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 29th Edition of the ACGIH® "Ventilation Manual" will also be available on the computer for use during the examinations: Figures 9-a, 9-e, 9-f, and Table 6-3.

USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

This list of equations is offered as assistance in taking the ABIH examinations. No assurance is given that this list is complete or that the use of this list will assure the successful completion of any examination. The variables used are the same as found in the reference source for the equation. No attempt has been made to standardize variables. [Metric (SI) equations are in brackets]

VENTILATION

$$Q = VA \quad V_1A_1 = V_2A_2 \quad TP = VP + SP \quad SP_1 + VP_1 = SP_2 + VP_2 + \sum losses_{1-2} \quad SP_h = -\left((F_h + 1)\mathrm{VP}_d\right)$$

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

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

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

$$ln\frac{(G - Q'C_{g2})}{(G - Q'C_{g1})} = -\frac{Q'(t_2 - t_1)}{V_r} \quad Q = \frac{(403)(SG)(ER)(m_i)(10^6)}{(MW)(C_g)} \quad \left[Q = \frac{(24)(SG)(ER)(m_i)(10^6)}{(MW)(C_g)}\right]$$

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

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

NOISE

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

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

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

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

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

USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

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[Metric (SI) equations are in brackets]

GENERAL SCIENCES, STATISTICS, STANDARDS

$$ppm = \frac{V_{contam}}{V_{air}} x10^6 \quad ppm = \frac{P_v}{P_{atm}} x10^6 \quad ppm = \frac{mg/m^3 x24.45}{m.w.} \quad \frac{P_1V_1}{nRT_1} = \frac{P_2V_2}{nRT_2} \quad V_{TS} = \frac{gd_p{}^2(\rho_p - \rho_a)}{18_\eta}$$

$$R_e = \frac{\rho dv}{\eta} \quad log\frac{I_o}{I} = abc \quad pH = -log_{10}[H^+] \quad K_a = \frac{[H^+]x[A^-]}{[HA]} \quad K_b = \frac{[BH^+]x[OH^-]}{[B]}$$

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

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

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

$$GM = 10^{\frac{\sum(\log x)}{n}} \quad GSD = \frac{84.13\%\ tile\ value}{50\%\ tile\ value} \quad GSD = \frac{50\%\ tile\ value}{15.87\%\ tile\ value} \quad SAE = 1.645CV_{total} \quad CV = \frac{SD}{\overline{X}}$$

$$E_c = \sqrt{E_1^2 + E_2^2 + \ldots + E_n^2} \quad t = \frac{\overline{x}_1 - \overline{x}_2}{SD_{pooled}\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad SD_{pooled} = \sqrt{\frac{(n_1 - 1)SD_1{}^2 + (n_2 - 1)SD_2{}^2}{n_1 + n_2 - 2}}$$

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

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

HEAT STRESS

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

USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

This list of equations is offered as assistance in taking the ABIH examinations. No assurance is given that this list is complete or that the use of this list will assure the successful completion of any examination. The variables used are the same as found in the reference source for the equation. No attempt has been made to standardize variables.

RADIATION

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

$$I = \left({}^1\!/_2\right)^A I_0 \qquad I = \left({}^1\!/_{10}\right)^B I_0 \qquad I_2 = \frac{I_1}{2^{\frac{X}{HVL}}} \qquad I_2 = \frac{I_1}{10^{\frac{X}{TVL}}} \qquad X = 3.32\log\left(\frac{I_1}{I_2}\right)(HVL) \qquad I = I_0 B e^{-ux}$$

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

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

$$D_s = \frac{1}{\emptyset}\left(\frac{4\Phi}{\pi TL} - a^2\right)^{1/2} \qquad spatial\ ave = \left(\frac{\sum_{i=1}^{N} FS_i^{\,2}}{N}\right)^{1/2} \qquad \mathrm{t} = \frac{0.003J/cm^2}{E_{eff}} \qquad t = \frac{EL}{ML}x0.1h \qquad O.D. = \log\frac{I_0}{I}$$

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

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

1 ft^3 =7.481 U.S. gal 1L=1.0566 qt 1 inch = 2.54 cm 1 lb=453.6 grams 1 gram=15.43 grains

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

TABLE 6-3. Summary of Hood Airflow Equations

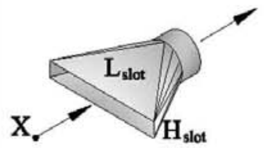
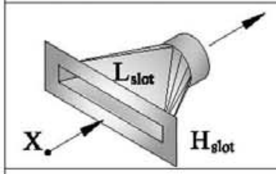
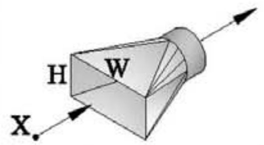
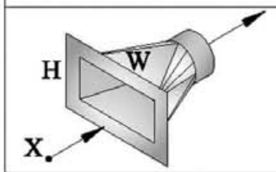
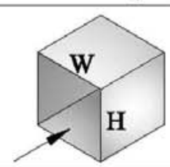
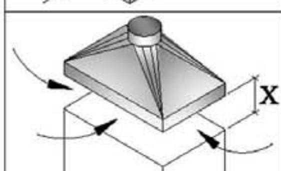
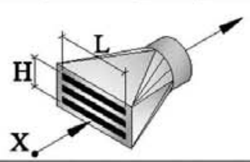
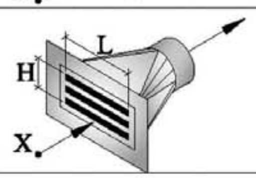
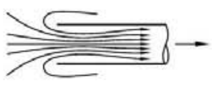
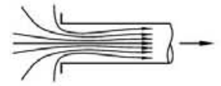
HOOD TYPE	DESCRIPTION	ASPECT RATIO, H/L	AIRFLOW
	Slot	0.2 or less	$Q = 3.7\ LV_xX$
	Flanged slot	0.2 or less	$Q = 2.6\ LV_xX$
	Plain opening	0.2 or greater and round	$Q = V_x(10X^2 + A_f)$ $A_f = WH$
	Flanged opening $W_f \geq \sqrt{A_f}$	0.2 or greater and round	$Q = 0.75V_X(10X^2 + A_f)$ $A_f = WH$
	Booth	To suit work	$Q = VA = V_fWH$
	Canopy	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	$Q = 0.75V_X(10X^2 + A_s)$ $A_s = HL$

FIGURE 9-a

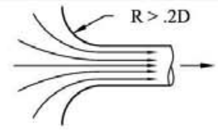


$F_h = 0.93$
$C_e = 0.72$
PLAIN DUCT END

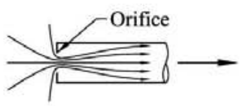


Conical	Rectangular
$F_h = 0.56$	$F_h = 0.64$
$C_e = 0.80$	$C_e = 0.78$

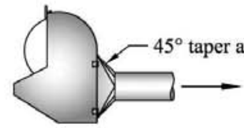
FLANGED DUCT END



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



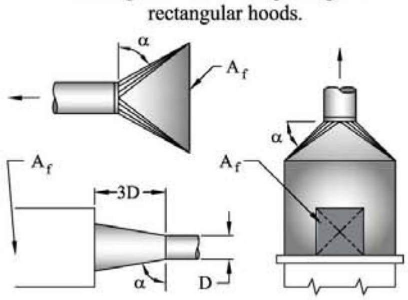
$F_h = 1.78$
$C_e = 0.60$
SHARP-EDGED ORIFICE



$F_h = 0.4$ (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.

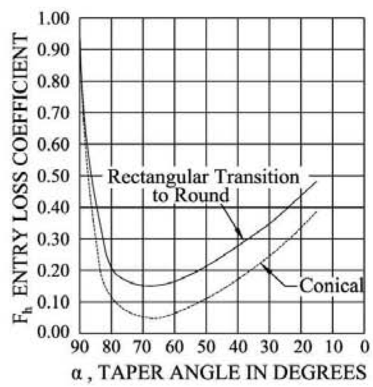


Face area (A_f) at least 2 times the duct area.

F_h Entry Loss Coefficient

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.

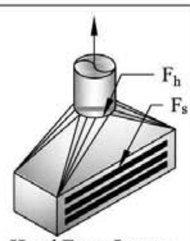


COMPOUND HOODS

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 coefficient, 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 coefficient is given by the above data for tapered hoods.



Hood Entry Loss = $F_s VP_s + F_h VP_d$
(See Chapter 6)

MISCELLANEOUS VALUES

HOOD	ENTRY LOSS COEFFICIENT 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 close elbow	0.80	0.56
Plain pipe plus close elbow	1.60	0.38

ACGIH®

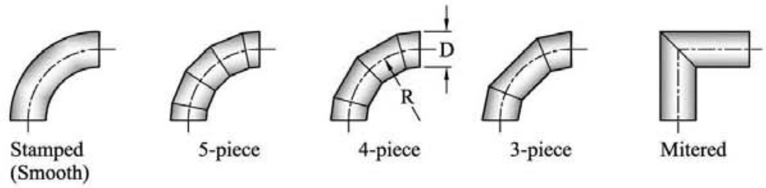
TITLE: HOOD ENTRY LOSS FACTORS

FIGURE: 9-a

DATE: 1-16

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

FIGURE 9-e



	R / D				
	0.75	1.00	1.50	2.00	2.50
Stamped	0.33	0.22	0.15	0.13	0.12
5-piece	0.46	0.33	0.24	0.19	0.17*
4-piece	0.50	0.37	0.27	0.24	0.23*
3-piece	0.54	0.42	0.34	0.33	0.33*

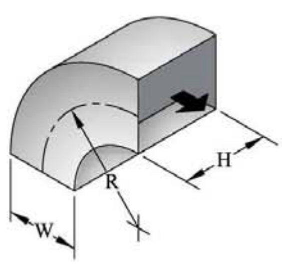
* extrapolated from published data

OTHER ELBOW LOSS FACTORS

Mitered, no vanes	1.2
Mitered, turning vanes	0.6
Flatback (R/D = 2.5)	0.05 (see Chapter 5, Figure 5-18)

NOTE: Loss factors are assumed to be for elbows of "zero length." Friction losses should be included to the intersection of centerlines.

ROUND ELBOW LOSS FACTORS



R/W	Aspect Ratio, H/W					
	0.25	0.5	1.0	2.0	3.0	4.0
0.0 (Mitered)	1.50	1.32	1.15	1.04	0.92	0.86
0.5	1.36	1.21	1.05	0.95	0.84	0.79
1.0	0.45	0.28	0.21	0.21	0.20	0.19
1.5	0.28	0.18	0.13	0.13	0.12	0.12
2.0	0.24	0.15	0.11	0.11	0.10	0.10
3.0	0.24	0.15	0.11	0.11	0.10	0.10

SQUARE & RECTANGULAR ELBOW LOSS FACTORS

ACGIH®

TITLE

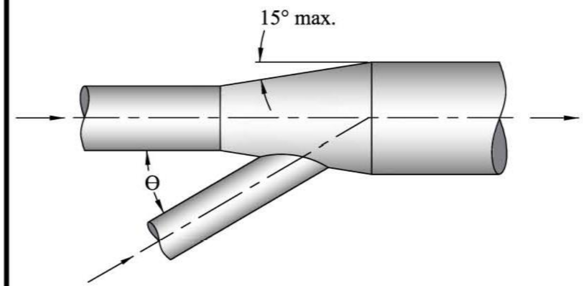
DUCT DESIGN DATA
ELBOW LOSS FACTORS

FIGURE 9-e

DATE 1-16

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

FIGURE 9-f

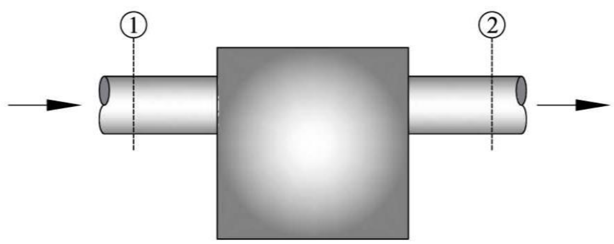


Angle Θ Degrees	Loss Factor
10	0.06
15	0.09
20	0.12
25	0.15
30	0.18
35	0.21
40	0.25
45	0.28
50	0.32
60	0.44
90	1.00

Note: Branch entry loss assumed to occur in branch and is so calculated.

Do not include a regain calculation for branch entry enlargements.

BRANCH ENTRY LOSS FACTORS



$$SP_2 - SP_1 = 1.5\ VP_2$$
$$F_h = 1.5$$
$$C_e = 0.8$$

TRAP OR SETTLING CHAMBER

ACGIH®	TITLE BRANCH ENTRY LOSS FACTORS AND LOSSES IN SETTLING CHAMBERS	FIGURE 9-f
		DATE 1-16

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