Gas-1

MINE GASES

☐ Contaminants – any undesirable substance not normally present in air or present in an excessive amount;

☞ Most common types underground: gases and dusts.

❖ Threshold Limit Value (TLV) as re-commended by ACGIH: airborne conc. of substance & conditions to which nearly all workers may be repeatedly exposed to without adverse health effects.

– TLVs are based on available info. from industrial experience, may vary from substance to substance;

– List is updated periodically.

Threshold Limit Value-Time Weighted Average (TLV-TWA);

Threshold Limit Value-Short Term Exposure Limit (TLV-STEL)

Air – most common gas underground

❖ O₂ - most important; quantity required ==> function of physical activity.

☞ Miner working at a moderate rate consumes 0.07 cfm of O₂ and expel 0.063 cfm of CO₂.

❖ O₂ Depletion – can be deadly; caused by dilution (by other gases) and oxidation (high- & low-temp.) process.

☞ Physiological effects will vary depending on individual.

❖ CO₂ - although part of normal mine air (0.03%), most often found in abandoned & unventilated areas. A mixture of CO₂ & air => blackdamp

☞ Fatal when displacing O₂

☞ Sources: rock strata, oxidation, fire and explosions, blasting, and human respiratory process.

☞ Symptoms: increased conc. will increase lung ventilation,

0.5%: breathe deeper and faster
3%: double lung ventilation
5%: 300% + in respiratory rate
10%: can be tolerated for only a few min.
18%: death

❖ CH₄ - Occurs in coal, metal and non-metal mines; legally, all coal mines are considered gassy

☞ Emission rate: varies; ranging from 2~4 cfm/ft² fresh coal face exposed or 40~400 cfm for gassy mines.

☞ Explosive range: 5 ~ 15%
Controlled by: dilution, sealing, and drainage.

- CO - although explosive, toxicity is the main concern - carboxyhemoglobin (COHb) formed by CO and hemoglobin; also referred to as "whitedamp".
  - Symptoms: from noticeable effect at 5-10% blood COHb conc. to death at 70-80%;
  - TLV-TWA: 50 ppm (0.005%);
  - TLV-STEL: 400 ppm (0.04%).

- \text{H}_2\text{S} - "stinkdamp"; toxic and explosive (4-44%); slightly heavier than air.
  - Sources: from heated gobs and carried in by groundwater
  - TLV-TWA: 10 ppm (0.001%);
  - TLV-STEL: 15 ppm (0.0015%).

- \text{SO}_2 - formed during blasting, internal combustion engines, or certain sulfur ores; much heavier than air;
  - TLV-TWA: 5 ppm (0.0005%);
  - TLV-STEL: 5 ppm (0.0005%).

- \text{NO}_x - although physiologically inert, they form several oxides, some of which are extremely toxic.
  - TLV-TWA: 5 ppm (0.0005%);
  - TLV-STEL: 5 ppm (0.0005%).

- \text{H}_2 - explosive (4-74%), can ignite at 5% \text{O}_2, as compared to 12% for \text{CH}_4.

- Radon - chemically inert; mainly in uranium mines, also traces in coal.

**Gas Detection and Monitoring**

- To provide a safe working environment underground:
  1. TWA is acceptable for each pollutant
  2. Choice of detection devices best suited for particular gas
  3. Detection location and frequency

- Fundamental Detection Principles –
  1. Filament & atalytic-oxidation: by measuring the conc. of combustion gases thru either the change in resistance in an electrical circuit or the heat generated during the oxidation process => CO, \text{CH}_4, etc.
     - Platinum has been used for its good stable temp-resistance charcateristics at 900-1000°C. They have been available since 1950s.
2. **Electrochemical**: measuring the amount of electrical current generated by reacting with special electrode $\Rightarrow O_2, CO, H_2S, NO_x$.

3. **Optical detection**: two types $\Rightarrow O_2, CO, H_2S, NO_x$.
   a. Infrared detector - since different gases absorb light at specific and distinct wavelength, conc. is determined by measuring the amount of absorption by passing light thru gas mixture;
   b. Interferometer – diff. gases have diff. refraction index, conc. is determined by measuring the difference in light velocity between gas and air

4. **Stain tubes**: conc. determined by detecting color changes in chemicals, which are proportional to gas conc.

**Control of Gases**

- **Prevention**, **Removal**, **Absorption**, **Isolation**, and **Dilution**.

**Methane Layering**

- Insufficient turbulence due to low airflow quantity will result in CH$_4$ remaining stratified and forming CH$_4$ layer moving along the roof.

- Ample air velocity and turbulence are the primary safeguards against layering

  - **Layering Number, $N_l$**:
    
    $$ N_l = \frac{V_u}{41} \left( \frac{b}{Q_g} \right)^{1/3} $$

    - $V_u$: Air velocity in upper half of airway, cfm;
    - $b$: Airway width, ft';
    - $Q_g$: Methane inflow, cfm

  - $N_l \geq 5$ is necessary for layering control in most cases.

**Dilution Requirements**

- Four limiting factors: (1) Contaminant quantity not excessive; (2) Source far away or low; (3) Low toxicity; (4) Contaminant inflow relatively uniform.

- Dilution requirement depends on: (1) Maximum Allowable Conc. (MAC); (2) Rate of contaminant inflow, and; (3) Contaminant inflow conc.

  $$ Q \geq Q_g \frac{1 - MAC}{MAC - B} $$

  - $Q$: Inflow air, cfm
\[ \tau \geq \frac{Y}{Q + Q_g} \ln \left[ \frac{QB + Q_g - (Q + Q_g)x_\tau}{QB + Q_g - (Q + Q_g)x_o} \right] \]

- **Y**: Volume of work space, \( \text{ft}^3 \);
- **Q**: Incoming airflow, cfm;
- **Q_g**: Gas inflow, cfm;
- **B**: Inflow gas conc.
- **x_o**: Conc. at working at time \( \tau_o \), \%;
- **x_\tau**: Conc. at working at time \( \tau \), \%.