Refrigeration and Air conditioning Engineering.

3rd year – refrigeration and Air conditioning Course

Lecture -7-

Duct design

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Duct Design Methods

Duct design methods for HVAC systems and for exhaust systems conveying vapors, gases, and smoke are the :

1- equal friction method

2-the static regain method

3- T-method.

The section on Industrial Exhaust System Duct Design presents the design criteria and procedures for exhaust systems conveying particulates.

Equal friction and static regain are non - optimizing methods, while the T-method is a practical optimization method. To ensure that system designs are acoustically acceptable, noise generation should be analyzed and sound attenuators and/or acoustically lined duct provided where necessary. Dampers must be installed throughout systems designed by equal friction, static regain, and the T-method because inaccuracies are introduced into these design methods by duct size round-off and the effect of close coupled fittings on the total pressure loss calculations.

Equal Friction Method

In the equal friction method, ducts are sized for a constant pressure loss per unit length. The shaded area of the friction chart is the suggested range of friction rate and air velocity.

When energy cost is high and installed ductwork cost is low, a low friction rate design is more economical. For low energy cost and high duct cost, a higher friction rate is more economical.

After initial sizing, calculate the total pressure loss for all duct sections, and then resize sections to balance pressure losses at each junction.

The objective of the static regain method is to obtain the same static pressure at diverging flow junctions by changing downstream duct sizes.

HVAC DUCT DESIGN PROCEDURES

1- Duct dimensions

The general procedure for HVAC system duct design is as follows:

a) Study the building plans, and arrange the supply and return outlets to provide proper distribution of air within each space. Adjust calculated air quantities for duct heat gains or losses and duct leakage. Also, adjust the supply, return, and/or exhaust air quantities to meet space pressurization requirements.

b) Select outlet sizes from manufacturers' data.

c) Sketch the duct system, connecting supply outlets and return intakes with the air-handling units/air conditioners. Space allocated for supply and return ducts often dictates system layout and ductwork shape. Use round ducts whenever feasible.

d) Divide the system into sections and number each section. A duct system should be divided at all points where flow, size, or shape changes. Assign fittings to the section toward the supply and return (or exhaust) terminals.

e) Size ducts by the selected design method. Calculate system total pressure loss; then select the fan.

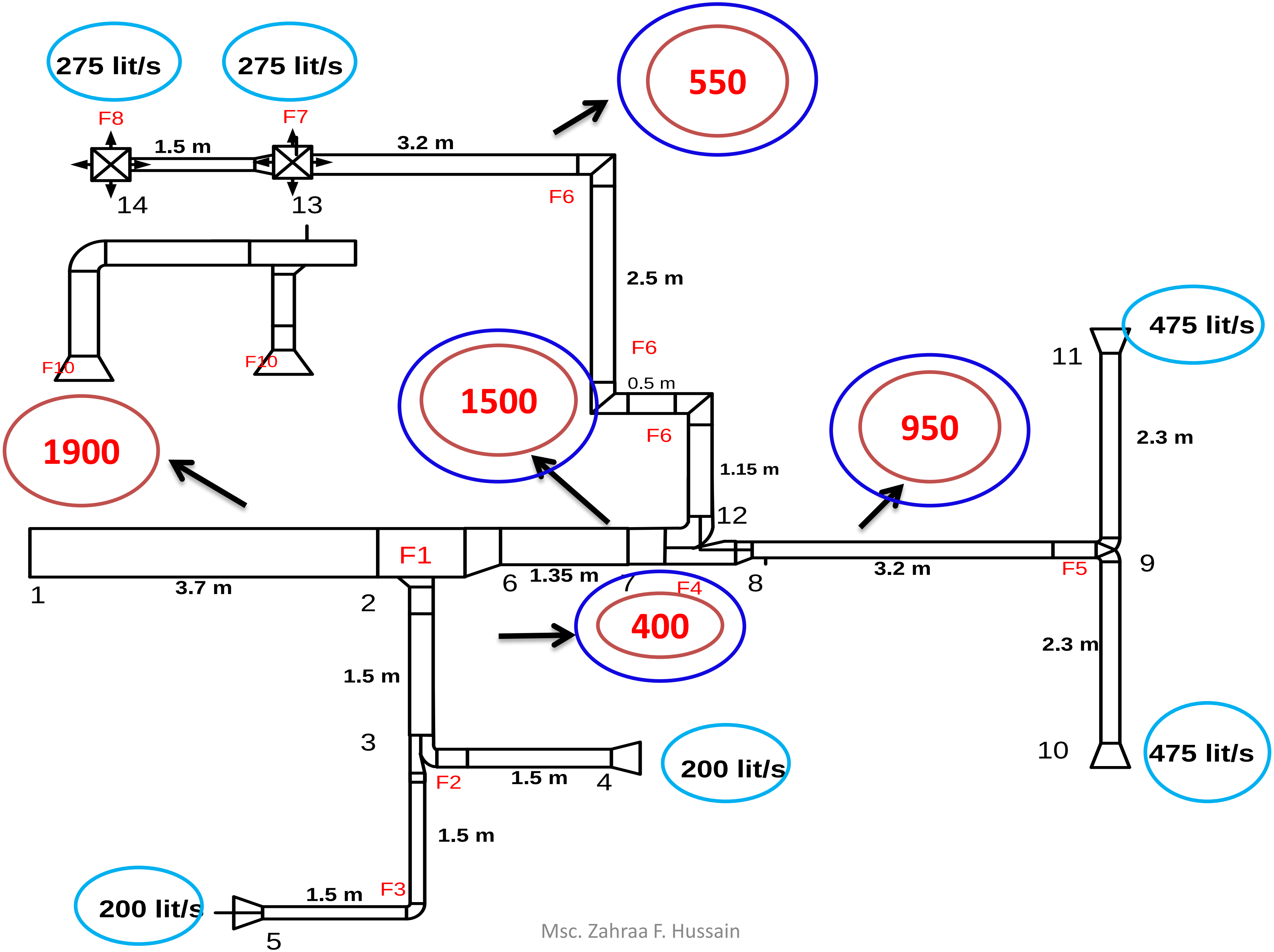
f) Lay out the system in detail. If duct routing and fittings vary significantly from the original design, recalculate the pressure losses. Reselect the fan if necessary.

g) Resize duct sections to approximately balance pressures at each junction.

h) Analyze the design for objectionable noise levels, and specify sound attenuators as necessary. Refer to the section on System and Duct Noise.

Example (2)

For the system illustrated by Figures belows, size the ductwork by the equal friction method. Determine the system resistance and total pressure unbalance at the junctions. The airflow quantities are actual values adjusted for heat gains or losses, and ductwork is sealed (assume no leakage), Air is at 1.204 kg/m^3 density. The supply system is constructed of rectangular ductwork. the maximum main duct height is 0.25 m



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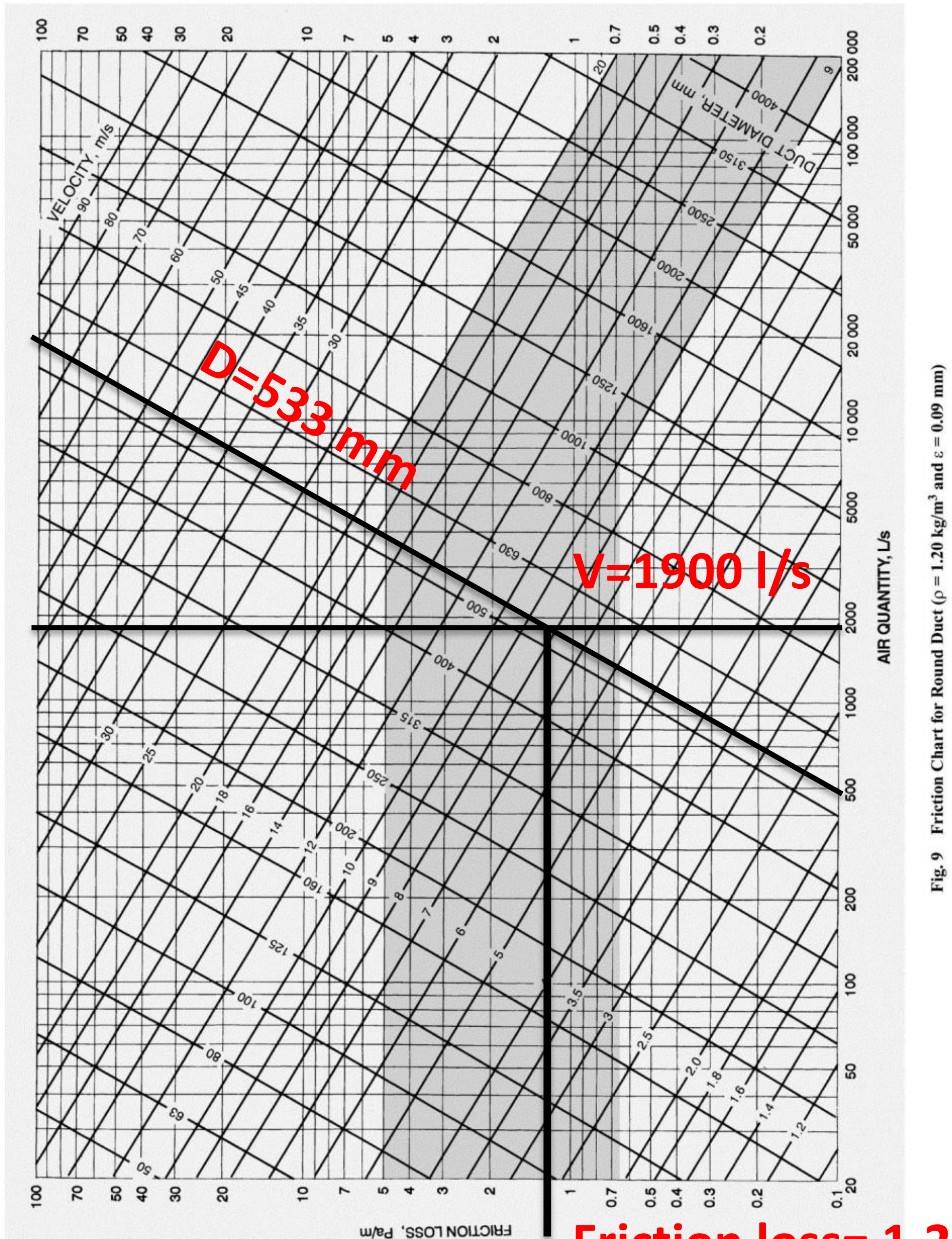
- **Main duct section (1-2)**
- **V=C.A**
- **V=1.9 m^3/s**
- **C=8.5 m/s (T2-1)**
- **1.9=8.5×A**
- **A=0.22335 m^2**
- $A = \pi \frac{D^2}{4}$
- $0.22335 = \pi \frac{D^2}{4}$
- $D = \sqrt{\frac{4*A}{\pi}} = \sqrt{\frac{4*0.22335}{3.14}} =$
- **D=0.533 m= 533mm**

Table (2-1) Air velocity in duct system (m/s)

APPLICATION	CONTROLLING FACTOR NOISE GENERATION Main Duct	CONTROLLING FACTOR — DUCT FRICTION			
		Main Duels		Branch Duct	
		Supply	Return	Supply	Return
Residences	3.0	5.1	3.0	3.0	3.0
Apartments Hotel Bedrooms Hospital Bedrooms	5.1	7.6	6.6	6.1	5.1
Private Offices Directors Rooms Libraries	6.1	10.2	7.6	7.1	6.1
Theatres Auditoriums	4.1	6.6	5.6	5.1	4.1
General Offices High Class Restaurants High Class Stores Banks	7.6	10.2	7.6	8.1	6.1
Average Stores Cafeterias	8.5	10.2	7.6	8.1	6.1
Industrial	12.7	15.2	9.1	11.2	7.6

C=8.5

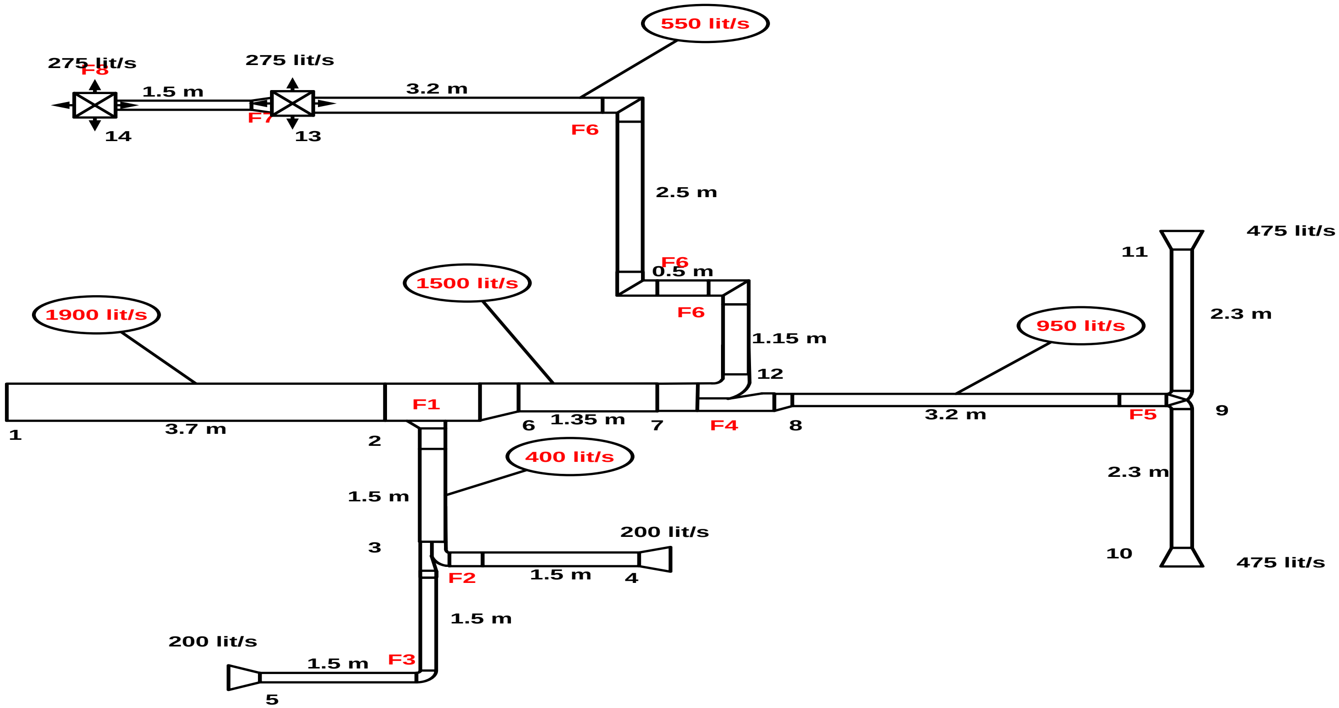


V=1900 l/s

D=533 mm

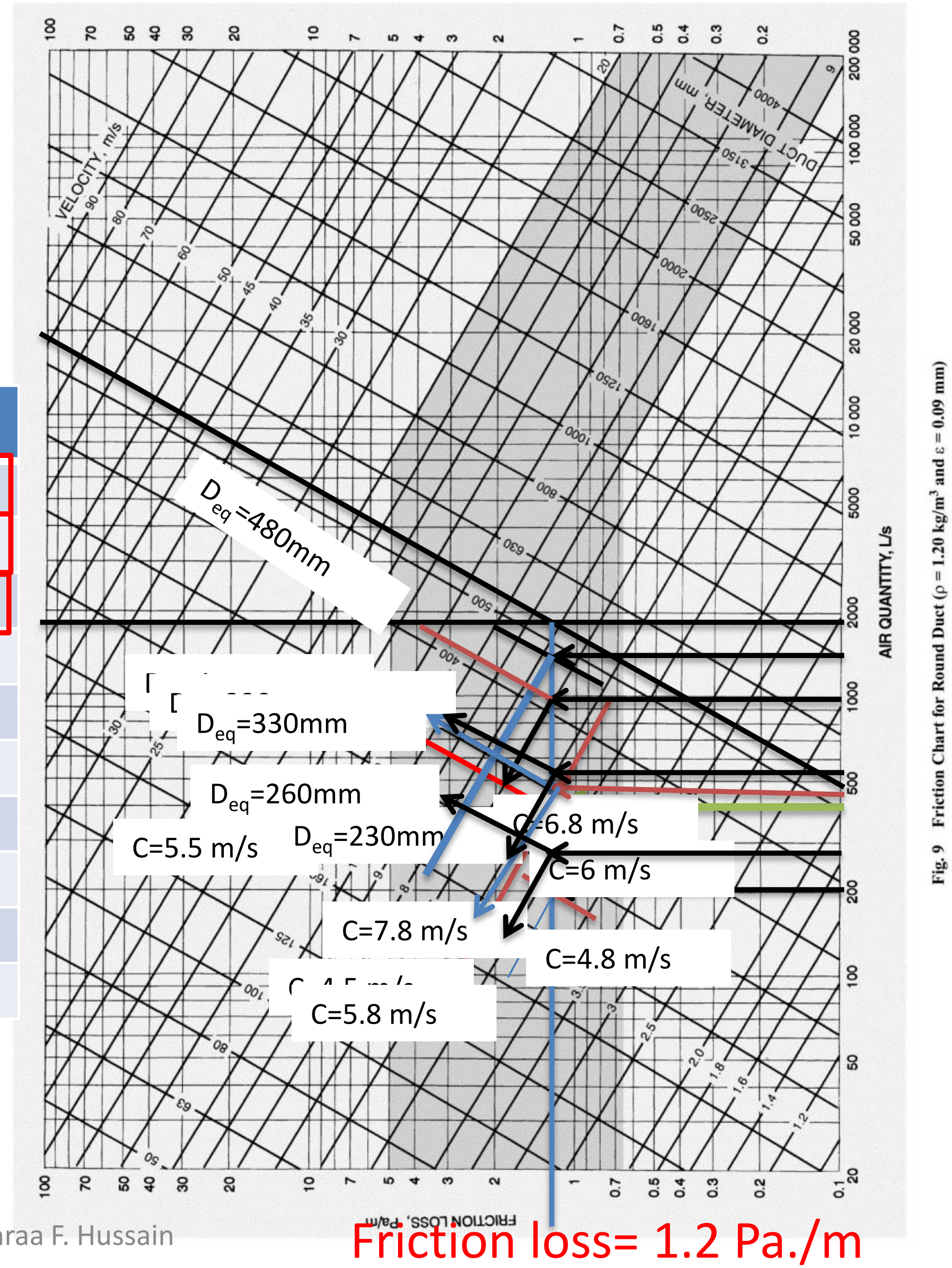
Friction line

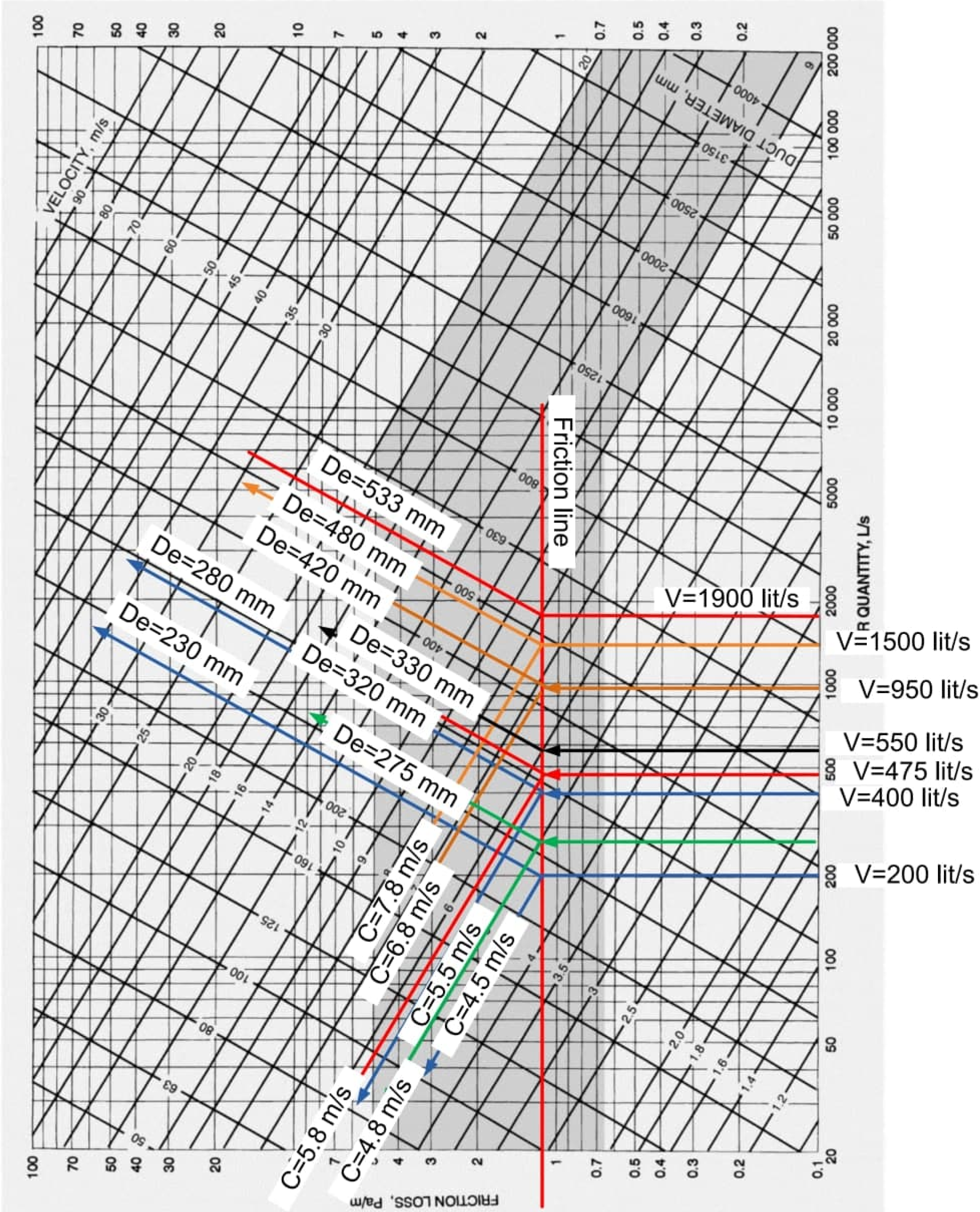
Friction loss= 1.2 Pa./m



Section	V	Deq.	C	W	H	L
1-2	1900					
2-3	400					
3.4	200					
3-5	200					
6-7	1500					
8-9	950					
9-10	475					
9-11	475					
12-13	550					
13-14	275					

Section	V	Deq.	C
1-2	1900	533	8.5
2-3	400	280	5.5
3.4	200	230	4.5
3-5	200	230	4.5
6-7	1500	480	7.8
8-9	950	420	6.8
9-10	475	320	5.8
9-11	475	320	5.8
12-13	550	330	6
13-14	275	260	4.8





VELOCITY, m/s
DUCT DIAMETER, mm
FRICTION LOSS, Pa/m
R QUANTITY, L/s
Friction line
De=533 mm
De=480 mm
De=420 mm
De=280 mm
De=330 mm
De=320 mm
De=230 mm
De=275 mm
V=1900 lit/s
V=1500 lit/s
V=950 lit/s
V=550 lit/s
V=475 lit/s
V=400 lit/s
V=200 lit/s
C=7.8 m/s
C=6.8 m/s
C=5.5 m/s
C=4.5 m/s
C=5.8 m/s
C=4.8 m/s

Table 2 Circular Equivalents of Rectangular Duct for Equal Friction and Capacity[a]

Lgth Adj.[b]	Length of One Side of Rectangular Duct (a), mm																			
	100	125	150	175	200	225	250	275	300	350	400	450	500	550	600	650	700	750	800	900
	Circular Duct Diameter, mm																			
100	109																			
125	122	137																		
150	133	150	164																	
175	143	161	177	191																
200	152	172	189	204	219															
225	161	181	200	216	232	246														
250	169	190	210	228	244	259	273													
275	176	199	220	238	256	272	287	301												
300	183	207	229	248	266	283	299	314	328											
350	195	222	245	267	286	305	322	339	354	383										
400	207	235	260	283	305	325	343	361	378	409	437									
450	217	247	274	299	321	343	363	382	400	433	464	492								
500	227	258	287	313	337	360	381	401												
550	236	269	299	326	352	375	398	419												
600	245	279	310	339	365	390	414	436												
650	253	289	321	351	378	404	429	452												
700	261	298	331	362	391	418	443	467												
750	268	306	341	373	402	430	457	482												
800	275	314	350	383	414	442	470	496												
900	289	330	367	402	435	465	494	522												
1000	301	344	384	420	454	486	517	546												
1100	313	358	399	437	473	506	538	569												
1200	324	370	413	453	490	525	558	590												
1300	334	382	426	468	506	543	577	610												
1400	344	394	439	482	522	559	595	629												
1500	353	404	452	495	536	575	612	648												
1600	362	415	463	508	551	591	629	665												
1700	371	425	475	521	564	605	644	682												
1800	379	434	485	533	577	619	660	698												
1900	387	444	496	544	590	663	674	713												
2000	395	453	506	555	602	646	688	728												
2100	402	461	516	566	614	659	702	743												
2200	410	470	525	577	625	671	715	757												
2300	417	478	534	587	636	683	728	771												
2400	424	486	543	597	647	695	740	784												
2500	430	494	552	606	658	706	753	797												
2600	437	501	560	616	668	717	764	810												
2700	443	509	569	625	678	728	776	822	866	950	1028	1102	1173	1240	1304	1366	1425	1483	1538	1644
2800	450	516	577	634	688	738	787	834	879	964	1043	1119	1190	1259	1324	1387	1447	1506	1562	1670
2900	456	523	585	643	697	749	798	845	891	977	1058	1135	1208	1277	1344	1408	1469	1529	1586	1696

Section	V (lit/s)	Deq. (mm)	C m/s	W (mm)	H (mm)
1-2	1900	533	8.5	1100	250
2-3	400	280	7	500	150
3.4	200	230	4.5	300	150
3-5	200	230	4.5	300	150
6-7	1500	480	7.8	900	250
8-9	950	420	6.8	650	250
9-10	475	320	5.8	650	150
9-11	475	320	5.8	650	150
12-13	550	330	6	700	150
13-14	275	260	4.8	400	150

Section	V (lit/s)	Deq. (mm)	C m/s	W (mm)	H (mm)
1-2	1900	533	8.5	1100	250
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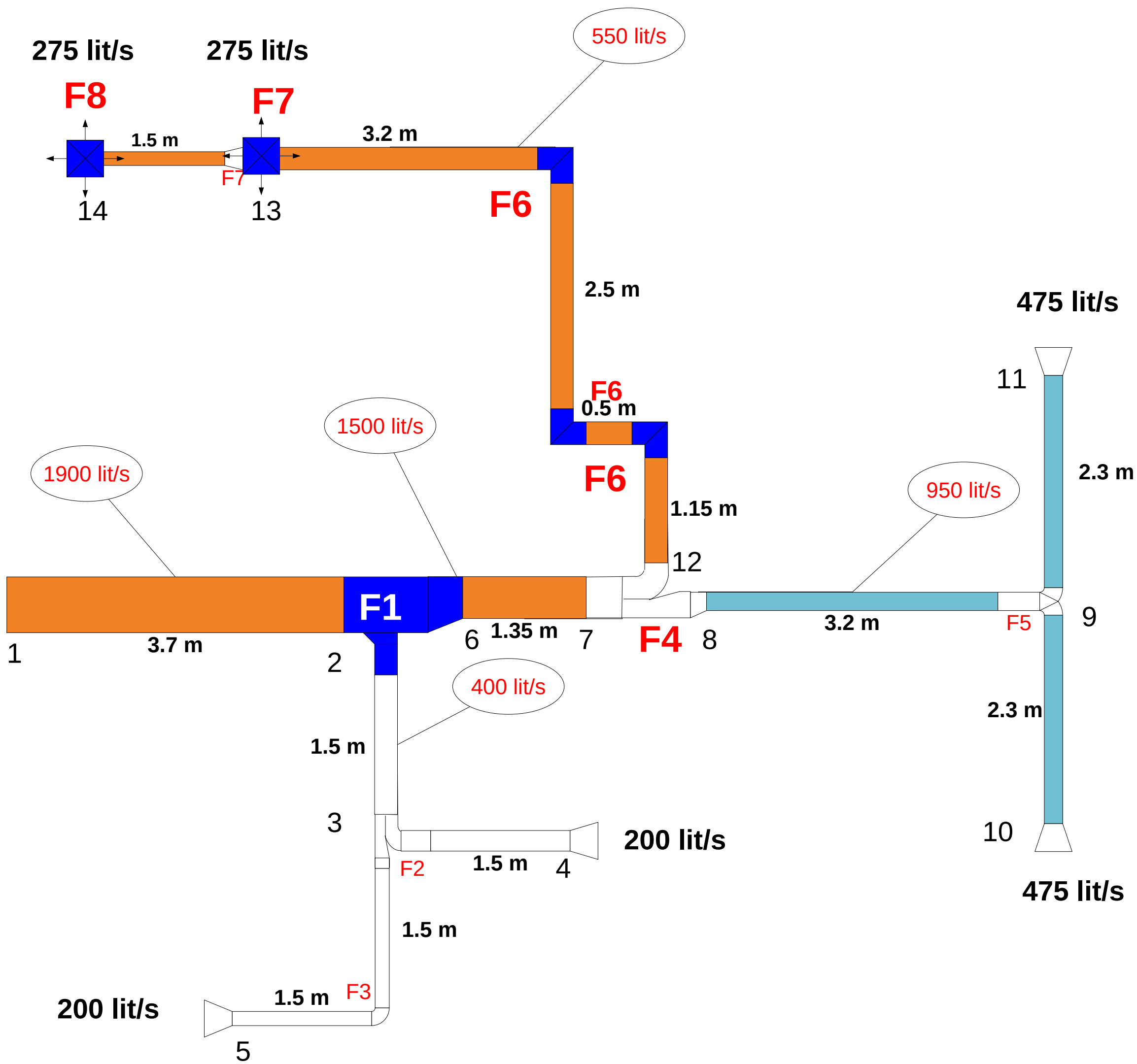
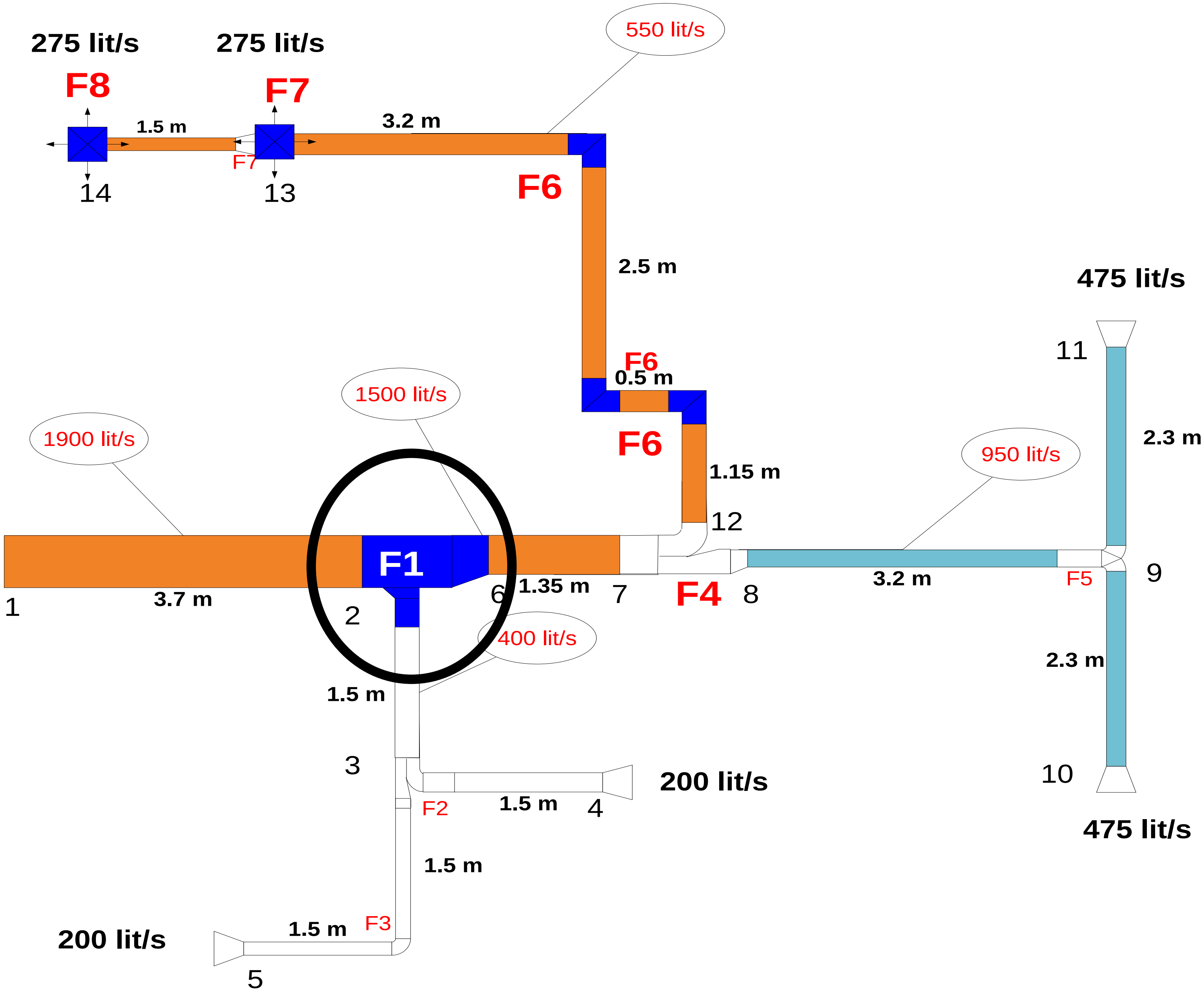
3.4	200	230	4.5	300	150
3-5	200	230	4.5	300	150
6-7	1500	480	7.8	900	250
8-9	950	420	6.8	650	250
9-10	475	320	5.8	650	150
9-11	475	320	5.8	650	150
12-13	550	330	6	700	150
13-14	275	260	4.8	400	150

- Maximum length of the duct:
- Path **(1-2-6-7-12-13-14)**=
- =3.7+1.35+1.15+0.5+2.5+3.2 +1.5=13.9 m
- **Path(1-2-6-7-8-9-11)= 3.7+1.35+3.2+2.3=10.55 m**
- Then the first path must be selected.
- **Fittings** in path (1-2-6-7-12-13-14) are:
- **F1, F4, F6,F7 and F8.**
- The pressure loss in the fittings above should be calculated

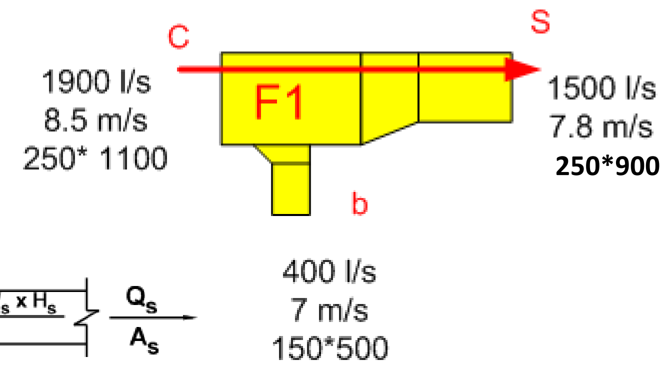


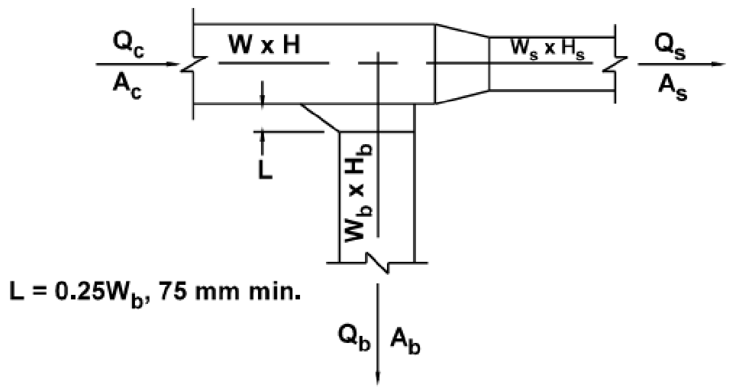


275 lit/s
275 lit/s
F8
F7
550 lit/s
1.5 m
3.2 m
F7
14
13
F6
2.5 m
475 lit/s
11
F6
0.5 m
1500 lit/s
1900 lit/s
F6
2.3 m
950 lit/s
1.15 m
12
F1
9
3.2 m
F5
6
1.35 m
7
F4
8
1
3.7 m
2
400 lit/s
2.3 m
1.5 m
3
200 lit/s
10
F2
1.5 m
4
475 lit/s
1.5 m
200 lit/s
1.5 m
F3
5

Fitting F1

1. Qc=1900 lit/s
2. Ac=1.1*0.25=0.275 m²
3. Qs=1500 lit/s
4. As=0.25*0.9=0.225





1. $\frac{A_s}{A_c} = \frac{0.225}{0.275} = 0.82$

2. $\frac{Q_s}{Q_c} = \frac{1500}{1900} = 0.789$

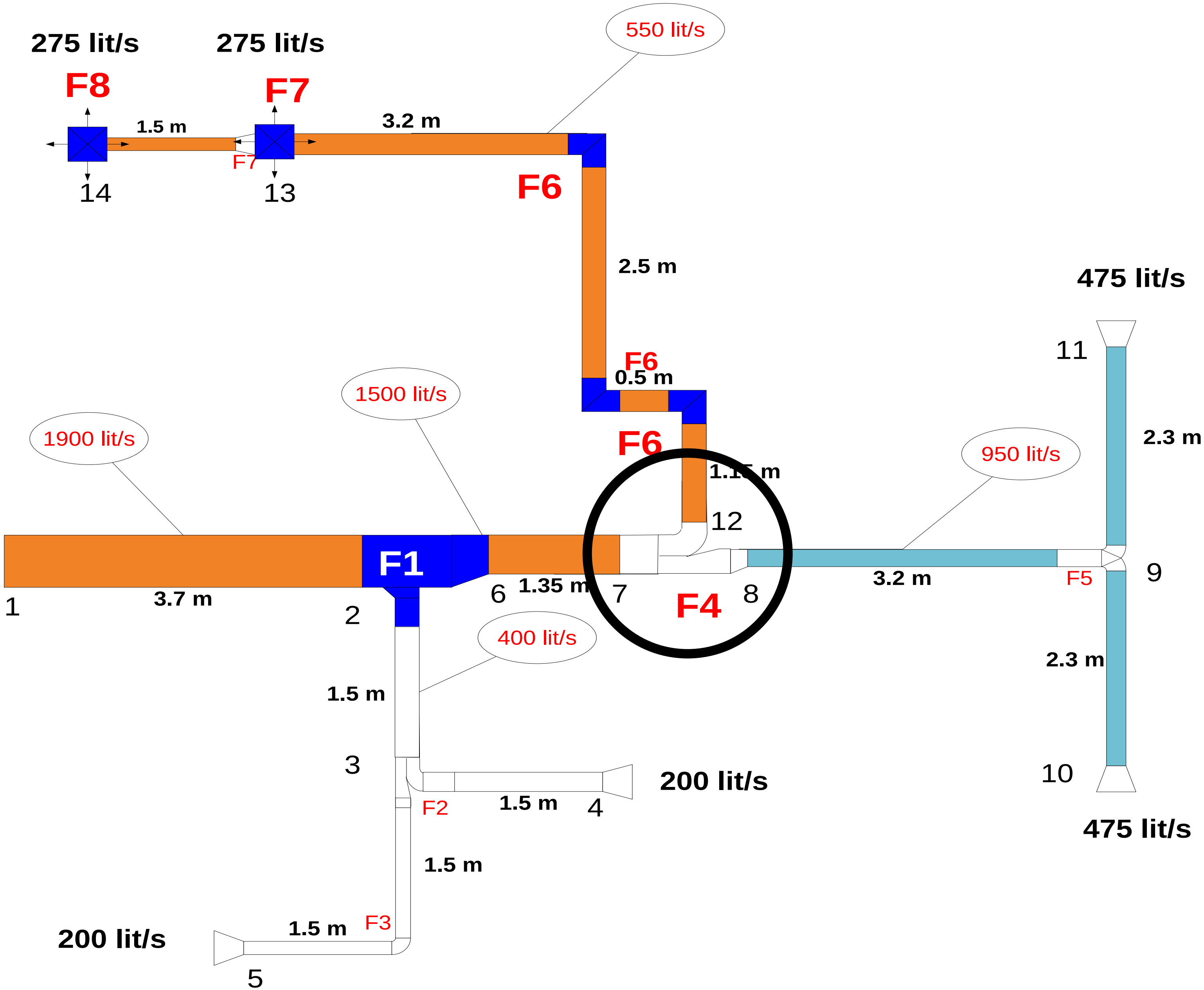
- $\Delta P = \frac{1}{2} . C_s \rho . C^2$
- $\Delta P(F1) =$

$\frac{1}{2} .\ 0.07 \times 1.204 \times 8.5^2$=3.044

C_s Values

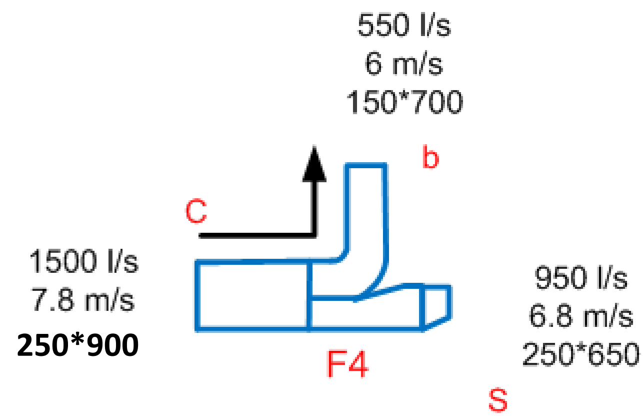
				Q_s/Q_c					
A_s/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.04								
0.2	0.98	0.04							
0.3	3.48	0.31	0.04						
0.4	7.55	0.98	0.18	0.04					
0.5	13.18	2.03	0.49	0.13	0.04				
0.6	20.38	3.48	0.98	0.31	0.10	0.04			
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04		
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04

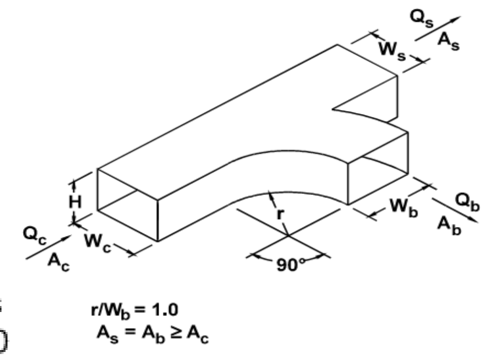
Cs=0.07


275 lit/s
275 lit/s
F8
F7
1.5 m
3.2 m
550 lit/s
F7
14
13
F6
2.5 m
475 lit/s
11
F6
0.5 m
1500 lit/s
1900 lit/s
F6
2.3 m
950 lit/s
1.15 m
12
F1
3.2 m
F5
9
6
1.35 m
7
8
1
3.7 m
2
F4
400 lit/s
2.3 m
1.5 m
3
200 lit/s
10
F2
1.5 m
4
475 lit/s
1.5 m
200 lit/s
1.5 m
F3
5

Fitting F4

SR5-1 Smooth Wye of Type $A_s + A_b \geq A_c$, Branch 90° to Main, Diverging





1. Qc=1500 lit/s
2. Ac=0.25*0.9=0.225 m^2
3. AS=0.65*0.25=0.1625
4. Qb=550 lit/s
5. Ab=0.15*0.7=0.105
6. $\frac{A_s}{A_c} = \frac{0.1625}{0.225} = 0.72$
7. $\frac{A_b}{A_c} = \frac{0.105}{0.25} = 0.42$
8. $\frac{Q_b}{Q_c} = \frac{550}{1500} = 0.367$

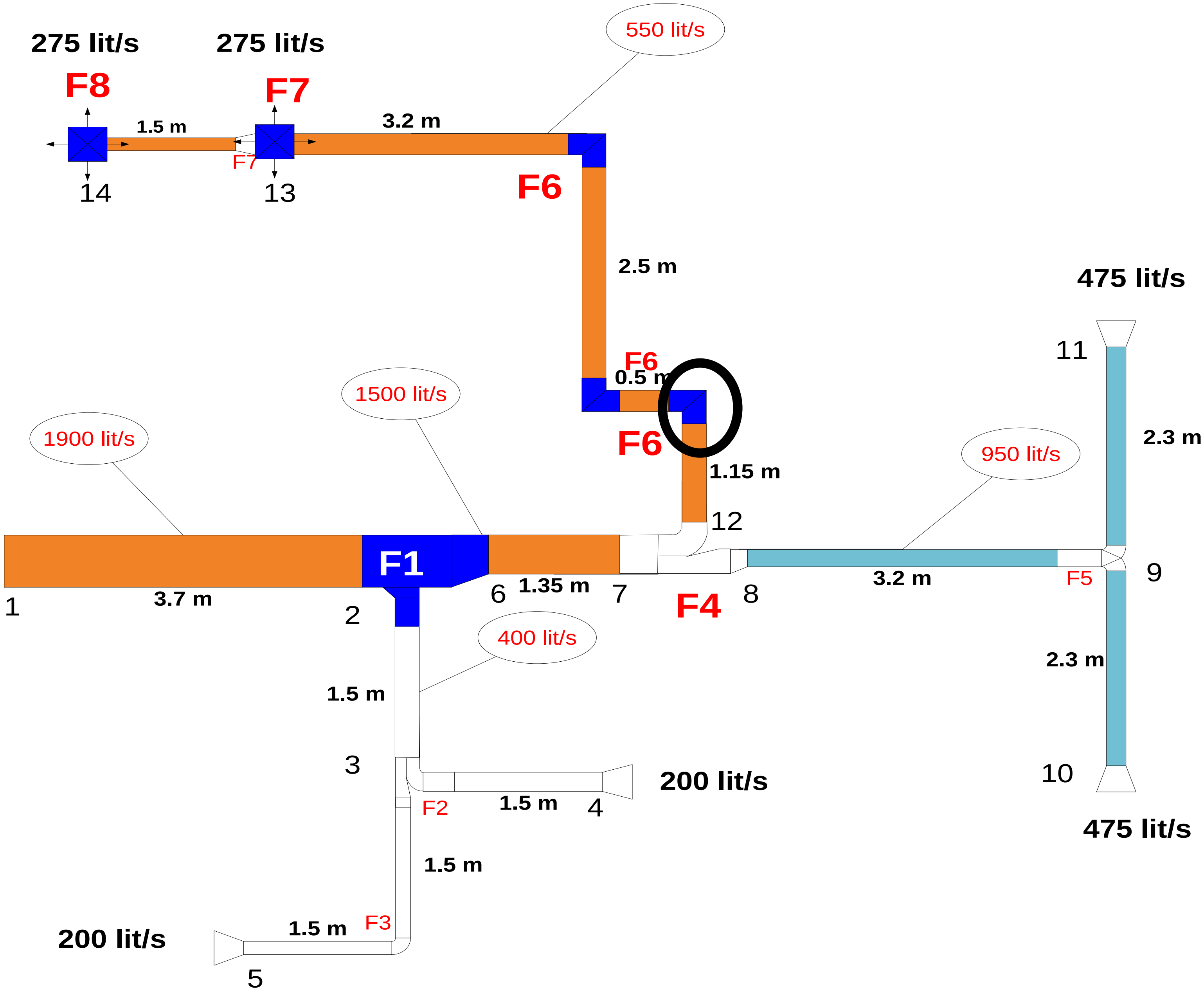
SR5-1 Smooth Wye of Type $A_s + A_b \geq A_c$, Branch 90° to Main, Diverging

C_o Values

A_s/A_c	A_b/A_c	Q_b/Q_c 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.50	0.25	3.44	0.70	0.30	0.20	0.17	0.16	0.16	0.17	0.18
	0.50	11.00	2.37	1.06	0.64	0.52	0.47	0.47	0.47	0.48
	1.00	60.00	13.00	4.78	2.06	0.96	0.47	0.31	0.27	0.26
0.75	0.25	2.19	0.55	0.35	0.31	0.33	0.35	0.36	0.37	0.39
	0.50	13.00	2.50	0.89	0.47	0.34	0.31	0.32	0.36	0.43
	1.00	70.00	15.00	5.67	2.62	1.36	0.78	0.53	0.41	0.36
1.00	0.25	3.44	0.78	0.42	0.33	0.30	0.31	0.40	0.42	0.46
	0.50	15.50	3.00	1.11	0.62	0.48	0.42	0.40	0.42	0.46
	1.00	67.00	13.75	5.11	2.31	1.28	0.81	0.59	0.47	0.46

Cs=0.47

- $\Delta P = \frac{1}{2}.C_s \rho. C^2$
- $\Delta P(F4) = \frac{1}{2}.0.47 \times 1.204 \times 7.8^2$
- =17.2 Pa.

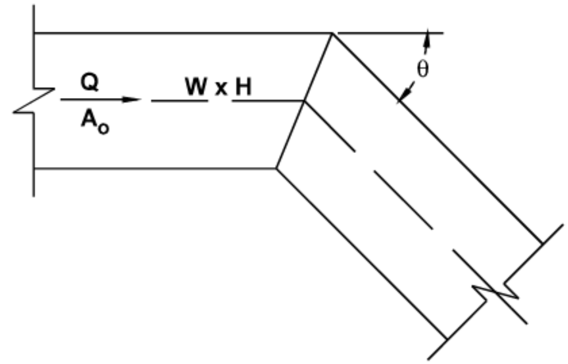


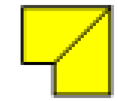
275 lit/s
275 lit/s
F8
F7
1.5 m
3.2 m
550 lit/s
F7
14
13
F6
2.5 m
475 lit/s
11
F6
0.5 m
1500 lit/s
1900 lit/s
F6
2.3 m
1.15 m
950 lit/s
12
F1
9
3.2 m
F5
6
1.35 m
7
8
1
3.7 m
F4
2
400 lit/s
2.3 m
1.5 m
3
10
200 lit/s
F2
1.5 m
4
475 lit/s
1.5 m
200 lit/s
1.5 m
F3
5

Fitting F6

CR3-6 Elbow, Mitered

	C_o Values									
	H/W									
θ	**0.25**	**0.50**	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**8.00**
20	0.08	0.08	0.08	0.07	0.07	0.07	0.06	0.06	0.05	0.05	0.05
30	0.18	0.17	0.17	0.16	0.15	0.15	0.13	0.13	0.12	0.12	0.11
45	0.38	0.37	0.36	0.34	0.33	0.31	0.28	0.27	0.26	0.25	0.24
60	0.60	0.59	0.57	0.55	0.52	0.49	0.46	0.43	0.41	0.39	0.38
75	0.89	0.87	0.84	0.81	0.77	0.73	0.67	0.63	0.61	0.58	0.57
90	1.30	1.27	1.23	1.18	1.13	1.07	0.98	0.92	0.89	0.85	0.83





F6

550 l/s
6 m/s
150*700

Cs=1.3

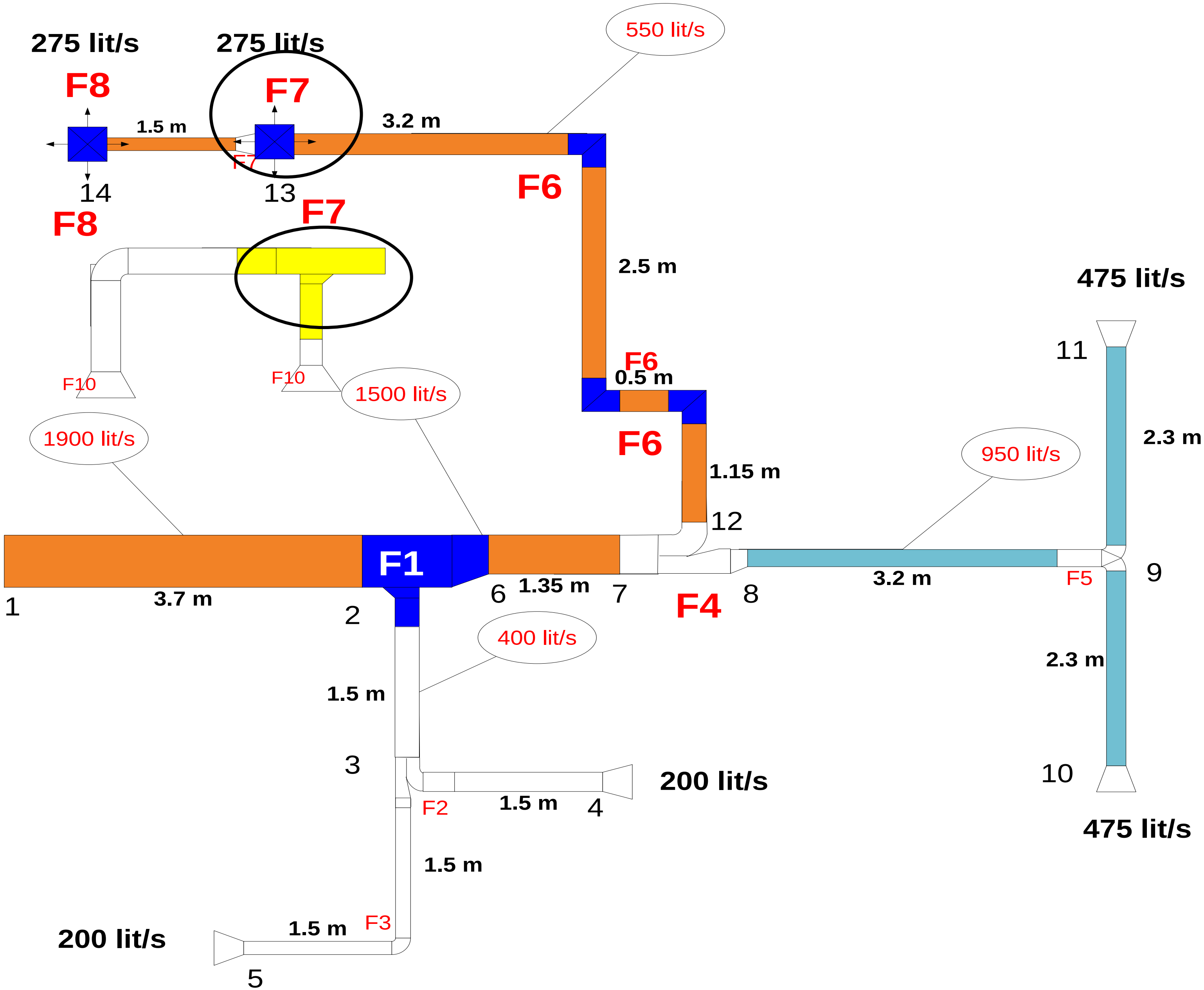
H=150 mm
W=700 mm

$$\frac{H}{W} = \frac{150}{700} = 0.21$$

$$\Delta P = \frac{1}{2}.\boldsymbol{C_s}\,\rho.\,C^2$$

$$\Delta P(F6) = \frac{1}{2}.\mathbf{1.3} \times 1.204 \times 6^2$$

=28.17 Pa.



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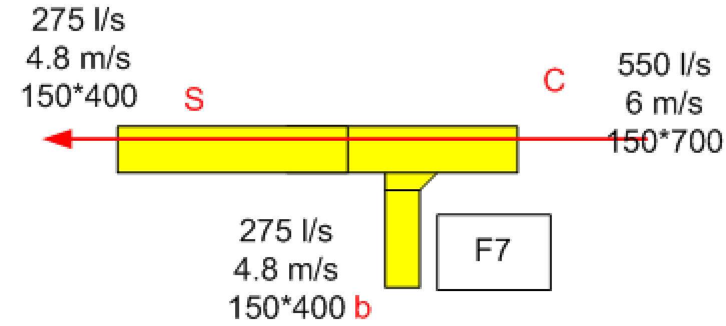
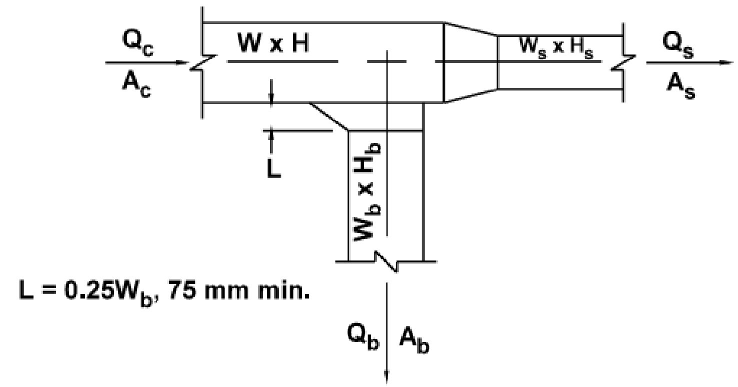
- From table

Fitting F7



SR5-13 Tee, 45 Degree Entry Branch, Diverging



1. Qc=550 lit/s
2. Ac=0.7*0.15=0.105 m^2
3. Qs=275 lit/s
4. As=0.4*0.15=0.06

5. $\frac{A_S}{A_c} = \frac{0.06}{0.105} = 0.57$

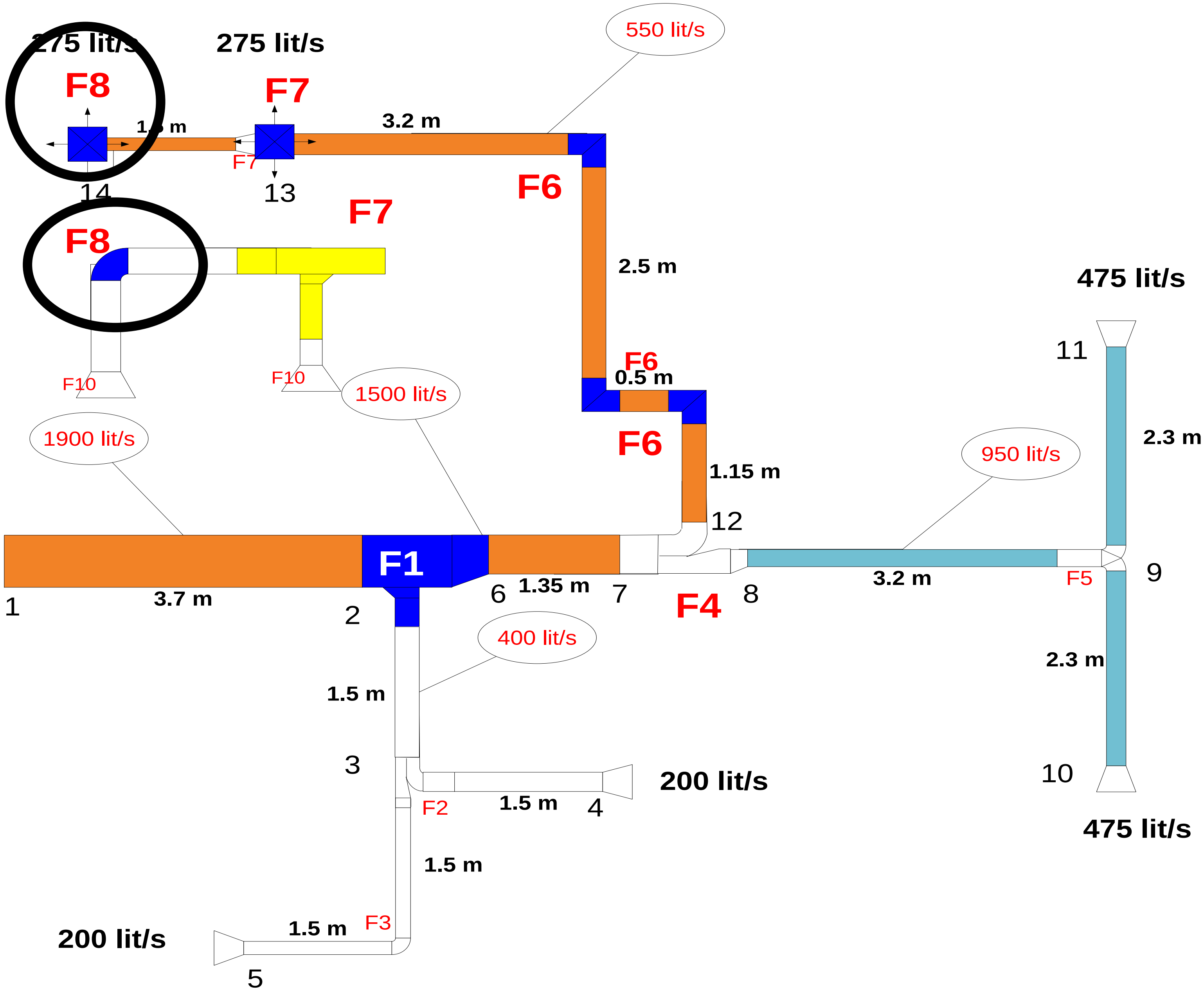
6. $\frac{Q_S}{Q_c} = \frac{275}{550} = 0.5$

C_s Values

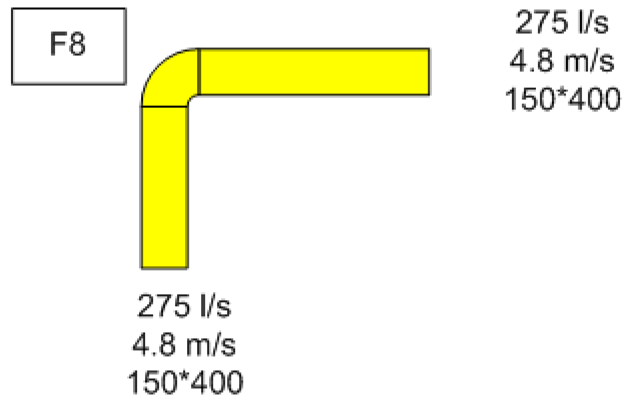
	Q_s/Q_c								
A_s/A_c	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.1	0.04								
0.2	0.98	0.04							
0.3	3.48	0.31	0.04						
0.4	7.55	0.98	0.18	0.04					
0.5	13.18	2.03	0.49	0.13	0.04				
0.6	20.38	3.48	0.98	0.31	0.10	0.04			
0.7	29.15	5.32	1.64	0.60	0.23	0.09	0.04		
0.8	39.48	7.55	2.47	0.98	0.42	0.18	0.08	0.04	
0.9	51.37	10.17	3.48	1.46	0.67	0.31	0.15	0.07	0.04

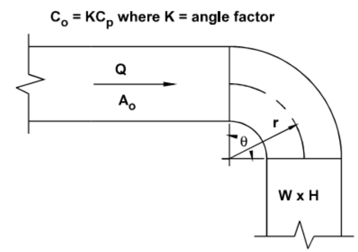
Cs=0.1

- $\Delta P = \frac{1}{2}.C_s \rho.C^2$
- $\Delta P(F7) = \frac{1}{2}.\mathbf{0.1} \times 1.204 \times 6^2$=2.167 Pa.



275 lit/s
275 lit/s
F8
F7
1.5 m
3.2 m
550 lit/s
F7
14
13
F7
F6
F8
2.5 m
475 lit/s
F10
F10
1500 lit/s
F6
0.5 m
11
1900 lit/s
F6
2.3 m
1.15 m
950 lit/s
12
F1
1
3.7 m
2
6
1.35 m
7
F4
8
3.2 m
F5
9
400 lit/s
2.3 m
1.5 m
3
200 lit/s
10
F2
1.5 m
4
475 lit/s
1.5 m
200 lit/s
1.5 m
F3
5





H/W=150/400=0.375

r/W=1.5

$\theta = 90$

Cp=0.22

K=1

$$\Delta P = \frac{1}{2} . KC_p \rho . C^2$$

$= \frac{1}{2} \times 1 \times 0.22 \times 1.204 \times 4.8^2$

= 3.05 Pa.

CR3-1 Elbow, Smooth Radius, Without Vanes

	C_p Values										
	H/W										
r/W	**0.25**	**0.50**	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**8.00**
0.50	1.53	1.38	1.29	1.18	1.06	1.00	1.00	1.06	1.12	1.16	1.18
0.75	0.57	0.52	0.48	0.44	0.40	0.39	0.39	0.40	0.42	0.43	0.44
1.00	0.27	0.25	0.23	0.21	0.19	0.18	0.18	0.19	0.20	0.21	0.21
1.50	0.22	0.20	0.19	0.17	0.15	0.14	0.14	0.15	0.16	0.17	0.17
2.00	0.20	0.18	0.16	0.15	0.14	0.13	0.13	0.14	0.14	0.15	0.15

Angle Factor *K*

θ	**0**	**20**	**30**	**45**	**60**	**75**	**90**	**110**	**130**	**150**	**180**
K	0.00	0.31	0.45	0.60	0.78	0.90	1.00	1.13	1.20	1.28	1.40

Pressure loss due fittings

- $\Delta \boldsymbol{P}_{t,f} =$ **3.044+ 17.2+3(28.17)+ 2.167+ 3.05 =110 Pa**
- **Pressure loss due duct length= duct length * Friction loss per meter**
- **= 13.9* 1.2=17 Pa**
- $\Delta \boldsymbol{P}_{t} =$ **110 + 17=127 Pa.**