IH&S 528 Midterm and Final Exam Reference Sheet

RADIATION

Dose Equivalent = Absorbed Dose (rads) x Quality Factor

↓

1 rad = 100 erg/gm = 0.01 Gy

1 rad = 0.876 R for gamma and X-rays

1Gy = 100 rad

VISCOSITY AND DENSITY

Viscosity of air at room temperature = 7.23 x 10^{-4} lb/ft-min
Density of dry air at room temperature (70°F) and sea level altitude is 0.075 lb/ft^3

$$df = \left(\frac{P_{bar} + SP_{duct}}{P_{std}}\right)\left(\frac{T_{std}}{T_{act}}\right)\left(\frac{1+w}{1+1.607w}\right)$$

DILUTION

$$VaporVol = \frac{\left(sp.grav. * \rho_{H2O} * Vol_{liquid}\right)}{MW} * 24.04\,L * \left(\frac{293.15}{273.15C + T}\right)\left(\frac{P_{atm}}{760_{mmHg}}\right)$$

$$k = \frac{Q}{mR_{vol}}$$

$$RoomChangesPerHour = \frac{60\,Q}{mR_{vol}}, \quad where\ Q = vol/\min$$

$$\begin{aligned} C_{t_1+\Delta t} &= C_{t_1}\,\mathrm{e}^{-\frac{Q\Delta t}{mR}} + \left(C_s + \frac{G\times 10^6}{Q/m}\right)\left(1-\mathrm{e}^{-\frac{Q\Delta t}{mR}}\right) \\ &= C_{t_1}\,\mathrm{e}^{-k\Delta t} + \left(C_s + \frac{G\times 10^6}{Q/m}\right)\left(1-\mathrm{e}^{-k\Delta t}\right) \\ &= C_{steadyState} + \left(C_{t_1} - C_{steadyState}\right)\mathrm{e}^{-k\Delta t} \end{aligned}$$

$$\begin{aligned} C_{avg} &= \left(C_s + \frac{G}{Q/m}\right) + \left(C_1 - C_s - \frac{G}{Q/m}\right)\left(\frac{R}{\Delta t\,Q/m}\right)\left(1-e^{-Q\Delta t/mR}\right) \\ &= C_{SteadyState} + \left(C_1 - C_{SteadyState}\right)\left(\frac{R_{vol}}{[Q/m]\Delta t}\right)\left(1-e^{-k\Delta t}\right) \end{aligned}$$

HOODS

$$Q = C_{cap}\, V_{control}\, (C_{table}\, L_x^2 + \text{Face Area})$$

$$Q = 3.7\, C_{cap}\, V_{control}\, L_x\, L_{slot}$$

$$Q = V\, A$$

Description	C_{cap}	C_{table}
unflanged, no obstructions	1	
flanged, no tabletop near	0.75	
well above a surface		1.0
tabletop within 1/3 Hood height		0.7
flange touching tabletop		0.6
Hood bottom touching tabletop		0.5

Recommended Capture Velocities*

Energy of dispersion	Examples	V, ft/min
Little motion	Evaporation from tanks, degreasing	75–100
Average motion	Intermittent container filling; low speed conveyor transfers; welding; plating; pickling	100–200
High	Barrel filling; conveyor loading; crushers	200–500
Very high	Grinding; abrasive blasting; tumbling	500–2000

Factors affecting choices within ranges

Strength of cross-drafts due to makeup air, traffic, etc.

Need for effectiveness in collection:

toxicity of contaminants produced by the source
exposures from other sources, which reduces acceptable exposure from this source quantity of air contaminants generated – production rate, volatility, time generated

* see also ANSI Z9.2–1979

ERGONOMICS

Table : Anthropometric Data

	Male				Female			
Measurement, cm	mean	std	5th	95th	Mean	std	5th	95th
forward function reach (includes body depth at shoulder)	79.3	5.6	70.1	88.5	71.1	3.9	64.7	77.5
Waist height	104.8	6.3	94.4	115.2	98.5	5.5	89.4	107.6
Elbow height	114.6	6.3	104.2	125.0	107.1	6.8	95.9	118.3
Eye height	146.4	7.8	133.5	159.3	135.3	6.6	124.4	146.2
Stature	177.5	6.7	166.4	188.6	164.5	7.2	152.6	176.4
Seated-elbow height	24.1	3.2	18.8	29.4	23.1	3	18.2	28.1
Seated-eye height	78.7	3.6	72.8	84.6	73.7	3.1	68.6	78.8
Weight, kg	83.2	15.1	58.3	108.1	66.4	13.9	43.5	89.3

	male				Female			
Measurement, in.	mean	std	5th	95th	Mean	std	5th	95th
forward function reach (includes body depth at shoulder)	31.2	2.2	27.6	34.9	28.0	1.5	25.5	30.5
Waist height	41.3	2.5	37.2	45.4	38.8	2.2	35.2	42.4
Elbow height	45.1	2.5	41.0	49.2	42.2	2.7	37.7	46.6
Eye height	57.6	3.1	52.6	62.7	53.3	2.6	49.0	57.6
Stature	69.9	2.6	65.5	74.2	64.8	2.8	60.1	69.4
Seated-elbow height	9.5	1.3	7.4	11.6	9.1	1.2	7.1	11.0
Seated-eye height	31.0	1.4	28.6	33.3	29.0	1.2	27.0	31.0
Weight, lbs	183.4	33.3	128.5	238.4	146.4	30.6	95.8	196.9

Adapted from Ergonomic Design for People at Work by Eastman Kodak Company (Van Nostrand Reinhold, NY (1983)

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Table : Recommended Values for Work Surfaces and Enclosure Dimensions

Parameter	Approach	Reasonable Range of Values (McCormick, 1993)
Work surface height, standing	Adjustable height surface or provide a moveable standing base for shorter workers. Work surface height higher if close inspection necessary, lower for coarse inspection and handling of heavy parts.	fine work: 37" – 49.5" light assembly: 32” - 42” heavy work: 29" to 30"
Work surface height, sitting	Adjust height of chairs and provide foot rests. Work surface height higher if close inspection necessary, lower for coarse inspection and handling of heavy parts.	fine work: 39" – 41.5" light assembly: 32.5” - 37” medium coarse work: 26" to 28.5"
Work surface width	Fixed width based on size of the pieces and the tools the worker handles. The maximum value is based on workers’ maximum reach while holding light objects. Effective grasp distance falls sharply with progressively heavier objects.	24" – 48”
Work surface depth	Fixed depth based on size of the pieces and the tools the worker handles. Worker effective, comfortable reach distance for shorter workers is less than 16” inches for light objects and is progressively lower for heavier objects.	≥ 24" *
Enclosing hoods:		
Hood width	Width required without hood plus at least 12 inches	≥ 36"
Hood depth	Width required without hood plus at least 12 inches	≥ 36"
Hood height inside the hood	Should clear workers head by ≥ 3" for tabletop hoods. Minimum for walk-in hoods is 84". Greater heights required if tools or work pieces must be lifted overhead	≥ 78"

DUCTS

Table I: Recommended Transport (ft/min) Velocities for Particulates

Abrasive blasting		3500-4000	Limestone dust		3500
Aluminum dust,	coarse	4000	Lint		2000
Barrel filling/dumping		3500-4000	Magnesium dust,	coarse	4000
Belt conveyors		3500	Metal turnings		4000-5000
Bins and hoppers		3500	Metalizing booth		3500
Brass turnings		4000	Paint spray		2000
Bucket elevators		3500	Paper		3500
Buffing/polishing,	dry	3000-4000	Plastics buffing dust		3800
	sticky	3500-4000	Plating		2000
Cast iron boring dust		4000	Rubber dust,	fine	2500
Ceramics,	glaze spraying	2500		coarse	4000
	dry operations	3500	Sandblast dust		4000
Carbon black or Clay dust		3500	Sander dust		2000
Coal, powdered		4000	Screens, flat or cylind.		3500
Cork, ground		2500	Silica dust		3500-4000
Cotton dust		3000	Soap dust		3000
Crushers		>3000	Soapstone dust		3500
Flour dust		2500	Soldering and tinning		2000-2500
Foundry,	general	3500	Tailpipe exhausts		3000
	mixer	3500-4000	Wood dust,	general	2500-4000
	swing grinding booth	3000		flour,light dry sawdust	2500
	tumbling mills	4000-5000		light dry shavings	2500
Grain dust		2500-3000		heavy shavings	3500
Grinding,	general	3500-4000		damp sawdust, blocks	3500
	portable hand	3500		heavy chips,waste,green	4000
Lead dust		4000	Wool		3000
	with small chips	5000	Zinc oxide fumes		2000
Leather dust		3500			

[*] from ANSI, ACGIH and other sources

AVAILABLE DUCT SIZES FOR VERY LARGE VENDORS

Stock Duct Sizes

Diameter	Increment
3" - 6"	0.5
6" - 10"	1.0"
10 - 24"	2.0"
24" - 48"	4.0"

FAN CALCULATIONS

$$\text{FanTP} = \text{TP}_{\text{outlet}} - \text{TP}_{\text{inlet}}$$

$$= \text{SP}_{\text{outlet}} + \text{VP}_{\text{outlet}} - \text{SP}_{\text{inlet}} - \text{VP}_{\text{inlet}}$$

$$\text{FanSP} = \text{FanTP} - \text{VP}_{\text{outlet}}$$

$$Power_{air} = \frac{FanTP \times FanQ}{constant}$$

Constant = 6356 in.w.g.-cfm/HP

0.7457 kw = 1 HP

Modify with η_{fan}, η_{drive}, η_{motor} to obtain other values of power

$$\eta_{\text{fan}} = \frac{Power_{\text{air}}}{Power_{\text{brake}}}$$

Using values from a fan table:

$$\eta_{\text{fan}} = \frac{Q_{table}\left[FanSP_{table} + \left(\frac{V_{outlet\ table}}{4005}\right)^2\right]}{Power_{\text{brake}}\ from\ table}$$

$$\text{FanTP}_{\text{table}} = \frac{\text{SP}_{\text{outlet}} + \text{VP}_{\text{outlet}} - (\text{SP}_{\text{inlet}} + \text{VP}_{\text{inlet}}) + (\text{F}_{\text{inlet}} \text{ x } \text{VP}_{\text{inlet}}) + (\text{F}_{\text{outlet}} \text{ x } \text{VP}_{\text{outlet}})}{density\ factor\ at\ fan\ inlet}$$

$$\text{FanSP}_{\text{table}} = \frac{\text{SP}_{\text{outlet}} - (\text{SP}_{\text{inlet}} + \text{VP}_{\text{inlet}}) + (\text{F}_{\text{inlet}} \text{ x } \text{VP}_{\text{inlet}}) + (\text{F}_{\text{outlet}} \text{ x } \text{VP}_{\text{outlet}})}{density\ factor\ at\ fan\ inlet}$$

$FanTP\ \alpha\ \omega^2$ $Q\ \alpha\ \omega$ $Power\ \alpha\ \omega^3$ $Power_{watts} = V_{volts} \times I_{amps}$

$I_{amps}\ \alpha\ \omega^3$ $,\ if\ voltage\ constant$

List of Incremental Fan Motor Sizes by HP (no headings in table)

$\frac{1}{4}$	$\frac{1}{3}$	$\frac{1}{2}$	$\frac{3}{4}$	1	1.5	2.5	3
5	7.5	10	15	20	25	30	40
50	60	75	100	125	150	200	

MEASUREMENT

Pipe Factor = V_{avg}/V_{cl}

$$V_i = 4005\left(\frac{VP_i}{df}\right)^{0.5} \qquad V_{avg} = \sum_1^n \left(\frac{V_i}{n}\right)$$

$$df = \left(\frac{P_{bar} + SP_{duct}}{P_{std}}\right)\left(\frac{T_{std}}{T_{act}}\right)\left(\frac{1+q}{1+1.607q}\right)$$

Correcting readings on device that purport to measure velocity:

SPCALC

$$VP = df\left(\frac{V}{4005}\right)^2$$

$SP_H = -\,\mathrm{abs}(SP_{filter}) - (1 + F_H)\,VP_{duct} - 1.78\,VP_{slot}$

$SPJ_{req} = -\,\mathrm{abs}(SP_{filter}) - 1.78\,VP_{slot} - (1 + F_H + N_{el}F_{el} + F_f[L/100] + F_{misc} + F_{entry})\,VP_{duct}$

< for branch at junction fitting >

$$SPJ = -\max\,magnitude\,of\left\{SPJ_{req_a} + SPJ_{req_b}\right\}$$

$$Q_a = Qt_a\sqrt{\frac{SPJ}{SPJ_{req_a}}}$$

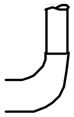
$$SP_{actual} = SP_{known}\left(\frac{Q_{actual}}{Q_{known}}\right)^x$$ for air-cleaning device. X = 0, 1, or 2, depending on type

$$D_t = 24\sqrt{\frac{Q_t}{\pi V_t}} \qquad Q_{submain_1} = Q_a + Q_b$$

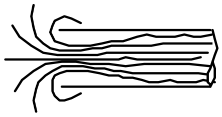
Hood Loss Coefficients, F_H

Simple Duct Transitions: $TP_H = -F_H\,VP_{duct}$ $\quad SP_H = -(1+F_H)\,VP_{duct}$

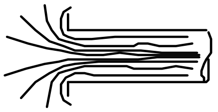
Assumptions: loss coefficients for taper transitions are valid only if the face area (A_{face}) is at least twice as great as the duct cross-sectional area (A_{duct}).
Adding an enclosure to the transition to the duct has no effect.
Adding a flange to a tapered transition has no effect.



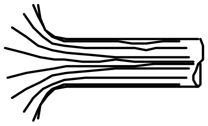
scoop entry
$F_H = 0.4$



Plain ($\theta = 0°$)
$F_H = 0.93$

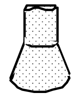


Flanged ($\theta = 90°$)
$F_H = 0.50$

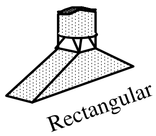


Bellmouthed
$F_H = 0.05$

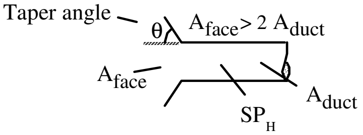
Table for Transitions



Conical



Rectangular

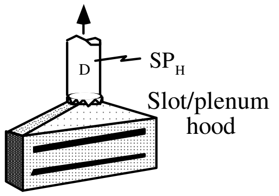


Taper Angle, θ	Conical	Rectangular	Comment
0°	0.93	0.93	i.e., unflanged duct
30°	0.08	0.17	tapered
45°	0.15	0.25	tapered
60°	0.26	0.35	tapered
90°	0.50	0.62	flanged

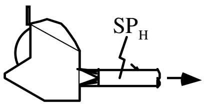
A_{face} = cross-sectional area of face $\quad A_{duct}$ = cross-sectional area of duct

Compound Hoods: (equations vary as shown below)

A compound hood has a restricted face opening followed by a plenum and a simple duct transition. Also, as seen with the grinding hood, SP_H for a compound hood with a fixed configuration can be computed using a empirical coefficient lumping face entry and duct transition losses together. Some components (e.g., settling chambers and baghouses) are not hoods, but experience losses that are computed like hood losses.



$F_{slot} = 1.78$
F_H = (see transitions above)
$SP_H = -F_{slot}VP_{slot} - (1+F_H)\,VP_{duct}$



Standard Grinding Hood

$F_H =$ 0.40 tapered
0.65 non-tapered
$SP_H = -(1+F_H)\,VP_{duct}$

Settling chamber, no baffles

F_H= (see transitions above)
$\Delta SP_{ab} = -(1+F_{Hb})VP_b$

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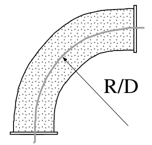
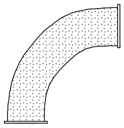
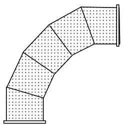


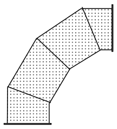
Radius of curvature



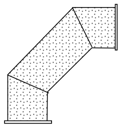
Smooth



5–piece



4–piece



3-piece

Round Ducts$^{(ref)}$

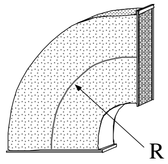
Number of pieces	R/D 0.50	0.75	1.00	1.50	2.00	2.50
stamped	—	0.33	0.22	0.15	0.13	0.12
7	—	0.39*	0.27*	0.20*	0.16*	0.15*
5	—	0.46	0.33	0.24	0.19	0.17*
4	—	0.50	0.37	0.27	0.24	0.23*
3	—	0.54	0.42	0.34	0.33	0.33*
mitered, no vanes	1.2	—	—	—	—	—
mitered, vanes	0.6	—	—	—	—	—
flatback	—	—	—	—	—	0.05

adapted from ASHRAE Fundamentals 1989, p.32.31 *extrapolated

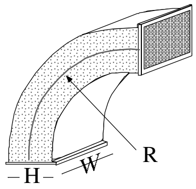
Table Vb: Rectangular ducts$^{(ref)}$

	R/H*				
W/H	0.5	0.75	1.0	1.5	2.0
0.25	1.3	0.57	0.27	0.22	0.2
0.5	1.3	0.52	0.25	0.2	0.18
0.75	1.2	0.48	0.23	0.19	0.16
1	1.2	0.44	0.21	0.17	0.15
1.5	1.1	0.4	0.19	0.15	0.14
2	1.1	0.39	0.18	0.14	0.13
3	0.98	0.39	0.18	0.14	0.13
4	0.92	0.4	0.19	0.15	0.14
5	0.89	0.42	0.2	0.16	0.14
6	0.85	0.43	0.27	0.17	0.15
8	0.83	0.44	0.21	0.17	0.15

H= length of one side w= length of other side R= radius of curvature



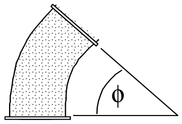
Poor Aspect Ratio



Good Aspect Ratio

Equivalent Number of 90° Elbows for Incomplete Turns

Angle of turn	%Fel
30	0.33
45	0.50
60	0.67
90	1.00



Angle of Turn

For a number (N_{el}) of 90° elbows in series with same loss coefficient: $SP_{el} = N_{el} F_{el}$

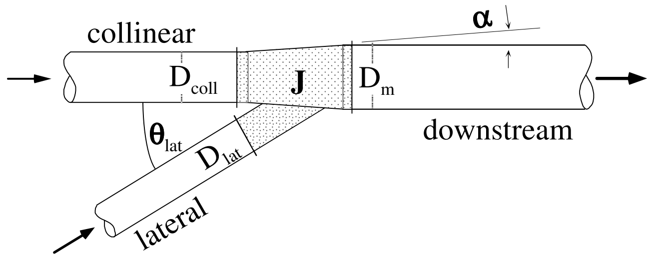


Table VIa: Approximated Upstream And Downstream Junction Coefficients(ref)

θ_{lat}	Collinear Duct 30°	45°	90°	θ_{lat}	Lateral Duct 30°	45°	90°
$F_{en_{coll}}$	-0.20	-0.20	-0.23	$F_{en_{lat}}$	0.11	0.11	-0.20
K_{coll}	0.76	0.64	0.28	K_{lat}	0.77	0.72	-0.60

Table VIb: Precise Upstream Junction Entry Pressure Coefficients (F_{en})(ref)

	$F_{en_{coll}}$, Collinear Duct				$F_{en_{lat}}$, Lateral Duct		
$\frac{D_{coll}}{D_m}$	$\theta_{lat}=$ 30°	45°	90°	$\frac{D_{lat}}{D_m}$	$\theta_{lat}=$ 30°	45°	90°
				0.30*	0.16	0.16	-0.09
0.40*	-0.31	-0.27	-0.20	0.40*	0.16	0.16	-0.10
0.50*	-0.30	-0.26	-0.20	0.50	0.14	0.14	-0.14
0.60*	-0.29	-0.25	-0.20	0.60	0.11	0.11	-0.19
0.70	-0.26	-0.24	-0.21	0.70	0.07	0.07	-0.29
0.80	-0.22	-0.21	-0.22	0.80*	-0.01	0.00	-0.43
0.90	-0.16	-0.17	-0.23	0.90*	-0.11	-0.10	-0.64
1.00	-0.08	-0.12	-0.25				

Table VIc: Precise Downstream Junction Pressure Coefficients (K)(ref)

	K_{coll}, Collinear Duct				K_{lat}, Lateral Duct		
$\frac{D_{coll}}{D_m}$	$\theta_{lat}=$ 30°	45°	90°	$\frac{D_{lat}}{D_m}$	$\theta_{lat}=$ 30°	45°	90°
				0.3*	0.82	0.86	0.04
0.4*	0.66	0.54	0.19	0.4*	0.81	0.84	-0.01
0.5*	0.66	0.55	0.20	0.5	0.80	0.79	-0.12
0.6*	0.68	0.56	0.21	0.6	0.77	0.72	-0.32
0.7	0.71	0.59	0.23	0.7	0.72	0.59	-0.65
0.8	0.75	0.63	0.27	0.8*	0.65	0.40	-1.16
0.9	0.80	0.69	0.31	0.9*	0.55	0.12	-1.89
1.0	0.89	0.77	0.38				

*Extrapolated beyond range of empirical data

Friction Losses

Table Xa: Roughness for Duct Materials(ref)

	ε		
Material (new)	feet	inches	mm
Flexible duct with uncovered wires; riveted steel; rough fiberglass lining	0.01	0.12	31
Riveted steel	0.003–0.03	0.036–0.36	9.1–91
Flexible duct with covered wires; rigid fibrous glass	0.003	0.036	9.1
Concrete	0.001–0.01	0.012–0.12	3.1–31
Cast iron	0.00085	0.010	2.6
Galvanized steel with joints every 2.5'	0.0005	0.0060	1.52
Asphalted cast iron	0.0004	0.0048	1.22
Longitudinal galvanized steel with 4' joints; galvanized steel with spiral seams with 1 to 3 ribs and 12' joints	0.0003	0.0036	0.914
Clean, uncoated carbon steel or iron; aluminum; PVC plastic; stainless steel	0.00015	0.00018	0.046
Drawn tubing	0.000005	0.000060	0.015
Glass	“Smooth”	“Smooth”	“Smooth”

(ref)Compiled from ASHRAE 1989 Fundamentals, White, and other sources

Table XIa: Friction Loss Coefficients (F_f) for ε = 0.0305 mm (0.0001 ft)$^{(ref)}$

ε = 0.0001 ft					
	V_{ref}, ft/min				
D in	1500	2000	2500	3500	5500
2.0	15.49	14.66	14.09	13.35	12.54
2.5	11.73	11.11	10.69	10.13	9.52
3.0	9.35	8.86	8.53	8.09	7.61
3.5	7.72	7.33	7.06	6.70	6.30
4.0	6.55	6.22	5.99	5.69	5.36
4.5	5.67	5.38	5.19	4.93	4.64
5.0	4.98	4.73	4.56	4.33	4.08
5.5	4.43	4.21	4.06	3.86	3.64
6.0	3.98	3.79	3.65	3.47	3.28
6.5	3.61	3.44	3.31	3.15	2.97
7.0	3.30	3.14	3.03	2.88	2.72
7.5	3.03	2.89	2.79	2.65	2.50
8.0	2.80	2.67	2.58	2.45	2.31
8.5	2.60	2.48	2.39	2.28	2.15
9.0	2.43	2.31	2.23	2.13	2.01
9.5	2.28	2.17	2.09	1.99	1.88
10	2.14	2.04	1.97	1.87	1.77
11	1.90	1.82	1.75	1.67	1.58
12	1.71	1.64	1.58	1.51	1.42
13	1.56	1.48	1.43	1.37	1.29
14	1.42	1.36	1.31	1.25	1.18
16	1.21	1.16	1.12	1.07	1.01
18	1.05	1.00	0.97	0.93	0.88
20	0.93	0.89	0.86	0.82	0.77
22	0.83	0.79	0.76	0.73	0.69
24	0.75	0.71	0.69	0.66	0.62
26	0.68	0.65	0.63	0.60	0.57
28	0.62	0.59	0.57	0.55	0.52
30	0.57	0.55	0.53	0.51	0.48
32	0.53	0.51	0.49	0.47	0.44
34	0.49	0.47	0.46	0.44	0.41
36	0.46	0.44	0.43	0.41	0.39
40	0.41	0.39	0.38	0.36	0.34
44	0.36	0.35	0.34	0.32	0.31
48	0.33	0.31	0.30	0.29	0.28
54	0.28	0.27	0.26	0.25	0.24
60	0.25	0.24	0.23	0.22	0.21
66	0.22	0.22	0.21	0.20	0.19
72	0.20	0.19	0.19	0.18	0.17

Table XId: Friction Loss Coeff. (F_f) for ε=0.0003–0.0005 ft$^{(ref)}$

	ε = 0.0003 ft			ε = 0.0004 ft		ε = 0.0005 ft	
	V_{ref} = 1500	3500	5500	1500	3500	1500	3500 fpm
D in	1200-2200	3500	5000-9900	1200-2200	2200-8500	1200-2200	2200-9900
2.0	17.00	15.36	14.81	17.67	16.19	18.31	16.96
2.5	12.81	11.59	11.18	13.30	12.20	13.76	12.75
3.0	10.18	9.22	8.90	10.55	9.69	10.91	10.11
3.5	8.39	7.61	7.34	8.69	7.98	8.97	8.32
4.0	7.10	6.44	6.22	7.35	6.75	7.58	7.03
4.5	6.13	5.57	5.37	6.34	5.83	6.53	6.07
5.0	5.38	4.88	4.72	5.56	5.11	5.72	5.32
5.5	4.78	4.34	4.19	4.93	4.54	5.08	4.72
6.0	4.29	3.90	3.77	4.43	4.08	4.56	4.24
6.5	3.89	3.53	3.41	4.01	3.69	4.12	3.83
7.0	3.55	3.23	3.12	3.66	3.37	3.76	3.50
7.5	3.26	2.96	2.86	3.36	3.09	3.45	3.21
8.0	3.01	2.74	2.65	3.10	2.86	3.19	2.96
8.5	2.79	2.54	2.46	2.88	2.65	2.96	2.75
9.0	2.60	2.37	2.29	2.68	2.47	2.75	2.56
9.5	2.44	2.22	2.15	2.51	2.31	2.58	2.40
10	2.29	2.09	2.02	2.36	2.17	2.42	2.25
11	2.04	1.86	1.79	2.10	1.93	2.15	2.00
12	1.83	1.67	1.61	1.88	1.74	1.93	1.80
13	1.66	1.52	1.47	1.71	1.58	1.75	1.63
14	1.52	1.39	1.34	1.56	1.44	1.60	1.49
16	1.29	1.18	1.23	1.33	1.23	1.36	1.27
18	1.12	1.02	1.14	1.15	1.06	1.18	1.10
20	0.99	0.90	0.99	1.01	0.94	1.03	0.97
22	0.88	0.80	0.87	0.90	0.83	0.92	0.86
24	0.79	0.72	0.78	0.81	0.75	0.83	0.77
26	0.72	0.66	0.70	0.74	0.68	0.75	0.70
28	0.66	0.60	0.64	0.67	0.62	0.69	0.64
30	0.61	0.55	0.58	0.62	0.57	0.63	0.59
32	0.56	0.51	0.54	0.57	0.53	0.59	0.55
34	0.52	0.48	0.50	0.53	0.49	0.54	0.51
36	0.49	0.45	0.46	0.50	0.46	0.51	0.48
40	0.43	0.39	0.43	0.44	0.41	0.45	0.42
44	0.38	0.35	0.38	0.39	0.36	0.40	0.37
48	0.35	0.32	0.34	0.35	0.33	0.36	0.34
54	0.30	0.28	0.31	0.31	0.28	0.31	0.29
60	0.26	0.24	0.27	0.27	0.25	0.28	0.26

Table XIe: Friction Loss Coefficients (F_f) for ε=0.001–0.1 ft

V_{ref} = 3500 ft/min Range= 1000–10,000 fpm							
	ε, ft						
D in	0.001	0.002	0.005	0.01	0.02	0.05 ft	0.1 ft
2.5	14.88	18.25	25.24	33.82	46.79	85.09	152.59
3.0	11.85	14.39	19.63	25.98	36.15	62.33	107.18
3.5	9.71	11.74	15.87	20.83	28.64	48.20	80.35
4.0	8.18	9.85	13.22	17.23	23.46	38.74	63.03
4.5	7.04	8.44	11.27	14.59	19.71	32.03	51.12
5.0	6.15	7.36	9.77	12.59	16.89	27.09	42.53
5.5	5.45	6.50	8.59	11.02	14.70	23.31	36.11
6.0	4.88	5.81	7.65	9.77	12.96	20.35	31.15
6.5	4.41	5.24	6.87	8.75	11.55	17.98	27.24
7.0	4.02	4.76	6.23	7.90	10.39	16.04	24.09
7.5	3.68	4.36	5.68	7.19	9.42	14.44	21.51
8.0	3.40	4.01	5.22	6.58	8.60	13.09	19.36
8.5	3.15	3.71	4.81	6.06	7.89	11.95	17.55
9.0	2.93	3.45	4.47	5.61	7.28	10.97	16.01
9.5	2.74	3.22	4.16	5.21	6.75	10.11	14.69
10	2.57	3.02	3.89	4.86	6.28	9.37	13.54
11	2.28	2.67	3.43	4.28	5.50	8.14	11.65
12	2.05	2.39	3.06	3.81	4.87	7.16	10.17
13	1.85	2.16	2.76	3.42	4.36	6.37	8.99
14	1.69	1.97	2.51	3.10	3.94	5.72	8.02
16	1.43	1.66	2.11	2.60	3.28	4.72	6.54
18	1.24	1.44	1.81	2.22	2.80	3.99	5.48
20	1.09	1.26	1.58	1.94	2.43	3.43	4.68
22	0.97	1.12	1.40	1.71	2.13	3.00	4.07
24	0.87	1.00	1.25	1.53	1.90	2.66	3.58
26	0.79	0.91	1.13	1.37	1.71	2.38	3.18
28	0.72	0.83	1.03	1.25	1.55	2.14	2.86
30	0.66	0.76	0.95	1.14	1.41	1.95	2.59
32	0.61	0.70	0.87	1.05	1.30	1.78	2.36
34	0.57	0.65	0.81	0.97	1.20	1.64	2.16
36	0.53	0.61	0.75	0.90	1.11	1.52	1.99
40	0.47	0.53	0.66	0.79	0.97	1.31	1.72
44	0.42	0.47	0.58	0.70	0.85	1.15	1.5
48	0.37	0.43	0.52	0.62	0.76	1.02	1.33
54	0.33	0.37	0.45	0.54	0.65	0.87	1.13
60	0.29	0.32	0.40	0.47	0.57	0.76	0.97
66	0.25	0.29	0.35	0.42	0.50	0.67	0.85
72	0.23	0.26	0.32	0.37	0.45	0.60	0.76

Table XIIa: Altitude Effects* on Air Density (df_{alt})

Altitude ft	df_{alt}	Bar.P. mmHg
-5000	1.190	904
-4500	1.170	889
-4000	1.150	874
-3500	1.130	859
-3000	1.111	844
-2500	1.092	830
-2000	1.073	815
-1500	1.054	801
-1000	1.036	787
-500	1.018	774
0	1.000	760
0	1.000	760
500	0.982	747
1000	0.965	733
1500	0.948	721
2000	0.931	708
2500	0.915	695
3000	0.898	683
3500	0.882	670
4000	0.866	658
4500	0.851	647
5000	0.835	635
5500	0.820	623
6000	0.805	612
6500	0.790	601
7000	0.776	590
7500	0.762	579
8000	0.748	568
8500	0.734	558
9000	0.720	547
9500	0.707	537
10000	0.693	527

* At 70°F

Density factor for altitude, $df_{alt} = [1-(6.73 \times 10^{-6}) \text{ Altitude}]^{5.258}$

Barometric Pressure, Bar.P = df (760 mmHg)