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Emergency inerting systems for coal-grinding applications

There is always a potential risk of explosions when handling combustible bulk solids and powders. Process technicians and engineers know how to estimate and minimise this risk. Nevertheless, devastating dust explosions occur too frequently. So-called 'hot-spots,' sudden spontaneous combustion and explosion risks lurk in every stage of the storage, processing and transportation of combustible powders. In the cement industry, this has relevance to coal-grinding systems. Here, Achim Rott from Yara Industrial GmbH explains the different types of inerting systems that can be used to prevent such explosions in the cement industry.

To have an explosion there needs to be oxygen (O_2), a fuel source and an ignition source in the same place at the same time. In the case of coal-grinding or storage (as one might find in a cement plant) it is not possible to remove the fuel (coal) or ignition source (grinding energy, heat, static charges) and so one has to concentrate on removing the third necessary component - O_2.

This fact has given rise to inerting systems that rely on the use of inert gases. Inert gases have a low level of reactivity and reduce oxygen concentration to below critical levels. By doing this, they prevent the occurrence of critical operating conditions and consequently any resulting explosions or fires. Different inert gases are effective to different extents and it is often not absolutely necessary to replace all of the O_2.

Inerting systems are an effective way to satisfy ATEX regulations that cover explosion prevention. In addition the inerting guidelines CEN/TR 15281, VDI 2263-2 and TRBS 2152-2 are used.

Generally, in terms of the European Directive 94/9/EG (Atex 95a) inerting systems are not seen as protection systems and hence are not subject to compliance with the requirements for this directive. An installation not in range of a possible dust explosion zone, in accordance with the European Directive 99/92/EG (Zone 20, 21, 22), is thus strongly recommended.

Description of the inerting process in coal-grinding systems

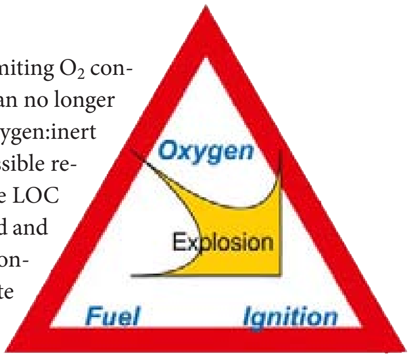
Inerting systems avoid dust explosions and smouldering fires in silos, coal mills and filter equipment by creating an inert atmosphere. In the case of abnormal levels of carbon monoxide (CO), oxygen or heat, the inerting process is initiated automatically through a process-control system. Constant and accurate monitoring of conditions is therefore essential.

In normal operation inerting occurs by using the exhaust of the rotary kiln or from hot gas generated during the operation of the coal mill plant. In case of an emergency shutdown, the coal mill plant inert gas is injected.

LOC and MAOC

The goal at all times is to reduce the limiting O_2 concentration (LOC) so that explosions can no longer take place. The LOC is the highest oxygen:inert gas ratio at which explosion is not possible regardless of the dust concentration. The LOC depends on the kind of coal that is used and needs to be determined separately in consultation with an expert. With lignite (brown coal) for example the LOC amounts to approximately 12% by volume using N_2 and approximately 14% when using CO_2. The maximum allowed O_2 concentration (MAOC) is an operational parameter that is set approximately 2-3% below the LOC.

Extinguishing smouldering fires is only possible at an O_2 concentration as low as 2–3%. To prevent these, the inerting process has to be repeated up to three or four times depending on the LOC when inerting is first started.



Above: When coal is ground in a mill, explosions are a significant risk. Inerting systems are an effective way to remove oxygen from the system, thus preventing explosions.

Flushing inerting method

In the flushing inerting method, the inert gas is introduced at the highest possible speed into different areas of the system to be inerted. As a result of the strong turbulence that is produced, the gases undergo thorough mixing and optimum inerting because pockets of high O_2 concentration are avoided.

This high-speed is reached through special nozzles in connection with the adjusted inert gas pressure at the valve station. The number and size of nozzles is calculated according to the geometrical empty volume of the space that has to be protected.

Yara's design principles

Yara's inerting systems have been designed in accordance with the following criteria, which with regards to the safety standards in coal grinding plants was developed in collaboration with the leading cement manufacturers (including Lafarge, Holcim, Cemex and HeidelbergCement) as well as European and Chinese engineering and coal-grinding plant manufacturers.

1. Carbon dioxide (CO_2).
2. Steam (H_2O).
3. Flue gases (low in O_2).
4. Nitrogen (N_2).
5. Noble gases such as Argon (Ar).

Above: Rank of the effectiveness of various inert gases as defined by VDI 2263 Part 2 – Guideline.

Right: High-pressure CO_2 inerting system for HeidelbergCement's new Tula Cement plant in Russia.

1. The maximum necessary inert gas volume has to be stored 2-3 fold, in addition to a security reserve that is double-stocked.

2. Withdrawal of the maximum amount of inert gas volume that could be needed should be possible within one hour.

3. The necessary inert gas capacity is calculated according to geometrical volumes of all components to be inerted. Calculation is based on the total geometrical volume of the coal grinding system (75% of silo net volume in case of two or more silos).

High-pressure CO_2 inerting systems

High-pressure CO_2 tanks have high inert gas capacities and compact tank dimensions. They are mainly used in countries with large seasonal temperature fluctuations, such as those in Europe, Russia, Central Asia and parts of the Americas.

The installation consists of a cylindrical container with a maximum design pressure of 80bar. The installation is operated in the range from 50-70bar. To keep tank operation pressure in winter between 50-65bar, up to three heaters with a maximum heating capacity of 19kW each are installed.

Below: Low-pressure CO_2 inerting system at Lafarge's Bamburi Cement plant in Kenya.

During the summer the high pressure tank is cooled either with cooling water or by being contained within an air-conditioned room. Tanks are available with capacities of 3-15t. When using high inert gas volumes, regeneration and pressure build up time is necessary, which depends on ambient temperature and installed heater capacity. CO_2 temperature and pressure are dependant on each other as shown below left.

The tank is always filled with deep cold CO_2 from a low pressure tanker (maximum pressure 20–25bar), which corresponds to a liquid CO_2 temperature of -20°C to -29°C. Monitoring of the CO_2 level and tank pressure is done using sensors that take weight and pressure measurements.

Below: CO_2 temperature and pressure relationship.

-30°C = 14.27bar
-25°C = 16.81bar
-20°C = 19.67 bar
-15°C = 22.89 bar
-10°C = 26.47 bar
- 5°C = 30.45 bar
0°C = 34.85 bar
+5°C = 39.72 bar
+10°C = 45.06 bar
+15°C = 50.93 bar
+20°C = 57.33 bar
+25°C = 64.32 bar
+30°C = 71.92 bar

The gas withdrawal valve of the CO_2 vessel is connected to the valve station by a flexible high-grade steel corrugated hose and high-grade steel high-pressure pipe. The valve station is a framework rack with integrated pressure-reduction and the individual electromechanical and manually-controlled valves for the inerting endangered parts of the system, flow meter and CO_2 gas detection system.

During the inerting process, gaseous CO_2 is withdrawn from the CO_2 tank and is taken into the valve station. The flow is monitored at the entry to the valve station using sensors. The CO_2 then flows into the pre-selected areas of the system and displaces the O_2. Inerting is triggered by the higher-ranking programmable logic control (PLC) in the control room, which permanently monitors the CO level, temperature and O_2 concentration during the grinding process and storage of coal dust. Inerting of the individual pieces of equipment is started by opening the corresponding electromechanical ball valves. The pressurised CO_2 flows into the system by means of nozzles once the appropriate ball valves are opened.

The electrical cabinet controls and monitors the CO_2 tank and the valve station and is designed according to individual customer specifications. Electrical control of the tank is self-regulated and is monitored by control circuits.

At the inlet pipe a flow sensor is mounted to detect leaks during stand-by operation. During normal operation the valve station and tank are controlled by the PLC. Additionally local control is integrated so that a manual inerting process is possible in emergency situations like a power shutdown. The position of all electromechanical valves is indicated by limit switches.

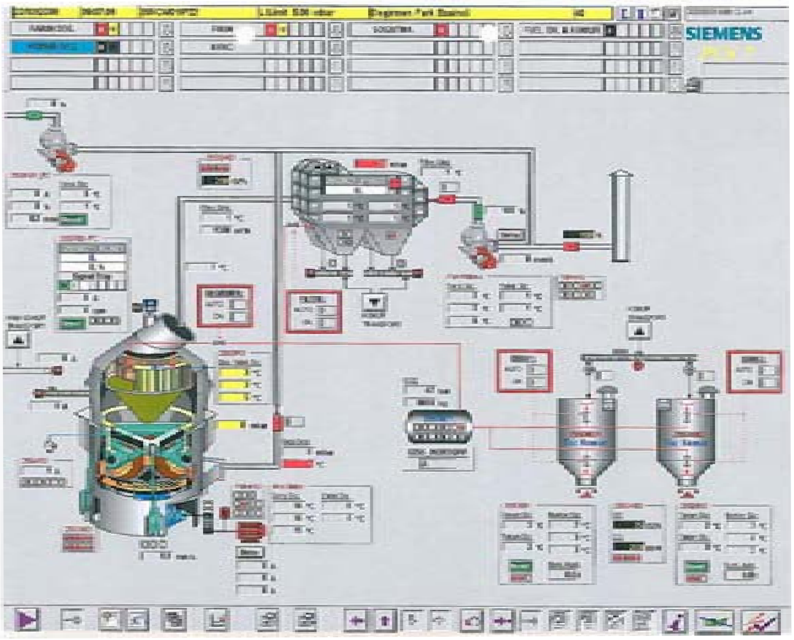
At present Yara installs state-of-the-art PLC systems with Profibus DP signal exchanges. This is integrated with higher control-centres.

Low-pressure CO_2 systems

Low-pressure CO_2 inerting systems combine the advantages of controlled storage in combination with the most up-to-date technology. Their functionality is comparable with high-pressure systems. The main difference is that they feature deep cold storage of liquid CO_2 with the help of an integrated refrigeration unit. For maximum inert gas discharge, the tanks are equipped with heating equipment to compensate for the drop in pressure.

Similarly to the high-pressure tanks, the low-pressure tanks are equipped with electrical weighing devices and pressure sensors for communication via the Profibus DP via the state-of-the-art PLC.

Because the CO_2 is taken in liquid form out of the vessel it has to be transformed into gaseous inert gas with the help of an evaporator. The most suitable kind of evaporators are ambient or atmospheric type because these are independent from any artificial power supply. Electrical evaporators or water-baths, which use power, risk malfunction in the event of a power shutdown. When one is attempting to make an inert atmosphere in a potentially explosive area, such malfunctions cannot be allowed.



Above: Visualisation screen-shot of the inerting system installed by Yara Industrial at AS Çimento's Bucak Plant in Turkey.

Right: New sewage sludge silo at Titan Cement's Thessaloniki plant in Greece.

Below: High-pressure N_2-pack inerting system with valve station installed at Lafarge's Rezina Cement plant in Moldova.

Low-pressure inerting systems are mainly used in countries with constant temperatures above +5°C, for example the Middle East, Africa, South Asia, Australia and Central America. The inert gas capacity is mainly dependant on the size of the evaporator and ambient temperature. Tanks are available in a range of sizes from 4–28t. The capacities and number of ambient evaporators needed are decided on an individual basis.

High-pressure battery systems

High-pressure battery inerting systems are used for small to medium CO_2 inerting capacities in places with limited infrastructure and where CO_2 is not available by road.

They are very compact and have many similar technical characteristics as discussed above including weighing sensors, pressure sensors and communication systems. Batteries are used with standard CO_2-steel cylinders for inert gas discharge and may be used in nearly all countries of the world. Weather conditions do have to be considered however, meaning that a small housing structure and/or heating may be necessary.

High pressure N_2-pack inerting system

These systems are used in countries with infrastructure that severely limits the availability of CO_2 by road. N_2 high pressure packs are provided with nine to 12 standard 200bar N_2 steel cylinders for inert gas discharge. Again, they can be used in nearly in all countries of the world.

The number of packs depends on the inert gas volume required. Multiple lines may be used and Yara designs feature automatic switching to ensure uninterrupted gas flow. In such a set-up, each line can provide sufficient inert gas for the entire coal-grinding system. Empty packs will be indicated by pressure sensors and have to be exchanged immediately. Pressure fluctuations caused by climate conditions do not affect N_2-pack based inerting systems, so erection outside with a protective roof is generally sufficient.

Inerting of secondary fuel silos

In recent years the cement and lime industry has substituted increasing amounts of coal (and other conventional fuels) with secondary fuels such as sewage-sludge, wood powder, fluff and others.

In close collaboration with Titan Cement, Schenck Process, AltmayerBTD and robecco, Yara upgraded the existing CO_2 inerting system at Titan's Thessaloniki plant in Greece in 2011.

This meant that the new 365m^3 sewage-sludge silo is now provided with inert gas by a single valve station erected near to the silo. Several injection points are used including at the top of the silo, at the ring pipe around the flat bottom of the silo and in the Schenck Multiflex dosing system.

During start-up, inert gas volumes have been successfully tested together with Titan's engineers and integrated into the PLC system. Based on this experience, Yara is now working on another sewage-sludge project with Titan Cement at a plant in Bulgaria.