

Gas Detection

Mining, health & safety practices, regulations

Mines can be hazardous environments and the possibility of fire, flood, explosion, asphyxiation, toxic gas poisoning and collapse has the potential to simultaneously affect a large number of people.

Among the many dangers one of the most significant is the build up of different gases. This can affect the worker by being poisonous or merely through the replacement of oxygen in the breathing air leading to suffocation.

Silent, but deadly, it's gas, and you need to be able to detect it and know what to do when it is detected. Preventing explosions and fires would eliminate the majority of fatalities in both mining and other industries. The chief inflammable gas is methane (CH₄), which constitutes 97 to 100 % of the inflammable constituent of firedamp. Good 'Health and Safety' practises, with conformation to the various regulations and legislation currently in place, allied to appropriate usage of Gas Detection instrumentation and quality Sensors would greatly reduce the overall numbers of fatalities and injuries.

The four main gases to consider

Besides air, which is made up of approximately 78% nitrogen and 21% oxygen, there are four main gases that concern workers in a coal mine. They are carbon dioxide (CO₂), carbon monoxide (CO), methane (CH₄), and hydrogen sulfide (H₂S). The levels and combinations of these gases along with the level of oxygen or air determine the danger.

The word Damp originally meant mist or vapour, but is now used as meaning gas, such as:

Fire-damp: is inflammable and consists chiefly of methane (marsh gas). Black-damp: extinguishes flame and causes death by

suffocation. It is composed of carbon dioxide and nitrogen. White-damp: is a subtle and extremely poisonous gas, also known as carbon monoxide. After-damp: is the gas resulting from an explosion; it nearly always contains dangerous amounts of carbon monoxide. Stink-damp: is hydrogen sulfide and is a very poisonous gas with a pungent smell of rotten eggs, but it is seldom found in dangerous quantities. >



Dangerous gases

Carbon dioxide, while not combustible or poisonous by itself, can kill with levels of 18% and above. If it is combined with a corresponding drop in the percentage of oxygen, levels as low as 3% can make breathing more difficult, with symptoms worsening as the percentage rises.

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Carbon monoxide, a colourless, odourless, poisonous gas, is the most dangerous gas to be dealt with in a mine. Unlike carbon dioxide, which as the levels increase the density makes it sink, carbon monoxide is lighter than air and subsequently more deadly because of it. Explosions can be caused either from fire damp or coal dust. In addition to being toxic it is also very inflammable. The blood readily absorbs carbon monoxide, the body is also slow to give it up, making treatment difficult and because the body continues to absorb the gas, even low levels can build up in the body causing death. It is at about 0.02% that one begins feeling the effects-in this case, slight giddiness, headache and breathlessness. If the level gets as high as 0.2%, death will take place in one to two hours.

Hydrogen Sulphide is caused by the decomposition of iron pyrites in a mine as a result of the dampness or presence of water. While considerably more deadly than carbon monoxide (and inflammable), amounts of this gas are usually only at trace levels. Like carbon dioxide, it is heavier than air and sinks. Hydrogen sulphide is exceedingly poisonous; it is five times as deadly as carbon monoxide, but it is seldom found in quantities dangerous to life, whilst its characteristic pungent odour gives warning of smaller quantities than would prove to be poisonous. Traces of the gas are associated with gob fires, but it seldom does any harm beyond causing discomfort to the eyes, nose, and throat. Physiological effects of Hydrogen Sulphide, 0.07 % in air, if breathed for a long period, may prove fatal, 1.0% will cause death in a very short time.

The breathing of oxygen is absolutely necessary to human life and for ordinary combustion, the effects of a decrease in oxygen percentage gives more difficulty in breathing and reducing ability to support combustion, 19% O₂ is a typical recommended minimum for breathing, whilst flames will extinguish between 17% and 15%.

Regulations and legislation

Each country has its own organisations for ensuring compliance with regulations and legislation and these include, but are not limited, to: UK: Health and Safety Executive (HSE), Safety and Health in Mines Research Advisory Board (SHMRAB), Mining Industry Committee (MIC), Europe: European Parliament/Community (EC), EC Research Fund for Coal and Steel (RFCS), USA: National Institute for Occupational Safety and Health (NIOSH), Mine Safety & Health Administration (MSHA), International Labour Organisation (ILO) - Mining, Australia: Office of the Queensland Parliamentary Counsel, China: Coal Mine Safety Bureau, Coal Science General Institute, China Coal Research Institute (CCRI), etc.

The most important factor in the demand for toxic gas monitoring in the UK is the legislation known as the Control Of Substances Hazardous to Health Regulations 1988 (COSHH). Similar legislation exists elsewhere or is being introduced and COSHH takes into account the European Commission Directive 80/1107/EEC. COSHH covers all toxic substances except those which have their own legislation (asbestos, lead, radioactive materials and materials present in mines). The regulations spell out what employers and in a few cases employees have to do. (Failure to comply is subject to the penalties of the Health and Safety at Work Act 1974).

The requirements are:

- *Assess the risks to health and what precautions are needed*
- *Introduce measures to prevent or control the risk*
- *Maintain equipment and observe procedures*
- *Monitor exposure of workers and carry out health surveillance*
- *Train employees about the risks and precautions*

Certain industries, especially mining, require that instruments meet specific approvals, such as those given for intrinsic and explosion safety such as UL, CSA, and MSHA, North American nationally recognised testing laboratories. In the expanding global marketplace, other intrinsic safety approvals commonly appear such as cUL (Canadian), ATEX (European), MA (China), SABS1515 (South Africa) and IEC (Australia).

The adoption of the Convention on ‘Safety and Health in Mines’ in 1995, which has set the principle for action on the improvement of working conditions in the mining industry, is important because: special hazards are faced by mineworkers; the mining industry in many countries is assuming increasing importance; earlier ILO standards on occupational safety and health, as well as the existing legislation in many countries, are inadequate to deal with the specific needs of mining. The Convention came into force in June 1998. As of December 2003, 21 countries had ratified the Convention and several others were working towards it. ▶

Mine Safety & Health Administration (MSHA), has responsibility for administration and enforcement of the Mine Safety and Health Act of 1977, which protects the safety and health of workers employed in the nation's mines. The Act applies to all mining and mineral processing operations in the United States, regardless of size, number of employees, or method of extraction.

China Coal Research Institute (CCRI), established in 1957 is an exclusive comprehensive research and development institute in Chinese coal industry. In the year of 1999, CCRI was turned into a key backbone enterprise under the direct leadership of the Central Enterprise Working Commission. There are 17 branches, institutes, centres and companies in CCRI and they are located in 11 large and medium cities, such as Beijing, Shanghai, Fushan, Xi'an, Taiyuan and others with over 5,000 employees.

In the recent years, with the deep reform of the science and technology system in China, CCRI has all directionally entered the market and has steadily turned from an R & D institute to an R & D trading institute. They have (for example) produced their own Portable Methane Indicator Alarm. They are responsible for Implementation of Regulations on Mine safety law for the PRC (MA Certification).

In many countries there is unregistered and unsafe small-scale mining. Uncontrolled mining has resulted in many accidents and illnesses. In some countries many more people are employed in small-scale, informal, mining activities than in the formal mining sector. Well in excess of 12 million people are engaged in small-scale mining. Unfortunately, non-fatal accident rates are routinely six or seven times higher than in larger operations. Moreover, there have been many disasters in recent years at small-scale

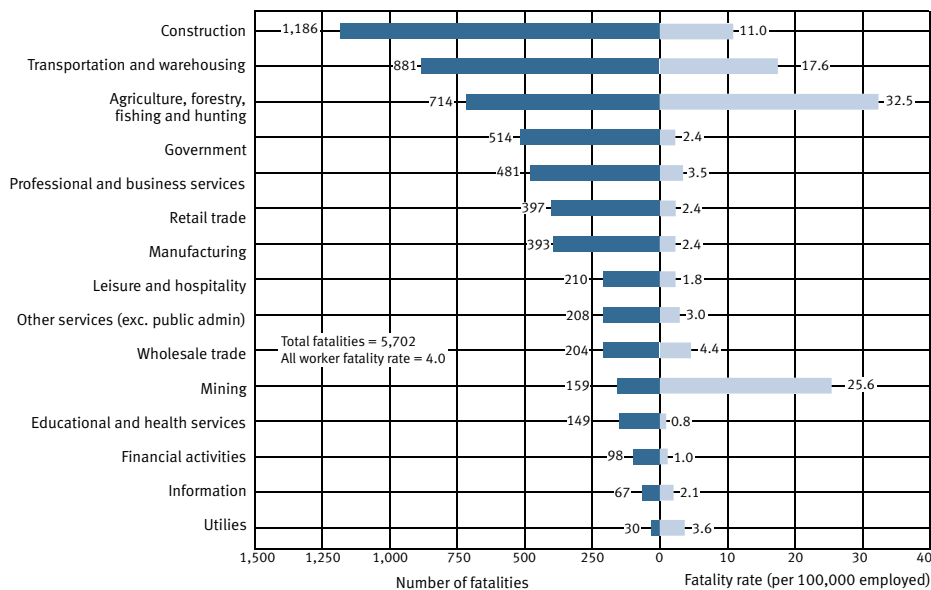
mines in developing countries when over ten and up to 100 deaths have occurred. That is not to say that there are no safe, clean small-scale mines, there are, but they tend to be in the minority.

The USA averages around 30 mining deaths per year, compared to some 6,000 in China and its safety record has been steadily improving over the past few decades, historically in excess of 30,000 mining deaths worldwide was not uncommon.

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The death toll from a recent mining explosion in north China was 35, whilst 12 others remained trapped underground. Local rescue headquarters stated that the trapped miners were unlikely to survive due to the high density of toxic gas inside the collapsed mine. The initial gas explosion ripped through the state-owned Jiaojiazhai coal mine, in Shanxi province and killed 17 miners on the spot. Mine operators failed to follow regulations and evacuate the mine after a power outage, which then led to the shutdown of the ventilation system and the accumulation of deadly gases. The blast occurred after power to the mine was restored. >

Number and rate of fatal occupational injuries by private industry sector, 2005



Although the construction sector recorded the highest number of fatal injuries, the highest fatality rates were in agriculture, forestry, fishing, hunting and in mining.

Rate = (Fatal work employment) x 100,000. Employment data based on the 2005 Current Population Survey (CPS) and Department of Defense (DOD) figures. SOURCE: US Department of Labor, Bureau of Labor Statistics, Current Population Survey, Census of Fatal Occupational Injuries and US Department of Defence 2005



Photo: Courtesy of BW Technologies

China mines produce about 70 percent of the coal for its power needs and are regarded as the most dangerous in the world. Officially almost 6,000 workers were killed in the country's industry in 2005 a rate of about 16 fatalities per day. Official statistics of the State Administration of Work Safety (SAWS) state that for the first eight months of 2006, through August, mine accidents have claimed 2,900 lives, this is a 25% decline over the same period in 2005. All told, China has witnessed 1,824 colliery incidents during the first eight months of 2006. China is eager to address the primary culprit behind its alarming coal mining fatalities, as evidenced by the Pre-Mining Degasification Symposium held in South China's Guizhou province. Sponsored by the province's Coal Mines Administration Bureau and the Coal Mine Safety Inspection and Supervision Bureau, executives gathered to discuss how the latest foreign technologies in gas detection could help degasify China's 2,000 coal mines, both improving mine safety and reducing China's global output of air pollution. Over time, as organic matter is converted to coal, methane, the primary constituent in natural gas, is produced during this process and stored in pockets within a coal seam. For every ton of coal produced, during the "coalification" process, more than 5000 cubic feet of methane is created. Coal mining releases this methane into the atmosphere. Because gas content is greater with depth, safety hazards increase during the underground coal mining process. Degasifying coalmines has been proven to help make those underground coal mines safer for miners. China is also concerned about its air emissions from coal mining. Worldwide, the coal mining industry released over 436 million metric tons of carbon dioxide equivalents in 2000.

That accounted for about 8 percent of the total industrial methane emissions that year (rising annually and expected to peak at around 45% by 2020. China, Russia, Poland and the United States account for over 77 percent of coal mining methane emissions. These emissions could be severely reduced if Chinese coalmines captured the methane gas for use in meeting energy needs, rather than being vented into the atmosphere.

General Safety Legislation and the implementation of good Gas Detection equipment are a fairly recent event in the whole history of mining. Japanese mine safety legislation was enacted in 1949. Improvements in safety and production in that mining industry have been achieved to a large extent under this legislation. 1986 was the introductory year for Gas Detectors in the UK. Coal mine canaries were made redundant, over 200 canary birds were phased out of Britain's mining pits, resultant from modern technology being introduced to replace the long-serving yellow feathered friend of the miner in detecting harmful gases that may be present underground. New electronic gas detectors replaced the bird because they are more effective in indicating the presence of pollutants in the air otherwise unnoticed by miners. The gas detectors typically carry an alarm and a digital reading that appears on a screen alerting miners to the extent of the gases. The removal of the canaries ended a mining tradition in Britain dating back to 1911, since when two canaries had been employed by each pit.

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The most common gases detected in the industry are combustible gas or LEL, carbon monoxide, hydrogen sulfide, and oxygen deficiency or enrichment. Combustible gas, such as natural gas (methane), with the correct mix of oxygen and a spark can produce explosions, also hydrogen sulphide, hydrogen, ethylene, nitrous oxide, etc., sometimes occur. The chief noxious gases are the very poisonous carbon monoxide and carbon dioxide. Hydrogen sulphide is extremely poisonous, but rarely occurs in dangerous quantity. Carbon monoxide exposure targets the cardiovascular system. Hydrogen sulfide exposure affects the respiratory and central nervous systems. A deficiency or excess of oxygen results in respiratory failure and increased risk of explosion. However, around 20-years of research and development have produced a multitude of gas detector instrumentation and the associated sensors required to detect the various gases, whilst new sensing methods are being developed constantly. Gas detection and monitoring ▶

instruments range from mounted and free standing fixed systems with wireless capabilities, to portable, battery-powered, personal alarms, of either single or multiple gases. There are different types subject to usage, for example, CO alarms - units that will detect the presence of CO and make an audio warning, these are generally what is referred to as domestic alarms used by consumers, CO Detectors - units that can detect CO and often other gases and have a visual display of CO ppm. These units can also have audio warnings and can also print out gas levels. These are referred to as industrial units and are used by emergency services, gas providers, Corgi installers, etc. CO detection is the generic word used which covers both consumer and industrial units.

Gas sensor types used in such instruments include Electrochemical, Catalytic Bead, Photo-Ionisation Detector (PID), infrared (NDIR), Metal Oxide and others, all read levels of specific gases or gas types, typically in parts per million (ppm) or percentage. A mixture of flammable gas or vapour with air (oxygen) can lead, if ignited, to a devastating explosion. Whether or not a certain mixture can explode depends on the type and the concentration of the gas or vapour involved. However, if these characteristics are known, measures can be taken to prevent a flammable mixture from exploding. If preventive measures are not adequate, an explosion may occur, in most cases resulting in considerable damage to property and personnel injuries and fatalities. The overpressure in an exploding gas cloud is generated either by the confinement of the expanding gases or by the increase in burning rate. If no vent openings are available, pressure will increase to maybe 10 times the initial pressure.

Sensors used for gas detection

There are many different technologies for sensors that are used in gas detection, such as:

Electrochemical Sensors - are employed for the detection of inorganic toxic gases such as CO, NO, NO₂, NH₃, H₂S, SO₂, HCN, Cl₂, HCl, PH₃, COCl₂ but also for O₂ or H₂. Measurements are usually taken within the range of threshold limit values (TLV), maximum concentration in workplaces, with alarm levels pre-set to the TLV value and double TLV value. Any gas which can be oxidized or reduced electrochemically can be detected by means of a fuel cell based electrochemical sensor. Other gases may be detected by galvanic electrochemical sensors.

Semiconductor - The target gas is chemisorbed on the surface of the semiconducting material (such as stannic dioxide; SnO₂) and partially oxidised by interaction with chemisorbed oxygen from ambient air. Changes are measured in the electric conductivity on the surface, caused by these interactions.

Catalytic - Target gas is oxidised at the surface of an electrically heated catalytic element. The increase in temperature of the filament is measured in relation to an inactive filament by the change of the electrical resistance in a Wheatstone bridge.

Infrared - Gases, which contain more than one type of atom absorb IR radiation. Therefore gases such as carbon dioxide,

carbon monoxide, methane, sulfur dioxide etc, can be detected by this means but gases such as oxygen, hydrogen, helium and chlorine cannot. The target gas absorbs, in an optical path, light of a specific wavelength in the IR range. The attenuation of light is measured in relation to a reference wavelength where no absorption occurs.

Photo-Ionisation Detector (PID) - Gas in the chamber is moved across the face of a lamp window, emitting light particles of high UV energy. An electric field between two electrodes attracts the ions towards them. At the electrodes, ions are neutralised by movement of a tiny electric current, so that it can be amplified and displayed as a gas concentration.

Gas detection applications

Many gas detection instruments are battery powered, portable instruments that are carried by workers to warn them of explosive gas build-up, the presence of Toxic gases and the level of Oxygen. These instruments need to be small and lightweight for applications such as Confined Space Entry, Hazardous Area Working and Gas Leak Protection.

Confined Space Entry, the most prominent application for portable gas detection instruments. The instrument is used to check the atmosphere of any confined space, including, mines, sewers, tanks and other vessels or chambers prior to entry for work or maintenance purposes. These instruments invariably are 'multi-gas'. They have 3 or even 4 sensors included in the package.

Hazardous Area Working, areas of industry where the build-up of flammable gas or vapour is an ever present danger. These instruments are very often the same multi-gas instruments used for confined space entry, but there are areas where single gas ▶

Photo: Courtesy of Industrial Scientific





monitors ('explosimeters') are used. Communications is also essential and any Gas detection equipment used will be required to communicate with other personnel, central control and rescue teams. It must have the following capabilities: function reliably as a wireless voice link over a specified range, be battery powered, with a low current (mAmps) drain, should be able to be certified intrinsically safe to ATEX standards, be compliant with the relevant European radio regulation and EMC standards under R&TTE Directive, work along side other wireless systems, have the ability to be operated intuitively in a point-to-point or group fashion, be small lightweight and suitable for the working environment of a mine, exploit current technology and gain a cost advantage, have a reasonable product/technology life expectancy.

Fuel, oxygen, and heat must be present at the same time for a fire or explosion to occur.

For example in the winter months, cold air entering a mine causes the mine surfaces to dry out, which increases the risk of fires and explosions. Miners should know about the various explosive materials found in coalmines and combinations of these materials. Some of the materials and possible combinations are: Explosion of methane alone, Explosion of coal dust alone, Coal dust explosion started by a methane ignition, Methane explosion started by a coal dust ignition, Explosion of other flammable gases alone such as acetylene, hydrogen, etc, Coal dust explosion started by an ignition of flammable gases. There are additional

possible combinations and sequences of events that could occur involving methane, other flammable gases, and coal dust. Explosions involving coal dust are usually the most violent and destructive, however, major explosion disasters have occurred which are believed to have resulted primarily from large methane accumulations.

In an underground coal mine, the fuel for a fire or an explosion can be an explosive mixture of flammable gas, a sufficient concentration of coal dust, or a combination of both. The heat to ignite the combustible mixture can come from sparks, electrical arcs, detonation of explosives, etc. Oxygen sufficient to support combustion is generally present throughout unsealed areas. Eliminating any one element of the fire triangle can prevent fires and explosions. Oxygen (air) sufficient to support combustion is generally present throughout unsealed areas in underground coalmines. If need be, seals can be used to prevent explosions by reducing or eliminating the oxygen in the mine air. The oxygen in an airtight, sealed area will be displaced by methane and other gases. Coal and mine timbers will also absorb oxygen. Eventually, the oxygen level in the air will be reduced below 12 percent rendering it incapable of supporting methane combustion.

Conclusion

The conclusion is that with the advent of gas sensors and detectors linked to the regulations and legislation, and reduction of unlicensed mines is clearly showing improvements in Health and Safety as indicated by the reducing volume of injuries and fatalities. ■

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