Air is flowing with a flow rate of 24 m^3/s in a roadway of 4 m width × 3 m height × 100 m length in an underground coal mine. Is there any danger of methane layering if the percentage of methane in the mine atmosphere is 3.5%?

$$\boxed{S_{index} = 3\sqrt{\frac{23\,V^2}{C\sqrt{F}}}}$$

$V \rightarrow$ velocity of air (m/s)
$C \rightarrow$ Mean CH_4 concentration (%)
$F \rightarrow$ area of cross-section (m^2)

Here, $S_{index} = 3\sqrt{\frac{23 \times \left(\frac{24}{12}\right)^2}{3.5\sqrt{12}}}$

$= 1.96$

Since, $S_{index} < 2 \Rightarrow$ there is ~~probable~~ danger of methane layering

$S_{index} < 2 \Rightarrow$ Danger of Methane Layering
$S_{index} > 2 \Rightarrow$ No danger

b) A long heading 5 m wide and 4 m high is ventilated by a forcing tube circulating 4 m^3/s of air at the face. Calculate the distance from the face at which all the +10 μm dust particles would have settled down from the airstream. The dust particles have a density of 2650 kg/m3. Assume your own data, if required. 5

Terminal Settling Velocity, $\boxed{v_t = \frac{D^2(\rho - a)g}{18\mu}}$

$D \rightarrow$ diameter of particle
$\rho \rightarrow$ density of particle
$a \rightarrow$ density of air
$g \rightarrow 9.8\ m/s^2$
$\mu \rightarrow$ air viscosity

Solⁿ

$$v_t = \frac{(10 \times 10^{-6})^2 (2650 - 1.2)\, 9.8}{18 \times \underbrace{1.8 \times 10^{-5}}_{\mu}}$$

$= 0.008$ m/s

Made with Goodnotes

Now,

Reynold's number

$$Re = \frac{\rho v D}{\mu} \quad D \rightarrow \frac{4A}{P}$$

$$= \frac{\overset{\rho}{1.2} \times \overset{v}{4} \times \overset{D}{\frac{4 \times 20}{18}}}{\underset{\mu}{1.8 \times 10^{-5}} \times 20}$$

$$= 59259 > 4000$$

$\Rightarrow$ Turbulent Flow

$$\therefore v_t \text{ (actual)} = 0.5 \times v_t \text{ (theoretical)}$$

$$= 0.5 \times 0.008$$

$$= 0.004 \text{ m/s}$$

Time required by particle to settle down from height of 4m $= \frac{4}{0.004}$

$$= 1000 \text{ sec}$$

Therefore,

Horizontal distance covered

$$= v \times t$$

$$= \frac{4}{20} \times 1000 = \boxed{200\text{ m}}$$

Made with Goodnotes

The following gives the working history of a miner at a copper mine:

Nature of work	Number of months worked	Average dust production in the respirable size range (mg/m^3)	Percentage of free silica in the respirable dust
Drilling	39	1.8	5.6
Mucking	48	2.4	8.2
Drill shop	85	0.9	4.8
Surface	72	0.4	0.5

Calculate cumulative dust dosage as well as his average dust exposure of the miner. Assume 150 working hours in a month. Estimate the exposure to dust hazard of the miner. Also find the factor of safety in dust exposure of miner according to the norm.

$$\boxed{\text{Cumulative Dust Dosage}} = (39 \times 1.8 + 48 \times 2.4 + 85 \times 0.9 + 72 \times 0.4) \times 150$$

$$= 43605 \text{ mg h m}^{-3}$$

$$\boxed{\text{Average Dust Exposure}} = \frac{43605}{(39 + 48 + 85 + 72) \times 150}$$

$$= 1.19 \text{ mg/m}^3$$

$$\boxed{\text{Average free silica percentage}} = \frac{\text{Total silica}}{\text{Total Dust}}$$

$$= \frac{(39 \times 1.8 \times 5.6 + 48 \times 2.4 \times 8.2 + 85 \times 0.9 \times 4.8 + 72 \times 0.4 \times 0.5)}{(39 \times 1.8 + 48 \times 2.4 + 85 \times 0.9 + 72 \times 0.4)}$$

$$= 5.91\,\%$$

Made with Goodnotes

$$\text{TLV (Threshold Limit Value)} \begin{cases} \dfrac{10}{\text{\% of free silica}} & (\text{\% of silica} > 5\%) \\[2ex] 2\ mg/m^3 & (\text{\% of silica} < 5\%) \end{cases}$$

Here, $\boxed{TLV} = \dfrac{10}{5.91} = 1.69\ \%$

[allowable respirable dust concentration]

Now,

$$\boxed{\text{Factor of Safety}} = \frac{TLV}{\text{\% of free silica}} = \frac{1.69}{1.19}$$

$$= 1.42$$

Made with Goodnotes

c) A miner works at a grizzly for 4.5 hours on an average per shift wearing a dust mask which is 90% efficient for -5 μm dust. He spends one hour on the average per shift in travelling inside the mine. Calculate his cumulative dust dosage in a 10-year working span taking 280 working shifts in a year on the average. Also calculate the average dust concentration he is exposed to and estimate his exposure to dust hazard if the respirable dust contains < 5% free silica. The average respirable dust concentration at the grizzly and in the general body of the mine air is 21 mg/m³ and 0.2 mg/m³.

Cumulative Dust Dosage

$$= (4.5 \times 21 + 1 \times 0.2) \times 10 \times 280 \times (1 - 0.9)$$

$$= 26516 \text{ mg h m}^{-3}$$

Average dust conc. $= \dfrac{26516}{(4.5+1) \times 10 \times 280}$

$$= 1.72 \text{ mg/m}^3$$

TLV, since % of free silica < 5%

$\longrightarrow$ 2 mg/m³

Now, FOS $= \dfrac{2}{1.72} = 1.16$

Made with Goodnotes

3) Determine the lower limit of the following gaseous mixture: 97% methane, 2% ethane and 1% hydrogen. What is the danger associated with gas concentration outside the limits of inflammability of methane?

As per Le Chatelier relation

% v/v of individual gas

LFL of mixture

$$\boxed{\frac{100}{L} = \frac{P_1}{L_1} + \frac{P_2}{L_2} + \frac{P_3}{L_3} + \dots}$$

LFL of individual gas

Here,

$$\frac{100}{L} = \frac{97}{5.4} + \frac{2}{3.2} + \frac{1}{4.1}$$

$$= 5.31\ \%$$

Gas	Lower limit (% by volume)
Acetylene (C_2H_2)	2.5
Carbon monoxide (CO)	12.5
Ethane (C_2H_6)	3.2
Ethylene (C_2H4)	3.1
Hydrogen (H_2)	4.1
Hydrogen sulphide (H_2S)	4.3
Methane (CH4)	5.4
Ammonia (NH3)	15

Made with Goodnotes

Drilling in a stone drift 3 m × 4 m in cross-section in a coal mine produces 1.5 gm of dust of < 5 μm size every minute. Calculate the airflow rate required to dilute the dust to the TLV if the intake air has a respirable dust load of 0.8 mg/m3 and the respirable dust has a free silica content of 8%.

$$TLV = \frac{10}{8} = 1.25 \text{ mg/m}^3$$

A/c,

$$0.8 + \frac{1.5 \times 10^3}{Q} = 1.25$$

$$\Rightarrow \frac{1.5 \times 10^3}{0.45} = Q$$

$$\Rightarrow Q = 3333.33 \text{ m}^3/\text{min}$$

$$\Rightarrow Q = \frac{3333.33}{60} = 55.55 \text{ m}^3/\text{s}$$

Made with Goodnotes

b) Define 'Lux'. What standards of lighting have been recommended for underground mines?

Floor illumination at a point directly below a light source in an underground garage of height 4 m is 40 lux. What is the floor illumination at a point 8 m away from the light source?

Ans

Illumination is generally measured in meter candles or foot candles or Lux (S.I Unit). One meter candle is the intensity of illumination on a surface 1 meter away from a source of 1 candle power.

$$\boxed{\text{Illumination} = \frac{\text{Intensity}}{d^2} \times \cos\theta}$$

d → distance

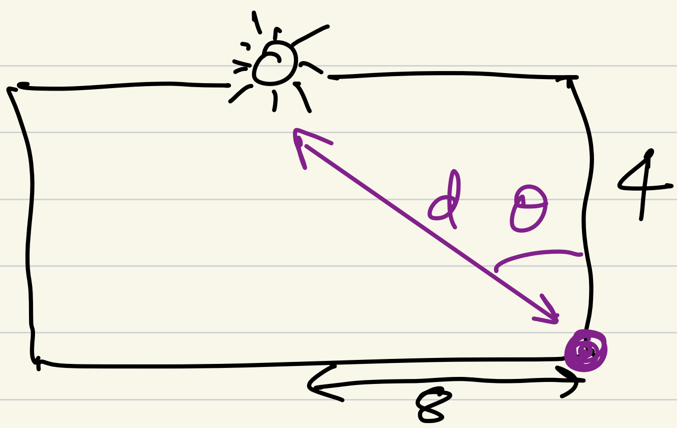
θ → angle of inclination

Here,

$$40 = \frac{I}{4^2} \times \cos 0^\circ$$

$$\Rightarrow \text{Intensity} = 640\,cd$$

Now,



$$d = \sqrt{8^2 + 4^2} = \sqrt{80}$$

$$\theta = \tan^{-1}\left(\frac{8}{4}\right) = 63.43$$

$$\therefore \text{Illumination} = \frac{640}{(\sqrt{80})^2} \times \cos 63.43$$

$$= 3.58 \text{ lux}$$

Made with Goodnotes

c) An incandescent headlight of a mining vehicle is of spot beam type with a beam angle of 30°. What is the spherical surface in m^2 subtended by the lighted beam at a distance of 5 m from the headlight?

$$\boxed{\text{Spherical surface subtended} = 2\pi r^2(1-\cos\theta)}$$

$$\text{Area subtended} = 2\pi \times (5)^2 \times (1-\cos 30^\circ)$$

$$= 21\ m^2$$

c) In an underground mine, a miner inhales the normal air and exhales the air containing 15.5% O_2 and 3.5% CO_2. What is the respiratory quotient of breathing for the worker?

$$\text{Respiratory Quotient} = \frac{\Delta CO_2}{\Delta O_2}$$

$$= \frac{CO_2\,[\text{exhaled} - \text{inhaled}]}{O_2\,[\text{inhaled} - \text{exhaled}]}$$

$$= \frac{3.5 - 0.03}{20.93 - 15.5}$$

$$= 0.63$$

Made with Goodnotes

How does analysis of air sample help in early detection of heating? Given below the analysis result of a sample taken from inside a sealed off fire area: $N_2 = 79.79\%$, $CO_2 = 8.44\%$, $CH_4 = 3.86\%$, $O_2 = 4.97\%$, $CO = 2\%$, and $H_2 = 0.94\%$. What does it indicate regarding (a) the condition of fire, and (b) air-tightness of the stoppings?

(a) CO_2 in atmospheric air in the sample

$$\frac{0.03}{79.04} \times 79.79$$

$$= 0.03$$

O_2 in atmospheric air

$$= \frac{20.93}{79.04} \times 79.79$$

$$= 21.12$$

$\therefore$ Graham's Ratio $= \dfrac{CO}{\Delta O_2}$

$$= \frac{2}{21.12 - 20.93}$$

$$= 10.52$$

$\downarrow$

Active Fire

(b) Since O_2 is very less (< 5%)

$\Rightarrow$ stoppings are air-tight

Made with Goodnotes

a) It is required to build a brick dam with a crushing strength of 17.5 kg/cm^2 against rise workings in an underground mine. The head of water is expected to be 120 m. A stream of water of about 2000 GPM is flowing through the gallery of 4 m width and 3 m height. Describe how you will construct the dam with special reference to (i) Selection of site, (ii) Thickness of dam.

Made with Goodnotes