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Martin FAŠKO, Jozef KRIŠ

Department of Sanitary and Environmental Engineering
– Faculty of Civil Engineering of the Slovak University of Technology Bratislava, Bratislava

PRESSURE MANAGEMENT WITHIN WATER DISTRIBUTION SYSTEM

ZARZĄDZANIE CIŚNIENIEM W SYSTEMACH DYSTRYBUCJI WODY

The article briefly describes pressure conditions in supply and distribution pipes of water supply distribution systems. Moreover, it describes research activities dealing with changes overflow in district meter area (DMA) at the variation of pressure in water supply distribution system. These changes have an impact on water consumption as well as water leakage during the night pressure regulation. Explanation of flow behaviour and water consumption at regulated pressure in the DMA would be a contribution for providers and owners of water supply systems when reducing water losses in water supply distribution systems.

1. Pressure management

Pressure management can be simply defined as a process of hydraulic pressure maintenance in the optimum range at a desired value (see Chapter 1). Pressure management is important for reliable and effective water supply and it includes the following:

- ensure of sufficient pressure level in water supply pipes for the need of consumer
- distribution of water from resource to consumer
- assure of sufficient pressure for fire protection in the case that water supply is used also for these purposes
- elimination of impacts of unsteady flow in pipeline

The pressure in distribution system is determined by water supply components such as:

- water reservoirs
- pumping stations, automated pumping stations
- pressure control valves

The pressure management is done in various ways. In most cases it is related to management of pressure in pressure zones or DMA where appropriate conditions for control of input pressures and discharges are created. The relationship between discharge and pressure is, in fact, the determining factor for the system control and therefore on-line monitoring is an ideal solution that can be applied. Components of pressure management include mostly pumping and regulation points of the system, i.e. automated pumping stations, control valves regulating inlet pressure and stabilization of outlet pressure. For pressure systems and long feeding pipes it is important to prevent the effect of unsteady flow. Elimination these effects can be done by appropriate selection of pipe materials (flexible material absorbing shock waves), proper protection against sudden shutdown or activation of pumps, electric valves, etc.

2. Pressure and water leaks

Water leaks are defined as real water losses that leaked out from pipes, fittings and water supply network installations and they were not used for the purpose of water supply. Real water losses include the following:

- water leaks in bursts of pipes (pipe defects)
- water leaks in bursts of fittings ("flowing" defects of fittings)
- leaks in joints of pipes and fittings
- leaks at overflow of accumulation reservoirs and water reservoirs

Water leaks do not include water loss at consumer's place beyond the point of water consumption metering. Water leaks are associated with the technical conditions of water supply system and they are categorized as follows:

- **apparent** (leaks are visible on the surface; accidents are accompanied by significant water leaks and they can be detected. Failures are usually reported by residents or operational staff during the check
- **hidden** (they are not noticeable on the surface, leaks have long-term effect and they are detected either by coincidence or after longer period when they become apparent)

Apparent failures are usually associated with large single water leak that can be detected. Hidden failures have a long-term effect. They are detected either by coincidence or after longer period when they become apparent. The total time of large apparent (reported) leaks is much shorter than the time of leaks caused by minor failures. Although the leakage at major failures is large, small hidden leaks lead to more significant water losses. The main causes of hidden leaks are failures of service pipes (over 70 % of real losses), failures of sealing material (12 %), defects of fittings (7 %), etc.

The soil, techniques of pipe placing, pipe material and age, pipe joints, water leaks from supply pipes, fittings and service pipes as well as lining, corrosion, water chemistry, changes of pressure and work of other involved persons are among the most essential effects causing failures of pipes.

The simplest method for water leakage reduction is the pressure management. It is proved that the pressure reduction in supply system results in decreased rate of flow from existing leaks and reduction of some consumption components. Moreover, it reduces the number of new leaks that occur and it improves the service life of infrastructure.

Foreign literature shows the results of the IWA research (REF. NO.5) verifying the relationship between pressure and rate of leakage. Furthermore, it has been proved that *the amount of leaks depends on pressure*

$$\frac{L_1}{L_0} = \left(\frac{P_1}{P_0} \right)^{N_1} \qquad (1)$$

The relationship describes reduction of pressure from P_0 to P_1 at water leakage changed from L_0 to L_1. N_1 is an exponent indicating relationship between pressure and leakage.

The pressure ratio (P_1/P_0) is the crucial element of the equation in contrast to the pressure difference. The exponent value has been defined based on night tests at reduced pressure and measurement of inflow and adequate pressure in the zone. The exponent value may vary from 0.5 to 2.5. (REF. NO.5)

For water leaks in flexible pipes: N_1=0.5

For water leaks in rigid pipes: N_1=1.5

For greater number of tests (loaded by weighted average) the ratio of mean pressure to leakage rate is close to linear dependence (N_1 = 1). (REF. NO.5)

Water losses in water supply systems will never be completely eliminated. There exists so-called technical limit of real water losses and it is not possible to reduce real water leaks below this limit. The limit is determined by the UARL parameter (Unavoidable Annual Real Losses). UARL include all kinds of water losses in distribution system in good infrastructure conditions for the system with quickly and effectively repaired leaks and bursts together with intensive active control of water losses.

3. Impact of pressure changes in water distribution system

Decrease or increase of pressure in water supply systems is relatively often repeated phenomenon. Both changes in pressure may have adverse effect on consumer or production processes. Low pressure ratio may lead to insufficient water supply (shutdown of operation, interruption of production processes at low pressure that can be eliminated using booster automated pumping stations). Considerable changes in pressure caused mostly by pressure surge may result in malfunction of appliances and production machines (in case that they are not equipped by safety fittings). Moreover, unexpected changes of pressure in supply system lead to shorter lifetime of pipes and increased frequency of bursts occurrence that is ten times higher than in water supply at the same medial pressure. Pressure management system serves as mechanism for control and regulation of pressure ratios in water supply system. The management system at control points of pressure zones or separately measurable district allows quick response to warnings on minimum pressures that are usually connected with water leaks.

Properly designed and maintained pressure ratios have several advantages:

- reduction of bursts occurrence (3-fold up to 4-fold decrease)
- reliable water supply
- increased capacity of fire protection
- longer lifetime of pipes

4. Water loss control in district meter area

The research and pedagogic activities of the Department of Sanitary and Environmental Engineering include measurement of water pressure and overflow as well as related water leaks in DMA and at that the entire distribution system. Water supply distribution systems in Lučenec have been selected for the purpose of measurement.

Water Loss Control in the Lučenec Distribution System

For the Lučenec water distribution system with 100 percent share of population supplied with drinking water (27 998 residents), 109,9 km long system of pipes (including 3 411 service supply pipes) and two pressure zones the mathematical model (calibrated and verified) has been developed. The model was also used for dividing of the supply system into 13 DMA. These DMA are using currently (see the next picture).

After consultation with the provider of distribution system three districts D_1, D_2 and E were selected. These districts are marked with a red line in figure 1. For the purpose of measurement it was necessary to reconstruct the shaft no. 12 because of installing the pressure reducing valve. (see the picture 3).

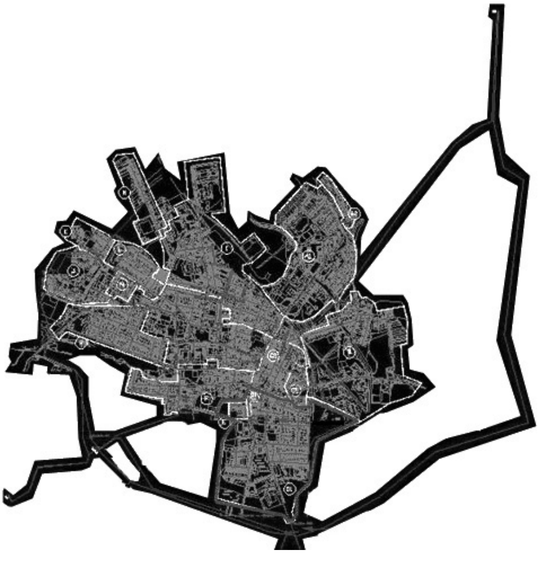

Fig. 1. Distribution System of the Town of Lučenec with District Meter Area

After reconstruction the shaft was connected to dispatching centre using remote control. Another requirement was to close the stop valves U-D1, U-D2, U-D3, U-D4 a U-D5 (see the picture 2). Moreover, it was necessary to install data loggers in the shafts no. 7 and 11 to record pressure and inflow to the districts D_1 and D_2.

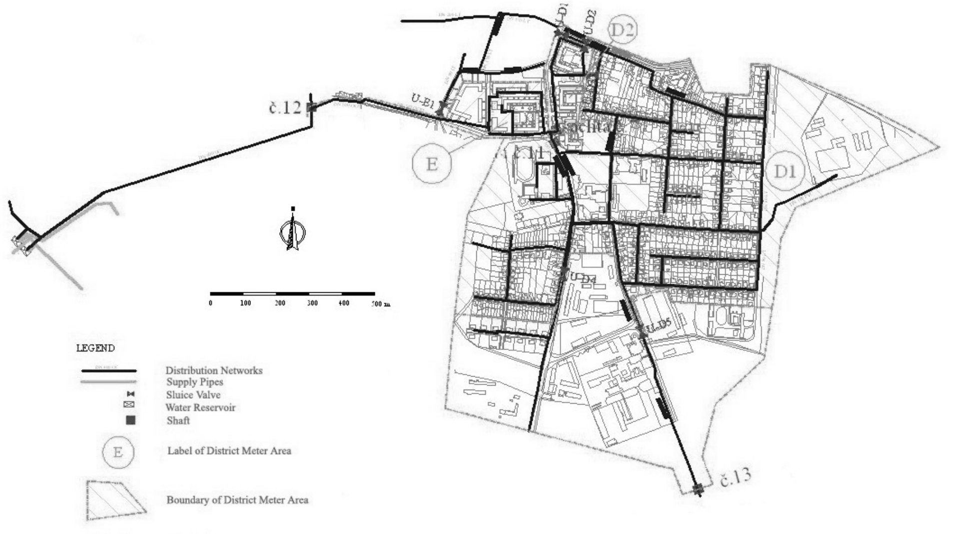

Fig. 2. District Meter Areas D_1, D_2 and E

5. Measurin and calculation

Measuring procedure is based on the pressure regulation in a given pressure zone using pressure reducing valve to reduce the pressure from 0.55 MPa down to 0.45 MPa, 0.40 MPa and 0.35 MPa. The values of pressure and inflow are recorded within the measurable districts. From the measured values only data of night flow with the maximum pressure in distribution system at desired setting of pressure reducing valve are used.

After calculation of the leakage exponent from measured values the results were verified also by the mathematical model using Mike Net software tool.

Fig. 3. Control shaft no. 12

6. Conclusion

The results of the research verified the values of leakage exponent published by J. Thornton and M. Farlay also in our operational conditions. The values of leakage exponent were ranged from 0.3 up to 1.5. In the following tables we can see that the values of leakage exponent are slightly lower compared to the values verified in mathematical model.

DMA Together		DMA D1		DMA D2	
P_1/P_0 [-]	N_1 [-]	P_1/P_0 [-]	N_1 [-]	P_1/P_0 [-]	N_1 [-]
1,01	0,1	1,00	0,0	0,96	-0,3
1,20	0,3	1,22	0,4	1,02	0,3
1,15	0,3	1,16	0,4	1,28	0,6
1,04	0,4	1,05	0,5	1,36	0,7
1,19	0,5	1,23	0,5	1,33	0,8
1,60	0,5	1,22	0,6	1,83	0,9
1,14	0,5	1,50	0,6	1,78	0,9
1,54	0,5	1,43	0,6	1,34	1,1
1,35	0,5	1,16	0,7	1,42	1,2
1,33	0,7	1,23	0,8	1,39	1,5

Right

DMA D1					
P_1/P_0 [-]	N_1 [-]	P_1/P_0 [-]	N_1 [-]	P_1/P_0 [-]	N_1 [-]
1,1	0,6	1,2	0,5	1,4	0,6
1,1	0,4	1,2	0,4	1,4	0,4
1,1	0,5	1,2	0,5	1,3	0,5
1,1	0,4	1,2	0,5	1,4	0,5
1,1	0,5	1,2	0,6	1,4	0,6
1,2	0,4	1,3	0,5	1,5	0,5
1,2	0,3	1,3	0,3	1,6	0,3
1,1	0,6	1,2	0,4	1,4	0,5
1,1	0,5	1,2	0,5	1,4	0,5
1,1	0,4	1,2	0,4	1,4	0,4
1,1	0,4	1,2	0,4	1,4	0,4
1,1	0,4	1,2	0,4	1,4	0,4

Left

Tab. 1. Right – values of leakage exponent from measured values for the districts D_1 and D_2
Left – verified values of leakage exponent from mathematical model for the district D_1

This phenomenon is caused by the factors having an effect on leakage exponent. This effect does not occur in the mathematical model. The factors having an effect on the leakage exponent are as follows:

- leak hydraulics
- pipe material behaviour
- soil hydraulics
- water demand

The most recent research in the UK recommends using a power law relationship with:

- linear pressure: leaks relationship in large zones and undertaking-wide assessment, or where no other evidences exists and high precision of results is not a priority
- different powers at different leakage levels, for smaller zones, or where more precision is required
- individual measurements of the pressure-flow relationship should be made where the precise relationship is critical

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