<table>
<thead>
<tr>
<th>NOVEMBER</th>
<th>TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>PROPERTIES AND BEHAVIOR OF AIR</td>
</tr>
</tbody>
</table>
«DE RE METALLICA» (Latin for On the Nature of Metals (Minerals)) is a book cataloguing the state of the art of mining, refining, and smelting metals, published a year posthumously in 1556 due to a delay in preparing woodcuts for the text.

The author was Georg Bauer, whose pen name was the Latinized «Georgius Agricola».
Plate from «DE RE METALLICA» showing three methods of ventilating mines
A- FIRST MACHINE DESCRIBED.
B- THIS WORKMAN, TREADING WITH HIS FEET, IS COMPRESSING THE BELLOWS.
C- BELLOWS WITHOUT NOZZLES.
D- HOLE BY WHICH HEAVY VAPOURS OR BLASTS ARE BLOWN OUT.
E- CONDUITS.
F- TUNNEL.
G- SECOND MACHINE DESCRIBED.
H- WOODEN WHEEL.
I- ITS STEPS.
K- BARS.
L- HOLE IN SAME WHEEL.
M- POLE.
N- THIRD MACHINE DESCRIBED.
O- UPRIGHT AXLE.
P- ITS TOOTHED DRUM.
Q- HORIZONTAL AXLE.
R- ITS DRUM WHICH IS MADE OF RUNDLES
«...miners are sometimes killed by the pestilential air that they breathe, and air "likened to the fiery blast of a dragon's breath...»

Georgius Agricola, 1556, «De re metallica»
VENTILATION

Ventilation refers to the movement of air around the mine to provide suitable quality and quantity of air to maintain a safe and healthy environment in which workers may work.

A mine ventilation system includes fans, airways, control devices to direct or restrict air flow, cooling and filtering air and systems for monitoring air quality and quantity.
AIR

Air is a mixture of a number of gases. Air is a perfectly mixed (homogeneous) mixture of gases, in spite of the fact that the various component gases have different densities.
### Nature and Composition of Air

<table>
<thead>
<tr>
<th>Gas</th>
<th>Volume</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.09%</td>
<td>75.55%</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.95%</td>
<td>23.13%</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.03%</td>
<td>0.05%</td>
</tr>
<tr>
<td>Argon others</td>
<td>0.93%</td>
<td>1.27%</td>
</tr>
</tbody>
</table>
PROPERTIES OF AIR

Chemical
Physical
Psychrometric
PSYCHROMETRY?

The field of engineering concerned with the determination of physical and thermodynamic properties of gas-vapor mixtures.

Psychrometry
Ψυχρόμετρον

Ψυχρόν + μέτρον
«Cold + measurement»
PSYCHROMETRIC PROPERTIES

- **Barometric pressure**, \( p_b \), is the atmospheric pressure as read by a barometer, in **in.Hg** or **psi**

- **Dry-bulb temperature**, \( t_d \), is the temperature indicated by a conventional dry thermometer, a measure of the sensible heat content of the air, in **°F**
PSYCHROMETRIC PROPERTIES

- Wet-bulb temperature, $t_w$, is the temperature at which water evaporating into air can bring the air to saturation adiabatically at that temperature; a measure of the evaporating capacity of the air; indicated by a thermometer with a wetted wick in °F.

- Adiabatic – refers to any change of state with no gain or loss of heat.
Psychrometric Chart

SI (metric) units
Barometric Pressure 101,325 kPa (Sea level)
based on data from
Carrier Corporation Cat. No. 794-001, dated 1975
PSYCHROMETRIC PROPERTIES

- When designing an air conditioning system, make the calculations.

- Using the chart, the state point of the air can be located at a given barometric pressure if any two properties, usually temperatures, are known.
# USEFUL GENERAL AIR CONSTANTS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight, $m$</td>
<td>28.97</td>
</tr>
<tr>
<td>Specific gravity, $s$</td>
<td>1</td>
</tr>
<tr>
<td>Gas constant, $R$</td>
<td>287.045 J/kg.K</td>
</tr>
<tr>
<td>Specific weight, $w$</td>
<td>29.92 in. Hg, 70°F</td>
</tr>
</tbody>
</table>

(at Standard conditions)
<table>
<thead>
<tr>
<th><strong>USEFUL GENERAL AIR CONSTANTS</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard barometric pressure,</strong> $p_b$ (sea level)</td>
</tr>
<tr>
<td><strong>Specific heat at constant pressure,</strong> $c_p$</td>
</tr>
<tr>
<td><strong>Specific heat at constant volume,</strong> $c_v$</td>
</tr>
<tr>
<td><strong>Ratio of specific heats at constant pressure and volume</strong></td>
</tr>
</tbody>
</table>
The hazards which are controlled by ventilation include:

- Oxygen (8)
- Danger Dust
- Danger Highly flammable
- Caution Asphyxiating gas
- Warning Harmful fumes

- Toxic Gas
- Radioactive
- Flammable
FACTORS CONTRIBUTING HAZARDS

Natural Factors
- Mining depth
- Climate
- Geology
- Gas content of strata
- Groundwater

Design Factors
- Mining Method
- Mine Layout
- Rock Fragmentation
- Seam Thickness
- Mine equipment
- Vehicular traffic
- Storage

HAZARDS

CAUTION
- Asphyxiant gas

DANGER
- Dust
- Highly flammable

Warning
- Harmful fumes

TOXIC GASES

DANGEROUS SUBSTANCES

METHODS OF CONTROL

Ancillary Factors
- Dust suppression
- Gas drainage
- Refrigeration systems
- Monitoring systems

Airflow Factors
- Main fans
- Booster fans
- Auxiliary ventilation
- Natural ventilation
- Regulators
AIR TEMPERATURE

Mine air temperatures are measured in SI units of Degrees Celsius.

The lowest (theoretically) possible temperature is –273.15°C (sometimes known as “absolute zero”).

\[ T(\text{K}) = T(\text{°C}) + 273.15 \]
Charles’ law states that the same rise of temperature produces in all gasses the same increase in volume, provided the pressure is kept constant.

\[
\frac{T_1}{T_2} = \frac{V_1}{V_2}
\]

T: Absolute temperature (K)
V: Volume occupied by gas
BOYLE’S LAW

Boyle’s law states that the volume occupied by a gas is inversely proportional to the absolute pressure exerted upon it, provided the temperature is kept constant.

\[ P_1 \times V_1 = P_2 \times V_2 \]

- \( P_1 \) = Initial absolute pressure
- \( V_1 \) = Initial volume occupied by gas
- \( P_2 \) = Final absolute pressure
- \( V_2 \) = Final volume occupied by gas
UNIVERSAL GAS LAW

Charles’ law and Boyle’s Law can be combined mathematically to produce what is known as the Universal Gas Law:

\[
\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}
\]
UNIVERSAL GAS LAW

For a given quantity (mass) of a given gas, \( \frac{P \times V}{T} \) is a constant. This constant is known as \( R \).

\( R \) varies depending on the gas type.

For dry air, \( R = 0.2871 \) kJ/kg assuming

\[
\begin{align*}
P & \text{ (kPa)} \\
T & \text{ (K)} \\
V & \text{ (m}^3/\text{kg)} \\
J & \text{ (1 N.m)}
\end{align*}
\]
DENSITY OF DRY AIR

The density of dry air can now be readily determined using the Universal Gas Law.

What is the density of dry air at a barometric pressure of 95 kPa and a dry bulb temperature of 25°C?

\[ V = \frac{P \times R}{T} \]
What is the density of dry air at a barometric pressure of 95 kPa and a dry bulb temperature of 25°C?

\[ V = \frac{R \times T}{P} \]

\[ V = \frac{0.2871 \times (25 + 273)}{95} \]

\[ V = 0.90 \text{ m}^3/\text{kg} \]

\[ \rho = \frac{1}{0.90} = 1.1 \text{ kg/m}^3 \]
200 m³/s of dry air at a temperature of 30°C and barometric pressure of 95 kPa flows down an intake shaft into a mine. At the bottom of the shaft, the air temperature is measured as 37°C and the barometric pressure is 102 kPa. What is the flow rate at the base of the shaft if there is no leakage and no moisture pick-up in the shaft?
UNIVERSAL GAS LAW

\[ V_2 = \frac{P_1 \times V_1 \times T_2}{T_1 \times P_2} \]

\[ V_2 = \frac{95 \times 200 \times (37 + 273)}{(30 + 273) \times 102} \]

\[ V_2 = 191 \text{ m}^3/\text{s} \]
The result shows that we have “lost” $9 \text{ m}^3/\text{s}$ of our airflow before it reaches the base of the shaft. The change in volume flow due to air compression is an important factor when designing and monitoring ventilation systems for deeper (e.g. 1,000m below surface) mines. For the majority of mines however, the change of volume due to compression of the air is small enough to be ignored.
MOISTURE IN MINE AIR

The amount of water vapor contained in a volume of air is dependent on the temperature of the air. At higher temperatures, the amount of water vapor that the air can contain increases.

When air contains the maximum possible amount of vapor at a given temperature, it is said to be saturated.
Condensation of water vapor can cause “fogging” and can sometimes be a problem in mine airways where warm, humid air is cooled below its dew point (e.g. by a mine air cooler).
MOISTURE IN MINE AIR

Condensation of water sometimes also occurs in upcast ventilation shafts – in this case the cooling of the mine air is caused by the reduction in air pressure as the air travels upwards (the opposite of autocompression). The condensed water droplets can cause problems with surface fan operation.
The “Standard” density of dry air at 20°C and 101,325 Pa barometric pressure is 1.2 kg/m³.

Unless otherwise stated, the performance figures supplied with mine fans assume that the fans will operate at standard air density.
\[ \rho = \frac{P - 0.378e}{0.287045 \times (273.15 + t_d)} \]

\( \rho \): Air density \((kg/m^3)\)  
\( P \): Atmospheric pressure \((kPa)\)  
\( t_d \): Dry-bulb temperature \( (^\circ C) \)  
\( e \): Partial pressure of water vapour \((kPa)\)

\[ e = \frac{e_{sw} \times (371.4 + 0.24t_d - 0.6t_w) - 0.24(t_d - t_w) \times P}{371.4 + 0.04t_d - 0.4t_w} \]

\[ e_{sw} = exp \left(\frac{17.27 \times t_w}{237.3 + t_w}\right) \]

\( e_{sw} \): Saturated water pressure at the wet-bulb temperature \((kPa)\)
What is the density of the air in a drive where the wet and dry bulb temperatures are (respectively) 25 and 30°C and the barometric pressure is 97.5 kPa.
\[
\rho = \frac{P}{R \times T}
\]

\[
\rho = \frac{97.5}{0.2871 \times (273 + 30)}
\]

\[
\rho = 1.121 \text{ kg/m}^3
\]
\[
\rho = \frac{P}{R \times T}
\]

\[
\rho = \frac{97.5}{0.2871 \times (273 + 30)}
\]

\[
\rho = 1.121 \text{ kg/m}^3
\]
\[ e_{sw} = \exp \left( \frac{17.27 \times 25}{237.3 + 25} \right) = 3.166 \text{ kPa} \]

\[ e = \frac{3.166 \times (371.4 + (0.24 \times 30) - (0.6 \times 25)) - 0.24(30 - 25) \times 97.5}{371.4 + (0.04 \times 30) - (0.4 \times 25)} \]

\[ e = 2.852 \text{ kPa} \]

\[ \rho = \frac{97.5 - 0.378 \times 2.852}{0.287045 \times (273.15 + 30)} \]

\[ \rho = 1.108 \text{ kg/m}^3 \]
AIR PRESSURE

In an underground mine fan produces the airflow. Fans create a pressure differential that causes the air to flow through the workings.

In ventilation for air to flow from one point to another there must be a difference in pressure between the two points. This difference in pressure is known as the ventilating pressure.
AIR PRESSURE

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In ventilation for air to flow from one point to another there must be a difference in pressure between the two points. This difference in pressure is known as the **ventilating pressure**.
AIR PRESSURE

1. Air will always flow from a high pressure point to a low pressure point and as long as this pressure is maintained, air will continue to flow,

2. The larger the pressure difference between these two points the greater the quantity of air will flow. This assumes the resistance between the two points remains unchanged.

3. Resistance to pressure reduces the ventilating pressure, ie the pressure is used up overcoming resistance to the airflow.

4. If the pressure difference between two points remains the same and the resistance to airflow between these points is increased the air quantity will decrease.
AIR PRESSURE

Pressure is the force applied per unit area and in ventilating terms is usually expressed in Pascals.

One Pascal (Pa) = One Newton per square meter (N/m2)
ATMOSPHERIC PRESSURE

The earth is contained in an atmosphere and by the force of gravity, it exerts a pressure on the surface of the earth caused by the weight of the air above.

Atmospheric pressure at sea level is equivalent to a mass of 10,000 kg on one square meter (m²) of surface and is expressed in the following ways:

1 Atmosphere,
1.013 Bar,
101.325 kPa,
1013 mb,
BAROMETRIC PRESSURE

Barometric pressure is simply a description of the instrument used to measure the pressure of the atmosphere in which it is situated. In mine workings the pressure measured using a barometer includes pressure changes caused by fans and therefore is not always be a true indication of the atmospheric pressure outside the mine.
STATIC PRESSURE (SP)

Direction of Airflow

To gauge

Static pressure inside the duct holds it open
Moving air possess “kinetic energy” which is the energy associated with motion. In mine ventilation this is termed “Velocity Pressure”.

The faster the air moves the greater velocity pressure will be and vice versa. Velocity pressure cannot be measured directly, however it can be measured indirectly using pitot tube.
**VELOCITY (DYNAMIC) PRESSURE (VP)**

\[ VP = \frac{\rho v^2}{2} \]

- \( VP \) = Velocity Pressure (Pa)
- \( \rho \) = Density of air (kg/m\(^3\))
- \( v \) = Velocity (m/s)
Total Pressure is the algebraic sum of the static pressure (potential energy) and the velocity pressure (kinetic energy) and is measured with a facing tube, parallel to the direction of flow.
MEASURING PRESSURE IN A DUCT

Direction of Airflow

Static Pressure

Velocity Pressure

Total Pressure
<table>
<thead>
<tr>
<th>NOVEMBER</th>
<th>TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>MINE GASES, DETECTION, AND MONITORING</td>
</tr>
</tbody>
</table>
“All substances are poisons; it is only the dose that separates the poison from the remedy”

Paracelsus, circa 15 c.
INTRODUCTION

When air enters any mine or other subsurface structure, it has a volume composition of approximately 78% nitrogen, 21% oxygen and 1% other gases on a moisture free basis.
INTRODUCTION

However, as the air progresses through the network of underground openings, that composition changes.

1- The mining of subsurface structures allows any gases that exist in the surrounding strata to escape into the ventilating airstream.

2- A large number of chemical reactions.
INTRODUCTION

The mining of subsurface structures allows any gases that exist in the surrounding strata to escape into the ventilating airstream.

Such strata gases have been produced over geological time and remain trapped within the pores and fracture networks of the rock. Methane and carbon dioxide are commonly occurring strata gases.
Oxidation reduces the percentage of oxygen and often causes the evolution of carbon dioxide or sulphur dioxide. The action of acid mine water on sulphide minerals may produce the characteristic odour of hydrogen sulphide while the burning of fuels or the use of explosives produce a range of gaseous pollutants.
Most of the fatalities resulting from mine fires and explosions have been caused by the toxic gases that are produced rapidly in such circumstances.
INTRODUCTION

A primary requirement of a mine ventilation system is to dilute and remove airborne pollutants. It is, therefore, necessary that the subsurface environmental engineer should be familiar with the physical and chemical properties of mine gases, their physiological effects, how they may be detected and preferred methods of control.
Threshold limit values of airborne substances refer to those concentrations within which personnel may be exposed without known adverse effects to their health or safety.
THRESHOLD LIMIT TYPES

Time-Weighted Average (TWA): the average concentration to which nearly all workers may be exposed over an 8 hour shift and a 40 hour work week without known adverse effects.

Short-Term Exposure Limit (STEL): is a time-weighted average concentration occurring over a period of not more than 15 minutes.

Ceiling Limit: It is the concentration that should not be exceeded at any time. This is relevant for the most toxic substances or those that produce an immediate irritant effect.
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OXYGEN, O$_2$

O$_2$ is the only gas whose concentration should be maintained above its recommended threshold limit value.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Breaths/min</th>
<th>Inhalation rate lt/s</th>
<th>O$_2$ consumption lt/s</th>
<th>CO$_2$ produced lt/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>At rest</td>
<td>12 – 18</td>
<td>0.08 – 0.2</td>
<td>≈ 0.005</td>
<td>≈ 0.004</td>
</tr>
<tr>
<td>Moderate work</td>
<td>30</td>
<td>0.8 – 1.0</td>
<td>≈ 0.03</td>
<td>≈ 0.027</td>
</tr>
<tr>
<td>Vigorous work</td>
<td>40</td>
<td>≈ 1.6</td>
<td>≈ 0.05</td>
<td>≈ 0.05</td>
</tr>
</tbody>
</table>
# THE EFFECTS OF OXYGEN DEPLETION

<table>
<thead>
<tr>
<th>Percent oxygen in air</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.0</td>
<td>Flame height on a flame safety lamp reduced by 50 percent.</td>
</tr>
<tr>
<td>17</td>
<td>Noticeable increase in rate and depth of breathing - this effect will be further enhanced by an increased concentration of carbon dioxide.</td>
</tr>
<tr>
<td>16</td>
<td>Flame lamp extinguished.</td>
</tr>
<tr>
<td>15</td>
<td>Dizziness, increased heartbeat.</td>
</tr>
<tr>
<td>13 to 9</td>
<td>Disorientation, fainting, nausea, headache, blue lips, coma.</td>
</tr>
<tr>
<td>7</td>
<td>Coma, convulsions and probable death.</td>
</tr>
<tr>
<td>below 6</td>
<td>Fatal.</td>
</tr>
</tbody>
</table>
# OXYGEN, $O_2$

$O_2$ is the only gas whose concentration should be maintained above its recommended threshold limit value.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Breaths/min</th>
<th>Inhalation rate lt/s</th>
<th>$O_2$ consumption lt/s</th>
<th>$CO_2$ produced lt/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>At rest</td>
<td>12 – 18</td>
<td>0.08 – 0.2</td>
<td>≈ 0.005</td>
<td>≈ 0.004</td>
</tr>
<tr>
<td>Moderate work</td>
<td>30</td>
<td>0.8 – 1.0</td>
<td>≈ 0.03</td>
<td>≈ 0.027</td>
</tr>
<tr>
<td>Vigorous work</td>
<td>40</td>
<td>≈ 1.6</td>
<td>≈ 0.05</td>
<td>≈ 0.05</td>
</tr>
</tbody>
</table>
Nitrogen constitutes approximately 78% of air and is, therefore, the most abundant gas in a ventilated system. It is fairly inert and occurs occasionally as a strata gas, usually mixed with other gases such as methane and carbon dioxide.
OXIDES OF NITROGEN, NO\textsubscript{x}

Nitric Oxide, (NO) and Nitrogen dioxide (NO\textsubscript{2}), both of which are classified as toxic.

The TWA exposure limit for NO is 25 ppm and that for NO\textsubscript{2} is 3 ppm. As yet an STEL for NO has not been set, but for NO\textsubscript{2} the STEL is 5 ppm.
<table>
<thead>
<tr>
<th>Concentration ppm</th>
<th>Typical Physiological Effects for NO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>TWA</td>
</tr>
<tr>
<td>50</td>
<td>Moderately irritating to eyes and nose</td>
</tr>
<tr>
<td>100</td>
<td>Irritant to respiratory passages and to the eyes</td>
</tr>
<tr>
<td>200</td>
<td>Breathed for 20 minutes may cause collapse</td>
</tr>
<tr>
<td>250</td>
<td>Severe pulmonary oedema, probably fatal.</td>
</tr>
</tbody>
</table>
CARBON DIOXIDE, CO$_2$

Variety of sources:
- strata emissions,
- oxidation of carbonaceous materials, internal combustion engines, blasting,
- fires,
- explosions and respiration.
CARBON DIOXIDE, CO$_2$

Stagnant mixtures of air in sealed off areas often have an increased concentration of carbon dioxide and decreased oxygen content. Such mixtures are sometimes called blackdamp.
<table>
<thead>
<tr>
<th>Percent carbon dioxide in air</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.037 – 0.038²</td>
<td>None, normal concentration of carbon dioxide in air.</td>
</tr>
<tr>
<td>0.5</td>
<td>Lung ventilation increased by 5 percent</td>
</tr>
<tr>
<td>2.0</td>
<td>Lung ventilation increased by 50 percent.</td>
</tr>
<tr>
<td>3.0</td>
<td>Lung ventilation doubled, panting on exertion.</td>
</tr>
<tr>
<td>5 to 10</td>
<td>Violent panting leading to fatigue from exhaustion, headache.</td>
</tr>
<tr>
<td>10 to 15</td>
<td>Intolerable panting, severe headache, rapid exhaustion and collapse.</td>
</tr>
</tbody>
</table>
CARBON MONOXIDE, CO

It has a density very close to that of air and mixes readily into an airstream unless it has been heated by involvement in a fire, in which case it may layer with smoke along the roof.
Carbon monoxide is a product of the incomplete combustion of carbonaceous material. Although colourless, it has the traditional name of *whitedamp*. The great majority of fires and explosions in mines produce carbon monoxide.
CARBON MONOXIDE, CO

Most fatalities that have occurred during such incidents have been a result of carbon monoxide poisoning. The mixture of gases, including carbon monoxide, resulting from a mine explosion, is often referred to as *afterdamp*. It is also formed by IC engines, blasting.
The new substance formed in the bloodstream, carboxyhaemoglobin (CO.Hb), is relatively stable and does not readily decompose. It accumulates within the bloodstream. This leaves a reduced number of red cells to carry oxygen molecules throughout the body.
<table>
<thead>
<tr>
<th>Blood Saturation (% CO·Hb)</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>None</td>
</tr>
<tr>
<td>10-20</td>
<td>Possible headache</td>
</tr>
<tr>
<td>20-30</td>
<td>Headache, dizziness</td>
</tr>
<tr>
<td>30-40</td>
<td>Severe headache, weakness, nausea, loss of judgement, dimming of vision, Possible collapse</td>
</tr>
<tr>
<td>40-50</td>
<td>Collapse</td>
</tr>
<tr>
<td>50-60</td>
<td>Collapse at rest, increased lung ventilation and pulse, convulsions</td>
</tr>
<tr>
<td>60-70</td>
<td>Convulsions, coma, depressed lung ventilation and pulse, disturbed judgement</td>
</tr>
<tr>
<td>&gt;70</td>
<td>Slow weak pulse, respiratory failure and death.</td>
</tr>
</tbody>
</table>
There are some significant psychological reactions. Low levels of blood saturation can give an appearance of intoxication including impairment of judgment and an unsteady gait preceding collapse. Victims may become silent and morose, and may resist or fail to comprehend instructions that will lead them to safety.
HYDROGEN, H₂

It is the most explosive of all the mine gases. Hydrogen occasionally appears as a strata gas and may be present in afterdamp at about the same concentrations as carbon monoxide. Dangerous accumulations of hydrogen may occur at locations where battery charging is in progress. Battery charging stations should be located in intake air with a duct or opening at roof level that connects into a return airway.
HYDROGEN SULPHIDE, H$_2$S

The presence of this highly toxic gas is readily detected by its characteristic smell of bad eggs. This has given rise to the colloquial name *stinkdamp*.

It has a narcotic effect on the nervous system including paralysis of the olfactory nerves.
Hydrogen sulphide is produced by acidic action or the effects of heating on sulphide ores. It is formed naturally by bacterial or chemical decomposition of organic compounds and may often be detected close to stagnant pools of water in underground mines.

Hydrogen sulphide may occur in natural gas or petroleum reserves. It can also be generated in gob fires.
# HYDROGEN SULPHIDE, H2S

<table>
<thead>
<tr>
<th>Concentration of hydrogen sulphide ppm</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 to 1</td>
<td>Detectable by smell.</td>
</tr>
<tr>
<td>5</td>
<td>Beginning of toxicity</td>
</tr>
<tr>
<td>50 to 100</td>
<td>Slight irritation to eyes and respiratory tract, headache, loss of odour after 15 minutes.</td>
</tr>
<tr>
<td>200</td>
<td>Intensified irritation of nose and throat.</td>
</tr>
<tr>
<td>500</td>
<td>Serious inflammation of eyes, nasal secretions, coughing, palpitations, fainting.</td>
</tr>
<tr>
<td>600</td>
<td>Chest pains due to corrosion of respiratory system, may be fatal.</td>
</tr>
<tr>
<td>700</td>
<td>Depression, coma, probable death.</td>
</tr>
<tr>
<td>1000</td>
<td>Paralysis of respiratory system, very rapid death.</td>
</tr>
</tbody>
</table>
Hydrogen sulphide is produced by acidic action or the effects of heating on sulphide ores. It is formed naturally by bacterial or chemical decomposition of organic compounds and may often be detected close to stagnant pools of water in underground mines.

Hydrogen sulphide may occur in natural gas or petroleum reserves. It can also be generated in gob fires.
**SULPHUR DIOXIDE, SO$_2$**

Highly toxic gas but one which, fortunately, can be detected at very low concentrations both by its acidic taste and the intense burning sensation it causes to the eyes and respiratory tracts.

<table>
<thead>
<tr>
<th>Concentration of sulphur dioxide ppm</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Acidic taste</td>
</tr>
<tr>
<td>3</td>
<td>Detectable by odour.</td>
</tr>
<tr>
<td>20</td>
<td>Irritation of eyes and respiratory system.</td>
</tr>
<tr>
<td>50</td>
<td>Severe burning sensation in eyes, nose and throat.</td>
</tr>
<tr>
<td>400</td>
<td>Immediately dangerous to life.</td>
</tr>
</tbody>
</table>
Methane is colourless, odourless and non-toxic. It has a specific gravity relative to air of only 0.55 and as a result, tends to layer against the backs in areas of low air velocity (laminar flow conditions). Methane is produced by bacterial and chemical action on organic material. It is evolved during the formation of both coal and petroleum, and is one of the most common strata gases.

HYDROGEN SULPHIDE, $\text{H}_2\text{S}$
METHANE, $\text{CH}_4$

Methane is not toxic but is particularly dangerous because it is flammable and can form an explosive mixture with air. This has resulted in the deaths of many thousands of miners. A methane: air mixture is sometimes referred to as firedamp.
Although methane is especially associated with coal mines, it is often found in other types of subsurface openings that are underlain or overlain with carbonaceous or oil-bearing strata. The methane is retained within fractures, voids and pores in the rock either as a compressed gas or adsorbed on mineral (particularly carbon) surfaces.
When the strata is pierced by boreholes or mined openings, then the gas pressure gradient that is created induces migration of the methane towards those openings through natural or mining-induced fracture patterns.

The explosible range for methane in air is normally quoted as 5 to 15 percent by volume, with the most explosive (stochastic) mixture occurring at about 9.8 percent.
The primary purpose of monitoring the concentrations of airborne pollutants in a mine is to ensure that the atmosphere provides a safe environment free from levels of toxicants that would create a hazard to health. There are essentially three matters to consider.
GAS DETECTION AND MONITORING

• The first is the **TLV** deemed to be acceptable for each pollutant.

• Second is the **choice of instrumentation** best suited for the detection and measurement of particular gases.

• Third, the question of **where and how frequently measurements are required** must be addressed.
Advances in the fields of electronics, electrochemistry have resulted in significant improvements in the accuracy and reliability of equipment for the detection and measurement of gas concentrations.

Instruments now available are capable of measuring concentrations of more than one gas and indicating fractions of a part per million for some toxic gases.
WHAT ARE THE FUNCTION OF GAS SENSOR AND TRANSMITTER?
A gas sensor is a device which detects the presence of various gases within an area, usually as part of a safety system.

This type of equipment is used to detect a gas leak and interface with a control system so a process can be automatically shut down.

A gas sensor can also sound an alarm to operators in the area where the leak is occurring, giving them the opportunity to leave the area.
Gas sensors can be used to detect combustible, flammable and toxic gases, and oxygen depletion.

This type of device is used widely in industry and can be found in a variety of locations such as on oil rigs, to monitor manufacture processes and emerging technologies such as photovoltaic.

Gas detectors are usually battery operated. They transmit warnings via a series of audible and visible signals such as alarms and flashing lights, when dangerous levels of gas vapors are detected.
As detectors measure a gas concentration, the sensor responds to a calibration gas, which serves as the reference point or scale.

As a sensor’s detection exceeds a preset alarm level, the alarm or signal will be activated. As units, gas detectors are produced as portable or stationary devices.

Originally, detectors were produced to detect a single gas, but modern units may detect several toxic or combustible gases, or even a combination of both types.
SOME APPLICATIONS OF GAS SENSOR:

- Process control industries
- Environmental monitoring
- Fire detection
- Alcohol breath tests
- Detection of harmful gases in mines
- Home safety
TYPES OF GAS SENSORS

- Metal Oxide Based
- Capacitance Based
- Acoustic Wave Based
- Calorimetric
- Optical
- Electrochemical
METAL OXIDE BASED GAS SENSORS
CAPACITANCE BASED GAS SENSORS
ACOUSTIC WAVE BASED GAS SENSORS
CALORIMETRIC GAS SENSORS
OPTICAL GAS SENSORS
ELECTROCHEMICAL GAS SENSORS
Primarily for the measurement of methane and other gases that will burn in air such as carbon monoxide, hydrogen or the higher gaseous hydrocarbons. If an electrical filament is heated to a sufficiently high temperature, then a combustible gas in the surrounding air will burn and, hence, elevate the temperature of the filament.
FILAMENT AND CATALYTIC OXIDATION (PELLISTOR) DETECTORS
FLAME SAFETY LAMPS

These lamps were introduced early in the nineteenth century for the purposes of providing illumination from an oil flame without igniting a methane-air mixture. Their use for illumination disappeared with the development of electric battery lamps. However, the devices were retained for the purposes of testing for methane and oxygen deficiency.
FLAME SAFETY LAMPS

TESTING FLAME

Nil methane
1⅓ per cent
2 per cent
5 per cent
7 per cent
10 per cent
15 per cent
20 per cent

GARFORTH LAMPS
Flame Shapes with Bulb Injection
FLAME SAFETY LAMPS

1815

2015