4th DAAAM International Conference on
Advanced Technologies for Developing Countries
September 21-24, 2005
Slavonski Brod, Croatia

LEAK DETECTION IN UNDERGROUND PIPELINES OF MUNICIPAL WATER DISTRIBUTION

Marko Blažević, Ivan Samardžić and Zvonimir Kolumbić

Potable water, pipelines, leak detection

1. Introduction

Potable water is one of the most valuable natural resources and Croatia is one of the rare countries, not only in Europe but also in the World, with respectable reserves of potable water. All the waters (polluted rivers, see) indeed can be converted to potable water but this is often followed by unacceptably high costs.

In Croatia there are about 130 water utilities dealing with potable water supply – raw water pumping, water conditioning and potable water distribution. These organizations are the owners of about 300 wells and about 300 000 kilometers of potable water distribution pipelines.

The age of the potable water distribution pipelines in Croatia varies from one up to almost 100 years and the average age is about 40 years. The faults and/or damages of the water pipes, fittings and connections are caused by water leakage from the water distribution pipelines [1]. Overall water losses in water distribution (difference between quantities of water delivery and authorized usage) are greater because of unmeasured usages and reading errors (Table 1).

Table 1 Kind of water losses in municipal water distribution system

Leakages	Errors
• leakage through the crevice of the pipelines • uncontrolled overflow of the accumulation tanks • leakage of the hydrant shaft • leakage of the fittings (valves, connections)	• human factor (wrong reading of the water gauge and/or, calculated consumption) • faulty individual water gauge of the consumer • faulty main water gauge of the utilities
Authorized unmeasured water consumption	Unauthorized unmeasured water consumption
• fire department • municipal connections • hydrant's net • street washing and sewer cleaning • processing water in water plant	• unauthorized connection to the pipelines • connections without water gauge • unauthorized uses of hydrants • bypassing the water gauges

In the literature published water losses of the potable water distribution systems vary considerably and range between 5 and 80 %. In Croatia the potable water losses also vary (Table 2) and the average loss is about 43 % [2]. In the water utilities Vodovod d.o.o. – Slavonski Brod, the loss in the year 2004 was 37 % [3].

Table 2 Water losses of the water utilities of Croatia

Utilities	Potable water losses, %	Utilities	Potable water losses, %
40	30 ÷ 40	30	40 ÷ 50
30	20 ÷ 30	30	< 20 and > 50

2. Type of damages

Systematic control of pipelines in the Vodovod d.o.o. – Slavonski Brod water utilities indicated that the pipeline damages arise from many reasons of which the most frequent are:

- **Application of improper pipes** – nominal pressure lower than requested.
- **Placing the pipes in the canal without sand bed** –allowing the pipeline dilatations.
- **Contact of the pipes with hard and harsh peaces** – polymers are sensible to the local stresses.
- **Ground deformations** – shear stress caused by ground cracking during long and hard drought.
- **Corrosion and/or erosion of the inner wall of the pipes** – the allowed pressure is diminished.
- **Polymer materials aging** – during exploitation allowed pressure of the polymer pipelines (PEHD, PVC) is diminished.

The water leakage can be apparent and hidden.

In the case of apparent leakage, water penetrates through the ground layers above damaged place and emerges at the ground surface. The time needed for water to emerge depends on: (a) depth of the damaged parts, (b) dimension of the crevice, (b) water pressure and (c) kinds of the ground layers. This time is between several seconds and several days.

Apparent leakage is very simple to detect – it is sufficient that the water utilities controller, during regular patrol along the pipelines trace, visually establishes that water emerges. Reparation follows after that. Figure 1 shows the typical case – underground pipeline was damaged and the water emerges to the ground surface.

Figure 1 Obvious leakage of pipeline

Figure 2 Hidden leakage of pipeline

In the case of hidden leakages water swells through the municipal sewerage system. Namely, the water under pressure drills and rinses ground layers between water distribution pipelines and municipal sewerage pipelines. Through the formed tunnel and connection of the two sewerage pipes potable water flows in the sewerage.

Water utilities have severe difficulties with hidden leakages because they are not visually detectable. In some cases such a leakage can last many years. Professional knowledge and sophisticated equipment are necessary for the hidden leakages detection. Figure 2 shows hidden leakage with formed tunnel to the sewerage pipelines [3].

3. Detection methods of damages

The board of the water utilities Vodovod d.o.o. – Slavonski Brod decided to purchase the equipment for hidden potable water leakage detection:

- **Macro location of the leakage detection** – correlator AquaCorr, made by Biwater Spectrascan, Great Britain, purchased in the year 1996.
- **Micro location of the leakage detection** – listening device Geophone, made by Biwater Spectrascan, Great Britain, purchased in the year 1996.

- **Flow rate measuring device** – ultrasonic flow-meter Fluxus ADM 6515, made by Flexi, Germany, purchased in the year 2004.
- **Pressure monitoring device** – pressure-logger Unimos 1000, made by Elster, Germany, purchased in the year 2004.

3.1 Ultrasonic flow-meter

The goal of the flow rate measurement by ultrasonic flow-meter is to determine the accurate quantity of potable water flowing through the pipeline [4]. Figure 3 shows application of the ultrasonic flow-meter in case of simultaneous water flow rate measurement on two pipelines. In Figure 4 the results of 24 hour flow-rate monitoring on the pipelines ND 300 mm are presented.

Figure 3 Flow-rate measurements

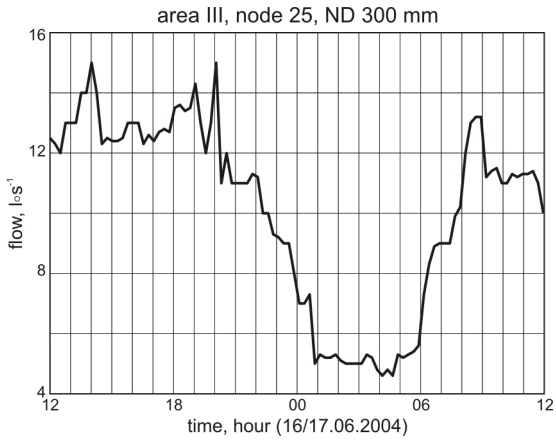

Figure 4 Flow rate monitoring results

The flow decrease from daily average values of about 13 l/s to nightly average values of about 5 l/s can be seen in Figure 4. As there is no nightly industrial consumption of potable water in the area of investigation, all 5 l/h can be calculated in losses and this is the first warning that faults and/or damages on pipelines have to be looked for. The experience indicates that the sensors have to be positioned laterally to avoid the influence of the settlings separated on the pipeline bottom. Separated settlings can cause significant measuring errors and in some cases even make measurements impossible.

3.2 Pressure logger

Pressure logger (Figure 5) records the water pressure in the specified time intervals [5]. The results of the pressure monitoring are presented in Figure 6. On the basis of the pressure monitoring results the conclusion about appearance of the water leakage can be drawn.

Figure 5 Pressure logger

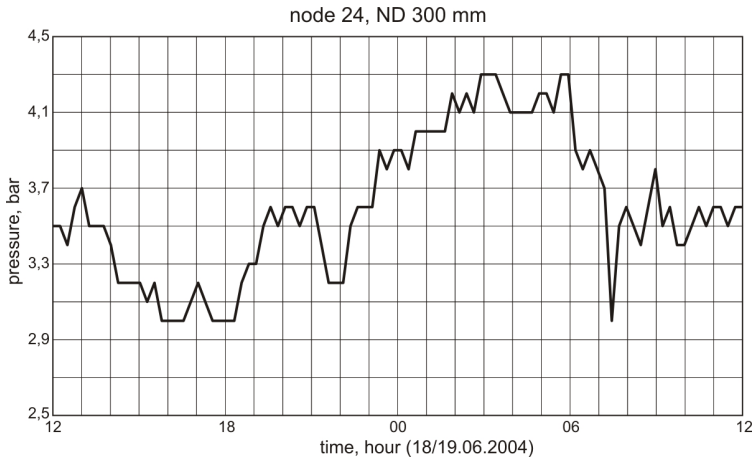

Figure 6 Pressure monitoring results

One effect of water leakage, besides the loss of water resources, is reduced pressure in the distribution pipelines. Relatively high values of the pressure in the night hours, between 23 and 06 hours (Figure 6), accordingly indicate that significant water leakages are not present in this area.

The graph analyses before and after reparation of the damaged pipelines are helpful for the hydraulic calculation of the pipelines [5].

3.3 Correlator

With Correlator the operator detects the leak macro location [6]. The measuring method is based on the analyses of the noise caused by water flow through the crevice, from high pressure zone in the pipelines to low pressure zone in the ground. The noise sound waves travel through the pipelines from the crevice in both directions at a time. Macro location of the crevice is determined by the correlation analyses of the times needed for the sound to attain two different points (Figure 7).

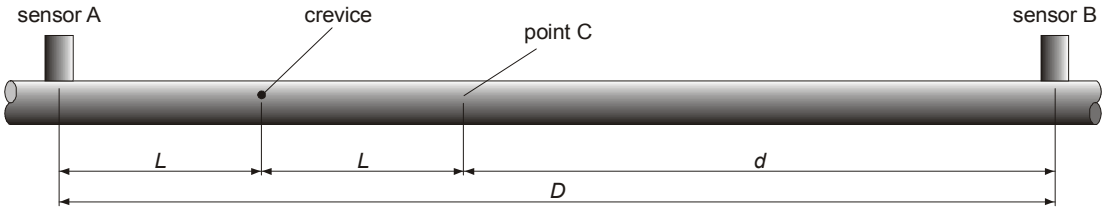

Figure 7 Crevice and correlator sensors positions

Distance L (Figure 7) can be calculated from:

$$L = \frac{D - v \circ T_d}{2}$$

where: v – sound velocity, dependent on the pipe's material and diameter (Table 3)

T_d – sound traveling time between points C and D

Table 3 Velocity of the noise spreading via wall of the pipes [6]

Pipeline material	Pipeline diameter, mm	Sound velocity, m/s
steel	50 ÷ 800	1350 ÷ 900
nodular iron	100 ÷ 1000	1320 ÷ 1050
nodular iron with concrete lining	300 ÷ 1000	1140 ÷ 1000
cast iron	100 ÷ 600	1280 ÷ 1060
copper	15 ÷ 30	1300 ÷ 1000
lead	all dimensions	1150
asbestos-cement	150 ÷ 500	1110 ÷ 840
Fiber-glass	50 ÷ 1400	1330 ÷ 1140
PVC	50 ÷ 150	475 ÷ 370
HDPE	50 ÷ 150	320 ÷ 280

In practice the measurements are complicated due to:

- presence of many pipeline crevices near sensors
- connection of the lateral pipelines near sensors
- unknown trace of the pipeline
- influence of the sound waves other than crevice noise (e.g. traffic)
- noise of the underground installations (e.g. pump).

The measurement with Corelator is presented in Figure 8 and the display with measuring results in Figure 10 (noise maximum 17 m from red sensor). In the beginning of the measurement, the operator entered actual data: material/diameter/length of the pipeline, its identification and the region/zone denotation.

3.4 Geophone

With geophone the operator detects the micro location of the leak (Figure 9, 11) by the noise "listening" [7].

Figure 8 Measurements with Corelator

Figure 9 Measurements with Geophone

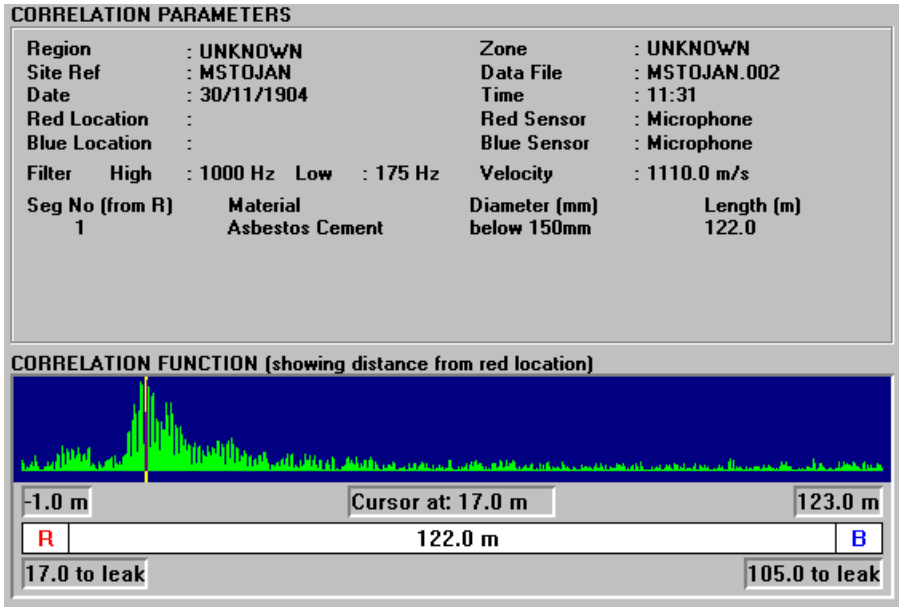

Figure 10 Display of the correlator

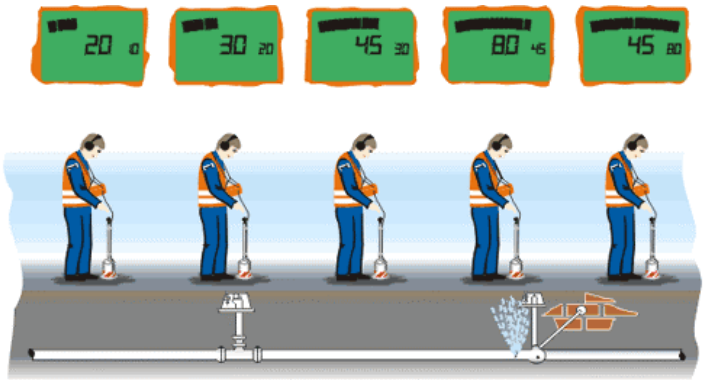

Figure 11 Geophone – function

The operator lays down the geophone sensor directly on the ground, listens to the noise and simultaneously watches the monitor. The louder the noise, the closer is the operator to the leak.

Small leaks under high pressure usually make more noise than larger leaks under low pressure (many large leaks make almost no sound whatsoever).

4. Savings

On average the loss of water was about 41 % in the year 2003, the same as in several previous years. In the year 2004 the water utilities Vodovod d.o.o. – Slavonski Brod intensified the control and maintenance of the potable water distribution net. After only four months of the leaks detection and repair the water losses were reduced to 37 %.

Table 4 presents calculations of the realized savings per year.

Table 4 Calculation of the savings

Total (100 %)	345.400 m^3	
Industry (24 %)	82.892 m^3	$\times$ 4,78 kn/m^3 = 396.224 kn
Households (76 %)	262.510 m^3	$\times$ 2,61 kn/ m^3 = 685.151 kn

Altogether: industry + households = 1.081.375 kn

5. Conclusion

The board of the water utilities Vodovod d.o.o. – Slavonski Brod was not satisfied with the potable water loss of about 41 % in the year 2003, although this value was under the average loss in Croatia. To combat the potable water losses, in addition to the random repair of the pipeline crevices, sophisticated measuring equipment should be purchased, operators educated and the distribution network systematically analyzed [8].

At a glance, it seems irrational to invest several hundred thousand kunas because of both slow return of the investment and great underground water reserves in the region of Slavonski Brod. Nevertheless, the experience gathered during 2004 confirms contrary conclusions. After only four month use of the new purchased equipment in the systematic analyses of the distribution net and leakage detection and repair, the water losses were reduced by 4 %, amounting to above one million kunas savings.

Intensified system analyses, control and maintenance works will be prolonged throughout the year 2005 so still greater savings can be expected. Particular attention will be devoted to the precise evidence and analyses of the pipeline failures and their repair. The main goal is to form internal norms for the maintenance of water distribution pipelines in the water utilities Vodovod d.o.o. – Slavonski Brod.

References

[1] Proceedings of the Scientific and Professional Conference "How to Protect Croatian Water Considering Water Supply and Draining Systems", Pula, June 2001

[2] Proceedings of the Seminar "Management of Water and Maintanance of Water Supply Systems", December 2004, Zagreb

[3] "VODA" Journal of Croatian Waterworks and Drainage Group, www.gvik.hr

[4] Flowmeter Fluxus ADM 6515 User's Guide, Flexim, http://ducker.ecnext.com/coms2/summary_0242-1545_ITM

[5] Pressure Data Logger UNIMOS 1000 User's Guide, Elster, www.elstermetering.com/en/1263.shtml

[6] Water Leak Correlator AquaCorr User's Guide, Biwater, http://www.biwater.com, http://www.plumbguarantee.co.za/frameset/body.htm

[7] Water Leak Correlator AQUAPHON User's Guide, Sewerin, http://www.sewerin.com/www/en_info.nsf/HTML/3363A5ACD48D07B1C1256C3E0023F211

[8] Company Archive, Vodovod, Slavonski Brod