Avrupa Bilim ve Teknoloji Dergisi
Özel Sayı, S.30-33, Ocak 2018
© Telif hakkı EJOSAT'a aittir
Konferans Bildirisi

www.ejosat.com ISSN:2148-2683

European Journal of Science and Technology
Special Issue, pp.30-33, Ocak 2018
Copyright © 2017 EJOSAT
Conference Paper

Physical Leakage Analysis in Water Distribution Networks By Daily Consumption Curve

Recep Kılıç[1*], Hüseyin Cinal[2]

[1]Corresponding author : Sakarya University, Vocational School of Sakarya, Adapazarı, Sakarya, Turkey, recepkilic@sakarya.edu.tr
[2]Sakarya Water And Sewerage Administration, Adapazarı, Sakarya, Turkey, huseyin.cinal@sakarya-saski.gov.tr

(First received 25 August 2013 and in final form 20 December 2013)

Abstract

The curve of daily water consumption in drinking water networks provides a lot of information on the physical status of the network. The existing physical leakage rate can be estimated by analyzing the network water consumption curve. Hence, precautions can be taken in order to prevent the physical leakages and water losses. In this study, the minimum night flow (MNF) that occurs in the determined measurement areas (DMA) in the current drinking water network was examined, and it was attempted to determine the required amount of consumption and water loss by determining the amount of leakage. Pressure management was started to be used in the distribution system, and the effect of pressure management on the water consumption in DMAs was examined. Operation and rehabilitation methods were suggested by determining the amount of physical leakage in the network.

Keywords: Physical Leakage, Water Demand, Water Distribution Network.

* Corresponding author : Sakarya University, Vocational School of Sakarya, Adapazarı, Sakarya, Turkey, recepkilic@sakarya.edu.tr, phone: +90 533 470 40 38

1. Introduction

Introduction

In many countries of the world there is an increasing evidence of inadequate water distribution systems, due to the deterioration of ageing infrastructure (especially pipes and pumps), the rapid growth of urbanization, and the statutory and contractual quality standards that have to be offered to consumers. In particular, regulatory bodies and water utilities are concerned about the importance of accurately assessing and controlling water losses, which may have a strong impact also on energetic costs (Nicolini et al., 2014).

The availability of drinking water has represented a key factor in the development of more advanced countries, and of the developing ones. Therefore efficiency and reliability of hydraulic networks are requirements sought by water networks administrators. Due to inefficient aqueduct systems every year more than 48 billions of cubic meters of water are lost all around the world, that correspond to an economic loss of more than 14 billions US-dollars. In the only United States of America, the American Water Works Association (AWWA) estimates that during the 2002 up to 10 billions kWh of electric energy were used to pump water that was lost in the leakages. The identification and localisation of water leakages is a challenging task due to the topographical complexity of the water systems to be analysed, that can be constituted by a large amount of users, ramifications of the pipes, and water tanks (Debiasi et al., 2014).

A number of methods exist for identifying leakage. The most established method is sectorization. This involves the permanent closure of isolation valves in the water distribution network to create discrete zones, commonly called district metered areas (DMA). The closed isolation valves are therefore commonly called boundary valves (BV). A flow meter is then installed at each DMA inlet and outlet. By measuring the flow during times of low customer demand (such as at night), an estimation for leakage can be made, and DMAs prioritized for repair (Wright et al., 2015).

The leakages quantification is done through a water balance on a system-wide basis in a restricted District Metering Area (DMA). Monitoring of leakages allows the engineers to quantify the water flow into the DMA thus discriminating when abnormal water consumptions can be associated to water losses. Flows and pressures are measured on different points on the DMAs usually constituted by up to 3,000 properties. During the data analysis only the information collected at night (between 02:00 AM and 04:00 AM) are considered because in this moment of the day it is registered the minimum flow (MNF), therefore the pressures and the effects of leakages on the water network are maximum (Debiasi et al., 2014).

1.1 Background Leakage

Water distribution system (WDS) losses may be classified as due to background losses (e.g., from joints, fittings, and small cracks), reported bursts, and unreported bursts. Bursts are intended as major water outflow events that are usually reported to water utilities and repaired since they are likely to produce major service disruptions. For this reason burst are commonly considered as accidents whose impact on WDS can be limited by improving active leakage control and the efficiency of detection and repair actions. Vice versa, background leakages are intended as outflows running from small cracks, holes, deteriorated joints or fittings, occurring along pipes. As diffused water outflows, background leakages do not result into evident and quick pressure drops through the network, thus they are not reported and run for longer time, producing relevant impact in terms of WDS water lost volumes. For this reason background leakages can be reduced by planning medium-long term interventions for asset rehabilitation and pressure management (Laucelli and Meniconi, 2015).

According to Torricelli's theorem, the rate of leakage Q1 is proportional to the square root of the pressure head H in a pipe.

$$Q_1 = C_1 A_1 \sqrt{2gH} \quad (1)$$

where

Cl is the discharge coefficient

Al is leak area

g is the acceleration due to gravity

h is the total head at the point of leak

Several researchers have conducted tests on orifice in pipes and the hydraulics is now very well understood. The rate of leakage is in fact proportional to the square root of the head at that particular leak point irrespective of the pipe material and size of hole, thereby confirming the relationship:

Q1αH0.5 (2)

However, leaks are not always of orifice type and therefore other shapes like circumferential and longitudinal cracks were investigated. A more general form of the leak equation which is proposed is:

$$Q_1 = CH^N \quad (3)$$

where

C is the leakage coefficient

N is the leakage exponent

Rewriting the leak flow equation 1 according to FAVAD:

$$Q_1 = C_d A_1 \sqrt{2g}\,(A_0 H^{0,5} + mH^{1,5}) \quad (4)$$

where

A_0 is the initial leak area

m is the slope of the head-area curve (Latchoomun et al., 2015)

1.2 Leakage Estimation Using Minimum Night Flow and Leakage Exponent

Latchoomun et al. (2015) used the Minimum Night Flow measurements in order to calculate the real losses of a DMA and computed leakage exponent N1. They showed that the MNF method and the calibration process yield similar results in terms of leakage estimation.

The Daily Real loss Volume DRLV is given by

$$DRLV = F_{nd} x Q_{mn} \quad (5)$$

where

Q_{mn} is the average minimum nightly leak flow rate (m3/h)

F_{nd} is the night day factor

Since the leak volume varies with demand pattern, the minimum night flow is multiplied by Fnd

$$F_{nd} = \sum_{i=0}^{24} \left(\frac{P_i}{P_{3-4}}\right)^{N1} \quad (6)$$

where

P = the average pressure at the point of observation in the DMA for every hour i

P3-4 is the average pressure during minimum night consumption between 3 to 4 AM

N1 being the leak exponent obtained from the MNF.

The overall leakage exponent of the DMA is obtained as 1.645 by using equation 7 [4].

$$\frac{Q_1}{Q_0} = \left(\frac{P_1}{P_0}\right)^{N_1} \quad (7)$$

where

Q_1 is the final flow,

Q_0 is the initial flow,

P_1 is the final pressure head

P_0 is the initial pressure head.

2. Methodology

In this study, the daily water consumption was measured by dividing the drinking water network into DMAs. A pressure reducing valve was used in order to adjust the pressure according to consumer needs. The water flow was measured instantly using an electromagnetic flow meter, and the pressure and flow were recorded. The change of the leakages was examined by taking the pressure under control.

2.1 Description of System

Serdivan drinking water network is situated in the center of Sakarya city, and it was partially improved and not replaced after the earthquake that occurred on 17 August 1999. Therefore, it is a network, in which the number of breakdowns each year is high and the leakages that result from non-surface failures, and thus the water loss is high.

The DMA in which the study was carried out is a region called “Serdivan 1”. Figure 1 shows the general overview of the DMA and is formed by HDPE and PVC-type pipes. The total length of the network is 9935 m. The subscriber connection lines consist of iron pipes (old connections) and HDPE. The pipe diameters in the system are 25-32 mm for subscriber connections, and 110, 125 and 180 mm in distribution lines. Table 1 presents the general information on DMA. DMA expresses the general structure of the network. Thus, the electromagnetic flow meter and PRV (pressure reducing valve) were mounted at the inlet and taken under monitoring (Figure 1).

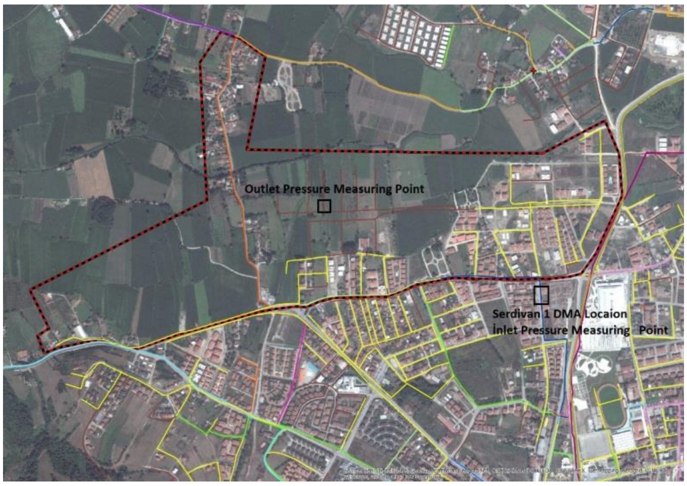

Figure 1. DMA of Serdivan 1 layout.

Table 2. Description of Serdivan 1 DMA.

Descriptions	2014	(%)
Total length of system (m)	9925	
Population served	4278	
Number of consumer	1337	
System daily average input volume (m^3)	700	100
Daily Average authorized consumption (m^3)	455	65
Daily water loss (m^3)	245	35

2.2 Case Study

The flow, inlet pressure and outlet pressure at the DMA inlet were measured and recorded. The current situation was determined by making an observation in this case for a certain period. The minimum required pressure in the network is 20 m. However, it was determined that the pressure inside the DMA is more than necessary. The flow and pressure values measured at the DMA inlet on 20.04.2014 are shown in Figure 2. The pressure increases when the flow decreases, and the pressure reaches the maximum level in the MNF.

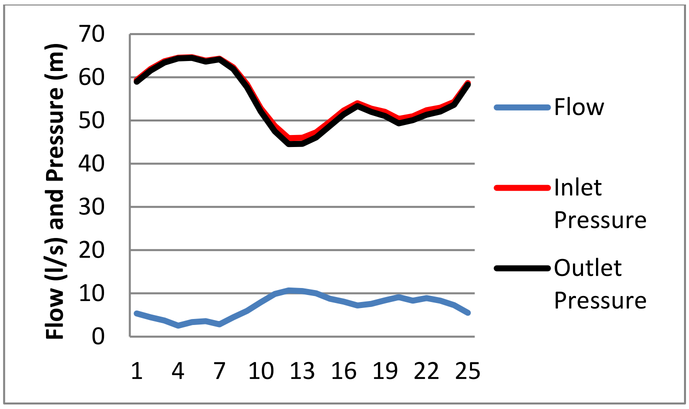

Figure 2. Flow and pressure.

The pressure was adjusted by using PRV so that the target value would be 35 m in such a way that there would be no decrease in the service quality of the users. Pressure was adjusted by using PRV. No decrease occurred in the user service quality after adjusting the pressure and the values measured in Figure 3 are observed. The outlet pressure remains constant independent of the inlet pressure and flow.

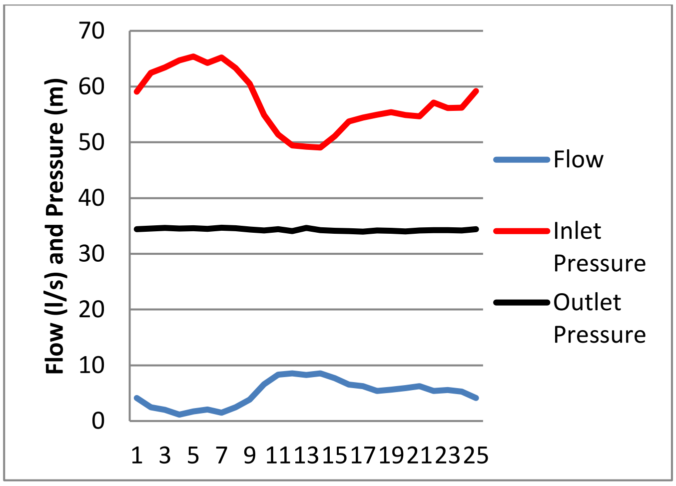

Figure 3. Flow and pressure chart.

3. Results

The computed average night day factor Fnd for normal flow using equation 6 is 19.50 h/day and the observed average MNF at the DMA entrance from data logger is 2.55 l/s or 9.18 m3/h. Therefore the DRLV according to equation 5 must be 7.46 m3/h or 2.07 l/s. 2.071/s of the measured 2.55 l/s MNF is DRLV, and only 0.48 l/s is night consumption. The average consumption in the DMA is 904.4 m3/d, in other words, 10.47 l/s on 20.04.2014 when the measurement was made. In this case, the water loss caused by the leakages in the network on 20.04.2014 is 20%.

The same equations did not give correct results for the practices made after the PRV. However, more consistent values were achieved when the calculations were made by taking the first inlet pressure as a reference after reducing the pressure, regardless of the PRV outlet pressures.

A decrease in the amount of water given to the DMA was determined after taking the pressure under control by using the PRV on 27.04.2014. After reducing the pressure, the daily consumption was measured as 621.8 m3/d, 7.20 l/s, on average, and MNF as 1.51 l/s. After reducing the pressure, the DRLV value was determined to be 0.97 l/s. It was determined that the amount of leakage in the network decreased to 13% with the reduction of the pressure.

4. Conclusion

Leakages in drinking water distribution networks can be determined by using many methods. However, a number of physical leakages in the infrastructure can be determined by determining only the daily consumption curve, and especially the minimum night flow (MNF) in the DMAs created when the technical capacities of local administrations are also taken into consideration. The breakdowns that are believed to exist in the DMA can be determined according to the amount of leakage determined. In this study, the water losses that result only from leakages were determined by identifying the MNF in the DMA. Hence, the development of activities for this objective can be helped by determining the target value that should be achieved by identifying the water consumption that must occur in each region. It will help the decision on replacing partial networks in the places where the MNF is very high.

References

Nicolini M., Giacomello C., Scarsini M., Mion M. 2014. Numerical modelling and leakage reduction in the water distribution system of, Procedia Engineering 70, 1241-1250. DOI: 10.1016/j.proeng.2014.02.137

Debiasi S., Giorgio Bort C.M., Bosoni A., Bertola P., Righetti M. 2014. Influence of hourly water consumption in model calibration for leakage detection in a WDS, Procedia Engineering 70, 467-476. DOI: 10.1016/j.proeng.2014.02.052

Wright R., Parpas P., Stoianov I. 2015. Experimental investigation of resilience and pressure management in water distribution networks, Procedia Engineering 119, 643-652. DOI: 10.1016/j.proeng.2015.08.917

Laucelli D., Meniconi S. 2015. Water distribution analysis accounting for different background leakage models, Procedia Engineering 119, 680-689. DOI: 10.1016/j.proeng.2015.08.921

Latchoomun L., Ah King R.T.F., Busawon K. 2015. A new approach to model development of Water distribution networks with high leakage and burst rates, Procedia Engineering 119, 690-699. DOI: 10.1016/j.proeng.2015.08.922