USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

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VENTILATION

$$Q = VA \qquad V_1 A_1 = V_2 A_2 \qquad TP = VP + SP \qquad SP_1 + VP_1 = SP_2 + VP_2 + h_L \qquad V = 4005\sqrt{VP} \qquad |SP_{\mathbf{h}}| = VP + h_{\mathbf{e}}$$

$$h_e = \frac{1 - C_e^{\,2}}{C_e^{\,2}} VP \qquad h_e = F_h x VP_d \qquad C_e = \sqrt{\frac{VP}{|SP_h|}} \qquad VP_{ave} = \left(\frac{\sqrt{VP_1} + \sqrt{VP_2} + ... + \sqrt{VP_n}}{n} \right)^2 \qquad VP_{\mathrm{r}} = \left(\frac{Q_1}{Q_3}\right) VP_1 + \left(\frac{Q_2}{Q_3}\right) VP_2$$

$$V = 1096\sqrt{\frac{VP}{\rho}} \qquad Q = 4005 C_e A \sqrt{|SP_h|} \qquad Q = 4005 A \sqrt{\frac{SP_{\mathrm{h}}}{df\,(1 + F_{\mathrm{h}})}} \qquad Q = 1096 A \sqrt{\frac{SP_{\mathrm{h}}}{\rho(1 + F_{\mathrm{h}})}} \qquad Q_{cor} = Q_{design}\sqrt{\frac{SP_{gov}}{SP_{duct}}}$$

$$Q' = \frac{Q}{K} \qquad t_2 - t_1 = -\frac{V_{\mathrm{r}}}{Q'} \ln\left(\frac{C_2}{C_1}\right) \qquad \ln\frac{(G - Q'C_2)}{(G - Q'C_1)} = -\frac{Q'(t_2 - t_1)}{V_{room}} \qquad C = \left(\frac{G}{Q'} x 10^6 \right) + C_{supply}$$

$$N_{changes} = \frac{60Q}{V_{room}} \qquad C = \frac{G}{Q'}\left(1 - e^{-Nt/60}\right) x 10^6 \qquad C = C_0 e^{-tN_{changes}} \qquad Q = \frac{(403)(s.g.)(ER)(K)(10^6)}{(m.w.)(C)} \qquad C = \frac{gx24.45x10^6}{MWxV}$$

$$Q_2 = Q_1 \left(\frac{Size_2}{Size_1}\right)^3 \left(\frac{RPM_2}{RPM_1}\right) \qquad P_2 = P_1 \left(\frac{Size_2}{Size_1}\right)^2 \left(\frac{RPM_2}{RPM_1}\right)^2 \qquad PWR_2 = PWR_1 \left(\frac{Size_2}{Size_1}\right)^5 \left(\frac{RPM_2}{RPM_1}\right)^3$$

$$FSP = SP_{out} - SP_{in} - VP_{in} \qquad FTP = TP_{out} - TP_{in}$$

NOISE

$$SPL = 20\left(\log\frac{P}{P_0}\right) \qquad SPL = 10\left(\log\frac{I}{I_0}\right) \qquad SPL_2 = SPL_1 + 20\ \log\left(\frac{d_1}{d_2}\right)$$

$$SPL_f = 10\ \log\sum 10^{\frac{SPL}{10}} \qquad SPL_f = SPL_i + 10\ \log(n) \qquad L_{\mathrm{w}} = 10\ \log\left(\frac{W}{W_{\mathbf{0}}}\right) \qquad W_0 = 10^{-12}\, watts$$

$$L_{Total} = L_1 + 10\ \log\left(10^{\frac{L_2 - L_1}{10}} + 1\right) \qquad L_{eq} = 10\ \log\left(\frac{1}{T}\sum_{i=1}^{N}\left(10^{\frac{L_i}{10}} t_i\right)\right) \qquad L_{PT} = 10\ \log\left(\sum_{i=1}^{N} 10^{\frac{L_{Pi}}{10}}\right) \qquad TL = 10\ \log\left(\frac{E_{\mathbf{i}}}{E_{\mathbf{t}}}\right)$$

$$L_{\boldsymbol{p}} = L_{\boldsymbol{w}} - 20\ \log_{10} r - 0.5 + DI + T \qquad DI = 10\ \log_{10} Q \qquad \%D = 100\left(\frac{C_1}{T_1} + \frac{C_2}{T_2} + ... + \frac{C_{\mathbf{i}}}{T_{\mathbf{i}}}\right)$$

$$T = 8/2^{(level - 85)/3} \qquad TWA_{eq} = 10\ \log\left(\frac{\%D}{100}\right) + 85dBA \qquad TWA = 16.61\ \log\left(\frac{\%D}{100}\right) + 90dBA \qquad f = \frac{(N)(RPM)}{60}$$

$$f = \frac{c}{\lambda} \qquad f_2 = 2\,f_1 \qquad f_c = \sqrt{f_1 f_2} \qquad f_2 = \sqrt{2}\,f_1 \qquad f_2 = \sqrt[3]{2}\,f_1$$

USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

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GENERAL SCIENCES, STATISTICS, STANDARDS

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

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

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

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

$$E_{fiber\ density} = \frac{\frac{f}{N_f} - \frac{B}{N_b}}{A_f} \qquad d = \frac{0.61\lambda}{\eta \sin\alpha} \qquad \bar{X} = \frac{X_1 + X_2 + \ldots + X_n}{n} \qquad SD = \sqrt{\frac{\sum(\bar{x} - x_i)^2}{n-1}} \qquad GM = \sqrt[n]{(x_1)(x_2)\ldots(x_n)}$$

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

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

$$LCL = \frac{C_A}{PEL} - \frac{SAE\sqrt{T_1^2{C_1}^2 + T_2^2{C_2}^2 + \ldots + T_n^2{C_n}^2}}{PEL(T_1 + T_2 + \ldots + T_n)} \qquad 95\%Conf = \bar{X} \pm 1.645\frac{SD}{\sqrt{n}} \qquad 95\%Conf = \bar{X} \pm 1.96\frac{SD}{\sqrt{n}}$$

HEAT STRESS

$$WBGT = 0.7t_{\mathrm{nwb}} + 0.2t_{\mathrm{g}} + 0.1t_{\mathrm{db}} \qquad WBGT = 0.7t_{\mathrm{nwb}} + 0.3t_{\mathrm{g}} \qquad \Delta S = (M - W) \pm C \pm R - E \qquad R = 15(t_w - 95)$$

$$C = 0.65v^{0.6}(t_\alpha - 95) \qquad E_{max} = 2.4v^{0.6}(42 - vp_w) \qquad cfm = \frac{Total\ Sensible\ Heat\ (BTU/hr)}{1.08(\Delta T)} \qquad HSI = \frac{E_{req}}{E_{max}} x100$$

USEFUL EQUATIONS FOR THE ABIH EXAMINATIONS

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RADIATION

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

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

$$\frac{1}{T_{1/2eff}} = \frac{1}{T_{1/2rad}} + \frac{1}{T_{1/2bio}} \qquad T_{1/2eff} = \frac{(T_{1/2rad})(T_{1/2bio})}{T_{1/2rad}+T_{1/2bio}} \qquad PD = \frac{E^2}{3770} \qquad PD = 37.7H^2 \qquad W = \frac{4P}{A} \qquad r = \left(\frac{PG}{4\pi EL}\right)^{1/2}$$

$$B_r = \sqrt{B_x{}^2 + B_y{}^2 + B_z{}^2} \qquad r_{NHZ} = \frac{1}{\phi}\left(\frac{4\Phi}{\pi EL} - a^2\right)^{1/2} \qquad r_{NHZ} = \frac{f_0}{b_0}\left(\frac{4\Phi}{\pi EL}\right)^{1/2} \qquad r_{NHZ} = \left(\frac{\rho\Phi\cos\theta}{\pi EL}\right)^{1/2} \qquad D_s = \frac{1}{\phi}\left(\frac{4\Phi}{\pi TL} - a^2\right)^{1/2}$$

$$spatial\ ave = \left(\frac{\sum_{i=1}^{N} FS_i{}^2}{N}\right)^{1/2} \qquad t = \frac{0.003J/cm^2}{E_{eff}} \qquad t = \frac{EL}{ML}x0.1h \qquad O.D. = \log\frac{I_0}{I} \qquad D_L = \sqrt{a^2 + \phi^2 r^2}$$

$$I_2 = I_1 x(magnification)^2 \qquad G = 10^{g/10}$$

CONSTANTS AND CONVERSIONS

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

1 ft^3=7.481 U.S. gal 1L=1.0566 qt 1 inch=2.54 cm 1 lb=453.6 gm 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 Currie=$3.7x10^{10}$ disint/sec (Becquerel)=$2.2x10^{12}$ dpm 1 Gray=100 Rad 1 Sievert=100 Rem

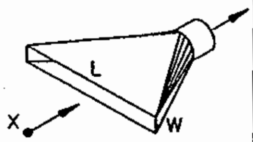
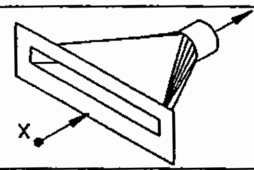
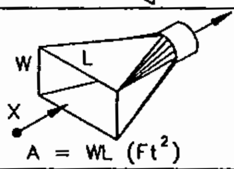
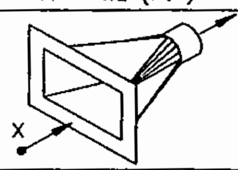
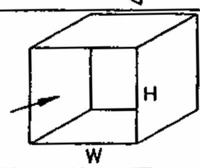
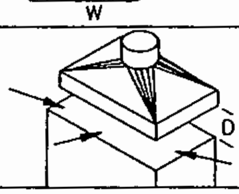
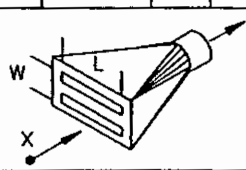
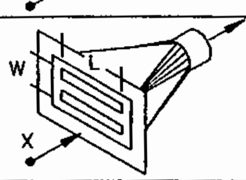
1 Tesla=10,000 Gauss 1 BTU=1054.8 joules=0.293 watt hr 1 cal=4.184 joules

speed of sound in air at 20°C=1130 ft/sec speed of light=$3x10^8$ m/sec

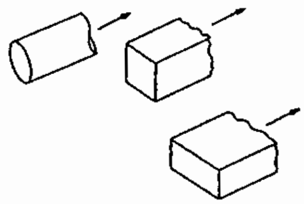
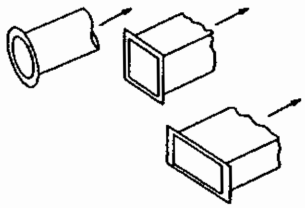
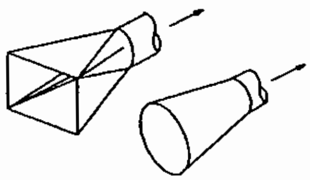
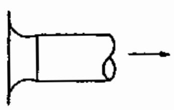
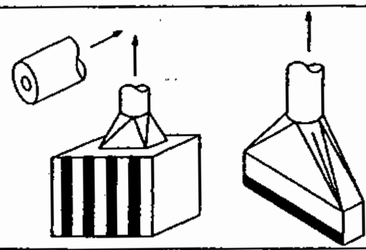
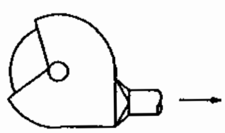
Planck's constant=$6.626x10^{-27}$ erg sec Avogadro's number=$6.024x10^{23}$

gas constant, R=8.314 J/mole K=0.082 L atm/mole K

g=981 cm/sec^2=32 ft/sec^2 A_c=385 mm^2 for 25 mm filter density of air=1.29 g/L at 1 atm, 0°C

HOOD TYPE	DESCRIPTION	ASPECT RATIO,W/L	AIR FLOW
	SLOT	0.2 OR LESS	Q = 3.7 LVX
	FLANGED SLOT	0.2 OR LESS	Q = 2.6 LVX
	PLAIN OPENING	0.2 OR GREATER AND ROUND	$Q = V(10X^2 + A)$
	FLANGED OPENING	0.2 OR GREATER AND ROUND	$Q = 0.75V(10X^2 + A)$
	BOOTH	TO SUIT WORK	Q = VA = VWH
	CANOPY	TO SUIT WORK	Q = 1.4 PVD SEE FIG. VS-99-03 P = PERIMETER D = HEIGHT ABOVE WORK
	PLAIN MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	$Q = V(10X^2 + A)$
	FLANGED MULTIPLE SLOT OPENING 2 OR MORE SLOTS	0.2 OR GREATER	$Q = 0.75V(10X^2 + A)$

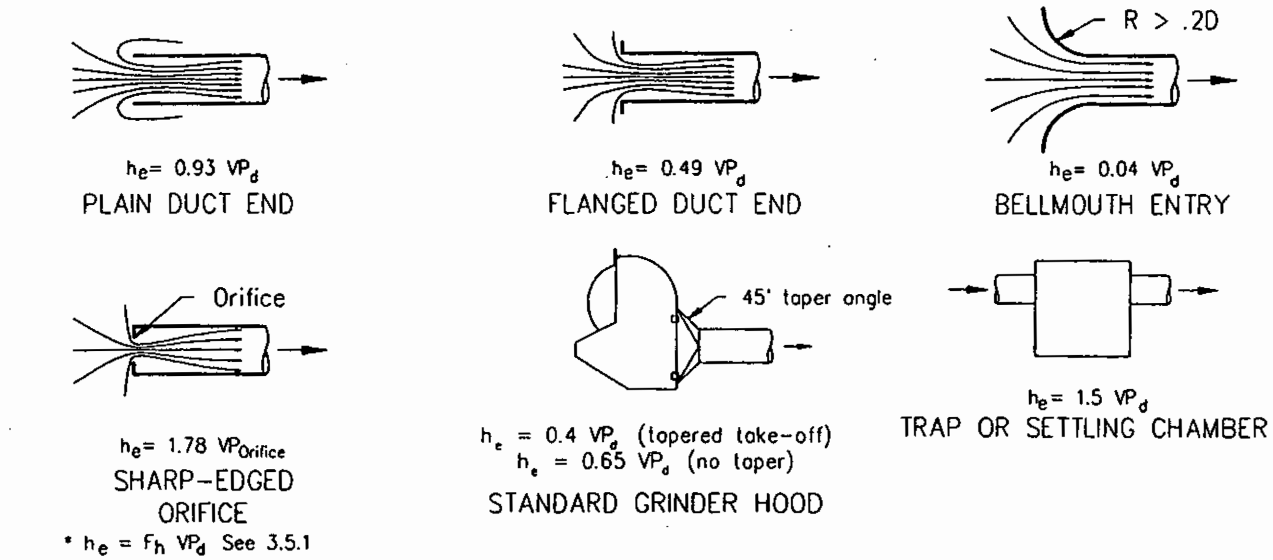
AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*HOOD TYPES*
	DATE *4–96* FIGURE *3–11*

HOOD TYPE	DESCRIPTION	HOOD ENTRY LOSS (F_h) COEFFICIENT
	PLAIN OPENING	0.93
	FLANGED OPENING	0.49
	TAPER OR CONE HOOD	SEE CHAPTER 10
	BELL MOUTH INLET	0.04
	ORIFICE	SEE CHAPTER 10
	TYPICAL GRINDING HOOD	(STRAIGHT TAKEOFF) 0.65 (TAPERED TAKEOFF) 0.40

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

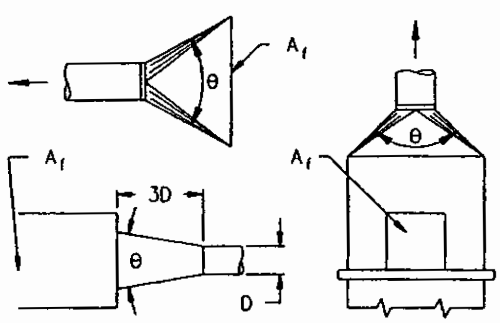
HOOD LOSS COEFFICIENTS

DATE 4–96 FIGURE 3–16



TAPERED HOODS

Flanged or unflanged; round, square or rectangular. θ is the major angle on rectangular hoods.

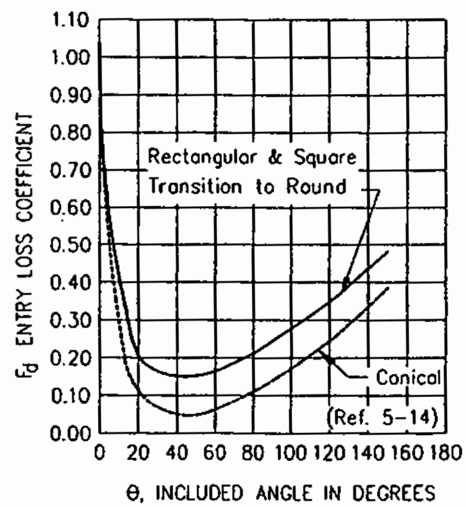


Face area (A_f) at least 2 times the duct area.

θ	ENTRY LOSS (h_h) ROUND	RECTANGULAR
15°	0.15 VP	0.25 VP
30°	0.08 VP	0.16 VP
45°	0.06 VP	0.15 VP
60°	0.08 VP	0.17 VP
90°	0.15 VP	0.25 VP
120°	0.26 VP	0.35 VP
150°	0.40 VP	0.48 VP
180°	0.50 VP	0.50 VP

VP = Duct VP = VP_d

Note: 180° values represent round ducts butted into back of booth or hood without a rectangular to round transition.

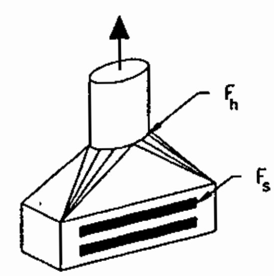


COMPOUND HOODS

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 3 and 10).

The duct entry loss coefficient is given by the above data for tapered hoods.



$h_e = F_s\ VP_s + F_h\ VP_d$

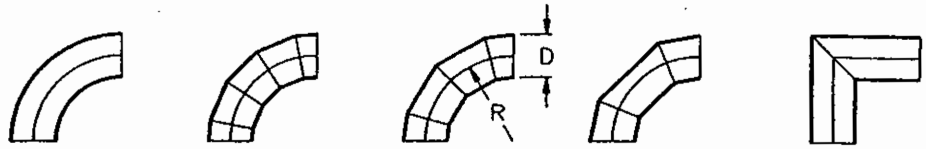
MISCELLANEOUS VALUES

HOOD	ENTRY LOSS COEFFICIENT F_h
Abrasive blast chamber	1.0
Abrasive blast elevator	2.3
Abrasive separator	2.3
Elevators (enclosures)	0.69
Flanged pipe plus close elbow	0.8
Plain pipe plus close elbow	1.60

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

HOOD ENTRY LOSS COEEFICIENTS

DATE *1–95* FIGURE *5–15*



	R/D					
	0.5	0.75	1.00	1.50	2.00	2.50
Stamped	0.71	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	0.90	0.54	0.42	0.34	0.33	0.33*

* extrapolated from published data

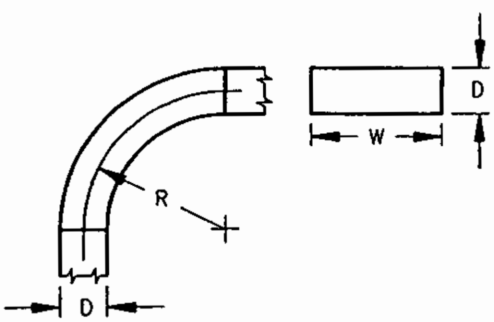
OTHER ELBOW LOSS COEFFICIENTS

Mitered, no vanes	1.2	
Mitered, turning vanes	0.6	
Flatback (R/D = 2.5)	0.05	(see Figure 5-23)

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 COEFFICIENTS

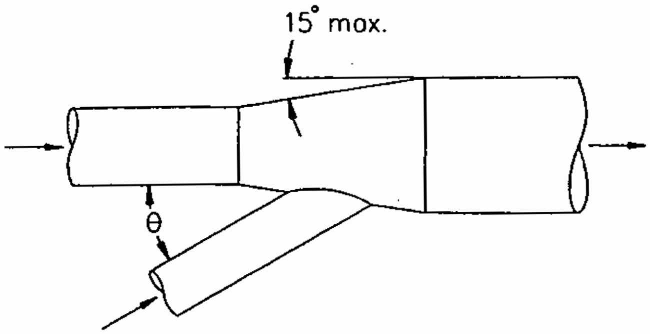
(Ref. 5.13)



R/D	Aspect Ratio, W/D					
	0.25	0.5	1.0	2.0	3.0	4.0
0.0(Mitred)	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 COEFFICIENTS

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*DUCT DESIGN DATA ELBOW LOSSES*	
	DATE *1-95*	FIGURE *5-16*

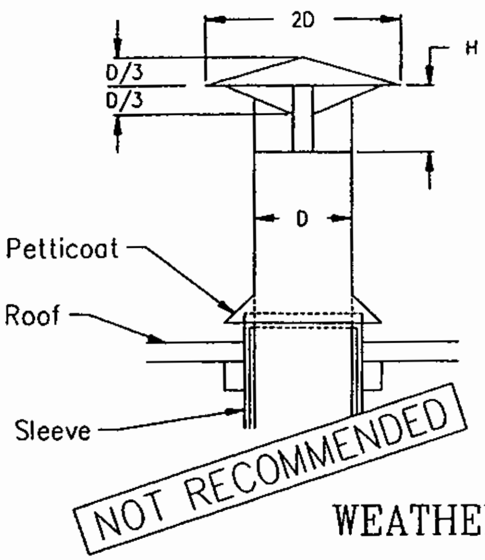


Note: Branch entry loss assumed to occur in branch and is so calculated.

Do not include an enlargement regain calculation for branch entry enlargements.

Angle θ Degrees	Loss Fraction of VP in Branch
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

BRANCH ENTRY LOSSES



H, No. of Diameters	Loss Fraction of VP
1.0 D	0.10
0.75 D	0.18
0.70 D	0.22
0.65 D	0.30
0.60 D	0.41
0.55 D	0.56
0.50 D	0.73
0.45 D	1.0

WEATHER CAP LOSSES

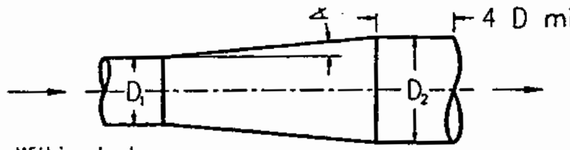
See Fig. 5-30

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS

DUCT DESIGN DATA

DATE *1-95* FIGURE *5-17*

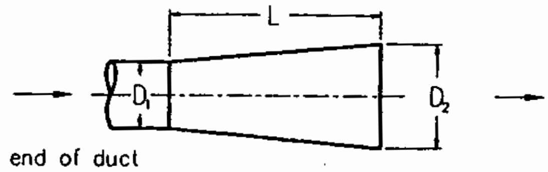
STATIC PRESSURE REGAINS FOR EXPANSIONS



Within duct

Regain (R), fraction of VP difference					
Taper angle degrees	Diameter ratios D_2/D_1				
	1.25:1	1.5:1	1.75:1	2:1	2.5:1
3 1/2	0.92	0.88	0.84	0.81	0.75
5	0.88	0.84	0.80	0.76	0.68
10	0.85	0.76	0.70	0.63	0.53
15	0.83	0.70	0.62	0.55	0.43
20	0.81	0.67	0.57	0.48	0.43
25	0.80	0.65	0.53	0.44	0.28
30	0.79	0.63	0.51	0.41	0.25
Abrupt 90	0.77	0.62	0.50	0.40	0.25

Where: $SP_2 = SP_1 + R(VP_1 - VP_2)$



At end of duct

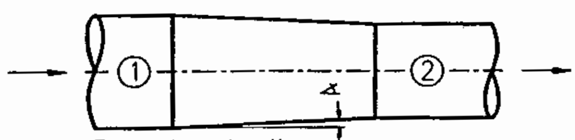
Regain (R), fraction of inlet VP						
Taper length to inlet diam L/D	Diameter ratios D_2/D_1					
	1.2:1	1.3:1	1.4:1	1.5:1	1.6:1	1.7:1
1.0:1	0.37	0.39	0.38	0.35	0.31	0.27
1.5:1	0.39	0.46	0.47	0.46	0.44	0.41
2.0:1	0.42	0.49	0.52	0.52	0.51	0.49
3.0:1	0.44	0.52	0.57	0.59	0.60	0.59
4.0:1	0.45	0.55	0.60	0.63	0.63	0.64
5.0:1	0.47	0.56	0.62	0.65	0.66	0.68
7.5:1	0.48	0.58	0.64	0.68	0.70	0.72

Where: $SP_1 = SP_2 - R(VP_1)$ *

*When $SP_2 = 0$ (atmosphere) SP_1 will be (−)

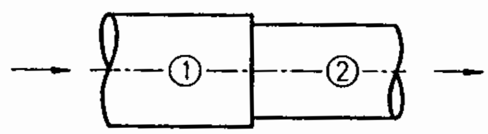
The regain (R) will only be 70% of value shown above when expansion follows a disturbance or elbow (including a fan) by less than 5 duct diameters.

STATIC PRESSURE LOSSES FOR CONTRACTIONS



Tapered contraction
$SP_2 = SP_1 - (VP_2 - VP_1) - L(VP_2 - VP_1)$

Taper angle degrees	L(loss)
5	0.05
10	0.06
15	0.08
20	0.10
25	0.11
30	0.13
45	0.20
60	0.30
over 60	Abrupt contraction



Abrupt contraction
$SP_2 = SP_1 - (VP_2 - VP_1) - K(VP_2)$

Ratio A_2/A_1	K
0.1	0.48
0.2	0.46
0.3	0.42
0.4	0.37
0.4	0.32
0.6	0.26
0.7	0.20

A= duct area, ft^2

Note:
In calculating SP for expansion or contraction use algebraic signs: VP is (+), and usually SP is (+) in discharge duct from fan, and SP is (−) in inlet duct to fan.

AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS	*DUCT DESIGN DATA*		
	DATE	*1−95*	FIGURE *5−18*