DEKRA Dust Explosion Guidance Series

DEKRA

NUMBER 3: SILO FILLING AND EMPTYING

Note: ***This guidance note is produced in good faith and may not cover all risks and eventualities with all equipment of this type. If in doubt, our process safety specialist team will be delighted to help you navigate risk assessment, basis of safety definition and testing requirements.***

POTENTIAL FIRE AND EXPLOSION CONSEQUENCES

- Ignition of a dust cloud external to the silo resulting in a flash fire causing potentially serious burns.
- Dust cloud deflagration within the silo and/or adjoining vessel/equipment resulting in blast effects including, flame ejection, pressure effects and/or projectiles with possible explosion propagation into upstream interconnected equipment.

OVERVIEW

In industries that handle solid materials in larger quantities, silos will be a very common sight. In the food industry, for example, silos for sugar, flour, cocoa, milk powder, etc. will be common in manufacturing facilities. The main process safety hazards are during filling and emptying of the silos where potentially explosive dusts can be roused to form a flammable cloud. Controlling this hazard requires good process safety design and careful operational management.

Photograph 1: Bank of Storage

Photograph 2: Storage Silos in the Agricultural Sector

SUMMARY OF DUST EXPLOSION RISKS

Most likely intrinsic ignition sources	Most common basis of safety	Test required to Support Basis of safety
• Unsuitable or malfunctioning electrical apparatus • Mechanical friction and hot surfaces • Mechanically generated sparks • Static electricity • Self-heating and ignition of dusts	Avoidance of ignition sources Possibly supported by Explosion Protection e.g. Venting or Suppression	• Ignition temperature of cloud and layer (MIT and LIT) • Minimum ignition energy (inductive spark) • Minimum ignition energy (capacitive spark) • Material Explosivity e.g. K_{st} (20 L Sphere) • Self-heating "basket" test series or other suitable thermal stability test

Peripheral / associated risks to consider:

- Flammable atmospheres inside aspirators / dust extraction systems – may require suitable ATEX electrical and non-electrical equipment (e.g. fan internals may need to be ATEX certified).
- Dust filter system should be subject to separate ATEX / DSEAR assessment.
- If explosion protection is employed, isolation devices should be fitted to inlet and outlet to prevent propagation of an explosion to other interconnected plant areas. This should include propagation of an explosion back to the offloading tanker.
- Thought should also be given to the risk of explosions in other interconnected vessels propagating into the silo. Isolation devices can block both exit and entry of explosions from and to vessels

RISKS

- Risk of a transient flammable dust cloud in the silo headspace during introduction of powder, and until it settles. Depending on how often the silo is filled, this flammable cloud could be intermittent or almost continuously.
- Deflagration that could cause the silo to deform or fail with subsequent blast effects. Sometimes silos are remote from the plant and personnel etc, however, often they are integral to the plant and located close by or in occupied areas. Their large size increases the potential scale of any explosion. This scale up effect can lead to significant damage and/or injury or fatalities. The location and internal volume of the silo therefore governs the overall scale of risk. The HSE provide guidance for when explosion protection may be required depending on the silo size and risk posed to personnel; this often leads to explosion venting being used as a secondary basis of safety, especially for larger silos.

- For silos filled at a high rate using methods such as pneumatic conveying, powder can accumulate significant static charge. Heaping large amounts of charged powder in a silo can lead to cone type discharges forming multiple arcs from a point on the surface of the powder to the silo wall (a calculable effect). Spark discharges can also be drawn from isolated conductive plant items that pose a similar ignition hazard. Electrostatic brush discharges can also occur within highly charged dust clouds and heaps although there is very strong evidence to date to support that these are not incendive to dust clouds. If silos are made from insulating materials e.g. plastic or fibreglass which is not uncommon or have internal insulating linings, then the possibility of propagating brush discharges needs to be considered. These are highly energetic and can ignite dust clouds, even ones which low ignition sensitivity. The use of all plastic silos also increases the likelihood and energy from the cone discharge mentioned above. It is recommended silos are of conducting, metallic construction to reduce this risk.

- Objects such as tramp metal that can be introduced into the silo during filling can collide with other metal objects at high speed and produce impact sparks. Single impact sparks could ignite sensitive dust clouds. If one of the metals is a light metal such as aluminium (not uncommon for a silo body material), then a thermite spark is possible and such sparks can ignite a wider range of materials than for example, steel impact sparks.

- Rotating equipment items such as screw conveyors often move too slowly to form incendive impact sparks. However, if metal to metal contact occurs, for example, a conveyor flight rubbing on the casing, heat can be generated by friction. This can result in localised temperatures in excess of the temperature required to auto-ignite a dust cloud (MIT) or create a smouldering nest of powder.

- In general, the above ignition sources can occur if equipment is not well maintained. ATEX compliant non-electrical equipment will help to avoid mechanical ignition sources due to special design and certification. But still needs to be maintained carefully. Powders are often delivered by third party vendors and discharged using the third-party equipment (e.g. onboard truck blower). Controlling the ignition risk created by the third- party equipment can be problematic.

- Self-heating behaviour of organic solids can present an ignition source and ignition temperatures tend to reduce dramatically with increasing scale and hence self-ignition can pose a serious ignition source risk. Fire-fighting silo fires is challenging and should be fully hazard assessed.

POTENTIAL SOURCES OF IGNITION

From the 13 identified sources of ignition taken from EN 1127-1, those which are considered most likely to occur with silo emptying and filling are:

1. Flames and hot gases (including hot particles)

2. Unsuitable or malfunctioning electrical apparatus

3. Mechanical friction and hot surfaces

4. Mechanically generated sparks

5. Static electricity

6. Chemical reactions and thermal decomposition leading to self-ignition of dusts

TESTING REQUIRED TO MITIGATE THE POTENTIAL SOURCES OF IGNITION

- Minimum Ignition Energy (Capacitive assessment) – to assess the potential of incendive spark discharges from isolated conductors and personnel.

- Minimum Ignition Energy (Mechanical spark assessment using series inductance) – to assess the potential of mechanical sparks.

- Minimum Ignition Temperature (dust cloud) – for correct specification of Temperature Class rating of ATEX equipment and used in conjunction with MIE (mechanical) to assess the potential of mechanical sparks.

- Layer Ignition Temperature (5 mm layer) – used with MIT (dust cloud) for the correct specification of Temperature Class rating of ATEX equipment.

- 20 L Sphere – Used to determine explosion severity of a material (Kst). This value is needed when sizing explosion relief panels and suppression systems.

- Self-heating “basket” test series – To determine the self-heating capability of the material. Full test series will allow safe storage volumes and durations to be calculated. Other thermal stability tests are available and may also be appropriate in some situations.

Typical Basis of Safety

The Basis of Safety for silos storing flammable powdered solids can either be the Control of Ignition Sources or a combination of Control of Ignition Sources and Explosion Protection e.g. Explosion Relief Venting or Explosion Suppression. Whether protection is required will depend on the outcome of the Ignition Source Risk Assessment. As far as possible, ignition sources should be controlled so as to reduce the demand on protection systems which themselves have a finte reliability. Often larger silos will have relief vents installed while controlling Ignition Sources as a backup or secondary Basis of Safety of Explosion Protection. This is common in very large silos where complete Control of Ignition Sources is impractical (cone discharges are hard to prevent for example) and particularly where the consequences might be severe.

As well as explosion protection, it is also possible to use an inerting method e.g. nitrogen blanketing to displace the oxygen from the headspace to prevent an explosion. This will require knowledge of the limiting oxygen concentration of the material. However, in DEKRA's experience, this is rarely used for bulk silos although has been observed when powders are particularly ignition sensitive or the explosion severity makes it hard to protect e.g. fine aluminium powder silos.

Other Considerations

If the material being stored has a self-heating potential, it will also generate heat and gas such as carbon monoxide (CO) when it begins to smoulder. The use of CO monitoring along with temperature monitoring (to detect heat generation) can be used as means to monitor the silo and give fore warning of an exothermic event in the bulk material.

Any instrumentation employed in the silo will need to be suitably ATEX certified to comply with the hazardous area inside the silo this would include any aspirator / dust filter.