Equation Sheets

The following pages of equations and conversions will be available on the computer on which the exams are given for use during the examinations. The following plates from the 31st edition of the ACGIH® Industrial Ventilation Manual will also be available on the computer for use during the examinations: Table 6-2, Figure 9-a.

August 1, 2024

USEFUL EQUATIONS FOR THE BGC CIH EXAMINATION

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VENTILATION

$Q = VA$ $\quad V_1A_1 = V_2A_2$ $\quad TP = VP + SP$ $\quad SP_1 + VP_1 = SP_2 + VP_2 + \sum losses_{1-2}$ $\quad SP_h = -[(F_h + 1)VP_d]$

$V = 4005\sqrt{\frac{VP}{df}}$ $\quad [V = 1.29\sqrt{\frac{VP}{df}}]$ $\quad VP = \left(\frac{V}{4005}\right)^2 df$ $\quad [VP = \left(\frac{V}{1.29}\right)^2 df]$ $\quad hood\ entry\ loss = F_h x VP_d$

$C_e = \sqrt{\frac{VP}{|SP_h|}}$ $\quad VP_r = \left(\frac{Q_1}{Q_3}\right)VP_1 + \left(\frac{Q_2}{Q_3}\right)VP_2$ $\quad Q = 4005(Ce)\sqrt{\frac{|SP_h|}{df}}(A)$ $\quad [Q = 1.29(Ce)\sqrt{\frac{|SP_h|}{df}}(A)]$

$Q = 4005C_eA\sqrt{|SP_h|}$ $\quad Q_{corr} = Q_{lower}\sqrt{\frac{SP_{gov}}{SP_{lower}}}$ $\quad Q' = \frac{Q}{m_i}$ $\quad t_2 - t_1 = -\frac{V_r}{Q'}ln\left(\frac{C_{g2}}{C_{g1}}\right)$

$ln\frac{(G-Q'Cg_2)}{(G-Q'Cg_1)} = -\frac{Q'(t_2-t_1)}{V_r}$ $\quad Q = \frac{(403)(SG)(ER)(S_f)(m_i)(10^6)}{(MW)(C_g)}$ $\quad [Q = \frac{(24)(SG)(ER)(S_f)(m_i)(10^6)}{(MW)(Cg)}]$

$N_{changes} = \frac{60Q'}{V_r}$ $\quad C_{g2} = G\frac{\left(1-e^{-\left(\frac{Q'\Delta t}{Vr}\right)}\right)}{Q'}$ $\quad C_{g2} = C_{g1}e^{-\left(\frac{Q'\Delta t}{V_r}\right)}$ $\quad C = \left(\frac{G}{Q'}10^6\right) + C_{supply}$ $\quad Q_2 = Q_1\left(\frac{d_2}{d_1}\right)^3\left(\frac{RPM_2}{RPM_1}\right)$

$P_2 = P_1\left(\frac{d_2}{d_1}\right)^2\left(\frac{RPM_2}{RPM_1}\right)^2$ $\quad PWR_2 = PWR_1\left(\frac{d_2}{d_1}\right)^5\left(\frac{RPM_2}{RPM_1}\right)^3$ $\quad FSP = SP_{out} - SP_{in} - VP_{in}$ $\quad FTP = TP_{out} - TP_{in}$

NOISE

$SPL\ or\ L_p = 20\ log\left(\frac{P}{P_0}\right)$ $\quad L_I = 10\ log\left(\frac{I}{I_0}\right)$ $\quad SPL_2 = SPL_1 + 20\ log\left(\frac{d_1}{d_2}\right)$ $\quad L_w = 10\ log\left(\frac{W}{W_0}\right)$

$W_0 = 10^{-12} watts$ $\quad L_{eq} = 10\log\left(\frac{1}{T}\sum_{i=1}^{N}\left(10^{\frac{L_i}{10}}t_i\right)\right)$ $\quad LPT = 10\ log\left(\sum_{i=1}^{N}10^{\frac{L_{P_i}}{10}}\right)$ $\quad TL = 10\log\left(\frac{1}{\tau}\right)$

$L_p = L_w - 20\log r - 0.5 + DI + CF$ $\quad [L_p = L_w - 20\log r - 11 + DI + CF]$ $\quad DI = 10\log\ Q$

$\%D = 100\left(\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C_i}{T_i}\right)$ $\quad T_p = \frac{T_c}{2(L_{AS}-L_c/ER)}$ $\quad TWA_{eq} = 10\ log\left(\frac{\%D}{100}\right) + 85dBA$

$TWA = 16.61\ log\left(\frac{\%D}{100}\right) + 90dBA$ $\quad f = \frac{(N)(RPM)}{60}$ $\quad f = \frac{c}{\lambda}$ $\quad f_2 = 2f_1$ $\quad f_c = \sqrt{f_1f_2}$ $\quad f_2 = \sqrt[3]{2}f_1$

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GENERAL SCIENCES, STATISTICS, STANDARDS

$$ppm = \frac{V_{contam}}{V_{air}} x10^6 \qquad ppm = \frac{P_v}{P_{atm}} \; x10^6 \qquad ppm = \frac{mg/m^3 \times 24.45}{m.w.} \qquad \frac{P_1V_1}{nRT_1} = \frac{P_2V_2}{nRT_2} \qquad V_{TS} = \frac{g\, d_p^2(p_p - p_a)}{18\eta}$$

$$Re = \frac{p\, dv}{\eta} \qquad log\,\frac{I_0}{I} = abc \qquad pH = -log_{10}[H^+\,] \qquad K_a = \frac{[H^+]\text{x}[A^-]}{[HA]} \qquad K_b = \frac{[BH^+]\times[OH^-]}{B}$$

$$P_{total} = X_1P_1 + X_2P_2 + \ldots + X_iP_i \qquad vapor/hazard\ ratio = \frac{sat.concentration}{exopsure\ guideline} \qquad TLV_{mix} = \frac{C_1}{TLV_1} + \frac{C_2}{TLV_2} + \ldots + \frac{C_n}{TLV_n}$$

$$TLV_{mix} = \frac{1}{\frac{F_1}{TLV_1} + \frac{F_2}{TLV_2} + \cdots + \frac{F_n}{TLV_n}} \qquad RF = \frac{8}{h} \times \frac{24-h}{16} \qquad RF = \frac{40}{h_w} \times \frac{168-h_w}{128} \qquad C_{asb} = \frac{(C_s - C_b)A_c}{1000A_f v_s}$$

$$C_{asb} = \frac{EA_C}{1000V_s} \qquad E_{fiber\ density} = \frac{\frac{f}{N_f} - \frac{B}{N_b}}{A_f} \qquad d = \frac{0.61\lambda}{\eta\sin\alpha} \qquad SD = \sqrt{\frac{\sum(\bar{x} - x_i)^2}{n-1}} \qquad GM = {}^n\sqrt{(x_1)(x_2)\ldots(x_n)}$$

$$GM = 10\,\frac{\sum(log_x)}{n} \qquad GSD = \frac{84.13\%\ tile\ value}{50\%\ tile\ value} \qquad GSD = \frac{50\%\ tile\ value}{15.87\%\ tile\ value} \qquad SAE = 1.645CV_{total}$$

$$CV = \frac{SD}{\bar{x}} \qquad E_c = \sqrt{E_1^2 + E_2^2 + \cdots + E_n^2} \qquad t = \frac{\bar{x}_1 - \bar{x}_2}{SDpooled\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \qquad SD_{pooled} = \sqrt{\frac{(n_1 - 1)SD_1{}^2 + (n_2 - 1)SD_2{}^2}{n_1 + n_2 - 2}}$$

$$LCL = \frac{C_A}{PEL} - \frac{SAE\sqrt{T_1^2C_1^2 + T_2^2C_2^2 + T_n^2C_n^2}}{PEL(T_1 + T_2 + \cdots + T_n)} \qquad RWL = LCxHMxVMxDMxAMxFMxCM \qquad LI = \frac{L}{RWL}$$

$$90\%Conf\ Interval = \overline{X} \pm 1.645\frac{SD}{\sqrt{n}} \qquad One\text{-}sided\ 95\%UCL\ on\ mean = \overline{X} + 1.645\frac{SD}{\sqrt{n}}$$

HEAT STRESS

$$WBGT = 0.7t_{nwb} + 0.2t_g + 0.1t_{db} \qquad WBGT = 0.7t_{nwb} + 0.3t_g \qquad \Delta S = (M - W) \pm C \pm R - E$$

USEFUL EQUATIONS FOR THE BGC CIH EXAMINATION

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RADIATION

$I_2 = I_1 \left(\frac{d_1}{d_2}\right)^2$ $Rem\ (RAD)(QF)$ $D = \frac{\Gamma A}{d^2}$ $A = A_i(0.5)^{\frac{t}{T_{1/2}}}$ $A_i = \frac{0.693}{T_{1/2}} N_i$ $A = A_i e^{\frac{-.693t}{T_{1/2}}}$

$I = \left(\frac{1}{2}\right)^A I_0$ $I = \left(\frac{1}{10}\right)^B I_0$ $I_2 = \frac{I_1}{2^{\frac{X}{HVL}}}$ $I_2 = \frac{I_2}{10^{\frac{X}{TVL}}}$ $x = 3.32log\left(\frac{I_1}{I_2}\right)(HVL)$ $I = I_0 Be^{-ux}$

$\frac{1}{T_{1/2eff}} = \frac{1}{T_{1/2rad}} + \frac{1}{T_{1/2bio}}$ $T_{1/2eff} = \frac{\left(T_{1/2rad}\right)\left(T_{1/2bio}\right)}{T_{1/2rad} + T_{1/2bio}}$ $S = \frac{E^2}{3770}$ $S = 37.7H^2$ $S = \frac{4P}{A}$

$r = \left(\frac{PG}{4\pi EL}\right)^{\frac{1}{2}}$ $r_{NHZ} = \frac{1}{\emptyset}\left(\frac{4\Phi}{\pi EL} - a^2\right)^{\frac{1}{2}}$ $r_{NHZ} = \frac{f_0}{b_0}\left(\frac{4\phi}{\pi EL}\right)^{\frac{1}{2}}$ $r_{NHZ} = \left(\frac{\rho\Phi cos\theta}{\pi EL}\right)^{\frac{1}{2}}$

$D_s = \frac{1}{\emptyset}\left(\frac{4\Phi}{\pi TL} - a^2\right)^{\frac{1}{2}}$ $spatial\ ave = \left(\frac{\Sigma_{i=1}^{N} FS_i^{\ 2}}{N}\right)^{\frac{1}{2}}$ t= $\frac{0.003J/cm^2}{E_{eff}}$ t= $\frac{EL}{ML}$ x $0.1h$ O.D.= $\log\frac{I_0}{I}$

$D_L = \sqrt{a^2 + \emptyset^2 r^2}$ $G = 10^{g/10}$

CONSTANTS AND CONVERSIONS

°F=9/5(°C)+32 °R=°F+460 K=°C+273.15 molar volume at 25°C, 1 atm=24.45L 1ft^3 =28.32L=7.481 U.S. gal

1L=1.0566 qt 1 inch = 2.54 cm 12 inch = 1 ft 1 lb=453.6 grams 1 gram=15.43 grains 1 qt = 2 pt 4 qt = 1 gal

1 atm=14.7 psi=760 mm Hg=29.92 in Hg=33.93 ft water=1013.25 mbar=101,325 pascals

1 Curie=$3.7x10^{10}$ disint/sec (Becquerel)= $2.2x10^{12}$ dpm 1 Gray=100 Rad 1 Sievert=100 Rem

1 Tesla=10,000 Gauss 1 BTU=1054.8 joules=0.293 watt hr 1 cal=4.184 joules

speed of sound in air at 68°F (20°C)=1130 fps (344 m/s) speed of light=$3x10^8$ m/s

Planck's constant=$6.626x10^{-27}$ erg sec Avogadro's number=$6.024x10^{23}$

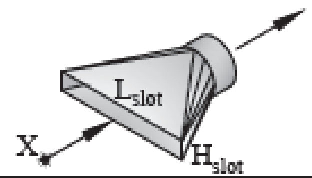
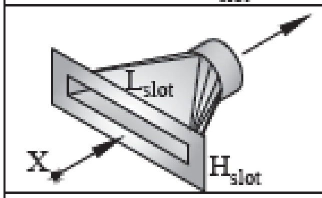
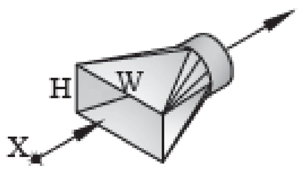
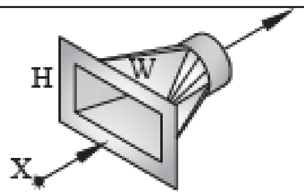
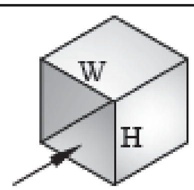
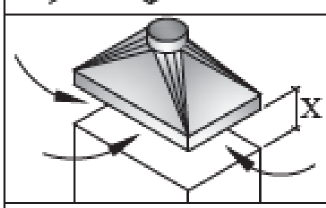
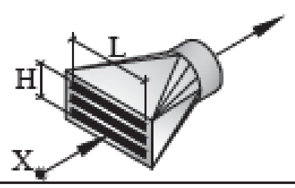
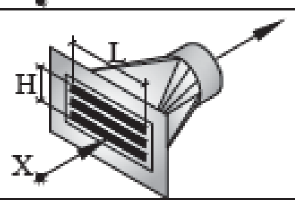
gas constant, R=8.314 J/mole K=0.082 L atm/mole K density of air=1.29 g/L at atm, 0°C

g=981 cm/sec^2 =32 ft/sec^2 A_c =385 mm^2 for 25 mm filter Af=0.00785 mm^2 $A = \pi r^2$

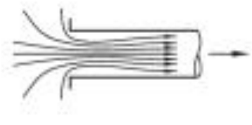
The density (ρ) of air at standard (normal) conditions is 0.075 lbm/ft^3 (1.25 kg/m^3) at sea level, 407" wg (101,325 Pa), 70°F (21°C) dry bulb temperature and zero moisture

TABLE 6-2. Summary of Hood Airflow Equations

Table 6-2. Summary of hood airflow equations

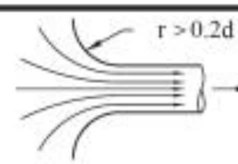
HOOD TYPE	DESCRIPTION	ASPECT RATIO, H/L	AIRFLOW
	Slot	0.2 or less	$Q = 3.7LV_xX$
	Flanged Slot $W_f \geq H_s$	0.2 or less	$Q = 2.6LV_xX$
	Plain Opening	0.2 or greater and round	$Q = V_X(10X^2 + A_f)$ $A_f = WH$
	Flanged Opening $W_f \geq \sqrt{A_f}$	0.2 or greater and round	$Q = 0.75V_X(10X^2 + A_f)$ $A_f = WH$
	Booth	To suit work	$Q = VA = V_f\ WH$
	Canopy (recommended for hot processes)	To suit work	$Q = 1.4\ PVX$ P = Perimeter of work or tank X = Height above work
	Plain multiple slot opening (2) or more slots	0.2 or greater	$Q = V_x\ (10X^2 + A_s)$ $A_s = HL$
	Flanged multiple slot opening (2) or more slots	0.2 or greater	$Q = 0.75V_x\ (10X^2 + A_s)$ $A_s = HL$

$F_h = 0.93$
$C_e = 0.72$
PLAIN DUCT END



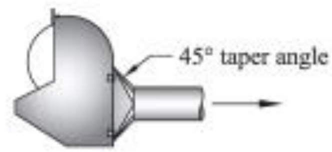
Conical	Rectangular
$F_h = 0.6$	$F_h = 0.6$
$C_e = 0.79$	$C_e = 0.79$

FLANGED DUCT END
(F_h value rounded)



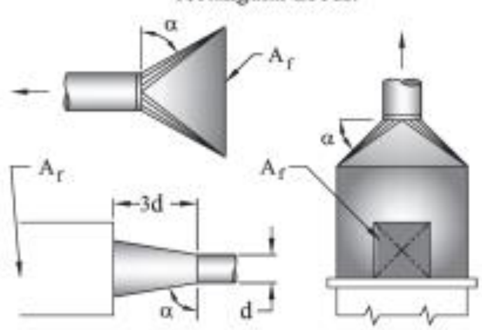
$F_h = 0.04$
$C_e = 0.98$
BELLMOUTH ENTRY

$F_h = F_s = 1.78$
$C_e = 0.60$
SHARP-EDGED ORIFICE



$F_h = 0.4$ (tapered take-off)
$C_e = 0.85$
$F_h = 0.65$ (no taper)
$C_e = 0.78$
STANDARD GRINDER HOOD

TAPERED HOODS
Flanged or unflanged; conical, square or rectangular. α is the major angle on rectangular hoods.

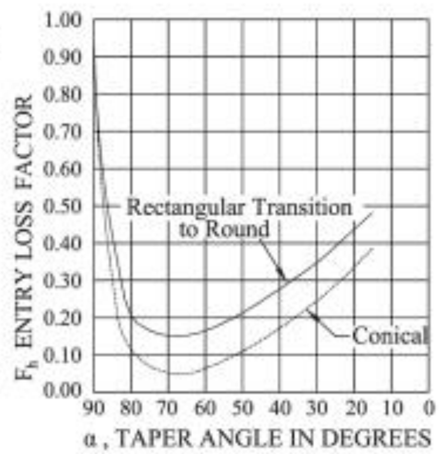


Face area (A_f) at least 2 times the duct area.

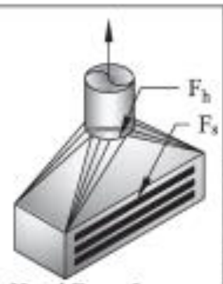
F_h Hood Loss Factor

α	Conical	Rectangular
90	0.93	0.93
80	0.11	0.19
70	0.06	0.13
60	0.08	0.16
50	0.12	0.21
45	0.15	0.25
40	0.18	0.28
30	0.25	0.35
20	0.34	0.43
10	0.44	0.52
0	0.56	0.64

Note: 0° values represent round ducts butted into back of booth or hood without a rectangular to round transition.



COMPOUND HOODS
A compound hood, such as the slot/plenum shown to the right, would have 2 losses, one through the slot and the other through the transition into the duct.
The slot entry loss factor, F_s, would have a value typically in the range of 1.00 to 1.78 (see Chapters 6 and 13).
The duct entry loss factor is given by the above data for tapered hoods.



Hood Entry Loss = $F_sVP_s + F_hVP_d$
(See Chapter 6)

MISCELLANEOUS VALUES

HOOD	ENTRY LOSS FACTOR F_h	HOOD FLOW COEFFICIENT C_e
Abrasive blast chamber	1.00	0.50
Abrasive blast elevator	2.30	0.31
Abrasive separator	2.30	0.31
Elevators (enclosures)	1.00	0.50
Flanged pipe plus adjacent elbow	0.80	0.56
Plain pipe plus adjacent elbow	1.60	0.38

ACGIH®

TITLE	FIGURE
HOOD ENTRY LOSS FACTORS	9-a
	DATE 1-19

CHECK CODES, REGULATIONS, AND LAWS (LOCAL, STATE, AND NATIONAL) TO ENSURE THAT DESIGN IS COMPLIANT.

Figure 9-a. Hood entry loss factors