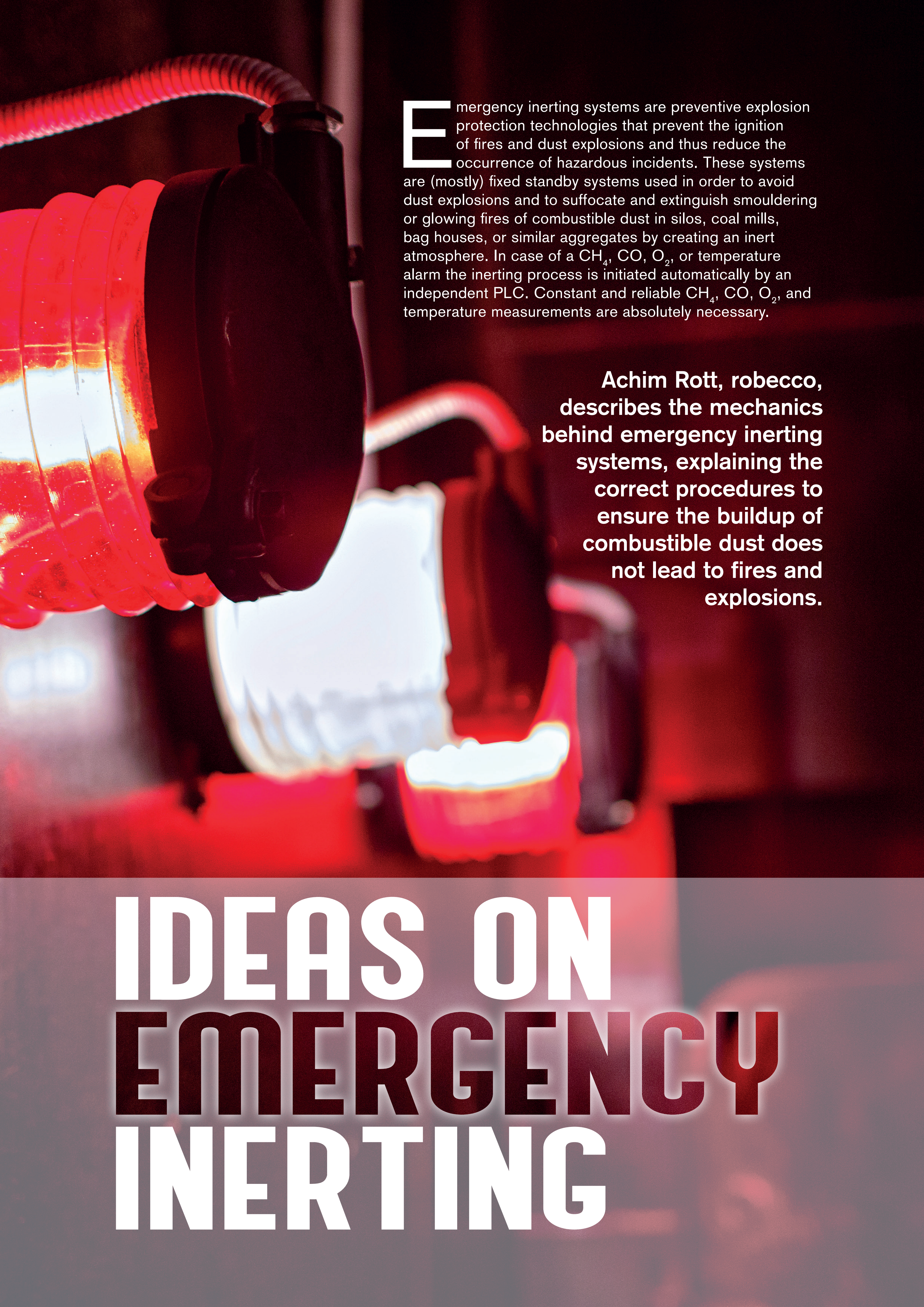

Emergency inerting systems are preventive explosion protection technologies that prevent the ignition of fires and dust explosions and thus reduce the occurrence of hazardous incidents. These systems are (mostly) fixed standby systems used in order to avoid dust explosions and to suffocate and extinguish smouldering or glowing fires of combustible dust in silos, coal mills, bag houses, or similar aggregates by creating an inert atmosphere. In case of a CH_4, CO, O_2, or temperature alarm the inerting process is initiated automatically by an independent PLC. Constant and reliable CH_4, CO, O_2, and temperature measurements are absolutely necessary.

Achim Rott, robecco, describes the mechanics behind emergency inerting systems, explaining the correct procedures to ensure the buildup of combustible dust does not lead to fires and explosions.

IDEAS ON EMERGENCY INERTING

Figure 1. CO_2 low-pressure tank with ambient evaporiser.

Figure 2. CO_2 high-pressure tank.

Table 1. Influence of temperature to the limiting oxygen concentration.	
Temperature (°C)	LOC (vol%)
20	14
95	13
200	11.5
300	10

A continuous reduction of the oxygen concentration to the limiting oxygen concentration (LOC) and a further reduction to the maximum allowed oxygen concentration (MAOC), with the injection of inert gas and permanent control and monitoring of the oxygen levels, is mandatory. The effectiveness of emergency inerting has to be verified via monitoring of the oxygen levels in the system. The maximum allowed O_2 concentration (MAOC) is an operational parameter that is set approximately 2 – 3% below the LOC, it is a safety margin set below the LOC.

In the case of abnormal levels of carbon monoxide (CO), oxygen, or heat, the inerting process is initiated automatically through an integrated process-control system. The goal at all times is to reduce levels to the LOC so that explosions can no longer take place. The LOC is the highest oxygen concentration at which an explosion cannot occur regardless of the dust concentration. The LOC depends on the kind of fuel that is used and needs to be determined separately in consultation with an authorised body. With lignite (brown coal) for example the LOC amounts to approximately 12% by volume using N_2,and approximately 14% when using CO_2.

Emergency inerting is discontinuous and can be used to prevent fires and explosions by extinguishing smouldering nests and glowing fires which can become the primary causes of the ignition and propagation of open fires.

Depending on the inert gas used (source VDI2263-2) effectiveness for inerting generally decreases in the following order:

- CO_2
- Steam
- Flue gases
- N_2
- Noble gases

The flow-through inerting method or the displacement inerting/flushing method is mostly practical. The necessary inerting time and inert gas volumes of individual aggregates with constant geometrical volumes is theoretically calculated during the engineering and design phase and has to be checked and corrected as necessary after commissioning by practical tests based on the measured MAOC value. The necessary inerting time and inert gas volumes of individual aggregates with variable geometrical volumes (e.g. silos) is theoretically calculated during the engineering and design phase according to different filling levels and has to be checked and corrected after commissioning using practical tests based on the measured MAOC value.

Inert gases have low levels of reactivity and are used to reduce oxygen concentrations to below critical levels. Inert gases act as simple asphyxiants, they displace the normal air and cause suffocation due to a lack of oxygen. By doing this, they prevent the occurrence of critical operating conditions and consequently any resulting explosions or fires. Different inert gases offer vary degrees of efficacy, and it is often not absolutely necessary to remove all of the O_2.

Nevertheless, extinguishing smouldering or glowing fires of combustible dusts and powders is only possible at oxygen concentrations of 2 – 3% (maximum). Therefore, the inert gas concentration and related oxygen level has to be kept up over a longer period (several hours or days) until the fire is suffocated or extinguished. Monitoring and control of the effectiveness of emergency inerting is only possible with a combination of CO/CH_4 and O_2 measurements. A single CO measurement does not indicate any effectiveness, since the inert gas is diluting the CO level without giving any reliable information about the remaining oxygen concentration.

By installing the correct monitoring equipment and software, the tell-tale signs of a fire and subsequently an explosion can be detected in sufficient time to initiate the emergency inerting system and prevent both the fire and the explosion from occurring.

Generally, it is recommended to erect emergency inerting systems outside of a dust explosion area zone (20, 21, 22) according to European ATEX guidelines 99/92/EC (user guideline) and 2014/34/EC (product guideline). In a case where the emergency inerting system must be erected within one of these dust explosion zones, an ATEX guideline must to be applied for.

Emergency inerting systems should be designed according to the following European directives:

- European Pressure Equipment Directive PED 2014/68/EC.
- European Machine guideline 2006/42/EC.
- Low voltage guideline 2014/35/EC.
- CEN/TR 15281:2022 Potentially explosive atmospheres. Explosion prevention and protection. Guidance on inerting for the prevention of explosions.

ATEX general requirements: principles of integrated explosion safety

Equipment and protective systems intended for use in potentially explosive atmospheres must be designed from the point of view of integrated explosion safety.[1]

In this vein, the manufacturer must take the following measures:

- Above all, if possible, to prevent the formation of explosive atmospheres which may be produced or released by equipment and by protective systems themselves (inerting).
- To prevent the ignition of explosive atmospheres, taking into account the nature of every electrical and non-electrical source of ignition.
- Should an explosion nevertheless occur which could directly or indirectly endanger persons and, as the case may be, domestic animals or property, to halt it immediately and/or to limit the range of explosion flames and explosion pressures to a sufficient level of safety.

It should be noted that the LOC decreases, with respect to the MAOC, as temperatures rise within the process. This has to be taken into consideration when adjusting alarm levels and inerting volumes.

Basic rule: Suffocating and extinguishing smouldering or glowing fires is only possible at a maximum oxygen concentration of 2 – 3%.

Emergency inerting process

In normal operation, inerting and the parallel process of drying ground coal occurs with flue gases of the rotary kiln plant or via the hot gas generator of the coal mill, ductwork, and baghouse. This is a continuous process and is monitored and controlled by the PLC at the control stand. But in the case of an emergency shutdown, suppliers recommend additional inerting when starting and stopping the coal mill, and in instances of a CO or temperature alarm, this is essential. Therefore, constant and accurate CO-, O_2, and temperature measurement and monitoring is a must throughout the coal grinding workshop and also at coal powder silos.

Emergency inerting is initiated either manually or automatically, based on readings taken from sample points positioned on the equipment being protected. In an automated system, the sample points deliver a sample of the gas within the equipment to analysers which then transmit the readings to a stand-alone or PLC for interpretation. If the readings are outside of the 'safe' parameters then a signal is given to start the inerting sequence. The signal opens automated valves which allow the inert gas to flow to the affected area. These valve(s) are connected between the inert medium storage and the injection nozzles at each piece of equipment; they distribute the flow of inert gas and regulate the pressure to each area.

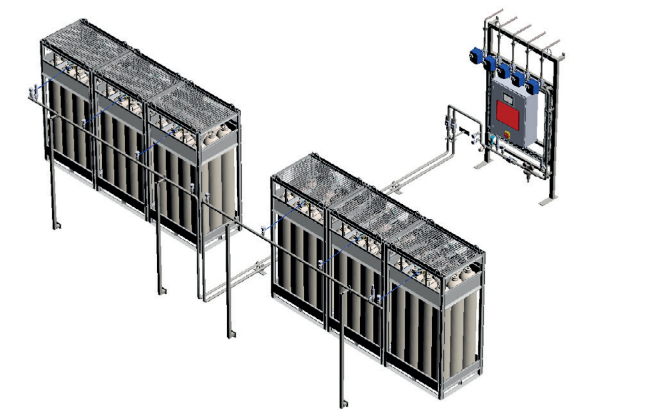

Figure 3. N_2 high-pressure steel cylinder system.

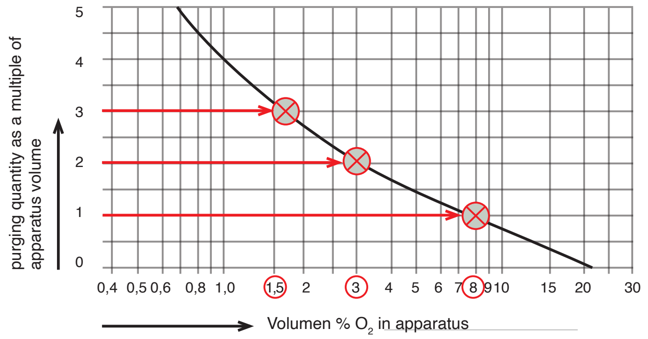

Figure 4. Theoretical purging quantity required.

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

Alarm level (AL) or alarm concentration (AC) is the highest setting for the alarm level at the PLC. It has to be established by considering realistic assumptions such as operational and instrumentation dependent conditions. The objective is to ensure that the alarm is triggered on time. The alarm level prevents the oxygen level from exceeding the MAOC. Different levels of oxygen, carbon monoxide, and temperature have to be fixed in the explosion protection document, according to ordinary ATEX, as well as by the operators and manufacturers of the coal grinding system during initiation.

Storage capacity, design, and flow rates of emergency inerting systems

In daily practice it is essential that inerting trips start immediately after detection of smouldering or glowing fires. Independent of the type and characteristics of combustible dust, the inerting trip and

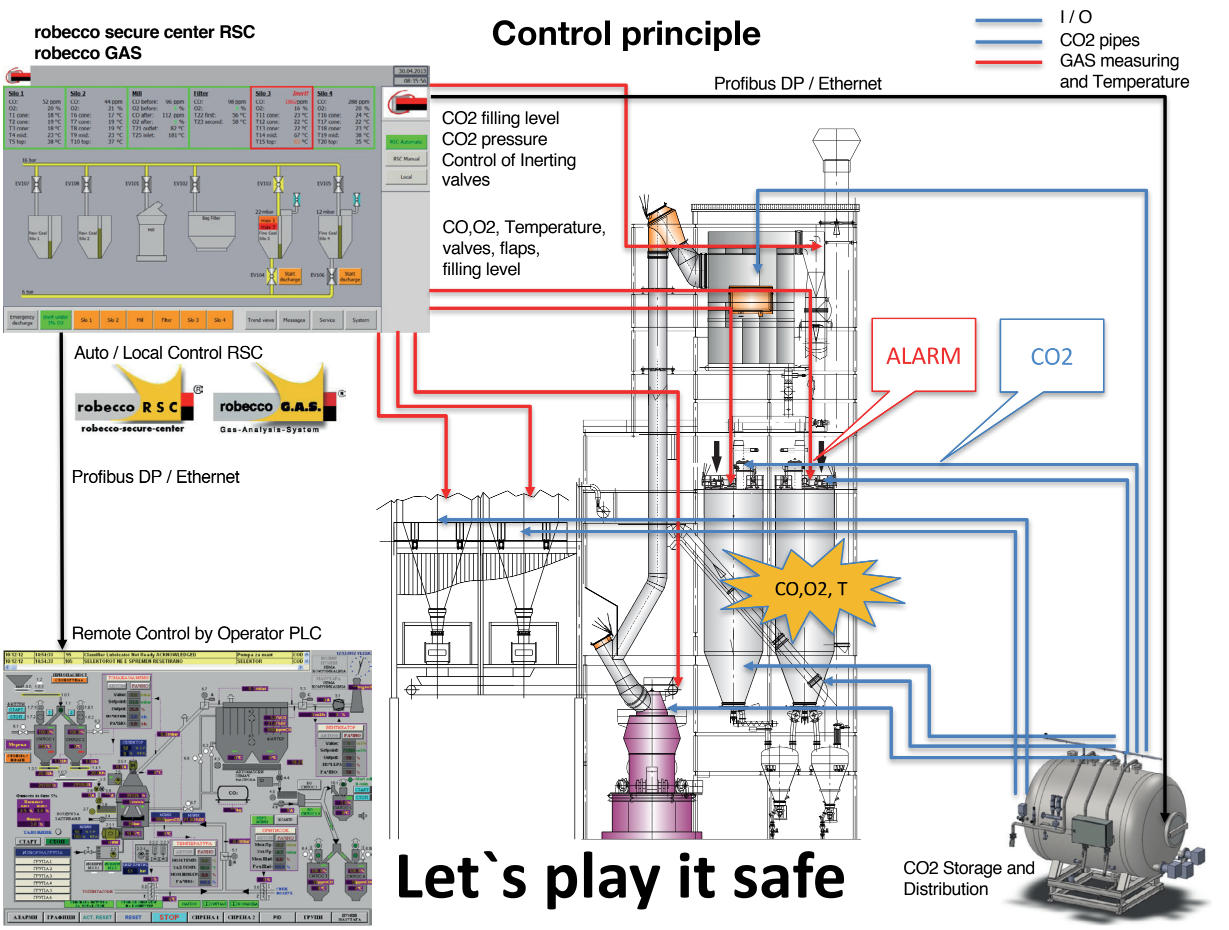

Figure 5. robecco's ATEX and CEN control principle of the inerting system, gas analyser, and robecco secure centre, according to ATEX.

related oxygen concentration (MAOC) has to be maintained until the fire is suffocated and extinguished, where the monitoring and control system indicates constant values in a safe range.

There are several emergency inerting systems available. Most popular are tank systems for CO_2 and N_2 which are designed to store sufficient liquefied inert gas capacities for repeating a number of inerting trips. Depending on the overall geometrical volumes of single aggregates, emergency inerting systems are designed to repeat inerting trips 3 – 4 times over, at which point the refilling of the tank is necessary. The storage capacity is also influenced by the local infrastructure of gas companies and the delivery times for refilling the tank. Also, these aspects have to be considered during the design and engineering phase.

Over the years, the following recommendations have been developed between the industry and customers in order to define the necessary sizes and flow rates of emergency inerting systems.

- The maximum inert gas volume shall be provide at least a 3 fold additional reserve capacity at minimum. This figure mainly depends on the characteristics of the combustible dusts and local infrastructure in terms of emergency inert gas supply. Figure 4, published by Expert Commission for Safety in the Swiss Chemical Industry (ESCIS), shows the theoretical inert gas quantity as a multiple of the vessel volume needed to achieve a specified residual oxygen content with ideal mixing.
- The maximum inert gas volume shall be discharged within 30 – 60 minutes in relation to the overall geometrical volume.

Monitoring and control of emergency inerting process

Efficient monitoring and control of the emergency inerting process is mandatory according to ATEX. Without it, effective inerting is not possible. The detection of smouldering or glowing fires has to be indicated by suitable, reliable, and persistent CO and CH_4 analyser systems. According to the ATEX and CEN guidelines, O_2 measurement is also mandatory in order to supervise and guarantee sufficient inert gas volumes and inerting effect even at O_2 concentrations of $< 3\%$.

In addition, the emergency inerting hardware installation needs to be monitored and functionally controlled as well. Functions of the inerting system such as the CO_2 filling level, filling weight, tank pressure, flow control, and automised valves all need to be monitored and controlled directly via the inerting system, whilst also maintaining direct communication with the central control room (CCR). ■