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The Effect of System Pressure on Head Loss Components (Part 1: Water Distribution within Buildings)

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Abstract— Frictional and separation losses as well as ratios of separation loss to the total head loss were calculated for a reservoir discharge range of 0.6L/s to 4.4L/s (with a corresponding range of number of sanitary appliances served of 8 to120) for reservoir elevations of 5.0m, 7.5m, 10.0m, 12.5m and 15.0m, for water distribution within a building. The effect of available pressure (due to reservoir elevation) on the separation loss fraction was studied. The study showed a general decrease in the separation loss fraction (and, therefore, an increasing fraction of the loss due to pipe friction) with increase in available system pressure.

Index Terms— Variation of Available Head, Water Distribution within Buildings

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1 INTRODUCTION

THE available pressure at any point in a fluid flow conduit is progressively reduced away from the pressure source (such as the elevated storage in a water distribution system) due to frictional losses and losses through fittings such as elbows, tees, reducers and valves. The latter loss is sometimes called separation loss.

Thus, extensive runs of conduit would result in increased frictional loss while multiplicity of fittings would result in increased separation loss.

However, the number and type of each fitting in a given run of conduit are specified such as to achieve proper functioning of the flow system. It can reasonably be assumed that for a given system configuration (for instance for a water distribution system serving a range of toilet rooms), the ratio between the frictional loss and the separation loss for a given index run of conduit may vary with varying source pressure. In the instance of the water distribution system, this source pressure is governed by the elevation of the water reservoir.

Furthermore, every given index run would have, associated with it, some system parameters such as length of run, number of appliances served and total fluid flow rate, which would be useful in a study on the distribution system.

In earlier works, the relationship between the varying system parameters of length of index pipe run, number of appliances served and total water flow rate from the reservoir, on one hand; and the fraction of the total pressure head loss which constitutes that due to separation loss, on the other hand, had been studied [1], [2].

In this paper, the variation of the separation loss fraction with available system head is studied for varying system parameters of index pipe length, number of appliances, and total water flow rate from the reservoir, in water distribution within buildings.

2 BASIC FLUID MECHANICS EQUATIONS

The basic fluid mechanics equations used in the analysis of the frictional and separation losses are the Hazen-Williams friction formula and the D'Arcy-Weisbach fitting loss equation, respectively.

The Hazen-William formula, in terms of easily measurable variables, may be expressed as [3]

$$h_f = 1.1374 \, x \, 10^{-3} \, d^{-4.867} \, q^{1.85} \quad (1)$$

for plastic pipe material,

where h_f = frictional head loss per metre run of pipe
d = pipe diameter (m)
q = flow rate (m^3/s)

Graphical presentations of the form of Eqn.1 (the so-called Pipe Sizing Graphs) [4], [5] which simplify the application of this equation are more commonly used in practice. In particular, pipe sizes are easily selected with a knowledge of the design flow rate q and a permissible maximum head loss per metre pipe run.

The D'Arcy - Weisbach fitting loss equation has been simplified as [6]

$$h_p = 0.08256 k d^{-4} q^2 \quad (2)$$

where h_p = head loss through the pipe fitting (m)
and k = loss coefficient of the fitting type

Values of k for common pipe fittings had been given as 0.75 for elbows, 2.0 for tees and 0.25 for gate valves [7].
Furthermore, Table 1 gives k values for reducers in terms of the ratio of upstream diameter d_1 to downstream diameter d_2; the k values so obtained being utilized with d_2 in Eqn. 2.

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2. ANALYTICAL RESULTS FOR THE FIRST INDEX PIPE RUNS

The water distribution configuration of Fig.1 represents a commonly accuring scenario in hotel buildings; where water is distributed to a range of toilet rooms. Each room contains a water closet, wash basin, bath tub and a water heater.

In the analysis of head losses in the first index pipe run of Fig. 1 the pipe run from A to B and up to the farthest fixture supplied by the branch from B is first considered (with the extension on the main distribution pipe from point B towards point C being considered as non-existent).

For this firstly considered distribution system presented in Fig. 2, analyses of frictional and separation losses are carried out for available distribution pressure heads of 2.5m, 5.0m, 7.5m, 10.0m and 12.5m; this variation of system head being achieved by varying the reservoir elevation.

Fig. 3 is an isometric presentation of Fig. 2. In Fig. 3 the pipe sections are labeled using boxes. The left side number in the box is the pipe section number, that on the top right is the measured pipe length (in m) and that on the bottom right is the flow rate (in L/s) in the pipe section.

The distribution system of Figs. 2 and 3 is analyzed as follows, as an example.

Loading units which account for the non-simultaneous use of all the installed sanitary appliances, are utilised to obtain the flow rates from the graph of loading units versus flow rates (Fig. 4) [7].

These units are taken as 2 for a water closet cistern, 1.5 for a wash basin,10 for a bath tub and 2 for a water heater cylinder. For loading units below 10, which are not presented in Fig. 4, linear extrapolation are made to obtain corresponding flow rates.

Now, for a reservoir height above point A in Figs. 2 and 3 of 5m, and a height of the water heater in pipe section 5 (which is the final section of the first index run) above point A of 2.5m, the pressure head H available in the first index run = 5m-2.5m = 2.5m. The measured length L of the index run is = 23.3m. Then, the rate of head loss per meter (H/L) should not exceed 2.5/23.3 = 0.107m/m run.

This H/L value and the sectional flow rates are used to select pipe sizes from the Pipe Sizing Graph of Fig. 5 [4]. For instance, for pipe section 1 which carries a flow rate of 0.60 L/s, a 25mm is selected (at point A in Fig 5). The actual values of maximum permissible head loss are obtained at the intersection of the lines of flow rate and pipe diameter. For pipe section 1, for instance, the actual maximum permissible head loss (at point A in Fig. 5) is 0.085m/m and the measured pipe length is 18.0m. Thus, the head loss due to friction for this pipe section is 0.085 x 18m = 1.53m.

Now, the installed fittings in pipe section 1 are 6 elbows, 3 gate valves and 1 tee; resulting in a total fitting loss (calculated using Eqn. 2) of 0.552m.

Other pipe sections in the index run are analyzed in like manner and the summary of pipe sizing estimates and the calculated head loss components are given in Table 2. Thus, the total frictional loss for this index run is 1.852m while the total separation loss in 0.732m.

Now, for the same number of sanitary appliances supplied of 8 and same flow rate from the reservoir of 0.60L/s; but with increased reservoir elevations above ground of 7.5m, 10.0m, 12.5m,and 15.0m (with corresponding elevations above the highest sanitary appliance outlet of 5.0m, 7.5m, 10.0m and 12.5m), Tables 3 to 6 are obtained as for Table 2. The variation of the head loss components with available distribution pressure for this first index run are summarized in Table 7.

The range of reservoir elevations above ground utilized in the analyses (i.e. 5.0m to 15.0m) is that normally utilized in simple water distribution within buildings.

In the secondly considered distribution system, presented in Figs. 6 and 7, the analysis is done for the pipe run from A to C and up to the farthest sanitary appliance supplied by the branch from C (again considering the extension on the main distribution pipe from point C towards D as non-existent).

Tables 8 to 12, respectively, represent the calculation summaries for water distribution to the secondly considered system of Figs. 6 and 7 under available pressure heads of 2.5m, 5.0m, 7.5m, 10.0m and 12.5m.

For each of the subsequently considered third, fourth and up to the fifteenth systems, head loss calculation are carried out in like manner for available heads of 2.5m, 5.0m, 7.5m, 10.0m and 12.5m; the fifteenth system being the one with the longest first index run from point A to the branch at O to P and up to the farthest appliance outlet supplied from point P (Fig. 1).

The progressive increase in the length of first index run provides the variation of the complexity of pipe work in terms of length of index run, total flow rate from the reservoir, and number of appliances supplied from the reservoir. Similar to Table 7, Tables 13 to 26 summarize the variation of the loss components with available distribution head for the increased complexities of distribution systems; these systems being the subsequently considered second, third and up to the fifteenth, respectively.

The Excel plots of Figs. 8 to 22, corresponding to Table 7 and Tables 13 to 26, respectively, show the variation of the fraction of head loss through pipe fittings in the first index runs with system head in water distribution within the building.

3. DISCUSSION OF RESULTS

For all flow rates and corresponding numbers of sanitary appliances supplied, there is a decreasing fraction of head loss through pipe fittings (and, therefore, an increasing fraction of the loss due to pipe friction) with increasing distribution system pressure. This variation shown by the Excel plots of Figs. 8 to 22 is of second order.

The graphs show a general increase in the plotted ratios with increasing flow rates (and correspondingly increasing number of appliances served).

The graphs are useful in predicting the ratio of loss through all installed fittings to the total head loss in index runs for different flow rates (with correspondingly different numbers of appliances served) and different available system pressures. For instance, for a distribution system having a total reservoir flow rate of 4.00L/s and an available pressure head of 9m, the predicted fraction of loss due to pipe fittings is 0.38, from Fig. 21.

Thus, with a knowledge of the frictional head loss component (which is usually easier to compute than the fittings component) the total head loss in the first index run is easily obtained.

4. CONCLUSION

Frictional and separation losses as well as the ratios of the separation loss to the total loss have been calculated for varying system complexities and available pressure heads in water distribution systems within a building. Excel plots which depict the effect of available system pressure on the ratio of separation loss to total head loss were thereby obtained.

The results are useful in estimating pressure losses in building water distribution systems.

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Table 1: Values of K for Reducers, in Terms of Ratio of Upstream Diameter (d_1) to Downstream Diameter (d_2) (Giles, 1977)

Ratio d_1/d_2	k
1.2	0.08
1.4	0.17
1.6	0.26
1.8	0.34
2.0	0.37
2.5	0.41
3.0	0.43
4.0	0.45
5.0	0.46

Table 2: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 2.5m to 8 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than re-ducers)	Reducers (mmxmm)	Loss thru fittings, h_p (m)
1	31.0	0.60	18.0	0.107	25	0.085	1.530	6 elbows, 3 gate valves, 1 tee	-	0.552
2	19.0	0.45	0.1	0.107	25	0.047	0.005	1 tee	-	0.086
3	7.0	0.24	2.5	0.107	20	0.065	0.163	1 tee	25 x 20	0.062
4	3.5	0.12	0.2	0.107	20	0.018	0.004	1 tee	-	0.015
5	2.0	0.07	2.5	0.107	15	0.060	0.150	1 elbow, 1 gate valve	20 x 15	0.017
			23.3				1.852			0.732

Table 3: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 5m to 8 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than re-ducers)	Reducers (mmxmm)	Loss thru fittings, h_p (m)
1	31.0	0.60	20.5	0.194	25	0.085	1.743	6 elbows, 3 gate valves, 1 tee	-	0.552
2	19.0	0.45	0.1	0.194	25	0.047	0.005	1 tee	-	0.086
3	7.0	0.24	2.5	0.194	20	0.065	0.163	1 tee	25 x 20	0.062
4	3.5	0.12	0.2	0.194	20	0.015	0.030	1 tee	-	0.047
5	2.0	0.07	2.5	0.194	15	0.060	0.150	1 elbow, 1 gate valve	20 x 15	0.009
			25.8				2.091			0.755

Table 4: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 7.5m to 8 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading units	Design flow (L/s)	Pipe length (m)	Permissible maximum H/L	Dia (mm)	Actual H/L	Frictional head loss, h_f (m)	Fittings (other than reducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	31.0	0.60	23.0	0.265	25	0.085	1.955	6 elbows, 3 gate valves, 1 tee	-	0.552
2	19.0	0.45	0.1	0.265	20	0.200	0.020	1 tee	25 x 20	0.220
3	7.0	0.24	2.5	0.265	20	0.065	0.163	1 tee	-	0.059
4	3.5	0.12	0.2	0.265	15	0.150	0.030	1 tee	20 x 15	0.050
5	2.0	0.07	2.5	0.265	15	0.060	0.150	1 elbow, 1 gate valve	-	0.008
			28.3				2.318			0.889

Table 5: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 10.0m to 8 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than reducers)	Reducers (mmxmm)	Loss thru fittings, h_p (m)
1	31.0	0.60	25.5	0.325	20	0.300	7.650	6 elbows, 3 gate valves, 1 tee	-	1.347
2	19.0	0.45	0.1	0.325	20	0.200	0.020	1 tee	-	0.209
3	7.0	0.24	2.5	0.325	20	0.065	0.163	1 tee	-	0.059
4	3.5	0.12	0.2	0.325	15	0.015	0.030	1 tee	20 x 15	0.047
5	2.0	0.07	2.5	0.325	15	0.060	0.150	1 elbow, 1 gate valve	-	0.009
			30.8				8.013			1.671

Table 6: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 12.5m to 8 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than reducers)	Reducers (mmxmm)	Loss thru fittings, h_p (m)
1	31.0	0.60	28.0	0.375	20	0.300	8.400	6 elbows, 3 gate valves, 1 tee	-	1.347
2	19.0	0.45	0.1	0.375	20	0.200	0.020	1 tee	-	0.209
3	7.0	0.24	2.5	0.375	20	0.065	0.163	1 tee	-	0.059
4	3.5	0.12	0.2	0.375	15	0.150	0.030	1 tee	20 x 15	0.047
5	2.0	0.07	2.5	0.375	15	0.060	0.150	1 elbow, 1 gate valve	-	0.009
			33.3				8.763			1.671

Table 7: Parameters of Distribution System for 8 Appliances and 0.60L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run(m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.852	0.732	2.584	0.283
5.0	2.091	0.755	2.846	0.265
7.5	2.318	0.889	3.207	0.277
10.5	8.013	1.671	9.684	0.173
12.5	8.763	1.671	10.434	0.160

Table 8: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 2.5m to 16 Appliances, 0.60L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than reducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	62.0	0.95	15.0	0.080	32	0.070	1.050	3 elbows, 2 gate valves, 1 tee	-	0.338
2	31.0	0.60	11.0	0.080	32	0.027	0.297	3 elbows, 2 gate valves, 1 tee	-	0.132
3	19.0	0.45	0.1	0.080	25	0.047	0.005	1 tee	32 x 25	0.091
4	7.0	0.24	2.5	0.080	20	0.065	0.163	1 tee	25 x 20	0.062
5	3.5	0.12	0.2	0.080	20	0.018	0.004	1 tee	-	0.015
6	2.0	0.07	2.5	0.080	15	0.060	0.150	1 elbow, 1 gate valve	20 x 15	0.017
			31.3				1.669			0.595

Table 9: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 5m to 16 Appliances, 0.95L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than reducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	62.0	0.95	17.5	0.148	32	0.068	1.190	3 elbows, 2 gate valves, 1 tee	-	0.338
2	31.0	0.60	11.0	0.148	25	0.085	0.935	3 elbows, 3 gate valves, 1 tee	32 x 25	0.370
3	19.0	0.45	0.1	0.148	25	0.047	0.005	1 tee	-	0.086
4	7.0	0.24	2.5	0.148	20	0.065	0.163	1 tee	25 x 20	0.062
5	3.5	0.12	0.2	0.148	20	0.018	0.004	1 tee	-	0.015
6	2.0	0.07	2.5	0.148	15	0.060	0.150	1 elbow, 1 gate valve	20 x 15	0.017
			33.8				2.447			0.888

Table 10: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 7.5m to 16 Appliances, 0.95L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading units	Design flow (L/s)	Pipe length (m)	Permissible maximum H/L	Dia (mm)	Actual H/L	Frictional head loss, h_f (m)	Fittings (other than reducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	62.0	0.95	20.0	0.207	32	0.070	1.400	3 elbows, 2 gate valves, 1 tee	-	0.338
2	31.0	0.60	11.0	0.207	25	0.085	0.935	3 elbows, 2 gate valves, 1 tee	32 x 25	0.370
3	19.0	0.45	0.1	0.207	20	0.200	0.02	1 tee	25 x 20	0.220
4	7.0	0.24	2.5	0.207	20	0.065	0.163	1 tee	-	0.059
5	3.5	0.12	0.2	0.207	15	0.150	0.03	1 tee	20 x 15	0.050
6	2.0	0.07	2.5	0.207	15	0.060	0.15	1 elbow, 1 gate valve	-	0.008
			36.3				2.698			1.045

Table 11: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 10m to 16 Appliances, 0.95L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than reducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	62.0	0.95	22.5	0.258	25	0.190	4.275	3 elbows, 2 gate valves, 1 tee	-	0.906
2	31.0	0.60	11.0	0.258	25	0.085	0.935	3 elbows, 3 gate valves, 1 tee	-	0.361
3	19.0	0.45	0.1	0.258	20	0.200	0.020	1 tee	25 x 20	0.220
4	7.0	0.24	2.5	0.258	20	0.065	0.163	1 tee	-	0.059
5	3.5	0.12	0.2	0.258	15	0.015	0.030	1 tee	20 x 15	0.047
6	2.0	0.07	2.5	0.258	15	0.060	0.150	1 elbow, 1 gate valve	-	0.009
			38.8				5.573			1.602

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Table 12: Calculations for Pipe Sizes and Head Loss Components for Water Distribution for an Available Head of 12.5m to 16Appliances, 0.95L/s Flow Rate

1	2	3	4	5	6	7	8	9	10	11
Pipe section No.	Loading unit	Design Flow (L/s)	Pipe length (m)	Permissible max. H/L	Dia. (mm)	Actual H/L	Frictional head loss h_f (m)	Fittings (other than re-ducers)	Reducers (mm x mm)	Loss thru fittings, h_p (m)
1	62.0	0.95	25.0	0.303	25	0.190	4.750	3 elbows, 2 gate valves, 1 tee	-	0.906
2	31.0	0.60	11.0	0.303	25	0.085	0.935	3 elbows, 3 gate valves, 1 tee	-	0.361
3	19.0	0.45	0.1	0.303	20	0.200	0.02	1 tee	-	0.220
4	7.0	0.24	2.5	0.303	20	0.065	0.163	1 tee		0.059
5	3.5	0.12	0.2	0.303	15	0.150	0.030	1 tee	-	0.047
6	2.0	0.07	2.5	0.303	15	0.060	0.150	1 elbow, 1 gate valve		0.009
			41.3				6.048			1.602

Table 13: Parameters of Distribution System for 16 Appliances and 0.95L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.669	0.595	2.264	0.263
5.0	2.447	0.888	3.335	0.266
7.5	2.698	1.045	3.743	0.279
10.5	5.578	1.602	7.175	0.223
12.5	6.048	1.602	7.650	0.209

Table 14: Parameters of Distribution System for 24 Appliances and 1.25L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.435	0.542	1.977	0.274
5.0	3.567	1.276	4.843	0.263
7.5	3.943	1.302	5.245	0.248
10.5	4.650	1.685	6.335	0.266
12.5	4.900	1.685	6.585	0.256

Table 15: Parameters of Distribution System for 32 Appliances and 1.55L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.127	0.453	1.580	0.287
5.0	3.100	1.160	4.260	0.272
7.5	3.749	1.302	5.049	0.258
10.5	5.793	1.861	7.654	0.243
12.5	7.118	1.991	9.109	0.219

Table 16: Parameters of Distribution System for 40 Appliances and 1.80L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.307	0.569	1.876	0.303
5.0	3.802	1.461	5.263	0.278
7.5	4.777	1.594	6.371	0.250
10.5	5.338	1.856	7.194	0.258
12.5	8.028	2.683	10.711	0.251

Table 17: Parameters of Distribution System for 48 Appliances and 2.20L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.272	0.692	1.964	0.352
5.0	2.476	1.123	3.599	0.312
7.5	4.337	1.627	5.964	0.273
10.5	4.112	1.630	5.742	0.284
12.5	6.698	2.309	9.007	0.256

Table 18: Parameters of Distribution System for 56 Appliances and 2.60L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.598	0.941	2.539	0.371
5.0	2.483	1.283	3.766	0.341
7.5	4.245	1.724	5.969	0.289
10.5	5.097	2.068	7.165	0.289
12.5	8.083	2.860	10.943	0.261

Table 19: Parameters of Distribution System for 64 Appliances and 2.70L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.539	0.864	2.403	0.360
5.0	2.349	1.362	3.711	0.367
7.5	4.625	1.936	6.561	0.295
10.5	5.421	2.217	7.638	0.290
12.5	6.892	2.645	9.537	0.277

Table 20: Parameters of Distribution System for 72 Appliances and 2.90L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run(m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.481	0.837	2.318	0.361
5.0	2.589	1.617	4.206	0.384
7.5	5.005	2.069	7.074	0.292
10.5	4.749	2.202	6.951	0.317
12.5	7.337	3.027	10.364	0.292

Table 21: Parameters of Distribution System for 80 Appliances and 2.95L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.279	0.881	2.160	0.408
5.0	2.944	1.715	4.659	0.368
7.5	4.304	2.079	6.383	0.326
10.5	5.114	2.443	7.557	0.223
12.5	6.283	2.783	9.066	0.307

Table 22: Parameters of Distribution System for 88 Appliances and 3.20L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.406	0.997	2.403	0.415
5.0	2.808	1.635	4.443	0.368
7.5	4.379	2.318	6.697	0.346
10.5	5.518	2.769	8.287	0.334
12.5	6.744	3.111	9.855	0.316

Table 23: Parameters of Distribution System for 96 Appliances and 3.50L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.571	1.136	2.707	0.402
5.0	2.977	1.822	4.799	0.380
7.5	4.467	2.666	7.113	0.374
10.5	5.465	2.937	8.402	0.350
12.5	7.320	3.507	10.827	0.324

Table 24: Parameters of Distribution System for 104 Appliances and 3.70L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.610	1.196	2.806	0.426
5.0	2.915	1.962	4.877	0.402
7.5	4.147	2.542	6.689	0.380
10.5	6.017	3.351	9.368	0.358
12.5	7.405	3.770	11.175	0.337

Table 25: Parameters of Distribution System for 112 Appliances and 4.00L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.627	1.223	2.850	0.429
5.0	2.671	1.821	4.492	0.405
7.5	4.059	2.658	6.717	0.396
10.5	6.722	3.857	10.579	0.365
12.5	7.551	4.088	11.639	0.351

Table 26: Parameters of Distribution System for 120 Appliances and 4.40L/s Flow Rate

Available Distribution Head (m)	Frictional Loss in 1st Index Run (m)	Loss Thru Fittings in 1st Index Run (m)	Total Loss in 1st Index Run (m)	Ratio of Loss Thru Fittings to Total Loss
2.5	1.549	1.246	2.795	0.446
5.0	2.900	2.041	4.941	0.413
7.5	4.311	2.880	7.191	0.401
10.5	6.292	3.434	9.726	0.353
12.5	6.986	3.667	10.650	0.344

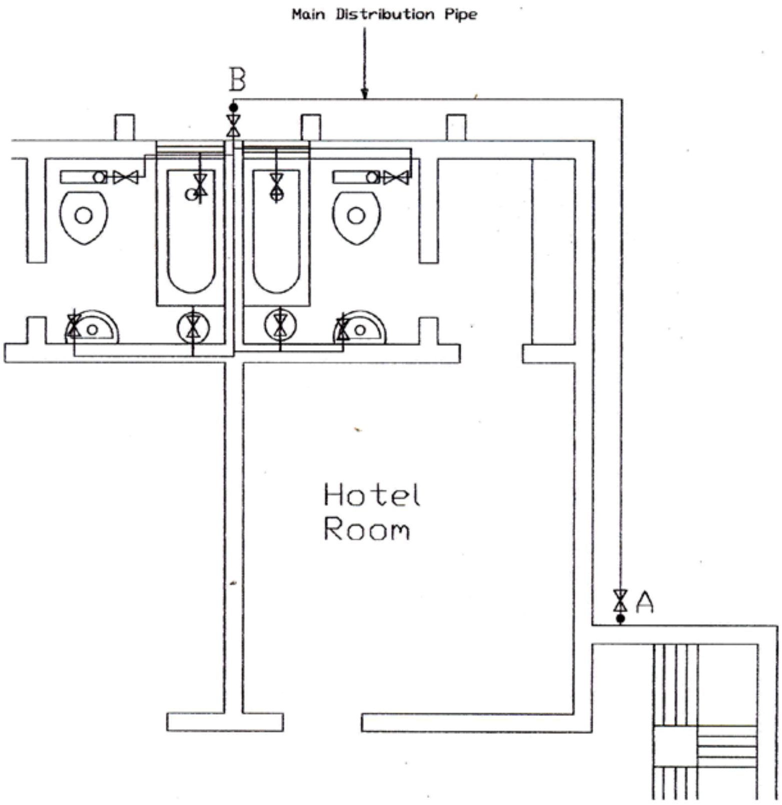


Figure 2 : Plan of Distribution System for 23.3m First Index Run,

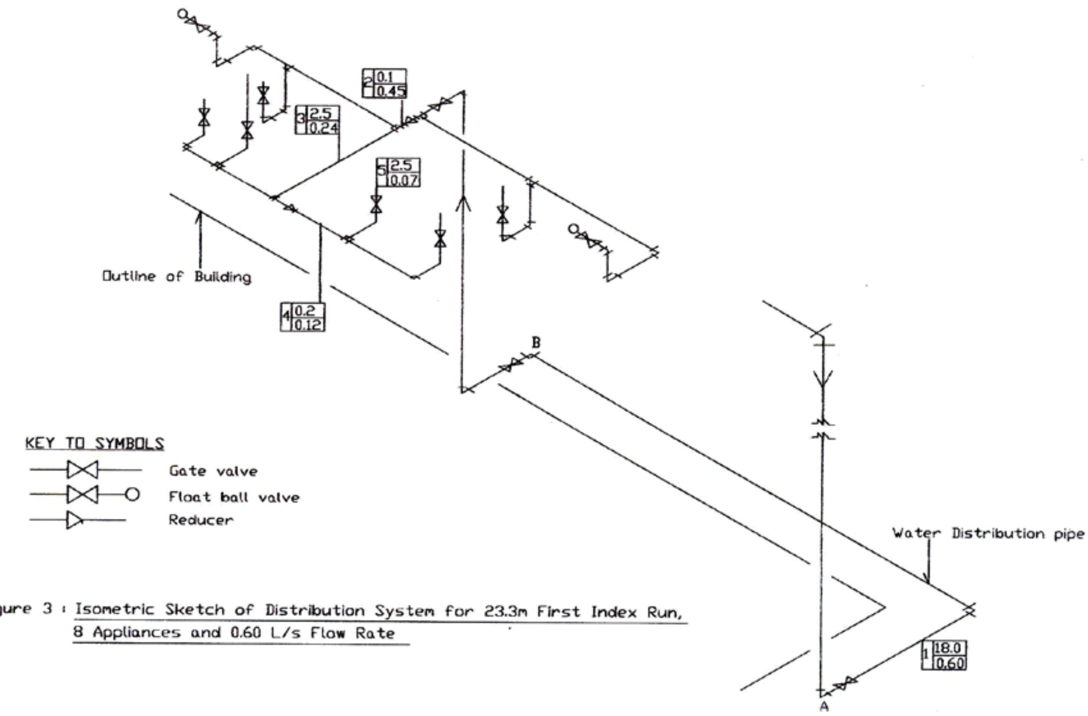


Figure 3 : Isometric Sketch of Distribution System for 23.3m First Index Run, 8 Appliances and 0.60 L/s Flow Rate

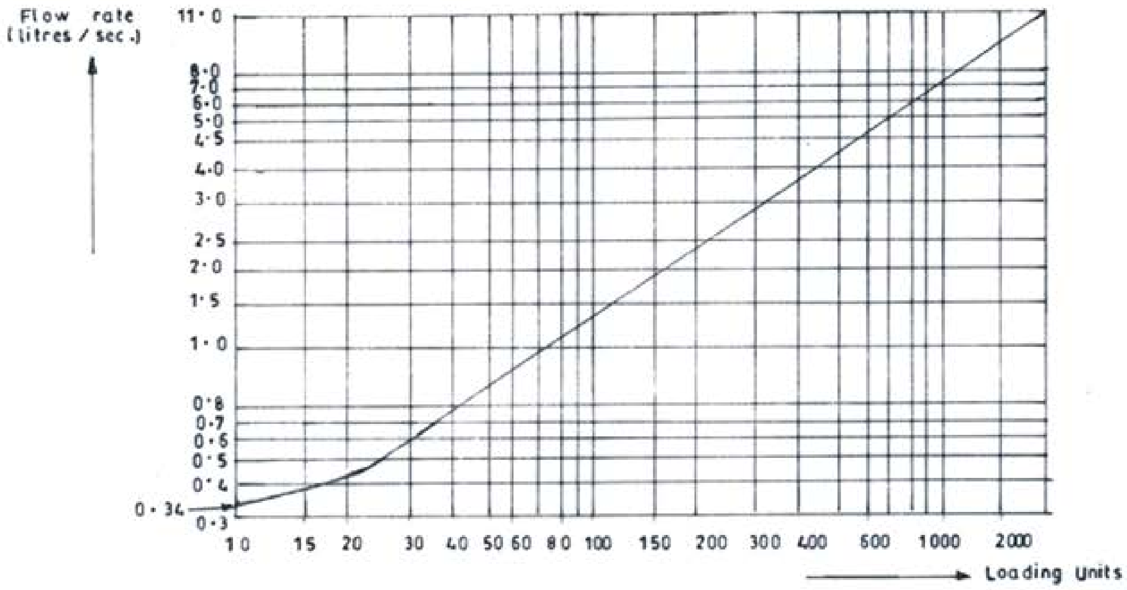
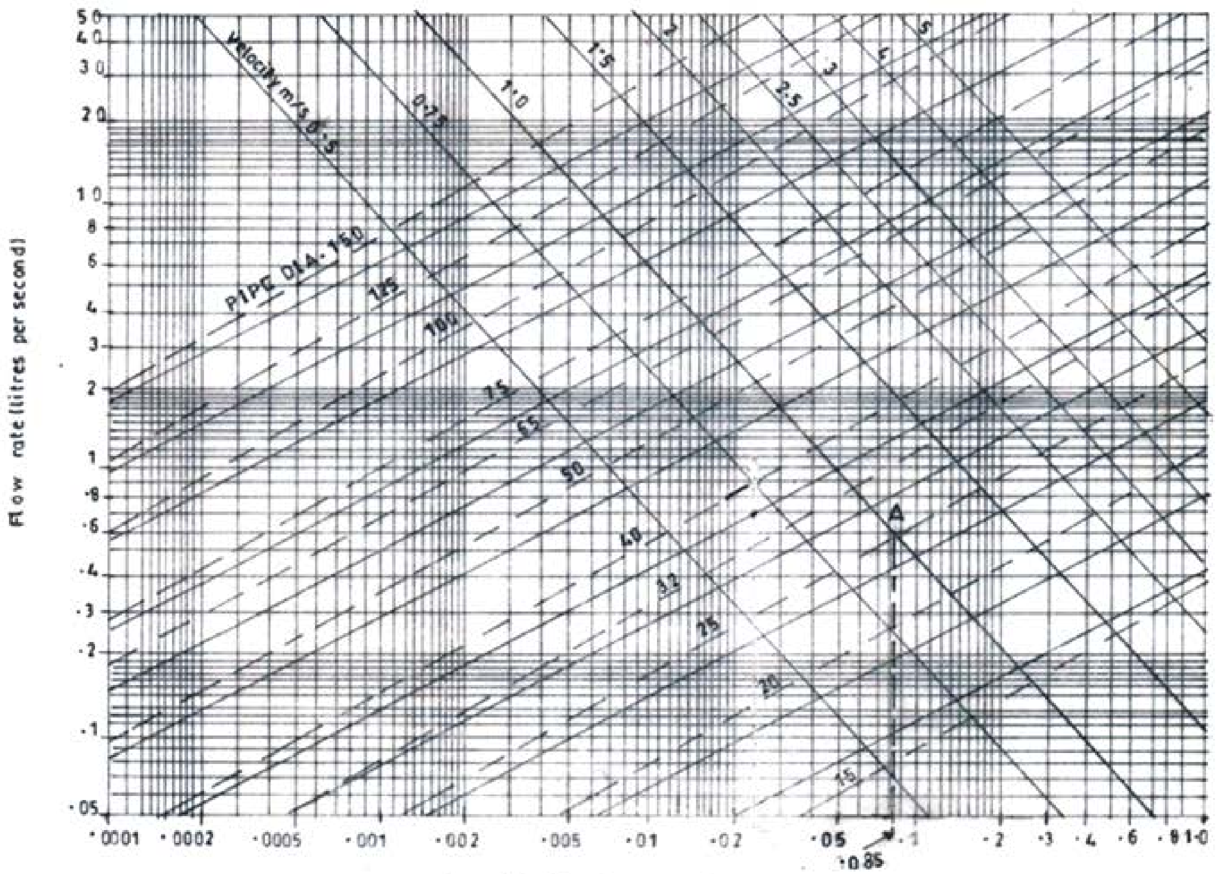


Figure 4 : Graph of Loading Unit Versus Flow Rate
(Institute of Plumbing, 1977)



Loss of head in metres per metre run

Copper, Lead and Plastics - - - Galvanised Steel ——

Figure 5 : Pipe Sizing Graph
(Institute of Plumbing, 1977)

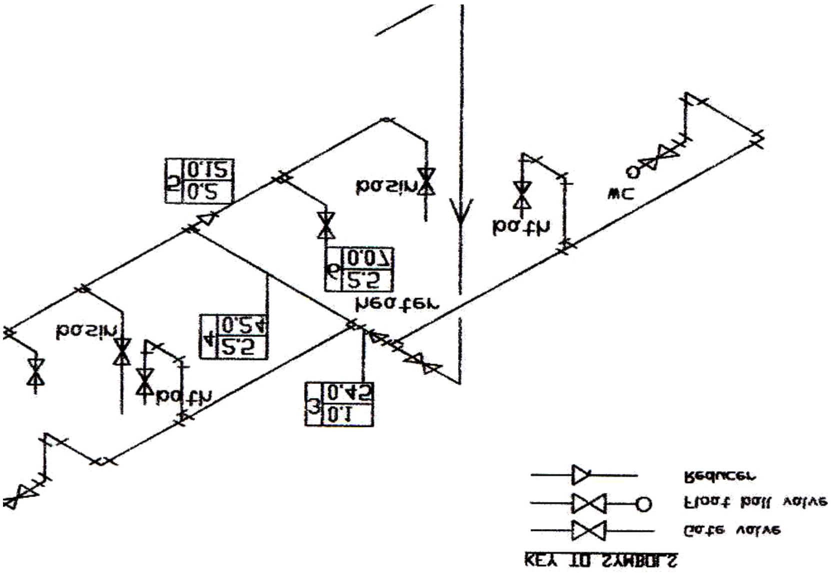
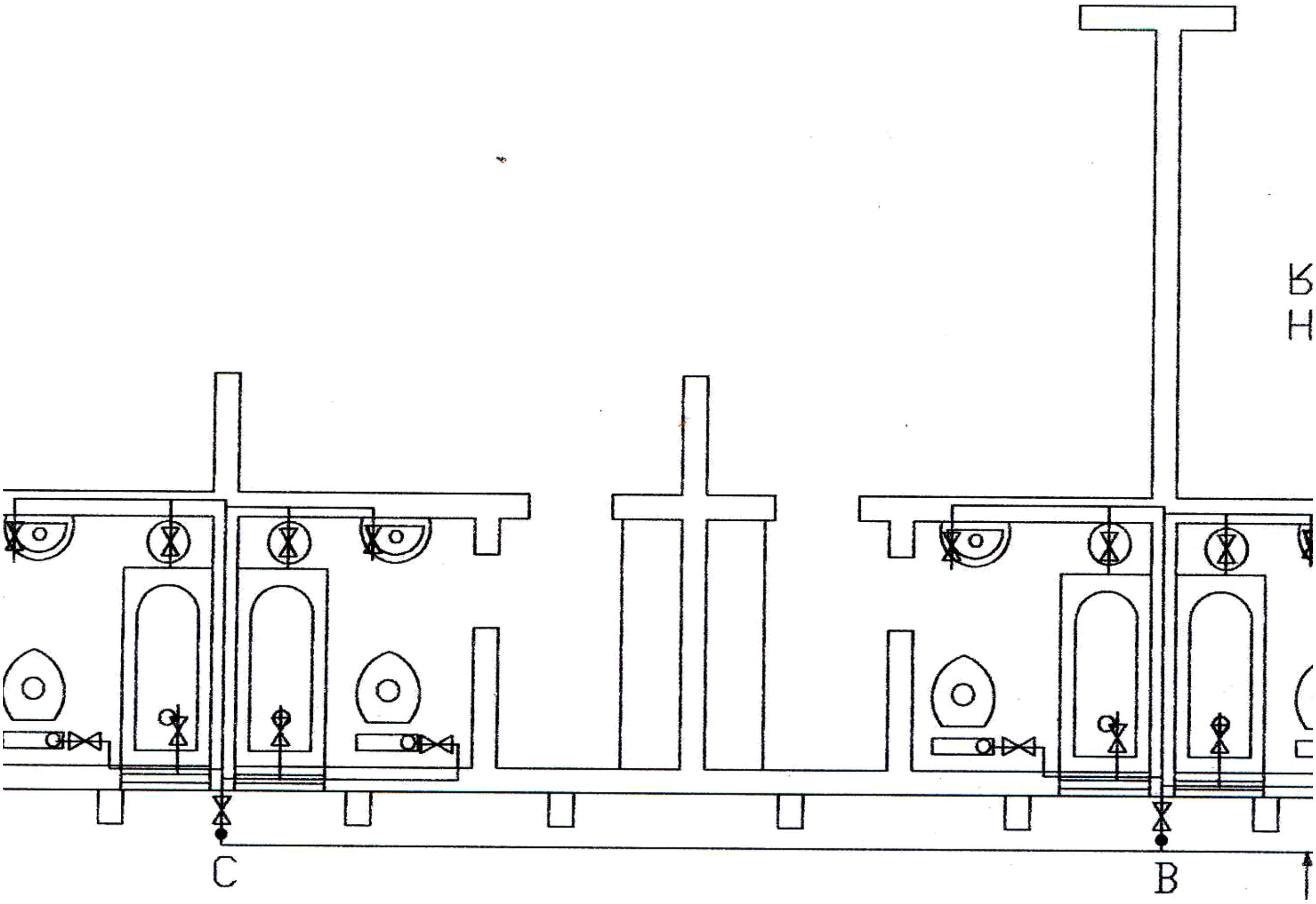


Figure 6 : Plan of Distribution System for 31.3m First Index Run.



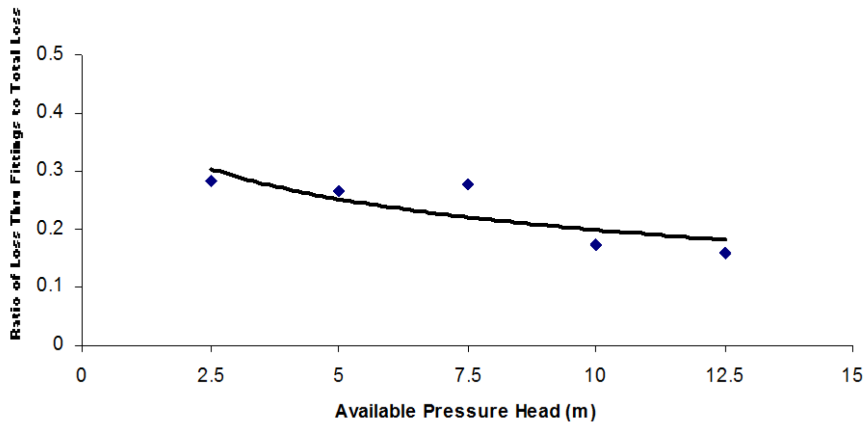


Fig. 8: Variation of Fitting Loss Fraction with Available Head for Distribution to 8 Appliances with 0.60 L/s

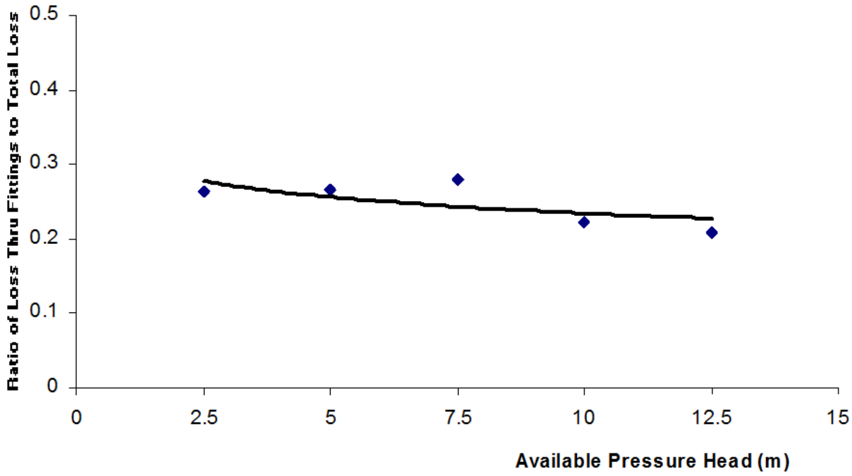


Fig. 9: Variation of Fitting Loss Fraction with Available Head for Distribution to 16 Appliances with 0.95 L/s

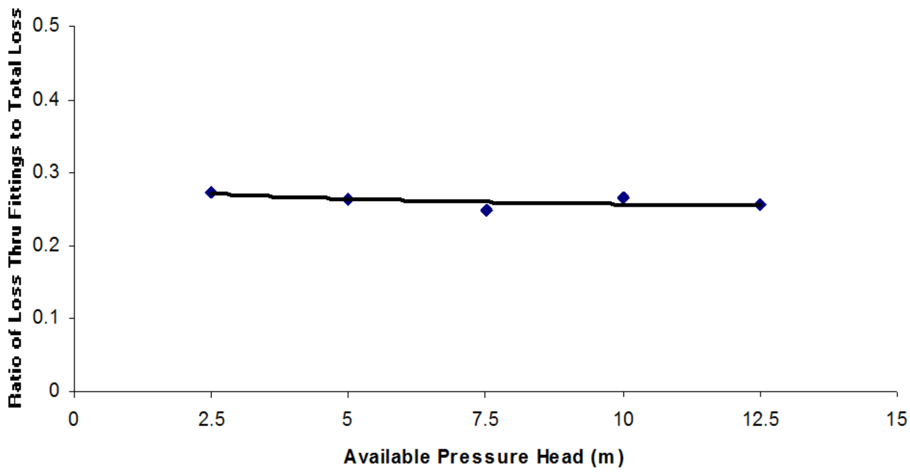


Fig. 10: Variation of Fitting Loss Fraction with Available Head for Distribution to 24 Appliances with 1.25 L/s

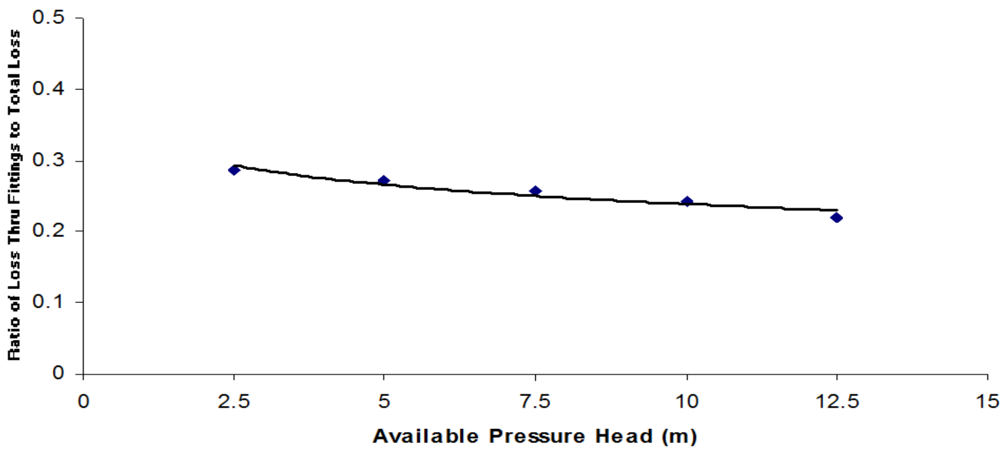


Fig. 11: Variation of Fitting Loss Fraction with Available Head for Distribution to 32 Appliances with 1.55 L/s

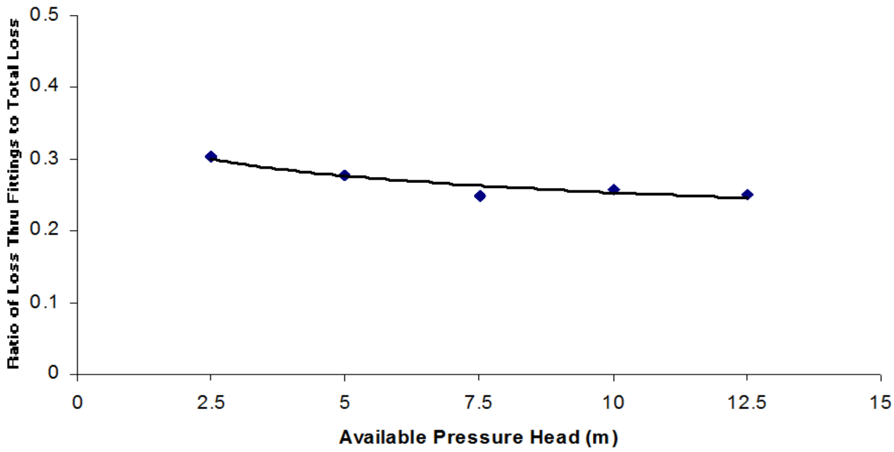


Fig. 12: Variation of Fitting Loss Fraction with Available Head for Distribution to 40 Appliances with 1.80 L/s

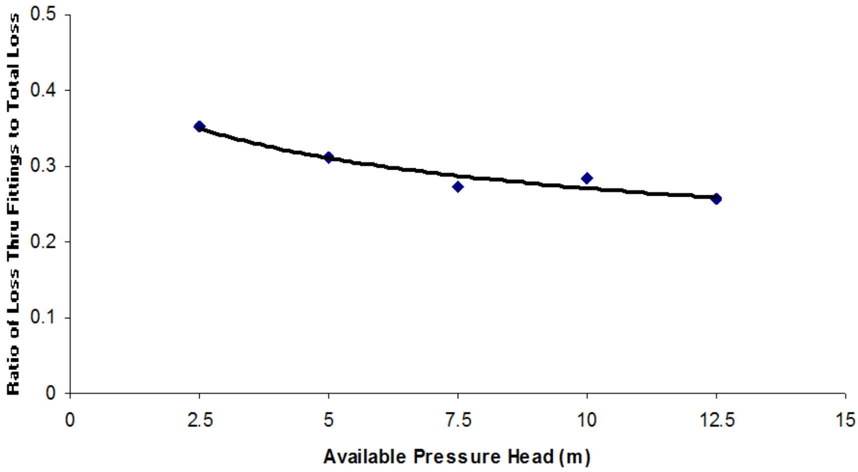


Fig. 13: Variation of Fitting Loss Fraction with Available Head for Distribution to 48 Appliances with 2.20 L/s

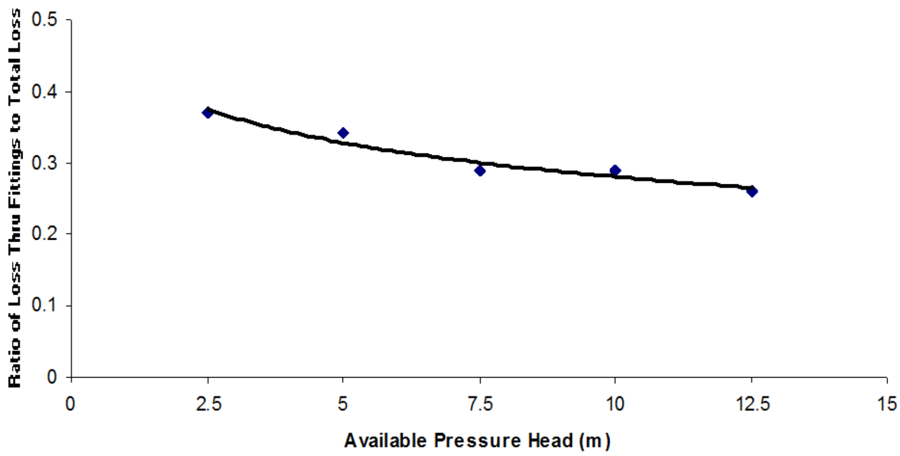


Fig. 14: Variation of Fitting Loss Fraction with Available Head for Distribution to 56 Appliances with 2.60 L/s

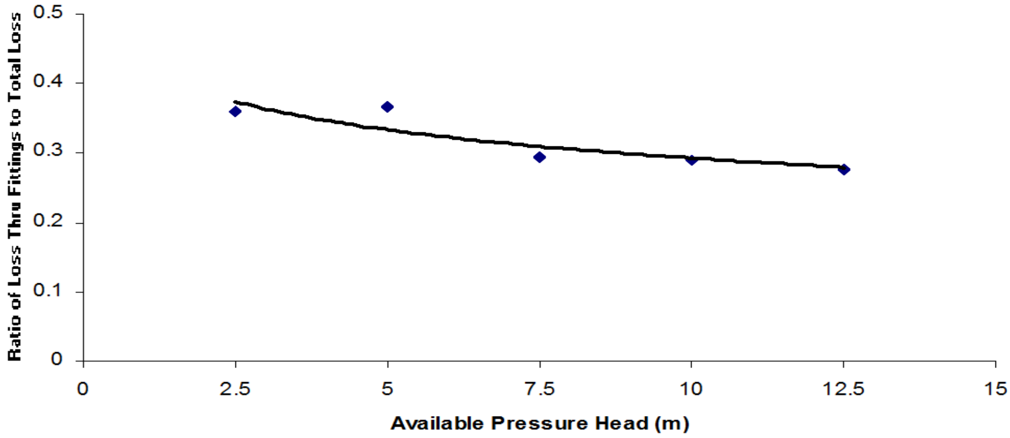


Fig. 15: Variation of Fitting Loss Fraction with Available Head for Distribution to 64 Appliances with 2.70 L/s

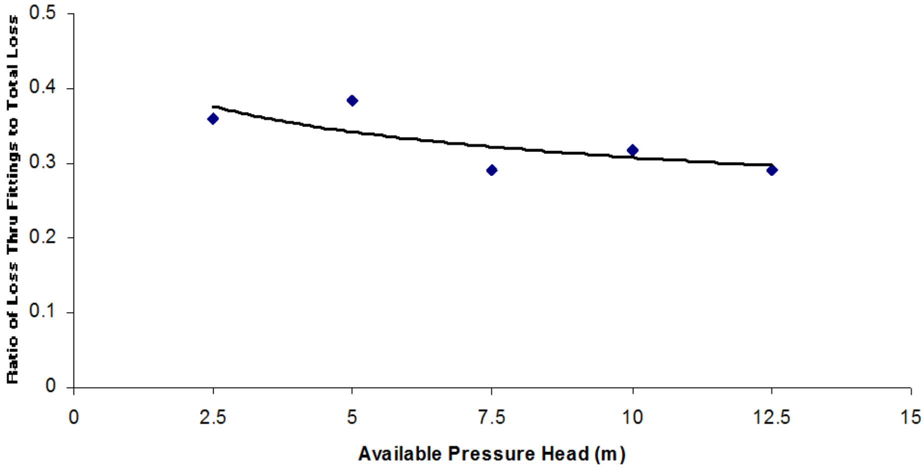


Fig. 16: Variation of Fitting Loss Fraction with Available Head for Distribution to 72 Appliances with 2.90 L/s

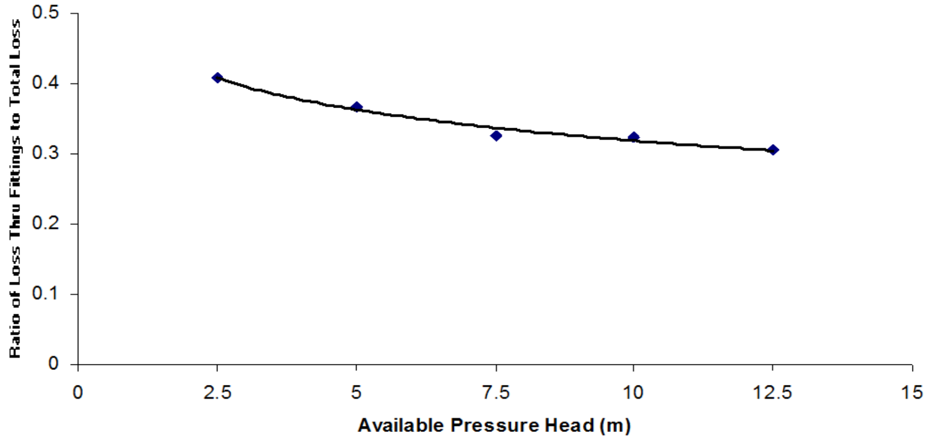


Fig. 17: Variation of Fitting Loss Fraction with Available Head for Distribution to 80 Appliances with 2.95 L/s

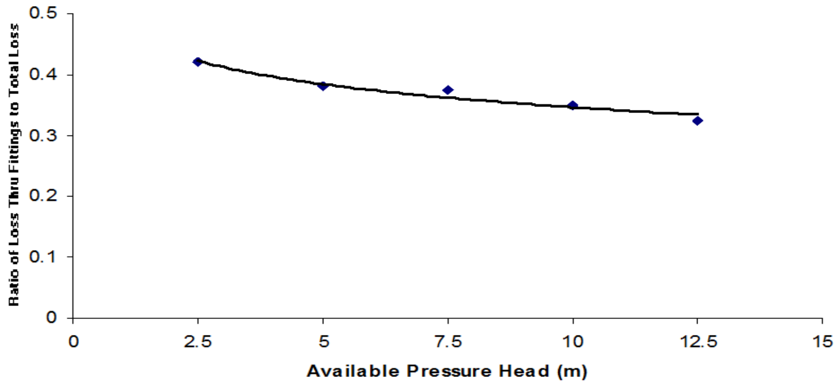


Fig. 18: Variation of Fitting Loss Fraction with Available Head for Distribution to 88 Appliances with 3.20 L/s

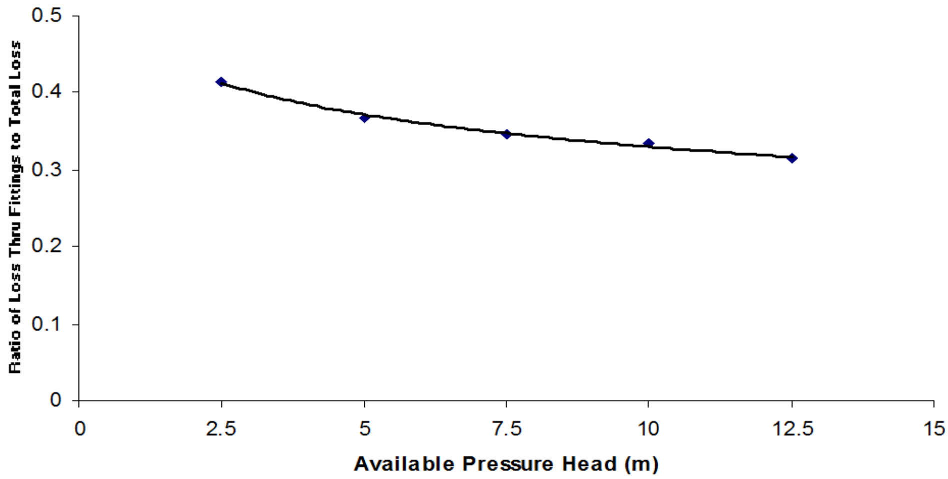


Fig. 19: Variation of Fitting Loss Fraction with Available Head for Distribution to 96 Appliances with 3.50 L/s

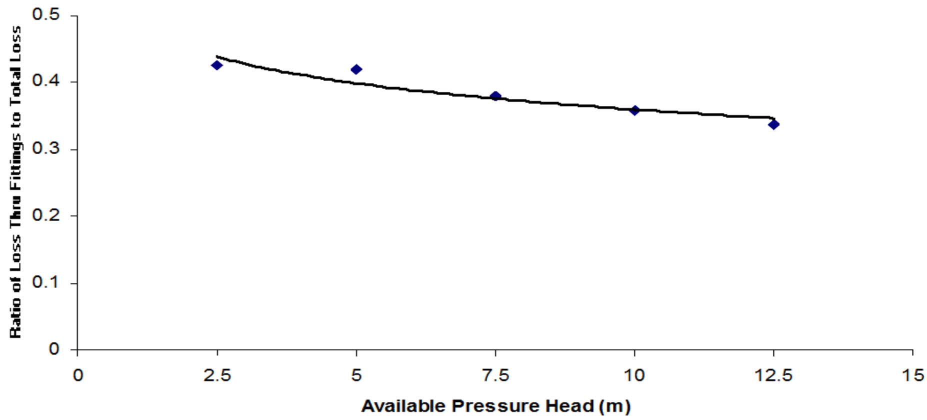


Fig. 20: Variation of Fitting Loss Fraction with Available Head for Distribution to 104 Appliances with 3.70 L/s

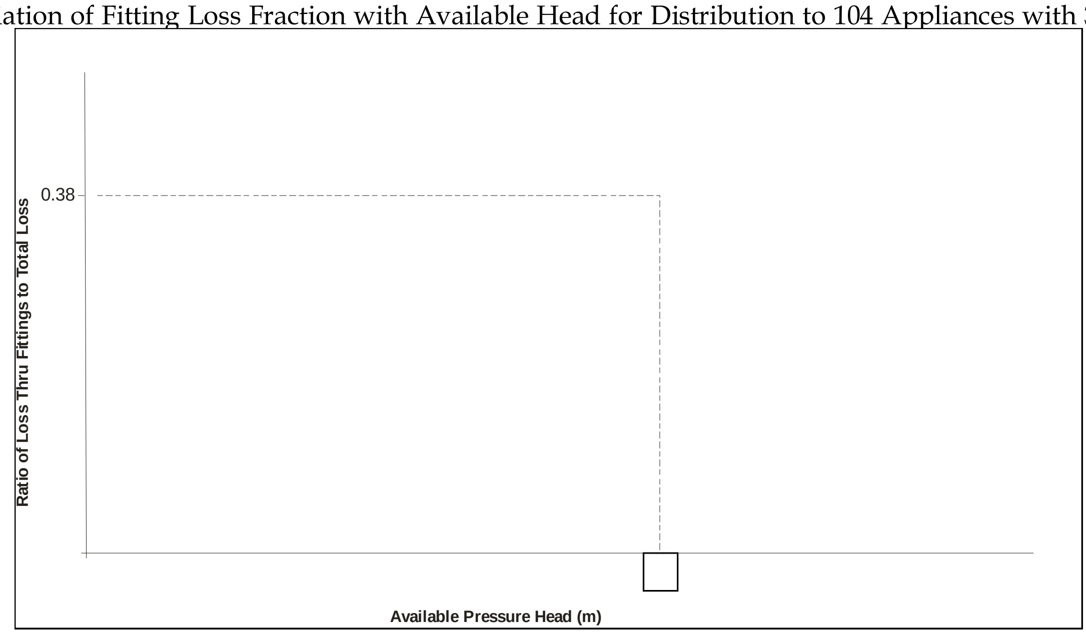


Fig. 21: Variation of Fitting Loss Fraction with Available Head for Distribution to 112 Appliances with 4.00 L/s

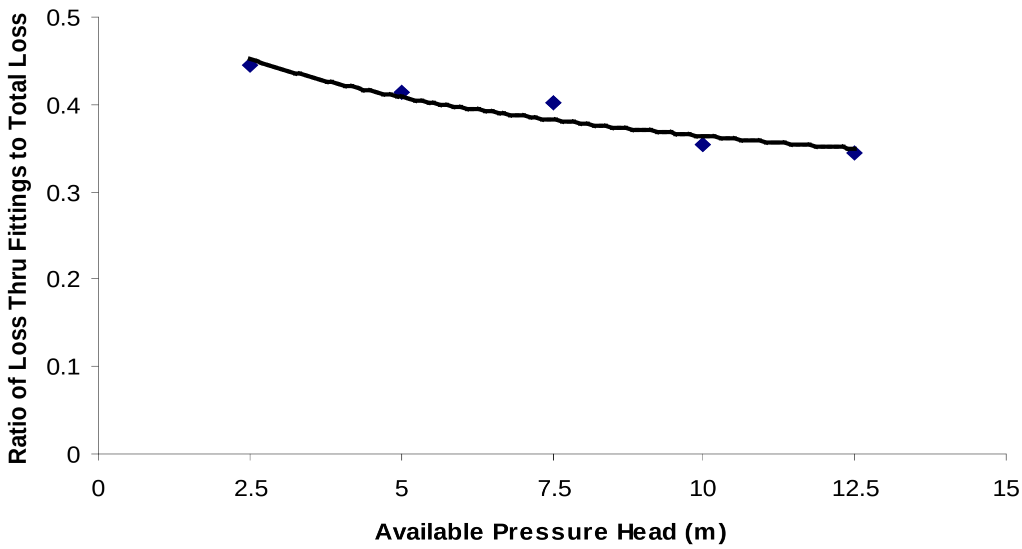


Fig. 22: Variation of Fitting Loss Fraction with Available Head for Distribution to 120 Appliances with 4.40 L/s