RIH / RAIH Certification 2019
IH Formulas

Gases / Vapours & Aerosols

Idea Gas Law

$PV = nRT$ *T is in degree K*

Volume and mass concentration

$$\text{ppm} = \frac{\text{mg/m}^3 \times 24.5}{\text{MW}}$$ *@ STP (25℃ & 1 atm)*

Saturation concentration

$$\text{SC (\%vol)} = \frac{\text{VP mmHg}}{\text{760 mmHg}} \times 100$$

$$\text{SC (\%vol)} = \frac{\text{VP kPa}}{\text{101.3 kPa}} \times 100$$

Dalton's Law

PP = % vol x total pressure of a mixture

Raoult's Law

PP of A = molar fraction of A x VP of A

PP of B = molar fraction of B x VP of B

Henry's Law

The amount of a gas (in moles) dissolved in a liquid is proportional to the partial pressure of the gas in the gas phase above the liquid.

Absorption of gases/vapours through respiratory system

$A\text{ (mg)} = R\%\cdot V(\text{m}^3\text{/min})\cdot C(\text{mg/m}^3)\cdot T(\text{min})$

Terminal settling velocity

$V_{ts} = \rho_p d^2 g / 18\eta$ *for particle >1µ*

V_{ts} is in cm/s

ρ_p is in g/cm^3

d is in cm

$g = 980$ cm/s^2

$\eta = 1.81\times10^{-4}$ dyne.s/cm^2

$V_{ts} = \rho_p d^2 g C_c / 18\eta$ *for particle <1µ*

$C_c = 1 + (2.67/PD_p)[6.23 + 2.01e^{-0.0821PDp}]$

Aerodynamic diameter

$d_a = d_s \sqrt{\rho}$

$d_a = d_e \sqrt{\{\rho_p / \chi\}}$ *for non-spherical particles*

Brownian diffusion

$x = \sqrt{(2Dt)}$

Air sampling

Measured mass concentration = measured mass / (flow rate x sampling time)

Detector tubes

$L = KCV$

L = length of stain

C = concentration of contaminant

V = volume of air sampled

K = a constant

Beer-Lambert Law

$I_t = I_o \exp(-KCL)$

I_t *= intensity of transmitted radiation*

I_o *= intensity of incident radiation*

C = concentration of gas
L = length of gas path
K = absorption coefficient

Absorbance = $\log (I_t / I_o) = KCL$

Flammable as detectors

$V = K \times H \times D \times C$
$V = K \times D \times C / LEL$ *for most flammable gases*
V = signal across the Whetstone Bridge
H = heat of combustion
D = coefficient of diffusion of flammable gas
C = concentration of flammable gas
K = a constant
LEL = lower explosive limit

Combined efficiency

= efficiency of 1st sampler + (100 – efficiency of 1st sampler) x efficiency of 2nd sampler

% Error of measurement = {(measured value – true value) / true value} x 100%

Cumulative error $E = \sqrt{(E_1^2 + E_2^2 + ...)}$

Time-weighted average (TWA)

$$TWA = \frac{C_1 \times T_1 + C_2 \times T_2 + ... + C_n \times T_n}{T_1 + T_2 + ... T_n}$$

Combined exposure index

$$\text{Combined exposure index} = \frac{C_1}{T_1} + \frac{C_2}{T_2} + ... + \frac{C_n}{T_n}$$

Biostatistics

Normal distribution

Mean

$$\overline{X} = \frac{\sum X_i}{n}$$

Standard deviation

$$S = \sqrt{\frac{\Sigma (Xi - \overline{X})^2}{n - 1}}$$

One-sided distribution formula for lower and upper 95% confidence limits.

For n > 30

$$UCL = \overline{X} + 1.645S / \sqrt{n}$$

$$LCL = \overline{X} - 1.645S / \sqrt{n}$$

For n < 30

$$UCL = \overline{X} + tS / \sqrt{n}$$

$$LCL = \overline{X} - tS / \sqrt{n}$$

Log-normal distribution

Geometric mean

$$\overline{X}g = \sqrt[n]{X_1 \times X_{2.} \cdots X_n}$$

$$= \text{anti} \ \log \left(\frac{\sum \log \ Xi}{n} \right)$$

Geometric standard deviation

$$Sg = \text{anti} \ \log \sqrt{\frac{n \sum \log^2 Xi - (\sum \log Xi)^2}{n(n-1)}}$$

For n > 30

$$\log UCL = \log \overline{X_g} + \left[\frac{1.645 \log S_g}{\sqrt{n}} \right]$$

$$\log LCL = \log \overline{X_g} - \left[\frac{1.645 \log S_g}{\sqrt{n}} \right]$$

For n < 30

$log(UCL) = lo\bar{g}\, x_G + \frac{(t*log\, S_G)}{\sqrt{n}}$

$log(LCL) = lo\bar{g}\, x_G - \frac{(t*log\, S_G)}{\sqrt{n}}$

Probability

For events that are not mutually exclusive i.e. they can occur alone or at the same time,

P (X or Y) = P(X) + P(Y) – P(X+Y)

For events that are mutually exclusive i.e. they can occur alone but cannot occur at the same time,

P (A or B) = P(A) + P(B)

Epidemiology

Prevalence rate per 1,000 = $\frac{\text{No. of existing events}}{\text{Population at risk}} \times 1{,}000$

Incident rate per 1,000 = $\frac{\text{No. of new events during a time period}}{\text{Population at risk}} \times 1{,}000$

Infection rate = number infected / population at risk of being infected

Attack rate = cases of disease / population at risk of being infected

Fatality rate = fatal cases / all cases of disease

Pathogenicity = cases of disease / total number infected

Virulence = cases of severe and fatal disease / all cases of disease

Odds Ratio or cross-product ratio estimates the chance of a particular event occurring in one population in relation to its rate of occurrence in another population.

Sensitivity is the proportion of the results classified as true positives that actually are positives

Specificity is the proportion of the results classified as true negatives that actually are negatives

Local Exhaust Ventilation

Q = V x A

$A = \pi (D/2)^2$

$R_e = \rho \times D \times V / \mu$

TP = SP + VP

V fpm= 4,005 √ {VP"w.g./ d}

V m/s = 4.043 √ {VP (mm w.g.) / d}

V m/s = 1.29 √ {VP (Pa) / d}

Density Correction Factor

d = d (temperature) x d (elevation) x d (static pressure) x d (moisture)

$$= \frac{T_{std}}{T_2} \times \frac{BP_2}{BP_{std}} \times \frac{(BP_{std} +/- SP)}{BP_{std}} \times \frac{(1 + w)}{(1 + 1.607w)}$$

Mass balance

$\rho_1 V_1 A_1 = \rho_2 V_2 A_2$

$\rho_1 Q_1 = \rho_2 Q_2$

Energy balance

TP_1 + losses = TP_2

$(SP_1 + VP_1)$ + Losses = $(SP_2 + VP_2)$

Momentum balance

$m_{in} \times V_{in} = m_{out} \times V_{out}$

$\rho_{in} A_{in} V_{in}^2 = \rho_{out} A_{out} V_{out}^2$

Dalla Valle Equation

Free hanging plain opening, tapered hood and bell-shaped hood

$Q = V (10 X^2 + A)$ *without flanging*

$Q = 0.75 V (10 X^2 + A)$ *with flanging*

Hood resting on workbench

$Q = V (5X^2 + A)$ *without flanging*

$Q = 0.75\ V(5X^2 + A)$ *with flanging*

Free hanging slot hood

$Q = 3.7\ V\ X\ L$ *without flanging*

$Q = 2.6\ V\ X\ L$ *with flanging*

Hood static presure

$SP_h = VP + h_e$

$= VP + f \times VP$

$= VP (1 + f)$

$C_e = \sqrt{\{1 / (1 + f)\}}$

Compound hood

Indirect Take-off

$SP_h = (VP_s + 1.78\ VP_s) + (VP_d + f \times VP_d)$

Direct Take-off

$SP_h = (VP_s$ or VP_d *whichever is higher* $+ 1.78\ VP_s) + (f \times VP_d)$

Equivalent Diameter

$$D_{eq} = 1.3 \frac{(L \times W)^{0.625}}{(L + W)^{0.25}}$$

$$D_{eq} = \frac{4\ A}{P}$$

Fanning or Darcy Equation

$$F = f \frac{V^2}{2g} \times \frac{L}{D}$$

Loeffler Equation

$$F = \frac{a\ V^b}{Q^c} \times L \times VP$$

$= k \times L \times VP$

Elbow (SP) loss = $k \times VP$

Branch entry loss = $k \times VP$

Duct contraction

$SP_2 = SP_1 - (1 - L)\ (VP_2 - VP_1)$

Duct expansion

$SP_2 = SP_1 + R\ (VP_1 - VP_2)$

$FTP = SP_{outlet} - SP_{inlet} + VP_{outlet} - VP_{inlet}$

$= SP_{outlet} + |SP_{inlet}| + VP_{outlet} - VP_{inlet}$

$= SP_{outlet} + |SP_{inlet}|$ if $VP_{outlet} = VP_{inlet}$

$FSP = SP_{outlet} - SP_{inlet} - VP_{inlet}$

$= SP_{outlet} - |SP_{inlet}| - VP_{inlet}$

AkW = Q (cms) x FTP (mm w.g.) / 102.2

AkW = Q (cms) x FTP (Pa) / 1,000

BkW = AkW / ME

SkW = k_{dl} x BkW

RHP > 1.33 x SkW

AHP = Q (cfm) x FTP (''w.g.) / 6356

BHP = AHP / ME

SHP = K_{dl} x BHP

RHP = 1.33 x SHP

Fan laws at STP

Q (cfm) varies directly as fan speed

TP & SP vary as the square of fan speed
HP or kW varies as the cube of fan speed

Fan law at non-STP

$Q_{non\text{-}STP} = Q_{STP}$

$FSP_{non\text{-}STP} = FSP_{STP} \times d$

kW or $HP_{non\text{-}STP} = HP_{STP} \times d$

$Q_{corrected} = Q_{design} \times \sqrt{(SP_{higher} / SP_{lower})}$

$VP_r = (Q_1/Q_3)\, VP_1 + (Q_2/Q_3)\, VP_2$

Pressure devices or aerodynamic velocity meters

$V = 4005 \sqrt{(VP / d)}$

$$V_c = V_r \times \frac{1}{\sqrt{d}}$$

Thermal anemometers or thermodynamic velocity meters

$$V_c = V_r \times \frac{1}{d}$$

Dilution Ventilation

Build-up stage

$$\log \frac{G - QC_2}{G - QC_1} = \frac{-Q}{2.303\,k}(t_2 - t_1)$$

$$t_2 - t_1 = -2.303\,k \frac{V}{Q} \log \frac{G - QC_2}{G - QC_1}$$

$$C_2\,\text{ppm} = \frac{G}{Q}\left(1 - e^{(-Q t / kV)}\right) \times 1{,}000{,}000$$

Steady state

$Q = k G / C$

$$Q\,(\text{lpm}) = \frac{24.1 \times E\,(\text{gm per min}) \times k}{MW \times C\,(\text{ppm}) \times 10^{-6} \times d}$$

$$Q\,(m^3/h) = \frac{24.1 \times SG \times E\,(\text{litre per hr}) \times k}{MW \times C\,(\text{ppm}) \times 10^{-6} \times d}$$

Purging

$$t_2 - t_1 = \frac{2.303\,kV}{Q} \log \frac{C_1}{C_2}$$

$C_2 = C_1\, e^{-Q(t_2 - t_1)/(kV)}$

Sensible heat

$$Q\,(\text{cmm}) = \frac{H_s\,(\text{watt})}{20\,(T_i - T_0)\,^\circ\text{C}}$$

$$Q\,(\text{cfm}) = \frac{H_s\,(\text{BTU / hr})}{1.08\,(T_i - T_0)\,^\circ\text{F}}$$

Latent heat

$$Q\,(\text{cms}) = \frac{H_l\,(\text{watt})}{45{,}000 \times \Delta h\,(\text{kg water / kg dry air})}$$

$$Q\,(\text{cfm}) = \frac{H_l\,(\text{BTU / Hr})}{}$$

0.67 x Δh (grains / lb)

Indoor Air Quality

Outdoor air supply (Q)

$$Q\ m^3/s = \frac{n \text{ x } G}{C_e - C_o}$$

n is the number of occupants

G is the rate of generation of carbon dioxide per person (0.011 ft^3/min or $5.3\text{x}10^{-6}$ m^3/s)

C_e is the equilibrium concentration of carbon dioxide at steady state

C_o is the outdoor carbon dioxide concentration (400 ppm)

Noise

$$I = \frac{W}{4\pi r^2} \qquad I = \frac{P^2}{\rho C}$$

$$Lw = 10 \log \frac{W}{W_O} \qquad W_0 = 10^{-12} \text{ w (1 picoWatt)}$$

$$Lp = 10 \log \frac{P^2}{{P_O}^2} \qquad P_0 = 20\ \mu Pa$$

$$\boxed{L_T = 10 \log[\sum 10^{\frac{L_i}{10}}]}$$

Metric unit *(R in m^2 Sabins; r in m)*

$$L_P = L_W + 10\,log[\frac{Q}{4\pi r^2} + \frac{4}{R}]$$

US unit *(R in ft^2 Sabins; r in ft)*

$$L_P = L_W + 10 \log[\frac{Q}{4\pi r^2} + \frac{4}{R}] + 10.5$$

$$R = \frac{\alpha S}{1 - \alpha}$$

$L_{p2} = L_{p1} - 20 \log (r_2 / r_1)$

Permissible exposure level

SPL = 85 - 10 log { T / 8 }

Permissible exposure time

$T = 8 / \{ 2^{(SPL - 85)/3} \}$

Noise dose D = t / T

$$D = \frac{t_1}{T_1} + \frac{t_2}{T_2} + \ldots + \frac{t_n}{T_n} = \sum_{i=1}^{n} \frac{t_i}{T_i}$$

Equivalent sound level (L_{eq})

$$\boxed{L_{eq} = 10 \log[\sum_{i=1}^{n} \frac{t_i}{T} \times 10^{\frac{L_i}{10}}]}$$

$$\boxed{L_{eq} = 85 + 10 \log \frac{D\%}{12.5 \times T}}$$

$L_{eq,\,8\,hr} = L_{eq,\,T\,hr} + 10 \log (T / 8)$

Mass Law

Metric unit

TL = 20 log (f × w) - 48

= 20 log f + 20 log w - 48

US unit

TL = 20 log (f × w) - 33

= 20 log f + 20 log w - 33

Transmission Loss (TL)

TL = 10 log (1/ t)

$= 10 \log (I_i / I_t)$

$t = I_t / I_i$

Vibration

Transmissibility (T)

$$T = \sqrt{\frac{1 + (f / f_n)^2 \delta^2}{\{1 - (f / f_n)^2\}^2 + 4 (f / f_n)^2 \delta^2}}$$

f is the shaking force frequency, c/s

f_n is the natural frequency of the system, c/s

δ is the damping ratio or factor – an indication of the ability of the isolator to dissipate energy

Isolation (I)

$I = (1 - T) \times 100\%$

Natural frequency (f_n)

$f_n = 4.98 / \sqrt{d}$ *d is the static deflection in cm*

Spring constant (K)

$K = W / d$

W is the weight on each mounting point of the machine, kg

K is the spring constant or stiffness of the isolator, kg/cm

Heat (Thermal Stressor)

Heat balance equation

$S = M \pm R \pm C - E$

Metric units

(Temp °C, V m/s, Pa = mm Hg)

$E_{max} = 14\, V^{0.6}(42 - P_a)$ *kcal/hr*

$C = 7.0\, V^{0.6}(T_a - 35)$ *kcal/hr*

$R = 6.6\, (T_w - 35)$ *kcal/hr*

$T_w = T_g + 1.8V^{0.5}(T_g - T_a)$ *°C*

US units (mixed)

(Temp °F, V ft/min, Pa mmHg)

$E_{max} = 2.4\, V^{0.6}(42 - P_a)$ *Btu/hr*

$C = 0.65\, V^{0.6}(T_a - 95)$ *Btu/hr*

$R = 15\, (T_w - 95)$ *Btu/hr*

$T_w = T_g + 0.13V^{0.5}(T_g - T_a)$ *°F*

WBGT Indoor (*without exposure to sun)*

$WBGT = 0.7T_{nwb} + 0.3T_g$

WBGT Outdoor (*with exposure to sun*)

$WBGT = 0.7T_{nwb} + 0.2T_g + 0.1T_a$

Heat Stress Index (HSI)

$$HSI = \frac{E_{req}}{E_{max}} \times 100\ \%$$

Allowable exposure time (AET)

$$AET\ (\text{minutes}) = \frac{2{,}440}{E_{req} - E_{max}}$$

Ergonomics

Body lever systems

$L \times l = F \times f$

NIOSH Lifting Equation

Recommended weight load (RWL)

$RWL = 23\ \text{kg} \times HM \times VM \times DM \times FM \times CM \times AM$

$HM = 25 / h$ cm *horizontal multiplier*

$VM = 1 - 0.003\ [(75 - v\ \text{cm})]$ *vertical multiplier*

$DM = 0.82 + 4.5 / d$ cm *distance multiplier*

FM: from table *frequency multiplier*

CM: 1.0(good), 0.95(fair), 0.9(poor) *coupling multiplier*

AM = 1 – 0.0032 x A *asymmetric multiplier*

ISO uses 25 kg is the max acceptable weight

Lifting Index (LI)

LI = Load / RWL

Muscle endurance time (T)

Static muscular effort

$$\text{Log } T = 1.0 - \frac{1.96 \times \%MVC}{100}$$

T = endurance time in minutes

MVC = max. voluntary contraction

Dynamic muscular effort

$$\text{Log } T = 4.0 - \frac{4.0 \times \%MAC}{100}$$

T = Endurance time in minutes

MAC = max. aerobic capacity i.e. max. oxygen a person can consume

Recovery time (RT)

Static muscular effort

$$RT = 18 \left(\frac{t}{T}\right)^{1.4} \cdot \left\{\frac{\%MVC}{100\%} - 0.15\right\}^{0.5} \cdot t$$

t = contraction or work time

T = endurance time in minutes

MVC = max. voluntary contraction

Dynamic muscular effort

$$RT = \frac{(\%MAC/100) - 0.33}{0.23} \times t$$

MAC = max. aerobic capacity

t = work time

Workplace Lighting

Intensity (I) = Luminous flux (F) / Solid angle (ω)

F (lumen) = I (candela) x ω (steradian)

Solid angle (ω) = S / r^2

Illumination level (E) = F / A

Illumination Level (E) = $\frac{\text{Intensity (I)}}{d^2}$

E (lux) = I (cd) / d^2 (ft)

Contrast = $\frac{\text{Luminance of Object} - \text{Background Luminance}}{\text{Background Luminance}}$

Brightness Ratio = $\frac{\text{Luminance of Object}}{\text{Background Luminance}}$

Reflectance = $\frac{\text{luminance (foot-lamberts)}}{\text{illuminance (foot-candles)}}$

Lighting design formula

E (lux) x A (m^2) = N x L (lumen / lamp) x CU x MF

CU is the utilization factor

MF is the maintenance factor

Radiation

Radioactive decay

$N = N_o e^{-\lambda t}$

λ is the decay constant)

$\lambda = 0.693 / t_{1/2}$

$t_{1/2}$ is the ½ life

Dose Equivalent (rem or Sv) = Absorbed Dose (rad or Gy) x QF

Internal dose rate for α and β emitters

$$D \text{ (rad/day)} = \frac{A\ (\mu Ci) \times 2.2 \times 10^{6}\ (dpm/\mu Ci) \times 1440\ (min/day) \times E\ (MeV) \times 1.6 \times 10^{-6}\ (erg/MeV)}{W\ (gm) \times 100\ (ergs/gm/rad)}$$

Effective, physical and biological half-life

$1 / T_{½\ eff} = (1 / T_{½\ phy}) + (1 / T_{½\ bio})$

Total Dose = $1.44 \times D_0 \times T_{½\ eff}$

D_0 is the initial dose rate/day

Inverse square law

$D_1 / D_2 = r_2^2 / r_1^2$

Shielding formula for X & Y Rays

$I = I_0 e^{-\mu x}$

$I = I_0 e^{-(0.693 / HVL) X}$

I = intensity or dose rate of a beam that penetrates a shield

I_0 = original intensity or dose rate

μ = linear attenuation coefficient = 0.693 / HVL

X = shield thickness

Beta radiation dose rate (D)

$$D\ (mrem/h) = \frac{338{,}000 \times A\ (mCi)}{r^2\ (cm)^2}$$

A is the source activity in mCi

r is the distance in cm from the source

Gamma radiation dose rate (D)

$$D = \frac{\Gamma A}{r^2}$$

D is the dose rate in R/h

Γ *is the specific gamma ray constant in R/mCi-h at 1 cm*

A is the source activity in mCi

r is the distance in cm from the source

$$D = \frac{5{,}000 \times A \times E \times f}{r^2}$$

D is the dose rate in mR/h

A is the source activity in mCi

E is the gamma photon energy in MeV

f is the fraction of disintegrations yielding the photon energy of E MeV

r is the distance in cm from the source