Cork Institute of Technology

Higher Certificate in Engineering in Building Services Engineering – Award

(NFQ – Level 6)

Autumn 2006

Building Services and Equipment II

(Time: 3 Hours)

Instructions
Answer FIVE questions,
All questions carry equal marks.

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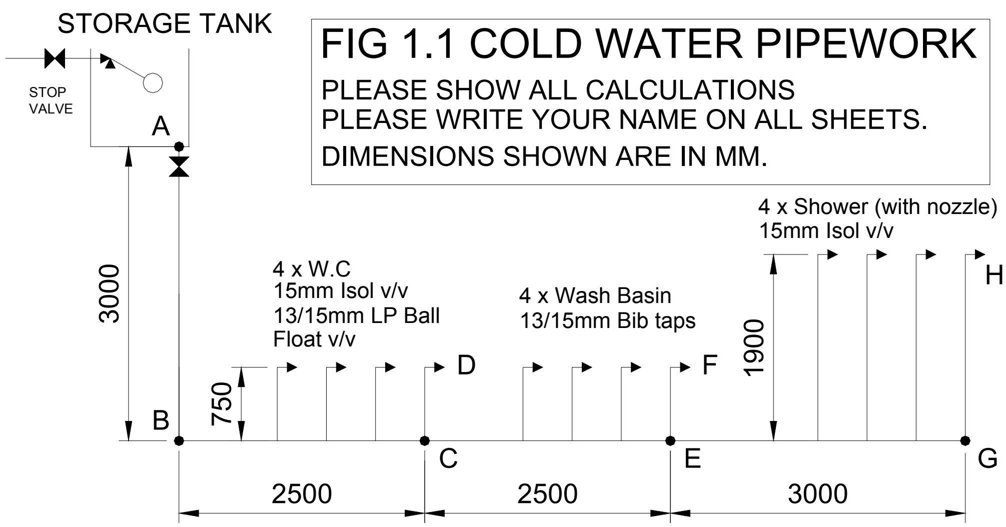
	Reference Material to be provided.	**Question**	**Location**
1.	Table 1, 2, 3and 4 – Hot and Cold Water Pipe work Design	Q1	(attached)
2.	CIBSE Table C4.18 Page C4-40 – Water 10^0C Copper Pipe.	Q1	(attached)
3.	Hot and Cold Water design Spreadsheet	Q1	(attached)
4.	CIBSE Table C4.11, Page 4-15 - Water 75^0C Med Grade Steel	Q4	(attached)
5.	CIBSE Table C4.36. -Velocity press loss factors.	Q4	(attached)
6.	Ductwork Design Sheet	Q5	(attached)
7.	CIBSE Fig C4.2 – Flow of Air in Round Ducts	Q5	(attached)
8.	CIBSE Table C4.33 – Velocity Pressure in Pa v's Velocity m/s	Q5	(attached)
9.	CIBSE Table C4.35 – Page 1&2 – Velocity Press Loss Factors	Q5	(attached)

Q1 (a) Fig 1.1 shows the cold water pipe work layout for a changing room area within a school. Determine the most economical diameters of the copper distribution pipes labelled AB, BC, etc. Assume a continuous demand due to peak usage.
Ensure you put your name on the sheet and attach the sheet to your answer book.

[15 marks]



(b) Having completed your detailed design it should show that insufficient head pressure is available to carry the desired volume of water to user point H.
Calculate the shortfall in head pressure available (Pa) and suggest the minimum changes required to correct such a fault. [5 marks]

Q2 (a) Fig 2.1 below shows a section of a wall. Using the data provided on the sketch calculate the thermal transmission (U Value) for the wall.
Table 2 – Rsi, Table 3 – Rso and Table 4 – Ra attached as reference. [8 marks]

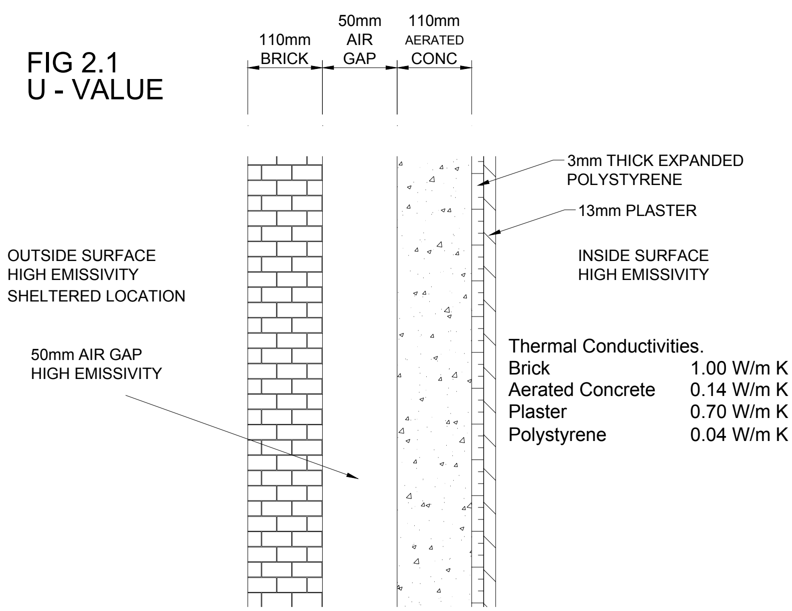


Table 2 - Rsi	**Internal surface resistances R_{si} in $m^2\ ^0C$ / W**		
Building element	Heat flow	Surface resistance ($m^2\ ^0C$ / W)	
		High Emissivity	Low
Walls	Horizontal	0.123	0.304
Ceilings, floor, flat	Upwards	0.106	0.218
Ceilings and floors	Downwards	0.150	0.562

Table 3 - Rso	**External surface resistances R_{so} in $m^2\ ^0C$ / W**			
Building	Emissivity	Surface resistance for stated exposure		
		Sheltered	Normal	Severe
Wall	High	0.08	0.055	0.03
	Low	0.11	0.067	0.03
Roof	High	0.07	0.045	0.02
	Low	0.09	0.053	0.02

Table 4 - Ra	**Unventilated Air Gap resistance R_a in $m^2\ ^0C$ / W**		
Air Space Thickness	Surface Emissivity	Thermal resistance ($m^2\ ^0C$ / W)	
		Heat flow Horizontal or Upwards	Heat flow Downwards
5 mm	High	0.11	0.11
	Low	0.18	0.18
20 mm	High	0.18	0.21
	Low	0.35	1.06

(b) Fig 2.2 shows the plan of an office on the second floor of a four storey building. The other floors have the same construction and heating design conditions.

From the data given and using convection heating, calculate the total rate of heat loss for this office. [12 marks]

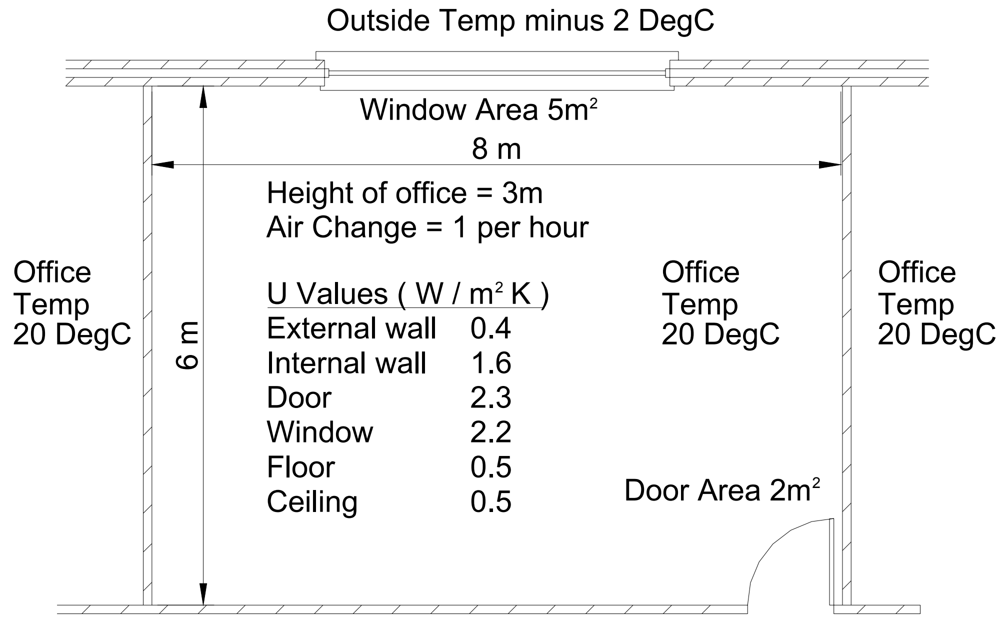


Fig 2.2 Heat Loss

Q3 (a) A two pipe LPHW central heating system is shown in Fig 3.1. The pipe work is medium grade steel. The heat output from each radiator does not allow for a fixed percentage heat loss from the insulated pipe work supplying those radiators.

Under the design conditions shown, find the following for pipe sections 1, 2 and 3.

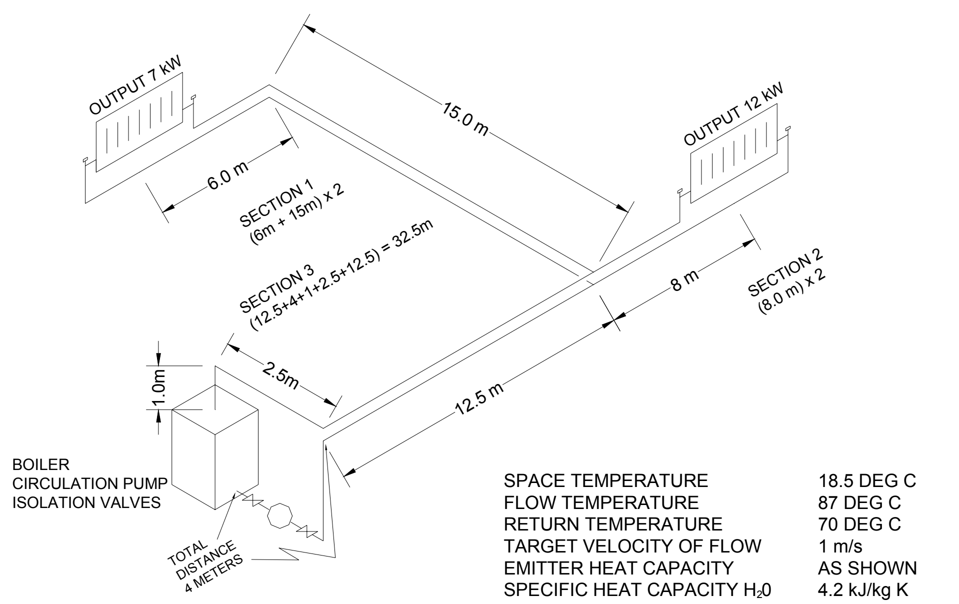
(i) Pipe diameter, (ii) Pressure drop per meter - dP_l, (iii) Length equivalent factor - l_e.

NB: it is not necessary to compare the actual heat loss from the insulated pipe work with the theoretical value estimated.

Table C4.12, Page C4-15, “Medium Grade Steel Water at 75^{0}C attached for reference.

Table C3.14 – heat emission from horizontal steel pipe – Not required. [10 marks]

FIG 3.1 LPHW HEATING TWO PIPE PARALLEL SYSTEM



(b) For the same LPHW circuit find the effective pipe length of the straight pipe plus fittings for all sections. From this find the total pressure drop on the index run.

Use this to derive a pump duty for the circulation pump in this circuit.

Bends are welded mild steel elbows and isolation valves are gate valves.

Table C4.36 – “Velocity Pressure Loss factors” attached for reference. [10 marks]

Q4 (a) The production area and associated rooms shown in Fig 4.1 below are to be supplied with air conditioned air through the supply air duct shown. The air is supplied from point A to supply air grilles at B, C, D and E. There are no change in levels between A and E.

Using the design criteria provided on the sketch and the ductwork design sheet attached, establish the most economical circular duct size for the layout shown in Fig 4.1.

Include all relevant information on the ductwork design sheet.

Ensure you put your name on the sheet and attach the sheet to your answer book.

Fig C4.2, Table C4.33 and Table C4.35 Page 1&2 attached as ref. [15 marks]

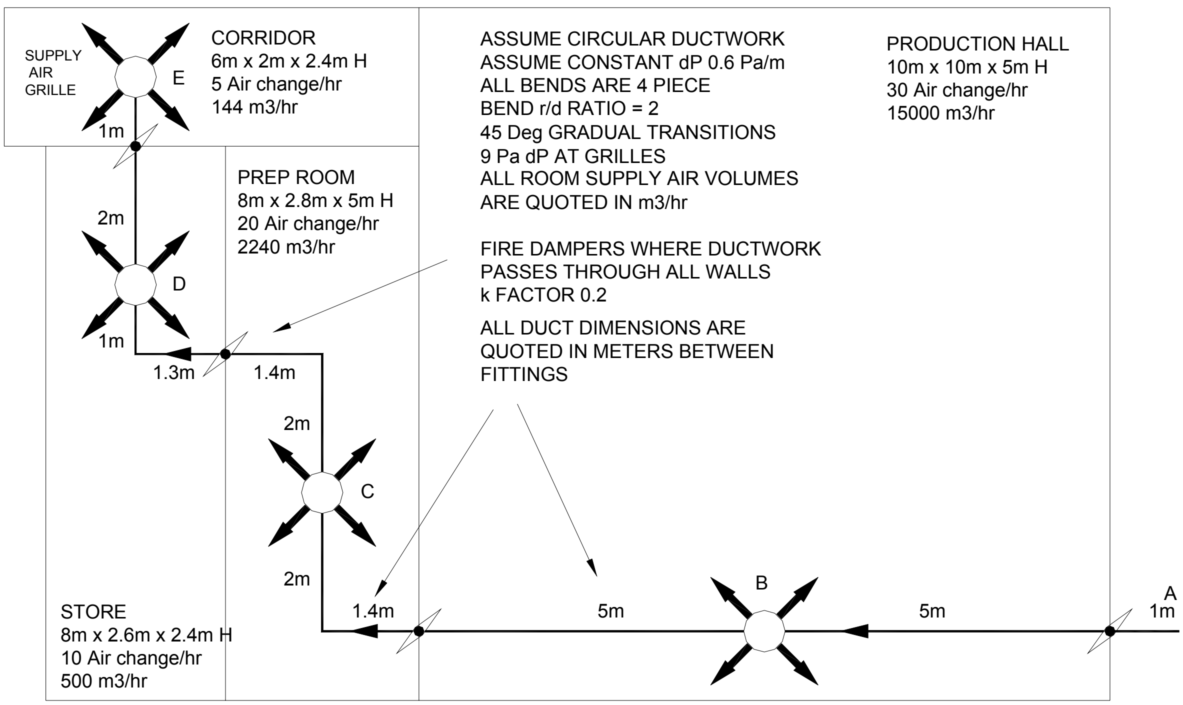


FIG 4.1 - DUCTWORK DESIGN

(b) Fig 4.1 shows fire dampers on each of the dividing walls between the rooms. With the aid of a neat sketch show the details of two different types of fire dampers commonly used in air conditioning ducting. [5 marks]

Q5 (a) Air conditioning is used to control the temperature, humidity, cleanliness and distribution of air within the air conditioned space. Filters are used in controlling the cleanliness of the air. Briefly describe three types of air filters that may be found in air conditioning systems indicating how each works. [6 marks]

(b) Draw a schematic of a "split system" packaged air conditioning unit in room cooling mode, complete with compressor, heating and cooling coils, reversing valve, expansion device, fans and direction of flow of the refrigerant.

Indicate on the schematic the state of the refrigerant immediately after the expansion device, i.e, High Pressure or Low Pressure, Liquid or gas. [8 marks]

Use the Psychrometric Chart attached to plot and determine the following conditions.

NB: It is not necessary to attach the chart to your answer book.

(c) In winter, cold air at a dry bulb of 5 Deg C and 60 % relative humidity enters a building through a heater battery and is heated to a dry bulb temperature of 20 Deg C, without adding moisture. From the Psychrometric chart find, [2 marks]

(c) i. The Wet Bulb temperature of the incoming air.

(c) ii The Relative Humidity of the heated air.

(d) The air in a room has a dry bulb temperature of 22 Deg C and a wet bulb temperature of 16 Deg C. From the Psychrometric chart find, [2 marks]

(d) i The Relative Humidity of the air.

(d) ii The temperature of the walls when condensation will occur.

(e) Air enters an Air Handling unit at a dry bulb temperature of 25 Deg C and 70 % relative humidity. The final condition required is a dry bulb temperature of 20 Deg C and 50 % relative humidity. From the Psychrometric chart find, [2 marks]

(e) i The reduction in moisture content of the air.

(e) ii The lowest temperature the air must be cooled to in order to achieve the reduced moisture content.

Q6. (a) With the aid of a neat sketch show all the equipment associated with a typical “wet” sprinkler system for a two storey building. [6 marks]

(b) Using a neat sketch show the general arrangement of an on site automatic sprinkler pump system including the water storage and water supply. [6 marks]

(c) Outline the type of portable fire extinguishers you would recommend for use on fires involving four of the following materials :- [4 marks]

No.	(i)	(ii)	(iii)	(iv)	(v)
Class	A	B	C	D	E
Fire Type	Wood & textiles	Petroleum	Gases	Inflammable metals	Electrical

(d) Briefly explain how each type of extinguisher described above is effective in fighting the relevant fire. [4 marks]

Q7 (a) Global warming is a phenomenon attributed to increased industrialisation of our planet. With the aid of a neat sketch describe how global warming has come about. [10 marks]

(b) Air pollution is a major contributor to global warming. Describe three types of air pollution, their sources, effects on humans and vegetation, and possible control measures to help reduce their level. [10 marks]

Tables 1, 2, 3 and 4 - Hot and Cold Water Pipework Design.

Table 1

Loading Units for various types of Sanitary Applications.

Location / Appliance	Loading Units
Dwellings and Flats	
W.C flushing cistern	2
Wash basin	1.5
Bath	10
Sink	3 - 5
Offices	
W.C flushing cistern	2
Wash basin (distributed use)	1.5
Wash basin (concentrated use)	3
Schools and Industrial Buildings	
W.C flushing cistern	2
Wash basin	3
Showers (with spray rose)	3
Public bath	22

It should be noted that certain sanitary appliances such as those fitted with spray taps, umbrella taps, shower nozzles or similar fittings require a continuous flow of water as long as such appliances are in use.

Table 2

Recommended minimum flow rates for Sanitary Appliances.

Type of appliance	Rate of Flow (l/s)
W.C flushing cistern	0.12
Wash basin	0.15
Wash basin with spray taps	0.04
Bath (private)	0.30
Bath (public)	0.60
Shower 9 with nozzle)	0.12
Sink with 13mm taps	0.20
Sink with 19mm taps	0.30
Sink with 25mm taps	0.60

Table 3

Frictional resistance of Fittings expressed in Equivalent Pipe Lengths

Copper			Galvanised Steel			
Nominal outside diameter (mm)	Equivalent length Meter run of pipe Elbow	Tee	Nominal outside diameter (mm)	Equivalent length Meter run of pipe Elbow	Bend	Tee
15	0.5	0.6	15	0.5	0.4	1.2
22	0.8	1.0	20	0.6	0.5	1.4
28	1.0	1.5	25	0.7	0.6	1.8
35	1.4	2.0	32	1.0	0.7	2.3
42	1.7	2.5	40	1.2	1.0	2.7
54	2.3	3.5	50	1.4	1.2	3.4
62	3.0	4.5	65	1.7	1.3	4.2
76	3.4	5.8	80	2.0	1.6	5.3
108	4.5	8.0	100	2.7	2.0	6.8

Table 4

Frictional resistance of draw off taps and globe type isolation valves expressed as equivalent pipe lengths

	Equivalent lengths in meters for nominal diameter fittings					
	13/15mm	19/22mm	25/28mm	35mm	42mm	54mm
Bib Tap, Pillar Tap, Globe type Isol v/v	5m	6m	9m	11m	14m	18m
Ball Float Valves HP	75m	40m	40m	35m	21m	20m
Ball Float Valves LP	8m					

Table 4.18 Flow of water at 10°C in copper pipes

q_m	= mass flow rate	kg.s^{-1}
c	= velocity	m.s^{-1}
$\Delta p/l$	= pressure drop per unit length	Pa.m^{-1}
l_e	= equivalent length of a component for $\zeta = 1$	m

* $(Re) = 2000$
† $(Re) = 3000$

COPPER, TABLE X

WATER AT 10°C

$\Delta p/l$	c	12 mm q_m	l_e	15 mm q_m	l_e	22 mm q_m	l_e	28 mm q_m	l_e	35 mm q_m	l_e	42 mm q_m	l_e	c	$\Delta p/l$
50		0.013	*0.2*	0.026	*0.3*	0.070	*0.5*	0.144	*0.7*	0.263	*1.0*	0.447	*1.3*		50
55		0.014	*0.2*	0.027	*0.3*	0.074	*0.5*	0.152	*0.7*	0.278	*1.0*	0.472	*1.3*		55
60		0.015	*0.2*	0.028	*0.3*	0.078	*0.5*	0.160	*0.7*	0.292	*1.0*	0.496	*1.3*		60
65		0.017	*0.3*	0.029	*0.3*	0.082	*0.5*	0.168	*0.7*	0.306	*1.0*	0.520	*1.4*		65
70	0.2	0.018	*0.3*	0.030	*0.3*	0.086	*0.5*	0.175	*0.8*	0.319	*1.0*	0.542	*1.4*		70
75		0.019	*0.3*	0.031	*0.3*	0.089	*0.5*	0.182	*0.8*	0.332	*1.1*	0.564	*1.4*		75
80		0.020	*0.3*	0.032	*0.3*	0.093	*0.5*	0.189	*0.8*	0.345	*1.1*	0.585	*1.4*		80
85		0.022*	*0.3*	0.033	*0.3*	0.096	*0.5*	0.196	*0.8*	0.357	*1.1*	0.606	*1.4*	0.5	85
90		0.019	*0.2*	0.034	*0.3*	0.099	*0.5*	0.203	*0.8*	0.369	*1.1*	0.626	*1.4*		90
95		0.020	*0.2*	0.035	*0.3*	0.103	*0.5*	0.209	*0.8*	0.381	*1.1*	0.646	*1.4*		95
100		0.020	*0.2*	0.036	*0.3*	0.106	*0.5*	0.216	*0.8*	0.392	*1.1*	0.665	*1.5*		100
110		0.021	*0.2*	0.038	*0.3*	0.112	*0.6*	0.228	*0.8*	0.414	*1.1*	0.702	*1.5*		110
120		0.022	*0.2*	0.040	*0.3*	0.117	*0.6*	0.239	*0.8*	0.435	*1.1*	0.738	*1.5*		120
130		0.023	*0.2*	0.041†	*0.3*	0.123	*0.6*	0.251	*0.8*	0.456	*1.1*	0.772	*1.5*		130
140		0.024	*0.2*	0.043	*0.3*	0.128	*0.6*	0.262	*0.8*	0.475	*1.2*	0.805	*1.5*		140
150		0.025	*0.2*	0.045	*0.3*	0.134	*0.6*	0.272	*0.8*	0.494	*1.2*	0.838	*1.5*		150
160		0.026	*0.2*	0.047	*0.3*	0.139	*0.6*	0.283	*0.9*	0.513	*1.2*	0.869	*1.6*		160
170		0.027	*0.2*	0.048	*0.3*	0.144	*0.6*	0.293	*0.9*	0.531	*1.2*	0.899	*1.6*		170
180	0.3	0.027	*0.2*	0.050	*0.3*	0.149	*0.6*	0.302	*0.9*	0.549	*1.2*	0.929	*1.6*		180
190		0.028	*0.2*	0.052	*0.3*	0.153	*0.6*	0.312	*0.9*	0.566	*1.2*	0.958	*1.6*		190
200		0.029	*0.2*	0.053	*0.3*	0.158	*0.6*	0.321	*0.9*	0.583	*1.2*	0.986	*1.6*		200
225		0.031	*0.2*	0.057	*0.3*	0.169	*0.6*	0.344	*0.9*	0.623	*1.2*	1.05	*1.6*		225
250		0.032†	*0.2*	0.061	*0.3*	0.180	*0.6*	0.365	*0.9*	0.662	*1.3*	1.12	*1.6*		250
275		0.034	*0.2*	0.064	*0.4*	0.190	*0.6*	0.385	*0.9*	0.698	*1.3*	1.18	*1.7*	1.0	275
300		0.036	*0.3*	0.067	*0.4*	0.200	*0.6*	0.405	*0.9*	0.734	*1.3*	1.24	*1.7*		300
325		0.037	*0.3*	0.071	*0.4*	0.209	*0.7*	0.424	*1.0*	0.768	*1.3*	1.30	*1.7*		325
350		0.039	*0.3*	0.074	*0.4*	0.218	*0.7*	0.442	*1.0*	0.801	*1.3*	1.35	*1.7*		350
375		0.041	*0.3*	0.077	*0.4*	0.227	*0.7*	0.460	*1.0*	0.833	*1.3*	1.41	*1.7*		375
400		0.042	*0.3*	0.080	*0.4*	0.236	*0.7*	0.477	*1.0*	0.864	*1.3*	1.46	*1.8*		400
425		0.044	*0.3*	0.083	*0.4*	0.244	*0.7*	0.494	*1.0*	0.894	*1.3*	1.51	*1.8*		425
450	0.5	0.045	*0.3*	0.085	*0.4*	0.252	*0.7*	0.511	*1.0*	0.924	*1.4*	1.56	*1.8*		450
475		0.047	*0.3*	0.088	*0.4*	0.260	*0.7*	0.527	*1.0*	0.952	*1.4*	1.61	*1.8*		475
500		0.048	*0.3*	0.091	*0.4*	0.268	*0.7*	0.542	*1.0*	0.980	*1.4*	1.66	*1.8*		500
550		0.051	*0.3*	0.096	*0.4*	0.283	*0.7*	0.572	*1.0*	1.04	*1.4*	1.75	*1.8*		550
600		0.054	*0.3*	0.101	*0.4*	0.297	*0.7*	0.601	*1.0*	1.09	*1.4*	1.83	*1.8*	1.5	600
650		0.056	*0.3*	0.106	*0.4*	0.311	*0.7*	0.629	*1.0*	1.14	*1.4*	1.92	*1.9*		650
700		0.059	*0.3*	0.110	*0.4*	0.324	*0.7*	0.656	*1.1*	1.19	*1.4*	2.00	*1.9*		700
750		0.061	*0.3*	0.115	*0.4*	0.337	*0.7*	0.682	*1.1*	1.23	*1.4*	2.08	*1.9*		750
800		0.063	*0.3*	0.119	*0.4*	0.350	*0.7*	0.708	*1.1*	1.28	*1.5*	2.16	*1.9*		800
850		0.066	*0.3*	0.123	*0.4*	0.362	*0.8*	0.732	*1.1*	1.32	*1.5*	2.23	*1.9*		850
900		0.068	*0.3*	0.127	*0.4*	0.374	*0.8*	0.757	*1.1*	1.37	*1.5*	2.30	*1.9*		900
950		0.070	*0.3*	0.131	*0.4*	0.386	*0.8*	0.780	*1.1*	1.41	*1.5*	2.37	*1.9*		950
1000		0.072	*0.3*	0.135	*0.4*	0.398	*0.8*	0.803	*1.1*	1.45	*1.5*	2.44	*2.0*	2.0	1000
1100		0.076	*0.3*	0.143	*0.4*	0.420	*0.8*	0.847	*1.1*	1.53	*1.5*	2.58	*2.0*		1100
1200		0.080	*0.3*	0.150	*0.4*	0.441	*0.8*	0.890	*1.1*	1.61	*1.5*	2.71	*2.0*		1200
1300		0.084	*0.3*	0.157	*0.5*	0.461	*0.8*	0.931	*1.1*	1.68	*1.6*	2.83	*2.0*		1300
1400		0.088	*0.3*	0.164	*0.5*	0.481	*0.8*	0.971	*1.2*	1.75	*1.6*	2.95	*2.0*		1400
1500	1.0	0.091	*0.3*	0.171	*0.5*	0.500	*0.8*	1.00	*1.2*	1.82	*1.6*	3.06	*2.1*		1500
1600		0.095	*0.3*	0.177	*0.5*	0.519	*0.8*	1.05	*1.2*	1.89	*1.6*	3.18	*2.1*		1600
1700		0.098	*0.3*	0.184	*0.5*	0.537	*0.8*	1.08	*1.2*	1.95	*1.6*	3.29	*2.1*		1700
1800		0.101	*0.3*	0.190	*0.5*	0.555	*0.8*	1.12	*1.2*	2.02	*1.6*	3.39	*2.1*		1800
1900		0.104	*0.3*	0.196	*0.5*	0.572	*0.8*	1.15	*1.2*	2.08	*1.6*	3.50	*2.1*		1900
2000		0.108	*0.3*	0.201	*0.5*	0.589	*0.8*	1.19	*1.2*	2.14	*1.6*	3.60	*2.1*	3.0	2000
2250		0.115	*0.4*	0.215	*0.5*	0.629	*0.9*	1.27	*1.2*	2.28	*1.7*	3.84	*2.2*		2250
2500		0.122	*0.4*	0.229	*0.5*	0.668	*0.9*	1.35	*1.2*	2.42	*1.7*	4.07	*2.2*		2500
2750		0.129	*0.4*	0.242	*0.5*	0.705	*0.9*	1.42	*1.3*	2.55	*1.7*	4.29	*2.2*		2750
3000	1.5	0.136	*0.4*	0.254	*0.5*	0.740	*0.9*	1.49	*1.3*	2.68	*1.7*	4.51	*2.2*		3000
3250		0.142	*0.4*	0.266	*0.5*	0.774	*0.9*	1.56	*1.3*	2.80	*1.7*	4.71	*2.2*		3250
3500		0.148	*0.4*	0.277	*0.5*	0.807	*0.9*	1.62	*1.3*	2.92	*1.7*	4.91	*2.3*	4.0	3500
3750		0.154	*0.4*	0.288	*0.5*	0.839	*0.9*	1.69	*1.3*	3.03	*1.8*	5.10	*2.3*		3750

Hot and Cold Water Pipework Design Spreadsheet

Pipework Description. ______________________________

Student / Project name.

Effective Pipe lengths

Pipe Section	Design Flow l/s	Est Pipe diam 1m/s	Measured length (m)	No. of T's x Equiv L	No. elbow x Equiv L	No.Valve x Equiv L	No.Taps x Equiv L	Effective Length

Critical Run

Pipe Section	Effective Length (m)	Head Available			Less residual Head req'd	Total dP (Pa) Allowable	Max dP / m allowable	Critical Run (min)
		Meters	kPa	Pa				

Pipe section sizing

Pipe Section	Effective Length (m)	Design Flow l/s	Chosen Pipe diam	Relevant dP_L(Pa/m)	dP for this section	Cumulative dP this run	Avaliable Head (Pa)	Confirm diam

Table 4.11 Flow of water at 75°C in medium grade steel pipes — *continued*

MEDIUM GRADE STEEL
WATER AT 75°C

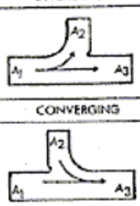
q_m = mass flow rate kg.s^{-1}
c = velocity m.s^{-1}
$\Delta p/l$ = pressure drop per unit length Pa.m^{-1}
l_e = equivalent length of a component for $\zeta = 1$ m

$\Delta p/l$	c	10 mm q_m	10 mm l_e	15 mm q_m	15 mm l_e	20 mm q_m	20 mm l_e	25 mm q_m	25 mm l_e	32 mm q_m	32 mm l_e	40 mm q_m	40 mm l_e	50 mm q_m	50 mm l_e	c	$\Delta p/l$
92.5		0.029	0.3	0.060	0.5	0.132	0.7	0.247	1.0	0.518	1.5	0.778	1.8	1.45	2.4		92.5
95.0		0.030	0.3	0.061	0.5	0.134	0.7	0.251	1.0	0.526	1.5	0.789	1.8	1.48	2.4		95.0
97.5		0.030	0.3	0.062	0.5	0.136	0.7	0.254	1.0	0.533	1.5	0.800	1.8	1.50	2.4		97.5
100.0		0.031	0.3	0.062	0.5	0.138	0.7	0.258	1.0	0.540	1.5	0.810	1.8	1.52	2.4		100.0
120.0	0.30	0.034	0.3	0.069	0.5	0.152	0.7	0.284	1.0	0.595	1.5	0.893	1.8	1.67	2.4		120.0
140.0		0.037	0.3	0.075	0.5	0.165	0.8	0.308	1.0	0.646	1.5	0.968	1.8	1.81	2.5		140.0
160.0		0.040	0.4	0.081	0.5	0.178	0.8	0.331	1.0	0.693	1.5	1.04	1.8	1.94	2.5		160.0
180.0		0.042	0.4	0.086	0.5	0.189	0.8	0.353	1.0	0.738	1.5	1.11	1.8	2.06	2.5	1.0	180.0
200.0		0.045	0.4	0.091	0.5	0.200	0.8	0.373	1.1	0.780	1.5	1.17	1.9	2.18	2.5		200.0
220.0		0.047	0.4	0.096	0.5	0.211	0.8	0.392	1.1	0.820	1.5	1.28	1.9	2.29	2.5		220.0
240.0		0.050	0.4	0.100	0.5	0.221	0.8	0.411	1.1	0.858	1.5	1.29	1.9	2.40	2.5		240.0
260.0		0.052	0.4	0.105	0.5	0.230	0.8	0.428	1.1	0.895	1.5	1.34	1.9	2.50	2.5		260.0
280.0		0.054	0.4	0.109	0.5	0.239	0.8	0.445	1.1	0.931	1.5	1.39	1.9	2.60	2.6		280.0
300.0		0.056	0.4	0.113	0.5	0.248	0.8	0.462	1.1	0.965	1.5	1.44	1.9	2.69	2.6		300.0
320.0	0.50	0.058	0.4	0.117	0.5	0.257	0.8	0.478	1.1	0.998	1.6	1.49	1.9	2.78	2.6		320.0
340.0		0.060	0.4	0.121	0.5	0.265	0.8	0.493	1.1	1.03	1.6	1.54	1.9	2.87	2.6		340.0
360.0		0.062	0.4	0.125	0.5	0.273	0.8	0.508	1.1	1.06	1.6	1.59	1.9	2.96	2.6		360.0
380.0		0.064	0.4	0.128	0.5	0.281	0.8	0.523	1.1	1.09	1.6	1.63	1.9	3.04	2.6		380.0
400.0		0.065	0.4	0.132	0.5	0.289	0.8	0.537	1.1	1.12	1.6	1.68	1.9	3.12	2.6		400.0
420.0		0.067	0.4	0.135	0.5	0.297	0.8	0.551	1.1	1.15	1.6	1.72	1.9	3.20	2.6	1.5	420.0
440.0		0.069	0.4	0.139	0.5	0.304	0.8	0.564	1.1	1.18	1.6	1.76	1.9	3.28	2.6		440.0
460.0		0.070	0.4	0.142	0.5	0.311	0.8	0.578	1.1	1.21	1.6	1.80	1.9	3.36	2.6		460.0
480.0		0.072	0.4	0.145	0.5	0.318	0.8	0.591	1.1	1.23	1.6	1.84	1.9	3.43	2.6		480.0
500.0		0.074	0.4	0.148	0.5	0.325	0.8	0.603	1.1	1.25	1.6	1.88	1.9	3.51	2.6		500.0
520.0		0.075	0.4	0.151	0.5	0.332	0.8	0.616	1.1	1.29	1.6	1.92	1.9	3.58	2.6		520.0
540.0		0.077	0.4	0.154	0.6	0.338	0.8	0.628	1.1	1.31	1.6	1.96	1.9	3.65	2.6		540.0
560.0		0.078	0.4	0.157	0.6	0.345	0.8	0.640	1.1	1.34	1.6	2.00	1.9	3.72	2.6		560.0
580.0		0.080	0.4	0.160	0.6	0.351	0.8	0.652	1.1	1.36	1.6	2.03	1.9	3.78	2.6		580.0
600.0		0.081	0.4	0.163	0.6	0.355	0.8	0.664	1.1	1.38	1.6	2.07	1.9	3.85	2.6		600.0
620.0		0.082	0.4	0.166	0.6	0.364	0.8	0.675	1.1	1.41	1.6	2.10	1.9	3.92	2.6		620.0
640.0		0.084	0.4	0.169	0.6	0.370	0.8	0.686	1.1	1.43	1.6	2.14	1.9	3.98	2.6		640.0
660.0		0.085	0.4	0.172	0.6	0.376	0.8	0.697	1.1	1.45	1.6	2.17	1.9	4.04	2.6		660.0
680.0		0.087	0.4	0.174	0.6	0.382	0.8	0.708	1.1	1.48	1.6	2.21	1.9	4.11	2.6		680.0
700.0		0.088	0.4	0.177	0.6	0.388	0.8	0.719	1.1	1.50	1.6	2.24	1.9	4.17	2.6		700.0
720.0		0.089	0.4	0.180	0.6	0.393	0.8	0.730	1.1	1.52	1.6	2.27	1.9	4.23	2.6		720.0
740.0		0.091	0.4	0.182	0.6	0.399	0.8	0.740	1.1	1.54	1.6	2.31	2.0	4.29	2.6	2.0	740.0
760.0		0.092	0.4	0.185	0.6	0.405	0.8	0.750	1.1	1.56	1.6	2.34	2.0	4.35	2.6		760.0
780.0		0.093	0.4	0.187	0.6	0.410	0.8	0.761	1.1	1.59	1.6	2.37	2.0	4.41	2.6		780.0
800.0		0.094	0.4	0.190	0.6	0.416	0.8	0.771	1.1	1.61	1.6	2.40	2.0	4.46	2.6		800.0
820.0		0.096	0.4	0.192	0.6	0.421	0.8	0.780	1.1	1.63	1.6	2.43	2.0	4.52	2.6		820.0
840.0		0.097	0.4	0.195	0.6	0.426	0.8	0.790	1.1	1.65	1.6	2.46	2.0	4.58	2.6		840.0
860.0		0.098	0.4	0.197	0.6	0.431	0.8	0.800	1.1	1.67	1.6	2.49	2.0	4.63	2.6		860.0
880.0		0.099	0.4	0.200	0.6	0.437	0.8	0.810	1.1	1.69	1.6	2.52	2.0	4.69	2.6		880.0
900.0		0.100	0.4	0.202	0.6	0.442	0.8	0.819	1.1	1.71	1.6	2.55	2.0	4.74	2.6		900.0
920.0		0.102	0.4	0.204	0.6	0.447	0.8	0.828	1.1	1.73	1.6	2.58	2.0	4.80	2.6		920.0
940.0		0.103	0.4	0.207	0.6	0.452	0.8	0.838	1.1	1.75	1.6	2.61	2.0	4.85	2.6		940.0
960.0		0.104	0.4	0.209	0.6	0.457	0.8	0.847	1.1	1.76	1.6	2.64	2.0	4.90	2.6		960.0
980.0		0.105	0.4	0.211	0.6	0.462	0.8	0.856	1.1	1.78	1.6	2.66	2.0	4.95	2.6		980.0
1000.0		0.106	0.4	0.213	0.6	0.467	0.8	0.865	1.1	1.80	1.6	2.69	2.0	5.00	2.6		1000.0
1100.0		0.112	0.4	0.224	0.6	0.490	0.8	0.909	1.1	1.89	1.6	2.83	2.0	5.26	2.7		1100.0
1200.0	1.0	0.117	0.4	0.235	0.6	0.513	0.8	0.950	1.1	1.98	1.6	2.96	2.0	5.49	2.7		1200.0
1300.0		0.122	0.4	0.245	0.6	0.535	0.8	0.990	1.1	2.06	1.6	3.08	2.0	5.72	2.7		1300.0
1400.0		0.127	0.4	0.254	0.6	0.555	0.8	1.03	1.1	2.14	1.6	3.20	2.0	5.94	2.7		1400.0
1500.0		0.131	0.4	0.263	0.6	0.576	0.8	1.07	1.1	2.22	1.6	3.31	2.0	6.16	2.7		1500.0
1600.0		0.136	0.4	0.272	0.6	0.595	0.9	1.10	1.1	2.29	1.6	3.42	2.0	6.36	2.7	3.0	1600.0
1700.0		0.140	0.4	0.281	0.6	0.614	0.9	1.14	1.2	2.37	1.6	3.53	2.0	6.56	2.7		1700.0
1800.0		0.144	0.4	0.290	0.6	0.632	0.9	1.17	1.2	2.44	1.6	3.64	2.0	6.76	2.7		1800.0
1900.0		0.148	0.4	0.298	0.6	0.650	0.9	1.20	1.2	2.50	1.6	3.74	2.0	6.94	2.7		1900.0

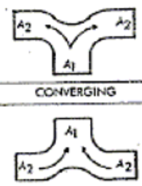
TABLE C4.36. Velocity pressure loss factors for pipe fittings.

TEES AND JUNCTIONS

(Based on velocity pressure of combined flow. Factors refer to the branch indicated by the subscript, e.g. ζ_2 is for flow to or from branch 2.)



DIVERGING / CONVERGING	ζ_2	ζ_3
	0.5 + (factor for bend or elbow as appropriate) + (factor for enlargement or reduction where bores differ)	0.2 + (factor for enlargement or reduction where bores differ)



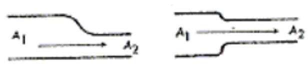
DIVERGING / CONVERGING	ζ_2
	0.5 + (factor for bend or elbow as appropriate) + (factor for enlargement or reduction where bores differ)

TONGUE TEE

$\zeta_2 = 4.5$ ($d < 20$mm)
$\zeta_2 = 3.0$ ($d \geq 20$mm)
$\zeta_3 = 3.0$

REDUCTIONS

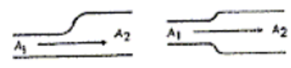
(Based on velocity pressure in smaller pipe.)



A_2/A_1	ζ	A_2/A_1	ζ
0.1	0.55	0.4	0.40
0.2	0.50	0.6	0.25
0.3	0.45	0.8	0.05

ENLARGEMENTS

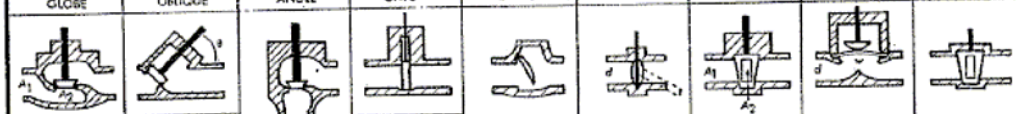
(Based on velocity pressure in smaller pipe.)



A_1/A_2	ζ	A_1/A_2	ζ
0.1	0.80	0.4	0.35
0.2	0.65	0.6	0.15
0.3	0.50	0.8	0.05

VALVES

(Figures are for valves fully open.)



GLOBE

d/mm	ζ for A_2/A_1 0.7	1.0
15	—	12
25	10	7
50	7	5
≥75	6	4

OBLIQUE

d/mm	ζ for θ 45°	60°
15	3	6
25	1.8	4
50	1.3	2.5
≥75	1.0	2.0

ANGLE: ζ = 5.0

GATE

d/mm	ζ
15	0.5
25	0.3
50	0.2
≥75	0.1

NON-RETURN: ζ = 2.0

BUTTERFLY

t/d	ζ
0.1	0.1
0.2	0.3
0.3	0.8

PLUG

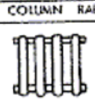
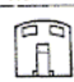
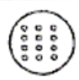
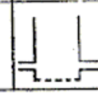
A_2/A_1	ζ
0.7	1.0
1.0	0.4

DIAPHRAGM

?/d	ζ
0.5	7.0
1.0	2.5
Venturi	0.5

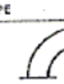
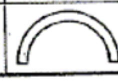
COCK or TAP: ζ = 10

OTHER ITEMS

COLUMN RADIATOR	PANEL RADIATOR	SECTIONAL BOILER	TUBE BOILER	LARGE VESSELS
 ζ = 5.0	 ζ = 2.5	 ζ = 2.5	 ζ = 8.0	 ENTRY ζ = 1.0 EXIT ζ = 0.4

ELBOWS AND BENDS

TYPE		10–25 mm	32–50 mm	65–90 mm	≥100 mm
MALLEABLE CAST IRON 90° ELBOW		0.8	0.7	0.6	0.6
MALLEABLE CAST IRON 45° ELBOW		0.6	0.6	0.5	0.5
MALLEABLE CAST IRON BEND		0.7	0.5	0.4	0.4
SCREWED MILD STEEL BEND		0.7	0.5	0.4	0.3
MALLEABLE CAST IRON RETURN BEND		0.9	0.8	0.8	—

TYPE		10–25 mm	32–50 mm	65–90 mm	≥100 mm
FLANGED CAST IRON BEND		0.5	0.5	0.5	0.5
WELDED MILD STEEL ELBOW		0.4	0.4	0.3	0.3
WELDED MILD STEEL BEND		0.4	0.3	0.3	0.2
COPPER PIPE ELBOW		1.0	0.8	0.5	—
PANEL RETURN BEND		0.6	—	—	—

Notes to Table C4.36.

Convergent flow at junctions
Where the velocity of flow in one branch of a tee, at a converging junction, is high relative to the velocity in the other, the pressure loss factor for the latter may be negative due to the injection effect.

Tapers
Where the included angle is 10° or less, take a factor of 0.2 for an enlargement and ignore for a contraction.

Valves
Individual designs may show wide variations over the values tabulated.

Radiators
The resistance to flow through a cast iron column radiator with S columns may be approximated by: $p = 5720\, M^2\, S^{0.15}$

Specialist equipment
Manufacturers' data should be consulted in those cases.

CORK INSTITUTE OF TECHOLOGY

Project:

DUCTWORK DESIGN SHEET

	DUCT SIZING (Fig C4.2)						DUCT LOSS (C4.2)				FITTING LOSS (C4.35)													GRILLE / DIFFUSER LOSS						
	A	B	C	D	E		F	G	H		I	J	K	L	M	N	O	P	Q	R	S	T				U	V	W	X	Y
	Duct Reference	Air Flow m3/s	Duct Diameter m	Velocity m/s	Rectangular mm		Straight Length m	Pressure Loss Pa/m	Total Duct Loss Pa		No. Bends, Branches, Tees	Zeta factor bends etc	Sub-Total for bends	No. Transitions	Zeta factor Transitions	Sub-Total for Transitions	No. Other Fittings	Zeta factor Other fittings	Sub-Total for others	Total Zeta factor (all fittings)	Velocity press Pv (Pa) C4.33	Total Fittings Loss (Pa) =ζ (zeta) x Pv.	Index run dP.	Throw	Height from ceiling	Neck Velocity m/s	Face Velocity m/s	Total Loss	Type	Size
1																														
2																														
3																														
4																														
5																														
6																														
7																														
8																														
9																														
10																														

	DESIGN DATA		
PROJECT	SIZING RES	NOISE LIMIT	dBa
FAN TYPE	TOT AIR VOL	DUCT INSUL	DUCT TYPE
DUCT LOSS	FITTINGS LOSS	REGSTR LOSS	TOT LOSS

Sketch

Rough Work

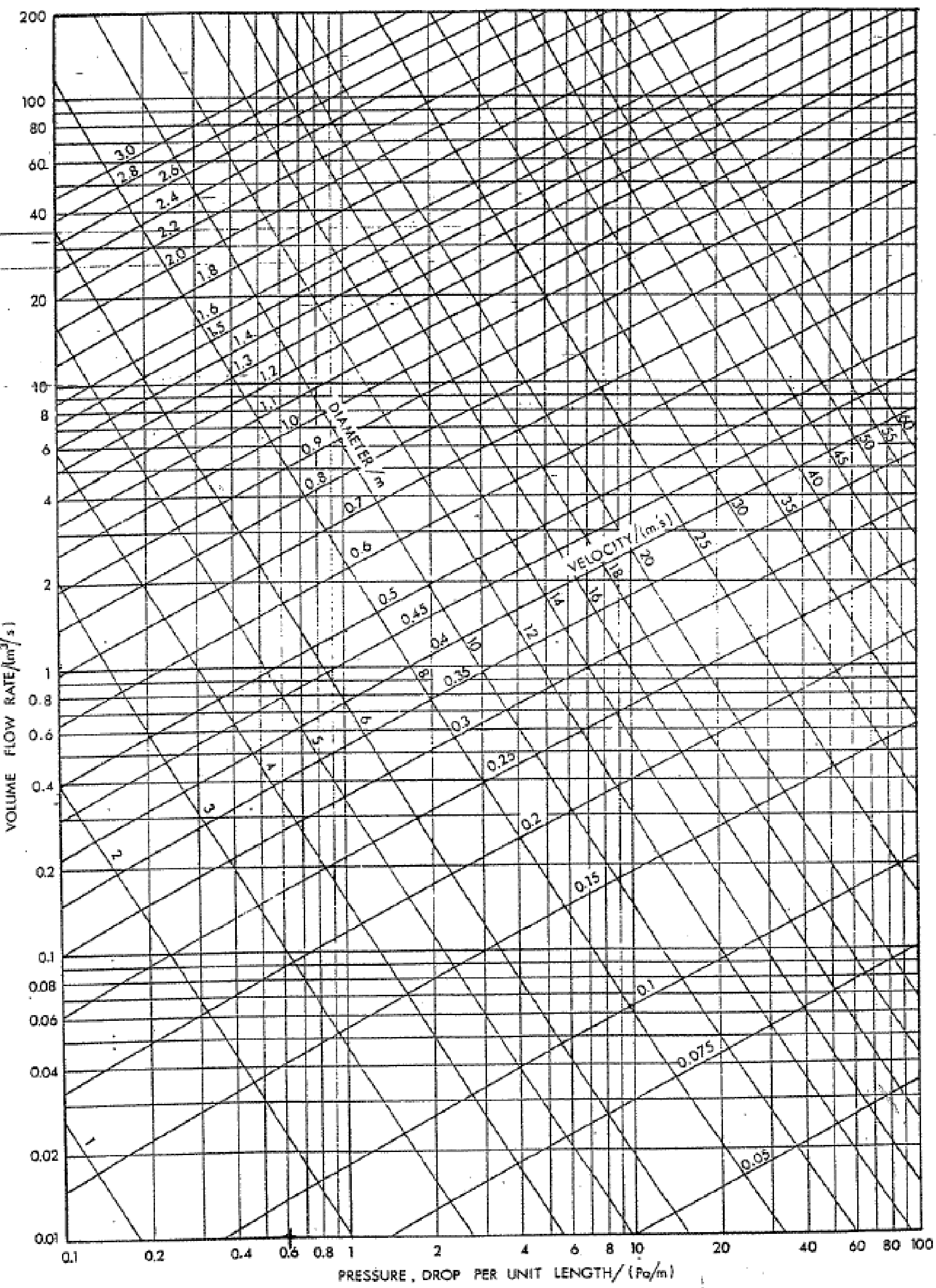


Fig. C4.2. Flow of air in round ducts.

Table C4.33. Velocity pressure in Pa against velocity in m/s.

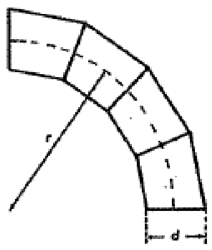
Velocity (m/s)	0·0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9
0	0·00	0·01	0·02	0·05	0·10	0·15	0·22	0·29	0·38	0·49
1	0·60	0·73	0·86	1·01	1·18	1·35	1·54	1·73	1·94	2·17
2	2·40	2·65	2·90	3·17	3·46	3·75	4·06	4·37	4·70	5·05
3	5·40	5·77	6·14	6·53	6·94	7·35	7·78	8·21	8·66	9·13
4	9·60	10·09	10·58	11·09	11·62	12·15	12·70	13·25	13·82	14·41
5	15·00	15·61	16·22	16·85	17·50	18·15	18·82	19·49	20·18	20·89
6	21·60	22·33	23·06	23·81	24·58	25·35	26·14	26·93	27·74	28·57
7	29·40	30·25	31·10	31·97	32·86	33·75	34·66	35·57	36·50	37·45
8	38·40	39·37	40·34	41·33	42·34	43·35	44·38	45·41	46·46	47·53
9	48·60	49·69	50·78	51·89	53·02	54·15	55·30	56·45	57·62	58·81
10	60·00	61:21	62·42	63·65	64·90	66·15	67·42	68·69	69·98	71·29
11	72·60	73·93	75·26	76·61	77·98	79·35	80·74	82·13	83·54	84·97
12	86·40	87·85	89·30	90·77	92·26	93·75	95·26	96·77	98·30	99·85
13	101·40	102·97	104·54	106·13	107·74	109·35	110·98	112·61	114·26	115·93
14	117·60	119·29	120·98	122·69	124·42	126·15	127·90	129·65	131·42	133·21
15	135·00	136·81	138·62	140·45	142·30	144·15	146·02	147·89	149·78	151·69
16	153·60	155·53	157·46	159·41	161·38	163·35	165·34	167·33	169·34	171·37
17	173·40	175·45	177·50	179·57	181·66	183·75	185·86	187·97	109·10	192·25
18	194·40	196·57	198·74	200·93	203·14	205·35	207·58	209·81	212·06	214·33
19	216·60	218·89	221·18	223·49	225·82	228·15	230·50	232·85	235·22	237·61
20	240·00	242·41	244·82	247·25	249·70	252·15	254·62	257·09	259·58	262·09
21	264·60	267·13	269·66	272·21	274·78	277·35	279·94	282·53	285·14	287·77
22	290·40	293·05	295·70	298·37	301·06	303·75	306·46	309·17	311·90	413·65
23	317·40	320·17	322·94	325·73	328·54	331·35	334·18	337·01	339·86	342·73
24	345·60	348·49	351·38	354·29	357·22	360·15	363·10	366·05	369·02	372·01
25	375·00	378·01	381·02	384·05	387·10	390·15	393·22	396·29	399·38	402·49
26	405·60	408·73	411·86	415·01	418·18	421·35	424·54	427·73	430·94	434·17
27	437·40	440·65	443·90	447·17	450·46	453·75	457·06	460·37	463·70	467·05
28	470·40	473·77	477·14	480·53	483·94	487·35	490·78	494·21	497·66	501·13
29	504·60	508·09	511·58	515·09	518·62	522·15	525·70	529·25	532·82	536·41
30	540·00	543·61	547·22	550·85	554·50	558·15	561·82	565·49	569·18	572·89
31	576·60	580·33	584·06	587·81	591·58	595·35	599·14	602·93	606·74	610·57
32	614·40	618·25	622·10	625·97	629·86	633·75	637·66	641·57	645·50	649·45
33	653·40	657·37	661·34	665·33	669·34	673·35	677·38	681·41	685·46	689·53
34	693·60	697·69	701·78	705·89	710·02	714·15	718·30	722·45	726·62	730·81
35	735·00	739·21	743·42	747·65	751·90	756·15	760·42	764·69	768·98	773·29
36	777·60	781·93	786·26	790·61	794·98	799·35	803·74	808·13	812·54	816·97
37	821·40	825·85	830·30	834·77	839·26	843·75	848·26	852·77	857·30	861·85
38	866·40	870·97	875·54	880·13	884·74	889·35	893·98	898·61	903·26	907·93
39	912·60	917·29	921·98	926·69	931·42	936·15	940·90	945·65	950·42	955·21
40	960·00	964·81	969·62	974·45	979·30	984·15	989·02	993·89	998·78	1003·69

TABLE C4.35. Velocity pressure loss factors for duct fittings — continued

RADIUS BENDS

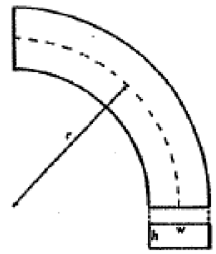
(Factors refer to the velocity pressure in the duct.)

CIRCULAR DUCTS, $\theta = 90°$



No. of pieces	ζ: $r/d = 1$	$r/d = 1.5$	$r/d = 2$	$r/d = 3$
(radius)	0.34	0.24	0.23	0.22
3	0.46	0.40	0.42	0.46
4	0.42	0.34	0.32	0.34
5	0.36	0.30	0.26	0.26

RECTANGULAR DUCTS, $\theta = 90°$



h/w	ζ: $r/w = 1$	$r/w = 1.5$	$r/w = 2$	$r/w = 3$
0.2	0.47	0.44	0.40	0.43
0.4	0.36	0.33	0.28	0.31
0.5	0.29	0.22	0.20	0.22
0.7	0.26	0.18	0.16	0.18
1.0	0.23	0.14	0.13	0.14
1.5	0.21	0.12	0.11	0.11
2.5	0.20	0.11	0.09	0.10
4.0	0.22	0.11	0.10	0.10
6.0	0.26	0.14	0.11	0.11

θ	Multiplying factors for ζ for $\theta \leq 90°$
20°	0.3
30°	0.5
45°	0.6
60°	0.8
75°	0.9
90°	1.0

MITRE BENDS

(Factors refer to the velocity pressure in the duct.)

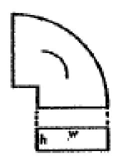
$\zeta = 1.25$

$\zeta = 1.22$

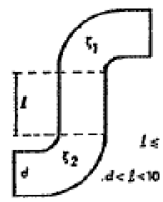
$\zeta = 0.72$

$\zeta = 0.67$

$\zeta = 0.35$ (or manufacturers' data)



h/w	ζ
0.2	0.5
0.4	0.4
0.5	0.3
≤0.7	0.2



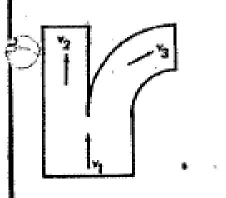
$l \leq d$: $\zeta = 0.9(\zeta_1 + \zeta_2)$

$d < l < 10d$: $\zeta = 0.8(\zeta_1 + \zeta_2)$

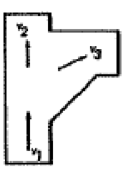
$l \geq 10d$: $\zeta = \zeta_1 + \zeta_2$

RECTANGULAR DUCT BRANCHES

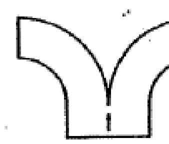
(Factors refer to the velocity pressure in the branch indicated by the subscript, e.g. ζ_2 is to be used with the velocity pressure in branch 2.)



v_2/v_1	ζ_2	v_3/v_1	ζ_3
0.6	0.34	0.6	3.5×bend loss
0.8	0.18	0.8	1.8 — " —
1.0	0.09	1.0	1.0 — " —
1.2	0.05	1.2	1.0 — " —



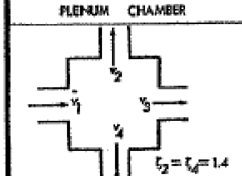
v_2/v_1	ζ_2	v_3/v_1	ζ_3
0.6	0.44	0.6	1.6
0.8	0.09	0.8	0.78
1.0	0.04	1.0	0.55
1.2	0.02	1.2	0.45



Use bend loss factor with entry velocity

RECTANGULAR DUCT BRANCHES — continued

PLENUM CHAMBER



$\zeta_2 = \zeta_4 = 1.4$

$\zeta_3 = 1.3$

CIRCULAR DUCT BRANCHES

(Factors refer to the velocity pressure in the branch indicated by the subscript, e.g. ζ_2 is to be used with the velocity pressure in branch 2.)

90° BRANCH

v_2/v_1	ζ_2
0.6	3.7
0.8	2.3
1.0	1.7
1.2	1.4

45° BRANCH

v_2/v_1	ζ_2
0.6	1.5
0.8	0.7
1.0	0.4
1.2	0.4

CONICAL BRANCH

v_2/v_1	ζ_2
0.6	2.0
0.8	1.2
1.0	0.8
1.2	0.6

Notes to Table C4.35.

Bend angles
Where bends turn through angles of less than 90°, the pressure loss factor may be presumed to vary in the proportion $\theta/90$ unless stated otherwise.

Changes of shape (transitions)
For tapered changes of shape where $\theta < 60°$ and $A_1 \approx A_2$, the

Splitters
Where straight ducts have splitters, the straight duct friction loss through each component part should be considered.

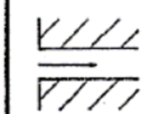
Approaches
The values for the pressure loss factors quoted here assume that the approaching velocity profile is regular. Any eccentricity or distortion may increase or decrease the loss.

Diameters
For rectangular ducts, the hydraulic mean diameter as given by

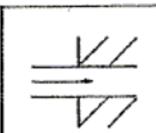
TABLE C4.35 Velocity pressure loss factors for duct fittings.

DUCT ENTRIES

(Factors refer to the velocity pressure in the duct.)

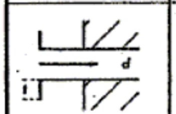


$\zeta = 0.5$



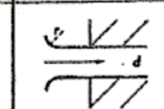
$\zeta = 0.95$

FLANGE



$t > d/25$, $\zeta = 0.5$

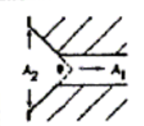
BELLMOUTH



$r = d/20$, $\zeta = 0.5$

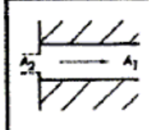
$r = d/12$, $\zeta = 0.15$

REDUCING



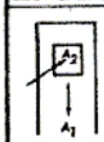
A_2/A_1	ζ ($\theta=60°$)	ζ ($\theta=90°$)	ζ ($\theta=120°$)
1.2	0.25	0.32	0.40
1.5	0.17	0.23	0.35
2.0	0.12	0.21	0.31
2.5	0.12	0.20	0.30

ORIFICE



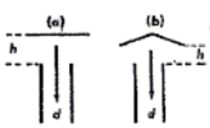
A_2/A_1	ζ
0.5	5.7
0.6	3.0
0.7	1.8
0.8	1.2
0.9	0.7
1.0	0.5

SIDE ENTRIES



$\Sigma A_2/A_1$	ζ
0.4	13.5
0.6	7.5
0.8	4.5
1.0	3.0
1.2	2.0
1.4	1.5
1.6	1.2
1.8	1.2

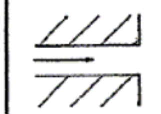
HOODS



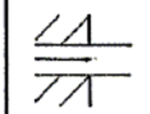
h/d	ζ (a)	ζ (b)
0.2	4.4	1.8
0.4	1.8	1.4
0.6	1.4	1.2
1.0	1.1	1.1

DUCT EXITS

(Factors refer to the velocity pressure in the duct and include the discharge.)

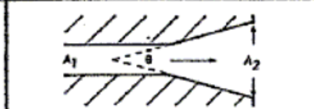


$\zeta = 1.0$



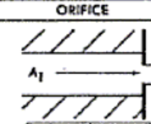
$\zeta = 1.0$

DIFFUSER



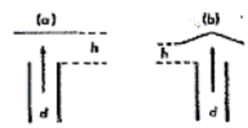
A_1/A_2	ζ ($\theta=10°$)	ζ ($\theta=20°$)	ζ ($\theta=30°$)	ζ ($\theta=40°$)
0.7	0.64	0.72	0.79	0.86
0.6	0.55	0.64	0.74	0.83
0.5	0.48	0.58	0.70	0.79
0.4	0.40	0.53	0.65	0.76
0.3	0.34	0.48	0.62	0.73

ORIFICE



A_2/A_1	ζ
0.5	7.8
0.6	4.7
0.7	3.0
0.8	2.0
0.9	1.3
1.0	1.0

HOODS

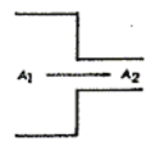


h/d	ζ (a)	ζ (b)
0.2	5.3	2.3
0.4	1.7	1.4
0.6	1.2	1.1
1.0	1.0	1.0

CONTRACTIONS

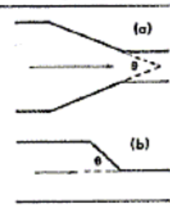
(Factors refer to the velocity pressure at the smaller area.)

ABRUPT



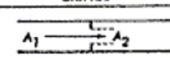
A_2/A_1	ζ
0.25	0.37
0.3	0.34
0.35	0.32
0.4	0.28
0.45	0.25
0.5	0.23
0.55	0.19
0.6	0.16
0.65	0.12
0.7	0.09

GRADUAL



θ	ζ (a)	ζ (b)
30°	0.02	0.07
45°	0.04	0.2
60°	0.07	0.4

ORIFICE

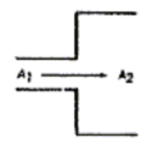


A_1/A_2	ζ
1.1	0.1
1.2	0.4
1.4	1.0
1.7	2.0
2.0	4.0

ENLARGEMENTS

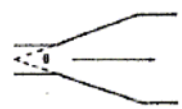
(Factors refer to the velocity pressure at the smaller area.)

ABRUPT



A_1/A_2	ζ
0.25	0.56
0.3	0.49
0.35	0.42
0.4	0.36
0.45	0.30
0.5	0.25
0.55	0.20
0.6	0.16
0.65	0.12
0.7	0.09

GRADUAL

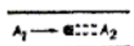


θ	Multiplying factors to be applied to ζ for abrupt fittings ●	■
10°	0.3	0.3
20°	0.5	0.6
30°	0.6	0.8
40°	0.9	1.0
50°	1.0	1.0

OBSTRUCTIONS

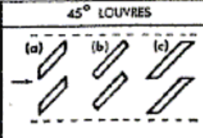
(Factors refer to the velocity pressure in the duct.)

STRUTS



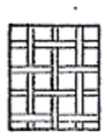
A_2/A_1	ζ ■	ζ ●	ζ (streamlined)
0.5	4.0	2.0	0.9
0.25	1.4	0.6	0.2
0.1	0.7	0.2	0.1

45° LOUVRES



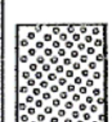
Free area ratio	ζ (a)	ζ (b)	ζ (c)
0.5	6.0	4.5	3.0
0.6	3.6	3.0	1.8
0.7	2.4	2.1	1.1
0.8	1.6	1.4	0.7

WIRE MESH



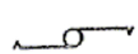
Free area ratio	ζ
0.2	17
0.3	6.2
0.4	3.0
0.5	1.7
0.6	1.0
0.7	0.6
0.8	0.3

PERFORATED SHEET



Free area ratio	ζ
0.2	51
0.3	18
0.4	8.3
0.5	4.0
0.6	2.0
0.7	1.0
0.8	0.4

OPEN DAMPERS



$\zeta = 0.5$

$\zeta = 0.2$