International Section Machine and System Safety
of the ISSA on the Prevention of Occupational
Accidents and Diseases

Working Group "Explosion Protection"
of the Section Machine and System Safety
in collaboration with the Section "Chemical Industry"

Dryers

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Contents

7. Dryers

The ignition hazard emanating from dryers is primarily dependent on process engineering (e.g. function principle, construction, temperature) as well as combustion and explosion characteristics of the products being processed. The influence of temperature on the minimum ignition energy (see "Basic Principles", Fig. 12)* is particularly important. The general assumption is that if the minimum ignition energy of dusts taking into account temperature is less than 10 mJ, constructional explosion protection measures or inerting are required. The temperature in the area of the dryer where explosive mixtures are expected to occur is decisive in this respect.
Self-ignition processes in dryers are influenced primarily by product deposits or caking. The higher the temperature, the higher the amount of product deposit and caking and the longer the product remains within the temperature field, the higher the risk is that an ignition will occur.
Dryers where the product is present as bulk material only (e.g. pan dryer) involve a distinctly lower dust explosion risk than dryers where process engineering requires the product to be dispersed.
Dryers with a direct heating system principally entail a higher ignition hazard than dryers with indirect heating.
The process-related reduction of the oxygen concentration in the combustion gases in dryers with a direct heating system in general does not represent an adequate explosion protection measure. Just as the steam generated during the drying process alone normally is not an adequate inerting measure. Inerting requires the targeted use of inert gas and must be monitored by measurement (cf. "Basic Principles", Section 2.2).
If the products being dried contain combustible solvents or if combustible gaseous substances can be generated during the drying process, a hybrid mixture is formed in the dryer (dust/gas/air mixture). As a rule, hybrid mixtures are more easily ignited and result in more violent explosions than pure dust/air mixtures. This hazard becomes significant when the concentration of combustible solvent vapors or combustible gases reach approx. 20% of their lower explosion limit.
It is important to observe for all types of dryers that fires or smoldering material may occur and be transmitted to adjoining equipment. This also applies to equipment with explosion decoupling (isolation).
Depending on the type of dryer and type of product, dust fires may be extinguished using water spray systems, steam, carbon dioxide and nitrogen.

* ISSA, *Dust Explosion Prevention and Protection for Machines and Equipment – Basic Principles*, International Section of the ISSA for Machine and System Safety, D-68165 Mannheim, 1998

7.1 Spray dryers

If suspensions of combustible solids are processed in spray dryers, the occurrence of explosive dust/air mixtures is to be expected. Even if estimate calculations (flow rate of solids/flow rate of air) result in average dust concentrations ranging below lower explosion limits of a dusty product, explosive dust/air mixtures could be formed in the bottom part of the dryer - in particular if it is cone-shaped.
The product is exposed to fairly low and short-term thermal stress in spite of high air inlet temperatures (evaporation heat). If product deposits or caking are formed on the wall or ceiling of the dryer, the assessment of thermal stress of a product must take into account a long-term stress which can lead to ignition. This can result in a dust fire or – in particular in the event of dropping smoldering lumps – to a dust explosion.

The explosion protection measures applied are "constructional explosion protection", "inerting" or, if applicable, "avoiding effective ignition sources".

The principal constructional explosion protection measures are explosion venting and explosion suppression. Explosion-resistant design for the maximum explosion pressure is not used, as a rule, because of the size of dryers. However, explosion decoupling measures (isolation) must be employed as well. If explosive dust/air mixtures are expected only in certain parts of the spray dryer, e.g. in the cone, this partial volume can be used as a basis for determining the dimension of constructional protection. If spray dryers have adjoining fluid bed dryers, they must either be explosion decoupled or the fluid bed dryers must be included in the safety concept.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) as sole protection measure is generally only possible if it is ensured that

- the temperature-related minimum ignition energy is not below the value of 10 mJ;
- hazardous dust deposits and caking are avoided and self-ignition processes are thus ruled out (if it is not possible to avoid dust

deposits, this may be acceptable if adequate methods of early detection (e.g. CO detection) recognize and combat self-heating or self-ignition at an early stage so that ignition-effective smoldering lumps are avoided);

- the surface temperatures are low so that dust/air mixtures cannot be directly ignited (as a rule, 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced by the heating system (no direct heating system, filtration of the supply air for the heat exchanger);
- spray discs are monitored so that any failures which may result in the disc being torn off are detected in time.

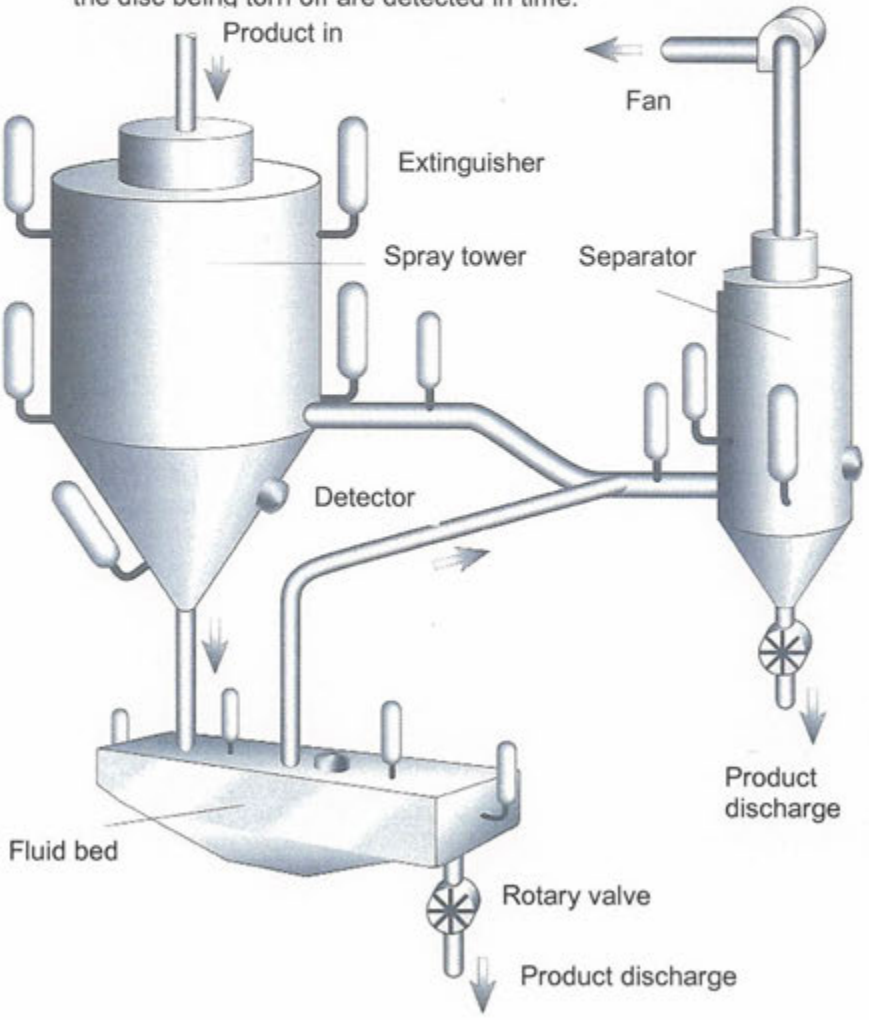

Fig. 1: Schematic representation of a spray dryer system protected by explosion suppression measures

7.2 Fluid bed dryers/granulators

If combustible solids are processed in fluid bed dryers in batch or continuous operation, the occurrence of explosive dust/air mixtures is to be expected. As products processed in fluid bed dryers frequently also contain combustible solvents, the occurrence of hybrid mixtures must be expected in such cases.
The products are exposed to thermal stress during processing which may last several hours in batch operation, depending on the product and process. In fluid bed dryers running in continuous operation, long-term thermal stress may also occur owing to caking and dead zones. This can cause self-ignition and subsequently a fire and/or explosion.
In practice, "constructional explosion protection" is used above all. Alternatively, explosion prevention measures such as "inerting" or, if applicable, "avoiding effective ignition sources" can be used.
For smaller equipment (volume of up to 1 m^3), the constructional explosion protection typically used is explosion-resistant design for maximum explosion pressure. In case of medium or large equipment, explosion venting or explosion suppression is used as a rule. Explosion tests have shown that it is possible to deviate from the general calculation principles for explosion venting and explosion suppression, owing to the process-technological features of fluid bed dryers.
For dusts classified as dust explosion classes St 1 and St 2, the protective measures "explosion venting" or "explosion suppression" in combination with a filter tray with a mesh size of not more than 250 µm and sufficient rigidity can prevent a flashback on the supply air side. This does not apply to explosions of hybrid mixtures or steam/air mixtures.
In any case, explosion decoupling measures (isolation) such as rapid-action gate and barrier valves must be used.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) as sole protective measure is generally only possible if it is ensured that

- the product is free from combustible liquids;
- the temperature-related minimum ignition energy does not fall below the value of 10 mJ;
- hazardous dust deposits and caking – in particular in the area below the filter tray – are avoided and self-ignition processes are thus ruled out;
- the surface temperatures are low, so that dust/air mixtures cannot be ignited directly (as a rule, max. 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced by the heating system (e.g. no direct heating system, filtration of the supply air for the heat exchanger).

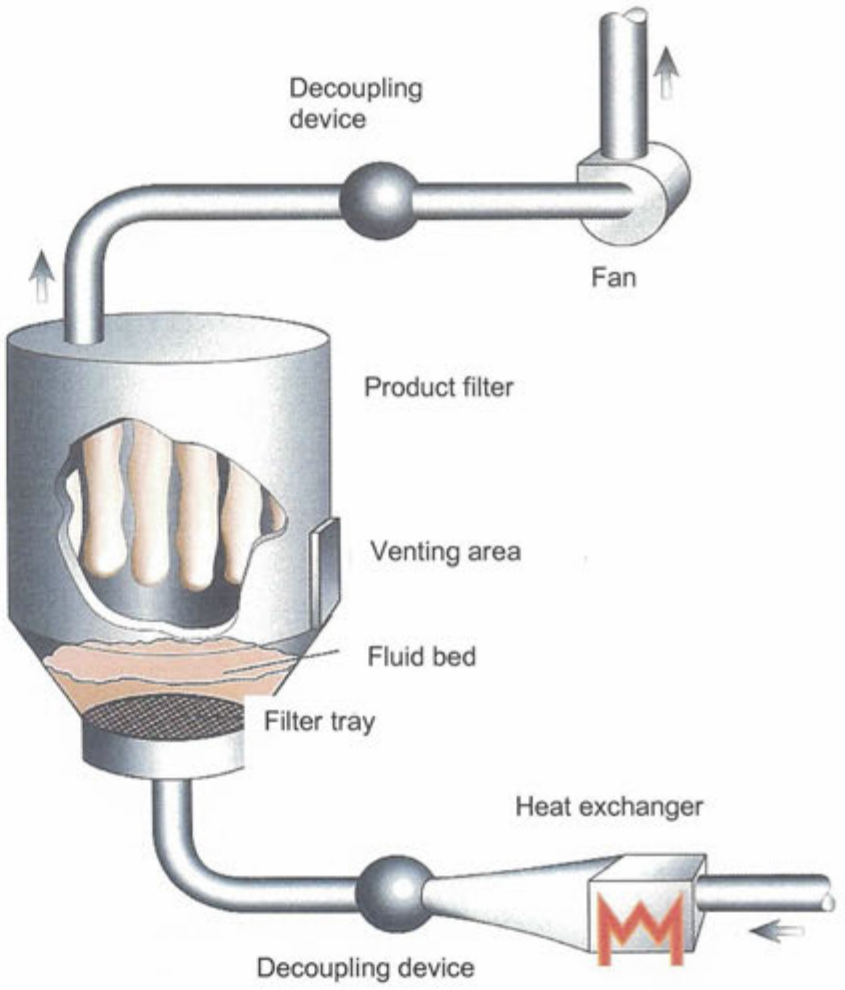

Fig. 2: Schematic representation of a fluid bed dryer with protection by explosion venting

7.3 Flash dryers

If combustible solids, e.g. in the form of pastes or filter cakes are processed in flash dryers, the occurrence of explosive dust/air mixtures is to be expected.
Even if estimate calculations (flow rate of solids/flow rate of air) result in average dust concentrations ranging below lower explosion limits of a powdery product, explosive dust/air mixtures cannot be ruled out.

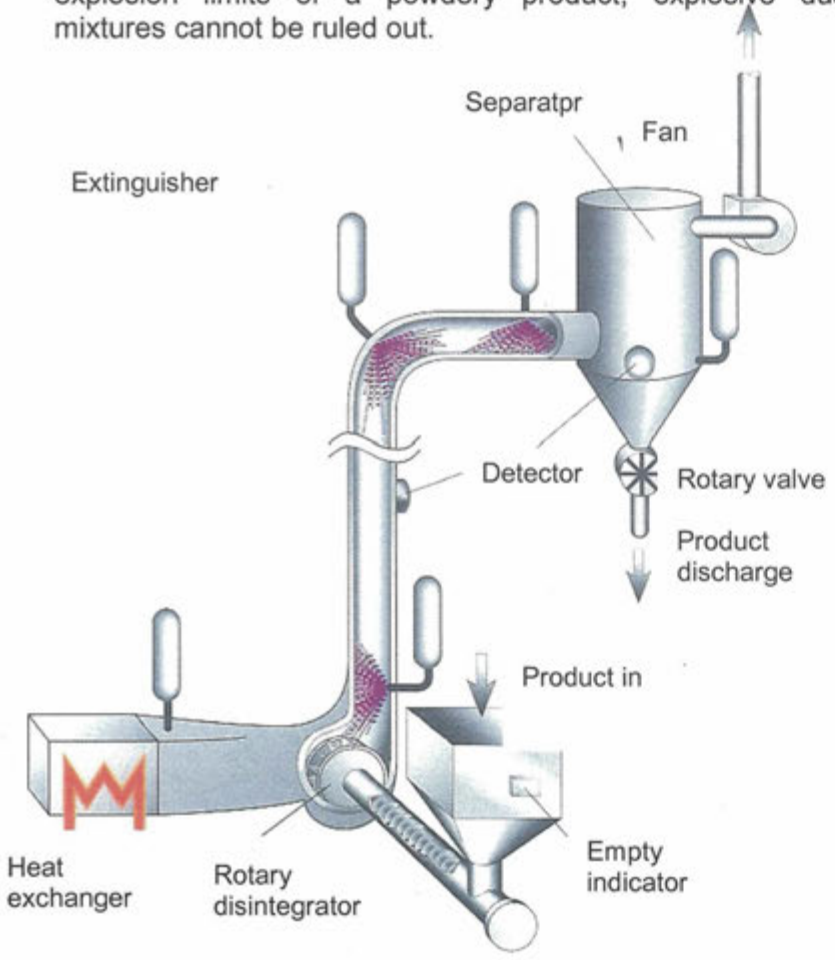

Fig. 3: Schematic representation of a flash dryer with protection by explosion suppression

The product is exposed to fairly low and short-term thermal stress in spite of high air inlet temperatures (evaporation heat). If product deposits and caking are formed on the wall or ceiling of the dryer, the assessment of thermal stress of a product must take into account a long-term stress which can rapidly lead to ignition, in particular in the area of the high inlet temperatures. This can result in a dust fire or – in particular in case of dropping smoldering lumps – in a dust explosion.
If rotary disintegrators are used, a higher ignition hazard is to be expected.
"Constructional explosion protection" is used above all.
The constructional explosion protection measures used predominantly are explosion venting and explosion suppression – both in combination with explosion decoupling (isolation). The elongated shape of the flash dryer must be taken into account in planning the protective measures.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) is only possible if it is ensured that

- the temperature-related minimum ignition energy does not fall below the value of 10 mJ;
- hazardous dust deposits and caking – in particular in the area of hot air inlet – are avoided and self-ignition processes are thus ruled out;
- the surface temperatures are low, so that dust/air mixtures cannot be ignited directly (as a rule, max. 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced by the heating system e.g. (no direct heating system, filtration of the supply air for the heat exchanger);
- when using rotary disintegrators, the input of tramp matter and thus the occurrence of friction and impact sparks as well as hot surfaces is avoided.

7.4 Fluidized bed dryers

If combustible solids are processed in fluidized bed dryers, the occurrence of explosive dust/air mixtures is to be expected depending on the proportion of dust.
The products are exposed to thermal stress during processing. Since fluidized bed drying is normally a continuous process, the thermal stress on the product passing through is fairly low.

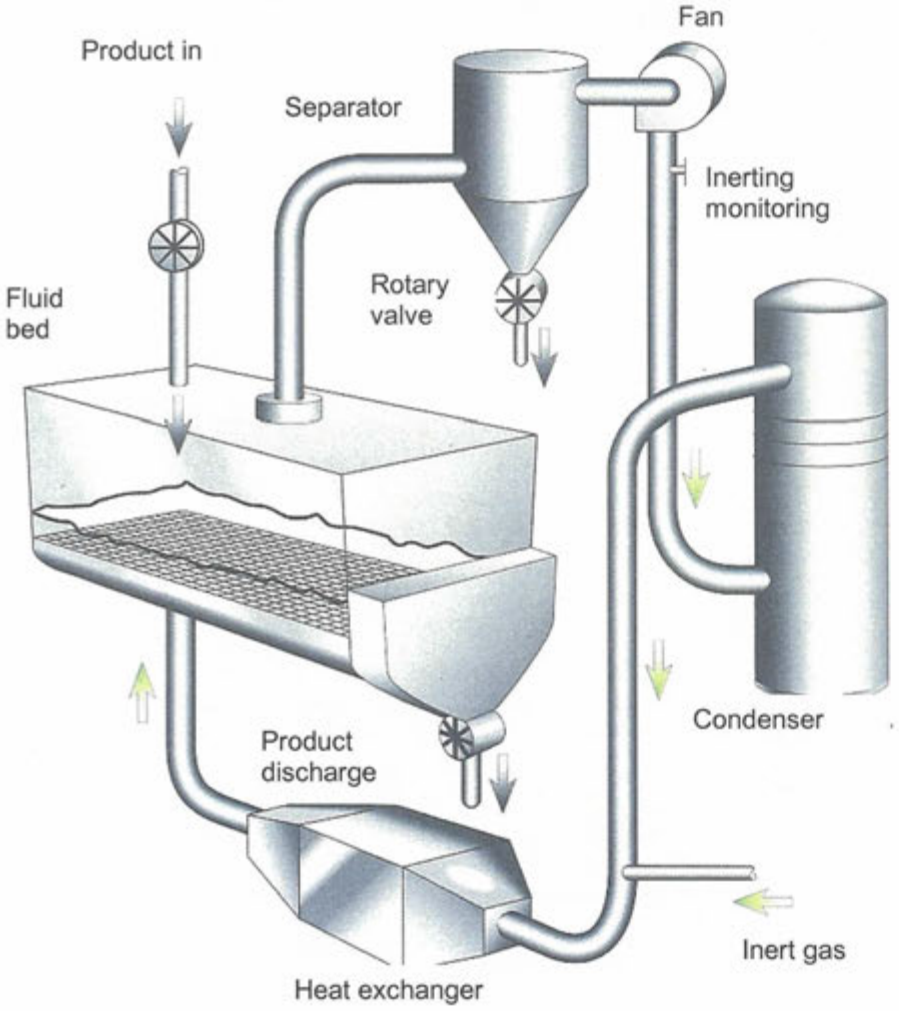

Fig. 4: Schematic representation of a fluidized bed dryer with protection by inerting (closed circulating system)

However, if product deposits or caking are formed, these will be subject to long-term thermal stress, which may lead to self-ignition processes and, as a consequence, to dust fires or dust explosions.

Preventive as well as constructional explosion protection measures can be used. When selecting and determining the protective measure, it is important to distinguish between dryers with integrated separators and dryers with external separators. Fluidized bed dryers with integrated separators are treated the same way as fluid bed dryers.

In case of fluidized bed dryers with external separators, the proportion of dust contained in the product being dried is of particular significance. Low dust proportions in the product result in explosive dust/air mixtures only in the separator. In this case, any necessary explosion protection measures can be restricted to the filtering separator. A practical solution is, for instance, the pressure relief in the separator applying the respective explosion decoupling measures, in particular in the connection pipe to the fluid bed.
If explosive dust/air mixtures are expected throughout the system, inerting or a constructional explosion protection measure can be used.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) as sole protection measure is generally only possible if it is ensured that

- the product is free from combustible liquids;
- the temperature-related minimum ignition energy does not fall below the value of 10 mJ;

- hazardous dust deposits and caking – in particular in the area below the filter tray – are avoided and self-ignition processes are thus ruled out;
- the surface temperatures are low, so that dust/air mixtures cannot be ignited directly (as a rule, max. 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced by the heating system (e.g. no direct heating system, filtration of the supply air for the heat exchanger);
- hazardous electrostatic charging of plant units is prevented, e.g. by grounding conductive parts and avoiding liners of non-conductive materials;
- the fan is located on the filtered air side of the separator.

7.5 Crushing and drying apparatus

High-speed mills are used to dry and simultaneously crush large quantities of solids. The drying medium is hot air or combusted gas which also serves to transport the crushed product along. If combustible solids are guided along this kind of crushing and drying equipment, the occurrence of explosive dust/air mixtures is to be expected during normal operation. In general, the flow rate of solids in relation to the flow rate of air is so high that the average dust concentrations are distinctly above the lower explosion limit.

Even if the air inlet temperature is high (e.g. 600°C), there is no imminent ignition hazard if the product temperature stays fairly low (as a rule, <100°C) owing to a short residence time and the evaporation heat withdrawn from the system. If product deposits or caking occur, however, the products are exposed to a longer thermal stress. Product deposits and caking are formed mostly in the hot-air duct below the grinding vessel or in the classifiers integrated in mills. Because of this long-term stress, self-ignition processes can occur resulting in smoldering lumps or a fire. This in turn can cause a dust explosion.

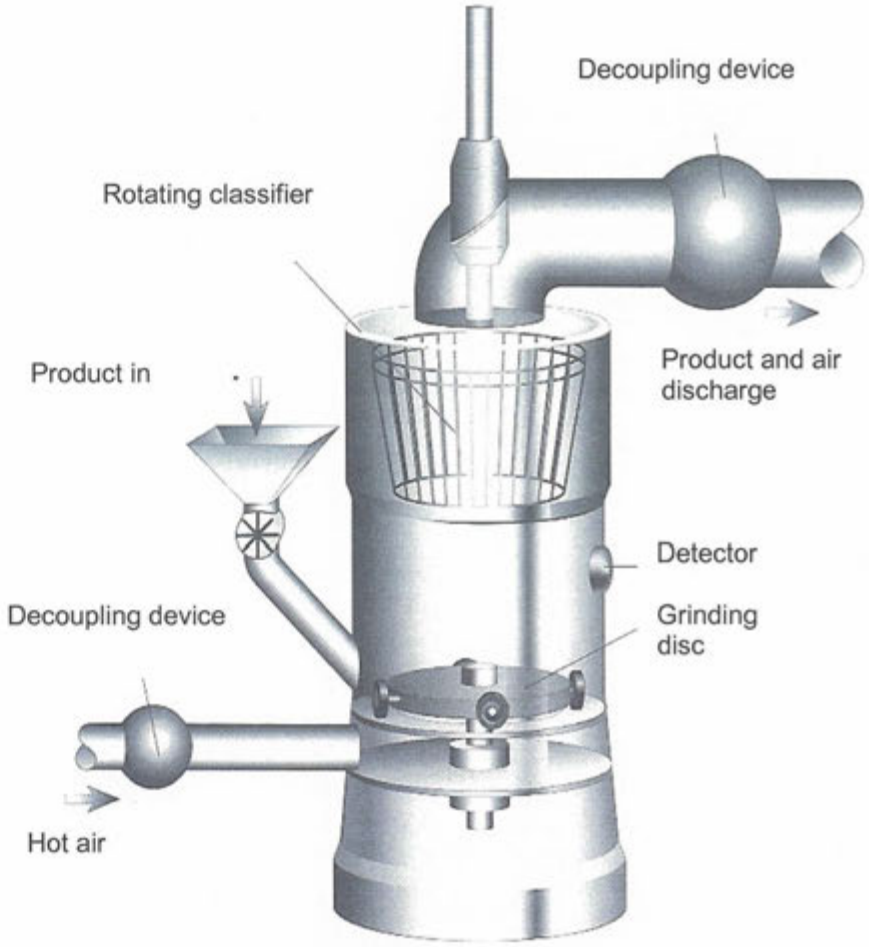

Fig. 5 *Schematic representation of crushing and drying apparatus with explosion-resistant design for the maximum explosion pressure*

In addition to the thermal stress, the products are simultaneously exposed to mechanical stress caused by the crushing process. Additional mechanical stress can be caused by dynamic classifiers integrated in the mill. The relative speeds of the moving parts are considerably higher than 1 m/s. In particular in cases when tramp matter is introduced or failures occur, mechanically generated sparks or hot surfaces cannot be ruled out. These may ignite both dispersed and deposited dust.
"Avoiding effective ignition sources" as sole protection measure is generally not applicable here because of the thermal and mechanical ignition hazards involved.
In particular "inerting" or "constructional explosion protection" is used in this context.
With respect to inerting, the maximum oxygen concentration permissible for operation for the specific product, taking into account the type of inert gas and the temperature dependence of the limiting oxygen concentration have to be determined.
The constructional explosion protection measures which can be used here are explosion-pressure-shock resistant design for the maximum explosion pressure as well as for a reduced explosion pressure in connection with explosion venting or explosion suppression. Explosion decoupling (isolation) measures are required (hot air supply, product feed, product discharge, air outlet) in addition. To what extent a decoupling in direction of adjoining parts of the plant is necessary depends, among others, on the length of the feed duct to the next apparatus and on the explosion protection provided for it.

7.6 Rotary dryers

Rotary dryers are suited for pourable to pasty bulk goods requiring to be dried in large quantities. The bulk goods to be dried are transported mechanically by rotation of the slightly inclined drum. The drying medium is hot air or combusted gas guided through the drum with or against the current. The processing of combustible bulk material may result in the formation of explosive dust/air mixtures.
Due to the mechanical transport procedures, the bulk material has a fairly long residence time in the drum. In normal operation, however, the thermal stress does not lead to any critical operating conditions. If bulk material with extremely varying particle sizes is used, product deposits and caking occur, and in case of a sudden stopping of the drum, the resulting thermal stress may lead to smoldering particles caused by self-ignition (sparks), smoldering lumps or a fire. This in turn can cause an explosion.
The explosion protection measures applied here are "inerting", "constructional explosion protection" or, if applicable, also "avoiding effective ignition sources".

With respect to inerting, the maximum oxygen concentration permissible for operation for the specific product, taking into account the type of inert gas and the temperature dependence of the limiting oxygen concentration have to be determined. When bulk materials with extremely high water content are used, the water steam released can further contribute to the inerting process.
The constructional explosion protection measure generally applied is explosion venting. Measures for explosion decoupling of the gas and product path must be taken into consideration additionally.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) as sole protection measure is generally only possible if it is ensured that

- the temperature-related minimum ignition energy does not fall below the value of 10 mJ;
- hazardous dust deposits and caking – in particular in the area of hot air inlet – are avoided and self-ignition processes are thus ruled out;
- the surface temperatures are low, so that dust/air mixtures cannot be ignited directly (as a rule, max. 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced from the hot gas generator in case of directly heated dryers;
- the product is free from combustible liquids;
- the gas inlet temperature is limited so that – in dependence on the maximum possible dust deposit - self-ignition processes cannot occur.

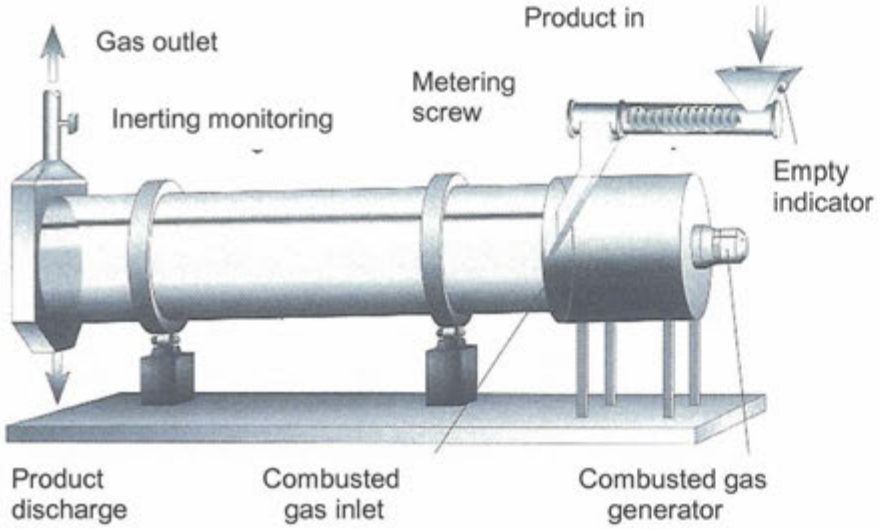

Fig. 6: Schematic representation of a drum dryer with inerting using combusted gas

7.7 Agitator dryers/paddle dryers

Agitator and paddle dryers are generally operated under vacuum conditions. If the dryer is operated at <0.1 bar, hazardous effects resulting from dust explosions are not to be expected, as a rule. In these cases, it is normally sufficient to ensure a vacuum of <0.1 bar and use inert gas to eliminate the vacuum.

A spontaneous decomposition (cf. "characteristics", Section 2.5.3)* of a product cannot be prevented using this protection measure. It can be initiated, e.g. by tramp matter that is introduced and jams between paddle and wall and thus leads to local overheating.
If a vacuum of <0.1 bar cannot be achieved, additional protective measures may be required. In this context, the fact that a vacuum of over 0.1 bar also has a favorable influence on the characteristics of dust (cf. "Basic Principles", Section 2.2.3) can be taken into account.
Any necessary constructional explosion protection measures are easier to implement in vacuum dryers because the process-related design results in higher equipment stability.

"Avoiding effective ignition sources" (cf. "Basic Principles", Section 2.3) as sole protection measure is generally only possible if it is ensured that

- the pressure-related and temperature-related minimum ignition energy does not fall below the value of 10 mJ;
- a high degree of filling (>70%) limits the occurrence of explosive dust/air mixtures;
- during the charging and discharging process, the dryer is operated at reduced speed (circumferential speed < 1m/s) and no so-called choppers or disintegrators are used;
- no hot surfaces are caused by the introduction of tramp matter. This can be achieved, for instance, by limiting the particle size of any possibly transmitted tramp matter so that

it cannot get stuck between moving parts and the wall;
- hazardous dust deposits and caking are avoided and self-ignition processes are thus ruled out;
- the surface temperatures are low, so that dust/air mixtures cannot be ignited directly (as a rule, max. 2/3 of the minimum ignition temperature of the dust cloud);
- no sparks are introduced from the heating system (e.g. no direct heating system, filtration of supply air via the heat exchanger).

* ISSA, *Determination of the Combustion and Explosion Characteristics of Dust,* International Section of the ISSA for System and Machine Safety, D-68165 Mannheim, 1995

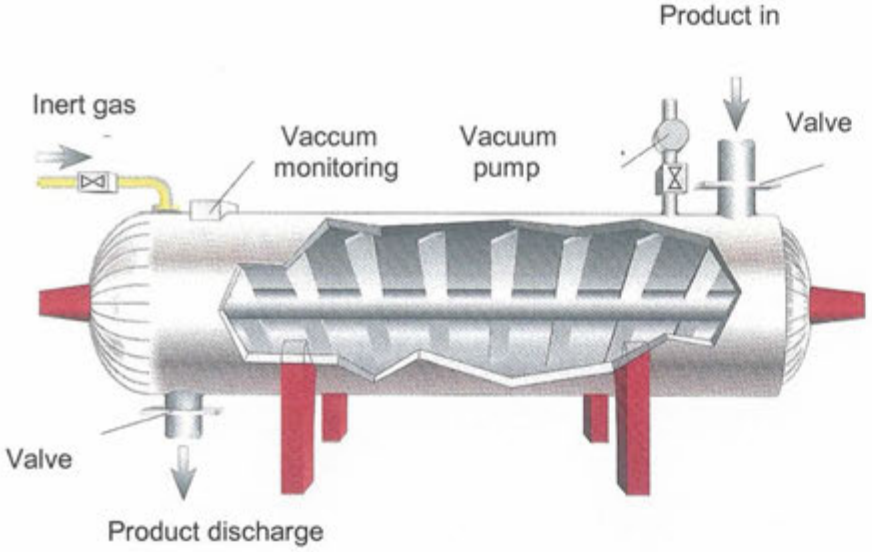

Fig. 7: Schematic representation of a vacuum paddle drye

7.8 Belt conveyor dryers/pan dryers

In belt conveyor dryers/pan dryers the products are not dispersed during the drying process. Depending on the product features (e.g. grain size, residual moisture) hazardous dust/air mixtures can at best occur in transition areas (e.g. discharge points). If extraction devices are provided in these areas, there is normally no explosion hazard. The explosion protection of separators requires separate considerations (cf. Collection of Examples, Section 4).
If explosive dust/air mixtures at discharge points cannot be avoided, adequate safety is achieved in the hazardous areas by "avoiding effective ignition sources".
In belt conveyor dryers/pan dryers, the first and foremost danger is the occurrence of fire. Fires can be caused especially by dust deposits in the area of the heating equipment.
Well-tried fire protection measures are:
- avoid hazardous dust deposits and caking;
- limit the residence time of the product in the temperature field.

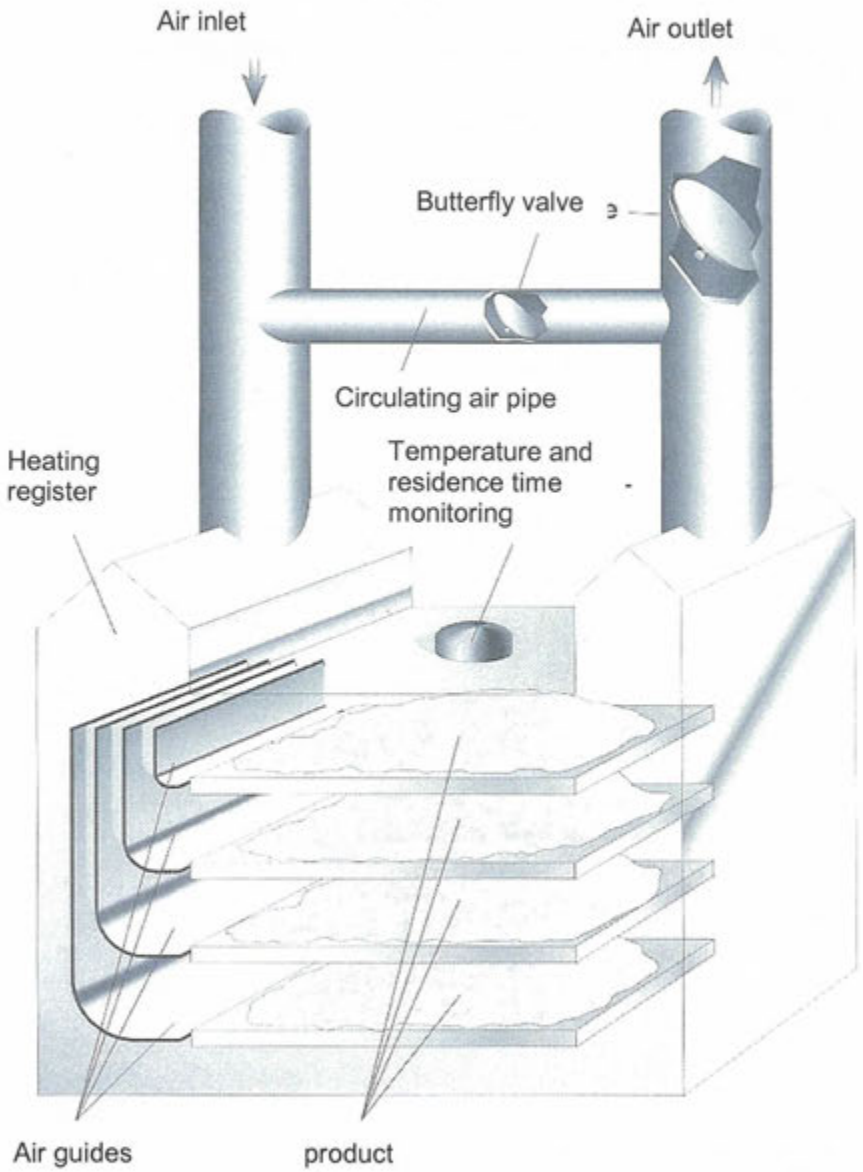

Fig. 8: Schematic representation of a pan dryer