1. Sealed off Areas

Underground mines contain areas which are sealed off after mining operations have been concluded in the area. These areas sometime have high combustible gas content due to the leaking of methane and other gases from the coal seam. Hence, these areas need to be periodically checked for gas levels to determine whether fires have started. When a mine fire breaks out these areas are maintained at a high pressure by the injection of inert gases such as nitrogen and carbon dioxide. Hence, gas only leaks out from these regions and never into them.

Combustible gases such as carbon monoxide, hydrogen, methane and hydrogen sulphide are often present in underground mines. These, along with coal dust, are often the fuel for mine fires. Mine fires also evolve these gases and others such as carbon dioxide. Several algorithms, referred to as gas ratios, are used to determine how strong fires in sealed off areas in mines are. The software developed by this author uses five of these gas ratios and the logic behind these ratios has been detailed.

1.1 Graham's Ratio

The strongest fires involve rapid evolution of carbon monoxide gas due to the excess availability of combustibles. Strong fires also display a rapid decrease in the concentration of oxygen gas which is consumed by combustion. The numerator of Graham's Ratio gauges the carbon monoxide concentration in the area. The denominator measures the oxygen deficiency by calculating the difference between initial and final oxygen levels.

$$GR = \frac{100 \times CO_f}{0.265 \times N_{2f} - O_{2f}}$$

Different values of Graham's ratio indicate various states of a mine fire:

- 0.4 or less indicates that the situation is normal and that no heating can be observed

- 0.5 is slightly greater than normal and indicates that a check-up is necessary
- 1 indicates that the heating exists in the area
- 2 indicates that extensive heating is occuring which can lead to a fire
- 3 and above indicates that a blazing fire is present

1.2 Young's Ratio

As a fire progresses from a smoldering one to a stronger flame the carbon dioxide percentage in the fire increases. Hence, in a similar way to Graham's Ratio which uses carbon monoxide, Young's ratio uses carbon dioxide in the numerator to check fire strength.

$$Young's\ Ratio = \frac{\Delta CO_2\%}{\Delta O_2\%}$$

- When the ratio is less than 25 this indicates superficial heating
- When it is over 50 this is representative of a higher intensity fire

1.3 Oxides of Carbon Ratio

This is the ratio of the carbon monoxide content to the carbon dioxide content. It is high for fuel rich fires and during flaming combustion. When its value is greater than 2 this indicates an active fire.

$$Oxides\ of\ Carbon\ Ratio = \frac{CO\%}{CO_2\%}$$

This ratio is unaffected by inflows of methane gas, air or inert nitrogen. As such it is a very good indicator when the gas mixture is being inertized with nitrogen and carbon dioxide.

1.4 Jones and Trickett Ratio

The Jones and Trickett ratio is based on the principle that different types of fuel produce different amounts of each gas. This ratio helps determine what exactly is burning and helps distinguish between a methane and a coal dust explosion.

$$JTR = \frac{CO_2\% + 0.75 \times CO\% - 0.25 \times H_2\%}{0.265 \times N_2\% - O_2\%}$$

- A value of less than 0.4 indicates extinguishment of the fire or greatly reduced coal temperatures

- A value from 0.4-0.5 indicates a methane fire
- 0.5-1 indicates a coal, oil or a conveyor belt fire
- 1-1.6 indicates a timber fire

1.5 C/H Ratio

The C/H ratio operates on the idea that temperature can be used to identify how much carbon and hydrogen have been part of the fuel of the mine fire. Hydrogen combusts in its entirety at a reduced temperature while carbon which has not combusted deposits as soot which results in a decrease in the ratio of carbon to hydrogen in the final resultant mixture.

$$C/H = \frac{3 \times (CO_2 + CO + CH_4 + 2C_2H_4)}{(0.2468N_2 - O_2 - CO_2 - 0.5H_2 + CH_4 + C_2H_4) + H_2 - CO}$$

- C/H ratios of up to 3 indicate superficial heating
- Values greater than 5 indicate active fire
- Values greater than 20 indicate blazing fire

1.6 Explosibility

It is important to predict whether an explosion is likely to happen in a sealed off area as explosions can cause a direct threat to life and can cause cave-ins which hamper rescue missions. This is usually done by measuring gas concentrations as certain mixtures of combustible gases and oxygen are combustible. In general an explosion requires 5 parameters to be satisfied: the presence of fuel, oxygen, ignition, confinement and dispersion of the gases involved.

Several methods are used in the mining industry in order to determine the explosibility of gas mixtures. The method used in the software created is the Coward's Revised Explosibility diagram.