

FLAMMABLE GAS DETECTION IN COAL MINES - A HISTORICAL PERSPECTIVE

Underground coal mines are dangerous places in which to work. This short article explores why, in part, this is so. It also provides conclusions that indicate how a study of one of the hazards encountered, namely flammable gas, and the associated control measures that were developed, may help reduce the risk to modern-day workers. These would not necessarily be coal miners, but workers in any enclosed environment where similar conditions could exist, e.g. tunnelling, confined spaces. It should be noted that the presence of flammable gas is only one of the hazards encountered in coal mines. Other significant hazards are associated with the industry, each with their own risks of death and injury.

Naturally occurring hydrocarbon gases that appear in underground coal mines have historically been given the name "firedamp", derived from the German word for vapour - "dampf". Its main component is methane, although other hydrocarbons can be present at lower concentrations.

Methane is generated when organic material decays in the absence of oxygen. In coal mines, it was produced during the formation of the coal and then subsequently trapped within the strata. The gas can also be found in underground sewers and tunnels, or enclosed spaces that either penetrate or are close to, for example, carbonaceous strata or waste disposal sites.

Not all coal seams contain significant quantities of firedamp. For example, with shallower workings, fractures in the overlying strata allow the gas to escape to the surface. Alternatively,

typically with deeper mines, the gas is trapped in the interstices of the coal, only to be released when the coal-bearing rocks are penetrated by tunnels. Here it mixes with the oxygen in the air provided for miners to breathe, generating potentially flammable atmospheres.

The rate of release of firedamp from coal can vary between mines and between locations in the same mine. Sometimes it is so low that flammable atmospheres are only created if the surrounding air remains stagnant for some time. At the other extreme, the firedamp can be held under pressure in pockets, resulting in violent outbursts of gas and rapid rises in ambient concentration.

With the expansion of the UK coal industry and the construction of deeper and more extensive coal mines, the latter half of the 17th century saw the reported appearance of firedamp underground. Experience showed that the gas could explode violently when it contacted the flame of a candle being used to illuminate a workplace. It has been estimated that up to the year 1812, 1200 or more British coal miners were killed by explosions of firedamp.

Early detection and control of firedamp

With necessity being the mother of invention, miners learnt to show the presence of firedamp by looking for changes in the shape and colour of their candle flames. For example, on approaching danger, the tip changed from yellow to greenish-blue. Once found, early 18th century miners recognised that accumulations of firedamp could be rendered safe by ventilating their workings with a current of air.

Unfortunately, the firedamp control measures being applied in coal mines up to the early part of the 19th century were not always effective. For example, in 1812 a disastrous explosion occurred at Felling Colliery, Northumberland, killing 92 men and boys. In response, a local parson, the Reverend Hodgson,



Figure 1: A modern flame safety lamp (Courtesy UK Coal Authority)

The Gas Analysis and Sensing Group invites selected speakers from its recent technical colloquia to provide an article for readers of IET. In this issue, Ian Unwin, ex-British Coal instrument development engineer and current part-time Lead Compliance Engineer with the Servomex Group Limited, reviews the historical background to the modern detection of flammable gases in mines and confined spaces. The next meeting of the GASG will be on Thursday 6 December 2018 at IET London with the topic "Detectable Me(thane)!" . For further details please see www.gasg.info



and others formed the "Sunderland Society for preventing accidents in coal mines". As the name suggests, its aim was to prevent anything similar from occurring in the future. One of the measures they took was to enlist the help of Sir Humphrey Davy. Eventually, he found that explosions caused by a naked flame would not propagate through fine wire gauzes. The result was the invention, in about 1817, of the Davy flame safety lamp. This was an oil flame enclosed in a protective gauze shield to reduce the firedamp ignition risk.

A modern flame safety lamp produced from about 1964 onward is shown in Figure 1. One of the many differences between this and the original Davy lamp is the glass viewing window. This allowed the flame to be more easily seen and increased the light output. The gauzes are above the glass window and behind the protective shield at the top of the lamp. As with the candle, miners learnt that the presence of firedamp could be shown by the shape and colour of the flame of a safety lamp. A lamp calibration chart given to coal mining trainees during the mid-1970s is shown as Figure 2.

From 1817 onwards, the Davy and other largely similar flame safety lamps became popular with colliery operators and, considering its work done, the Sunderland Society disbanded itself. Unfortunately, the statistics suggest that this was somewhat premature and that the effectiveness of the flame safety lamp in reducing the number of coal mine explosions should have been more thoroughly assessed. For example, it was later shown that flame safety lamps could cause explosions when exposed to high speed currents of flammable gas. Also, the protective gauze was prone to damage. Mis-use was another issue with the early lamps, with numerous accidents occurring when the gauze was removed, sometimes to light tobacco pipes and cigarettes.

Faced with an ever-increasing and unacceptable accident rate amongst coal miners despite the introduction of flame safety lamps, from the late 19th century onwards there was an increased interest in the application of science, technology and legislation to the improvement of mine safety. Unfortunately, data suggests that any measures that were consequently introduced were not totally successful. For example, between 1817 and 1967, nearly 15,000 men and boys were killed by firedamp explosions in British coal mines, over 1,400 of which died in just four incidents!

Electronic firedamp detectors

Although flame safety lamps may have been perceived as being a means by which the risk of firedamp explosions could be reduced, with the gauze in place their light outputs were notoriously low. This resulted in the occurrence of a disabling condition called "miner's nystagmus" whereby, a sufferer's eyes oscillated up and down uncontrollably. Affected miners were unable to see where they were going and in extreme cases they had to be met by their wives at the pit top and guided home.

As a control measure for nystagmus, workers were provided with electric lanterns. Whilst this reduced the incidence of the condition, it also removed the automatic firedamp warning capabilities previously provided by a worker's flame lamp. In response, a wide range of non-flame-based firedamp detectors and monitors were developed for coal mine use. Typically, they relied on the combustion of the flammable gas on an electrically heated platinum wire. Unfortunately, they were not generally suitable for routine use, being complicated to operate. Also, evaporation from the filament led to short-term calibration drift, reducing accuracy.

In 1958 the UK Safety in Mines Research Establishment developed the "pellistor" flammable gas sensor. Compared with the hitherto used platinum wire sensors, this was much more suitable for use underground. It was formed from a small porous ceramic bead with a catalyst deposited on its surface to increase the rate of combustion of flammable gas. The assembly was heated electrically using an embedded platinum coil, whose resistance was used as an indicator of its temperature. This increased due to the heat of combustion generated by flammable gas present. The level of metal evaporation was reduced by the enclosure of the heater coil within the bead and a reduced operating temperature facilitated by the catalyst, thereby improving the stability of the sensor. Pellistors, or pellistor-like devices, were subsequently included in a wide range of fixed and hand-held firedamp detectors and monitors, also called "methanometers", for use underground in coal mines. Some examples are shown in Figure 3.

In the UK, fixed pellistor-based methanometers for coal mine use were developed from about 1970 onwards. They were designed to be installed at strategic locations underground,

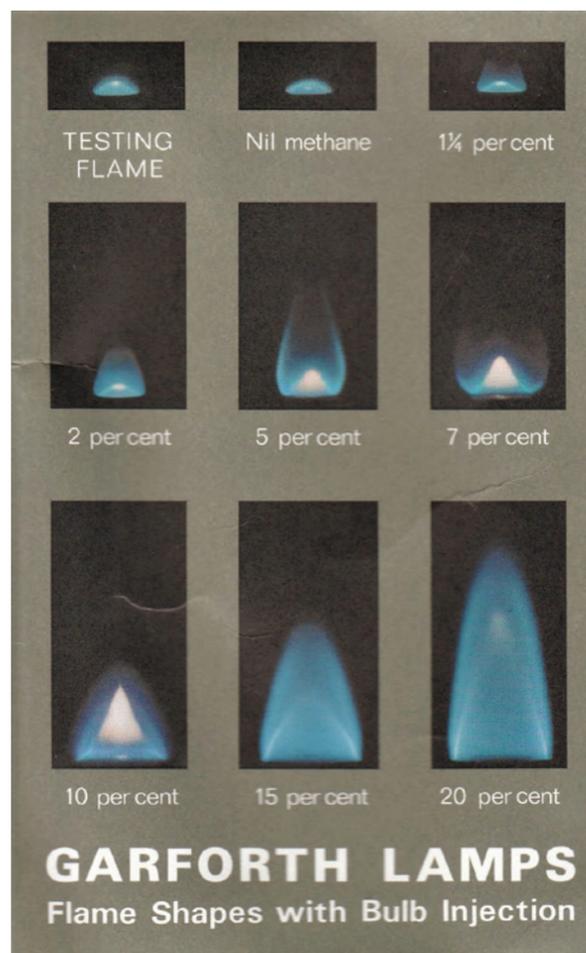


Figure 2: Flame safety lamp calibration chart (Courtesy UK Coal Authority)

typically to monitor the methane concentrations entering and leaving a coal face. They provided a local indication of measured methane concentration and could transmit a signal to a surface control room, which could be several kilometres away. Should the measured methane concentration rise above a pre-set level, typically 1.25% v/v (ca 25% of the lower explosive limit or LEL), local and/or remote alarms could be raised.

Portable, battery powered methanometers were also developed. Hand-held devices of the type shown in Figure 3 could be used by mine officials to carry out inspections for gas. Where small groups of miners were required to work in locations where firedamp could appear, automatic firedamp detectors were available. Operating continuously, they included bright red lamps that automatically flashed when the methane concentration rose above a pre-set concentration.

Unfortunately, pellistors also had their problems. As an example, they could suffer permanent loss of sensitivity when exposed

to commonly found substances such as silicones. Furthermore, investigations showed that even when shielded behind a sintered diffusion cover, pellistors could be affected by the speed of the air current flowing past them. Pellistor-based methanometers were still in use at the end of the 1990's when the UK coal industry was privatised.

The later firedamp hazard

Unfortunately, and despite all its best efforts, the late 20th century coal mining industry could not rid itself of the firedamp hazard, with explosions still occurring due to unanticipated events. As an example, in 1982, 40 men were seriously injured in an explosion at Cardowan Colliery, Strathclyde. Leading up to this accident, a small change in the arrangement for ventilating a partially complete coal face led to the creation of a plug of firedamp. This then entered an adjacent working coal face. After travelling about 650 m, the gas plug had been diluted to a concentration just above the LEL for firedamp. This was ignited by a frictional spark created when a steel pick on a coal cutting machine struck sandstone in the stratum below the coal seam. The accident report written by HM Inspect of Mines and Quarries recommended that urgent attention be given to the installation of continuously motoring equipment to automatically cut off electricity from equipment that could generate frictional sparks. This was one of the last explosions of firedamp in British Coal mines to result in a relatively large number of injuries, suggesting that lessons had been learnt, in the UK at least.

Conclusions

The legacy of the deaths of several thousand coal miners is that today we can draw the following conclusions:

- 1 Workings containing carbonaceous material may also contain accumulations of flammable gas.
- 2 Even if the emission rate of flammable gas is very low, a failure to provide a ventilating air flow to dilute it can result in potentially explosive accumulations.
- 3 Hazard control measures should be fully evaluated to show they are effective and do not introduce any new hazards.
- 4 However stringent the control measures in place, always expect the unexpected. For example, a small change in working practices or environmental conditions (both on the surface and underground) can allow flammable gas to accumulate. Once this occurs, the atmosphere has the potential to explode.
- 5 Although gas detection technology and its use in the prevention of accidents is ever improving, in the past added impetus for change has been provided by several disastrous events in coal mines.
- 6 Flammable gas detectors do not save lives by themselves, they need to be accompanied by relevant manual and/or automatic control measures that remove the identified hazard.

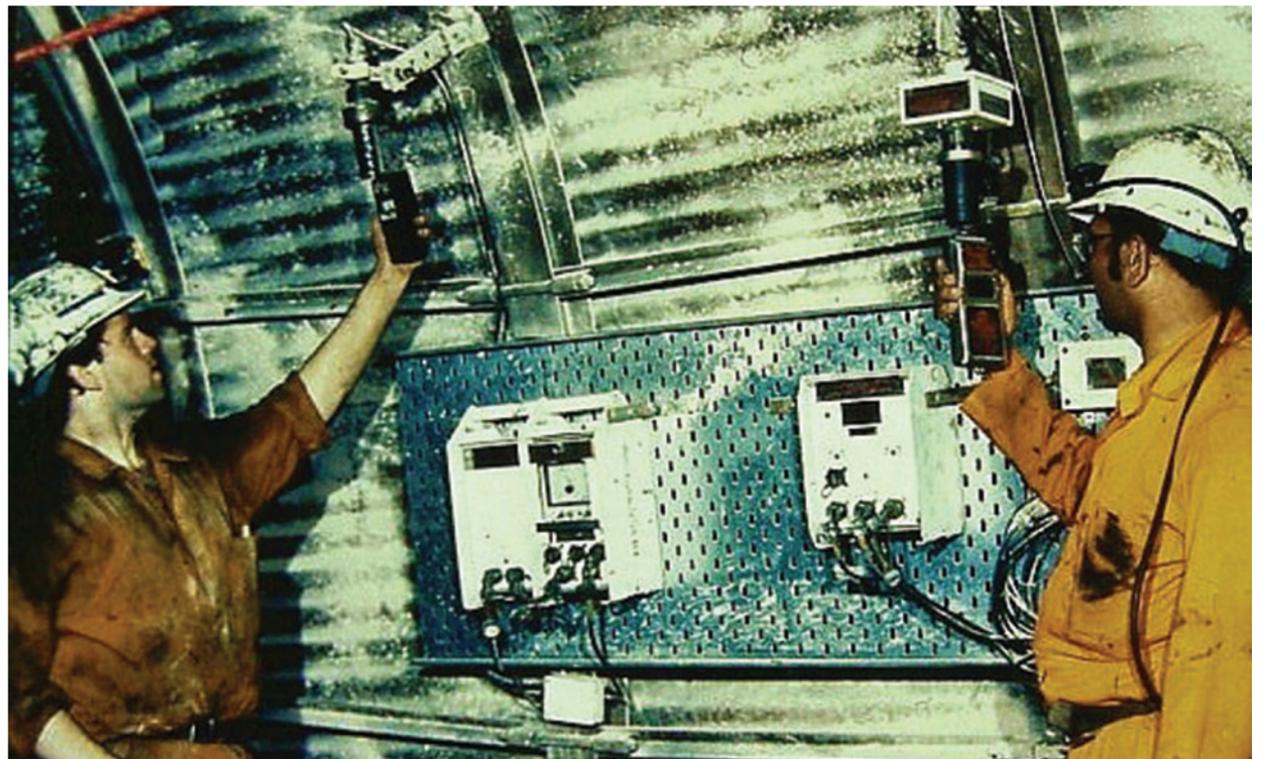


Figure 3: Fixed and hand-held methanometers underground (Courtesy UK Coal Authority)

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