Name: **Admission No.** **Serial No.**

Indian Institute of Technology (Indian School of Mines) Dhanbad

Department of Mining Engineering

Endsem Exam Summer Semester 2023-2024

Course for 2nd, 3rd, 4th B.Tech. and Integrated M.Tech. (53 nos.)

Subject: Mine Environmental Engineering (Code: MND406)

Time: 180 minutes (1:00PM–4:00PM) **| Venue:** NLHC LH 9 -10 **| Date:** 16-07-2024 **| Maximum Marks:** 84

Answer all questions of the ***three*** *sections and* ***marks*** *are assigned against each section*

Use of ***Scientific Calculator*** *is allowed*

Section A: Numerical Type Questions – 40 marks

Answer all the questions and each question carries ***4 marks***

1. A lamp having a candle power of 300 in all directions is provided with a reflector that directs 70% of total light uniformly on a circular area 40 m diameter. The lamp is hung at 15 m above the area. Calculate the illumination

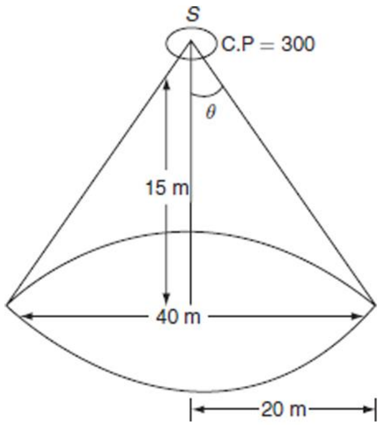
(i) on the circular area.

$$A = \frac{\pi}{4}D^2 = \frac{\pi}{4}(40)^2 = 400\pi\ m^2$$

$$Solid\ angle\ (\omega) = 2\pi(1-\cos\theta) = 2\pi * \left(1 - \frac{15}{\sqrt{15^2+20^2}}\right)$$

$$= 0.8\pi\ steradian$$

Illumination, E = $\frac{Flux}{Area} = \frac{CP*\omega}{A} = \frac{300*0.8\pi}{400\pi} * 0.7 = 0.42\ lux$



(ii) at the center.

$$= \frac{\varphi}{A} * 0.7 = \frac{CP*\omega}{A} * 0.7 = \frac{300*4\pi}{400\pi} * 0.7 = 2.10\ lux$$

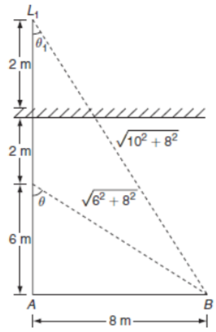
(iii) at the edge of the surface without reflector.

$$= \frac{300}{d^2}\cos\theta = \frac{300}{d^2} * \frac{15}{d} = \frac{4500}{d^3} = \frac{4500}{\left(\sqrt{20^2+15^2}\right)^3} = 0.288\ lux$$

2. A lamp of 250 candela is placed 2 m below a plane mirror that reflects 60% of light falling on it. The lamp is hung at 6 m above ground. Find the illumination at a point on the ground 8 m away from the point vertically below the lamp.

$$\frac{250}{\left(\sqrt{6^2+8^2}\right)^2} * \frac{6}{\sqrt{6^2+8^2}} + \frac{250*0.6}{\left(\sqrt{10^2+8^2}\right)^2} * \frac{10}{\sqrt{10^2+8^2}}$$

$$= 1.5 + 0.71 = 2.21\ lux$$

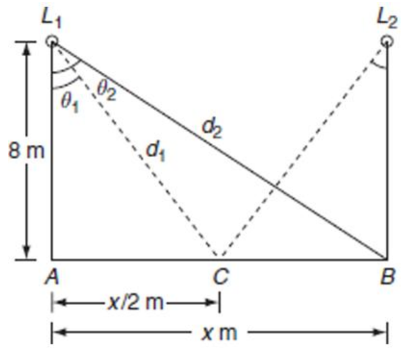


3. Two similar lamps having luminous intensity 500 CP in all directions below horizontal are mounted at a height of 8 m. What must be the spacing between the lamps so that the illumination on the ground midway between the lamps shall be at least one-half of the illumination directly below the lamp.

$$E_c = \frac{1}{2}E_{A/B}$$

$$\frac{500}{d_1^2}\cos(\theta_1) + \frac{500}{d_1^2}\cos(\theta_1) = \frac{1}{2}\left(\frac{500}{8^2} + \frac{500}{d_2^2}\cos(\theta_2)\right)$$

$$2 * \frac{500}{d_1^2}\cos(\theta_1) = \frac{500}{2}\left(\frac{1}{8^2} + \frac{1}{d_2^2}\cos(\theta_2)\right)$$



$$\frac{2}{\left[8^2+\left(\frac{x}{2}\right)^2\right]}*\frac{8}{\sqrt{8^2+\left(\frac{x}{2}\right)^2}}=\frac{1}{2}\left(\frac{1}{8^2}+\frac{1}{8^2+x^2}*\frac{8}{\sqrt{8^2+x^2}}\right)$$

$$\frac{32}{\left(64+\frac{x^2}{4}\right)^{\frac{3}{2}}}=\frac{1}{64}+\frac{8}{(64+x^2)^{\frac{3}{2}}}$$

x = 19.11 m

4. Design a gravity settling chamber to remove all the iron particles size of 35 µm (density = 7.6 g/cm^3) from a dust-laden gas stream. The following information is given as:

Gas specification: air at ambient condition with flow quantity (Q) =130 ft^3/s, uniform horizontal velocity (u) = 10 ft/s, viscosity of gas = 1.23 x 10^{-5} lb/ft-s and density of gas = 0.0775 lb/ft^3.

density = 7.6 g/cm^3 = 474.5 lb/ft^3 = 7600 kg/m^3
Q =130 ft^3/s = 3.70 m/s
u = 10 ft/s = 3.05 m/s
viscosity of gas = 1.23 x 10^{-5} lb/ft-s = 1.83 x 10^{-5} kg/m-s
density of gas = 0.0775 lb/ft^3 = 0.00124 g/cm^3 = 1.24 kg/m^3

$D<\frac{1.141x10^{-3}}{\rho^{\frac{1}{3}}}=58\ \mu m$ **> 35 μm; flow is laminar**

settling velocity of iron particles = $\frac{D^2(\rho-\rho_a)g}{18\mu}=$ **0.27 m/s**

Cross-section area = $\frac{Q}{u}=\frac{130}{10}=13\ ft^2=1.21\ m^2$

width = height = 1.10 m

Settling time = $\frac{1.10}{0.27}=4.0\ s$

Settling chamber length = 3.05 x 4.0 = 12.20 m (Ans: 11-12 m)

5. (i) A particle 'A' of diameter 10 µm settles in an oil of specific gravity 0.9 and viscosity 1 Pa-s under Stoke's law. Compare the settling velocity of a particle 'B' of diameter 20 µm with particle 'A'.

$v_t=\frac{D^2(\rho-\rho_a)g}{18\mu}$

$v_t\propto D^2$

settling velocity of particle 'B' of diameter 20 µm is four times of settling velocity of particle 'A'

(ii) What is the force required (in Newtons) to hold a spherical balloon of stationary in water at a depth of 'H' from the air-water interface? The radius of balloon is 0.1 m and filled with air.

Drag force is required from water to hold a spherical balloon of stationary in water

$$Drag\ Force=\textbf{Buoyancy}-\textbf{gravitational}$$
$$=\frac{\pi D^3}{6}(\rho_w-\rho_a)\text{g}=\frac{\pi(0.2)^3}{6}(1000-1.23)*9.8=\textbf{41 N}$$

OR

The force required = Buoyancy force - Gravitational force.
Buoyancy force = mass of fluid displaced x g.
The mass of fluid displaced = density of fluid x volume of the balloon = $1000*\frac{4}{3}\pi(0.1)^3=\frac{4}{3}\pi$
Buoyancy force = $\frac{4}{3}\pi g$.
Gravitational force = mass of the balloon x g.
mass of the balloon = density of air x volume = $1.225*\frac{4}{3}\pi(0.1)^3=0.001225*\frac{4}{3}\pi$
Gravitational force = $0.001225*\frac{4}{3}\pi g$
The force required = Buoyancy - gravitational = $\frac{4}{3}\pi g(1-0.001225)=\frac{4}{3}\pi g*0.998=\frac{4}{3}\pi g$**= 41.8 N**

6. (i) Blasting in a raise liberates 6 m^3 of toxic fumes. The raise is 1.2 m x 2.0 m in cross-section and had advanced 14 m from level. If the auxiliary ventilator supplies 23.5 m^3/min of fresh air to the face, how long will it take to dilute the fumes to a concentration of 100 ppm?

Volume of the raise = 1.2 m × 2.0 m × 14 m = 33.6 m^3
Volume of toxic fumes produced = 6 m^3
Dilute it to 100 ppm = 100 x 10^{-6} = 100 x 10^{-4} % = 0.01 %
Equation used to calculate the time required to dilute blasting fumes
$t = 2.303 \frac{V_m}{Q} \log \frac{q}{V_m c} + \frac{V - V_m}{Q}$
where t = time, V_m = volume of the tunnel over which the mixing of the gases produced at the face, and air delivered by the fan occurs, c = concentration at time (t), V = volume of tunnel, Q = quantity of air flow, q = total volume of nitrous fumes produced
Assume auxiliary ventilator discharge at a distance of 10 m.
$V_m = 10 * 1.2 * 2.0 = 24$ m^3
V = 33.6 m^3
Q = 23.5 m^3/min
$t = 2.303 \frac{V_m}{Q} \log \frac{q}{V_m c} + \frac{V - V_m}{Q}$ $= 2.303 \frac{24}{23.5} \log \frac{6*100}{24*0.01} + \frac{33.6-24}{23.5} = 8.40\ min$

(ii) The rate of emission of dust at a coal face is 100 billion particles per minute. Calculate the quantity of air required to be circulated to the face in order to dilute the dust to a safe concentration of 850 ppcc Assume general body air to have a dust concentration of 200 ppcc.
Let air required be Q m^3/s
850 x 10^6 x Q = $\frac{100*10^9}{60}$ + 200 x 10^6 x Q
650 x 10^6 x Q = $\frac{10^{11}}{60}$
Q = 2.56 m^3/s = 153.60 m/min

7. (i) Calculate the change in surface area, if 1 cm^3 of quartz is comminuted to particles of 1 μm^3 size? Shape considered is spherical or cubical
Let number of spherical particles of 1 μm^3 size are 'n'
n*1 μm^3 = 1 cm^3
n*10^{-18} m^3 = 10^{-6} m^3
n = 10^{12} particles
Radius of 1 cm^3 size spherical shape dust particle = 6.2 mm

$$\frac{4}{3}\pi r^3 = 10^{-6}\ m^3$$

Surface area of 1 cm^3 size particle = $4\pi r^2$ = 483 mm^2
Radius of 1 μm^3 size spherical shape dust particle = 62 µm
Surface area of 1 μm^3 size particle = 0.05 mm^2
Surface area of 10^{12} particles of 1 μm^3 size particle with radium of 62 µm = 0.05 * 10^{12} = 5*10^{12} mm^2
Change in surface area = 4.83*10^{-4} m^2

(ii) What will happen to the viscous resistance offered by air against the motion of small particles due to change in their surface area?
Owing to the large surface area, there is a greater viscous resistance to the motion of small particles in air as compared to large ones.

(iii) What will happen to the viscous resistance offered by air, if 1 μm^3 size dust particles are further reduced to ultra fine particles?
Stokes' law of gravitational settling does not hold good for very fine particles, since when particles become small compared to the mean free path of gas molecules, the viscous resistance decreases and consequently the terminal velocity increases. For such particles Cunningham developed the following relation: $v_c = v_s\left(1 + 1.7\frac{l}{D}\right)$ where v_c = true terminal velocity, v_s = terminal velocity as calculated by Stokes' equation (equation 2.7) and l = mean free path of the gas molecules ≈10^{-7} m under ordinary atmospheric conditions. For particles above 0.5 µm in size, v_c differs very little from v_s, though it is about five times as high as v_s for 0.05 µm particles.

8. Determine terminal settling velocity in water of a spherical sand particle of 0.5 mm diameter. The density of the sand is 2.65 x 10^3 kg/m^3 and the viscosity of water is 1.0 x 10^{-3} kg/m-s.

for laminar, Re < 3 and $v_t = \frac{D^2(\rho-\rho_w)g}{18\mu} = 0.23$ m/s

$$\frac{v_t D \rho_w}{\mu} < 3$$

$$\frac{D^2(\rho-\rho_w)g}{18\mu} * \frac{D\rho_w}{\mu} < 3$$

$$\frac{D^3(2650-1000)*9.81}{18*(1.0*\ 10^{-3})^2} * 1000 < 3$$

$$D^3 < 3.336 * 10^{-12}$$

$$D < 1.49 * 10^{-4} = 149\ \mu m$$

for turbulent, Re > 1000 and $v_t = \left[\frac{3Dg(\rho-\rho_w)}{\rho_w}\right]^{\frac{1}{2}} = 0.15$ m/s

$$\frac{v_t D \rho_w}{\mu} > 1000$$

$$\left[\frac{3Dg(\rho-\rho_a)}{\rho_w}\right]^{\frac{1}{2}} \frac{D\rho_w}{\mu} > 1000$$

$$\frac{3 * D^{\frac{3}{2}} * (\rho-\rho_a)^{\frac{1}{2}} * \rho_w^{\frac{1}{2}} * g^{\frac{1}{2}}}{\mu} > 1000$$

$$\frac{3 * D^{\frac{3}{2}} * (2650-1000)^{\frac{1}{2}} * 1000^{\frac{1}{2}} * 9.8^{\frac{1}{2}}}{1.0*\ 10^{-3}} > 1000$$

$$D^{\frac{3}{2}} > 8.29 * 10^{-5}$$

$D > 1.9$ mm = 1900 µm

Flow is intermediate as 500 µm lies between $149 - 1900\ \mu m$

$v_t = \frac{0.209(\rho-\rho_w)^{\frac{2}{3}} g^{\frac{2}{3}} D}{(\rho_w \mu)^{\frac{1}{3}}} = \frac{0.209*(2650-1000)^{\frac{2}{3}}*9.8^{\frac{2}{3}}*5*10^{-4}}{(1000*1.0*10^{-3})^{\frac{1}{3}}}$= 0.067 m/s

9. Calculate the endurance of a self-contained closed-circuit compressed-oxygen apparatus for mine rescue and recovery work with following details: oxygen cylinder capacity = 400 liters; unused oxygen in exhaled air= 67%; breathing rate = 40 liters per minute (l/min) for 60% of the time used and 20 liters per minute (l/min) for 40% of the time used.

Let endurance (time) is ‘t’ in minutes

Total oxygen in liters consumed by wearer in endurance time ‘t’ = 0.33*[(0.40*t*20)+(0.60*t*40)]

= 10.56 t

10.56 t = 400

t = 37.88 min

10. Calculate the number of arch dams required to handle maximum water pressure of 100 MPa from the following data: external radius of arch ring = 80 m; internal radius of arc ring = 76 m; safe compressive stress of material used = 200 kgf/cm^2.

200 kgf/cm^2 = 20 MPa

$$t = \frac{r_i}{n\frac{\sigma_s}{p} - 1}$$

$$4 = \frac{76}{n\frac{20}{100} - 1}$$

$$19 + 1 = \frac{20 * n}{100}$$

$$n = 100$$

Following relation may be useful where symbols have their usual meanings:

Design of water dams	Dynamics of small dust particles	
$t = \frac{pr_e}{\sigma_s} = \frac{pr_i}{\sigma_s - p}$	$R = \frac{C_D \rho_a A v^2}{2}$	$v_t = \left[\frac{3Dg(\rho-\rho_a)}{\rho_a}\right]^{\frac{1}{2}}$

$t = r_i\left[\frac{1}{\sqrt{1-\frac{2h}{\sigma_s}}} - 1\right]$	$R_e = \frac{v_t D \rho_a}{\mu}$ $C_D = 0.44$ $C_D = \frac{24}{R_e}$ $C_D = \frac{44}{\sqrt{Re}}$	$v_t = \frac{D^2(\rho-\rho_a)g}{18\mu}$ $v_t = \frac{0.209(\rho-\rho_a)^{\frac{2}{3}} g^{\frac{2}{3}} D}{(\rho_a\mu)^{\frac{1}{3}}}$

Section B: Short Answer Type Question (Answer in 2-3 lines/pointwise) – 29 marks

*Answer all the questions and each question carries **1 mark***

11. Differentiate between:

(i) Long and short service rescue breathing apparatus

The long-service apparatus are used for periods of 2 or more hours by mine rescue crews for long-range rescue and recovery work and has an oxygen reserve of 300 to 400 litres.

The short-service apparatus are used as auxiliary apparatus for short periods of half to three-quarters of an hour for rescuing miners in an emergency when they pave to be brought through irrespirable and poisonous atmospheres. They have an oxygen reserve of 120, 150 or 200 litres.

(ii) Closed and opened circuit rescue breathing apparatus

The closed-circuit apparatus is an oxygen-circulating apparatus of the regenerative type in which the oxygen used up by the wearer is supplemented from an oxygen reserve, the unwanted carbon dioxide in the exhaled air being absorbed at the same time by a regenerating chemical absorbent.

In the open-circuit apparatus, oxygen or air from a compressed-oxygen of compressed-air reserve is supplied to the wearer and the exhaled oxygen or air is discharged into the open and is put to no further use. They are also called reservoir or non-regenerative apparatus.

(iii) Intrinsically safe and flame-proof equipment

Intrinsically safe for electronic equipment to be used in underground environment and not capable of causing any explosion

flame-proof equipment- electrical equipment do not cause explosion

(iv) Proto IV and Drager BG 4 Rescue Breathing Apparatus

Drager BG 4:

(1) It has 3-and 4-hour approval ratings;

(2) The low-oxygen warning device is located in the oxygen regulator instead of in the demand regulator assembly or valve box;

(3) A second pressure gauge is mounted on the oxygen cylinder;

(4) It incorporates a divider in the breathing hose facepiece connector;

(5) The oxygen metering nozzle is located on the oxygen regulator; and

(6) The cylinder valve of 'step clutch' design.

(7) The CO_2 absorbent in the canister consisting mostly of $Ca(OH)_2$ is not packed-bed design but is suspended in a wire mesh offering low exhalation resistance.

(v) Chemical oxygen self-rescuer and filter self-rescuer

In the chemical-oxygen self-rescuers, a chemical bed is used which, upon contact with the moisture in the exhaled air, evolves a plentiful supply of pure oxygen for meeting the breathing requirements, and, by subsequent reaction, absorbs the exhaled carbon dioxide. The chemical employed is potassium tetroxide (K,O,) which liberates oxygen and absorbs carbon dioxide according to the equations:

$2K_2O_4 + 2CO_2 \rightarrow 2K_2CO_3 + 3O_2$

$2K_2O_2 + 2H_2O \rightarrow 4KOH + 3O_2$

$2KOH + CO_2 \rightarrow K_2CO_3 + H_2O$

Filter self-rescuers are emergency gas respirators which provide instant respiratory protection against carbon-monoxide gas such as occurs in mines after fires or explosions and thus enable the wearer to escape to a place of safety. They do not generate oxygen.

(vi) Partly-lung governed and predetermined constant dosage apparatus

In apparatus with a constant dosage, oxygen at a definite predetermined rate, 2 litres per minute, is supplied to the wearer when he is working hard but when the wearer is not working hard the excess oxygen is lost.

In apparatus with constant and lung-governed dosages, oxygen is supplied to the wearer at a constant rate of 1.5 litres per minute and, if the wearer requires more, a lung-governed oxygen admission valve provides an additional supply which his exertion may demand. They are widely used throughout the world.

(vii) Air-lift and submersible pumps

De-watering of a flooded mine in which water has risen into the shaft(s) may be done by suspended electrical vertical centrifugal/turbine pumps, air-lift pumps, or electrical submersible pumps installed in the shaft. In the air-lift pump (Fig. 8.19), compressed air produced by an efficient compressor is used for pumping out water. The compressed air is fed through a pipe to the bottom end of a larger pipe immersed in water where it forms a mixture with water having a density less than that of water so that it rises upwards through the larger pipe constituting the rising main. The actual head of an air -lift pump is given by $H = \frac{\eta t(\rho_w - \rho_m)}{\rho_m}$ (m)

where n = efficiency which depends on the ratio H: t; t = immersion depth (m); ρ_w = density of water to be pumped (kg/m3); ρ_m = density of compressed air-water mixture (kg/m3). Generally, the immersion depth is made 1.5 to 2 times the lift head. The main advantages of the air-lift pumps are: (a) there are no wearing parts, (b) fabrication is simple, (c) any kind of pipes can be used, and (d) water containing mud and sand can be pumped. The disadvantages, however, are that an efficient compressor must be available and the efficiency in normal operation is not higher than 0.2 to 0.3. They can be used only in emergencies as at low t: H ratios which are usually encountered in mines, the high cost on compressed air does not play an important role. Air-lift pumps had been used in the past for raising water from flooded shafts. Where electricity is available, submersible pumps offer the easiest means of dewatering mine shafts. The submersible pump is of the multi-stage centrifugal type with a motor coupled to it and the drive is from below. The squirrel cage motor is of the completely 'wet' type in which the motor is cooled and lubricated by water which circulates vigorously between the rotor and the stator and throughout the windings. The circulation ensures efficient cooling of the conductors and enables a high horsepower output to be obtained from a small frame size motor.

(viii) Sump and water dams

Sump is to deal with the normal water influx but also with any sudden inflows or irruptions of water, or powerful feeders that may be encountered so that mine safety is assured.

Water dams are permanent artificial barriers or seals built in mine workings including shafts, slopes, drifts and adits under any one of the following circumstances:

(1) To guard against irruptions of water from adjacent water-bearing strata;

(2) To guard against irruptions of water from adjacent old workings;

(3) When approaching water-logged workings and draining off the water by ~ means of boreholes;

(4) To limit the amount of pumping by allowing water in worked-out areas to accumulate behind the dams;

(5) To reduce or eliminate acid water being discharged in mines with the acid mine drainage problem;

(6) To seal off operating mines that will close in the future;

(7) To isolate acid-producing zones in a mine where they can be identified from active mine workings where natural barriers cannot be provided; and

(8) In most cases, to withstand the maximum hydrostatic pressure that may develop.

(ix) Dewatering by means of narrow roadways and long boreholes

De-watering by means of narrow mine roadways

This method is feasible only when it is possible to approach a water-logged area sufficiently near to it and when the water pressure is less.

De-watering by means of long boreholes

This method of de-watering is adopted when the water pressure is great and boring and tapping must be done from great distances by using special safety boring apparatus. One may have to drive narrow roadway(s) in order to have a suitable location with respect to the water pool. For the success of the method, an exact knowledge of location of the water-logged area is necessary.

(x) Wet suppression and dry suppression of dust

(a) dry drilling causes less bit wear (bit wear with dry drilling is one-third to half of that due to wet drilling) and has a higher rate of penetration than wet drilling;

(b) wet drilling produces sloppy working conditions, particularly when drilling - upward holes as in roof bolting;
(c) in deep and hot mines, wet drilling causes discomfort by increasing the humidity of the mine air;
(d) clayey and shaly beds, when saturated with water from wet drilling, become weak thus having a deleterious effect on roof control.

(xi) Silicosis and asbestosis

silicosis is the most dangerous since it can affect people fatally and is progressive in nature. Silicosis is characterized by the development of nodular fibrosis in the lung tissue. The nodules appear as protrusions in the lung tissue and histologically consist of a concentric development of fibrous tissue.
Asbestosis is pathologically and to some extent symptomatically distinct from silicosis. Pathologically, asbestosis involves the development of tough areas in the lung due to the presence of fibrous tissue. The fibrosis in asbestosis is different from the nodular fibrosis typical of classical silicosis. The lung radiograph shows a diffuse ground glass or cobweb-like appearance. Here the fibrosis is believed to be caused by the mechanical action of long asbestos fibres which get lodged in the alveolar walls causing morbid growth of fibrous tissue in the region. As a result, the alveolar walls or the septa separating alveoli get thickened owing to the presence of both asbestos fibres and asbestosis bodies. This is substantiated by the fact that the fibrosis-producing character of asbestos is almost completely eliminated if the asbestos is thoroughly pulverized so that no particle in it exceeds two micrometres in length.

(xii) Collagenous and non-collagenous pneumoconiosis

Noncollagenous pneumoconiosis is caused by nonfibrogenic dusts and is characterized by
(i) alveolar architecture remaining in tact.
(ii) minimal stromal reaction consisting mainly of reticulin fibres and
(iii) reversibility of dust reaction.
Examples of noncollagenous pneumokoniosis are stannosis caused by tin oxide and barytosis caused by barium sulphate.
Collagenous pneumokoniosis is characterized by
(i) permanent alteration or destruction of alveolar architecture,
(ii) collagenous stromal reaction of moderate to maximal degree and
(iii) permanent scarring of lungs.
It may be caused by fibrogenic dusts or altered tissue response to non-fibrogenic dusts.

(xiii) Newtonian and stokes velocity of dust

turbulent motion where the resistance is proportional to the square of the velocity (Newton)
Stokes, holds good for streamline flow where the resistance varies directly as velocity.

(xiv) Cunningham's Law and Stoke's Law

Stokes' law of gravitational settling does not hold good for very fine particles, since when particles become small compared to the mean free path of gas molecules, the viscous resistance decreases and consequently the terminal velocity increases.
For such particles Cunningham developed the following relation: $v_c = v_s\left(1 + 1.7\frac{l}{D}\right)$
where v_c **= true terminal velocity,** v_s **= terminal velocity as calculated by Stokes' equation and** l **= mean free path of the gas molecules** $\approx 10^{-7}$ **m under ordinary atmospheric conditions.**

(xv) Relief valve and bypass valve in rescue breathing apparatus

A bypass valve to supply oxygen direct to the wearer should the reducing valve or the lung-governed admission valve through any cause fail to act properly. The valve is usually designed as a self-closing push-buttonA lung-governed oxygen admission valve or regulator in the case of automatic lung-governed apparatus to supply the wearer with oxygen in the exact quantity which his exertion may demand. There are two types of lung-governed oxygen admission valves: the lever-arm type and the diaphragm type. In the first type, the valve is automatically actuated by the rise and fall of the breathing bag which is in turn controlled by the rate of respiration and oxygen consumption. In the second type, the valve is actuated by the negative pressure produced by the wearer's respiratory effort and is independent of the movement of the breathing bag.
Warning signals or alarms to give a clearly audible whistling or hooting sound in case the reducing valve fails to shut off at the proper pressure or the cylinder is approaching exhaustion.

A relief or excess-pressure valve to release any excess pressure and to avoid accumulation of nitrogen in the respiratory system in the event of the oxygen contained in the cylinder not being perfectly pure. It may be located on the facepiece or on the breathing bag and operated manually or automatically by the breathing bag itself when the latter expands.

(15 marks)

12. Classify mine rescue apparatus.

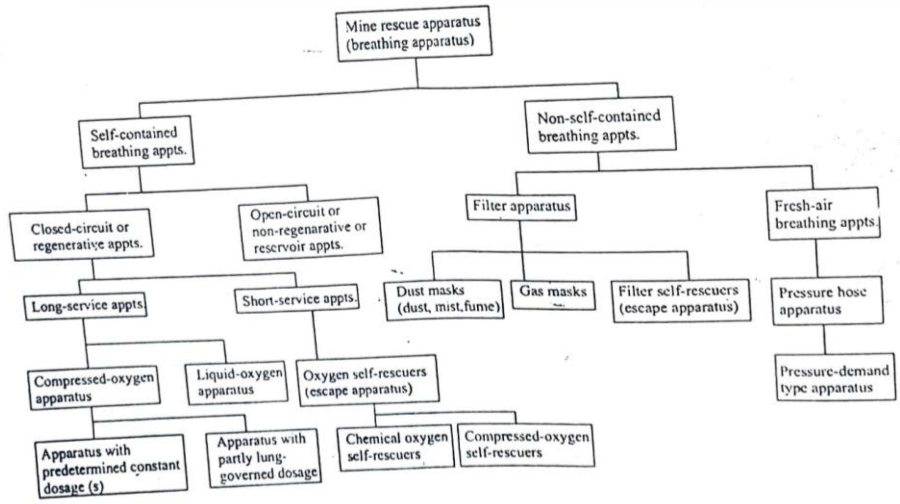


Figure 7.3 Classification of mine rescue apparatus.

13. What are the different ways of expressing dust concentration and which one is universally accepted?

Concentration of dust can be expressed as (a) mass of dust per unit volume of air, (b) number of particles per unit volume and (c) surface area of particles per unit volume.

Mass concentration of the respirable fraction of dust is widely accepted today as the relevant concentration.

14. What should be the minimum length of hole bored straight ahead of the face when approaching a water-logged working from its (i) bottom side (ii) if its exact location is not known?

When approaching a water-logged area from its bottom side, the determined value of s should be increased by 50 per cent.

A further 25 m should be added to it if the exact location of the area is not known.

$$L_{min} = s + l$$

where $s = \frac{pb}{4\tau}$ = the shortest safe distance between the approaching working and the water-logged area calculated as indicated above. l is the expected length of pull.

15. Why occurrences of coaldust are more frequent in winter season?

The drying out of the deep mine workings due to air currents increases the hazard due to coal dust in winter more than in summer months.

16. Arrange the following dams in the order of their ease of building: flat, arch and spherical. Mention the two most effective measures for consolidation of roadway dust.

Flat > arch > spherical

Dust consolidation methods:

(a) the calcium chloride method commonly used in British coal mines and

(b) the Salt crust process sometimes used in Germany.

17. Suppose you are a trained to perform CPR and you observed that a miner has suffered a heart attack while working in the mine. Discuss stepwise procedure of performing CPR over the miner.

It combines expired air resuscitation and external cardiac compression.

If during expired air resuscitation, a pulse is not present, external cardiac compressions must be started immediately.

The patient is laid on a hard flat surface and the first-aider then determines the pressure point for cardiac compressions by locating the bony tip of the breast bone (sternum) with his ring finger, placing two fingers just above that point.

He places the heel of his hand adjacent to the fingers and then places the second hand on top of the first.

Positioning his shoulders directly over the patient's breastbone, he presses downwards keeping arms straight so that the sternum is depressed 38 to 50 mm exerting about 40 to 50 kgf of pressure on the breast bone.

The time spent in depressing and releasing the sternum must be the same.

If there is one first-aider, one-person CPR, compressions should be carried out at a rate of 60 to 90 per minute with two breaths with the nostrils pinched off (lung ventilation) after each 15 compressions in a row.

If there are two first-aiders, two-person CPR, they should position themselves on opposite sides of the patient.

One first-aider should perform compressions at a rate of 60 per minute while the other is inflating the lungs after every fifth compression.

Compressions must be continuous and not interrupted for lung inflation.

After four complete cycles of breaths and compressions, the pulse should be checked within five seconds and, if it is present, check for breathing.

If there is a pulse but no spontaneous breathing, continue rescue breathing and continuously monitor the pulse.

Cardiopulmonary resuscitation should be continued for at least 30 minutes.

CPR must be done by trained persons.

With an untrained person, the victim may suffer a fractured rib, a lacerated liver, or a punctured lung.

If a heart attack is witnessed before giving CPR, a thump with clenched fist over the breastbone as hard as one can be given, can make the heart start beating and permit the victim to breathe again.

18. When a free fall particle attains the terminal settling velocity?

A small particle falling in the gravitational field of the earth will be opposed by the viscous resistance of air which will increase with increasing velocity of the particle until the particle has no acceleration. The resistance of air then balances the gravitational force and the particle falls at a constant velocity called the terminal settling velocity.

19. Why there is less retention of dust particle of size less than 1 μm in human lungs?

The percentage of retention increases with ultrafine particles, whose deposition is governed more by Brownian motion than gravitational settling, but tissue damage caused by very fine particles is neglible, probably because of the fact that very fine particles are too quickly dissolved to produce any toxic effect.

20. What is inundation? Mention the worst disaster due to inundation till date.

An inrush or irruption of water is a sudden inflow of large quantities of water into mine workings causing their inundation. The worst disaster being that in Chasnalla (1975) when 375 miners were killed.

21. What are the different causes of inundation?

Inundations by surface waters

Inundations by surface waters may occur after sudden and abnormally heavy rains when the surface mine outlets such as shafts, inclines, and adits may get flooded or subsidence fractures reaching the surface get submerged.

They are very dangerous as large quantities of water break into the mine within a short time preventing escape of workmen.

Inundations from overlying strata

Inundations from the overlying strata can occur under one or more of the following conditions:

(1) When impervious strata are pierced by mine workings;
(2) When fissures or fracture planes develop in impervious strata due to subsidence communicating with water-bearing strata above;
(3) Where faults, fissures or fracture planes in communication with a water-bearing bed are intersected by mine workings;
(4) Where the deposit occurs under a water-bearing bed, lying uncomformably on the eroded surface of the deposit;
(5) When a mine working is too near to the surface and accidental holing has taken place into a pond, stream bed, or outcrop workings;
(6) Where boreholes drilled for prospecting have not been sealed-off; and
(7) Mining coal from beneath the seabed as at Ellington mine, UK Coal.
Inundations from water-logged workings
Inundations from water-logged workings occur when they are accidentally holed or when barrier pillars fail due to inadequate design.
They are not easily predictable and the danger from them is especially great in semi-steep and steep formations.
These measures can be divided into: surface measures and underground measures.
The surface measures aim at preventing dangerous accumulations of water on the mine surface.
The underground measures offer protection against inundations.
Both surface and underground measures may be adopted to control inundations with varying degrees of effectiveness depending largely upon geological and hydrological conditions.
Before mining, a suspected water-rich area could be drained by drilling of building a reliable drainage system.
Surface measures
They can be further divided into: (a) measures against flooding of mine main entries or outlets; and (b) measures against seepage of surface waters.
The selection of one or more remedial measures is governed by the cost-benefit ratio and the method of financing.

22. Discuss the preventive measures against inundations.
Measures against flooding of mine main entries
These consist of the following:
(1) Locating shaft sites away from faults especially formed by major tensional stresses;
(2) Laying mouths of shafts, inclines, and adits above the high-water mark and lining them for the first 20 m with watertight lining.
(3) Filling up with debris and other sealing materials all abandoned shafts and boreholes which have ceased to serve any purpose with the existing mine;
(4) Cutting diversion drains or ditches or erecting embankments or concrete walls on the surface to intercept and conduct the surface run-off water away; and
(5) Constructing dams and reservoirs in the upper reaches of rivers to prevent their flooding.
Measures against seepage of surface waters
Depending on the nature of the bed(s), surface water (streams, ponds, tanks, lakes) lose considerable quantities of water which may enter mine workings or form water pools in the strata. The infiltration of surface waters can be controlled by one or more of the following measures:
(1) Straightening, cleaning, widening, and grading stream channels to provide free flow of water especially in areas with vertical fractures, subsidence, or high-permeability rocks;
(2) Silting or lining stream beds with concrete or rubble masonry;
(3) Grouting the river bed with cement to stabilise and seal it;
(4) In the case of near-surface mines, laying ponds and tanks dry if they form a cause of water influx in mines;
(5) Diverting streams/rivers, if technically and economically feasible, with safety to new and safe channels;
(6) Back-filling surface excavations or subsided areas with impervious materials to an established hydraulic gradient that will ensure natural drainage;
(7) Diverting run-off to prevent its infiltration into fissures on subsided areas;
(8) Conducting run-off across pervious or subsided areas of the mining property by means of flumes;

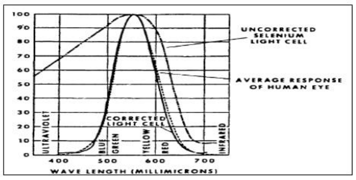
(9) Grouting overlying strata to reduce permeability and the flow; a seismic reflection survey on the surface will reveal the location of subsurface anomalous structures such as fractures, joints or faults for the drilling and grouting programme.
(10) Leaving outcrop barrier pillars of adequate size;
(11) Selecting a method of extraction, especially of thick seams, by which the Strata subside uniformly without fracturing. For extraction under important waterways, hydraulic stowing is the best method of roof control; and
(12) Afforestation along river banks.
Underground Measures
These protect life and property against inundations. They consist of the following measures:
1. General lowering of the water table to below the level of the workings by borehole pumps was extensively applied for a long time for opencast mines but it suffers from the disadvantage that a stage might be reached when further dewatering would severely interfere with water resources, wells, etc.
2. Avoiding blasting and drilling operations near suspected water-logged workings.
3. Leaving safety water pillars or barriers. A safety water pillar is that portion of the bed that is left unmined:
(i) below an overlying water formation along boundary line or lines of adjoining properties;
(ii) between parts of a mine;
(iii) below surface streams, tanks and lakes;
(iv) around shafts; or
(v) along major faults.
Its principal function is to act as a dam to prevent water accumulations from suddenly breaking into mine workings. Lack of maintenance of dependable pillars by depending on old surveys and incorrect old plans had resulted in several mine disasters in the past.
The vertical thickness of the safety pillar against water-bearing strata overlying a bed is generally prescribed by the mining regulations. In coal mines, it should not be less than 20 m.
The width of a safety pillar between adjacent mines is usually prescribed by the mining regulations. In coal mines, it should be at least 20 m on either side of the boundary line at right-angles to it.
If possible, a mine should be laid out in districts or panels according to their hydrology. The panels should have substantial safety barriers on three sides with a minimum number of entries or drivages through them so that, after mining, each panel can be isolated from the others.
The width of a safety pillar-barrier to be maintained against abandoned waterlogged workings depends on the following factors:
(1) The degree of uncertainty regarding the exact location of the old workings;
(2) The thickness of the bed;
(3) The nature of the bed whether it is friable, contains dirt partings, or has been crushed and fractured by folding;
(4) The inclination of the bed and the direction of the pillars in relation to the line of full dip;
(5) The maximum hydrostatic head;
(6) The nature and condition of the adjacent strata whether pervious or broken;
(7) The method of extraction and roof control on the side of the pillar;
(8) The presence of faults, their throw and direction; and
(9) Effect of mining other beds.
The geophysical electrical resistivity determination method can be used with reasonable certainty for determination of coal barrier thickness against water logged workings or delineation of hidden water-filled galleries within the barriers. There is, however, no general rule or formula for determining the size of safety pillars as no rule can possibly serve all cases.
4. Supporting roadways not coming under the influence of mining operations with water-tight lining.
5. Cementation of fractured strata in the roof containing water in fissures.
6. Driving drainage tunnels or adits to de-water the property. This method had been practised in certain metalliferous mines in the early days of mining.
7. When driving through hard ground traversed by water-bearing fissures, adopting a technique of diamond drilling cover ahead of the advancing face in which long holes (100 m) are drilled ahead of the face from bays (40 m apart) excavated on alternate sides of the roadway (Fig. 8.1);

8.. Providing adequate sump and pumping capacities at predetermined points for dealing with inrushes of water even where safety pillars are provided.
9. Erecting water dams or hydraulic seals to seal abandoned sections of the mine.
10. Erecting bulkhead doors in mine workings with immediate danger of inundation.
11. Providing additional lodgement capacity in worked-out area(s) to which sudden inrushes of water may be directed in an emergency.

23. Explain the different methods of dust sampling.
(a) filtration,
(b) sedimentation,
(c) inertial precipitation,
(d) thermal precipitation,
(e) electrical precipitation and
(f) optical methods based on light scattering.

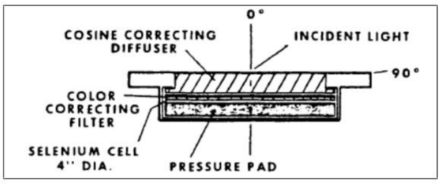
24. Mention the general requirements of self-contained breathing apparatus.
(1) Safety and reliability: (2) Simplicity: (3) Comfort: (4) Weight: (5) Compactness: (6) Durability: (7) Initial cost and ease and cost of maintenance. (8) Compliance with the country's national standards.

25. What is cosine and color correction in a photometer?
Color Correction: The response of the human eye (spectral luminous efficiency) for photopic (daylight) vision is shown in figure 2.7, along with the response curve for a typical uncorrected selenium photocell. The response of the cell differs significantly from that of the eye. This difference would cause a significant error in the measurement of visible light if the cell were not color corrected. This problem is corrected by the placement of filters on the surface of the photocell, which adjusts the response of the assembly to closely match that of the human eye. The response of a color-corrected photocell is also shown in figure 2.7.



(Source:www.cdc.govNioshminingpubspdfsic9074.pdf)
Figure 2.7: Function of color correcting filter on response of photocells.

The response of a photocell changes as the angle of light falling on its surface changes. At high angles of incidence, a greater portion of incoming light is reflected from the cell surface. This is because the reflectance of most surfaces increases as the angle of incidence increases. Errors in light measurement caused by these factors alone may be as much as 25 pct. The problem is corrected by placement of a diffusing cover over the photocell. This cover adjusts the level of light received by the cell to the correct proportion for various angles of incidence (fig 2.8).



(Source:www.cdc.govNioshminingpubspdfsic9074.pdf)
Figure 2.8: Diffusing cover for cosine correction on photometers.

Section B: Descriptive Answer Type Question (Answer in 5-6 lines/pointwise) – 15 marks
*Answer all the questions and each question carries **3 marks***

26. Draw a spirogram showing Tidal Volume (TV), Inspiratory Reserve Volume (IRV), Expiratory Reserve Volume (ERV) Residual Volume (RV), Total Lung Capacity (TLC) and Vital Capacity (VC) in milliliters.

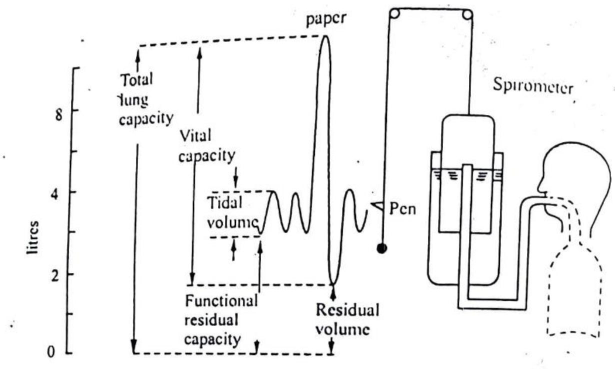
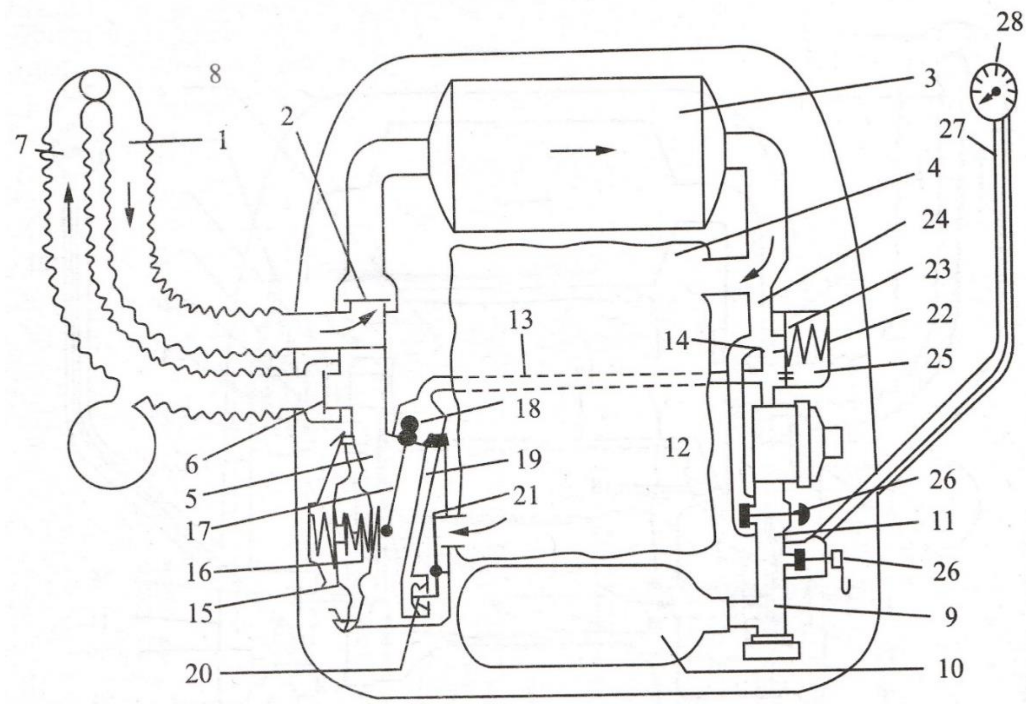


Figure 7.2 Spirogram.

IC = TV (500 ml) + IRV (3000 ml) = 3500 ml
FRC = ERV (1100 ml) + RV (1200 ml) = 2300 ml
VC = IRV (3000 ml) + TV (500 ml) + ERV (1100 ml) = IC (3500 ml) + ERV (1100 ml) = 3600 ml
TLC = VC (4600 ml) + RV (1200 ml) = IC (3500 ml) + FRC (2300 ml) = 5800 ml

27. Discuss the design features **explaining each component/part** of closed-circuit modern self-contained compressed oxygen-breathing apparatus (figure shown below).



A steel cylinder of 1 or 2-litre capacity containing medical oxygen under high pressure not less than 120 bar (g), usually 135, 150, 200 or 300 bar (g), for supplying the wearer with oxygen. Modern designs of steel cylinders are lighter than the older ones. A 2-litre light-weight cylinder weighs only 2.7 kgf. The cylinder is fitted with a main valve which should be opened fully and locked in the open position when the apparatus is being worn.

A pressure reducing valve to reduce the pressure of the oxygen contained in the cylinder and allow it to be supplied to the wearer at a fixed rate and at a pressure slightly higher than the atmospheric. The reducing valves usually operate with spring-loaded rubber diaphragms.

A regenerator purifying canister or purifier cartridge to absorb the carbon dioxide exhaled by the wearer. It is a removable sheet metal container or canister charged or filled with a specially prepared chemical which will completely absorb carbon dioxide over the prescribed wearing period. Exceptions, however, are the Siebe-Gorman Mark IV and Mark V Proto apparatus in which the absorbent is placed at the bottom of the breathing bag. As a regenerating chemical, alkali (anhydrous sodium hydroxide), lithium hydroxide, and soda lime (a mixture of sodium hydroxide and calcium hydroxide) are used. Extensive comparative tests with regenerators filled with alkali and soda-lime conducted by the Draegerwerk Liibeck showed that, although the efficiency of absorption of carbon dioxide can be considered the same for the two chemicals, alkali has a decisive advantage over soda-lime in that the dry and wet bulb temperatures of the inspired air with apparatus using alkali are significantly lower than with apparatus using soda lime Investigations by the US Bureau of Mines showed that LiOH has the greatest, capacity for CO_2 absorption as compared to NaOH or soda lime.

A breathing bag to serve as an air reservoir from and into which the wearer breathes. The bag also provides flexibility to the circulatory system. It is made of high-grade sheet rubber or rubberized fabric, gas-impervious, and usually has one compartment with a useful capacity of 4 to 6 litres. Exception, however, is the Proto apparatus in which the bag has two compartments which are in communication near the bottom of the bag. In some apparatuses, the bag is fitted with a relief or excess-pressure valve to allow escape of excess air while in some apparatus of the lung-governed type, it operates the oxygen admission lever.

A mouthpiece or facepiece assembly to permit breathing entirely through the mouth or nose. The mouthpiece assembly consists of a soft rubber mouthpiece shaped to fit smugly between the lips and teeth of the wearer, a nose clip, a T shaped connecting piece, two inhalation and exhalation breathing tubes that connect with the rest of the apparatus, and a head harness that holds the mouthpiece in place. The full mask facepiece assembly consists of a moulded silicone rubber facepiece, a connecting piece, and breathing tubes. The all-vision or wide-vision facepiece covering the whole face permits breathing through the nose and also protects the eyes without use of goggles. Impediments to a good face-to-mask seal are facial hair, eye glasses, denture problems, widely varying racial characteristics, and skin irregularities. Full facepieces restrict peripheral vision in varying degrees and preclude the use of normal eye glasses. Half-mask facepieces reduce these problems somewhat. Users should, therefore, be clean-shaven. The effectiveness of the fit of the facepiece must be checked each time the apparatus is worn. In order to have non-zero minimum inhaled CO_2 level, facepieces are sometimes provided with a nose cup, which reduces the facemask deadspace volume thereby reducing the average inhaled CO_2 level.

The breathing tubes consist of 25 mm diameter strong highly flexible, deeply corrugated tubes of ageing-resistant rubber with a fabric insert or neoprene. They are long enough to permit the wearer to turn his head without much difficulty. They are fixed so that, when worn, they pass either under the left arm of the wearer before connecting to the mouthpiece or facepiece (Draeger) or over the shoulder (Biopack 240 of Biomarine). When the tubes pass under the left arm, the shoulders are left free to carry materials.

Inhalation (inspiratory) and exhalation (expiratory) valves to compel the circulating air to travel in one direction. The valves are usually of spring-loaded mica-disc type or of neoprene rubber type and are extremely sensitive. They are located in the circulatory system differently by different manufacturers. In the Draeger apparatus, they are located inside the apparatus casing.

A pressure gauge to indicate to the wearer the available supply and duration of oxygen in the oxygen cylinder. It is built into a strong brass case and is mounted on a special flexible high-pressure tube attached to the outlet of a pressure-gauge valve which is provided on the high-pressure fitting of the reducing valve.

A bypass valve to supply oxygen direct to the wearer should the reducing valve or the lung-governed admission valve through any cause fail to act properly. The valve is usually designed as a self-closing push-button valve.

A lung-governed oxygen admission valve or regulator in the case of automatic lung-governed apparatus to supply the wearer with oxygen in the exact quantity which his exertion may demand. There are two types of lung-governed oxygen admission valves: the lever-arm type and the diaphragm type. In the first type, the valve is automatically actuated by the rise and fall of the breathing bag which is in turn controlled by the rate of respiration and oxygen consumption. In the second type, the valve is actuated by the negative pressure produced by the wearer's respiratory effort and is independent of the movement of the breathing bag.

Warning signals or alarms to give a clearly audible whistling or hooting sound in case the reducing valve fails to shut off at the proper pressure or the cylinder is approaching exhaustion.

A relief or excess-pressure valve to release any excess pressure and to avoid accumulation of nitrogen in the respiratory system in the event of the oxygen contained in the cylinder not being perfectly pure. It may be located on the facepiece or on the breathing bag and operated manually or automatically by the breathing bag itself when the latter expands.

A preflushing device incorporated in modern design of the apparatus to automatically flush out the apparatus with 7 to 8 litres of oxygen when the cylinder valve is opened to purge the nitrogen-rich ambient air initially found in the breathing circuit.

A saliva trap to accumulate saliva of the wearer. It may be provided with a release valve to permit discharge of saliva accumulations to the outside as well as release any excess pressure without any external air being drawn into the apparatus. The saliva trap is located either in the inhalation tube or at the base of the mouthpiece or facepiece.

A casing to protect the breathing bag, regenerator, reducing valve, and other vital parts against direct blows and falling material. It is made of light metal of great strength, tough moulded fibre glass, or stainless steel and is designed so that it permits ease of passage through narrow mine workings. The back of the casing (carrying frame) has openings to enable the wearer to reach the handwheel of the cylinder main valve, bypass valve, pressure gauge valve, and for pressure-gauge tube and breathing tube unions.

Carrying harness of nylon designed to wear and remove the apparatus quickly,

Coolant

28. Explain dust hood design relationships for rate of flow in a perfect hood and actual flow in an exhaust hood, hood entry loss, coefficient of entry due to vena contracta and static and velocity pressure, explaining meaning of each term used.

where

F = a dimensionless number

Hood Design Relationships. In the previous discussions, a number of relationships have been developed to describe the functioning of an exhaust hood. These relationships are summarized below.

1. Rate of flow in a perfect hood, from 2.3.4

$$Q = 4005\sqrt{VP} \times A$$

where

$$VP = SP_h$$

2. Rate of actual flow in an exhaust hood

$$(2.7.7) \quad Q = 4005\, C_e \sqrt{SP_h} \times A$$

3. Hood entry loss

$$h_e = SP_h - VP$$

4. Coefficient of entry

$$C_e = \sqrt{VP/SP_h}$$

In addition, the coefficient of entry and the hood entry loss can be related to one another. The following develops this relationship:

Relationship of C_e to h_e

$$C_e = \sqrt{VP/SP_h}$$

$$C_e = \sqrt{(h_e/F)/(h_e + VP)}$$

$$C_e = \sqrt{(h_e/F)/[h_e + (h_e/F)]}$$

$$(2.7.8) \quad C_e = \sqrt{1/(1 + F)}$$

Relationship of h_e to C_e

$$C_e = \sqrt{VP/SP_h}$$

$$C_e = \sqrt{VP/(h_e + VP)}$$

$$C_e^2 = \frac{VP}{h_e + VP}$$

$$(2.7.9) \quad h_e = \frac{(1 - C_e^2)}{C_e^2} VP$$

Some Problems. The following problems are presented to help the student to understand the relationships involved.

1. Given a 6-inch round hood with a measured SP_h = 2 inches H_2O, find the flow into the hood, the duct velocity, the duct VP, the hood entry loss, and the hood entry factor (F).

Solution

To find the flow into the hood

$$Q = vA$$

$$= 4005\sqrt{VP} \times A$$

$$= 4005\, C_e \sqrt{SP_h} \times A \quad (2.7.7)$$

For a plain round hood, C_e = 0.72

$$Q = 4005(0.72)\sqrt{0.196}$$
$$Q = 800 \text{ cfm}$$

To find duct velocity

$$Q = vA$$

$$v = \frac{Q}{A}$$

$$v = \frac{800}{0.196}$$

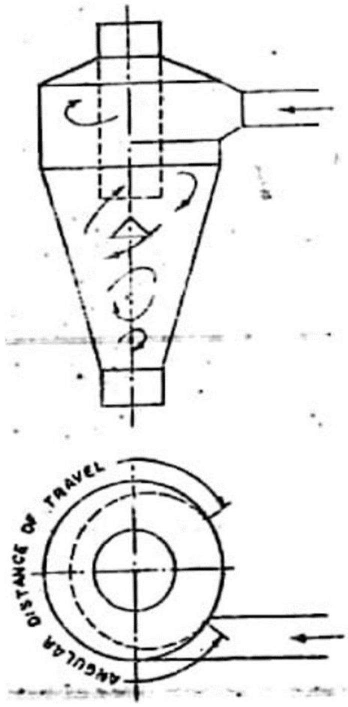
$$v = 4082 \text{ fpm}$$

To find duct VP

$$v = 4005\sqrt{VP}$$

$$VP = (v/4005)^2$$

29. Discuss cyclone separator with a suitable diagram. Derive expressions for centrifugal settling velocity and terminal velocity of gravitational settling in cyclone separator.



Here, the dust-laden air is imparted a rotating motion by virtue of its tangential entry into the cyclone.
Owing to this rotational motion, the dust particles are subjected to a centrifugal force which imparts them a radial acceleration.
This radial acceleration is much higher than the acceleration due to gravity.
The air-stream entering the cyclone travels down in an outer vortex or spiral during the course of which it deposits its dust load on the walls of the cyclone and the clean air travels up again in an inner vortex before entering the exit duct.
The centrifugal force F acting on a dust particle moving with an angular velocity ω is given by the relation $F = \frac{\pi D^3}{6}(\rho - \rho_a) r\omega^2$ **(2.24)**

where r = radius of curvature of the path of the particle, D = diameter of the particle, ρ = density of the particle and ρ_a = density of air.
For attaining the terminal centrifugal settling velocity, F must be equal to the air resistance which, for spherical particles in streamline motion, is equal to $3\pi\mu D v_c$, (see equation 2.4)

or, $\frac{\pi D^3}{6}(\rho - \rho_a) r\omega^2 = 3\pi\mu D v_c$ **a**

or, $v_c = \frac{r\omega^2(\rho - \rho_a)D^2}{18\mu}$ **(2.25)**

where v_c = centrifugal settling velocity.

Combining equations 2.25 and 2.7 we have $v_c = \frac{r\omega^2}{g} v_t = \frac{v^2}{rg} v_t$ **(2.26)**

where v_t = terminal velocity of gravitational settling and v = linear velocity of the rotating gas-stream.
Equation 2.26 shows that for any particle size, the centrifugal settling velocity can be increased by either increasing the speed of rotation of the air-stream or by decreasing the value of r.

It is for this reason that smaller cyclones are more efficient than larger ones.
The factor $\frac{v^2}{rg}$ is termed the separation factor.

30. Mention the stagewise preventive and suppressive measures against dust.
Successful dealing with dust in mines in order to keep its concentration in the mine air below the dangerous limit consists of
(a) prevention of the production of dust,
(b) prevention of the dust, already formed, getting air-borne and
(c) dilution and suppression of the air-borne dust.

*****************************QUESTION PAPER ENDS HERE*****************************