Explosion hazard assessment should always be based on the minimum ignition energy of the finest particle size fraction that may be present. This fraction is usually obtained by sieving a sample through a 63 μm sieve.

NOTE 1 For a list of MIE of powders see BIA-Report 12/97 "Combustion and explosion characteristics of dusts". A method for determining the MIE is given in IEC 61241-2-3, ASTM E2019-03 and EN 13821.

NOTE 2 MIE of powders are notoriously variable depending on many parameters not commonly detailed in literature data sources (particle size distribution, solvent/moisture content etc.).

If the relevant minimum ignition energy is above 1 J and there are no flammable gases and vapours present, special measures to avoid ignition hazards due to static electricity are usually not necessary. A possible exception to this is the case where propagating brush discharges are possible (see 9.2 d)).

NOTE Precautions might be necessary to minimise electrostatic shock risks. See 12.2.

Bulk materials are classified into 3 groups depending on their volume resistivity:

a) low resistivity powders, with volume resistivities $\rho \leq 1$ MΩ m;

b) medium resistivity powders, with volume resistivities 1 MΩ m $< \rho \leq$ 10 GΩ m;

c) high resistivity powders, with resistivities $\rho >$ 10 GΩ m.

NOTE For methods to measure the resistivity see IEC 60079-32-2[7].

In practice, low resistivity powders are rare. Even metal powders do not remain conductive for very long because oxide films form on the surface and increase their resistivity. An exception is, however, carbon black.

During handling of bulk materials electrostatic charging normally occurs. In addition to avoiding the hazardous accumulations of charge additional explosion protection measures may have to be taken as inerting, the use of explosion resistant equipment, explosion venting or explosion suppression.

9.2 Discharges, occurrence and incendivity

The build up and retention of charge on powder or equipment creates a hazard only if the charge is suddenly released in the form of a discharge which can cause an ignition. Charged powder and equipment can give rise to several types of discharge and they vary greatly in incendivity (see A.3.2 to A.3.7). The incendivity and other details of these discharges relevant to powder handling are as follows:

a) Spark discharges: The incendivity of spark discharges can usually be assessed by comparing the stored energy (see A.3.2), with the MIE of the combustible powder in question (see C.6). Spark discharges can be avoided by earthing all conductive parts of equipment, conductive products and also people;

b) Brush discharges: The present state of knowledge indicates that independent of their MIE combustible powders cannot be ignited by brush discharges, providing there are no flammable gases or vapours (see A.3.4). When handling large amounts of medium or high resistivity powders, brush discharges cannot be avoided (see B.3.7);

c) The presence of contaminations (e.g. solvent, grease or moisture) may affect the potential ignition hazard when using insulating plastics in the presence of dusts.

d) Care should be taken when handling solvent wet powders, as they may release flammable vapours over a long period of time with a much lower MIE than the pure powder. Consideration should also be given to whether MIE results less than 1 mJ are actually due to such mechanisms, rather than the powder alone.

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7 To be published.

e) Corona discharges: Corona discharges cannot ignite combustible powders. When handling large amounts of medium or non-conductive powders, corona discharges cannot be avoided;

f) Propagating brush discharges: The energy released in a propagating brush discharge can be calculated and values in excess of 1 J are typical. Examples of a calculation and more details of propagating brush discharges are given in B.3.9;

g) Cone discharges: Cone discharges can occur when highly charged powder is loaded into a silo. It is considered likely that flammable gases and vapours and also combustible powders can be ignited by these discharges (see also A.3.7);

h) Lightning-like discharges: Such discharges, though theoretically possible, have not been observed in industrial operations.

9.3 Procedural measures

9.3.1 General

The process parameters should be set in a way that minimises electrostatic charging. This should be achieved by implementing some or all of the following precautions:

a) increasing the conductivity of the bulk material, e.g. by coating,

b) replace insulating equipment by earthed conductive equipment,

c) humidification of powders,

d) ionisation,

e) reducing the quantity of fines in the bulk, e.g. avoiding fine fractions caused by wear and abrasion,

f) limiting dispersion, e.g. dense phase conveying instead of dilute phase conveying,

g) reducing the conveying speed, throughput or air velocity,

h) avoiding big heaps of bulk material,

i) preferring gravity transport to pneumatic transport,

j) using conductive or antistatic hoses for pneumatic transport.

9.3.2 Humidification

If humidification is used as measure to dissipate charges from bulk material, usually 70 % relative humidity at 23 °C is necessary. This method may not be effective for high speed conveying and for warm products. It may also adversely affect the flow properties of some powders.

NOTE Air is a poor conductor of electricity. Humidification is not effective as a means of dissipating the charge from a dust cloud. However, high relative humidity does decrease the surface resistivity of many powders – with the exception of most polymers – and, therefore, might increase the rate of charge decay on bulked powder.

9.3.3 Hoses for pneumatic transfer

The definitions of antistatic and conductive hoses in 7.7.3.4 do not apply for hoses for the use with pneumatic transport of bulk materials. For such pneumatic transport the leakage resistance from any place of the inner wall of the hose should be less than 100 MΩ (measured according to ISO 8031).

9.3.4 Ionisation

The conductivity of dust/air mixtures can be increased by ionisation. It may be possible to avoid dust deposits by ionisation. It is not possible to avoid hazards when dealing with large amounts of bulk material and of large dust clouds.

NOTE It is difficult to provide the necessary ionisation for relatively large distances, e.g. more than 100 mm. Furthermore the total charge to be neutralized is often larger than an ionisation system may provide.

Local discharges from pointed, earthed conductive probes or wires can be of value in both dust clouds and bulked powders when the electric field strength is close to the breakdown value. The earthed conductive probes or wires should not break off in total or in parts.

NOTE 1 Such earthing probes or wires placed at the bulking point as powder enters a container can reduce the energy of individual discharges to a low level. They can also provide a safe route to earth for accumulated charge when powder enters an insulating container.

NOTE 2 Detached parts (e.g. if parts of the probe or wire break) might behave as charged capacitors and cause spark discharges.

NOTE 3 In the case of active ionisers, contamination of points might lead to ohmic heating possibly causing fires which needs to be prevented.

9.4 Bulk materials in the absence of flammable gases and vapours

9.4.1 General

For these purposes it is assumed that the powder is handled and processed free from any flammable gases and vapours, if:

a) with non-flammable bulk material the concentration of gases and vapours is below their lower explosive limit (LEL),
b) with flammable bulk material the concentration of gases and vapours is below 20 % of their LEL.

NOTE This is often met if immediately after a drying process the total residual concentration of solvent in the bulk material is below 0,5 %, the powder is subsequently handled at ambient temperature, and no further fine fraction generating process is carried out.

9.4.2 Equipment and objects made of conductive or dissipative materials

In hazardous areas all equipment and objects made of conductive and dissipative materials should be earthed, e.g. laminated packages with conductive layers and non-stationary coated containers.

For the following situations the earthing requirement may be abandoned/relaxed:

a) if it can be shown that objects made of conductive and dissipative materials do not become charged during normal operation and possible malfunctions; or
b) if the maximum energy that can be stored on the isolated objects is much lower than the MIE of the bulk material, or
c) if the capacitance of the object does not exceed the applicable value given in Table 2.

9.4.3 Equipment and objects made of insulating materials

Equipment and objects made of insulating materials are only permissible if no hazardous charge build up will occur. If equipment and objects made of insulating materials in the form of pipes, hoses, containers, sheets, coatings and liners are used charge build up has to be expected.

Charging of insulating surfaces may result in propagating brush discharges with typical energies in excess of 1 J when backed with conductive areas in a distance less than 10 mm. If insulating films, layers or coatings with a breakdown strength below 4 kV are used they will not result in propagating brush discharges incendive to bulk materials.

As charging of isolated conductive material may cause spark discharges, the combination of conductive, dissipative and insulating materials is only permitted providing that all conductive and dissipative parts are properly earthed.

9.4.4 Dust separators

In separators for flammable dusts insulating filter fabrics should not interrupt the earthing connections of parts made of conductive or dissipative materials, e.g. supporting cages of filter sleeves or metal clamps to keep the filter socks in place. Particularly when the MIE of the bulk material is lower than 3 mJ ensuring earthing of all metal parts such as clamps, etc. having a capacitance greater than 10 pF is of great importance. This limit is due to the practical experience that it is nearly impossible to make sure that even the smallest metal parts (single screws, clamps etc.) are always earthed by cable connections. The earthing and bonding should be guaranteed by the construction itself and/or by the properties of the materials used.

For this purpose the use of filter fabrics made of fibre containing conductive threads, or the use of normal filter socks with copper straps sewed around the end of the filter socks which automatically bond the supporting cages and metal clamps have proven to be very useful.

Filter fabrics made from conductive and earthed material should always be used where flammable vapours are present or where non-metallic conductive powders with a MIE less than 30 mJ are handled. Such fabrics should also be used for combustible metallic dusts having MIE less than 30 mJ provided that dry media type dust collectors are not expressly prohibited by prevailing regulation. The resistance to earth should be below 100 MΩ. The use of fibres containing conductive threads also helps to reduce charge on the powder and filter by corona discharge.

NOTE Al, Mg, Ti and Zr dusts usually have MIE of less than 30 mJ whereas Fe, Co, Ni, Cu and Mn dusts usually exceed this limit. More details can be found in NFPA 484, *Standard for combustible metal*.

9.4.5 Silos and Containers

9.4.5.1 General

Bulk materials should be handled and processed in such a way that a hazardous charge build up is avoided. A hazardous charge can be accumulated on the bulk material as well as on the wall of the silo or container.

NOTE This applies to large silos and containers as well as also to small mobile containers, bins, drums, bags, FIBC or other packages. The specific requirements for FIBC are given in 9.6.

Figures 1 to 3 detail how to analyse whether the bulk material itself can be charged to a hazardous amount during the filling of a silo or container. If required, measures against the occurrence of cone, lightning like or spark discharges have to be taken. The flow diagram to be chosen depends on the resistivity of the bulk material:

Figure 1: Assessment of low resistivity bulk material ($\rho \leq 1$ MΩ m)

Figure 2: Assessment of medium resistivity bulk material (1 MΩ m $< \rho \leq$ 10 GΩ m)

Figure 3: Assessment of high resistivity bulk material ($\rho >$ 10 GΩ m)

NOTE In Figures 2 and 3 $W_{cone\ discharge}$ means the maximum expected energy of the cone discharge (see A.3.7).

As an alternative to the measurement of the strength of the electrical field above the powder heap, this field strength may be estimated by modelling the electrical field within the silo taking into account charge relaxation during the filling procedure. Such model calculations should be based on the charge to mass ratio, bulk density and filling rate of the powder, the relative permittivity and resistivity of the bulked powder as well as on the silo geometry. If the radially directed electrical field stays below 3 MV/m, the criterion for the field of the bulked powder is fulfilled. The difference between the 500 kV/m average electrical field over the gap of the discharge and 3 MV/m limit value is based on the field distribution within silos, where the maximum field is always directed radially against the wall of the silo measured at the silo wall and not axially directed measured above the powder heap.

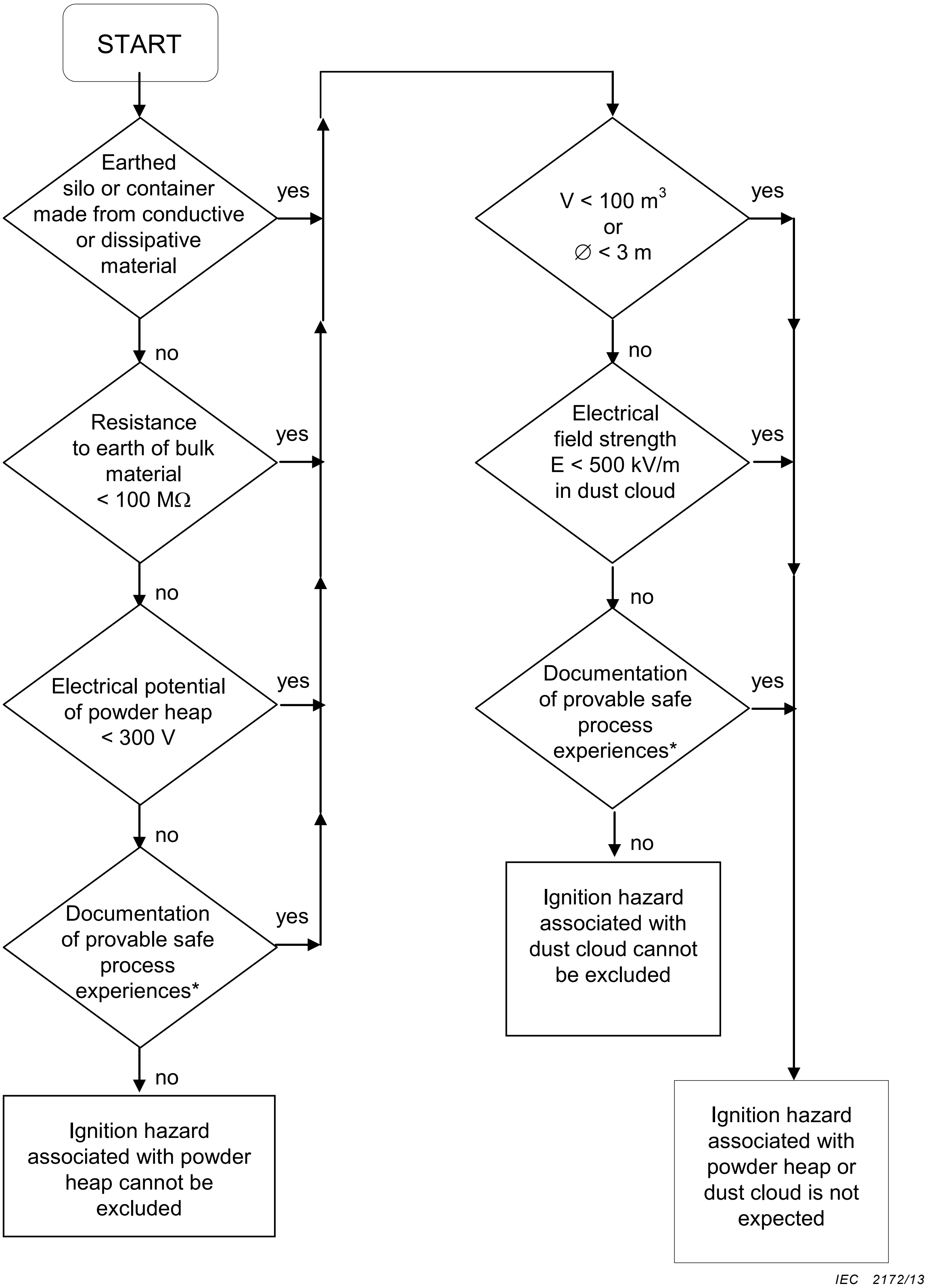
To assess the charge build up on the wall of the silos and containers 9.3 as well as 9.4 should be considered in addition.

During discharging of silos and containers in the absence of flammable gases and vapours no hazardous charge build up on the bulk material has generally to be expected. In addition all discharge and transfer devices require a separate analysis.

NOTE See also 9.3.

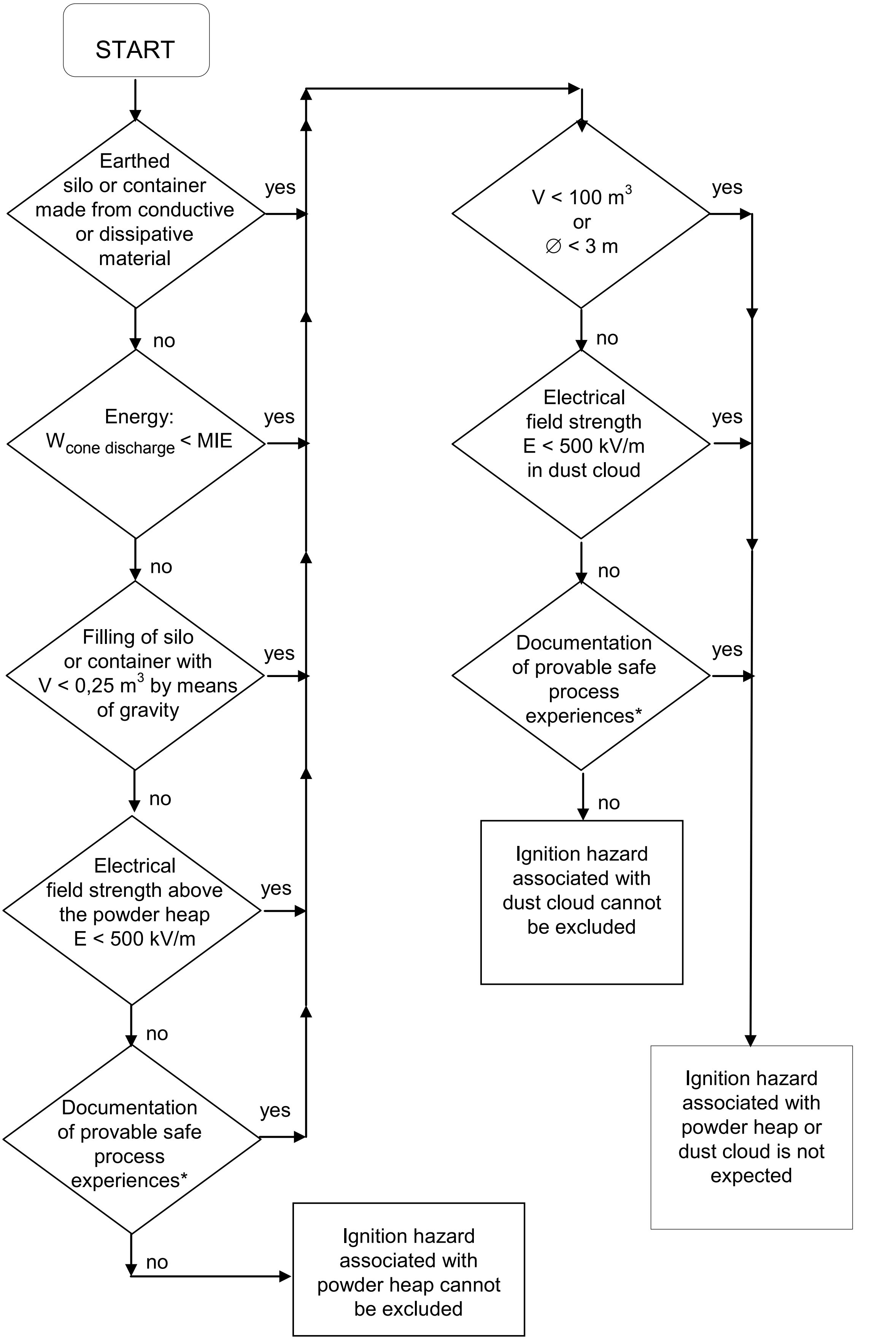
It should however be kept in mind that most discharging operations represent a filling operation for the successive silo or container.

Conductive silos and containers should be earthed and dissipative silos and containers should be in contact with earth during filling and emptying.



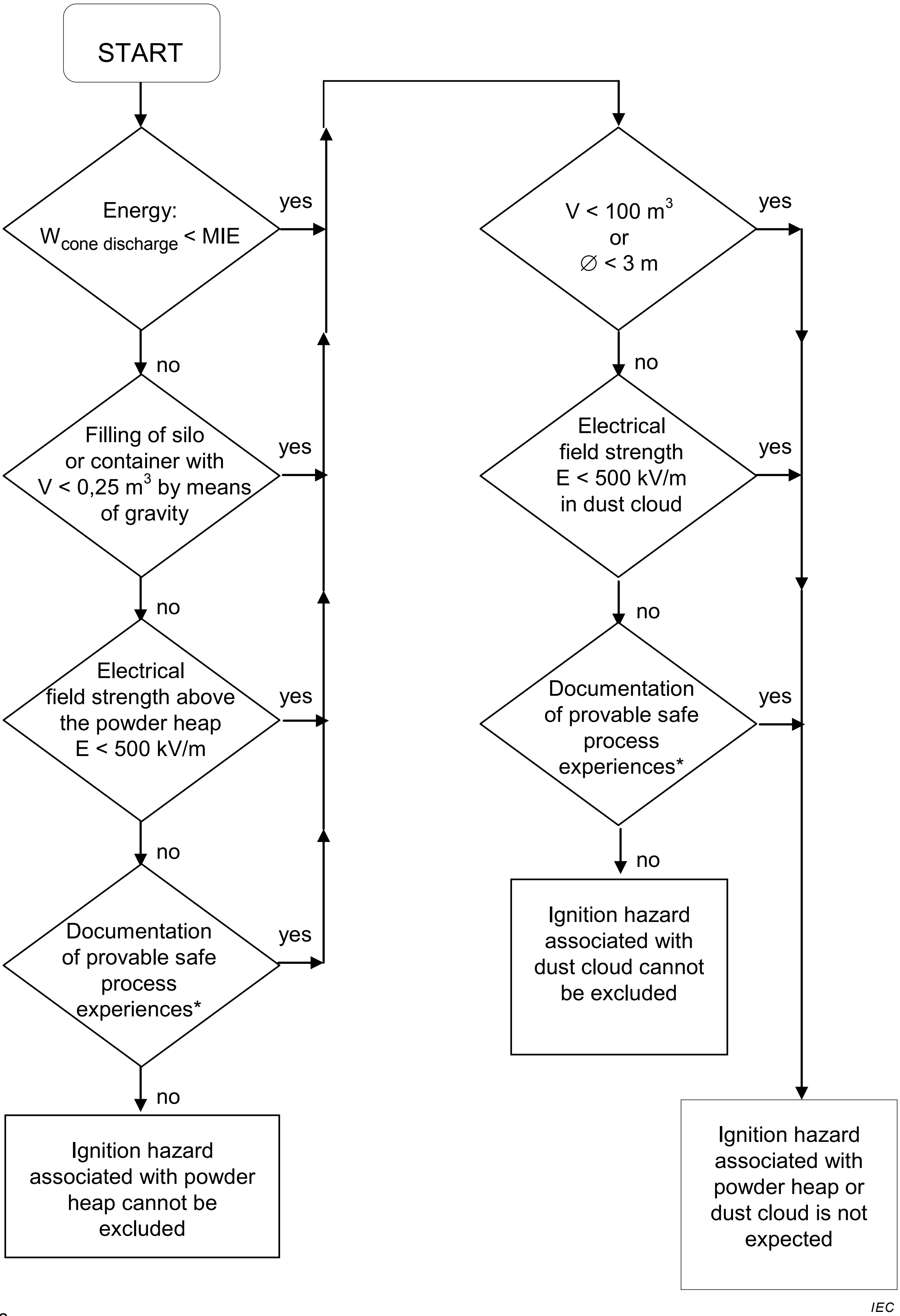
* see 9.4.5.2

Figure 1 – Flow diagram: Assessment of bulk material with ρ ≤ 1 MΩ m



* see 9.4.5.2

Figure 2 – Flow diagram: Assessment of bulk material with 1 MΩ m < ρ ≤ 10 GΩ m



* see 9.4.5.2

Figure 3 – Flow diagram: Assessment of bulk material with ρ > 10 GΩ m

9.4.5.2 Documentation of provable safe process experiences

If according to one of the flow diagrams in Figures 1 to 3 the ignition hazard is excluded based on the decision step "Documentation of proven safe process experiences", the explosion hazards should have been analysed in detail and subjected to an assessment. In this context it has to be kept in mind that minor changes in the process, product, equipment, packages, etc. may have a significant effect on the occurrence and incendivity of discharges as well as on the occurrence and concentration of an explosive atmosphere. The relevant justification explaining even the most marginal changes and their possible consequences should be explained in an explosion protection document. In any case, protective measures should to be taken (e.g. explosion venting, inerting, design for containment) where credible ignition sources cannot be excluded and flammable atmosphere is present.

NOTE In Europe, the explosion protection document is written according to Directive 99/92/EC.

9.4.5.3 Conductive and dissipative containers with conductive or dissipative liners

In addition to the measures listed in 9.3, only conductive and dissipative liners should be used in hazardous areas if they are safely earthed and if they remain earthed when taken out of or put into the container. This can be established e.g. by a reliable contact to earth via the container and a reliable contact to earth via the person when the liners are taken out or put into the container. Otherwise conductive and dissipative liners should not be taken out of or put into the container in a hazardous area.

9.4.5.4 Conductive and dissipative containers with insulating liners

Insulating liners should in general be avoided due to the risk of propagating brush discharges. They may only be used if, in addition to the measures listed in 9.3, at least one of the following conditions is met:

a) Volume $< 0{,}25$ m^3,

b) Breakdown voltage < 4 kV (6 kV in the case of woven materials),

c) Liner thickness > 10 mm

d) Documented evidence that no propagating brush discharges will occur.

NOTE Propagating brush discharges may occur depending on the thickness, the resistivity and the breakdown voltage of the liner as well as on the electrical properties of the bulk material. They are not expected for thin paint and polymeric coatings < 50 µm typically found inside containers due to the low breakdown voltage of such coatings.

If the bulk material has a resistivity of less than 100 MΩ m it should be earthed.

Earthing can be achieved e.g. by introducing one or several metal rods or metal pipes into the container leading down to the bottom of the container. These should be introduced prior to the addition of the conductive bulk material.

9.4.5.5 Insulating containers

Insulating containers should in general be avoided due to the risk of propagating brush discharges. They may only be used, if in addition to the measures listed in 9.3 at least one of the conditions a) – d) in 9.4.5.4 is met. If the bulk material has a resistivity of less than 100 MΩ m it should be earthed. Cone discharges should be avoided.

NOTE Propagating brush discharges may occur depending on the thickness, the resistivity and the breakdown voltage of the container as well as on the electrical properties of the bulk material.

9.4.5.6 Insulating containers with liners

Conductive liners should not generally be used in insulating containers due to the risk of them being isolated from earth. If conductive liners are indispensable they should reliably be earthed.

Insulating liners in insulating containers should be assessed as insulating containers according to 9.4.5.5.

9.5 Additional requirements for bulk material in the presence of flammable gases and vapours

9.5.1 General

In the presence of flammable gases or vapours a combination of the gas or vapour concentration and the suspended bulk material concentration (see 3.14) determines whether a flammable gas or vapour/air mixture or a so called hybrid mixture (mixture of flammable gases or vapours and flammable dusts in air) is formed. The minimum ignition energy (MIE) of the mixture is mainly determined by the amount of gas or vapour and commonly lies below the MIE of the pure dust. The flammable gas/vapour may arise from another source (e.g. if a powder is added to a flammable liquid), or from the powder itself (e.g. if it contains significant solvent or may evolve flammable gas).

Special care should be taken when handling solvent wet powders, because when handling large amounts of medium or insulating powders, brush discharges incendive for the evolved gas / vapour or hybrid atmosphere cannot be avoided.

Rather than differentiating between low, average or high resistivities of bulk materials as is the case when no flammable gases or vapours are present, the important limit of the bulk material resistivity in the presence of flammable gases or vapours is only 100 MΩ m.

The following requirements do apply only to gases and vapours of the explosion groups IIA and IIB. In hazardous zones of explosion group IIC inerting is necessary.

9.5.2 Measures for resistivity greater equal 100 MΩ m

The open handling of solvent wet bulk materials with a resistivity greater equal 100 MΩ m should generally be avoided. Where handling of such materials cannot be avoided, additional measures of explosion prevention or protection are normally required, particularly when handling large quantities. Such measures are

a) inerting,
b) processing of the solvent wet material under vacuum,
c) processing at a temperature significantly below the flash point,
d) processing within explosion proof equipment,
e) exclusion of the hybrid mixture, or
f) special constructional measures.

NOTE As handling of bulk material with a resistivity greater equal 100 MΩ m commonly generates a high level of electrostatic charges, brush discharges cannot be avoided and ignition is therefore possible.

9.5.3 Measures for resistivity less than 100 MΩ m

If the resistivity of the bulk material is less than 100 MΩ m, e.g. in case of bulk material containing a polar solvent, the bulk material should be handled in conductive earthed equipment or any other type of equipment that provides a sufficiently large earth point for the bulk material.

NOTE 1 In case of large amounts of bulk material a representative sample is required for an assessment of the resistivity. Instead of the resistivity also the nature and the amount of the solvent content can be used for an assessment.

NOTE 2 The bulk material as well as the flammable liquid might become charged to a hazardous level when filled into a container or added to a liquid.