RESTRICTION ORIFICE FOR EQUITABLE SUPPLY IN WATER DISTRIBUTION SYSTEM

Dr Jacob Chandapillai*, **Gopan C K,**
Fluid Control Research Institute,
Palakkad, Kerala, India.
*e-mail: jacobchandapillai@fcriindia.com

ABSTRACT:

Disparity in supply among different consumers in a water distribution network due to water shortage at source is a common problem faced in many water distribution systems. Depending upon the head available at each consumer connections the supply varies drastically among the consumers. Various types of flow control devices are being used to control pressure in the network and to achieve uniform supply to all consumers.

In this paper use of restriction orifice as flow control element in a rural water distribution network is presented. A rural water distribution system facing severe disparity in supply among various consumers is studied. The network serves 42 houses in different locations. The performance of the network using restriction orifices of various sizes are analyzed and presented. It was found that the restriction orifice is an efficient device to regulate flow in water distribution network to achieve equitable water distribution.

KEYWORDS:

Water distribution network, equity, flow control, restriction orifice, flow control device, disparity.

1.0 INTRODUCTION:

Water shortage is a regular phenomenon and supply is intermittent when the availability of water at source is limited due to resource constraints. In this deficit condition, each consumer will try to collect maximum water until their demands are completely met and the limited water available at source gets exhausted in short duration [4]. Since there is no proper control over the quantity of water supplied to each consumer, the disparity in supply is obvious. The term "supply" refers to the actual delivery of water from the network to the consumers [6]. If the shortage is faced only by a few consumers, it becomes quite severe and amounts to showing injustice to them, especially when it is a daily phenomenon.

Pressure management or equitable supply to consumers is widely considered as an operational problem which is accomplished with the help of valves [8], which will create the desired pressure drop. However, this procedure requires accurate measurement or computation of pressure at outlets with design, fabrication and installation of above fixtures, tailor-made for each location. The main draw-back of this procedure is the wilful tampering of valves by consumers and clogging.

When there is a shortage of water at the source, it is necessary to supply available quantity amount the consumers equitably to avoid any disparity in supply among the consumers. It is necessary to control the delivery in such a way that the desired quantity is delivered to all consumers. There are two concepts which can be adopted for achieving this. One is volume control and the other is flow rate control. Compared to volume control methods, flow rate control methods are relatively simple and cost effective. Any obstruction in the flow path will create pressure loss which will result in a reduction in flow rate. In order to distribute the available water equitably among the consumers, it is better to control the flow rate to each consumer proportional to the quantity intended to supply [2]. The advantage of flow rate control is that any amount of available water can be equitably distributed to all the consumers in the water distribution network.

RESTRICTION ORIFICE

Restriction orifice plate creates a pressure loss and hence throttles the flow rate. For this water distribution system the flow control device selected is a restriction orifice plate. The orifice plates are designed in such a way that the excess pressures at many locations are dissipated and only the desired flow is passed through the orifice.

Here the performance of the network is studied by using orifice plate of same geometry at all consumer nodes. Simple orifice plates are made using 2 mm thick SS plate which makes it very economical.

The required water demand at each supply node is assumed as 3 lpm to 5 lpm. The flow characteristics of different orifice plates were studied and a 3 mm bore orifice is selected so that equitable water distribution is achieved in all consumer locations. The laboratory test result of 3 mm orifice plate is shown in fig 1.

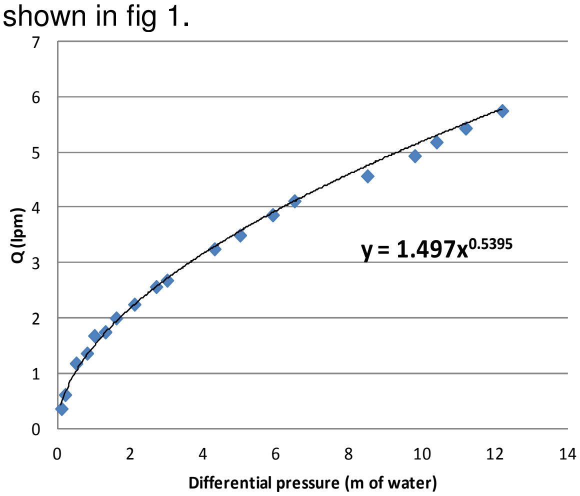

Figure 1. Flow characteristics of 3 mm orifice plate.

CASE STUDY

A water distribution network in a rural area of Thrissur district of Kerala is considered for the study. There are 42 house hold connections in the network with open well as the water source. Water is pumped from the open well to an elevated reservoir of capacity 14600 litres. The network covers an area of 0.99 sq.km. The elevation of the reservoir is 62 m from mean sea level. The house hold connections are at different elevations, from 38 m to 58 m. The layout of the water distribution network is given in fig. 2

Flow rate to consumers vary from zero to many times the demand. People residing in high pressure areas collect more water than people residing in low pressure areas. This disparity in supply is quite severe in some networks [5]. In this area there many consumers complaining about very low flow rate in their connection and hence not getting adequate quantity of water. When the network was analysed it was observed that the pressure and hence flow is zero at as many as 10 consumer locations when every consumer is trying to draw water. It is observed that there is a variation of 83 % in flow rate during this situation. The pipe line data of the water distribution network is given in table 1.

A throttling device is required to control flow in the network for getting water in all consumer connections at sufficient pressure. Throttling of valves installed in the distribution system does not provide any control at the downstream locations and hence equitable supply in consumer connections cannot be achieved. Therefore it is required to provide flow control measures at every consumer connections.

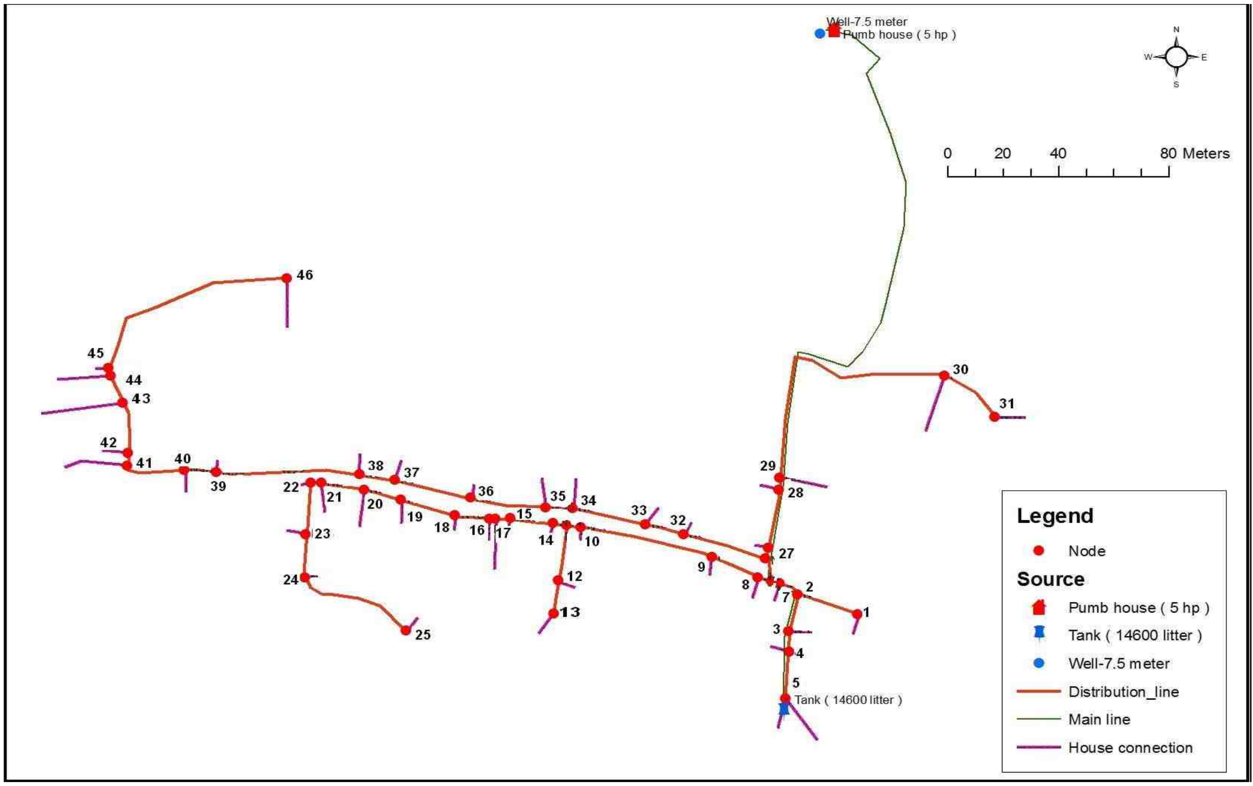

Figure 2. Layout of water distribution system

Nodes connected	Length (m)	Node connected	Length (m)
1 - 2	23.3	23 - 24	16.8
2 - 3	14.7	24 - 25	44.8
2 - 6	8.2	26 - 27	4.8
3 - 4	7.5	26 - 32	31.1
4 - 5	18.0	27 - 28	22.6
6 - 7	3.3	28 - 29	4.6
7 - 26	9.3	29 - 30	103.3
7 - 8	4.8	30 - 31	24.9
8 - 9	18.8	32 - 33	14.7
9 - 10	48.7	33 - 34	26.7
10 - 11	5.2	34 - 35	9.8
11 - 12	21.7	35 - 36	27.3
11 - 14	5.1	36 - 37	29.0
12 - 13	13.9	37 - 38	13.0
14 - 15	15.6	38 - 39	51.8
15 - 16	5.1	39 - 40	11.2
16 - 17	2.2	40 - 41	23.2
17 - 18	12.5	41 - 42	4.7
18 - 19	20.4	42 - 43	19.4
19 - 20	14.1	43 - 44	11.7
20 - 21	15.9	44 - 45	3.1
21 - 22	3.7	45 - 46	81.4
22 - 23	19.5	-	-

Table 1. Line data of the network. Diameter of all pipes is 50 mm.

RESULTS

The performance of the network with 3 mm orifice plate installed at all consumer nodes has been analysed and found that 3 lpm to 5 lpm supply is available in nodes where there was zero supply before the installation of orifice plate. High flow rates at many nodes have come down to the desired limit, maximum flow rate being 7.3 lpm. It is observed that the standard deviation in flow rates in various nodes also has drastically reduced from 9.9 lpm to 1.1 lpm. The variation in flow rates in the network was 83.4 % before the installation of orifice. This is reduced to 23.9 % and the average flow rate in the network has been reduced from 11.9 lpm to 4.7 lpm, which is within the desired limit.

The flow rates and pressure at all nodes (consumer connections) before and after installation of restriction orifice are tabulated in table 2. A fairly equitable distribution is obtained by the use of restriction orifice plate designed for the available head and required demand.

Node no.	Before installation of restriction orifice		After installation of restriction orifice	
	Supply (lpm)	Pressure (m)	Supply (lpm)	Pressure (m)
1	0	0	2.94	3.49
3	10.52	1.04	2.82	3.23
4	15.92	2.35	2.99	3.59
5	22.77	4.74	2.97	3.54
6	4.69	0.21	3.59	5.03
8	0	0	3.51	4.84
9	5.25	0.27	3.82	5.66
10	12.68	1.5	4.37	7.26
12	0	0	3.69	5.3
13	0	0	3.69	5.3
14	11.91	1.33	4.35	7.2
15	14.85	2.05	4.64	8.1
16	14.59	1.98	4.63	8.08
17	14.5	1.96	4.63	8.08
18	9.61	0.87	4.31	7.09
19	13.77	1.77	4.61	8.02
20	17.17	2.73	4.9	8.96
21	17.12	2.71	4.89	8.95
22	17.12	2.71	4.89	8.94
23	13.55	1.71	4.6	7.97
24	0	0	3.96	6.04
25	0	0	3.6	5.08
27	8.61	0.7	4.17	6.64
28	21.56	4.26	5.33	10.47
29	23.87	5.2	5.58	11.44
30	35.63	11.42	7.16	18.14
31	32.22	9.37	6.74	16.21
32	0	0	4.07	6.35
33	7.09	0.48	4.35	7.19
34	8.94	0.76	4.59	7.94
35	7.41	0.52	4.57	7.87
36	0	0	4.51	7.71
37	5.58	0.3	4.77	8.52
38	1.91	0.04	4.75	8.46
39	0	0	4.69	8.27
40	0	0	4.97	9.2
41	11.22	1.18	5.22	10.1
42	14.98	2.09	5.49	11.06
43	20.25	3.77	6.21	13.93
44	24.88	5.64	6.66	15.84
45	27	6.63	6.87	16.81
46	30.62	8.48	7.29	18.73
Minimum:	**0**	**0**	**2.8**	**3.2**
Maximum:	**35.6**	**11.4**	**7.3**	**18.7**
Average:	**11.9**	**2.2**	**4.7**	**8.6**
Std. dev:	**9.9**	**2.8**	**1.1**	**3.9**
% variation:	**83.4**	**127.4**	**23.9**	**45.4**

Table 2. Analysis results before and after installation of restriction orifice (Ø3 mm).

The performance of the network by using different sizes of orifices at different locations was also analysed. In this case the variation in flow rate can be further reduced by 10 %.

A design chart for sizing of orifice for required flow rate with respect to available pressure is also developed from the experimental data. The relation between flow rate, head (H) available at the upstream of the orifice and coefficient 'K' is given by the relation, $Q = KH^n$.

From the experimental data of the orifice plates tested at FCRI, a relation between the coefficient 'K' and the orifice diameter is derived. The value of K can be calculated from the required flow rate and available head at each node. From figure 4 the orifice diameter corresponds to the calculated K can be determined. The flow characteristics of orifices for n = 0.5 are presented in figure 4.

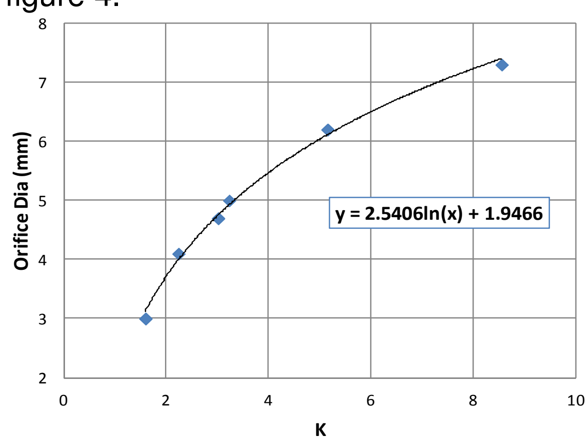

Figure 4. Flow characteristics of orifice plates.

One of the major limitations of orifice is the possibility of clogging. Solid particles carried by the flow can cause clogging of the orifice. It is not easy to remove the orifice plate for cleaning. This is mainly because of restricted access to the orifice to avoid the possibility of tampering. Hence the problem of clogging may be avoided by using a filter (fig 5) installed at the upstream of the orifice.

A graphical representation of flow rates, before and after installation of orifice plate in various nodes is given in fig. 3.

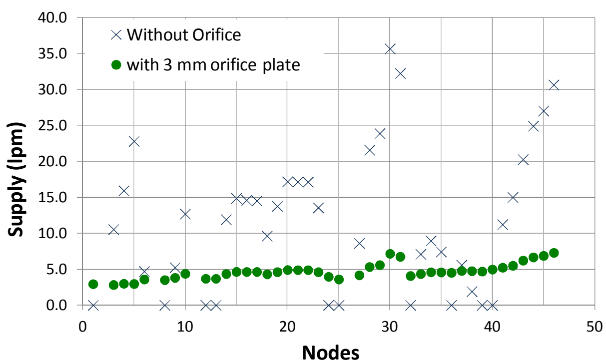

Figure 3. Flow rate at different nodes before and after installing orifice.

Figure 5. Filter and fixtures with sealing arrangement.

Conclusion

It is proved that a properly designed orifice plate is effective for implementation at consumer connections in water distribution networks for equitable distribution of available water. The device studied here is simple orifice plate fabricated in 2 mm thick SS sheet. The restriction orifice designed is simple to fabricate and quite cost effective. Installation of orifice at site can be done easily using standard fixtures available in the market and the installation can be carried out almost in a tampered proof manner. The variation in flow rate in the network could be drastically reduced by using a properly sized orifice plate.

References

[1] Ashley MJ, Kocha ME, Routh JD (2000) Some experiences with depressurized and low flow systems in the UK. Proc. Intl Seminar on Intermittent Drinking Water Supply Syst Manag, IWWA, Mumbai.

[2] Bhave, P. R., and Gupta R. (2000). “Design, performance and operation of regional rural water supply systems”, Journal of Indian Water Works Association, 32(4), Oct.-Dec.2000.

[3] “Distribution network analysis for water utilities”, AWWA Manual M32, American Water Works Association, 1989.

[4] Jacob Chandapillai (1991) “Realistic Simulation of Water Distribution System” ASCE Journal of Transportation Engineering, Vol.117, No.2.

[5] Jacob Chandapillai, R.Narayana Iyer (2001) Equitable distribution of water through pipe network under low supply situation” Proc. of the 4th international conference on Water Pipeline Systems, organized by BHR Group 28-30 March 2001, York, U.K.

[6] Jacob Chandapillai, K.P Sudheer, S.Saseendran (2001) “Design of water distribution network for equitable supply” Water Resources Management, EWRA, Springer. DOI: 10[1].1007 – s11269-011-9923-x.

[7] Jacob Chandapillai, K.P Sudheer, S.Saseendran (2010) “Flow control in water distribution networks for equitable supply” Proc. of the thirty Seventh National and Fourth International Conference on Fluid Mechanics and Fluid Power, Chennai, December 16-18, 2010.

[8] Liberatore S., Sechi G.M., (2009). Location and Calibration of Valves in Water Distribution Networks Using a Scatter-Search Meta-heuristic Approach. Water Resources Management, vol. 23.

[9] Reddy LSrinivasa, Elango K (1989) Analysis of Water distribution networks with head dependent outlets.

[10] Vairavamoorthy K (2000) An appropriate design tool for intermittent water supply systems. Proc. Of the international seminar on Intermittent drinking Water Supply System Management, IWWA, Mumbai.

[11] Walski, T. M. (1984). Analysis of water distribution systems. Van Nostrand Reinhold Company, Inc.

Presenting author Biodata

Name : Dr. Jacob Chandapillai

Designation : Director

Company : Fluid Control Research Institute

Qualification : Ph D

Area of Expertise : Dr. Jacob Chandapillai, Director FCRI is head of the Institute since 2012. Since 2005, he has been heading the department of Water management. Dr Jacob works on modelling, simulation and control of water distribution systems and networks. His key areas of research and application are equitable water distribution and modelling, its application to participatory decision processes of water management systems and firewater network analysis.

Significant Achievements: He has completed his doctoral degree and post-graduation from IIT Madras. He has been doing active Research and Development in the area of water distribution networks. He is involved in several committees taking critical decisions in water management in India. He is member of several steering and advisory committees (e.g. turbine testing facility for AHEC, IIT, Roorkee, Central Water Power Research Station, TC for assessment of Theerapadham project of Kerala Water Authority, TC for implementation of AMR water meters for MCGM, Mumbai, TC for calibration of National Accreditation Board for Testing and Calibration Laboratories (NABL), Indian (BIS) and International Standards (ISO)Iand reviewers of several international journals.

Number of Papers Published in Journals: 6

Number of Papers Published in Conferences: 12