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Static Electricity

Ignition hazards and protection measures

International Section on the Prevention of Occupational Risks in the Chemical Industry of the International Social Security Association (ISSA)

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THE INTERNATIONAL SOCIAL SECURITY ORGANIZATION (ISSA)

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To emphasize occupational safety in plants (including the plastics, explosives, oil and rubber industries), the

INTERNATIONAL SECTION
OF THE ISSA
FOR THE PREVENTION
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was formed in 1970. The Chair and the Secretariat are located at the headquarters of the Berufsgenossenschaft der chemischen Industrie (professional association of the chemical industry), D-69115 Heidelberg, Germany.

To improve occupational safety and the protection of health in plants, the

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was established in 1975. It handles questions regarding the safety of machines, installations and systems. Chair and Secretariat: Berufsgenossenschaft Nahrungsmittel und Gaststätten (professional association of the food and catering industry), D-68165 Mannheim, Germany.

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A practical guide

Published by:

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Preface

The **I**nternational **S**ocial **S**ecurity **A**ssociation (ISSA) has set itself the task of using professionally oriented sections to publicize by information exchange, publications and colloquia the risks such as industrial accidents and occupational diseases recognized in the field of social security and to offer suggestions for their prevention.
The committee of the "Chemistry Section" of the ISSA has set up an "Explosion Protection Working Party" to promote the international exchange of information among experts and to develop jointly solutions to specific problems. The Working Party aims to contribute to a high and, among industrial countries, comparable standard of technology in the field of explosion protection. It is ready and willing to pass on its knowledge to countries less well developed industrially.
This compendium has been compiled in close cooperation with the "Machine Protection" section of the ISSA and should allow project engineers, plant managers, safety experts, etc. with no specialized knowledge of static electricity to assess whether ignition hazards due to static electricity can arise in their own plant or during the construction, equipping and erection of installations. The compendium is not intended to solve the question of whether protection measures are necessary and feasible as the widely different national regulations preclude any reliable generalizations. Rather, it concentrates on identifying the problems and formulating solutions to meet the protection aims.

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Contents

Explosion hazard and electrostatic charging – Overview

When does an explosion hazard arise?

An explosion hazard can arise when flammable gases, liquids or dusts are produced, stored or processed in a plant and the gases, vapors, mists (liquid droplets) or dusts are present as a mixture with air (explosible mixture). (See ISSA booklets "Gas explosions" and "Dust explosions".)

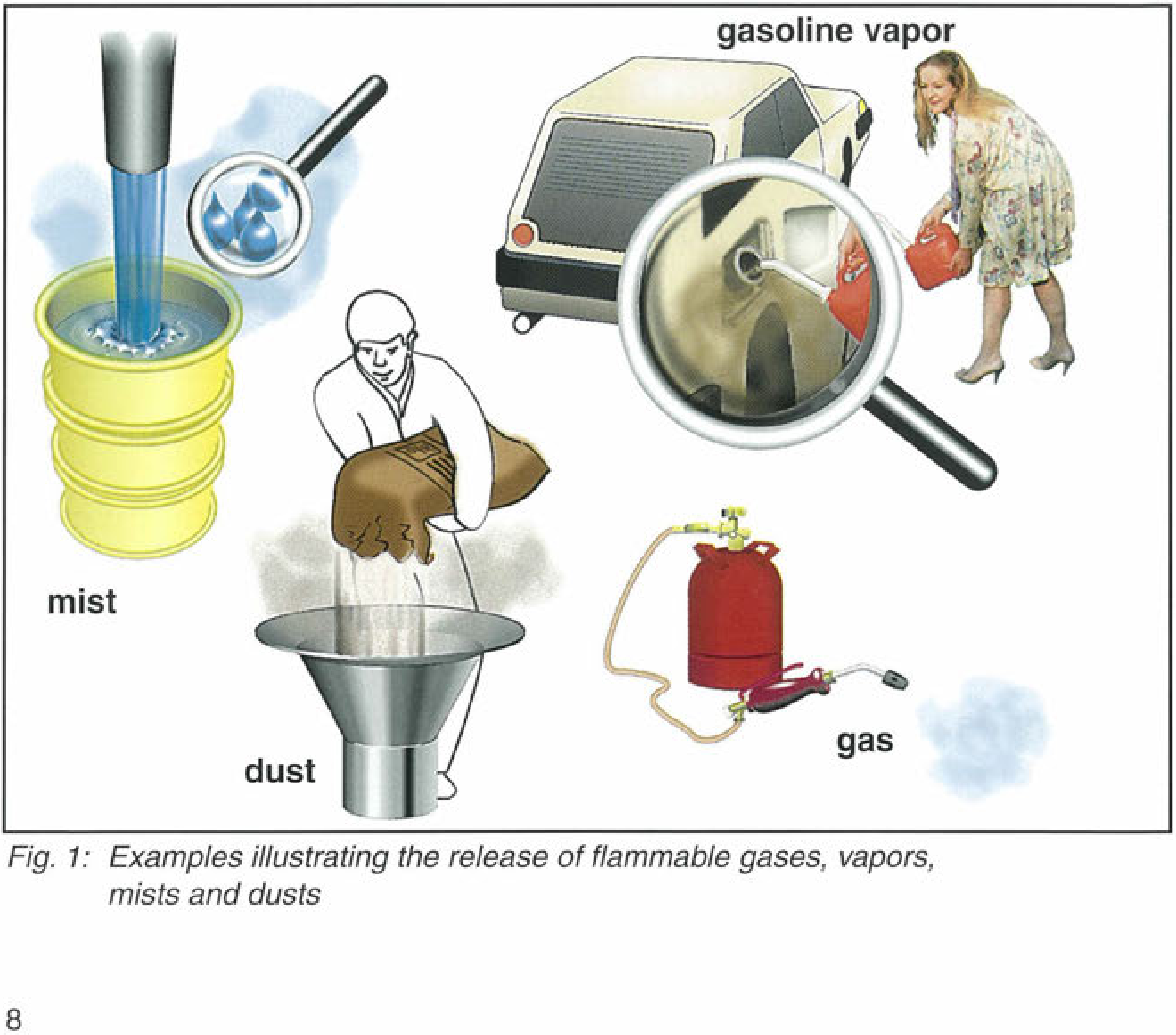


Fig. 1: Examples illustrating the release of flammable gases, vapors, mists and dusts

What is an explosible mixture?	An explosible mixture is present when flammable gases, vapors, mists or dusts are present in such quantities in air that spontaneous flame propagation (explosion) occurs after ignition.

When does an explosion occur?	An explosion requires the simultaneous presence at the same location of • fuel or flammable material (gas, vapor, mist or dust) in sufficient quantity and effectively mixed with • sufficient oxygen (usually air) for the combustion and • an effective ignition source.

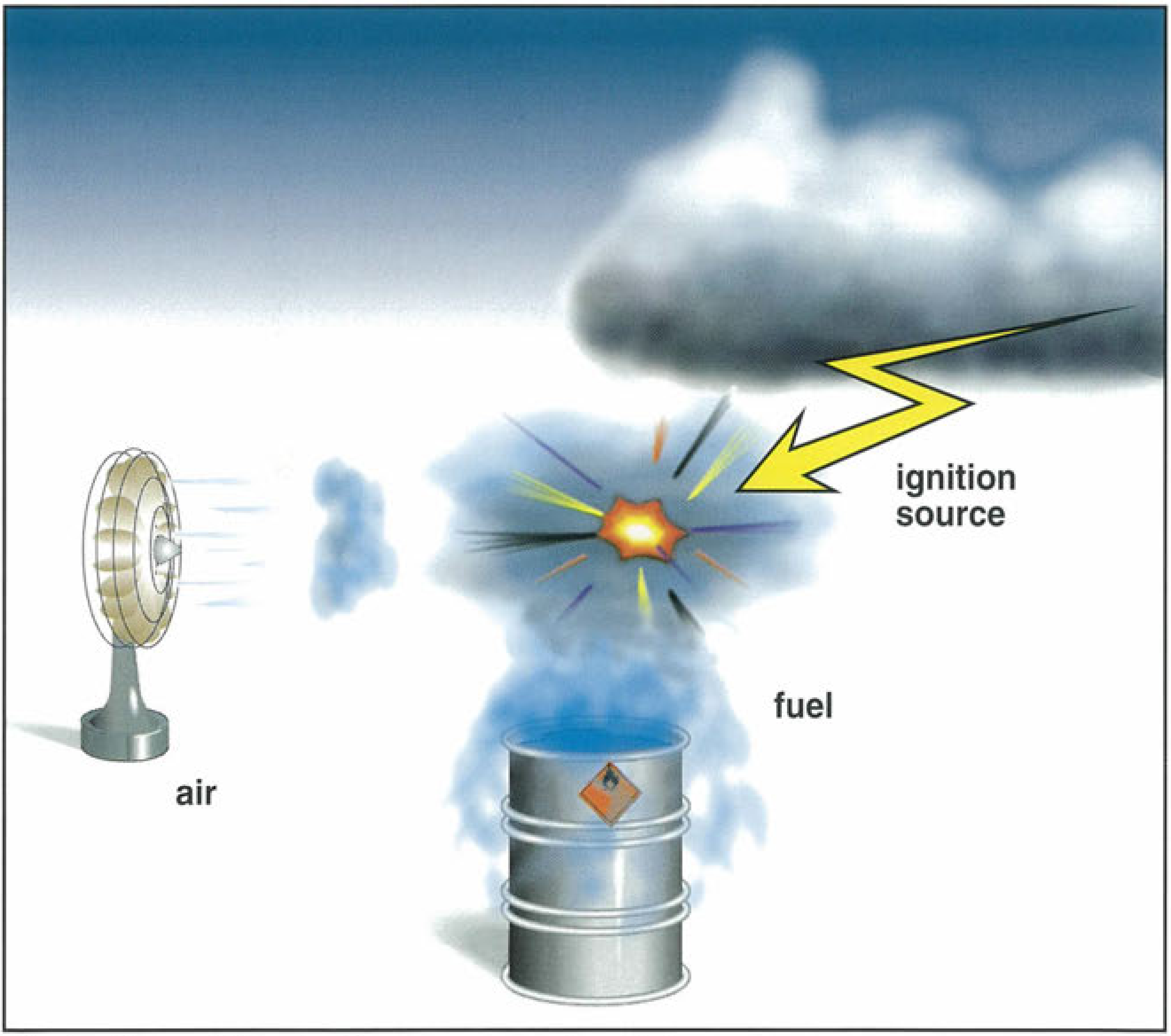


Fig. 2: Prerequisites for the occurrence of explosions

What are effective ignition sources?

There are a large number of different ignition sources in industrial practice (e.g. hot surfaces, fire, flames, smoldering material, mechanically and electrically generated sparks and discharges of static electricity) which differ according to, among other things, their energy content. The explosible mixtures also exhibit different ignition sensitivity.

Not every ignition source has sufficient energy to ignite all types of explosible mixtures, i.e. not every ignition source is incendive in a given situation.

It is usually necessary to investigate the ignition sources in detail to assess the ignition hazard in conjunction with the expected explosible mixtures.

These aspects will be considered in the following detailed discussion of discharges resulting from electrostatic charging.

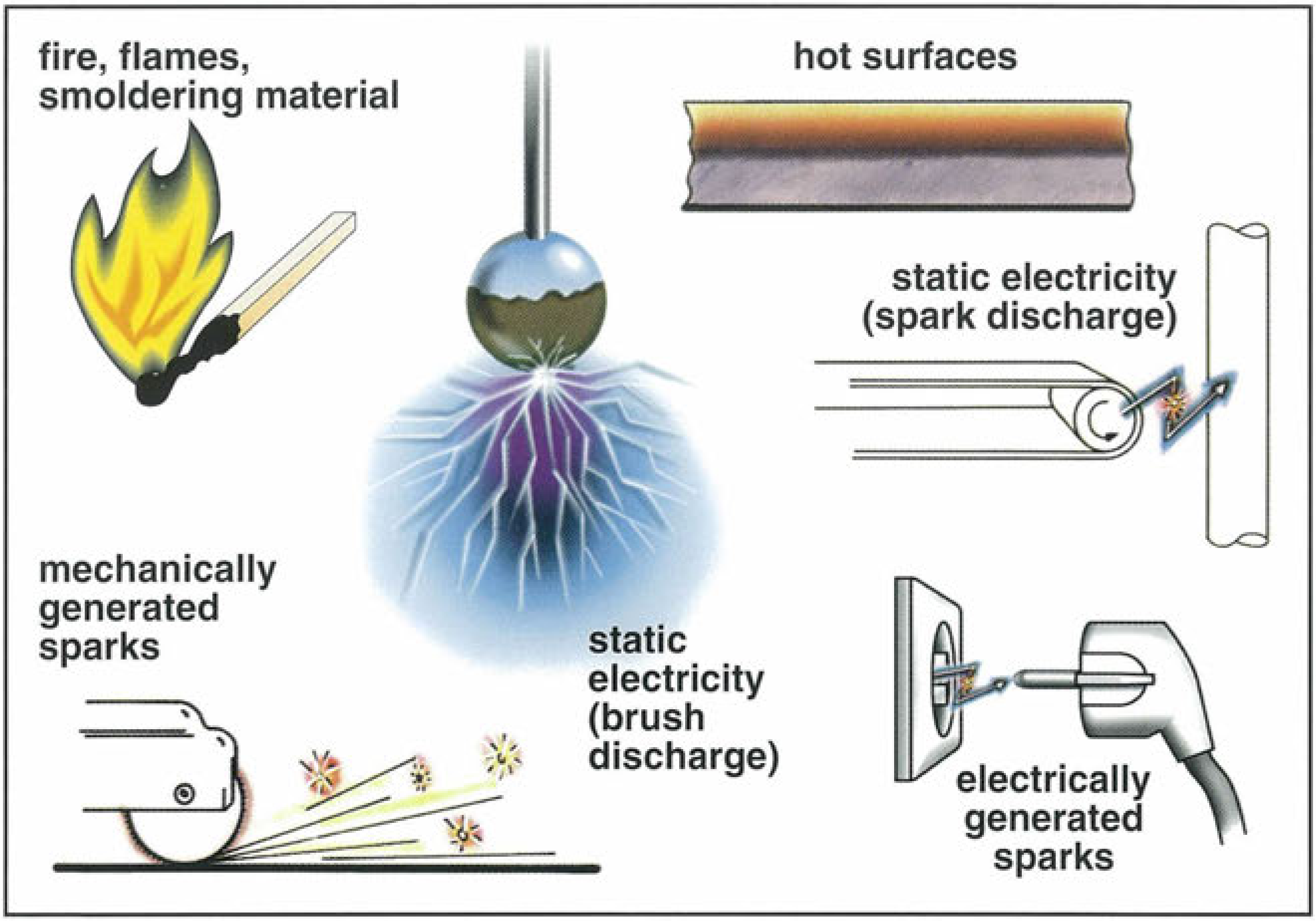


Fig. 3: Examples of possible ignition sources

When does an electrostatic charge become an ignition hazard?

An electrostatic charge by itself does not necessarily represent an ignition hazard. Such a hazard exists only when the charge is so high that discharges occur owing to the high electric field.

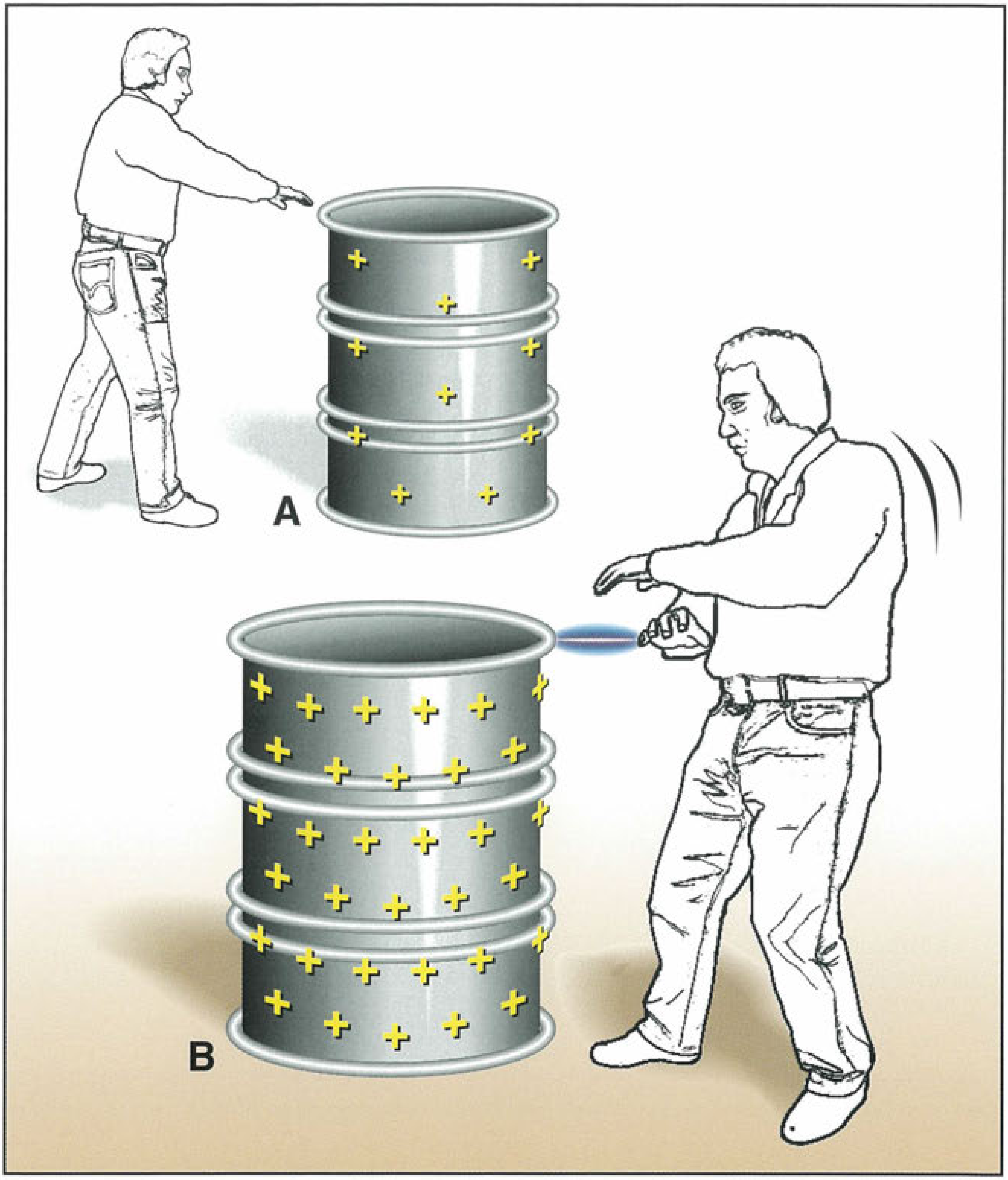


Fig. 4: Charge accumulation – A: low charge ➪ no spark discharges
– B: high charge ➪ spark discharges (ignition hazard)

How does a discharge of static electricity occur?

The individual steps which lead to the occurrence of a discharge are always the same:

- **Charge separation:** Separation processes (usually between product and plant units) lead to charging of the surfaces in contact.
- **Charge accumulation:** Charges can accumulate on products, plant units, packaging containers and persons, etc.
- **Charge dissipation:** As soon as a connection of sufficient conductivity is established between ground[1)] and the sites of the accumulated charge, the charge can safely flow to ground.
- **Discharge:** If the charge continues to accumulate because the charges formed in the separation processes can not flow to ground quickly enough, a discharge will occur when the breakdown field strength is reached.

[1)] US terminology is used in this booklet. In the UK the terms "earth", "earthing" etc. are commonly used for "ground", "grounding" etc.

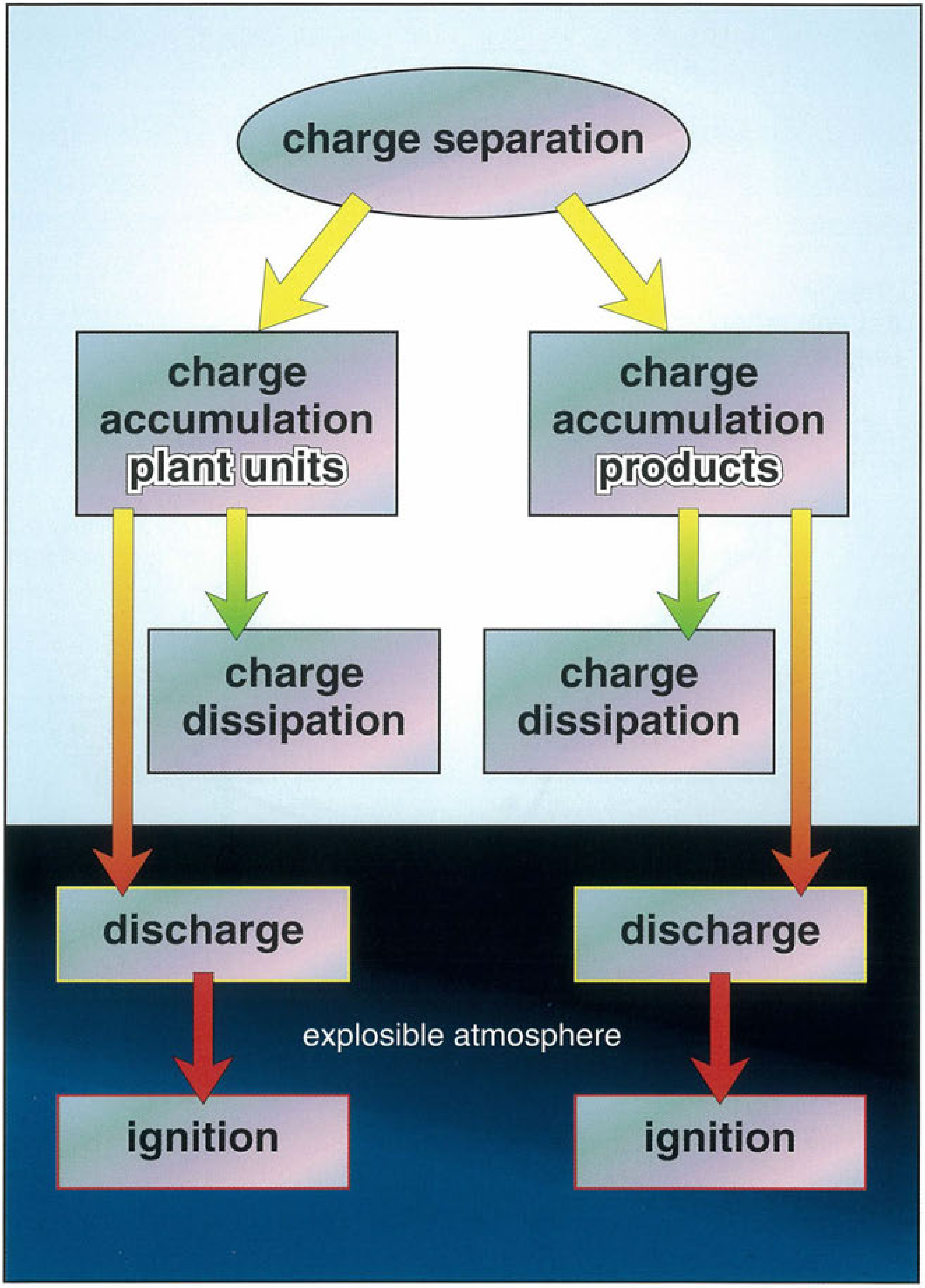


Fig. 5: Basic scheme of electrostatics: from charge separation up to possible ignition of an explosible atmosphere (explosion)

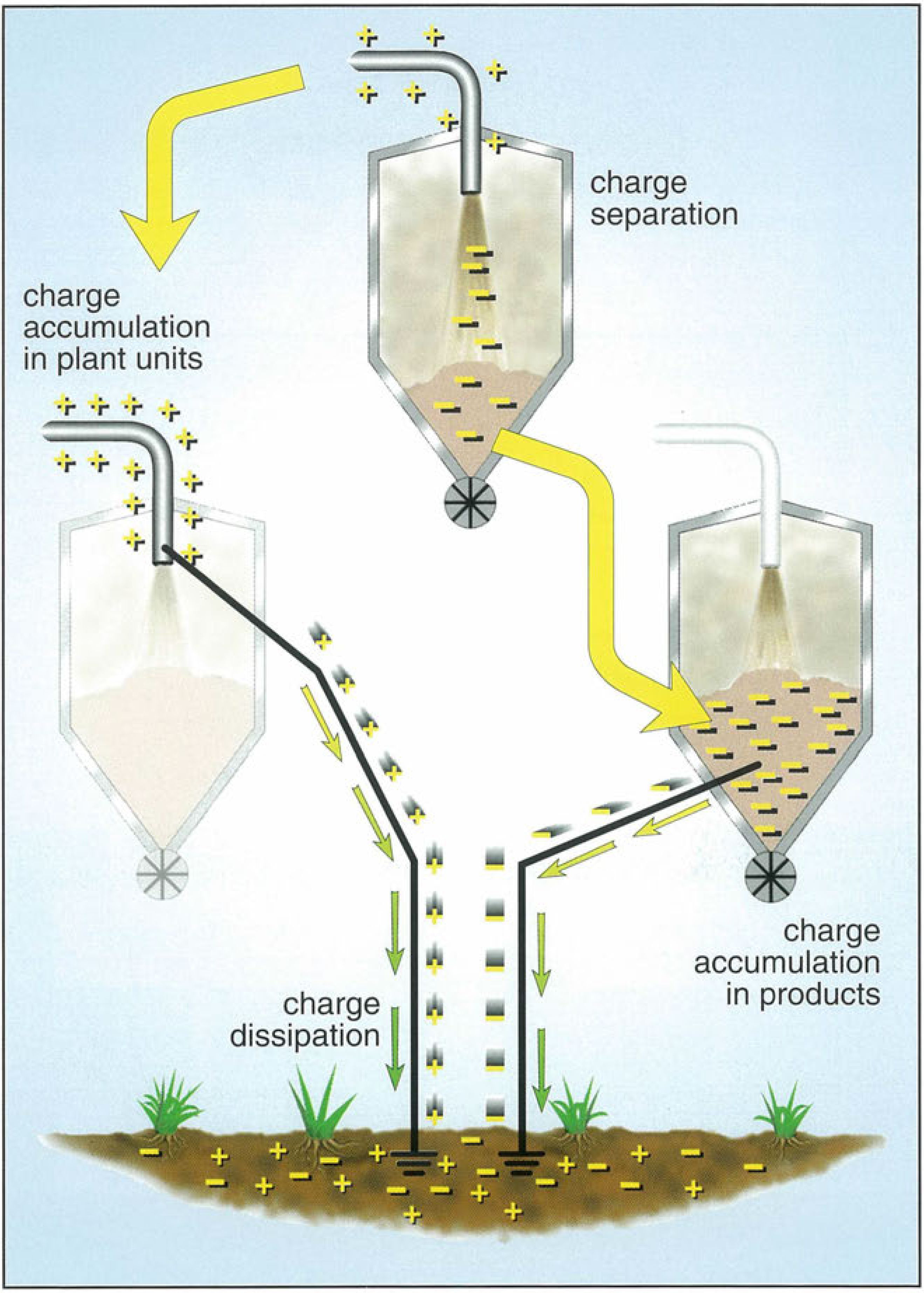


Fig. 6: Basic scheme of electrostatics: schematic representation of the steps: charge separation, charge accumulation and charge dissipation

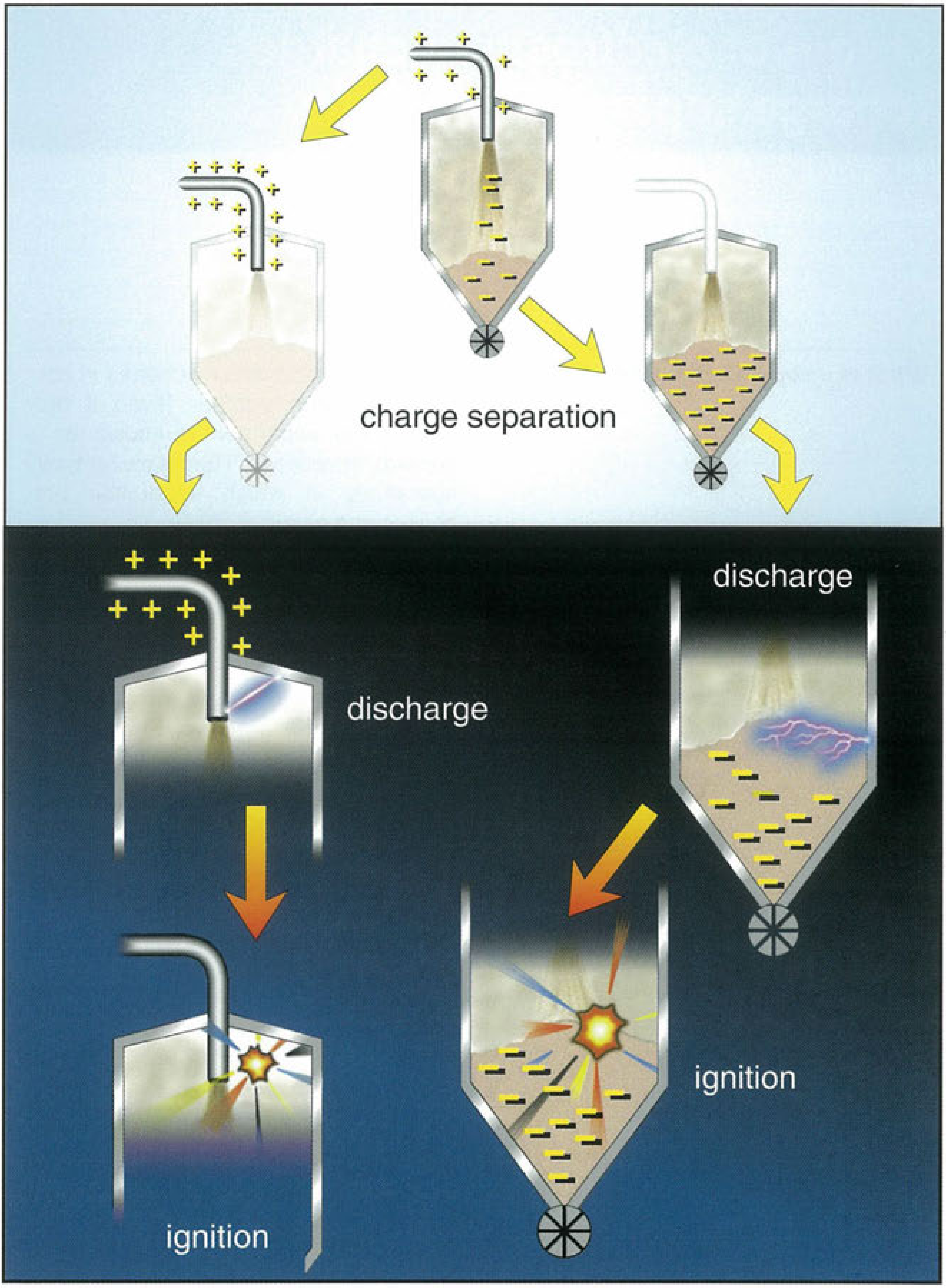


Fig. 7: Basic scheme of electrostatics: schematic representation of the steps: charge separation, charge accumulation, discharge and ignition of an explosible atmosphere (explosion)

Origin of electrostatic charges (charge separation)

What is a separation process?	Every process in which surfaces in contact with each another (even if only briefly) are separated is known as a separation process. The following typify operations in which separation processes can occur: • transfer of products • person walking on floor • unrolling of a film • movement of a conveyor belt over a guide roller • flow of a liquid through a pipeline • filtration of a suspension • atomizing or spraying of a liquid • pouring bulk material out of a bag or container • pneumatic transport of bulk material through a pipeline • impact of dust particles with the wall of a separator

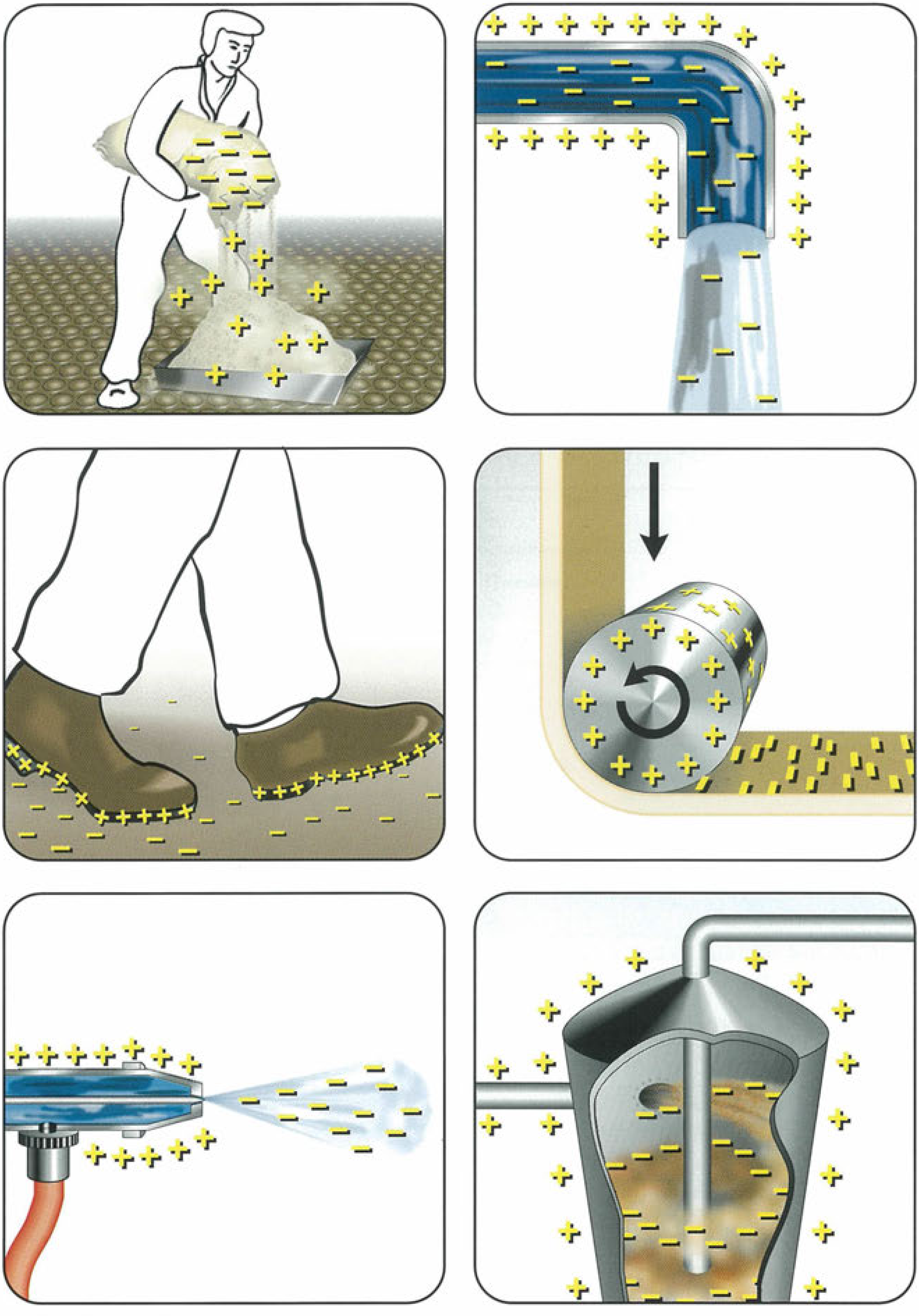


Fig. 8: Examples of separation processes

When is a substance insulating (nonconductive)?

The insulating properties of solids, bulk materials and liquids are determined by measurement of the electrical resistance.

- Typical insulating solids include practically all types of plastic such as polyethylene (PE), polypropylene (PP), polyvinylchloride (PVC) and polytetrafluoroethylene (PTFE). Note particularly that dry organic products can also be insulating.
- Typical insulating liquids include hydrocarbons such as hexane, heptane, benzene, toluene and xylene.

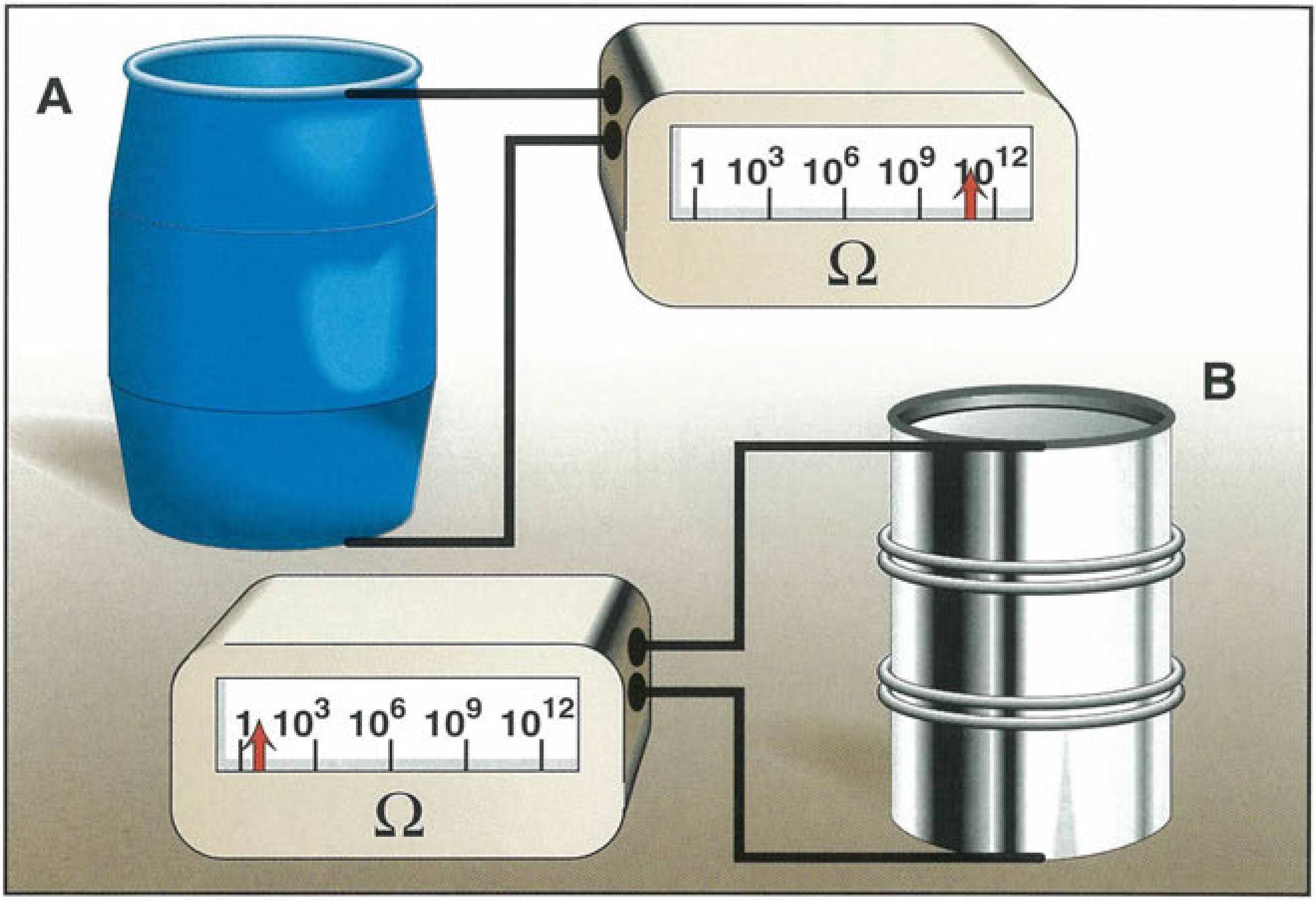


Fig 9: Characterization of the insulating properties by measurement of the electrical resistance: – A: plastic container (insulating, nonconductive) – B: metal drum (conductive)

Electrostatic charge must always be anticipated in separation processes if one of the contact surfaces is electrically insulating.

Do other charging mechanisms exist in addition to separation processes?	A charging mechanism which does not involve separation processes is **induction.** It is a physical phenomenon which is characterized by the ability of charges on a conductive surface to be moved by the effect of charges on a neighboring surface (electric field) so that charging results. Typical example: person with insulating shoes in the vicinity of a charged plastic bag.

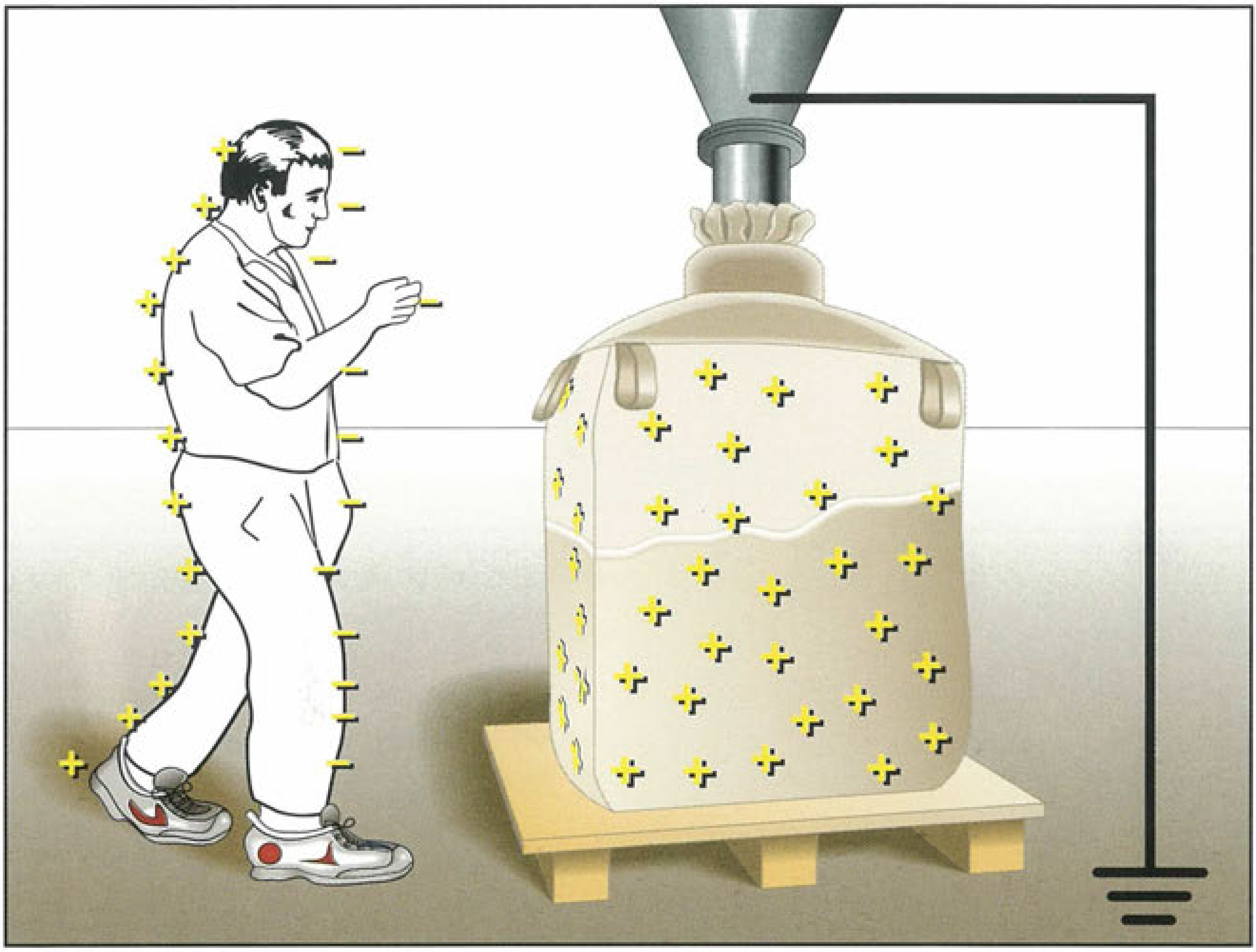


Fig. 10: Charging of a person insulated from ground (nonconductive shoes) by induction

Nongrounded metal parts and persons can also be charged by electric induction phenomena.

Accumulation of charges and charge dissipation

Where can charges accumulate?	Charges can accumulate on/in
	
	• conductive parts electrically isolated from ground, e.g.
	  • on the human body when insulating footwear is worn or the floor can not dissipate charges
	  • on a metal pipe isolated by nonconductive seals
	  • on a metal drum standing on an insulating base
	  • on metal powder contained in an insulating drum.
	
	• surfaces of insulating materials or products, e.g.
	  • on the surface of a plastic bag
	  • on the surface of a plastic pipe
	  • on the surface of an insulating filter cloth.
	
	• insulating liquids, suspensions and emulsions
	
	• deposits of insulating bulk materials
	
	• clouds of charged dust particles and/or droplets.

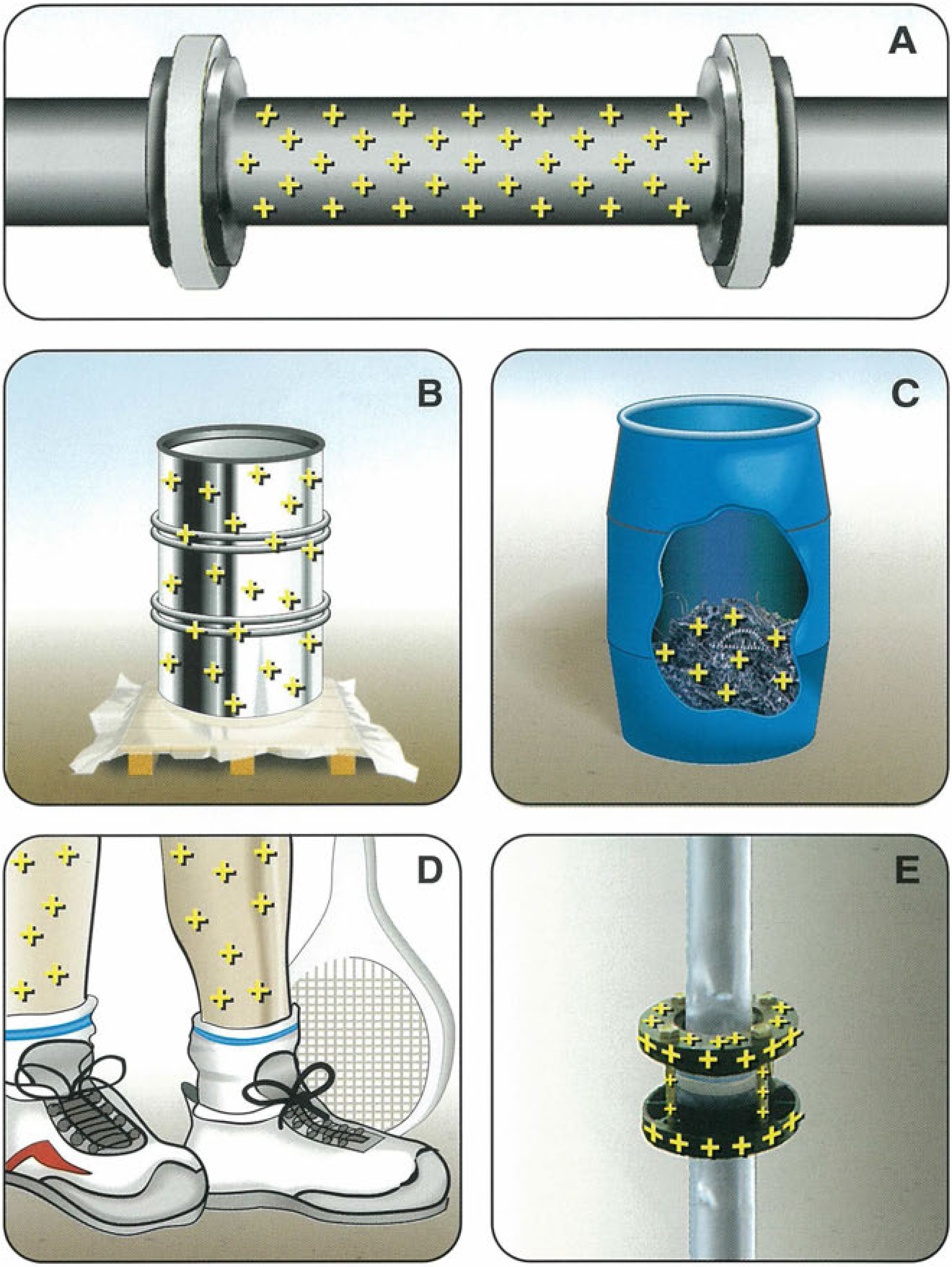


Fig. 11: Examples of charge accumulation on conductive parts electrically insulated from ground – A: pipe section with insulating seals B: metal drum on insulating support C: metal turnings in plastic container D: person with insulating footwear E: metal flange on glass pipe

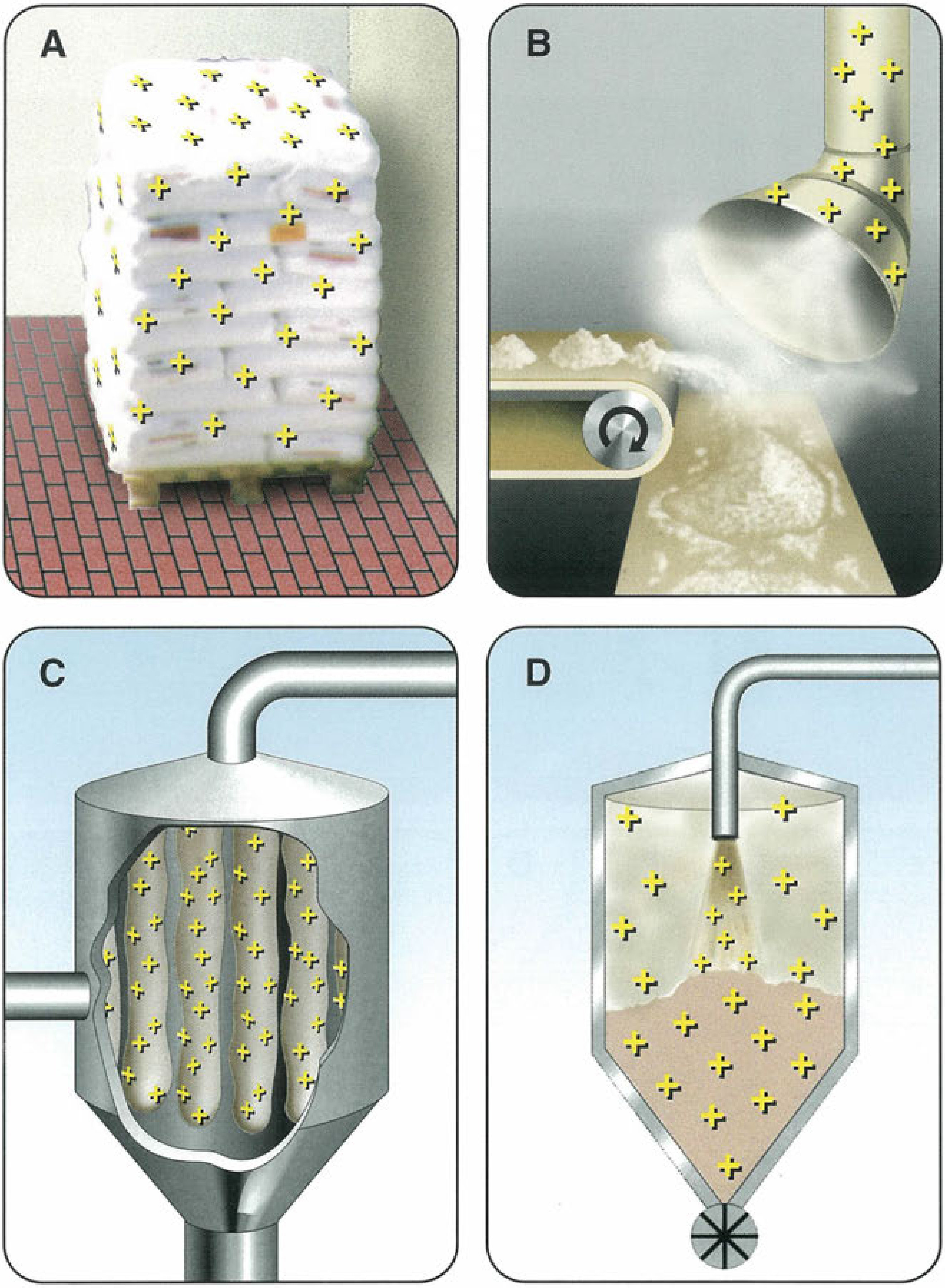


Fig. 12: Examples of charge accumulations on surfaces of insulating materials or products – A: shrink film B: plastic suction device C: nonconductive filter bag D: insulating bulk material

When are charges dissipated?	Charges are dissipated when the charged object is electrostatically conductive and grounded.

What measured quantities are used for the assessment of the electrostatic conductivity (charge dissipation)?	In the assessment of charge dissipation, the electrical resistance is decisive. Depending on the situation to be assessed, different types of resistance are measured: • The **resistivity** is the material-specific resistance of a solid, a liquid or bulked powder (material constant). • The **conductivity** is the reciprocal of the resistivity of a substance (material constant). It is specified primarily for liquids. • The **surface resistance** is used to assess the charge dissipation from the surface of a solid. • The **volume resistance** is the total resistance between 2 points of an object and depends on the material and geometry (e.g. volume resistance between the lining and sole of a shoe). • The **leakage resistance** is the total resistance between a point and ground. It is often called the ground leakage resistance or the leakage resistance to ground.

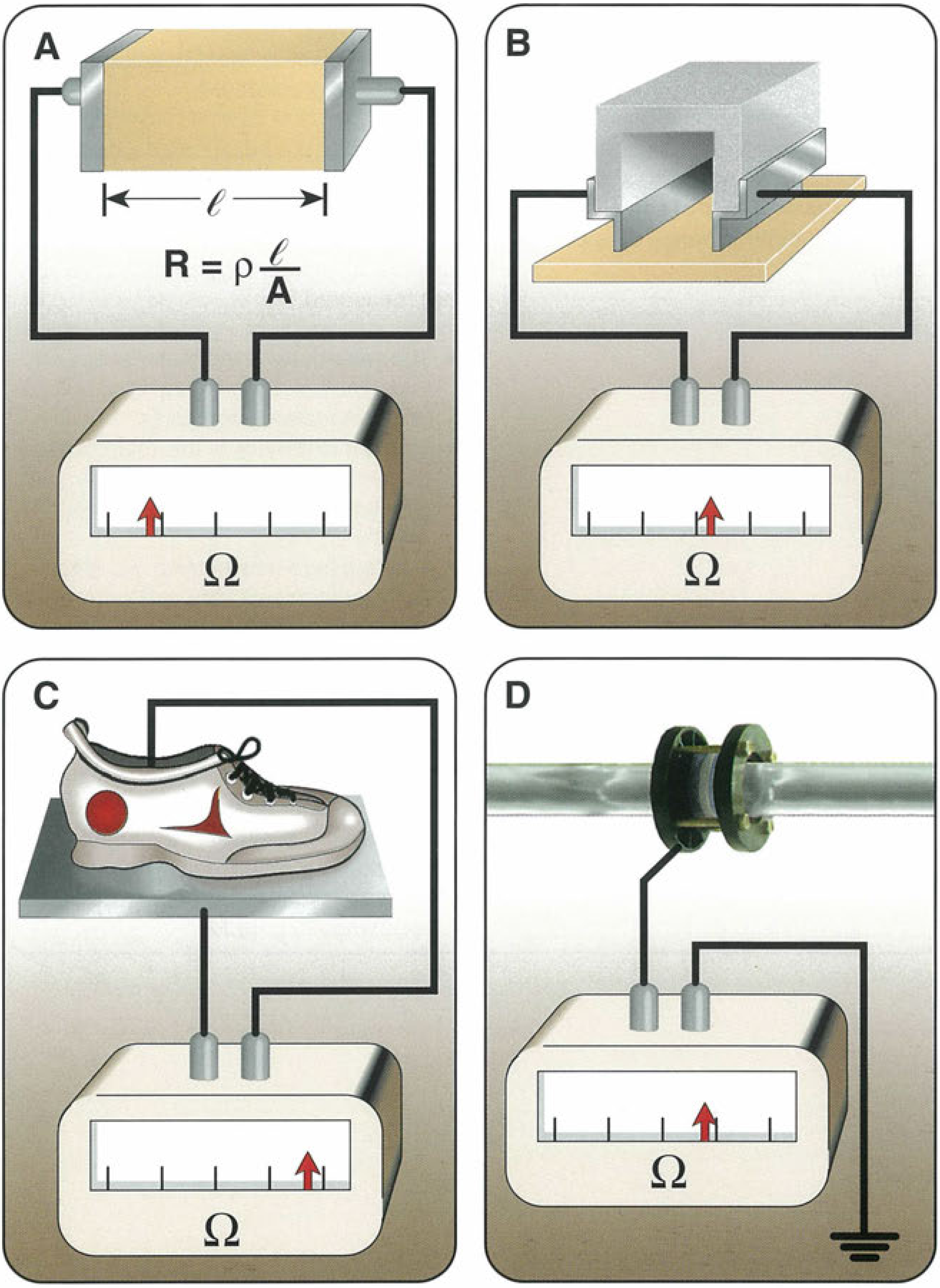


Fig. 13: Examples of measurements to determine resistance
A: resistivity *B: surface resistance*
C: volume resistance of shoes *D: ground leakage resistance*

Are there safe limits for the different types of resistance?

The limit values of the resistance required for hazard-free charge dissipation depend on the type of the resistance (resistivity, surface resistance, etc.). Further, different values for the limits may be specified in different national guidelines. The following standard values have proved their worth in actual practice:

- Grounding of plant units: Leakage resistance to ground (ground leakage resistance) $\leq 10^6\ \Omega$
- Grounding of persons: Volume resistance of the footwear and ground leakage resistance of the floor $\leq 10^8\ \Omega$

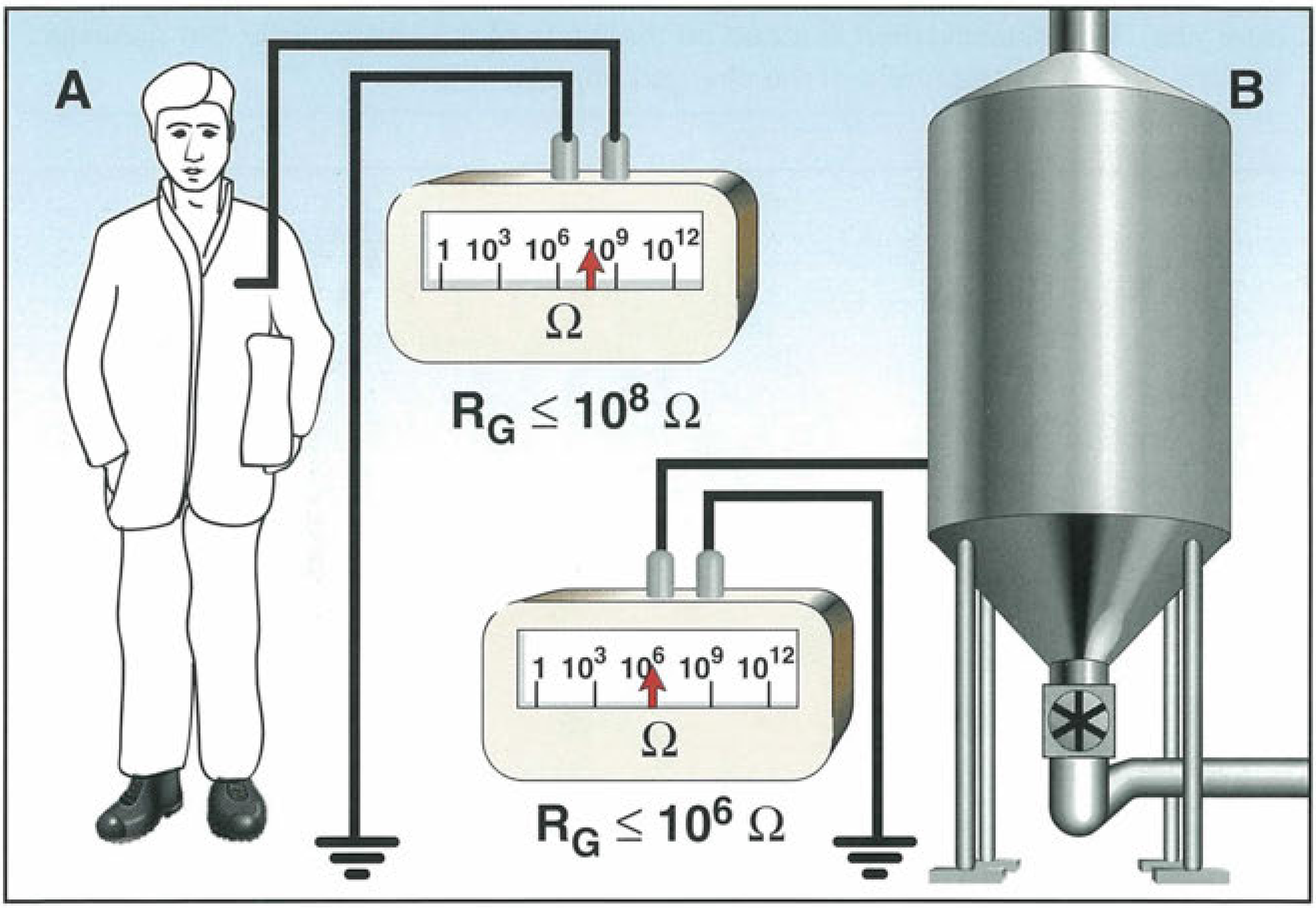


Fig. 14: Upper limit values for ground leakage resistances in practice.
A: grounding of persons B: grounding of plant units

Resistance measurements for the assessment of electrostatic hazards require special measuring instruments and must be performed only by trained personnel.

Types of discharge and incendivity

If the electric field becomes very powerful as a result of a high charge density (charge accumulation in a small space), a discharge occurs when the breakdown field strength is reached. To assess the incendivity (ignition effectiveness) of a discharge, the energy released in the discharge process is decisive. Depending on the operational situation, the energy released may be only a fraction of the total amount of energy contained in the accumulated charge. The conditions under which all or only a fraction of the stored energy is released by a discharge process are known from experience and theoretical considerations. Discharges can be classified into different types which can be assigned various energy values and hence incendivities (equivalent energies). This classification is made on the basis of the conductivity, the geometry and the spatial arrangement of the charged objects.

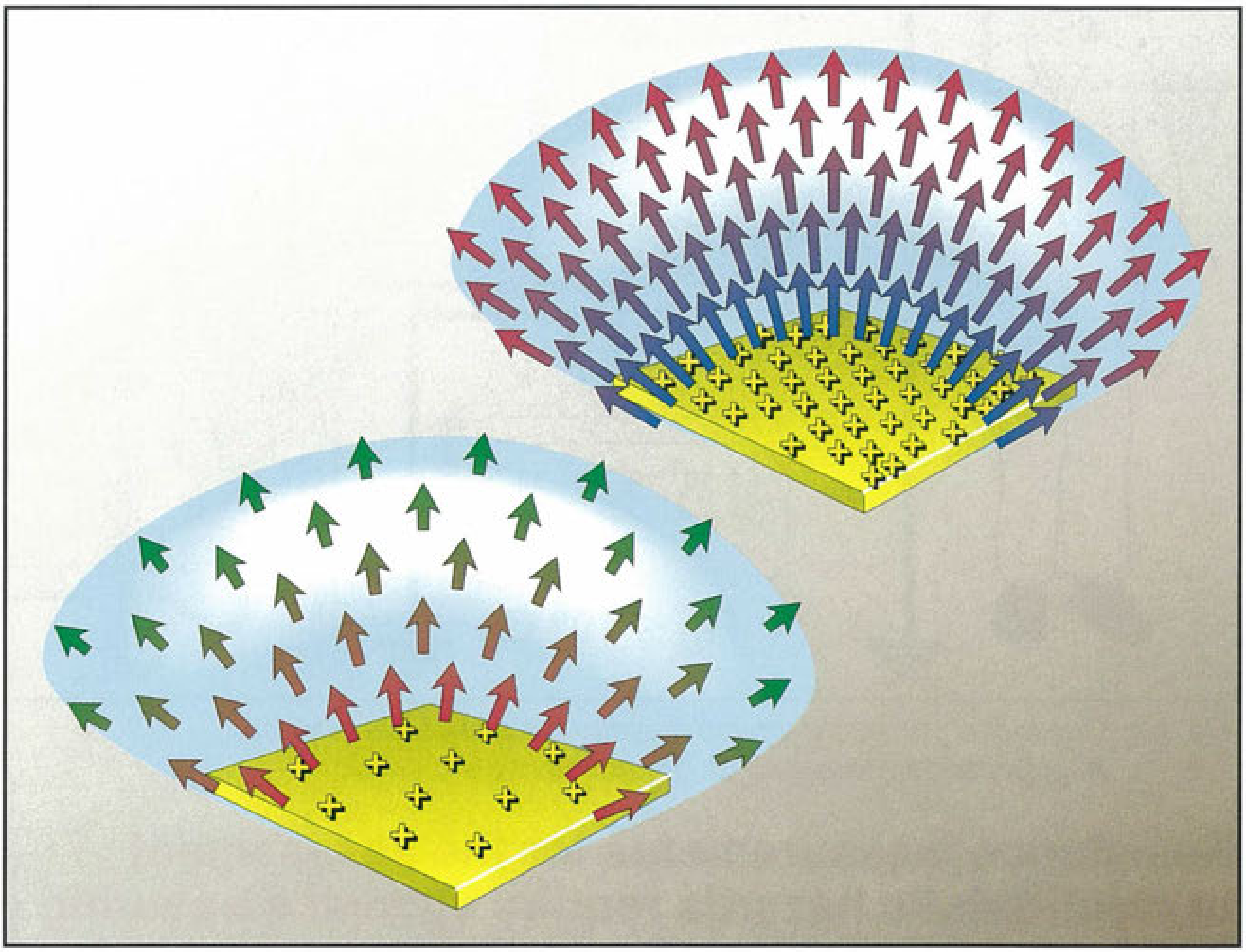


Fig. 15: Relation between charge density and field strength – the higher the charge density, the higher the field strength (length of arrows)

When does a discharge occur?	A discharge occurs when the electric field reaches the breakdown field strength as a result of a high space or surface charge density (charge accumulation).

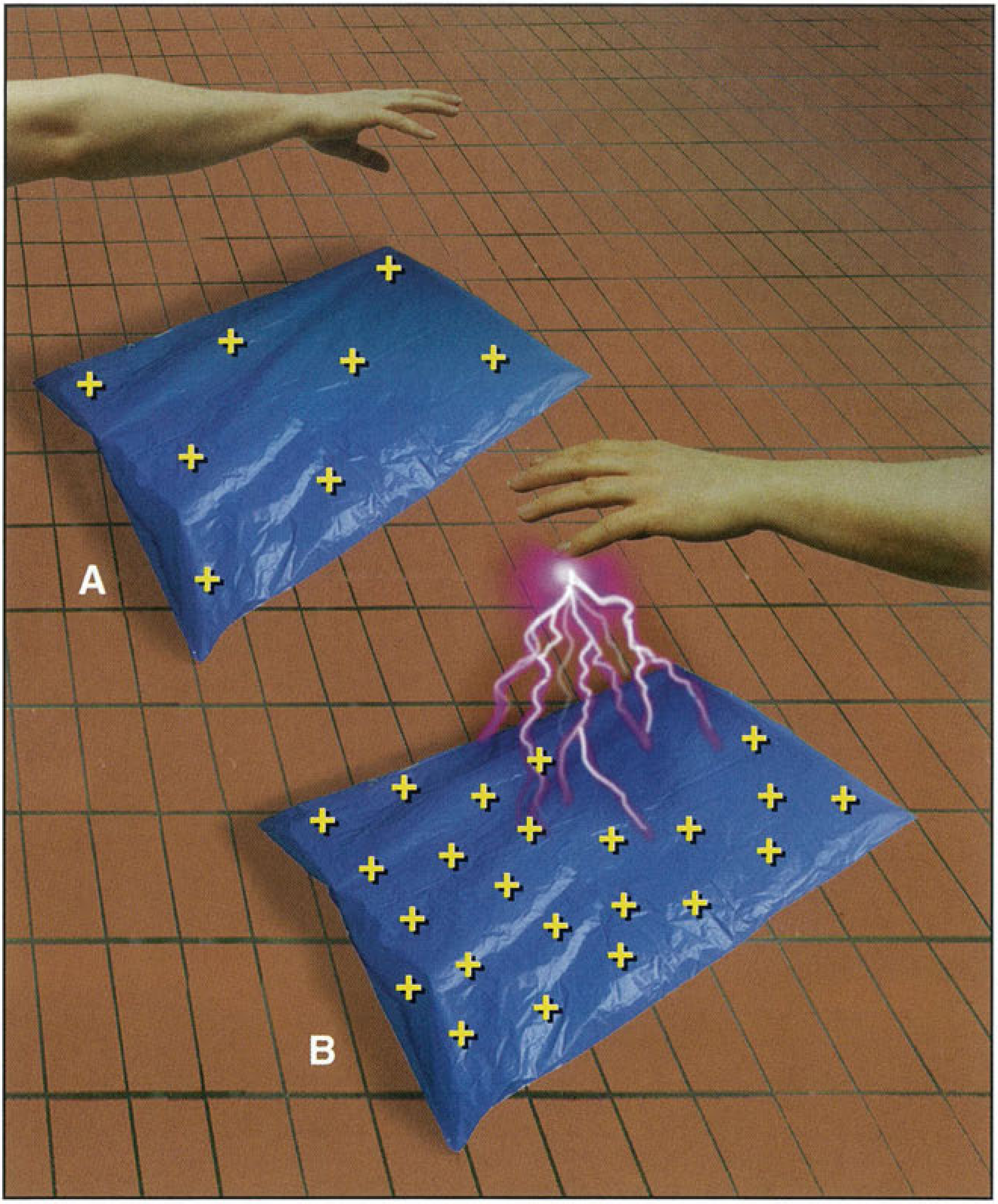
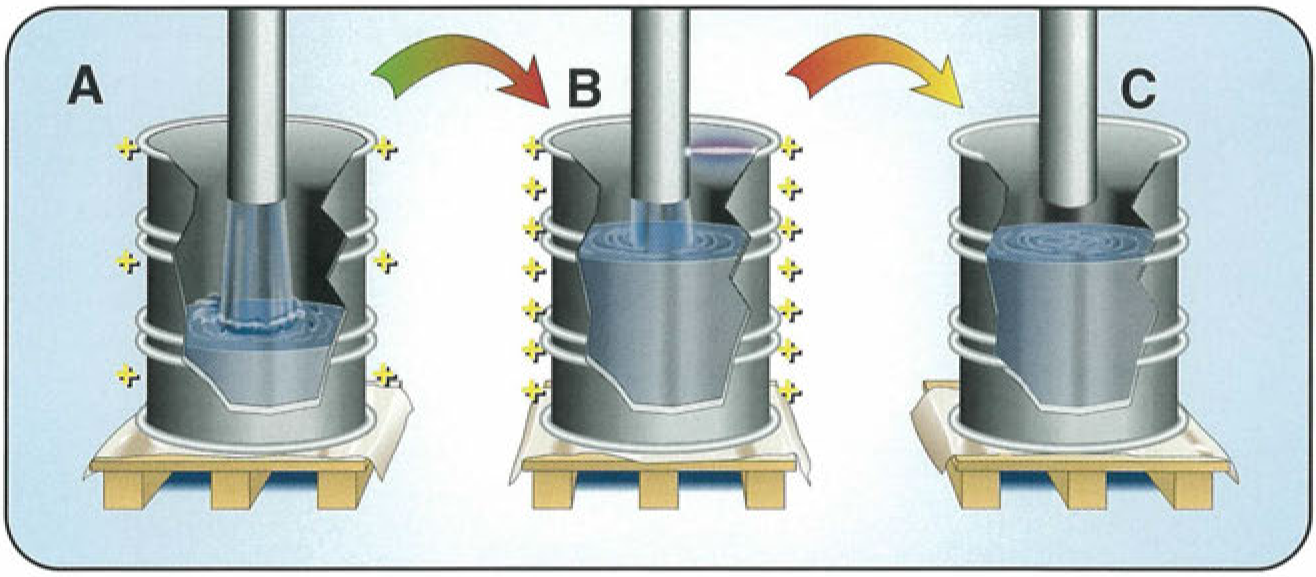


Fig. 16: Relation between field strength and discharge
A: low field strength ➪ no discharge   B: high field strength ➪ discharge

How incendive is a discharge?

Depending on the operational situation, discharges with different energy can occur. Their incendivity is determined by the amount of energy released. The discharges can be divided into different types with different incendivities.



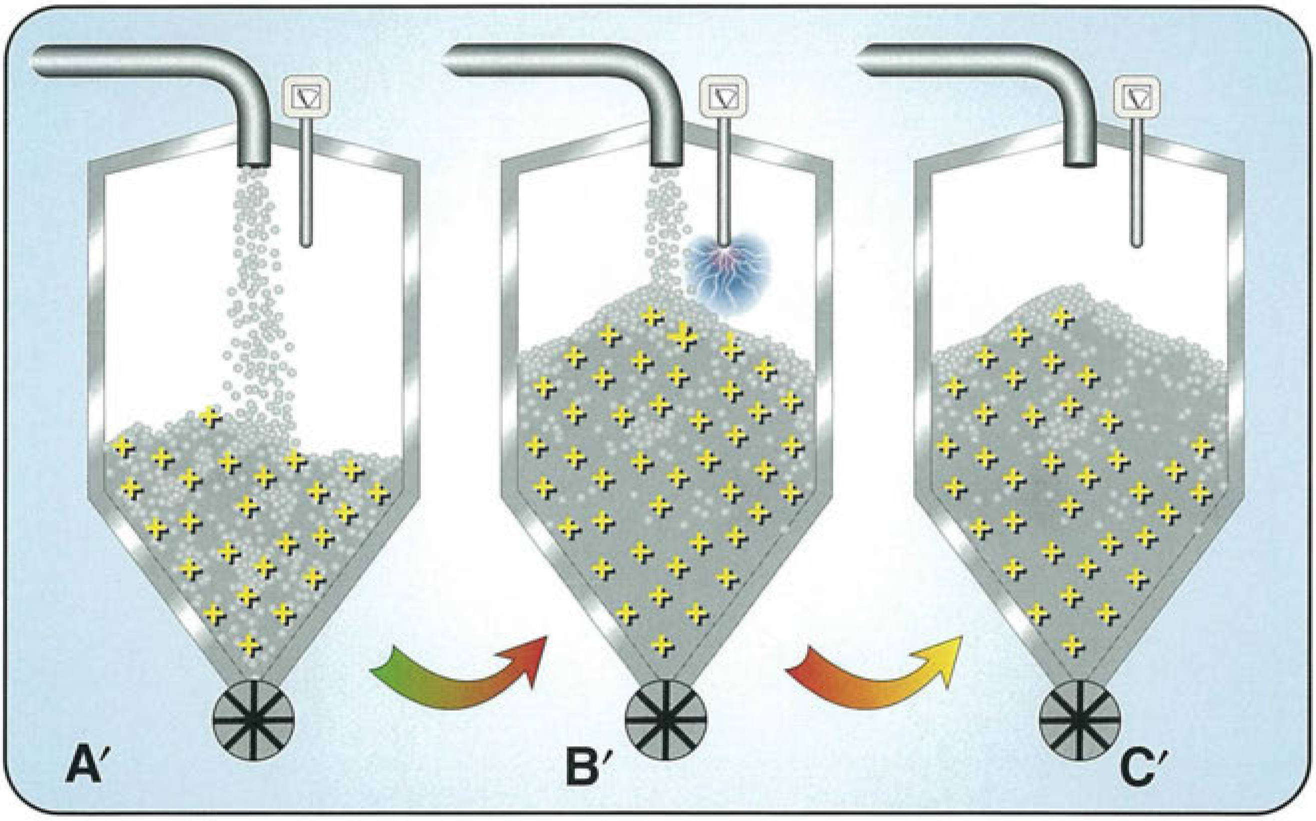


Fig. 17: Different types of discharge with metal drums and insulating product in silos – A: separation process and charging B: spark discharge C: complete charge dissipation A' : separation process and charging B': brush discharge C': locally restricted charge dissipation

How sensitive are explosible mixtures to ignition?	The ignition sensitivity of a substance with regard to its ignition by discharges resulting from electrostatic charging is determined by the minimum ignition energy of the explosible mixture in question.

What is the minimum ignition energy (MIE)?	The minimum ignition energy of an explosible mixture is understood to mean the lowest energy in the form of a capacitor discharge needed to just ignite the most ignitable mixture of a combustible material and air under standard conditions.

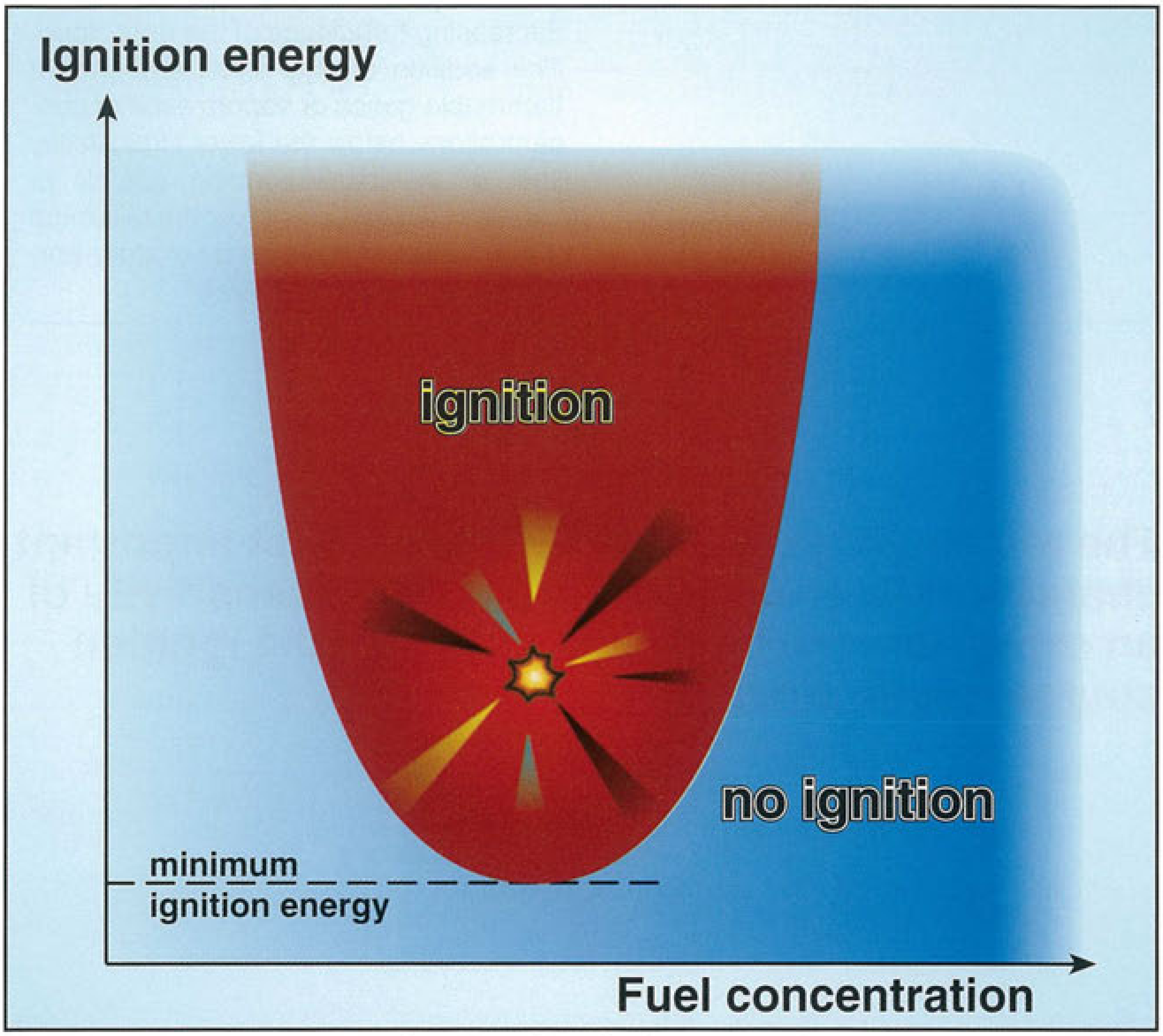


Fig. 18: Ignition energy as a function of the fuel concentration

What are the minimum ignition energies of explosible fuel /air mixtures?	The minimum ignition energy of typical solvent vapor/air mixtures is ca. 0.3 to 1 mJ. Very easily ignitable substances such as acetylene, hydrogen and carbon disulfide have MIE values less than 0.025 mJ in admixture with air. The minimum ignition energy of combustible dusts covers a wide range. While some dusts have a minimum ignition energy less than 10 mJ, in certain cases the value of this characteristic may be even lower than 1 mJ. The minimum ignition energy of a dust/air mixture always decreases with increasing fineness and dryness of the product as well as with increasing temperature and decreasing turbulence of the dust cloud. The addition of only small amounts of flammable gases or vapors even in concentrations below the lower explosibility limit of the corresponding gas/air or vapor/air mixture can lower the minimum ignition energy of a dust/air mixture (formation of a hybrid mixture).

The minimum ignition energy is the most important characteristic to describe the ignition sensitivity of an explosible mixture with respect to the ignition source "static electricity".

How incendive are discharges?	The incendivity of a discharge with respect to the ignition of an explosible mixture is determined by the minimum ignition energy (MIE) of the explosible mixture and the incendivity (energy released) of a discharge.

What types of discharge are known?	The types of discharge hitherto observed in practice are: • Spark discharge • Brush discharge • Corona discharge • Propagating brush discharge • Cone discharge Further, lightning-like discharges of the type observed in the ash clouds formed when a volcano erupts are conceivable although they have never been detected in dust clouds generated under industrial conditions.

Type of discharge	Effectiveness as an ignition source for mixtures with air of		
	hydrogen, acetylene, etc. MIE $\leq$ 0.025 mJ	solvent vapors MIE > 0.025 mJ	dry combustible dusts MIE > 1 mJ
Spark	+	+	+
Brush	+	+	(-)[1]
Propagating brush	+	+	+
Corona	(+)	-	-
Cone	+	+	+

[1] Ignition of dusts highly sensitive to ignition can not be excluded with certainty

Table 1: Incendivity of various types of electrostatic discharge

What is a spark discharge?

A spark discharge is a discharge between two conductive objects at different potentials. It occurs when the electric field in the space between the 2 conductive objects reaches the breakdown field strength.

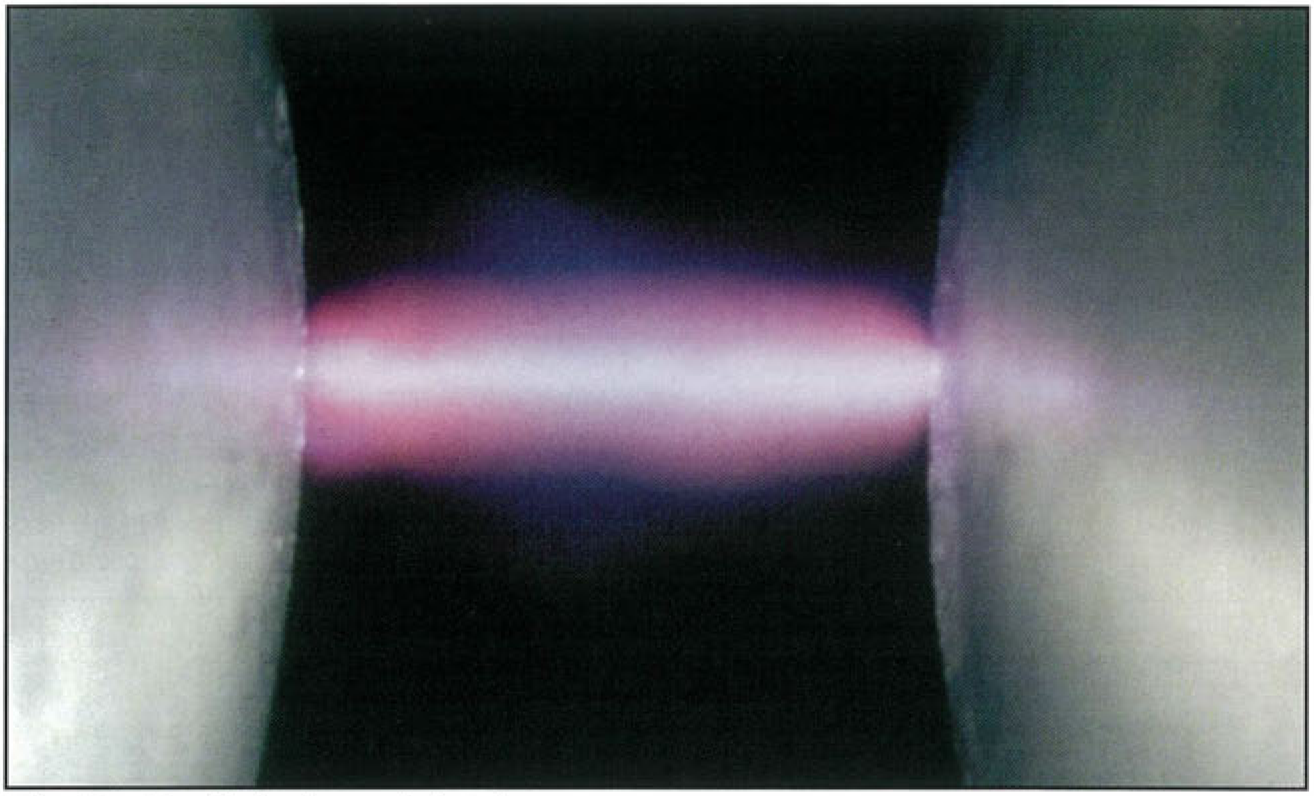


Fig. 19: Spark discharge (photo)

When do spark discharges occur in industrial practice?

Spark discharges usually occur in industrial practice when conductive objects (plant units, metal drums, products, persons) which are not grounded are charged and when a suitable spark gap is present. This is the case, for instance, if a conductive, grounded object is in the vicinity and the breakdown field strength in the intervening space is exceeded.

Spark discharges can occur with, e.g.

- a conductive length of pipe isolated by seals
- a person with insulating footwear
- a metal drum on an insulating base
- a conductive liquid in an insulating plastic drum.

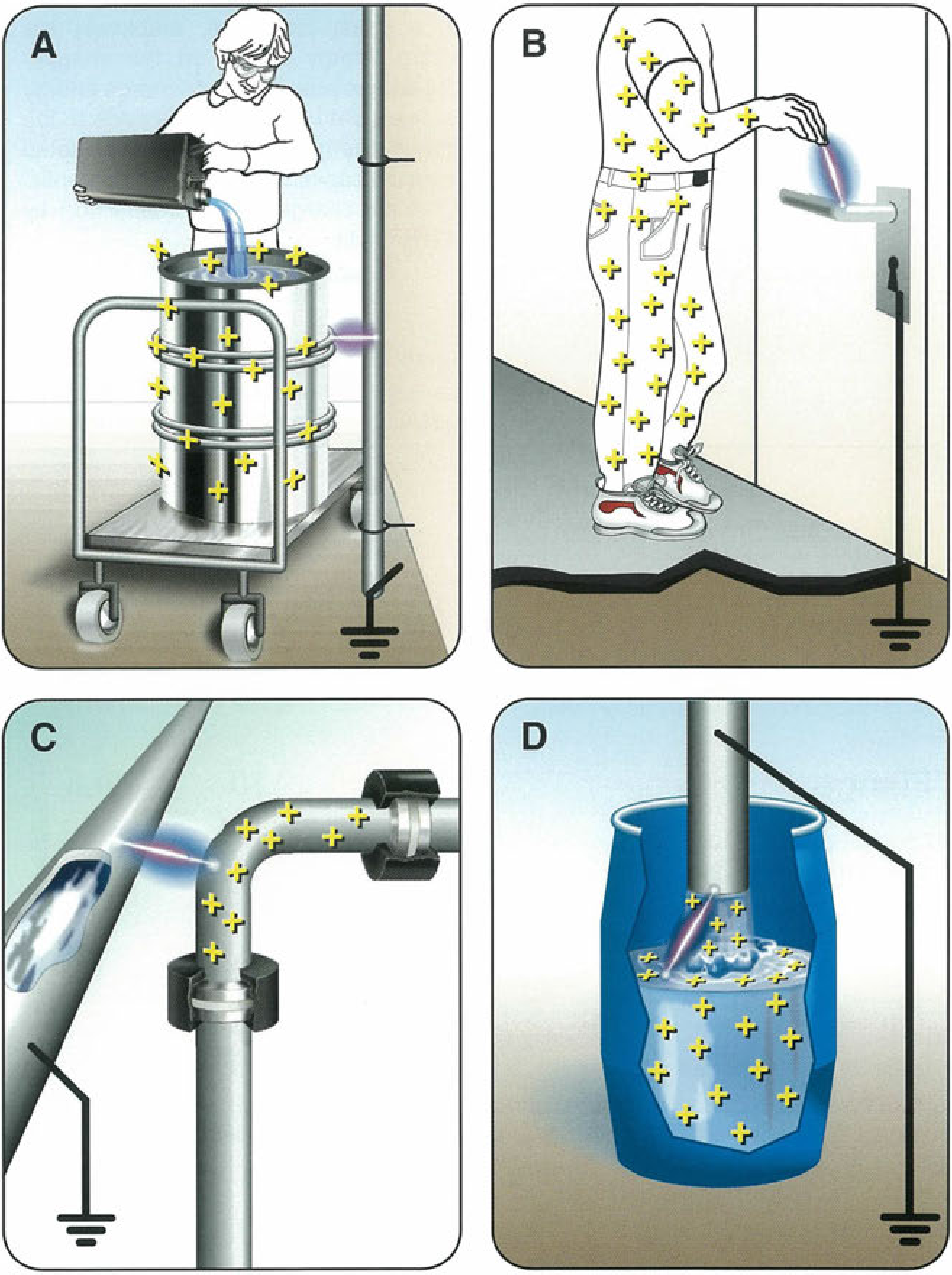


Fig. 20: Examples illustrating the occurrence of spark discharges in practice
A: metal drum insulated from ground B: person insulated from ground by shoes C: pipe elbow isolated by seals D: conductive liquid insulated by plastic container

How incendive are spark discharges?

In a spark discharge, practically the entire energy stored on the charged object is released. The discharge energy W therefore virtually corresponds to the stored energy, which can be calculated from the capacitance C and the potential U of the charged object (capacitor) by the formula

$$W = \tfrac{1}{2} C \cdot U^2$$

Spark discharges must therefore always be regarded as incendive for explosible gas/air, vapor/air and dust/air mixtures.

Charged object	Capacitance C [pF]	Potential U [kV]	Energy W [mJ]
Flange	10	10	0.5
Small container (50 l)	50	8	2
Person	150	12	11
Metal drum (200 l)	200	20	40

Table 2: Typical values for the energy of spark discharges in practice

How can spark discharges be avoided?

Spark discharges can be avoided by grounding all conductive objects (plant units, drums, products, persons, etc.).

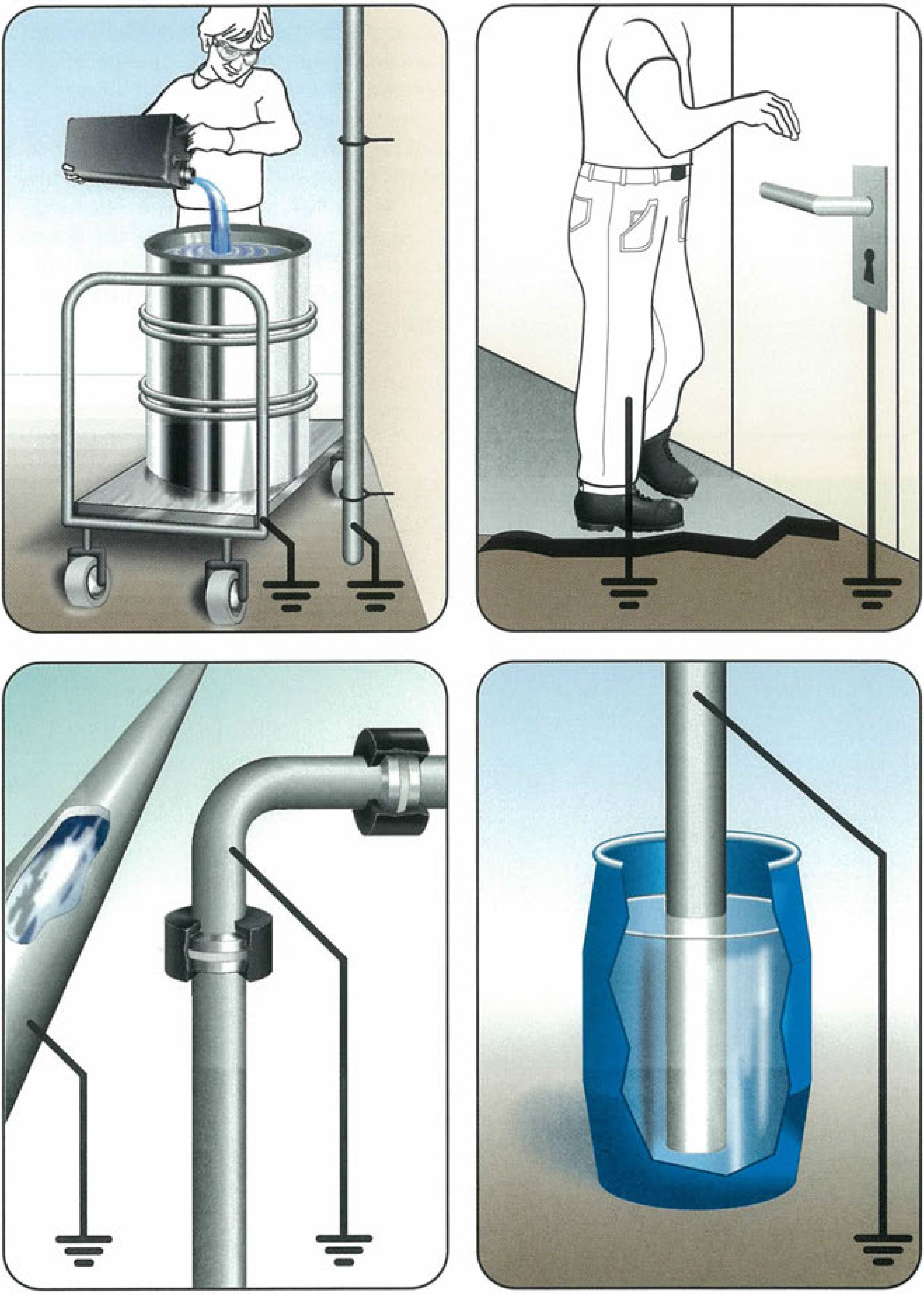


Fig. 21: Examples illustrating the avoidance of spark discharges by grounding all conductive parts and products (cf. Fig. 20)

What is a brush discharge?

Brush discharges can occur when a conductive, grounded and curved object (electrode) with a radius of curvature typically between 5 and 50 mm is exposed to a high electric field, e.g. emanating from a highly charged surface of a nonconductive material. The discharge is propagated from the site of the greatest curvature (highest field strength) into the intervening space as a bright discharge channel which after a few millimeters changes in appearance to fine branches (hence the name brush discharge).

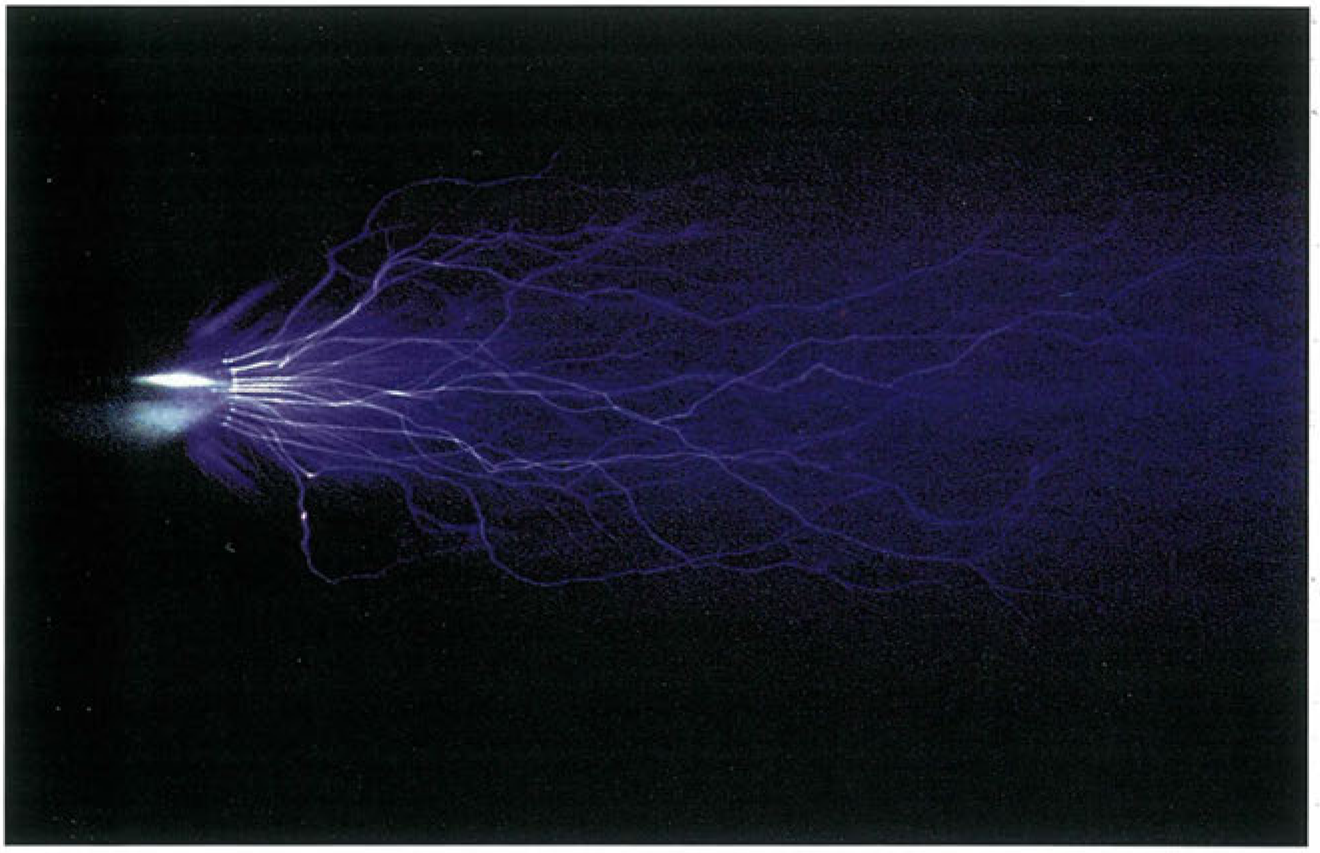


Fig. 22: Brush discharges (photo)

When do brush discharges occur in industrial practice?

For a brush discharge to occur, it is immaterial how the high electric field is generated. The following are typical examples taken from industrial practice:

- Approach of a conductive electrode, such as a tool or human finger tip to a highly charged insulator surface (e.g. plastic pipe for the conveyance of liquids or dusts, plastic bag, plastic drum, filter bag, film web or conveyor belt).
- Emptying of solids out of a plastic bag or shaking out a plastic bag in the vicinity of metal fittings (e.g. above the manhole of a reaction vessel).
- Addition of a nonconductive liquid at a high rate to a tank and the approach of the charged liquid surface to internal conductive, grounded fittings.
- Lowering of a conductive, grounded sampling can onto a highly charged liquid surface for sampling purposes.
- Projection of conductive, grounded internal fittings into a highly charged dust cloud or a highly charged cloud of droplets.
- Addition of insulating, powdered product to drums, vessels or silos, approach of the highly charged dust heap to internal fittings or lowering of a conductive, grounded sampling can for sampling purposes or a level probe to determine the level.
- Projection of flagpoles, antennae, ship masts or ice picks into high atmospheric fields (St. Elmos fire during thunderstorms).

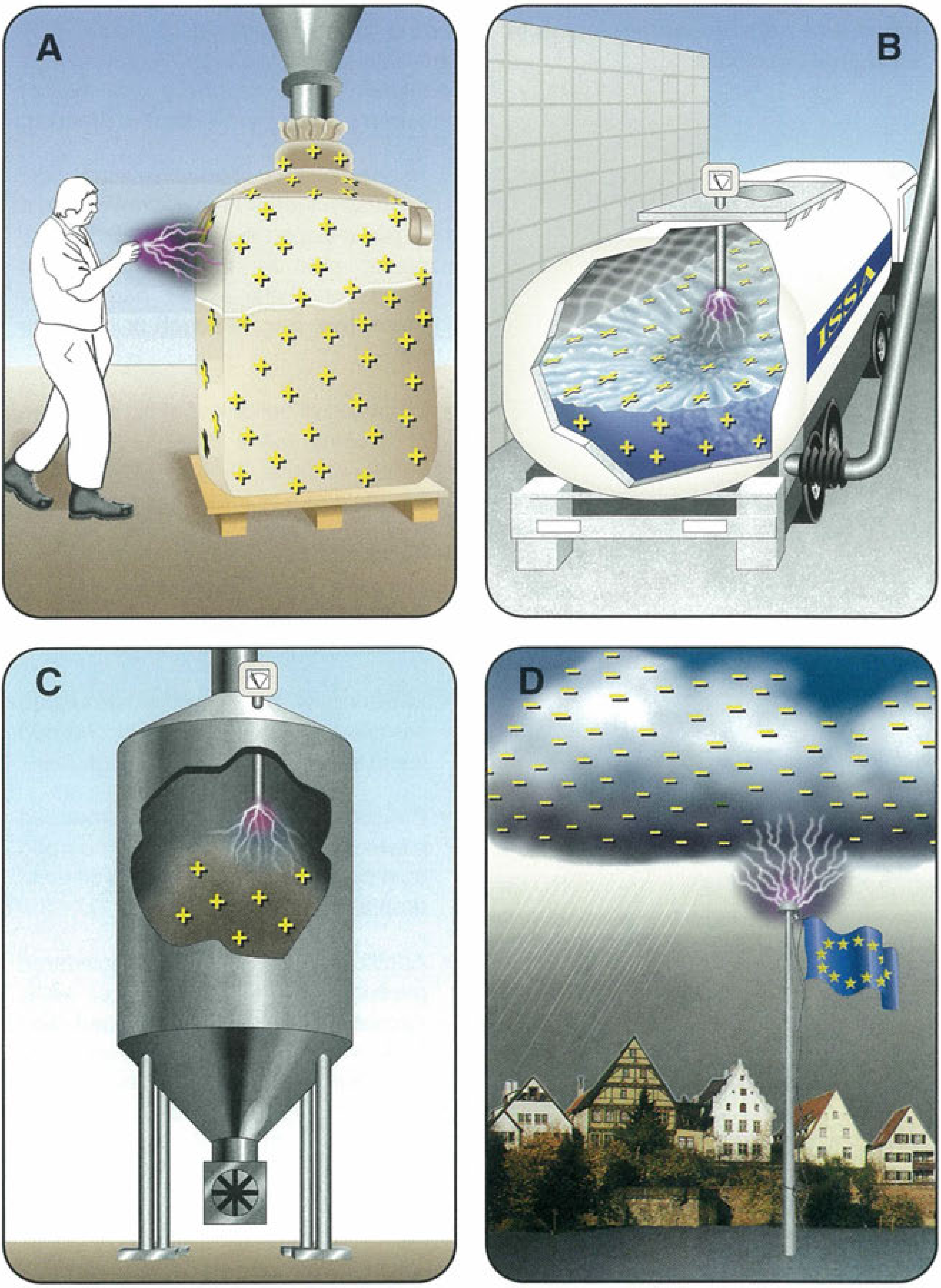


Fig. 23: Examples of brush discharges in practice – A: through charged bulk material container B: through charged insulating liquid C: through charged dust cloud D: through charged storm cloud

How incendive are brush discharges?

The energy of brush discharges is difficult to determine directly. Measured values for the equivalent energy determined with gases are in the range of a few millijoules. While our present knowledge suggests that an ignition of dust/air mixtures is not expected with brush discharges, the ignition of readily ignitable dusts by such a discharge can not be excluded with certainty. On the other hand, the ignition of gas/air or vapor/air mixtures by brush discharges must be expected.

How can brush discharges be avoided?

Brush discharges can be avoided by eliminating high electric fields through, e.g. use of conductive materials and grounding them, limiting the surface of nonconductive objects or use of shielding measures.

Fig. 24: Avoidance of brush discharges through use of conductive, grounded packaging containers (no plastic bags, no plastic containers)

What is a corona discharge?

The corona discharge can be regarded as a special case of a brush discharge. If the radius of curvature of the grounded electrode introduced in a high electric field is very small (< 1 mm), the field will be disturbed only in the immediate vicinity of the tip. This gives rise to a very weak discharge restricted to the neighborhood of the tip which usually propagates continuously. There is no need to go into further details of corona discharges as under the same conditions and assuming a worst-case scenario, brush discharges which have a much higher energy can also occur.

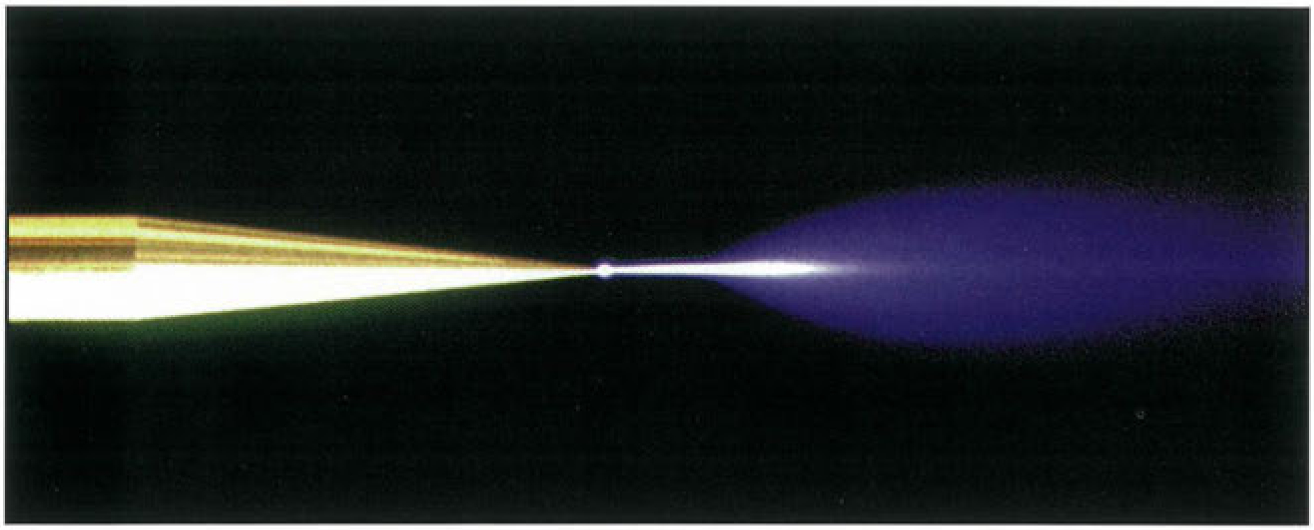


Fig. 25: Corona discharge (photo)

What is a propagating brush discharge?

A propagating brush discharge is a discharge along the surface of a thin dielectric (insulating) layer, very highly charged on both sides with charges of opposite polarity. The dielectric layer may be in the form of a separate sheet or a coating on a metal surface.

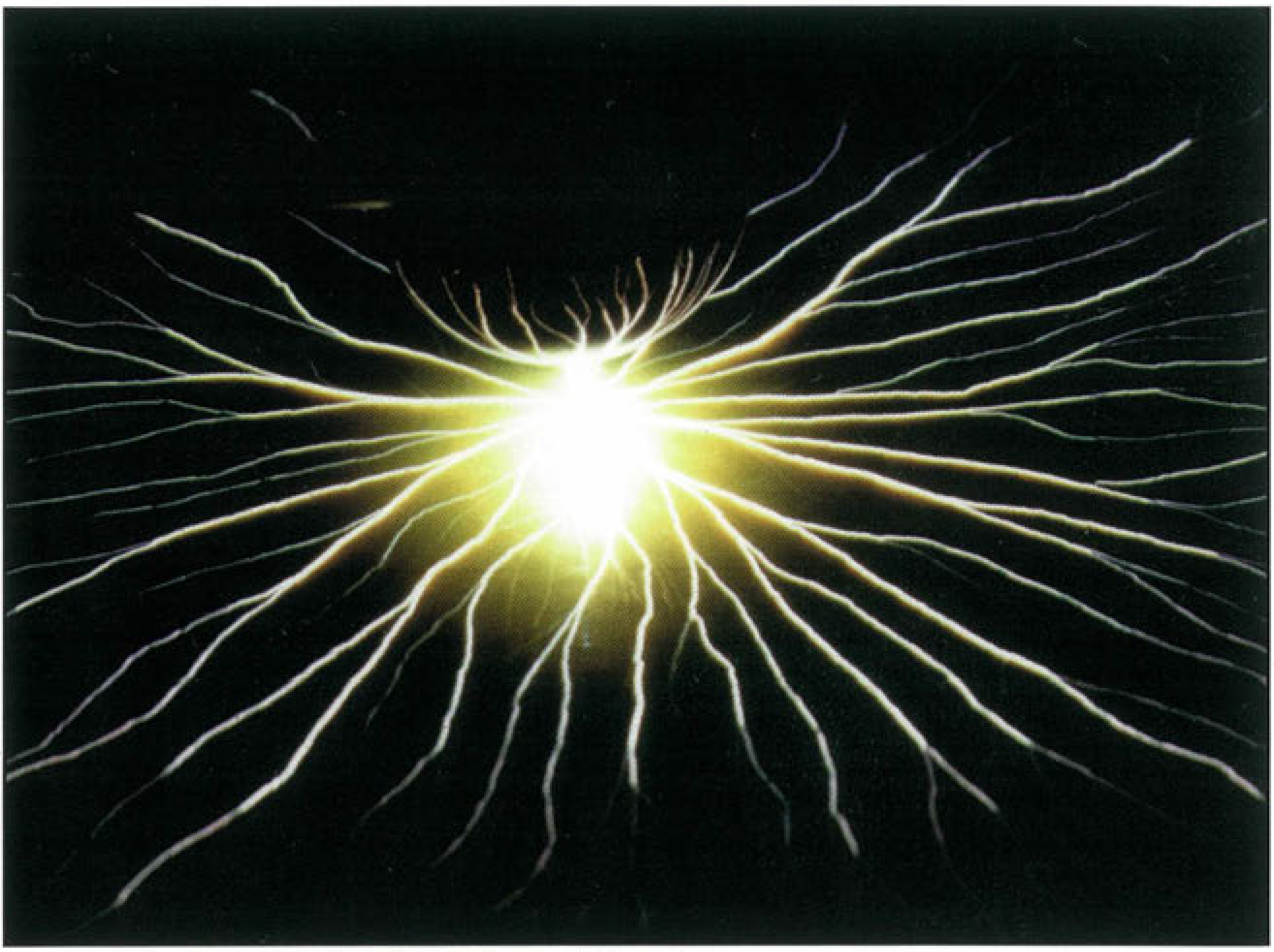


Fig. 26: Propagating brush discharge (photo)

How do propagating brush discharges occur in industrial practice?

Charging processes with high separation rates together with insulating materials of high dielectric strength (high electric breakdown strength) are needed. Typical combinations occur in the following operations:

- pneumatic dust conveying at a high rate through an insulating pipeline or through a conductive pipeline with an insulating inner coating.

- conveying of insulating liquids at a high rate through an insulating pipeline or through a conductive pipeline with an insulating inner coating.

- continuous impingement of fresh dust particles on the same insulator surface or on a metal surface with an insulating coating (e.g. in a dust separator or on the front windshield of an aircraft when flying through a cloud containing ice or dust particles).

- rapidly circulating conveyor belts or drive belts which are either insulating or coated on one side with conductive material.

- filling of large drums and silos with highly charged, insulating product.

Separation processes during manual operations (e.g. rubbing insulating surfaces, pouring powder out of a plastic bag), the surface charge densities found are usually not high enough to cause formation of propagating dust discharges.

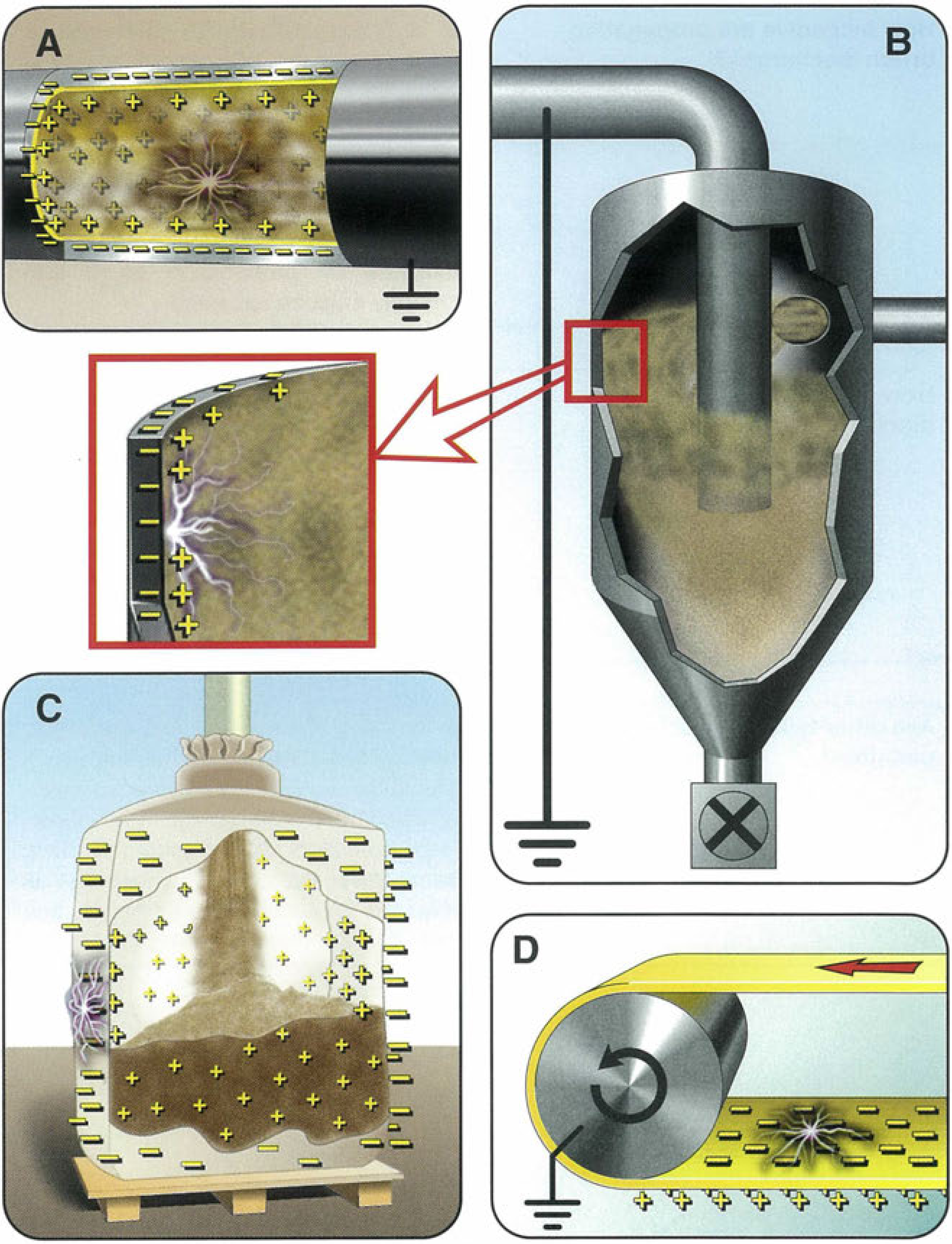


Fig. 27: Examples of propagating brush discharges in practice
A: in a pipeline with insulating inner coating
B: in a dust separator with insulating inner coating
C: on an insulating bulk material container
D: on a high speed, insulating conveyor belt

How incendive are propagating brush discharges?

In a propagating brush discharge, a large part of the total stored energy is released. The stored energy can be calculated by assuming mathematical correlation with a plate capacitor. Even for charged areas of 0.1 m^2 it can amount to several joules. Ignition of explosible gas/air, solvent vapor/air and dust/air mixtures by propagating brush discharges must be expected.

How can propagating brush discharges be avoided?

Propagating brush discharges can be avoided by the use of conductive materials or materials of low dielectric strength. Insulating layers (in the form of a coating on a metal surface or a self-supporting wall) with a breakdown voltage of less than 4 kV can be used. No propagating brush discharges will occur at such layers.

Are other types of discharge possible?

In the filling of large silos and containers with highly insulating bulk materials (e.g. pneumatic addition of polymers), isolated discharges at the bulked material surface, so-called cone discharges, have been observed. Special knowledge is required to assess the formation and incendivity of these discharges.

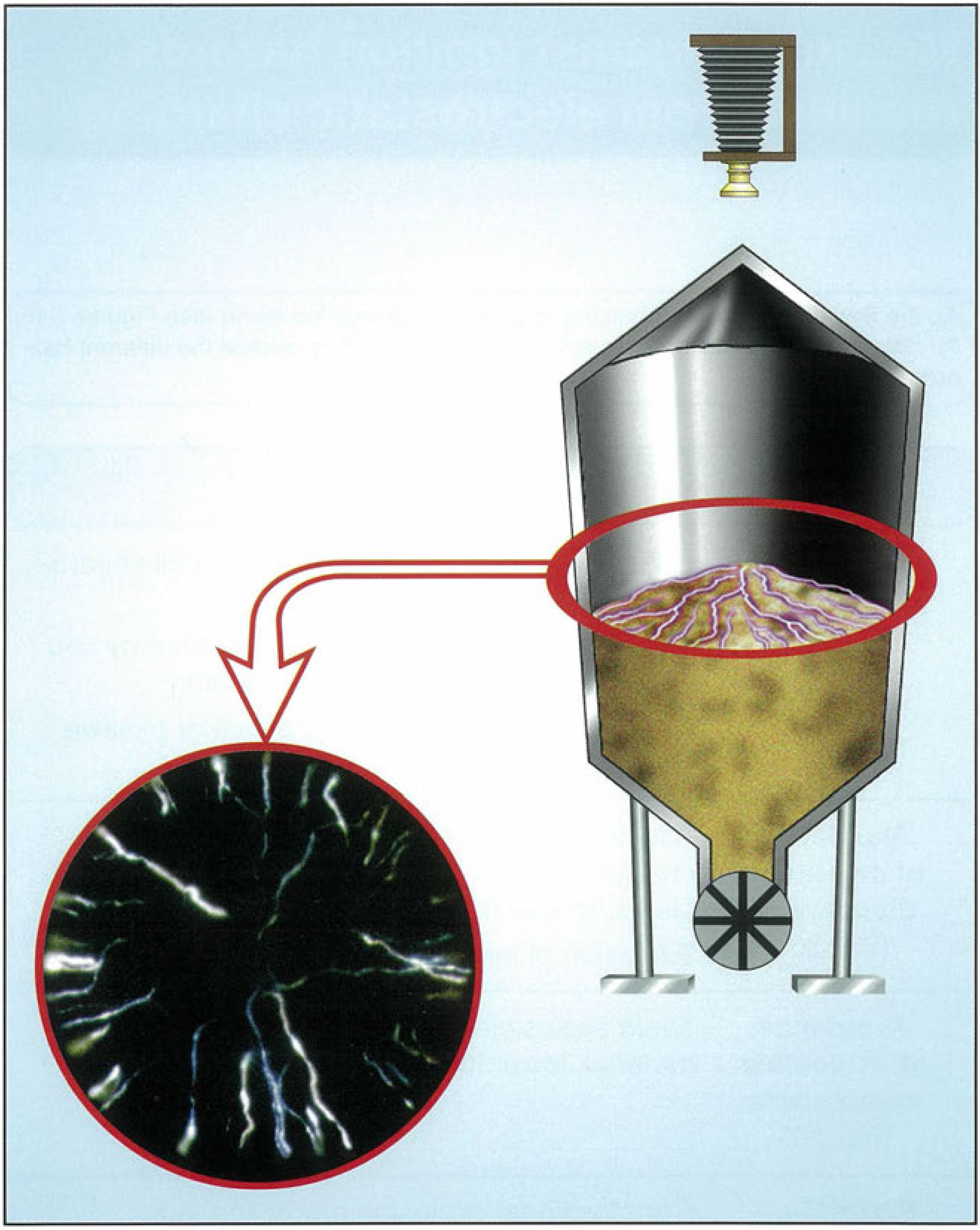


Fig. 28: Cone discharges (photo)

Measures against ignition hazards resulting from electrostatic charging

As the flow chart from the charging to ignition is always the same (see Figures 5 to 7), different categories of measures can be considered to combat the different hazards.

Goal	Measures
Avoidance of high charges (Fig. 29)	Keep charging rate low by restricting all separation and conveying rates Assist nonhazardous charge dissipation by use of conductive materials and grounding Neutralize charges by use of active or passive ionizers
Avoidance of incendive discharges (Fig. 30)	Assess the incendivity of the possible discharges and the ignition sensitivity of the possible explosible mixtures Exclusion of incendive discharges
Avoidance of explosible atmosphere (Fig. 31)	Avoid explosible concentrations of flammable material, lower the oxygen content (inerting)
Restriction of explosion effects to a tolerable level (Fig. 31)	Constructional explosion protection, e.g. explosion venting, explosion suppression

Table 3: Protection measures

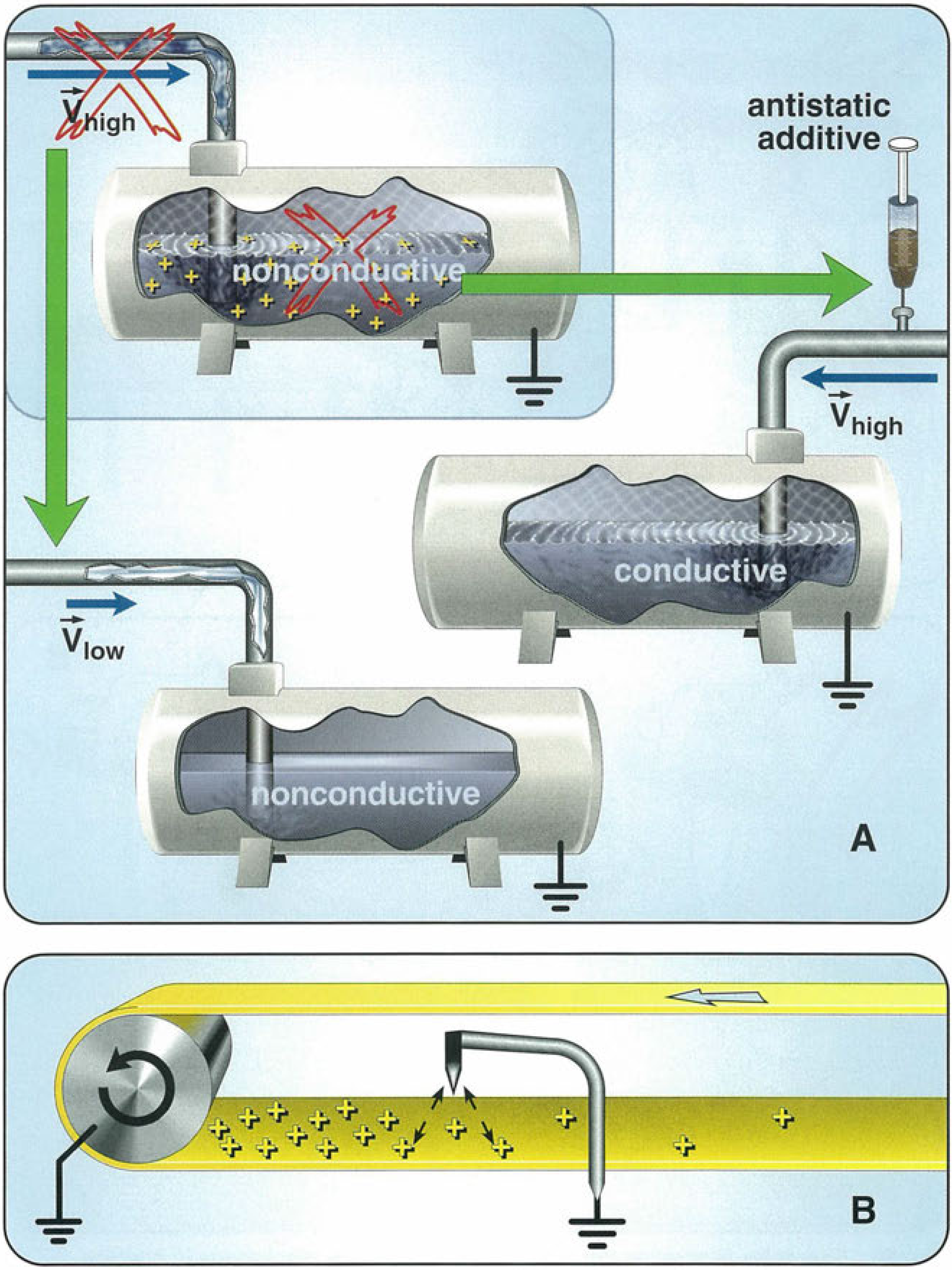


Fig. 29: Examples illustrating the avoidance of high charges in practice
A: with nonconductive liquids: increase the conductivity by addition of additive or restrict the flow rate
B: with insulating solid surfaces: charge neutralization

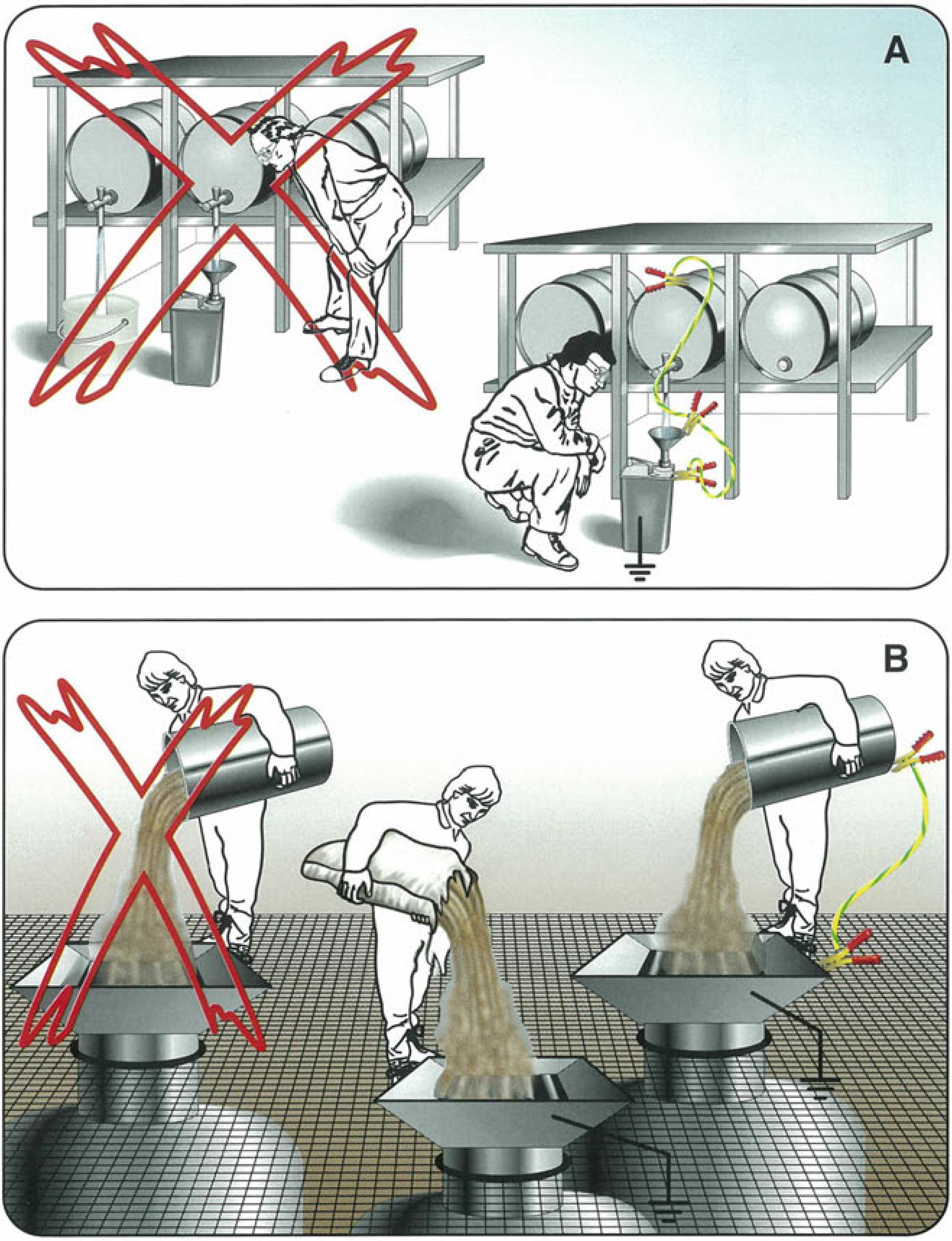


Fig. 30: Examples illustrating the avoidance of incendive discharges in practice
A: transfer of flammable liquids: use only conductive containers and ground
B: filling of combustible dusts: ground all conductive parts; small plastic containers, e.g. bags, bulk containers and drums are admissible in the absence of flammable gases or vapors

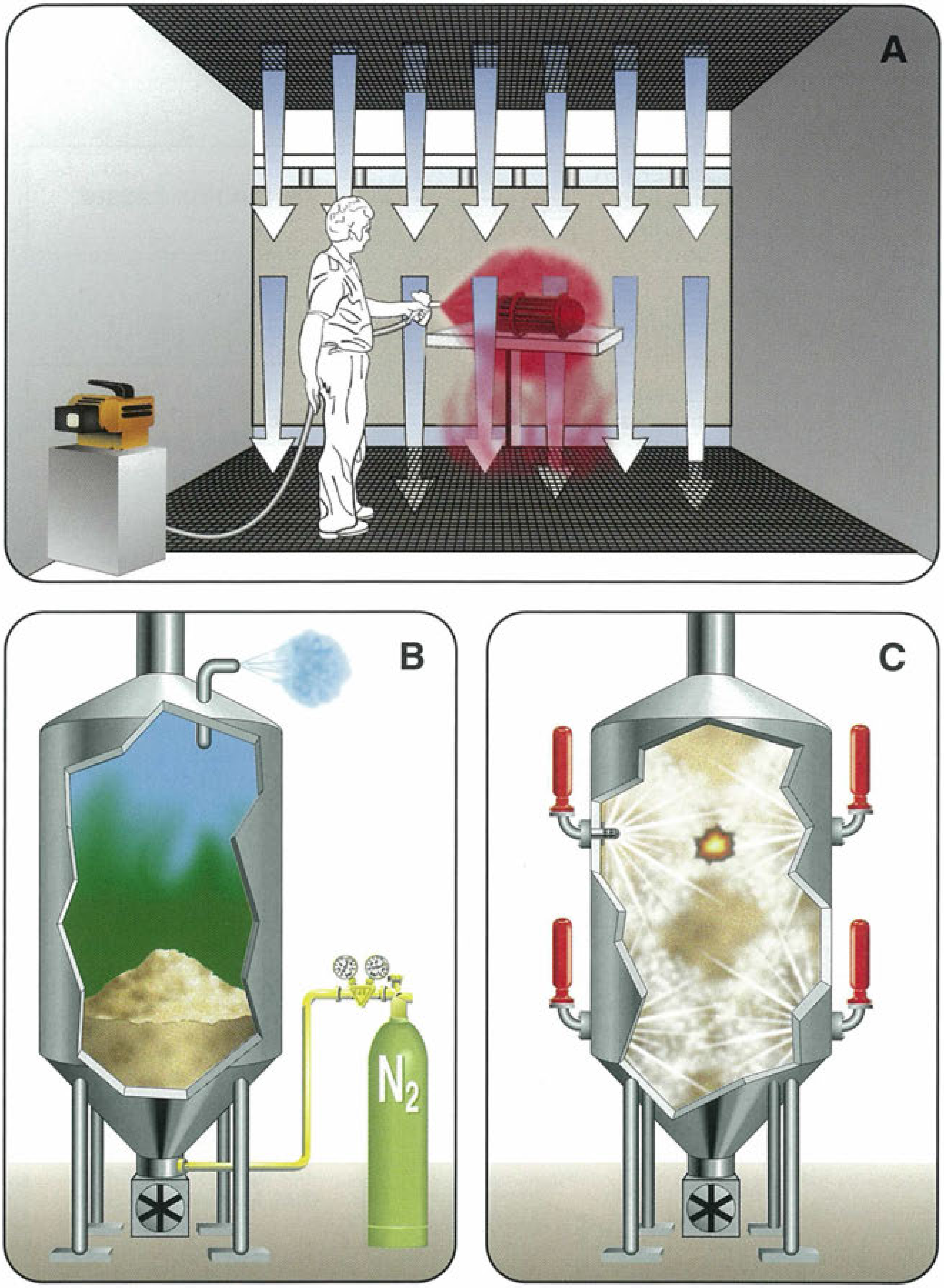
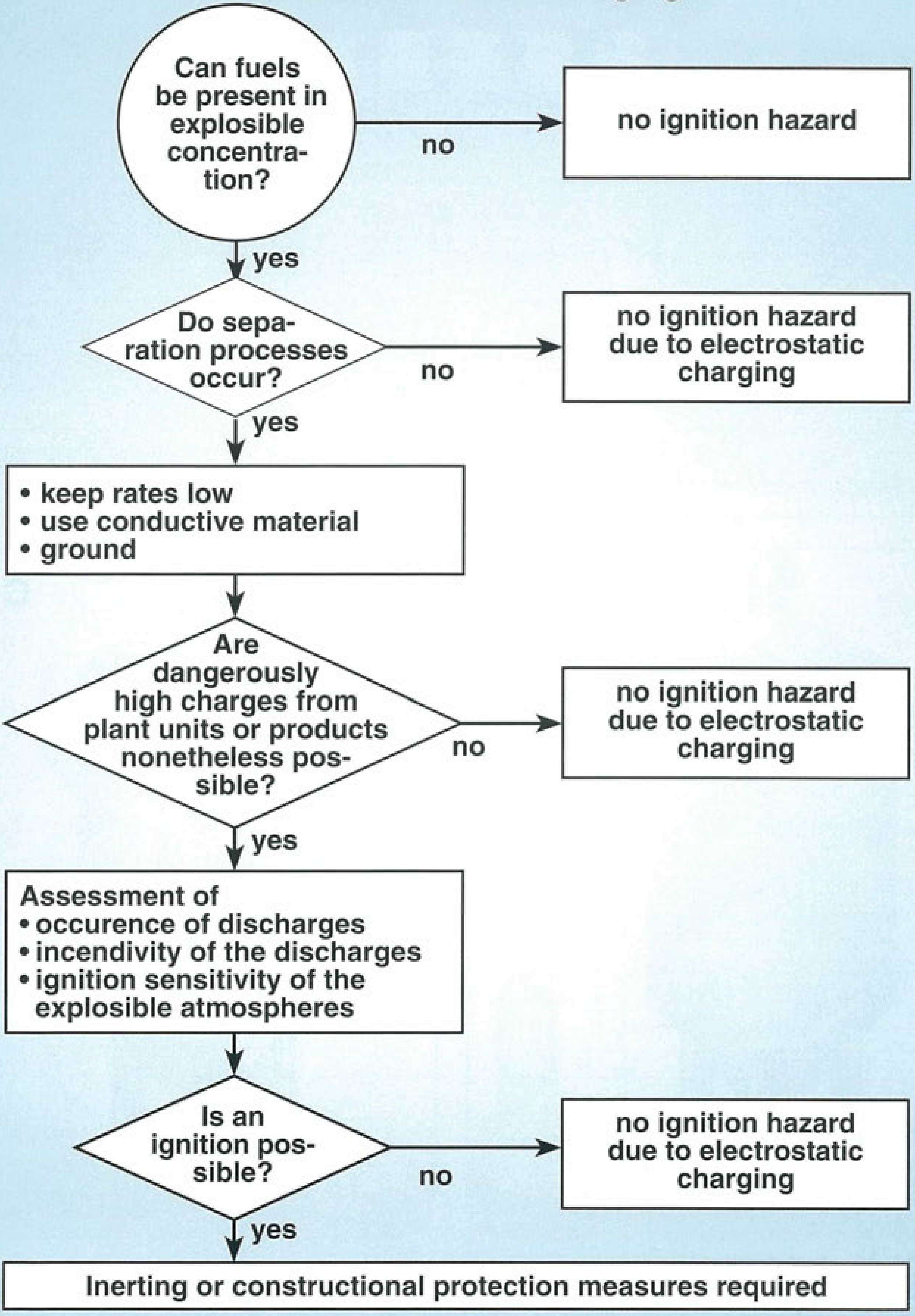


Fig. 31: Examples of protection measures
- *Avoidance of explosible atmospheres – A: ventilation B: inerting*
- *Constructional protection measure – C: explosion suppression*

Decision tree for assessment of the ignition hazards due to electrostatic charging



Handling of flammable liquids and gases

For correct assessment of the hazards associated with flammable liquids and gases and the measures to be taken, the material properties such as conductivity and flash point (in the case of liquids) as well as the minimum ignition energy must be known. The general recommendations listed in what follows are intended to serve as examples illustrating how ignition hazards resulting from charging can be combated in actual practice. In addition to the protection discussed, special situations in industrial practice may require different or additional protection measures. Details of limit values have been intentionally omitted as these differ in different countries.

In the handling of flammable liquids in the presence of air, an explosible atmosphere must always be anticipated if the working temperature is above the flash point of the liquid.

When does a hazard exist and what is its cause?

- Flammable liquids can form explosible vapor/air mixtures if the temperature is not sufficiently below the flash point (see ISSA booklet "Gas explosions").
- Flammable liquids can lead to an explosible atmosphere through spraying (mist of fine droplets) even at temperatures below their flash point.
- Flammable gases can form explosible gas/air mixtures (see Fig. 2).
- Liquids can experience a dangerously high charge buildup or lead to such a situation with plant units, drums, etc. during, e.g. flow, transfer, stirring or spraying (see Fig. 32).

Even the addition of minor amounts of insoluble solids (suspensions) or immiscible liquids (emulsions) can result in extraordinarily high charging of the liquid (see Fig. 33).

Pure gases are not charged during flow. In industrial practice, however, gases often contain particles or droplets as impurities, which can become charged (see Fig. 34).

Secondary processes (e.g. man walking, rubbing of an insulator surface, movement of a conveyor belt) can give rise to high charges (see Figs 8 and 35).

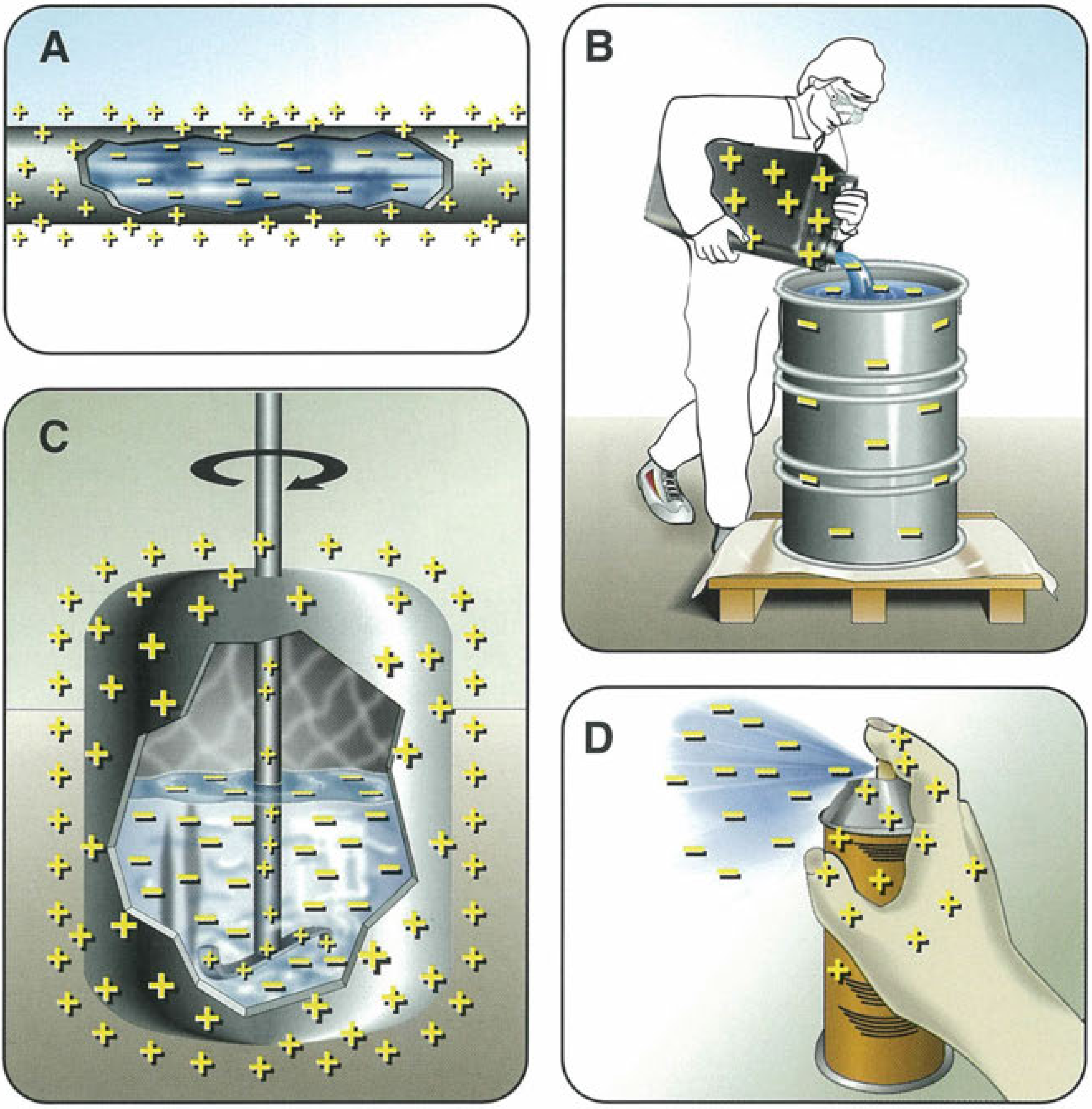


Fig. 32: Examples illustrating the formation of high charges in practice
A: flow of a nonconductive liquid through a pipe (metal, glass, plastic)
B: transfer of a nonconductive liquid
C: stirring of a nonconductive liquid
D: spraying of a liquid (conductive or nonconductive)

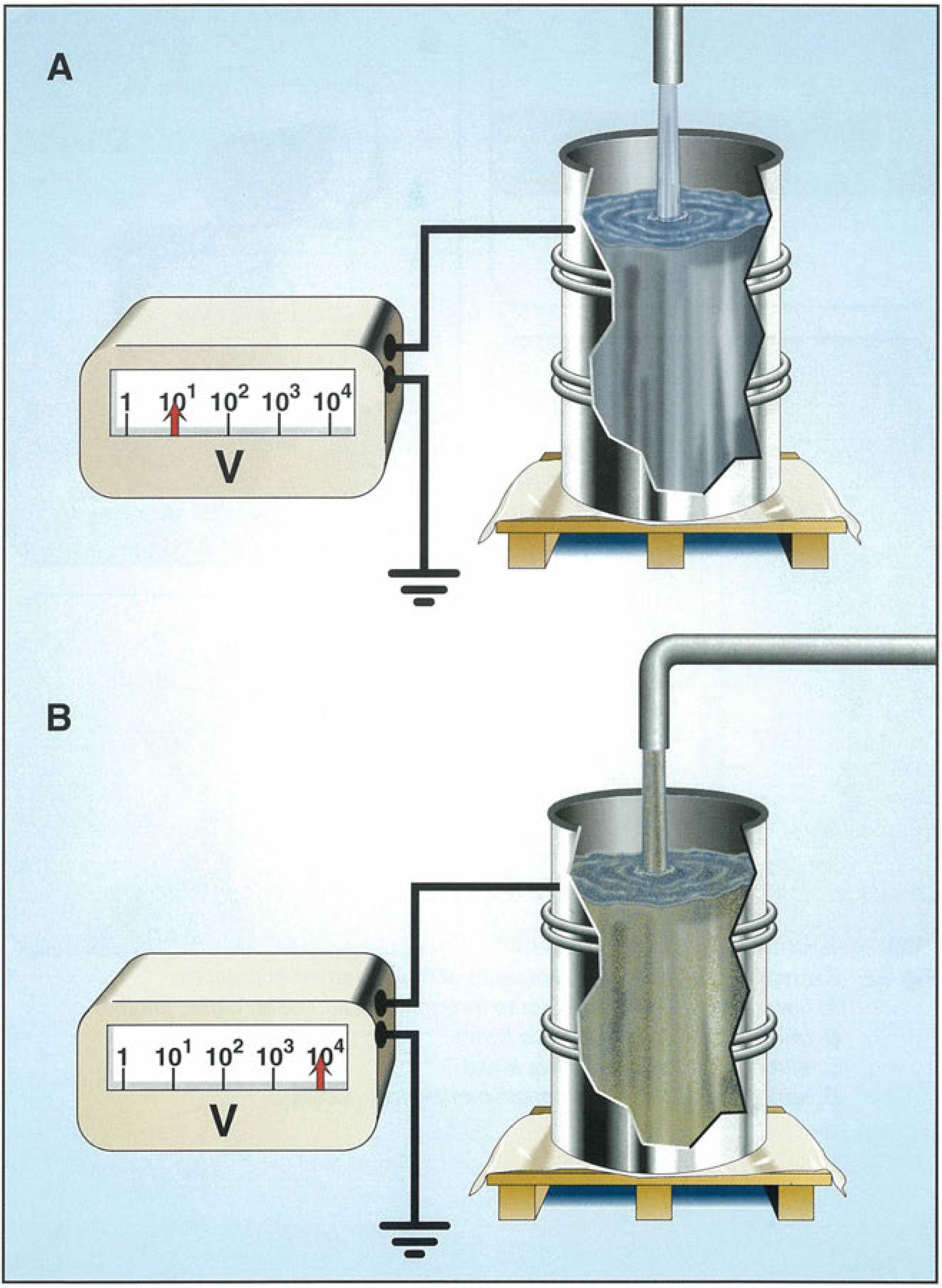


Fig. 33: Increasing the charging of liquids by admixture of nonconductive solids (suspensions)
A: pure liquid ➪ low charge B: suspension ➪ high charge

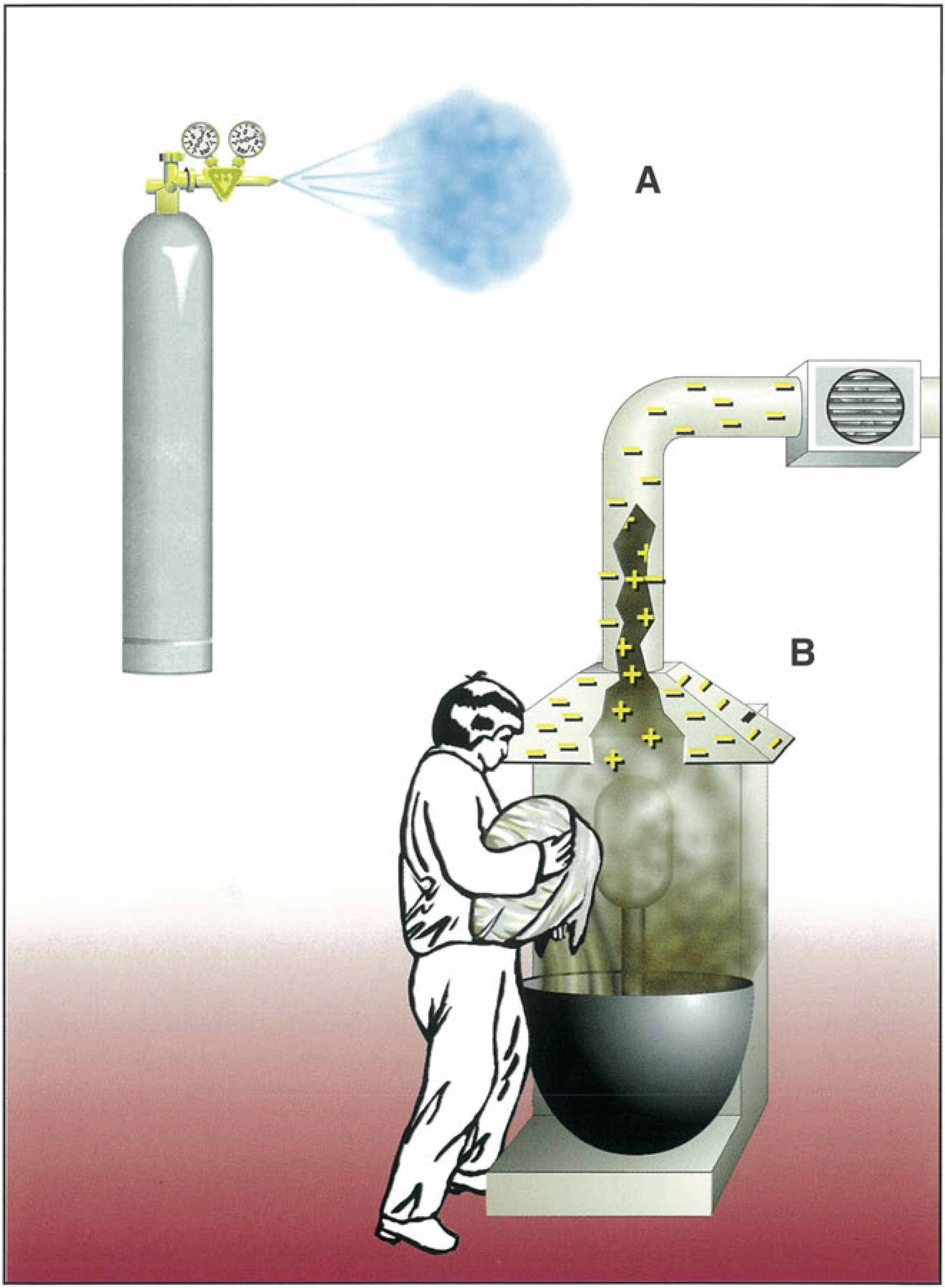


Fig. 34: Gas flow (separation process)
A: flow of pure air ➪ no charge
B: flow of contaminated air ➪ charging of the dust particles

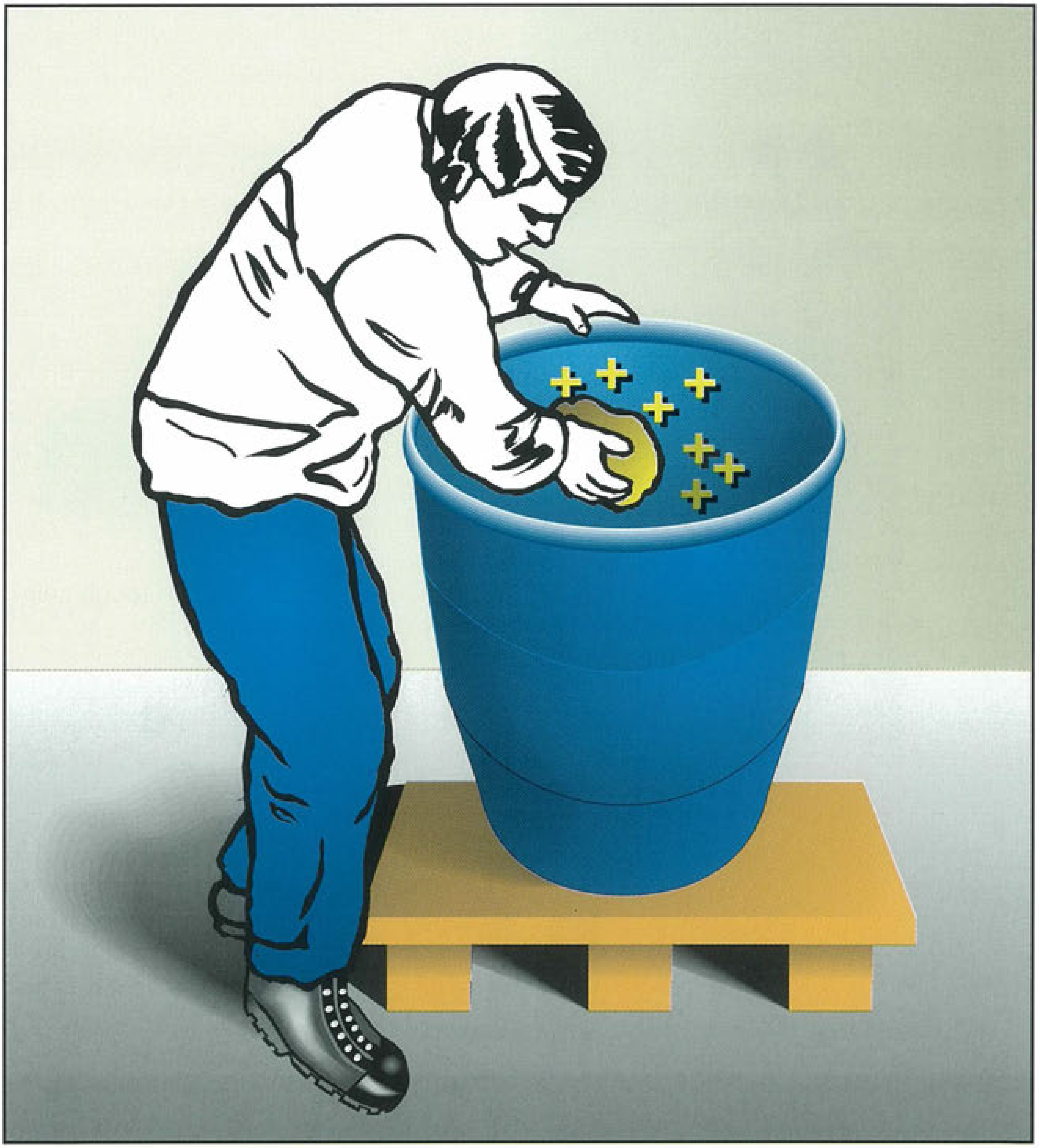


Fig. 35: Formation of high charges through friction (secondary processes)

What types of discharge must be avoided?

- Spark discharges
- Brush discharges
- Propagating brush discharges

Corona discharges must be avoided only in the presence of gases highly sensitive to ignition such as hydrogen, acetylene and carbon disulfide.

What measures have proved their worth in practice?	• Use only conductive pipes, hoses, containers, etc. and ground. (Insulating materials are admissible only for small nominal diameters or volumes.) • If insulating inner coatings are present, e.g. in pipes, hoses and containers, special requirements (dependent on coating thickness, conductivity of the liquid, etc.) must be considered. • Ground conductive equipment in pipelines (valves, flaps, etc.) and in containers (floats, fill pipes, agitators, etc.). • Ground metal flanges on glass lines of large nominal diameter. • Insert fill pipes to container base. • Restrict flow velocity. • Avoid spraying of liquids through suitable design of fill pipe outlet. • In the atomizing of liquids (e.g. for cleaning purposes), special measures may possibly be necessary. • Ground persons by means of conductive shoes and floors. • Avoid open addition of solids to a flammable solvent in a container as inerting is no longer assured in such a case. If not possible, add only from conductive, grounded drums and ensure grounding of personnel and any working aids (funnels, discharge pipes, etc. must be conductive). • With locally restricted high charges (e.g. on paper or film webs), neutralize charges by passive or active ionizers. Ionizers may be installed only by appropriately trained personnel and may not be operated in the presence of readily ignitable gases or vapors such as hydrogen, acetylene or carbon disulfide.

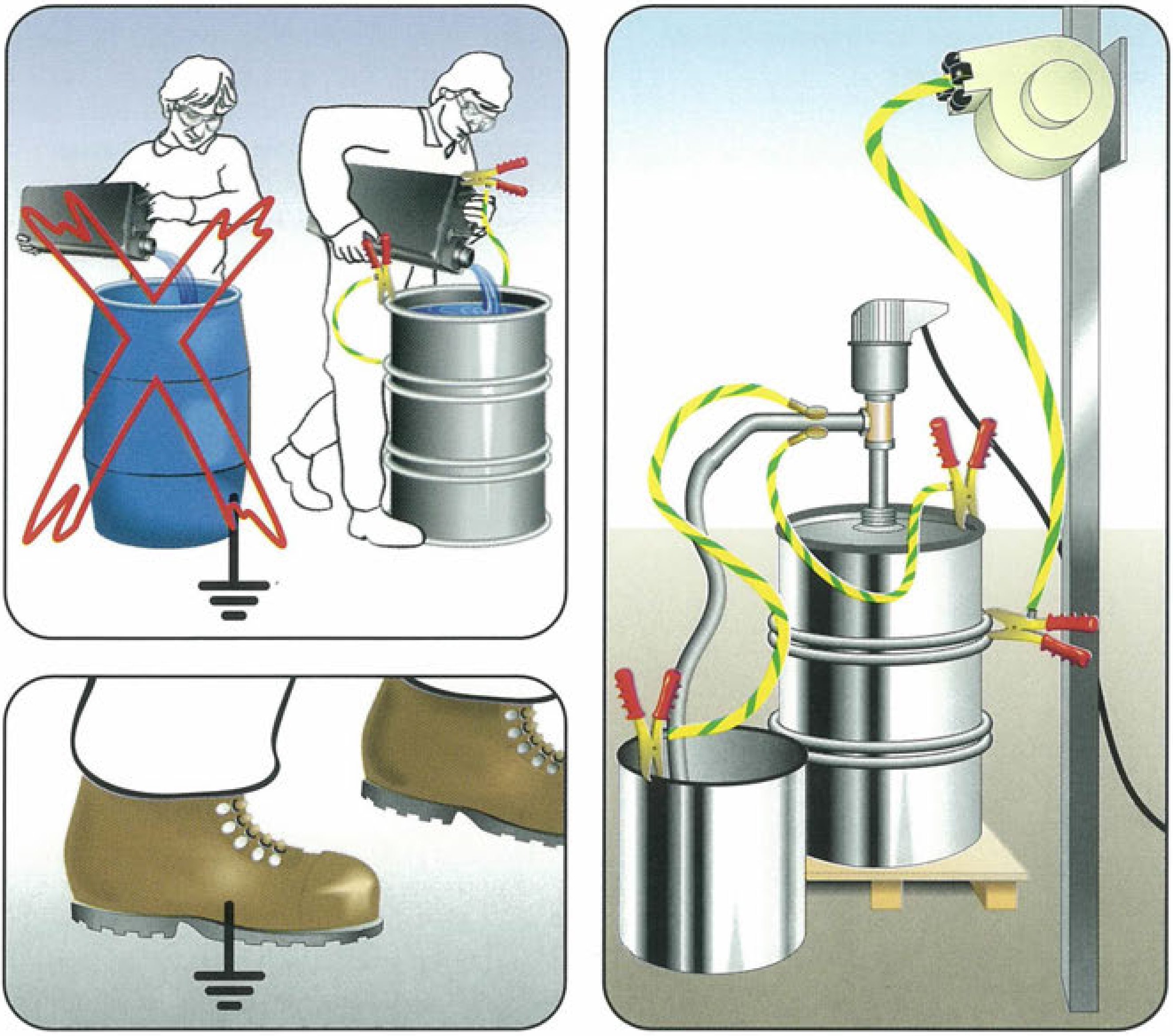


Fig. 36: Examples of measures in the handling of flammable liquids in practice: Use only conductive drums and ground during transfer. Ground all conductive plant units (including drum pump) during transfer. Ground persons by means of antistatic shoes and conductive floors

Grounding of persons and all conductive plant units, products, packaging material, etc. is one of the important measures to avoid the buildup of dangerously high charges.

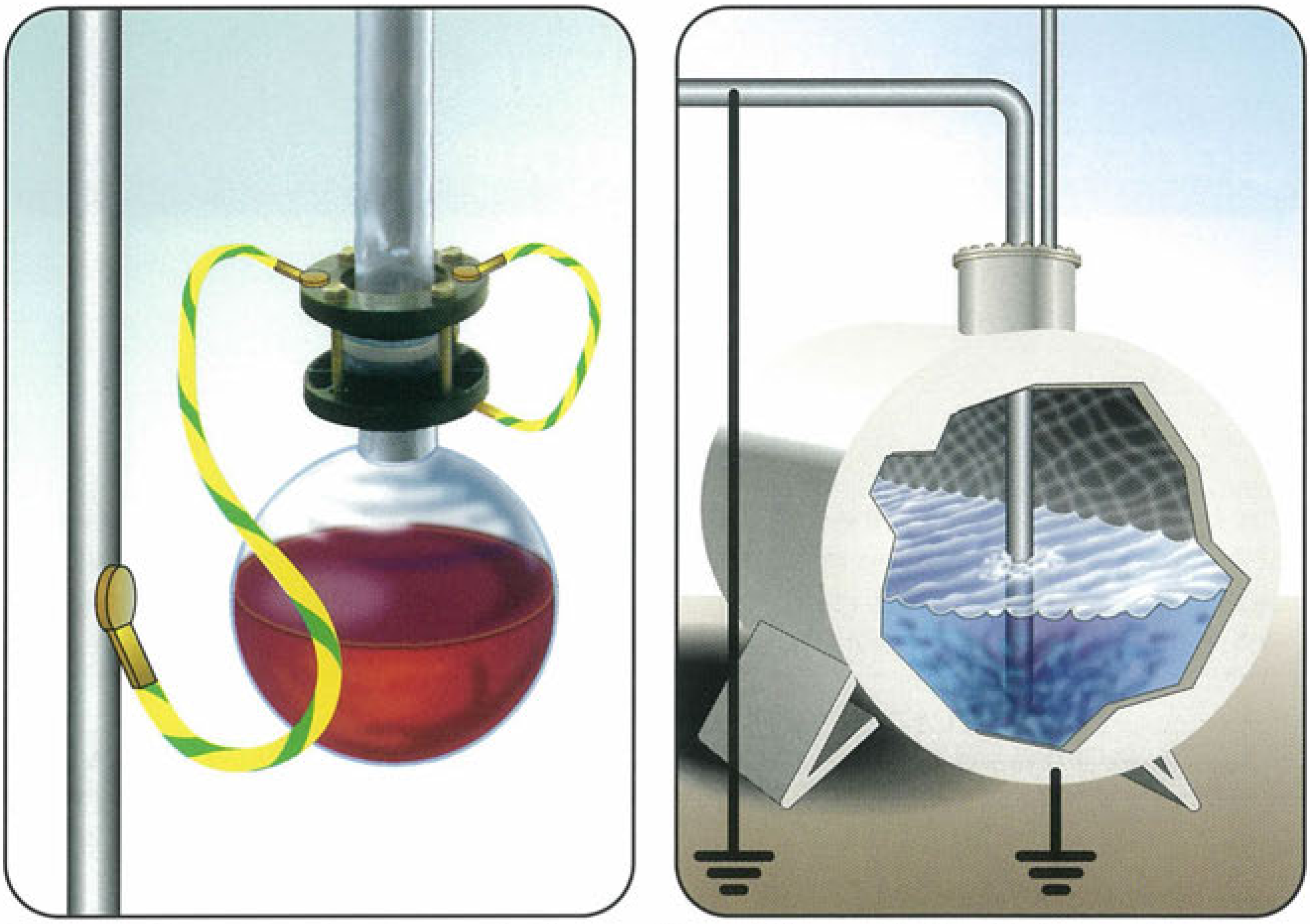


Fig. 37: Examples of measures in the handling of flammable liquids in practice: Ground metal flanges on glass and plastic pipes. Fill large tanks or containers using dip pipe, restrict flow rate, improve conductivity of the liquid

Suspensions and emulsions of flammable, nonconductive liquids must be handled only under inert conditions.

Handling of suspensions and emulsions of flammable liquids

For correct assessment of the hazards associated with suspensions and emulsions of flammable liquids and the measures to be taken, the material properties such as conductivity and flash point (in the case of liquids) as well as the minimum ignition energy of the vapor/air mixture in question must be known.

When does a hazard exist and what is its cause?

- The electrostatic charge buildup in the case of suspensions and emulsions is generally many times greater than with pure liquids.
- It is virtually impossible to avoid dangerously high charge buildups in the handling of nonconductive suspensions and emulsions even with conductive and grounded installations. No safe limits for conveyor and agitation speeds, etc. are known.
- With regard to other considerations, the hazards associated with suspensions and emulsions of flammable liquids are always the same as those found with the pure flammable liquids.

What types of discharge must be avoided?

The types of discharge which have to be avoided are the same as those in the handling of pure flammable liquids and gases. Note, however, that with suspensions and emulsions of nonconductive liquids it is virtually impossible to avoid brush discharges and thus special measures have to be implemented irrespective of the type of construction of the installation.

What measures have proved their worth in practice?

- In the handling (e.g. centrifuging, filtering, conveying) of flammable, **non-conductive** suspensions and emulsions, measures to avoid explosible atmospheres (e.g. inerting, working below the flash point) must be taken.
- In the handling of flammable, **conductive** suspensions and emulsions, the measures normally employed with pure flammable liquids must be implemented.

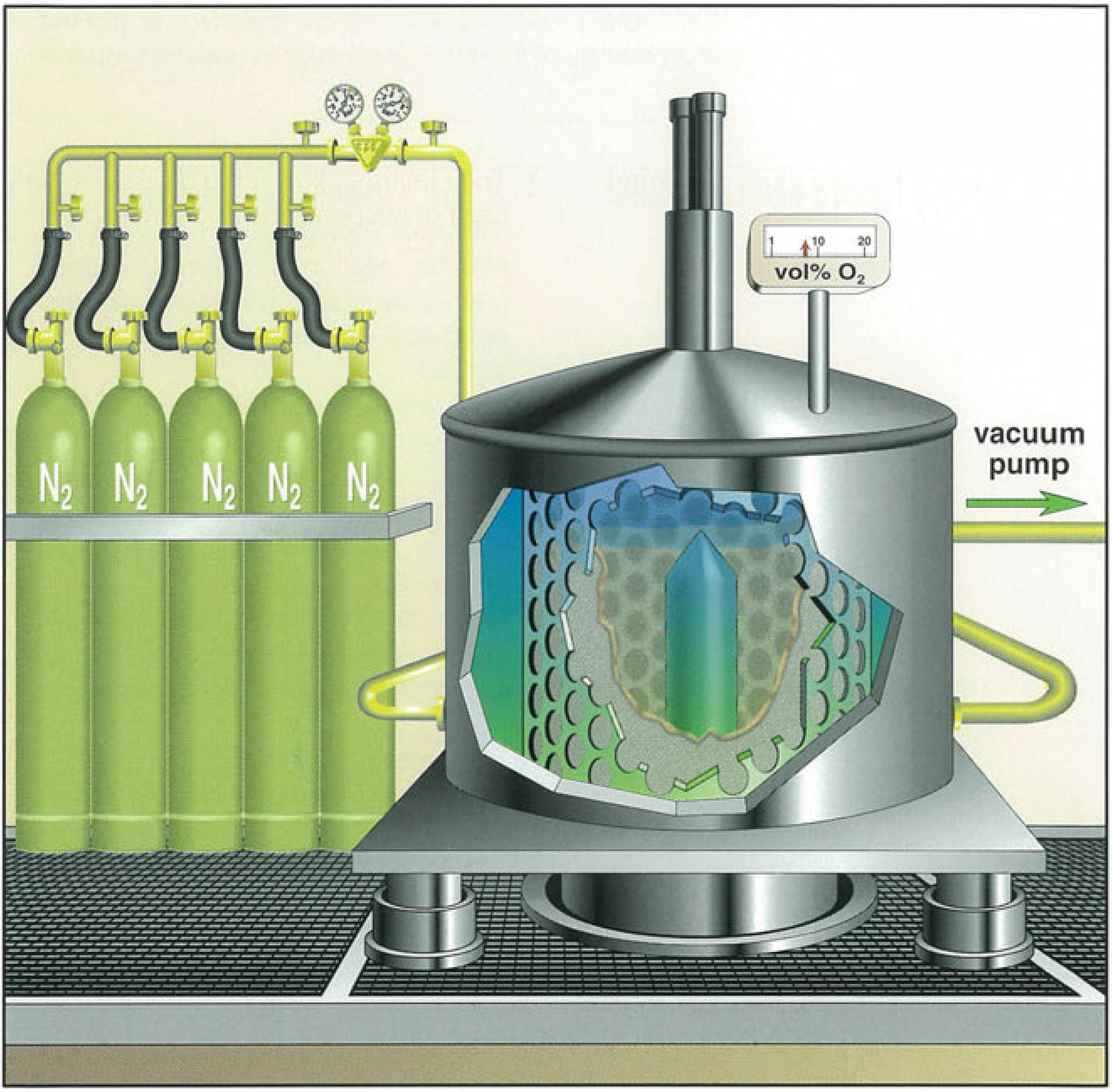


Fig. 38: Inerting of a centrifuge as an example of an explosion protection measure in the handling of suspensions and emulsions of flammable liquids

Handling of flammable bulk materials in the absence of flammable gases and vapors

For correct assessment of the hazards associated with flammable bulk materials and the measures to be taken, the material properties such as the resistivity of the bulk material and the minimum ignition energy of the dust/air mixture in question must be known.

When does a hazard exist and what is its cause?

- In the handling of flammable bulk materials (powdered products with a particle size < 0.5 mm or coarse grained products containing fine dust), explosible dust/air mixtures can be formed.
- Bulk materials can experience a dangerously high charge buildup or lead to such a situation with plant units, drums, etc. during, e.g. conveying, transfer, milling, mixing, separating or screening.
- Secondary processes (e.g. man walking, movement of a conveyor belt) can lead to dangerously high charges.

In the presence of flammable gases or vapors, hybrid mixtures can be formed. This must be taken into account when assessing the hazard (e.g. open addition of solids to a flammable solvent in a container, see p. 57).

Many dusts have such a low minimum ignition energy that they can be ignited by the ignition source "static electricity".

What types of discharge must be avoided?

- Spark discharges
- Propagating brush discharges
- Cone discharges

According to our present knowledge, brush discharges can be tolerated as long as no dusts with an extremely low minimum ignition energy are present. Present evidence suggests that corona discharges can also be tolerated.

What measures have proved their worth in practice?

- Ground conductive containers, apparatus, plant units, equipment, etc.
- For the large-scale handling of highly insulating flammable bulk material (bulk volumes > 2 m^3), use only conductive and grounded containers, apparatus, plant units, equipment, etc. and ground. Do not apply any insulating inner coatings.
- Fabricate pneumatic conveyor lines of conductive material and ground. Do not apply any insulating inner coatings. If not possible, use only coatings with a low electric breakdown strength (breakdown voltage U_B < 4 kV).
- In the handling of bulk materials which form readily ignitable dust/air mixtures, ground persons (conductive shoes and floors).
- In the filling of large silos and containers with highly insulating, flammable bulk materials, explosion protection measures over and above the measure "avoidance of effective ignition sources" may be necessary, depending on the minimum ignition energy, particle size distribution, etc.

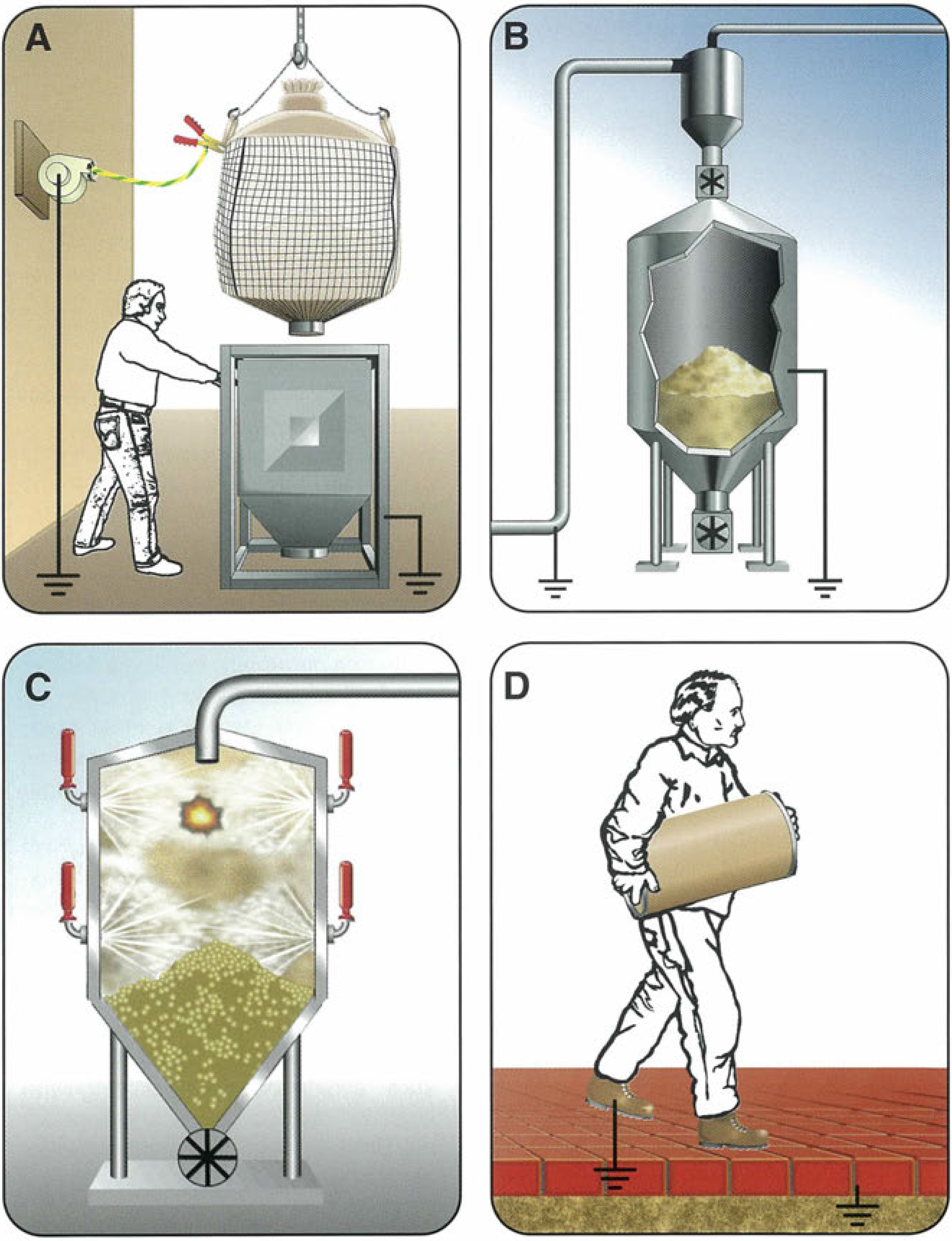


Fig. 39: Examples of measures in the handling of combustible dusts in practice – A: grounding of all conductive vessels and packaging containers during transfer B: grounding of all conductive plant units C: use of constructional explosion protection measures (e.g. explosion suppression) D: grounding of persons when handling bulk materials very sensitive to ignition

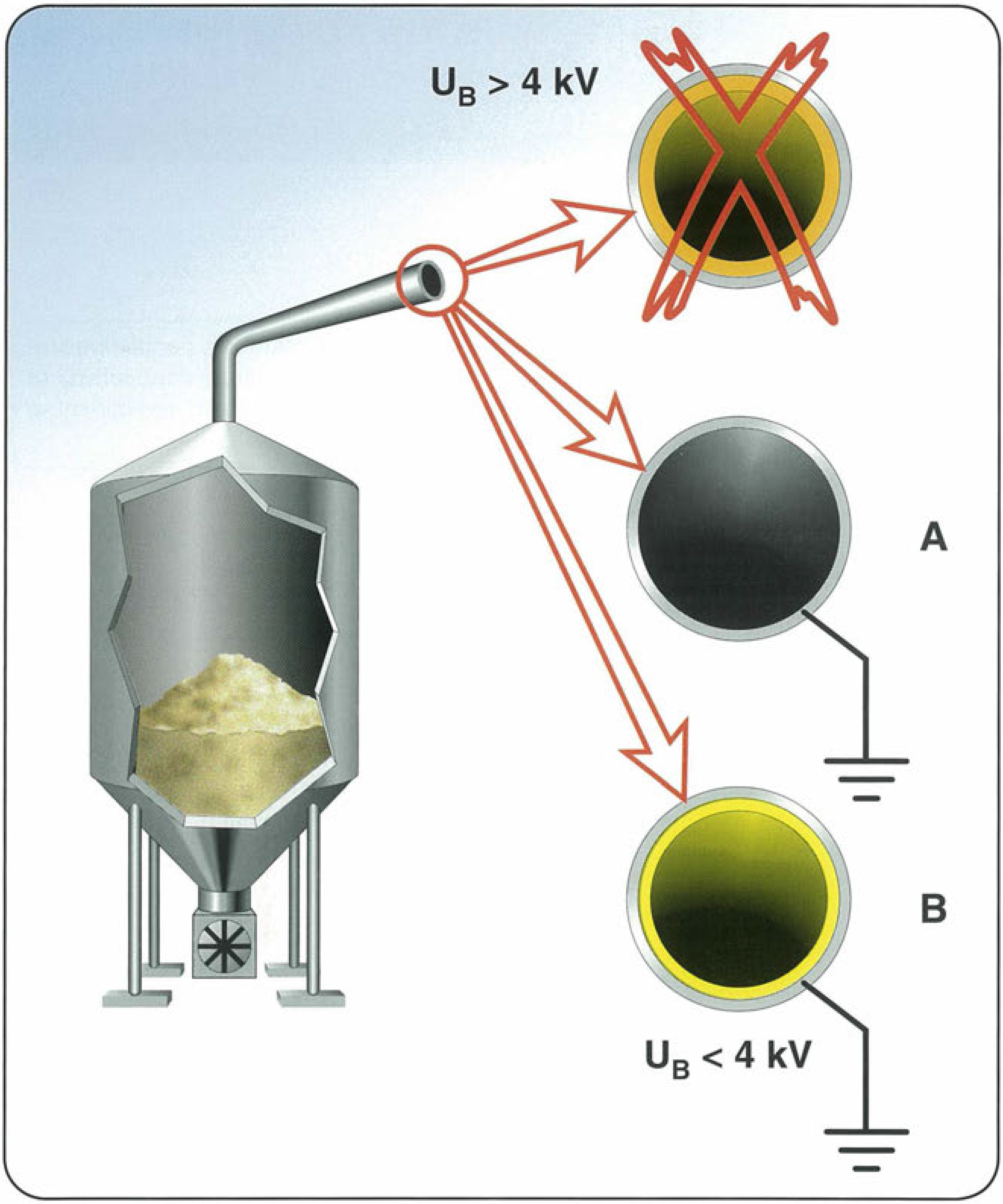


Fig. 40: Examples of measures in the pneumatic transport of combustible dusts in practice – A: grounding of all conductive parts and no insulating inner coating of feed pipe B: grounding of all conductive parts and use of an inner coating with maximum 4 kV breakdown voltage

Nonconductive bulk materials containing solvent must be handled only under inert conditions.

Handling of bulk materials containing flammable solvents

For correct assessment of the hazards associated with bulk materials containing solvents and the measures to be taken, the material properties such as conductivity of the solvent-containing bulk material, flash point of the flammable liquid and minimum ignition energy of the vapor/air mixture in question must be known.

When does a hazard exist and what is its cause?

- The high charge of insulating solvent-containing bulk material (the charge buildup in insulating bulk materials is many times higher than in insulating liquids) in the presence of the explosible solvent vapor/air mixture results in a major ignition hazard.
- It is virtually impossible to avoid dangerously high charge buildup in the handling of insulating, solvent-containing bulk materials even with conductive and grounded installations.
- With regard to other considerations, the hazards associated with bulk materials containing flammable solvents are always the same as those found with the pure flammable solvents.

What types of discharge must be avoided?

The types of discharge which have to be avoided are the same as those in the handling of pure flammable liquids and gases. Note, however, that with insulating solvent-containing bulk materials it is virtually impossible to avoid brush discharges and thus special measures need to be implemented.

What measures must be taken?

- In the handling of nonconductive bulk materials containing flammable solvents, measures to avoid explosible atmospheres (e.g. inerting, working below the flash point) must be implemented.
- In the handling of conductive bulk materials containing flammable solvents, the measures normally employed with pure flammable liquids must be implemented.

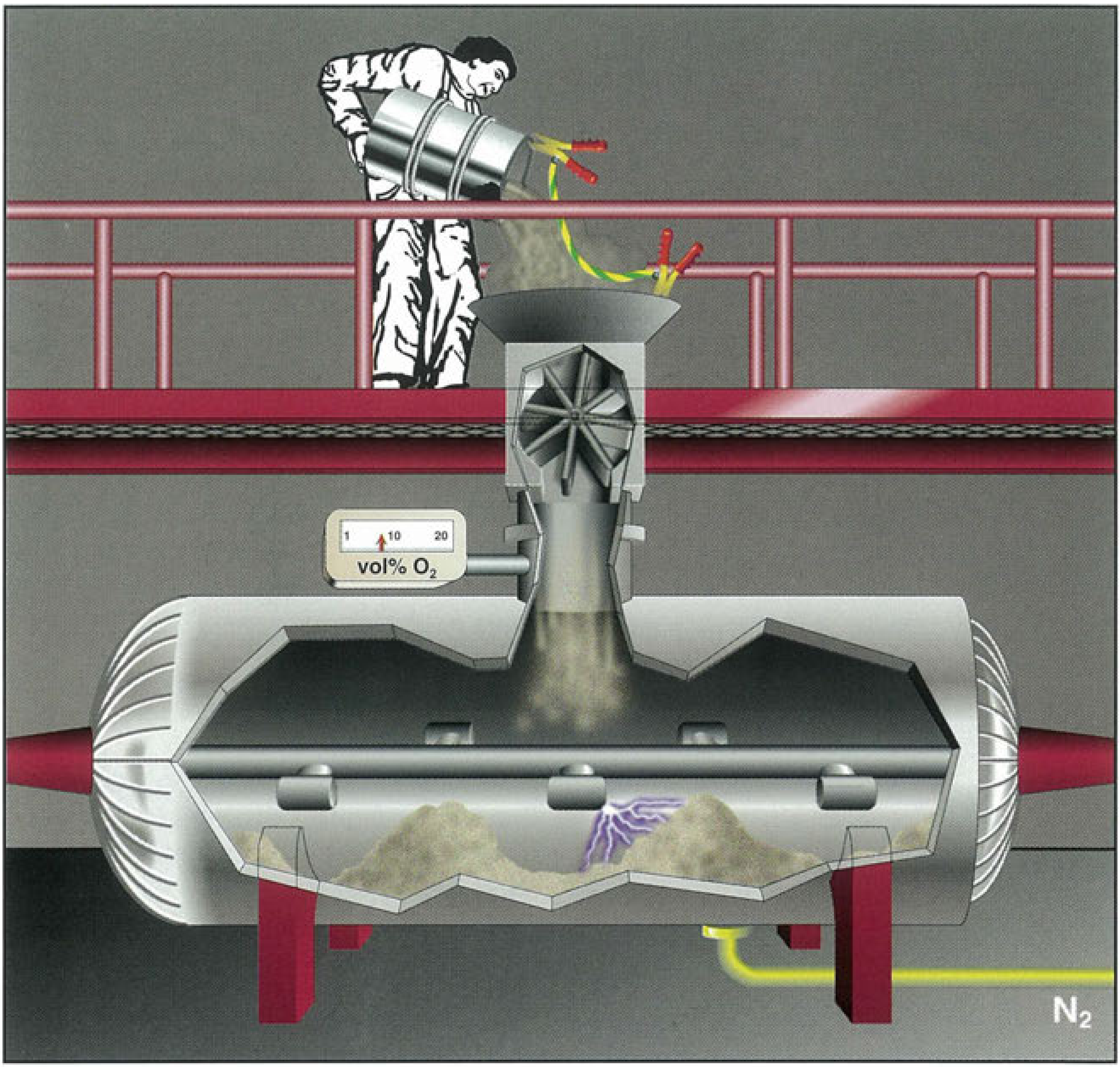


Fig. 41: Closed filling of an inerted paddle dryer as a practical example of an explosion protection measure in the handling of bulk material moist with solvent

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ISSA Publications – Explosion protection

(ISSA) Section for the Chemical Industry
Working party "Explosion protection"

Protection against dust explosions (English, German, French, Italian, Spanish)
(1987)

Protection against explosions caused by flammable gases, vapors or mists in admixtures with air (English, German, French, Italian)
(1988)

Safety of liquefied gas installations (propane and butane) (English, German, French, Italian, Spanish)
(1992)

Static electricity – ignition hazards and protection measures (English, German, French, Italian)
(1996)

Address for orders: ISSA Section Chemistry
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Germany

(ISSA) Section Machine Safety
Working party "Dust explosions"

Fundamentals for the prevention of dust explosions

- Preventive and constructional protection measures (English, German, French)
  (1987)
- Collection of examples (English, German, French)
  (1990)

Explosion suppression (English, German, French)
(1990)

Determination of the combustion and explosion characteristics of dusts (English, German, French)
(1996)

Address for orders: ISSA Section Machine Safety
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Notes

Notes

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The activities of the ISSA International Sections comprise:
- the exchange of information between interested bodies involved in the prevention of occupational risks in various countries;
- the organization of meetings of expert committees and working groups, round table discussions and colloquia on an international level;
- surveys and studies;
- the promotion of research work;
- the publication of information pertinent to its aims.

Further information on these activities and general aspects of the work of the ISSA in the field of occupational safety can be found in the folder "Safety Worldwide". This booklet is available from the Secretariat of the Section in English, French, German and Spanish.

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