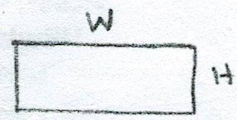
Duct Design

- **Introduction.**

In any mechanical – circulation heating, cooling, or ventilating system the fan or fans must have adequate capacity to deliver the air quantity required at a static pressure equal to or slightly greater than the total resistance offered by the duct system.

The sizes of the ducts are set by the maximum air velocities which can be used without causing undue noise or without causing exessive friction loss.

For a rectangular duct, a ratio of $\frac{W}{H}$ is called aspect ratio, and it is equal to 6:1 (good practice), and the ratio should never exceed 10:1



- **Duct – design procedure :–**

1. Lay out the most convenient system of placing the various ducts to obtain adequate distribution and to facilitate construction.

2. Calculate the cfm requirements at each duct outlet, zone of the building (Heating or Cooling load).

3. Determine the sizes of these outlet branches, using a proper velocity or pressure drop to deliver the required quantity.

4. Calculate the size of each duct by one of the following methods:

(a) The Assumed - Velocity Method, (Velocity - reduction method):

تستخدم لمنظومة الناسب بسيطة نسبياً وتكون السيطرة على الجريان في الفروع (branches) باستخدام dampers

The highest velocity is taken at the fan outlet, and the velocities are lowered in the main after various branches are taken off.

(b) The constant - pressure - Drop Method, (Equal - friction method)

(c) Balanced - Pressure - Loss Method.

هذه الطريقة تجمع بين (b & a) ولكن مقدار الانخفاض في الضغط في الفروع تكون مماثلة لـ (Main Duct)

(d) Static - Regain Method.

5. Pressure losses in a duct:

It is occurs from:

i. frictional resistance to flow

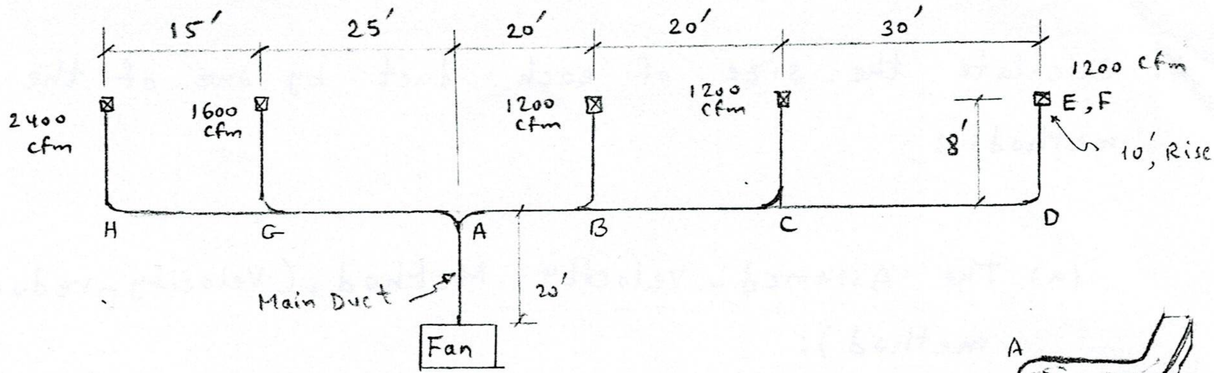
ii. changes of area (shock losses)

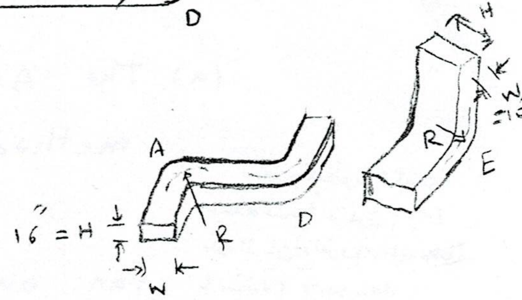
iii. " in diriction (shock & turbulence)

يقل الضغط نتيجة زيادة سرعة جريان الهواء، حيث تزداد السرعة عند تصغير مساحة مقطع الانبوب، اما عند زيادة المساحة فتقل السرعة ويزداد الضغط ويسمى بـ (diffusion)

Ex. 1

Design a duct system supplying several offices, as shown in fig. The maximum air capacity required is shown. The building limitations are such that the depth of the trunk ducts cannot exceed 16", and the vertical flues cannot be deeper than 10".





solution (based on, b- method)

Total cfm = 4000 + 3600 = 7600 cfm

The velocity at main duct is taken as 1200 fpm (Table 12-4)

The duct area, $A = \frac{HW}{144}$ (ft^2)

$$Q = AV = \left(\frac{H \times W}{144}\right)(V)$$

$$7600 = \left(\frac{16 \times W}{144}\right)(1200)$$

$\therefore$ W = 57"

From table (12-2), the circular equivalent (D) is,

D = 31.5"

From Fig.(12-4), the friction loss in the main duct (7600 cfm, D = 31.5")

f = 0.076 (in. H_2O / 100')

branch (AB), 3600 cfm, f = 0.076

From Fig. (12-4), $\therefore$ D = 23.4"

From Table (12-2), $\therefore$ W = 30" (when H = 16")

branch (BC), 2400 cfm, f = 0.076

From Fig. (12-4), $\therefore$ D = 20.3"

From Table (12-2), $\therefore$ W = 22" (when H = 16")

branch (CDE), 1200 cfm, f = 0.076

From fig. (12-4), $\therefore$ D = 15.2"

From table (12-2), $\therefore$ W = 12" (when H = 16") riser (EF) , 1200 cfm , $f = 0.076$

from fig. (12-4) , $\therefore$ $D = 15.2''$

From table (12-2) , $\therefore W = 20''$ (when $H = 10''$)

Check about the velocity in the riser EF

$$V = \frac{144 * Q}{HW} = \frac{144 * 1200}{(20)(10)} = 864 \text{ fpm}$$

This value is compared with the maximum recommended in table (12-4) , it is **acceptable**.

For the left branch , employ the same methods.

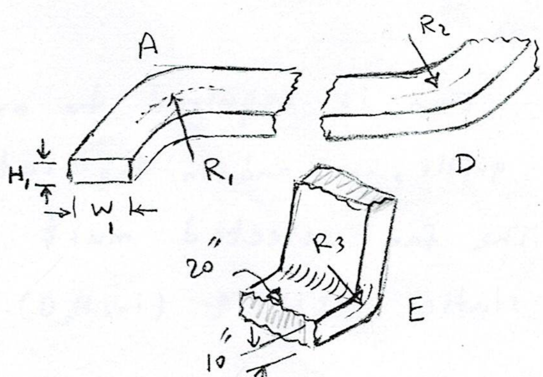
To find the (L/W.) values for the appropriate elbows , use fig (12-8)

$$\frac{L}{W} = \left[0.33 \frac{R}{W}\right]^{-2.13 \left(\frac{H}{W}\right)^{0.126}}$$

لغرض اختيار (Fan) المناسبة يتم اختيار
أطول مسار ثم نحسب Leq

(AF) is the longest duct

$$L_{eq} = \left(\frac{L}{W}\right) * \left(\frac{W}{12}\right) \quad \text{(ft)}$$



ان قيمة ($\frac{H}{W}$) لا تزيد عن (2) لذلك نأخذه
قيمة (R/W) = 1.5 ، بينما عندما تكون ($\frac{H}{W}$)
(2) فالنزمان ($\frac{R}{W}$) نأخذها 0.75 .

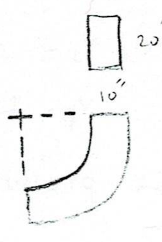
* $R/W = 1.5$ for branches.

* $R/W = 0.75$ for riser

$$\therefore \quad L_{eq_A} = (4)\left(\frac{\overset{30}{\cancel{32}}}{12}\right) = 10.7'$$

$$L_{eq_D} = (4.7)\left(\frac{12}{12}\right) = 4.7'$$

$$L_{eq_E} = (25)\left(\frac{10}{12}\right) = 21'$$



$$L_{eq_F} = (25)\left(\frac{10}{12}\right) = 21'$$

$\therefore$ Total equivalent length for elbows $= 10.7 + 4.7 + 21 + 21$

$= 57.4'$

Total length $= 20' + 20 + 20 + 30 + 8 + 10 + 57.4 = 165.4'$

• Calculation of Frictional loss :

(Total equivalent length) $\simeq$ (Length) + (equivalent additional length for elbows)

$= 108 + 57.4 = 165.4'$

Total duct & elbow friction loss $= 165.4 * 1.1 * \frac{0.076}{100}$ (safty factor 10%)

$= 0.138$ in. H_2O

$$* \; SPR = 0.5 \left\{ \frac{(1200-864)(1200+864)}{16040000} \right\} = 0.022 \text{ in. } H_2O$$

The net static pressure loss in duct, bends, ...

$= 0.138 - 0.022 = 0.116$ in. H_2O

Fan is required to overcome the accessory equipment (filters, grille, ---) and in the return system.
The fan selected must have a static pressure not less the total static pressure (in. H_2O) when delivering 7600 cfm.

$$* \text{ (static pressure regain) } SPR = \frac{1}{2}\left\{\left(\frac{V_s}{4005}\right)^2 - \left(\frac{V_f}{4005}\right)^2\right\} \quad (\text{when } V_f < V_s)$$

or

$$= \frac{1}{2}\left\{\frac{(V_s - V_f)(V_s + V_f)}{16040000}\right\}$$

where, V_s = start velocity,

V_f = final velocity

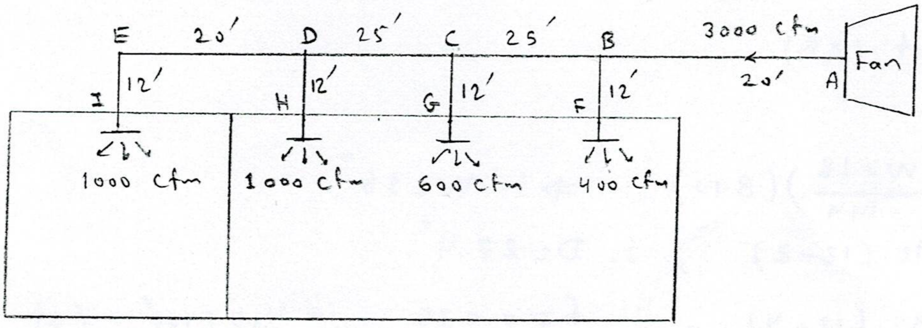
$$\text{(static pressure loss) } SPL = 1.05\left\{\left(\frac{V_s}{4005}\right)^2 - \left(\frac{V_f}{4005}\right)^2\right\} \quad (\text{when } V_f > V_s)$$

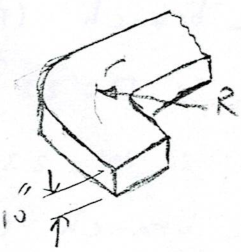
- Static – Regain Method of Design:

Figs. (12-11) & (12-12) have been prepared to facilitate computations, table (12-6) can be used to advantage where the pressure drop between outlets is large because of the great length of the duct or because of fitting losses.

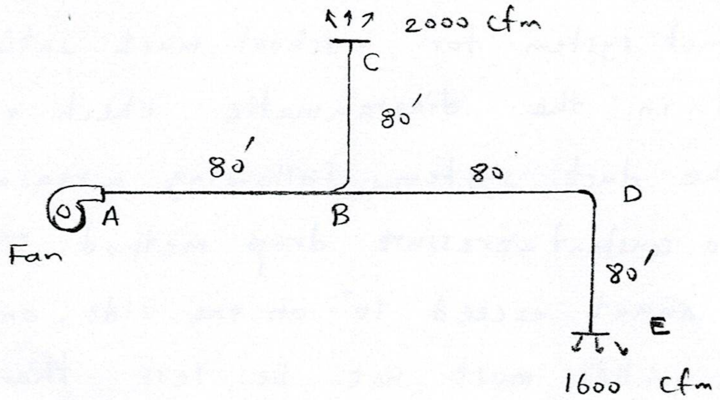
Ex. 2

A duct system for a school must satisfy the conditions indicated in the diagrammatic skech of fig shown. Size the duct system, following a reasonable design and using a constant-pressure drop method. The maximum depth of duct cannot exceed 10" on one side, and the pressure at the outlet grilles must not be less than 0.05 in. of water.





Q1. A standard air passes through the duct system of a residence as shown in fig. The average velocity at main duct is 800 fpm. The duct depth is chosen to be (18"), by using the constant - pressure drop method find the ducts size and the total pressure at point (A).



Solution

- Main Duct (AB)

$Q = A \cdot V$

$3600 = \left(\frac{W * 18}{144}\right)(800) \Rightarrow \therefore W = 36''$

From table (12-2) , $\therefore D = 27.4''$

From Fig. (12-4) , $\therefore f = 0.035$ in $H_2O/100'$ (at 3600 cfm, $D = 27.4''$)

- branch (BC) [2000 cfm, f = 0.035)

$\therefore D = 22''$

$\therefore W = 23''$

- branch (DE) [1600 cfm, f = 0.035)

$D = 20.5''$

$\therefore W = 19''$

check :

$Q = A \cdot V$

$$1600 = \left(\frac{19 * 18}{144}\right) * V$$

$\therefore V = 674$ fpm

The velocity is O.K.

$$Leq_{fD} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right)$$

$$= (4.2)\left(\frac{19}{12}\right) = 6.65'$$ $\frac{R}{W} = 1.5$

Total length $= 80 + 80 + 80 + 6.65 = 246.65'$

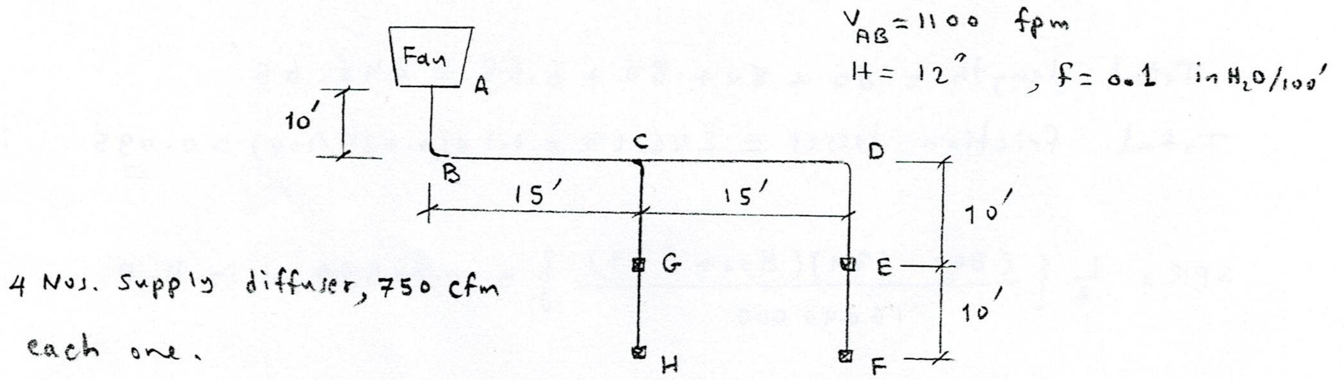
Total friction losses $= 246.65 * 1.1 * (0.035/100) = \underline{0.095}$ in. H_2O

$$SPR = \frac{1}{2}\left\{\frac{(800-674)(800+674)}{16040\,000}\right\} = 0.00579 \text{ in. } H_2O$$

Net static pressure loss $= 0.095 - 0.00579$

$= \underline{0.08921}$ in. H_2O

Q2. Air Passes through the duct system of an office as shown in fig. The average velocity at main duct is 1100 fpm. The duct depth is chosen to be (12"), by using the constant-pressure drop method ($f = 0.1$ in $H_2O/100'$), find the ducts size and the total pressure at point A.



Solution

Main Duct (ABC)

$Q = 3000$ cfm

$= A.V = \left(\frac{W * 12}{144}\right) * 1100 \quad \Rightarrow \therefore W = 32.7"$

$\& \ D = 21"$

branch (CG) & (CDE) (1500 cfm, $f = 0.1$)

$D = 16"$ $\quad \therefore W = 18"$

branch (GH) & (EF) (750 cfm, $f = 0.1$)

$D = 12.5"$ $\quad \therefore W = 11"$

check

$750 = \left(\frac{12 \times 11}{144}\right).V \quad \Rightarrow \therefore V = 818$ fpm

$L_{eq_B} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right) = (3.6)\left(\frac{32.7}{12}\right) = 9.81'$ $\qquad \frac{H}{W} = 0.367$

$L_{eq_D} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right)$ $\qquad\qquad$ $\frac{H}{W} = \frac{12}{18} = 0.666$

$= (4.1)\left(\frac{18}{12}\right) = 6.15'$

$L_{eq\,total} = 9.81 + 6.15 = 16'$

Total length $= 10 + 15 + 15 + 10 + 10 + 16 = 76'$

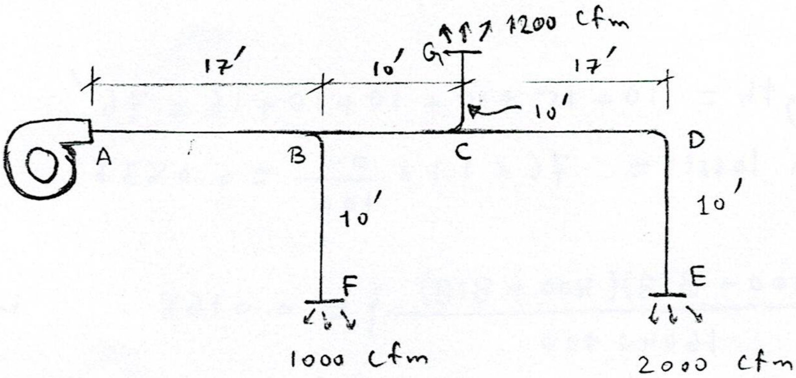
Total friction losses $= 76 * 1.1 * \frac{0.1}{100} = 0.0836$ in H_2O

$S.P.R = \frac{1}{2}\left\{\frac{(1100 - 818)(1100 + 818)}{16040\,000}\right\} = 0.0168$ in H_2O

$\therefore$ Net static press. loss $= 0.0836 - 0.0168$

$= 0.0667$ in H_2O

Q_3. Air passes through the duct syitem of industrial building as shown in fig. The average velocity at main duct is 1300 fpm. The duct depth is chosen to be (16"), by using the constant pressure drop method (f = 0.13 in H_2O / 100'), find the ducts size and the total pressure at point A.



Solution

Main Duct (AB)

$Q = 1000 + 2000 + 1200 = 4200$ cfm

$Q = A.V = \left(\frac{W*16}{144}\right) * 1300 = 4200$

$\therefore W = 29''$

& $D = 23.3''$

branch BF (1000 cfm, f = 0.13)

$\therefore D = 13.5''$ $\therefore W = 10''$

branch CG (1200 cfm, f = 0.13)

$D = 14''$ $\therefore W = 11''$

branch CDE (2000 cfm, f = 0.13)

$D = 17.5''$ $\therefore W = 16''$

check

$2000 = \left(\frac{16*16}{144}\right) . V \Rightarrow \therefore V = 1125$ fpm

$L_{eq_D} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right) = (4.5)\left(\frac{16}{12}\right) = 6'$ $\frac{H}{W} = 1$ & $\frac{R}{W} = 1.5$

Total length $= 17 + 10 + 17 + 10 + 6 = 60'$

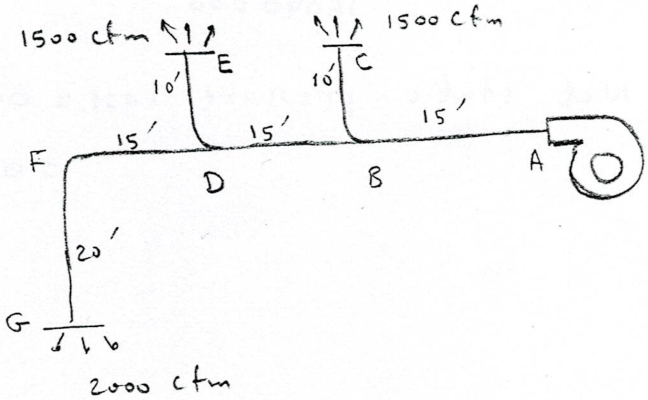
Total friction losses $= 60 * 1.1 * \frac{0.13}{100} = 0.0858$

$$SPR = \frac{1}{2}\left\{\frac{(1300-1125)(1300+1125)}{16040000}\right\} = 0.0132$$

Net static pressure loss $= 0.0858 - 0.0132$

$= \underline{0.0726}$

Q4. A duct system for a school must satisfy the conditions indicated in the diagrammatic skech of fig. shown. The maximum depth of duct cannot exceed (16") on one side. The average velocity at main duct is (1250 fpm). By using the constant-pressure drop method find the ducts size and the total pressure at point (A) if (f = 0.09 in H_2O/100')



solution

- Main duct (AB):

$Q = A.V$

$5000 = \left(\frac{W.H}{144}\right).V = \left(\frac{W*16}{144}\right)*1250$

$\therefore W = 36''$

- branch CB: (1500 cfm, f = 0.09) [branch DE same]

$D = 16.5''$ $\therefore W = 14''$

- branch BD: (3500 cfm, f = 0.09)

$D = 23''$ $\therefore W = 28''$

- branch DFG: (2000 cfm, f = 0.09)

$D = 18.4''$ $\therefore W = 18''$

check

$2000 = \left(\frac{18*16}{144}\right)*V$ $\Rightarrow \therefore V = 1000$ fpm it is O.K.

$Leq_F = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right) = (4.3)\left(\frac{18}{12}\right) = 6.45'$ $\frac{H}{W} = 0.88$ & $\frac{R}{W} = 1.5$

Total length $= 65 + 6.45 = 71.45'$

Total friction losses $= 71.45 \times 1.1 \times \frac{0.09}{100} = 0.0707$ in H_2O

$SPR = \frac{1}{2}\left\{\frac{(1250-1000)(1250+1000)}{16040000}\right\} = 0.0175$

Net static pressure loss $= 0.0707 - 0.0175$

$= 0.053$

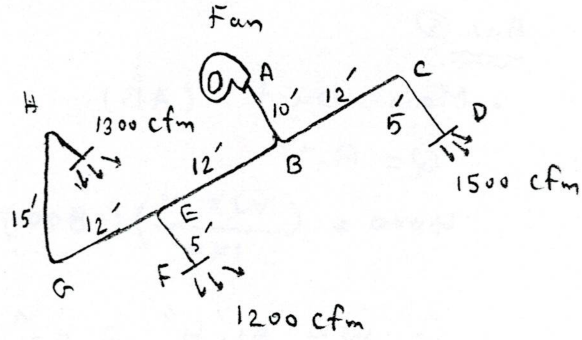
Q5

Residence

$V_{AB} = 800$ fpm

depth (trunk ducts) = 14"

" (riser) = 10"



Use the constant-pressure drop method to compute:

i. Ducts size.

ii. Total pressure loss at A.

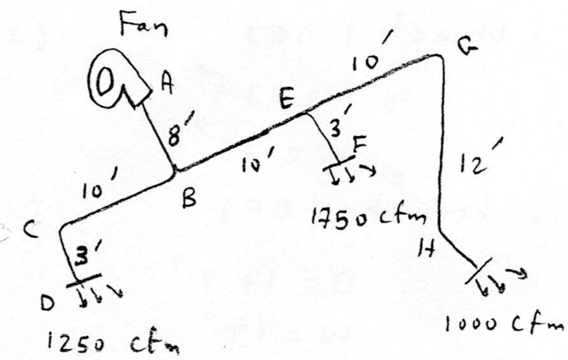
Q6

Office

$V_{AB} = 1200$ fpm

depth (trunk ducts) = 16"

" (riser) = 10"



Use the constant-pressure drop method to compute:

i. Ducts size

ii. Total pressure loss at A.

Ans. 5

- Main Duct (AB)

$Q = A \cdot V$

$4000 = \left(\frac{W * 14}{144}\right)(800)$

$\therefore W = 51.4'' \approx 52''$

$D = 28.1''$

$f = 0.04$ in. $H_2O/100'$

- branch (BCD) , (1500 cfm)

$\therefore D = 19.5''$

$W = 23''$

- branch (BE) , (2500 cfm)

$\therefore D = 23.5''$

$W = 35''$

- branch (EF) , (1200 cfm)

$\therefore D = 17.7''$

$W = 19''$

- branch (EG) , (1300 cfm)

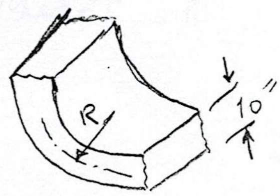
$\therefore D = 18.3''$

$W = 20''$

- branch riser (GH) , (1300 cfm)

$\therefore D = 18.3''$

$H = 30''$



Check

$Q = A \cdot V$

$1300 = \left(\frac{30 * 10}{144}\right) V$

$\therefore V = 624$ fpm

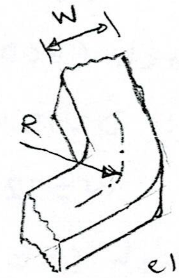
but the range of velocity from table (12-4) is (650-800) fpm then we will chose 650 fpm

$$1300 = \left(\frac{H * 10}{144}\right) * 650$$

$\therefore H = 28.8'' \approx 29''$

$$L_{eq} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right)$$

- elbow (B)



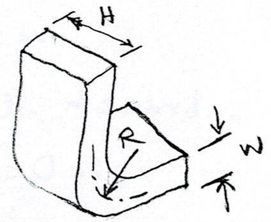
elbow - B

$\frac{H}{W} = \frac{14}{35} = 0.4$, $\frac{R}{W} = 1.5$

$\therefore \frac{L}{W} = 3.8'$

$$L_{eq_B} = (3.8)\left(\frac{35}{12}\right) = 11.1'$$

- elbow (G)



elbow _ G

$\frac{H}{W} = \frac{29}{10} = 2.9$, $\frac{R}{W} = 0.75$

$\therefore \frac{L}{W} = 30'$

$$L_{eq_G} = (30)\left(\frac{10}{12}\right) = 25'$$

also $L_{eq_H} = 25'$

Total equivalent length $= 10 + 12 + 12 + 15 + (11.1 + 25 + 25)$
$= 110.1'$

Total friction loss $= 110.1 * 1.1 * \frac{0.04}{100} = 0.048$ in. H_2O

$$SPR = \frac{1}{2}\left[\frac{(800-650)(800+650)}{16\ 040\ 000}\right] = 0.00678 \text{ in. } H_2O$$

Net static pressure loss $= 0.048 - 0.00678$
$= 0.0416$ in. H_2O

Ans. 6

- Main Duct (AB)

$Q = A \cdot V$

$4000 = \left(\frac{W * 16}{144}\right) * 1200$

$\therefore W = 30''$

$D = 23.7''$

$f = 0.09$ $in. H_2O / 100'$

- branch (BCD), (1250 cfm)

$\therefore D = 15.4''$

$W = 12.5 \simeq 13''$

- branch (BE), (2750 cfm)

$\therefore D = 20''$

$W = 21''$

- branch (EF), (1750 cfm)

$\therefore D = 17.2''$

$W = 16''$

- branch (EG), (1000 cfm)

$\therefore D = 14.2''$

$W = 11''$

- branch riser (GH), (1000 cfm)

$\therefore D = 14.2''$

$H = 17''$

check

$Q = A \cdot V$

$1000 = \left(\frac{10 * 17}{144}\right) V$

$\therefore V = 847$ fpm O.K.

$L_{eq} = \left(\frac{L}{W}\right)\left(\frac{W}{12}\right)$

• elbow (B)

$$\frac{H}{W} = \frac{16}{21} = 0.76 \qquad , \frac{R}{W} = 1.5$$

$$\therefore \frac{L}{W} = 4.3$$

$$L_{eq_B} = (4.3)\left(\frac{21}{12}\right) = 7.5'$$

• elbow (G)

$$\frac{H}{W} = \frac{17}{10} = 1.7 \qquad , \frac{R}{W} = 1.5$$

$$\therefore \frac{L}{W} = 4.9$$

$$L_{eq_G} = (4.9)\left(\frac{10}{12}\right) = 4.1'$$

also $L_{eq_H} = 4.1'$

Total equivalent length $= 8 + 10 + 10 + 12 + (7.5 + 4.1 + 4.1)$

$= 55.7'$

Total friction loss $= 55.7 * 1.1 * \frac{0.09}{100} = 0.055$ in. H_2O

$$SPR = \frac{1}{2}\left[\frac{(1200 - 847)(1200 + 847)}{16\ 040\ 000}\right] = 0.0225 \text{ in. } H_2O$$

Net static pressure loss $= 0.055 - 0.0225$

$= 0.0324$ in. H_2O