product plugs in conjunction with conveying elements, such as screw conveyors, can also be used for explosion isolation.
- **Active systems** require suitable control systems to trigger them. In the event of an explosion, the external energy required to actuate the active systems is then released via these control systems. There must be a certain distance between the installation location of the detector and the actuator, which results from the response time of the device and the explosion behavior.

- **Active systems** include quick-acting slide valves, the active explosion protection valve and the chemical (extinguishing agent) barrier.
- The chemical barrier in conjunction with a suppression system can also replace the explosion venting device.

Explosion propagation hazards
When an explosion propagates from one to another volume, increased explosion pressures will arise in the second volume. Dangers arise when the second volume is (much) smaller than the first one. To prevent propagation, explosion isolation is necessary. However, the closure of the decoupling device causes an additional overpressure in the primary vessel. This pressure can be up to 3 times higher than the calculated reduced explosion pressure.

Figure 12:
Explosion propagation through ducting

Figure 13:
Preventing explosion propagation via a duct by means of a required quick-acting slide valve

Explosion diverters

The propagation of dust explosions via connecting ducts can be prevented in many cases by installing an explosion diverter. In this way, a dusty air conveying line can be routed via an explosion diverter to the downstream separator, e.g. a filter system. The explosion diverter is characterized by a special duct routing in which a 180° reversal of the flow direction takes place.

Explosion diverters can practically prevent explosion propagation in both directions. However, experimental studies show that propagation cannot always be prevented. E.g., the probability of explosion propagation from the outer to the inner pipe is higher than vice versa. Furthermore, explosion propagation is promoted if high under pressures are present on the "downstream side" (the side facing away from the explosion). Especially in case of slow explosions with limited pressure build-up, where the venting devices do not respond, explosion propagation must be expected.

Rotary valve

When designed as a protective system, rotary valves can prevent the propagation of explosion flames. There is also hardly any pressure increase in downstream systems. Rotary valves are suitable for safeguarding product in- and outlets on vessels and apparatus. Furthermore, these valves create a decoupling between the upstream and downstream plant areas.

In addition to a flame and ignition resistance an adequate explosion pressure resistance is essential. To be able to cover a wide range of explosion loads pressures to be expected in practice due to dust explosions, rotary valves are generally designed for an overpressure of 10 bar. Both properties, but especially that of the ignition resistance, must be proven in explosion tests.

Passive explosion protection valve

Passive explosion protection valves are primarily suitable for installation in pipelines with low dust loads. Typical applications include the clean air outlet of filter systems, where these valves are used to protect the fans located in the clean air outlet from excessive high pressure loads in case of a filter explosion. The valve is closed by the kinetic energy of the pressure wave (passive system). However, flames may pass in case of explosions with limited overpressures.

Fast-closing slide valve

Compared to the passive valves, fast-closing slide valves have the advantage that, prior to activation, the closing element is located outside the pipeline cross-section. The cross-section thus remains free and can be executed without obstructions or dead corners, hence no dust can accumulate. For this reason, fast-closing slide valves can be used in pipelines regardless of dust loading. Both flame and pressure detection can be applied.

Chemical barrier

If a flame front is detected, a control system opens the valves of the extinguishing agent containers, whereupon extinguishing agent is dispersed into the duct. This will extinguish the flame. There must be a certain distance between the location of the detector and the location of the extinguishing nozzle, which results from the response time of the barrier and the explosion/flame speed. The extinguishing process does not stop the propagating pressure wave. The piping (also downstream the barrier) must be designed for the maximum expected explosion pressure. Flame detection must be applied.

Explosion detection

Suitable detection is required to trigger active protection systems. In principle, detection can be based on pressure or flame.
With pressure detection, a distinction can be made between mechanical and electronic detectors.

Advantages and disadvantages:

- **Mechanical detectors (membrane)**
  - \+ rather insensitive to dirt
  - \+ The sensitivity to vibration can be reduced by applying two detectors installed at a 90 degrees angle: activation when both detectors detect pressure.
  - – Re-adjustment required

- **Electronic detectors**
  - \+ Can be programmed to respond to a static pressure value and to a rate of pressure rise
  - \+ No danger due to resonance vibrations

- **Flame detection**
  (especially required for weak explosions)
  - \+ Response time < 2 ms
  - – Monitoring the sensor optics for blindness due to fouling

Isolation through product plug

In case of vented silos, explosion isolation can be obtained at the product outlet by maintaining always a minimum product layer in this outlet. The presence of this layer must be controlled by 2 level detectors.

Both detectors are hard-wired and connected to the drive of the discharge device (e.g. pneumatically operated flap valve) such that product discharge is only allowed when both detectors signal product.

The level indicators must be approved for use in potentially explosive atmospheres. The minimum height of the product layer (H) depends on the bulk density of the stored product (SD) and the diameter of the discharge opening (D) and is calculated as follows:

Bulk density SD ≥ 1 kg · dm^{-3} $\quad H = D$

Bulk density SD < 1 kg · dm^{-3} $\quad H = \frac{D}{SD}$

Numerical value equation:
H [m], D [m], SD [kg·dm^{-3}]

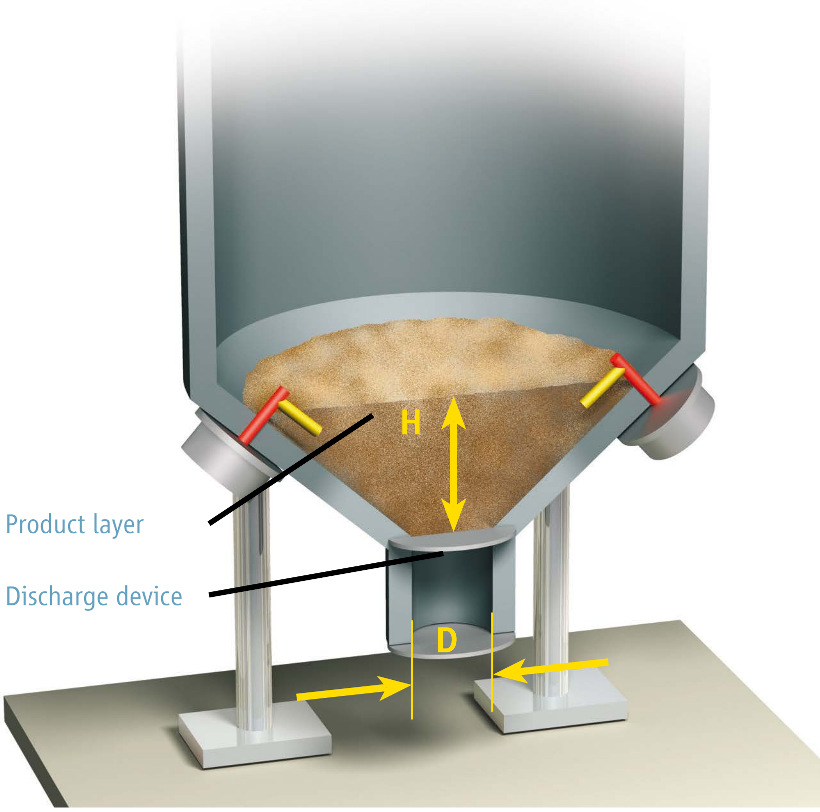


Figure 14:
Explosion isolation at product outlet, realized by a product plug (minimum height of product layer)

When using the explosion isolation measure "product plug", a mass flow behavior at emptying is always compulsory for the silo concerned. In case of funnel flow, cavities or pipe formations may occur within the material column, which might prevent sufficient coverage with bulk material above the discharge opening. An important prerequisite for a proof of mass flow is a silo design based upon the results of shear tests (A. W. Jenike or Schulze). Products with flowability factors ffc ≤ 4 are critical.

Explosion isolation by tubular screw conveyor
Tubular screw conveyors are usually operated with a filling ratio between 30 and 50 %. Thus, the upper part of the screw tube is not filled with product. To achieve a product plug, individual screw flights are removed shortly before the screw discharge. This enables a build-up of product forming a product plug. The actual build-up of the product plug depends on its flowability.

Actual decoupling in such screw conveyor by product plugs, depends on the product properties.

The main requirements of this type of explosion isolation are:

- During empty operation, bulk material plugs remain at the missing screw flights if the flowability factor ffc < 5 (e.g. cellulose, powdered sugar, milk powder, wood flour, wheat flour)
- Even without product plug, no flame propagation occurs for dusts with minimum ignition energy ≥ 100 mJ; (Minimum ignition energy measured with inductance. Reference is wood flour)
- With product plugs no flame propagation occurs for dusts with minimum ignition energy ≥ 10 mJ; (Minimum ignition energy measured with inductance. Reference is cellulose)

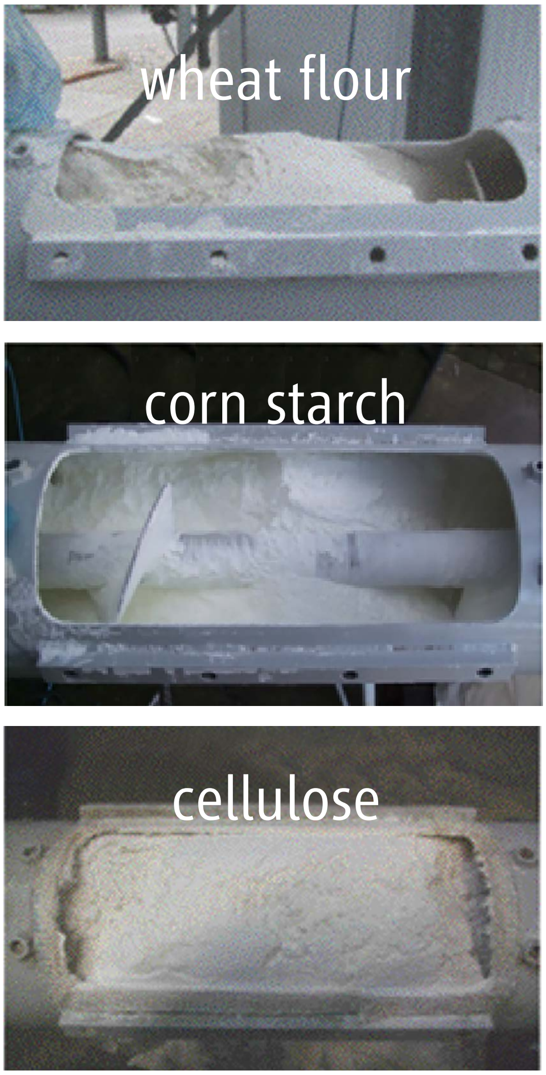


Figure 15:
State of the product plug after the screw has been emptied for at three products: wheat flour, corn starch and cellulose (Prof. Siegfried Radandt)

- No flame propagation for dusts with minimum ignition energy ≥ 5 mJ and ffc < 10 if
  - "empty running" is technically impossible and
  - 2 screw flights have been removed.

- Explosion overpressure: p_{red} = 0.2 bar to 2 bar

- Validity range:
  - Maximum diameter of the tubular screw conveyor: d = 200 mm
  - Minimum distance from product inlet to outlet: l_{min} = 1.80 m
  - Maximum gap width between screw flights and housing: s = 7 mm

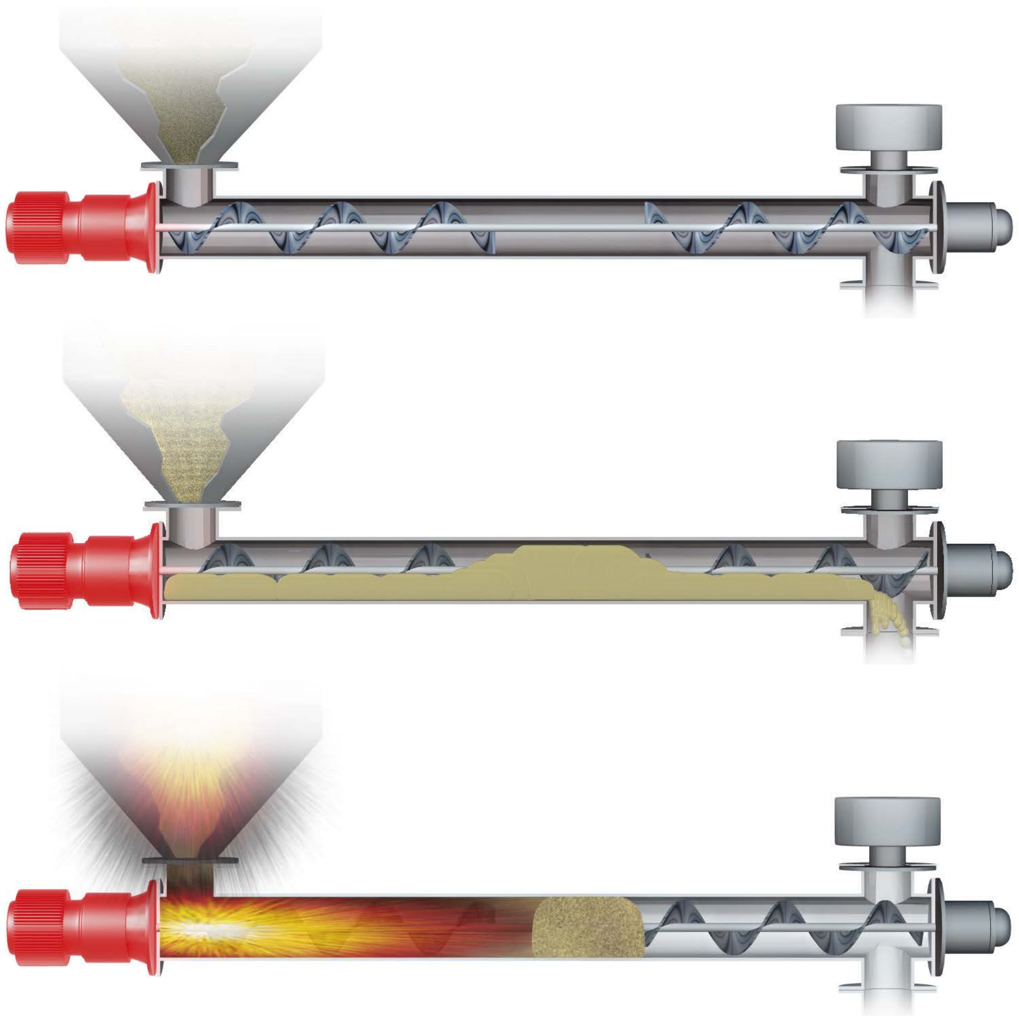


Figure 16:
Application of a tubular screw conveyor for explosion isolation
Creation of a material plug by removing 1, 1.5 or 2 screw flights. If possible, the plug should remain in place even if no more bulk material is fed when the conveyor is running empty.

4.5.3 Organizational measures

Apart from general organizational measures, the following specific organizational measures are important for raw material reception:

Requirements for suppliers:
- Product specifications, such as particle size, moisture content and impurities
- Special specifications for storage and transport (including packaging)

Requirements for vehicles (trucks and road tankers) regarding unloading
- Grounding the truck and road tanker
- Obey minimum waiting times prior to unloading enabling cooling down of hot vehicle parts

Measures to reduce dust generation
- Limit conveying speeds and drop heights
- Adequate extraction

Further organizational measures
- Dedicated training of employees and operators of wheel loaders/clearing vehicles (also on ships)
- Frequent cleaning of the unloading area
- Regular cleaning of trucks, road tankers and front loaders with special attention to the engine compartment
- Regular inspection and maintenance of trucks, road tankers, wheel loaders/clearing vehicles: Do not use overheated or damaged electrical components
- Limit number of employees near unloading activities.

4.6 Interfaces

In principle, all other process steps (such as storage, drying, packaging, ...) are to be considered as possible interfaces.

Safety-related parameters
Since no mechanical processing, heating, or cooling normally takes place during raw material reception, the safety-related parameters of the products should not change during raw material acceptance. The characteristic data of the product reception can thus be used as input values for the subsequent process steps.
However, following should be noted:
- Abrasion can produce (slightly) more fine dust.
- Particularly in case of bulk material reception, the formation of dust clouds is to be expected, so that an increased proportion of fine dust can be deposited on the bulk material due to sedimentation.

Ignition sources
For products with a burning class BZ > 2, the presence of smoldering product or smolder nests should be expected.
Insulating products can be charged very high, especially when high speeds are involved (pneumatic conveying, rapid discharge via chutes). As a result, dangerous electrostatic discharges may arise in one of the next process steps.

List of figures

Index

P

Q

R

S

T

V

W

Z

ISSA Publication Series (Explosion Protection)

Section on Prevention in the Chemical Industry

Section on Machine and System Safety

- Dust explosions – protection against explosions due to flammable dusts, ISSA-32 ISSA Chemistry Section, version 2002, 2nd edition (PDF in English, German and Italian)

- Dust Explosion Incidents, ISSA-43 ISSA Chemistry Section, version 2005, 1st edition (PDF in German and English)

- Identification and evaluation of Hazards, determination of measures Part 7 Hazards due to explosions, ISSA-42 ISSA Chemistry Section and Machine and System Safety Section, version 2021, 2nd edition (PDF in German), ISBN 978-92-843-0156-0

- Gas explosions – protection against explosions due to mixtures of flammable gases, vapors, or mists with air, ISSA-34 ISSA Chemistry Section, version 1999 (under revision)

- Avoiding Effective Ignition Sources in Potentially Explosive Atmospheres, ISSA-40 ISSA Chemistry Section and Machine and System Safety Section, version 2013 (under revision), 1st edition (PDF in German and French), ISBN 978-92-843-7184-6

- Collection of examples “Dust explosion protection on machines and apparatus”, Part 1: Mills, crushers, mixers, separators, screening machines, ISSA 38 ISSA Machine and System Safety and Chemistry Sections, version 2021 (PDF in German), ISBN 978-92-843-2182-7

- Collection of examples “Dust explosion prevention and protection for machines and equipment”, Part 2: Conveyors, transfers and receivers, ISSA 39 ISSA Machine and System Safety Section and Chemistry Section, version 2014 (in revision, PDF in German and English), ISBN 978-92-843-7182-2

- The PAAG/HAZOP method and other fieldproven methods, Risk Assessment in Plant Safety, ISSA-01 ISSA Chemistry Section, version 03/2020, 5th edition (PDF in German), ISBN 92-843-7037-X

- Static electricity – Ignition hazards and protective measures, ISSA-35 ISSA Section Chemistry, Status 1995/1996 (under revision)

- Practical aids for the preparation of the explosion protection document ISSA-36 ISSA Sections Chemistry and Machine and System Safety, Status 2021, 2nd edition (PDF in German language)

The ISSA

Creating social security

ISSA, the International Social Security Association is the world's leading umbrella organization for institutions, government agencies and authorities concerned with social security.

In a narrower sense, social security means protection against the consequences of "social risks". In addition to reduction in earning capacity due to occupational accidents, occupational diseases and occupational disability, this also includes illness, unemployment, assumption of family burdens, ageing and death of employed persons. In a broader sense, social security also includes an active labor market policy, a public education system and a balancing tax policy.

The ISSA was founded in 1927 by 17 European non-governmental organizations as the "International Conference of National Unions of Mutual Benefit Societies and Sickness Insurance Funds". Today, the ISSA has around 350 institutions, government agencies and authorities in more than 150 countries on all continents and is based at the United Nations International Labour Organization (ILO) in Geneva. The substantive work is carried out in 13 specialist committees, including those focusing on occupational accidents and diseases, health benefits and health insurance, employment policy and unemployment insurance, and family benefits and survivors' insurance.

Preventing occupational risks

The "Special Commission on Prevention" plays an important role within the ISSA. It consists of 14 international sections and deals with work-related risks in various sectors such as the chemical industry, mining, electricity, and transportation, but also with cross-cutting issues such as machine and system safety, information and prevention culture. The Special Commission coordinates the joint activities of the International Sections on Risk Prevention and other ISSA prevention activities.

As one of the first sections of the Special Commission, the International Section on Prevention in the Chemical Industry was founded in Frankfurt am Main in June 1970. It is committed to the prevention of occupational accidents and diseases in the chemical and allied industries, particularly in plastics and rubber, paints and coatings, pharmaceuticals and cosmetics, and specialty chemicals and petroleum refining. The chair and secretariat are held by the Berufsgenossenschaft Rohstoffe und chemische Industrie in Heidelberg.

In 1975, the ISSA International Section on Machine and System Safety was founded. Its objective is to increase safety and health protection at work worldwide in the field of machine and system safety. The chair and secretariat are held by the Berufsgenossenschaft Nahrungsmittel und Gastgewerbe in Mannheim.

Chemical industry | Machine and System Safety | Transportation | Construction industry | Information | Mining | Agriculture

Communicating expertise

A particular thematic focus in many branches of industry, e.g. the chemical and food industries, is dealing with explosion risks. Therefore, in 1978, the working groups 'Hazardous Substances' and 'Explosion Protection' were established within the Section on Prevention in the Chemical Industry. In order to exploit synergy effects and increase efficiency, the 'Explosion Protection' working group merged with the corresponding working group of the Section on Machine and System Safety in 2008.

Intensive informal discussions are held in the working groups, brochures and instruction media are developed and workshops are organised to promote the international exchange of experience among experts and to develop targeted-oriented solutions for selected problems.

In this way, the Section on Prevention in the Chemical Industry and the Section on Machine and System Safety aim to contribute to a high level of technology that is comparable among industrialised countries and to pass on their knowledge to industrially less developed countries.

Authors

Dr. A. Arnold, Mannheim (D)
Prof. Dr. U. Barth, Wuppertal (D)
Dr. M. Glor, Allschwil (CH)
A. Harmanny, Kontich (B)
Dr. Z. Kramar, Ljubljana (SI)
M. Mayer, Osterburken (D)
G. Nied, Osterburken (D)
Dr. R. Ott, Meggen (CH)
Prof. Dr. S. Radandt, Brühl-Rohrhof (D)
Dr. M. Scheid, Frick (CH)
G. Van Laar, Hamm (D)

Collaboration

Dr. H.-J. Bischoff, Mannheim (D)
M. Bloch, Altfortville (F)
Dr. S. Causemann, Sankt Augustin (D)
Dr. M. Gschwind, Lucerne (CH)
K. Kopia, Vienna (A)
Dr. O. Losert, Heidelberg (D)
F. Marc, Paris (F)
J. Parra, Münchwilen (CH)
Dr. G. Pellmont, Binningen (CH)
B. Poga, Heidelberg (D)
F. Pera, Roma (I)
B. Sallé, Paris, France (F)
R. Siwek, Kaiseraugst (CH)
M. von Arx, Lucerne (CH)

Graphics

Dieter Settele, Mannheim (D)

Occupational health and safety | Electricity, gas, water | Research | Iron and metal industry | Prevention culture | Education and training | Trade issa | INTERNATIONAL SOCIAL SECURITY ASSOCIATION

Section on Prevention in the Chemical Industry
Section on Machine and System Safety

Explosion Safety of Bulk Material Plants

Module: Raw Material Reception

This ISSA brochure "Raw Material Acceptance" is one module of the series "Modular Structure" for explosion safety of bulk materials handling equipment. For these ISSA "Modular Structure" brochures, a concept has been developed that makes it easier to divide the assessment for a plant with regard to explosion risk into smaller units, so-called "modules". In addition to a clear layout, this enables a targeted and process-oriented approach. This means that individual assessments of machines from the ISSA example collections "Dust explosion protection for machines and equipment", Part 1 and Part 2 and of processes/ modules from this series of ISSA brochures can be used and linked together at the end for the overall plant risk assessment.

Edition 04/2025
ISBN 978-92-843-4137-5