Then, HI duct section loss =

$$\frac{20 \text{ ft} \times 0.095}{100} = 0.019 \text{ in. wg (line 14)}$$

The loss coefficient for transition H (converging flow) is obtained from Table A-12, Figure A using θ = 30 degrees (use the upstream velocity based on 3000 cfm) to compute the V_p, assuming that there is not an instant change in the upstream airflow velocity. This will hold true for each similar fitting in this example.

$$\text{Velocity} = \frac{3000}{20} \times \frac{18}{144} = 1200 \text{ fpm}$$

$V_p = 0.09$

$$\frac{A_1}{A} = \frac{20 \text{ in.} \times 18 \text{ in.}}{20 \text{ in.} \times 14 \text{ in.}} = 1.29 \text{ and } C = 0.05$$

H fitting loss =

$$C \times V_p = 0.05 \times 0.09 = 0.005 \text{ in. wg (line 15)}$$

The loss values in column L (0.019 and 0.005) are again totaled and entered on line 15 in column M (0.024 in. wg).

7.5.2.6 Duct Section IJ

Duct section IJ is calculated as the above duct sections. The same type of transition is used (1000 cfm, 970 fpm, 13.9 in. diameter, with a 14 × 12 in. duct size selected at a 14.2 in. diameter equivalent):

IJ duct loss =

$$\frac{30 \text{ ft} \times 0.095}{100 \text{ ft}} = 0.029 \text{ in. wg}$$

If the 14.2 in. circular equivalent of the 14 ×12 in. duct is re-plotted on the chart in Figure A-1 for 1000 cfm, a velocity of 900 fpm and a friction loss of 0.080 will be obtained. A recalculation for the IJ duct loss is:

IJ duct loss =

$$\frac{30 \text{ ft} \times 0.080}{100 \text{ ft}} = 0.024 \text{ in. wg}$$

Since the new value is 0.003 in. wg, a rounded value of 0.024 in. wg is entered on line 16. However, if this were calculated on a computer, the larger (safer) amount would be used.

Transition at I (Table A-12, Figure A):

$$\frac{A_1}{A} = \frac{20 \text{ in.} \times 14 \text{ in.}}{14 \text{ in.} \times 12 \text{ in.}} = 1.67 \text{ and } C = 0.05$$

$$\text{Velocity} = \frac{2000}{20} \times \frac{14}{144} = 1029 \text{ fpm}$$

$V_p = 0.07$,

I fitting loss =

$$C \times V_p = 0.05 \times 0.07 = 0.004 \text{ in. wg (line 17)}$$

The "J" elbow is smooth, long radius without vanes (Table A-10, Figure F) having a $\frac{R}{W}$ ratio of 2.0. As $\frac{H}{W} = \frac{12}{14} = 0.86$, the loss coefficient of 0.16 is used.

By applying values of the 14.2 in. equivalent duct diameter and the duct velocity of 900 fpm to the *Reynolds Number Correction-Factor Chart*, it is found that a correction factor must be used. The actual average velocity is:

$$V = \frac{1000}{14} \times \frac{12}{144} = 857 \text{ fpm}$$

The equations under Note 3 for A-20 are solved to allow the correction factor to be obtained.

$$D = \frac{2HW}{H + W} = \frac{2 \times 12 \text{ in.} \times 14 \text{ in.}}{12 \text{ in.} + 14 \text{ in.}} = 12.92 \text{ in.}$$

$$R_e = 8.56\,DV = 8.56 \times 12.92 \times 857$$

$R_e = 94{,}780$

$R_e 10^{-4} = 9.48$

From the table (Note 3), the correction factor of 1.32 is obtained and the V_p of 0.05 for 857 fpm is used.

Fitting loss =

$$C \times V_p \times K_{Re} = 0.16 \times 0.05 \times 1.32 = 0.011 \text{ in. wg}$$

(enter on line 18).

If the K_{Re} correction factor was not used, the calculated loss of 0.008 in. wg (0.16 × 0.05) is 0.003 in. wg lower than the value used. On a long, winding duct run with many elbows, this could become significant.

The volume damper at J has the same coefficient as that used at F. Using the V_p for 857 fpm:

Damper Loss =

$$C \times V_p = 0.04 \times 0.05 = 0.002 \text{ in. wg (line 19)}$$

Figure B of Table A-15 (Tee, Rectangular Main to Round Branch) should not be used for a round tap at the end of a duct run, nor should Figure Q for a square tap under the same conditions, as the total airflow is going through the tap. The closest duct configurations in the Appendix would be the mitered elbows in Table A-10, Figures C, D, or E. The average loss coefficient value for a 90 degree turn from these figures is 1.2, which is the recommended value to use.

Obviously, if there was ample room in the ceiling, the use of a vaned- or long-radius elbow and a rectangular to round transition would be the most energy efficient and have the lowest combined pressure loss. Therefore, the loss of the fitting at the diffuser should be calculated:

Fitting loss =

$$C \times V_p = 1.2 \times 0.05 = 0.060 \text{ in. wg.}$$

(enter on line 20).

The diffuser pressure loss from Figure 7-1 for the diffuser at J includes the pressure losses for the damper with the diffuser. The 0.14 in. wg is entered on line 21 in column L.

In Table 7-1, the pressure losses on lines 16 through 21 in column L are totaled (0.241 in. wg) and the value entered on line 21 in column M and on line 16 in column N.

Starting from the bottom (line 16), the pressure losses of each section in column M are accumulated in column N, resulting in a total pressure loss of 0.492 in. wg (line 4) for the duct run B to J (the assumed longest duct run). This total is added to the 0.90 in. wg on line 3 of column M (Fan Plenum B) for the total pressure loss of 1.382 in. wg. This is the design total pressure at which supply fan B must operate for 8000 cfm. The value of 1.382 in. wg is entered on line 1 in columns N and O. The numbers in column N and O are calculated after columns A to M.

Attention is called to the progressively lower value of the velocity pressure as the velocity continues to be reduced; velocity pressure is proportional to the square of the velocity. By carefully selecting fittings with low-loss coefficients, actual dynamic pressure loss values become very low. However, straight-duct loss values per 100 ft remain constant, as these losses depend only on the friction-loss rate selected. The minor modification at the last duct section was made because of the rectangular duct size selected.

The last section of duct (IJ), with all of its fittings and the terminal device had over half the pressure loss generated by the complete duct run (BJ). This is because all of the fittings in the main run had a static regain (included in the loss coefficients), with each lowering of the airstream velocity that reduced the actual pressure loss of each section.

7.5.2.7 Duct Section FM

As the branch duct run F to M is similar to duct run G to J, one would assume the duct sizes would be the same. This assumes the branch pressure loss of the wye at F had approximately the same pressure loss as the 20 ft of duct from F to G (0.019 in. wg) and the elbow at G (0.014 in. wg for a total loss of 0.033 in. wg). However, to compute the complete duct run from A_1 to M, lines 1 to 9 (A_1 to F) in column M must be totaled (1.067 in. wg), and the result entered on line 1 (column M) of the table in Table 7-1 (a) using a new duct sizing form.

Referring again to Table A-11, Figure V (used before for the wye at F), and using the same ratios as before, $\left(\frac{A_b}{A_s} = 1.0;\ \frac{A_b}{A_c} = 0.5 \text{ and } \frac{Q_b}{Q_c} = 0.5\right)$, the *branch* loss coefficient C = 0.52.

F fitting loss =

$$C \times V_p = 0.52 \times 0.11 = 0.057 \text{ in. wg (line 2)}$$

It should be noted that the fitting *entering* velocity of 1333 fpm is used to determine the velocity pressure for the computations. The branch loss of 0.057 in. wg for fitting F is compared to the 0.033 in. wg computed above for duct EG and elbow G. As the difference between them of 0.024 in. wg is within the 0.05 in. wg allowable design difference, the fitting used at F was a good selection.

However, the A_1M duct run will have a 0.024 in. wg greater pressure loss than the A_1J duct run. It appears the assumed "longest run" did not have the greatest pressure loss although, again, the difference was within 0.05 in. wg. This also confirms the need for the use of balancing dampers in each of the 20 ×18 in. ducts at F.

The information for the "branch" volume damper at F can be copied from line 12 of Table 7-1, since all conditions are the same. This will be entered on line 3 of Table 7-1 (a). The calculations then are made for the 10 ft of 20 ×18 in. duct (FK):

FK duct loss =

$$\frac{10 \text{ ft} \times 0.095}{100} = 0.010 \text{ in. wg}$$

(enter on line 4).

The pressure losses on lines 2, 3, and 4 in column L are totaled and entered on line 4 in column M (0.071 in. wg) of Table 7-1 (a).

The pressure loss of the K to M duct section is identical to the H to J duct section, including the diffusers. Therefore, lines 15 and 21 in column M of Table 7-1 are totaled (0.265 in. wg) and entered on line 5 in columns M and N of Table 7-1 (a).

Finally, the figures in column M are entered in column N, starting from the bottom, to obtain the new total pressure loss of 1.403 in. wg for the fan B duct system (line 1, column 0). This loss is only 0.021 in. wg higher than the A_1J duct system pressure loss (Table 7-1), but it is the higher total pressure loss value to be used in the selection of Fan B.

7.5.2.8 Duct Section EN

Using the balance of the duct sizing form Table 7-1 (a), the next duct run to be sized is the branch duct EQ. The pressure loss for the duct system from A_1 to E is obtained by totaling lines 1 to 7 of Table 7-1 and entering the 1.049 in. wg value on line 7 in column M.

Data for duct section EN is obtained (2000 cfm, 1140 fpm, and 18.2 in. diameter, with 20 × 14 in. being the selected rectangular size) using the same 0.095 in. wg friction-loss rate. This rate has changed only once in this example up to this point:

EN duct loss =

$$\frac{10\text{ ft} \times 0.095}{100\text{ ft}} = 0.010\text{ in. wg}$$

(enter on line 8).

The data used before for computing the "main" loss coefficient for Wye E (Table A-11, Figure V) is again used to obtain the "branch" loss coefficient, *see* Duct Section EF.

$$\frac{A_b}{A_s} = 0.33$$

$$\frac{A_b}{A_c} = 0.25$$

$$\frac{Q_b}{Q_c} = 0.25$$

(the preliminary calculations to branch EN are verified).

C (branch) = 0.43 (by interpolation)

E fitting loss =

$$C \times V_p = 0.43 \times 0.13 = 0.056\text{ in. wg (line 9)}$$

The loss values in column L (0.010 + 0.056) are totaled and entered on line 9 in column M (0.066 in. wg).

7.5.2.9 Duct Section NP

Data for the 55 ft duct run from N to P is computed using the lower friction loss rate from duct section IJ, and the 14 × 12 in. rectangular size again is selected using 14.2 in. diameter, 0.08 in. wg per 100 ft friction loss rate, and a 900 fpm velocity.

NP duct loss =

$$\frac{55\text{ ft} \times 0.08}{100\text{ ft}} = 0.044\text{ in. wg}$$

(enter on line 10).

At N, a 45 degree entry tap is used for branch duct NS and a 30 degree transition is used to reduce the duct size for the run to P. From Table A-12, Figure A:

$$\frac{A_1}{A} = \frac{20 \times 14}{14 \times 12} = 1.67$$

$C = 0.05$ for $\theta = 30$ degree,

$$\text{Velocity} = \frac{2000}{20} \times \frac{14}{144} = 1029\text{ fpm,}$$

$V_p = 0.07$

N fitting loss =

$$C \times V_p = 0.05 \times 0.07 = 0.004\text{ in. wg (line 11)}$$

The volume damper at N has the same numbers as used above for the damper at J:

Damper loss =

$$C \times V_p = 0.04 \times 0.05 = 0.002\text{ in. wg (line 12)}$$

At 0, a smooth radius elbow with one splitter vane is selected (Table A-10, Figure G):

$\frac{R}{W} = 0.25$, $\frac{H}{W} = \frac{12}{14} = 0.86$ and $C = 0.12$ (by interpolation)

0 fitting loss =

$$C \times V_p = 0.12 \times 0.05 = 0.006\text{ in. wg (line 13)}$$

The cumulative loss of 0.056 in. wg (0.044 + 0.004 + 0.002 + 0.006) is entered on line 13 in column M.

7.5.2.10 Duct Section PQ

Data for the last 20 ft of duct is obtained from Figure A-1 and Table A-2 (500 cfm, 810 fpm, 10.7 in. diameter), which is the equivalent of a 12 × 8 in. rectangular size:

PQ duct loss =

$$\frac{20\text{ ft} \times 0.095}{100\text{ ft}} = 0.019\text{ in. wg}$$

(enter on line 14).

The loss coefficient for transition P is obtained from Table A-12, Figure A (converging flow) using θ = 45 degree:

$$\frac{A_1}{A} = \frac{14 \times 12}{12 \times 8} = 1.75$$

$C = 0.06$

Velocity = 857 (from the 14 × 12 in. duct)

P fitting loss =

$$C \times V_p = 0.06 \times 0.05 = 0.003\text{ in. wg (line 15)}$$

The fitting at Q is a mitered 90 degree change-of-size elbow (Table A-10, Figure E).

$$\frac{H}{W} = 8/12 = 0.67; \frac{W_1}{W} = \frac{16}{12} = 1.33$$

$$\text{Velocity} = \frac{500}{12} \times \frac{8}{144} = 750\text{ fpm and } V_p = 0.04$$

A fitting loss coefficient of 1.0 is selected. Plotting the data on the *Reynolds Number Correction-Factor Chart* indicates that a correction factor will be required.

$$D = \frac{2 \times 8\text{ in.} \times 12\text{ in.}}{8\text{ in.} + 12\text{ in.}} = 9.6\text{ in.}$$

$R_e = 8.56$

$DV = 8.56 \times 9.6 \times 750 = 61{,}632$

$R_e 10^{-4} = 6.16$ and $K_{Re} = 1.09$

Q fitting loss =

$$1.0 \times 0.04 \times 1.09 = 0.044\text{ in. wg}$$

(enter on line 16).

The pressure loss of 0.13 in. wg on the drawing (Figure 7-1) for the 16 × 8 in. grille is entered on line 17.

The pressure losses on lines 14-17 in column L are totaled (0.196 in. wg) and the value entered on line 17 in column M and on line 14 in column N. Starting from the bottom (line 14), the pressure losses of each section in column M are accumulated in column N, resulting in the total pressure loss of 1.367 in. wg. This is entered on line 7 in columns N and O.

The A_1M duct-run pressure loss of 1.430 in. wg is 0.063 in. wg higher than the 1.367 in. wg pressure loss of the A_1Q duct run. This gives a result that is slightly above the 0.05 in. wg suggested good design difference. Nevertheless, adding balancing dampers in the branch ducts at N, should allow the TAB technician to properly balance the system.

7.5.2.11 Duct Section NS

The pressure losses from A_1 to N (lines 7 to 9) are totaled (1.115 in. wg) and entered on line 18 in column M. The last section of the supply-duct system is sized using the same procedures and data from above:

NR duct loss =

$$\frac{8\text{ ft} \times 0.080}{100\text{ ft}} = 0.006\text{ in. wg}$$

(enter on line 19).

A 45 degree entry rectangular tap is used for the branch duct at N. From Table A-11, Figure N:

$$\frac{V_b}{V_c} = \frac{857}{1029} = 0.83\text{ (Use 1.0)}$$

$$\frac{Q_b}{Q_c} = \frac{1000}{2000} = 0.5\text{ and } C = 0.74$$

Velocity = 1029 fpm and $Vp = 0.07$

N fitting loss =

$$C \times V_p = 0.74 \times 0.07 = 0.052\text{ in. wg}$$

(enter on line 20).

The data for the volume damper in the branch duct at N, is the same as on line 12, which can be copied and entered on line 21. The total of lines 19-21 in column L of 0.060 can be entered on line 21 in column M.

Using the data from line 14:

RS duct loss =

$$\frac{20\text{ ft} \times 0.095}{100\text{ ft}} = 0.019\text{ in. wg}$$

(enter on line 22).

R Transition loss =

$$C \times V_p = 0.06 \times 0.05 \text{ (from line 15)} = 0.003 \text{ in. wg}$$

enter on line 23).

S Elbow loss =

$$C \times V_p \times K_{Re} \text{ (from line 16)} = 1.0 \times 0.04 \times 1.09 = 0.044 \text{ in. wg}$$

(enter on line 25).

The losses for Run RS in column L are totaled and 0.196 in. wg value is placed in column M on line 25 and in column N on line 22.

The section losses in column M are again added from the bottom in column N, and the total system loss from A_1 to S (1.371 in. wg) is entered on line 18 in columns N and O. This loss again is almost equal to that of the other portions of the duct system.

7.5.2.12 Balancing Damper Setting Calculations

If the NS branch loss had been substantially lower, reasonable differences could have been compensated for by adjustments of the balancing damper. The damper loss coefficient used in each case was based on θ = 0 degree (wide open). The preliminary damper setting angle θ can be calculated in this situation as follows, assuming a total system loss difference of 0.038 in. wg between points S and Q for this example:

System loss difference = 0.038 in. wg

N damper loss (set at 0 degree) = 0.002 in. wg

N damper loss (set at ? degrees) = 0.040 in. wg (0.038 + 0.002)

Damper loss =

$$C \times V_p \text{ or } C = \frac{\text{Damper loss}}{V_p} = \frac{0.040}{0.50} = 0.80$$

Referring back to Table A-15, Figure B, the loss coefficient when C = 0.80 would require a damper angle θ of about 15 degrees (by interpolation). The duct airflow and velocity at the damper would still remain at the design values. Points S and Q of the duct system would then have the same total pressure loss relative to point A_1 or fan B.

7.5.3 Additional Discussion

Other advantages of the above duct sizing procedures are when using columns M and N, the designer can observe the places in the duct system that have the greatest total pressure losses and locate where the duct construction pressure classifications change, *see* Table 4-1 and Figure 4-1 in Chapter 4. After the duct system is sized, these static pressure "flags" should be noted on the drawings as shown on Figure 7-1, to obtain the most economical duct fabrication and installation bids.

Building-pressure allowance for supply air duct systems should be determined from building ventilation requirements considering normal building infiltration. Allowance in the range of 0.02 to 0.1 in. wg for building-pressurization is normally used. The designer should determine the proper building-pressurization value based upon individual system requirements and location. Consideration should also include elevator shaft ventilation requirements, tightness of building construction, building stack effect, and fire and smoke code requirements.

Finally, the system pressure loss checklist in of Chapter 8 should be used to verify that all system component pressure losses have been included in the fan total-pressure requirements. Be sure some allowance has been added for possible changes in the field. These additional items should be shown on the duct-sizing work sheets.

DUCT SIZING WORK SHEET
(U.S. UNITS)
DATE ____________ PAGE 1 OF 1
PROJECT SAMPLE BUILDING LOCATION FIRST FLOOR SYSTEM EXHAUST AIR

	A	B	C		D	E	F	G	H	I	J	K	L	M	N	O
	DUCT RUN	SEC–TION	ITEM		FLOW CFM	FRIC-TION PER 100′	VELOC-ITY FPM	V_p	LOSS COEFF	EQUIV DIAM	RECTANGU-LAR SIZE	CORR FACT.	LOSS PER ITEM	LOSS PER SECTION	CUMULA-TIVE LOSS	TOTAL LOSS
1	PLENUM Z	A_1Z	–	H.R DEVICE	8000	–	500	–	–	–	–	–	0.30		1.272	1.272
	”	Z	–	FAN	8000	–	1595	0.16	–	–	–	–	0.24	0.54		(A_1T)
3	RUN YT	YW	30′	DUCT	8000	0.08	1500	–	–	32.8	30 × 30	–	0.024		0.732	
4	”	Y	–	SYSTEM EFFECT	8000	–	1500	–	–	–	–	P	0.280			
5	”	Y	–	TRANS	8000	–	1280	0.10	0.24	–	30 × 30 / 330	–	0.024			
6	”	Y	90°	ELBOW	8000	–	1280	0.10	0.44	–	30 × 30	–	0.044	0.372		
7	”	WU	100′	DUCT	6000	0.08	1400	–	–	28.0	30 × 22	–	0.080		0.360	
8	”	W	45°	ENT. TAP	8000 / 2000	–	1280	0.10	0.33	–	30 × 30 / 14 × 14	–	0.033			
9	”	W	–	TRANS	8000 / 6000	–	1309	0.11	0.20	–	30 × 30 / 30 × 22	–	0.022			
10	”	V	90°	ELBOW	6000	–	1309	0.11	0.16	–	30 × 22	–	0.018	0.153		
11	”	UT	20′	DUCT	3000	0.08	1180	–	–	21.7	22 × 18	–	0.016		0.207	
12	”	U	90°	ENT. TAP	6000 / 3000	–	1309	0.11	0.53	–	30 × 22 / 48 × 18	–	0.058			
13	”	U	–	TRANS	6000 / 3000	–	1091	0.07	0.25	–	30 × 22 / 22 × 18	–	0.018			
14	”	T	90°	ELBOW	3000	–	500	0.02	1.75	–	22 × 18 / 48 × 18	–	0.035			
15	”	T	–	GRILLE	3000	–	–	–	–	–	48 × 18	–	0.080	0.207		
16	”															
17	RUN WX	WX	20′	DUCT	2000	0.20	1550	–	–	15.3	* 14 × 14	1.93	0.077		0.360	
18	”	W	45°	ENT. TAP	8000 / 2000	–	1280	0.10	–0.37	–	30 × 30 / 14 × 14	–	–0.037			
19	”	X	180°	TRAMS	2000	–	1469	0.13	0.33	–	14 × 14 / 36 × 16	–	0.043			
20	”	X	–	GRILLE	2000	–	–	–	–	–	36 × 16	–	0.080			
21	”	W	SET 22°	VOL DAMP	2000	–	1469	0.13	1.52	–	14 × 14	–	0.197	0.360		
22																
23																
24																
25																

Table 7–2 Duct Sizing, Exhaust Air System – Example 2 (I–P)

NOTE: * Indicates duct lining used. Sizes are interior dimensions.

DUCT SIZING WORK SHEET
(U.S. UNITS)
DATE ____________ PAGE 1 OF 2
PROJECT SAMPLE BUILDING LOCATION CONF AREA SYSTEM SUPPLY AIR

	A	B	C		D	E	F	G	H	I	J	K	L	M	N	O
	DUCT RUN	SEC– TION	ITEM		FLOW CFM	FRIC- TION PER 100′	VELOC- ITY FPM	V_p	LOSS COEFF	EQUIV DIAM	RECTANGU- LAR SIZE	CORR FACT.	LOSS PER ITEM	LOSS PER SECTION	CUMULA- TIVE LOSS	TOTAL LOSS
1	PLE- NUM A	A	–	SYSTEM EFFECT	20,000	–	2190	–	–	40.9	44 × 32	RS	0.290		2.875	2.875
2	”	B	90°	ELBOW	20,000	–	2045	0.26	0.15	40.9	44 × 32	–	0.039	0.329		(AS)
3	RUN CS	CF	80′	DUCT	20,000	0.30	3200	–	–	34.0	–	–	0.240		2.546	
4	”	C	20°	TRANS	20,000	–	2045 / 3200	0.64	0.05	–	44 × 32 / 340	–	0.032			
5	”	D	–	SOUND ATTEN.	20,000	–	–	–	–	34.0	–	–	0.260			
6	”	E	90°	ELBOW	20,000	–	3200	0.64	0.15	34.0	–	–	0.096	0.628		
7	”	FH	50′	DUCT	10,000	0.30	2700	–	–	26.0	–	–	0.150		1.918	
8	”	F	45°	WYE	20,000 / 10,000	–	3200	0.64	0.28	34 / 26	–	–	0.179			
9	”	F	45°	ELBOW	10,000	–	2700	0.45	0.15	26.0	–	0.6	0.041			
10	”	G	90°	ELBOW	10,000	–	2700	0.45	0.15	26.0	–	–	0.068	0.438		
11	”	HO	40′	DUCT	5000	0.30	2300	–	–	20.0	–	–	0.120		1.480	
12	”	H	45°	WYE	10,000 / 5000	–	2700	0.45	0.51	26 / 20	–	–	0.230			
13	”	H	0°	VOL DAMP	5000	–	2300	0.33	0.20	20.0	–	–	0.066			
14	”	N	90°	ELBOW	5000	–	2300	0.33	0.15	20.0	–	–	0.050	0.466		
15	”	OP	30′	DUCT	4000	0.34	2250	–	–	18.0	–	–	0.102		1.014	
16	”	O	45°	WUE	5000 / 4000	–	2300	0.33	0.01	20	–	–	0.003			
17	”	O	60°	TRANS	4000	–	2250	0.32	0.06	20 / 18	–	–	0.019	0.124		
18	”	PQ	30′	DUCT	3000	0.36	2150	–	–	16.0	–	–	0.108		0.890	
19	”	P	45°	WYE	4000 / 3000	–	2250	0.32	0.01	18.0	–	–	0.003			
20	”	P	60°	TRANS	3000	–	2150	0.29	0.06	18 / 16	–	–	0.017	0.128		
21	”	QR	30′	DUCT	2000	0.32	1880	–	–	14.0	–	–	0.096		0.762	
22	”	Q	45°	WYE	3000 / 2000	–	2150	0.29	0.01	16.0	–	–	0.003			
23	”	Q	60°	TRANS	2000	–	1880	0.22	0.06	16 / 14	–	–	0.013	0.112		
24	”	–	–	**SUB–TOTAL FROM PAGE 2 0F 2**									–	0.650	0.650	
25	”															

Table 7–3 Duct Sizing, Exhaust Air System – Example 3 (I–P)

NOTE: * Indicates duct lining used. Sizes are interior dimensions.

DUCT SIZING WORK SHEET
(U.S. UNITS)
DATE ____________ PAGE 2 OF 2
PROJECT SAMPLE BUILDING LOCATION CONF AREA SYSTEM SUPPLY AIR

	A	B	C		D	E	F	G	H	I	J	K	L	M	N	O
	DUCT RUN	SEC– TION	ITEM		FLOW CFM	FRIC- TION PER 100′	VELOC- ITY FPM	V_p	LOSS COEFF	EQUIV DIAM	RECTANGU- LAR SIZE	CORR FACT.	LOSS PER ITEM	LOSS PER SECTION	CUMULA- TIVE LOSS	TOTAL LOSS
1	RUN CS	RS	30′	DUCT	1000	0.19	1290	–	–	12.0	–	–	0.057		0.650	
2	(CONT.) ”	R	45°	WYE	2000 / 1000	–	1880	0.22	0.04	14.0	–	–	0.009			
3	”	R	60°	TRANS	1000	–	1290	0.10	0.06	14 / 12	–	–	0.006			
4	”	S	45°	ELBOW	1000	–	1290	0.10	0.15	12.0	–	0.6	0.009			
5	”	S	5′	FLEX DUCT	1000	0.19	1290	0.10	–	12.0	–	1.95	0.019			
6	”	S	–	VAV BOX	1000	–	–	–	–	–	–	–	0.550	0.650		
7																
8																
9																
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23																
24																
25																

Table 7–3(a) Duct Sizing, Exhaust Air System – Example 3 (I–P) (Continued)

NOTE: * Indicates duct lining used. Sizes are interior dimensions.

7.6 RETURN AIR (EXHAUST AIR) DUCT SYSTEM–SIZING EXAMPLE 2

The exhaust air duct system of fan "Y" shown in Figure 7-1 will be sized using lower main duct velocities to reduce the fan power requirements. This will conserve energy and, therefore, lower the operating costs. However, the duct sizes will be larger, which could increase the initial cost of the duct system.

Attention is called to the discussion in Section 5.42. All of the static pressure and total pressure values are negative, with respect to atmospheric pressure on the suction side of the fan. Applying this concept to Equation 5-5:

Fan $SP = TP_d - TP_s - V_{pd}$ (Equation 5-4)

Fan $SP = TP_d - (-TP_s) - V_{pd}$

Fan $SP = TP_d + TP_s - V_{pd}$

as $TP = SP + V_p$, then:

Equation 7–2

$$\text{Fan } TP = TP_d + TP_s$$

Where:

$TP_d = TP$ of fan discharge

$TP_s = TP$ of fan suction

Using the suction side of Equation 7-2, all of the system pressure-loss values for the exhaust system (suction side of the fan) will be entered on the worksheet as positive numbers.

7.6.1 Exhaust Air Plenum Z

Pressure-loss data for the discharge side of the heat-recovery device A1Z is entered on line 1 of Table 7-2 in column L (0.30 in. wg). As the backwardly-curved blade fan Z free discharges into the plenum, a tentative fan selection must be made in order to obtain a velocity or velocity pressure to use to calculate the pressure loss. Most centrifugal fans are rated with duct connections on the discharge side. A loss due to "no static regain" must be added for the free discharge into the plenum.

From manufacturer's data, $Vp = 0.16$ and $C = 1.5$ from Table A-13, Figure I:

Z Fan pressure loss =

$$C \times V_p = 1.5 \times 0.16 = 0.24 \text{ in. wg}$$

(enter on line 2).

The plenum loss total of 0.54 in. wg is entered on line 2 in column M.

7.6.2 Exhaust Air System

7.6.2.1 Duct Section YW

Using 8000 cfm, 1500 fpm is selected from the chart in Figure A-1, which establishes the duct-friction loss at 0.08 in. wg per 100 ft of duct and the diameter at 32.8 in. From Table A-2, a 30 × 30 in. rectangular duct can be selected for the YW duct section and the computed friction loss value entered in column L.

YW duct loss =

$$\frac{30 \text{ ft} \times 0.08}{100} = 0.024 \text{ in. wg}$$

(enter on line 3).

The fan-intake connection must be examined for a possible System-Effect Factor, which can be added to the system losses, or deducted from the fan rating. For this example, it will be added to the system losses. Using a radius elbow with an inlet transition*, see* Figure 6-10a and no duct between, R/H = 0.75 indicates the use of the "P" System Effect Curve. Using the chart in Figure 6-1, a velocity of 1500 fpm indicates a System Effect Factor of 0.28 in. wg (entered on line 4).

The use of an inlet box, *see* Figure 6-20, would reduce the loss.

The dynamic friction loss of the elbow and transition must also be computed. Table A-7, Figure F can be used for the elbow, and Table A-8, Figure D for the transition.

Transition Y:

$$\tan\left(\frac{\theta}{2}\right) = \frac{D - 1.13\sqrt{HW}}{2L} = \frac{33 - 1.13\sqrt{30 \times 30}}{2 \times 2}$$

$$\tan\left(\frac{\theta}{2}\right) = \frac{33 - 33.9}{4} = 0.225$$

$$\frac{\theta}{2} = 12.68 \text{ degrees and } \theta = 25.36 \text{ degrees}$$

From Table A-8, Figure B:

$$\frac{A_1}{A < 2} \text{ and } C = 0.24 \text{ (by interpolation)}$$

$$\text{Velocity} = \frac{8000}{30} \times \frac{30}{144} = 1280 \text{ fpm}$$

From Table A-4 or by calculation,

V_p = 0.10 in. wg

Y Transition loss =

$$C \times V_p = 0.24 \times 0.10 = 0.024 \text{ in. wg}$$

(enter on line 5).

Elbow Y:

$\frac{H}{W} = 1.0$, $\frac{R}{W} = 0.75$, $C = 0.44$

Using the equivalent diameter, a quick check of the *Reynolds Number Correction-Factor Chart* on page A.15 indicates that no correction is needed.

Y Elbow loss =

$$C \times V_p = 0.44 \times 0.10 = 0.044 \text{ in. wg}$$

(enter on line 6).

Note that the combined pressure loss of 0.348 in. wg (0.280 + 0.024 + 0.044) for the system effect, transition and elbow are far greater than the loss when using an inlet box (loss coefficient of 1.0):

Inlet box loss =

$$C \times V_p = 1.0 \times 0.10 = 0.10 \text{ in. wg}$$

The total for YW (0.372) is entered on line 6 in column M.

7.6.2.2 Duct Section WU

Using 6000 cfm and 0.8 in. wg per 100 ft, 1400 fpm is established with 28.0 in. diameter. Using Table A-2 rectangular size of 30 × 20 in. is selected (keeping one side the same size).

WU duct loss =

$$\frac{100\,ft \times 0.08}{100} = 0.08 \text{ in. wg}$$

(enter on line 7).

A converging 45 degree entry fitting will be used at W., *see* Table A-10, Figure F.

To obtain the "main" loss coefficient, the note in Fitting A-10F refers to Fitting A-10B:

Using Table A-10B (Main Coefficient):

$$\frac{Q_b}{Q_c} = \frac{2000}{8000} = 0.25 \text{ and } C = 0.33$$

(by interpolation)

W fitting loss =

$$C \times V_p = 0.33 \times 0.10 = 0.033 \text{ in. wg}$$

(enter on line 8).

Note that 0.10 is the velocity pressure of the 30 × 30 in. downstream section (note direction of flow).

The diverging flow transition at W with an included angle of 30 degree uses Table A-8, Figure E because of the change of only one duct dimension.

$$\frac{A_1}{A} = \frac{30 \times 30}{30 \times 22} = 1.36 \text{ (use 2) and } C = 0.20$$

Upstream section velocity =

$$\frac{6000}{30} \times \frac{22}{144} = 1309 \text{ fpm.}$$

V_p = 0.11 (from Table A-4 or by calculation)

W transition fitting loss =

$$C \times V_p = 0.20 \times 0.11 = 0.022 \text{ in. wg}$$

(enter on line 9).

Using a radius elbow without vanes (Table A-7, Figure F) at V, the following data is used:

$$\frac{H}{W} = \frac{22}{30} = 0.73 \text{ and } \frac{R}{W} = 2.0$$

$C = 0.16$

Again, using the equivalent diameter of 28.0 and the velocity of 1309 fpm, a check of the *Reynolds Number Correction-Factor Chart* indicates that no correction is needed.

V fitting loss =

$$C \times V_p = 0.16 \times 0.11 = 0.018 \text{ in. wg}$$

(enter on line 10).

As before, the total section loss of 0.145 in. wg is entered in column M.

7.6.2.3 Duct Section UT

The total-pressure loss is always the same as the static pressure when there is no velocity change. For the duct section UT this equals:

UT duct loss =

$$\frac{20 \text{ ft} \times 0.08}{100} = 0.016 \text{ in. wg} = 0.016$$

(enter on line 11).

From Figure A-1 where a 21.7 in. diameter duct and 1180 fpm was obtained for 3000 cfm. A 22 × 18 in. rectangular duct is selected from Table A-2. A converging 90 degree tee fitting (Table A-10, Figure D) will be used at U, but the "main" loss coefficient is obtained from Figure A-10B.

$$\frac{Q_b}{Q_c} = \frac{3000}{6000} = 0.5 \text{ and } C = 0.53$$

U fitting loss =

$$0.53 \times 0.11 \text{ (downstream } V_p) = 0.058 \text{ in. wg}$$

(enter on line 12).

The U transition loss coefficient is found in Table A-8, Figure B and the following data computed:

$$\frac{A_1}{A} = \frac{30 \times 22}{22 \times 18} = 1.67 \text{ (use 2)}$$

$\theta = 30$ degree

$C = 0.25$

$$\text{Velocity} = \frac{3000}{22} \times \frac{18}{144} = 1091 \text{ fpm}$$

$V_p = 0.07$ (upstream duct)

U fitting loss =

$$C \times V_p = 0.25 \times 0.07 = 0.018 \text{ in. wg}$$

(enter on line 13).

The pressure loss for the change-of-size elbow at T will again be computed using Table A-7, Figure E. Caution should be used to determine airflow direction:

$$\frac{H}{W} = \frac{18}{48} = 0.38, \quad \frac{W_1}{W} = \frac{24}{48} = 0.5$$

$C = 1.75$ (by interpolation and extrapolation)

Velocity of the upstream section (grille size) =

$$\frac{3000}{48} \times \frac{18}{144} = 500 \text{ fpm}$$

$V_p = 0.02$

T fitting loss =

$$C \times V_p = 1.75 \times 0.02 = 0.035 \text{ in. wg}$$

(enter on line 14).

Turning vanes could be added to the change-of-size mitered elbow, but no loss coefficient tables are available. If single-blade turning vanes reduce the C = 1.2 of a standard 90 degree mitered elbow to about C = 0.15, the C – 1.75 used above could be reduced to approximately C = 0.22 (using the same ratio).

The pressure loss of 0.08 in. wg for the exhaust grille at T is taken from Figure 7-1 and entered on line 15.

The section losses in column M are again added from the bottom in column N, and the Y fan duct system total of 1.272 in. wg entered on line 1 in columns N and O.

7.6.2.4 Duct Section WX (Modified Design Method)

Branch WX must now be sized, but a visual inspection indicates that the pressure drop from W to X would be much less than that of the long run from W to T. The cumulative loss of 0.360 in. wg for duct run W to T (line 7, column N), is also the total pressure loss requirement for the short 20 ft duct run. A 0.05 in. wg value is an acceptable pressure difference between outlets or inlets on the same duct run.

In an attempt to dissipate this pressure, a velocity of 1550 fpm and a duct friction loss rate of 0.2 in. wg per 100 ft (15.3 in. diameter) are selected for the 2,000 cfm flow rate (Figure A-1). One inch thick duct lining (correction factor = 1.93 from Figure A-2 and Table A-1) also can be added for noise control and increased friction. A balancing damper is to be used for final adjustments. The computations using this modification of the design method are:

WX duct loss =

$$\frac{20 \text{ ft} \times 0.2}{100 \text{ ft}} \times 1.93 = 0.077 \text{ in. wg}$$

(enter on line 17).

Select the rectangular size of 14 × 14 in. from Table A-2.

The converging 45 degree entry fitting used at W (Table A-10, Figure F) is reviewed again to determine the branch loss coefficient.

$$\frac{Q_b}{Q_c} = 0.25,$$