The incidence and development of explosive hazards are usually described by the so-called explosion triangle. However, it is often overlooked that beyond the three factors: inflammable material, oxygen and an effective source of ignition, a further necessary condition of a specific mixture of oxygen and inflammable material must be given, in order to reach ignition or explosion.

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Dust explosion protection in a hard coal-fired power plant in Gdansk

Type and mixture of dust particles affect zone classification

by Thorsten Arnhold and Piotr Szymanski
With regard to the distribution of combustible material in an oxygen-containing atmosphere there is a basic difference between combustible dusts on the one hand, and gases, vapours or mists in the air on the other hand: due to the high specific weight of dust particles, these collect on the floor or on the surface of objects after a short period where they form layers of dust. If these layers cover hot surfaces or if exothermic chemical reactions occur in their interior, this can lead to smouldering fires which remain undetected for a long time. A dangerous explosive atmosphere can only occur if a sufficiently strong flow of air (wind, storm, pressure wave, draught) whirls up the dust layer and thus causes a mixing of the combustible material with oxygen. This specific property of combustible dust often leads to an underestimation of the explosive risk. If the formation of extensive dust layers is allowed in plants, then a single strong airflow can provoke the risk of explosion. A closed dust layer of less than 1 mm in thickness may be sufficient for this. If no adequate measures are taken to prevent sources of ignition, then it may easily come to an explosion. The particular danger of dust explosions is, that the pressure wave generated by the initial explosion causes whirling of neighbouring dust layers and may then cause a dangerous mixture with subsequent ignition. In the past, dust explosions, virtually in the form of chain reactions, occurred frequently and destroyed entire plants.

The risk can certainly be reduced and possibly even eliminated by thorough and regular cleaning of the plant areas concerned through the removal of easily visible layers of dust on the floors and surfaces of equipment. Moistening poorly accessible sections together with cleaning measures are also probate means of minimising risks. But dusts also differ from combustible gases, vapours or mists and in other ways. Whereas these can be characterised relatively clearly via physical and chemical parameters, for example, the flash point, the lower and upper explosion limits or their density in terms of their explosive behaviour, this is not the case for most dusts. Although there are key parameters for dusts, such as the minimum ignition temperature of a dust cloud or the lower explosion limit, it already becomes difficult to safely determine the upper explosion limit in practice, albeit with great imprecision. The concrete behaviour of dust in the formation of dangerous explosive atmospheres depends strongly on the grain size of the dust particles and the grain size distribution in the dust. As these two values are generally process-related, it is very difficult to predict the characteristic behaviour of a dust in relation to generating dangerous explosive atmospheres.

In the past few years, this was also an experience made in several hard coal-fired power plants in Poland. The hazard of hard coal dust in mining has been well known for years. In the power plants, the hard coal is transported to the furnaces on long conveyor belts (Figures 2 and 3). The coal is largely so coarse-grained that there is no immediate risk of dust explosion. However, unavoidable abrasion across the whole transportation path, from conveying to the power plant and onwards to the combustion process, leads to fine coal dust in dangerous amounts. Therefore, the areas in the immediate access surroundings (mainly open conveyor belts) have been declared as zone 22 for years.

As part of the exploitation of bio-fuels, finely ground bio-mass consisting of wood waste and other dried bio-products have, for several years now, been added to the hard coal in Poland to increase the efficiency of energy production. Investigations were conducted in the Polish power plants of the EDF Wybrzeże company in Gdansk and EDF Rybnik prior to changing the process, with the objective of adapting protective measures to prevent explosions in the new conditions. As there were no clear key parameters for the new bio-mass powder, an investigation was commissioned by the Polish inspection authorities for explosion protection, Główny Instytut Górnictwa (KDB), and a Warsaw-based materials research institute. The test methods applied have been internationally recognised and established for a few years, and are also described in the international standard IEC 60079-20-2 Material characteristics – Combustible dusts test methods.

Figure 2: Explosion protected, optical-acoustic signal equipment (YODALEX) above the conveyor belt

Figure 3: Explosion protected cable-operated switch for emergency stop of the conveyor belts
**Fuel supply lines**
- Lighting and emergency lighting
- Terminal boxes and distribution boards,
- Control stations
- Power outlets
- Audiovisual display devices
- Visual monitoring
- Electric motors for conveyor belts and fans
- Electric heating for the water mist system

**Shafts, feed**
- Electric motors
- Positioning switches
- Lighting and emergency lighting

**Coal bunker**
- Visual monitoring
- Audiovisual monitoring

**Fuel mill**
- Electric motor for coal mill
- Visual monitoring
- Lighting and emergency lighting
- Terminal boxes and distribution boards

**Electric filters, desulphurisation**
- Electric heating

**Pump rooms, pipelines**
- Audiovisual display devices
- Visual monitoring
- Lighting and emergency lighting
- Terminal boxes and distribution boards
- Control stations
- Electric motors for pumps

**Turbine room**
- Audiovisual display devices
- Visual monitoring
- Lighting and emergency lighting
- Terminal boxes and distribution boards
- Control stations

**Ignition oil tanks**
- Heating of tanks – immersion heaters
- Heating of pipelines – heating cables
- Visual monitoring
- Audiovisual monitoring
- Terminal boxes
- Lighting
- Heating and protection of electrical equipment and automation systems (heating cables, housing with heating units)
The investigations showed that the determined key parameters, such as ignition temperature of the dust cloud, Kst value and derived dust explosion class, resulted in a higher risk level than for the previous exclusive processing of hard coal. As the grain sizes of the bio-particles and their distribution allowed the conclusion of a considerably higher probability of generating dangerous, explosive atmospheres, it was decided to modify zoning. The immediate vicinity of the conveyor belts and adjacent stairs, paths and working platforms, were now classified as Zone 21, and only the more remote parts of the plant remain as Zone 22.

This reclassification of the Ex zones resulted in a major reconstruction of most of the plant, as not only did the electrical installation and lighting need to be replaced with Category 2 products (Figure 4), but also the large drive engines.

Despite the high level of expenditure, EDF and the Polish engineering company ASE, who developed and implemented the explosion protection concept, are convinced that the effort was absolutely necessary to ensure continued safe and reliable operation of the power plant.