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Method of the Weak Point Verification of Elements of a Water Distribution System

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Abstract

The present article is a result of theoretical considerations made on the basis of exploitation tests conducted by the author and concerning the search for weak points in the process of the exploitation of water distribution systems. The points cause disruptions in the functioning of water supply systems and have a serious effect upon the reliability of their functioning. This is why, weak points of water distribution systems should be systematically eliminated by undertaking activities aimed at their search as a result of tests in normal utilization conditions, verification, and removal.

1. Definition of a Weak Point

For the needs of the present document, the term "weak point" has been defined as follows:

> A weak point in water distribution systems is an element damaged during exploitation or an element with high probability of damage, which can be repaired, replaced, or modernized to limit frequency of damages (Denczew 2000).

Weak points in water distribution systems can include:

- water supply connections made in the past with the help of the so-called quarter-rotary cock,
- left-wise bolts,
- deep fire protection hydrants,
- choke compensators sealed with graphite cord and others.

Damage to elements of water distribution systems occurring during their utilization make us frequently assume weak points . This is why we should:

- systematically search for and verify of weak points,

- examine and analyze reasons for their occurrences,
- undertake steps aimed at eliminating weak points of elements of the water distribution systems.

The present divagations refer only to weak points to technically conditioned damages, and not, for instance, to defects caused by other factors, including: material defects, mechanical damage, etc.

2. Methodology of the Identification of Weak Points in Elements of Water Distribution Systems

The methodology of the identification of weak points in water distribution systems' elements, constitutes a set of logical actions ending in an analysis confirming the correctness of the qualification of the tested damage in a group of damages that can be eliminated, or those, the frequency and scope of which can be limited by means of available technical and technological means within an economically acceptable level of costs.

The block scheme of the analysis of damages to elements occurring during the functioning of the water distribution systems is represented in Fig. 1.

As it can be seen from the above figure, the presented methodology consists of many activities ordered in a logical sequence of a vertical configuration. It is aimed at an identification of weak points in the process of the water distribution systems' utilization and their elimination.

3. Short Description of Individual Actions

The tests, control, and overview of elements of the water distribution systems shall be conducted for the needs of the analysis (identification of features, the course and reasons of the occurrence of damages), as well as to determine actions to eliminate them or prevent the occurrence of damages in the process of the exploitation of the said systems (Praktyczny 1997–1998).

In order to identify weak points in the process of the exploitation of water distribution systems, complete recognition of all factors leading to damage by means of analysis is necessary. Information necessary to undertake preventive actions aimed at preventing the occurrence of damage to the element itself, or other elements within the tested water distribution system and prolong of the faultless functioning T_{pb} of these elements (T_{pb} – time that elapses between consecutive damages) is available. The T_{pb} time is one of the basic indexes of the reliability of the water distribution systems' functioning. It is included in the readiness index (K_g), which is determined as a probability that the element of the water distribution system will be suitable at any moment t in certain utilization conditions

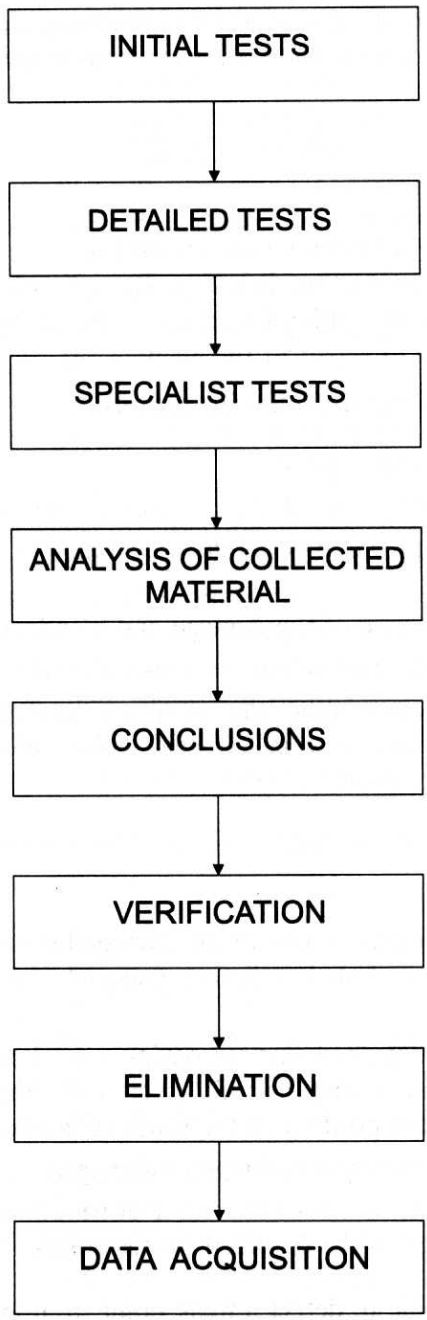

Fig. 1. Methodology of identification of weak points in elements of water distribution system (flow chart)

(Kwietniewski et al. 1998, Wieczysty 1990). The index in practice means a probabilistic evaluation of the availability of water distribution elements within the scope of the given task performance. The stationary form of this index is:

$$K_g(t) = \frac{T_{pb}}{T_{pb} + T_o}, \tag{1}$$

where:

T_{pb} – average time of faultless functioning [h],
T_o – average renovation time [h], $T_o = T_{on} + T_n$, where:
  T_{on} – time of waiting for repair of the element [h],
  T_n – time of repair of the element [h].

Initial tests should cover the following actions:

- security of the damaged point,
- attempt at initial diagnosis of the cause of the damage,
- preparation of graphic and visual documentation of the damaged place and its surroundings,
- evaluation of the scope of the damage and its effects,
- determination of the technology for removal of the damage,
- analytical conclusions whether the initial test conducted creates possibilities to qualify the damage as so-called weak points and whether detailed tests will be carried out or not.

Should initial tests be insufficient, detailed tests should be carried out and include the following:

- description of the existing state of the damaged element (including the construction year of the whole installation, material of the ducts, soil conditions, etc.),
- description of the damaged element paying special consideration to external (static and dynamic loads), as well as internal (thermal, hydraulic loads, physico-chemical composition of the water) conditions of its functioning,
- determination of the cause and type of damage,
- attempt to qualify elements of the water distribution system on the basis of the form of damage to the so-called "weak points".

It is not always possible to detect a weak point from initial and detailed tests. In such situations specialized tests should be undertaken, these including:

- an overall evaluation of the state of the duct material,
- resistance tests,

- tests of the internal and external corrosion of the duct wall,
- macro- and microscopic tests.

The basic condition for the correct realization of specialized tests includes a proper sampling of the duct material, its security, storage, and transport.

The initial, detailed, and specialist tests of the damaged water distribution system element should afford a sufficient amount of information to enable a complex analysis and formulating of conclusions concerned causes of damage to the element.

Having formulated the conclusions verification of the weak point should be conducted and, in on confirming the fact, the damaged elements should be replaced, repaired, or modernized.

4. Analysis of Damage to Elements of Water Distribution Systems

Preparation of the presented method of the verification of weak pointS in water distribution systems' elements is based on results of the extent of damage to elements on the example of the water supply system in Warsaw, but the tests were conducted in conditions of normal exploitation.

The frequency of damage is determined by the ratio of the amount of damage at a certain time Δt, the length of time interval and number of all the elements tested (Kwietniewski et al. 1998, Wieczysty 1990).

The relation facilitating determination of the value of the index determination on the basis of data arising from the exploiting of the water supply system is the following:

$$C(t) = \frac{R(t, t + \Delta t)}{n\Delta t}, \tag{2}$$

where:

$R(t, t + \Delta t)$ – damage during time Δt,
Δt – length of the time section, into which the observation period has been divided,
n – number of objects tested.

The total damage to the water distribution system in Warsaw in the years 1996–1999 is presented in Fig. 2.

The unit frequency of damage C_L is determined by the damage per unit of the length of duct L (e.g. 1 km) within a certain period of time (e.g. one year) (Kwietniewski et al. 1998), hence:

$$C_L = \frac{C}{L} \left[\mathrm{a}^{-1}\mathrm{km}{-}1\right]. \tag{3}$$

Values of the C_L index are illustrated in tables 1, 2, and 3.

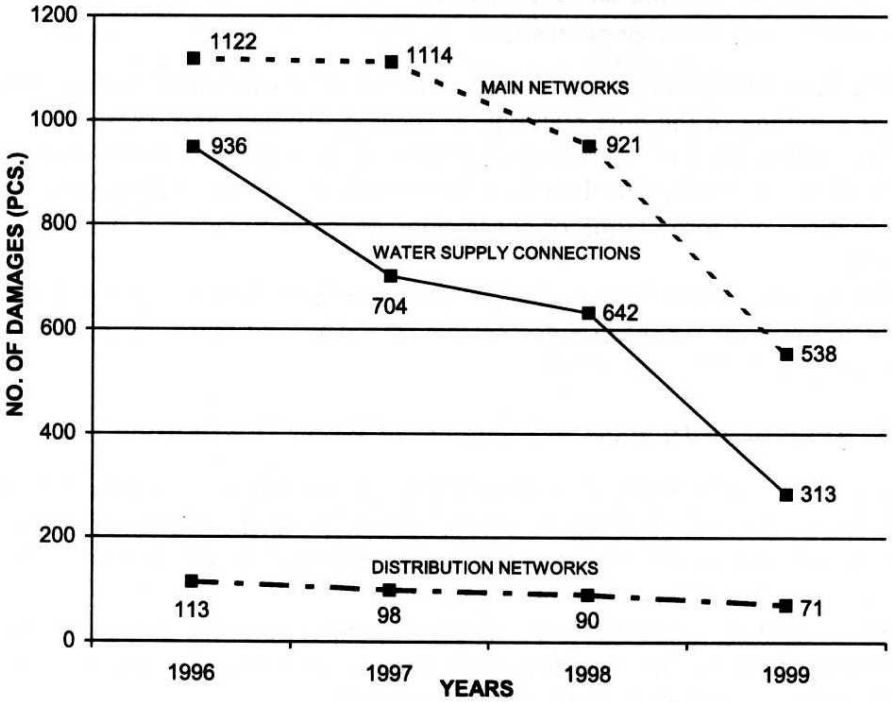

Fig. 2. Total number of damages to the potable water distribution system in Warsaw

Table 1. Unit frequency of damage to the sub-system of water supply main networks in Warsaw in 1996–1999

YEAR	LENGTH OF THE SUB-SYSTEM OF WATER SUPPLY MAIN NETWORKS	FREQUENCY OF DAMAGES C $[a^{-1}]$	UNIT FREQUENCY OF DAMAGES C_L $[a^{-1}km^{-1}]$
1996	370	113	0.31
1997	373,2	98	0.26
1998	376	90	0.24
1999	379,3	71	0.19
Total on the average	374,6	93	0.25

A detailed analysis of results of the damage tests has enabled us search for weak points in the water distribution systems' elements and formulate the following conclusions:

- elements of the distribution networks of the system undergo most damage,
- he smallest amount of damage was determined in elements of main networks,
- considerable damage was noted in water supply connections, most of them of Ø 50 mm.

Table 2. Unit frequency of damage to the sub-system of water supply distribution networks in Warsaw in 1996–1999

YEAR	LENGTH OF THE SUB-SYSTEM OF WATER SUPPLY DISTRIBUTION NETWORKS	FREQUENCY OF DAMAGES C $[a^{-1}]$	UNIT FREQUENCY OF DAMAGES C_L $[a^{-1}km^{-1}]$
1996	1588.0	1122	0.71
1997	1603.6	1114	0.69
1998	1621.9	921	0.57
1999	1631.8	538	0.33
Total on the average	1611.3	924	0.58

Table 3. Unit frequency of damage to the sub-system of water supply connections in Warsaw in 1996–1999

YEAR	LENGTH OF THE SUB-SYSTEM OF WATER SUPPLY CONNECTIONS	FREQUENCY OF DAMAGES C $[a^{-1}]$	UNIT FREQUENCY OF DAMAGES C_L $[a^{-1}km^{-1}]$
1996	603.3	936	1.55
1997	614.5	704	1.15
1998	622.7	642	1.03
1999	635.9	313	0.49
Total on the average	619.1	649	1.06

5. Checking the Weak Point of Elements of the Water Distribution System

Pursuant to tests of damages in elements of the water distribution system a method of checking weak points in water distribution networks was worked out. This is presented in Fig. 3.

The main task of the method presented includes the detection and checking of weak points and their systematic elimination to increase the reliability and safety of functioning of elements of the water distribution system. This consequently leads to a reduction in costs of exploitation of these systems.

6. Conclusions

The method presented is aimed at the systematic elimination of weak points of elements of a water distribution system and prolongation of failure-free functioning of these elements. Its application in exploitation will enable to achieve measurable effects in the form of minimization of costs of exploiting water distribution systems and increase the reliability of their functioning.

The weakest elements of the water distribution system in Warsaw were indicated as a result of the application of the method of verifying the weak points. It allowed us remove them, which can be prove with the results of exploitation tests,

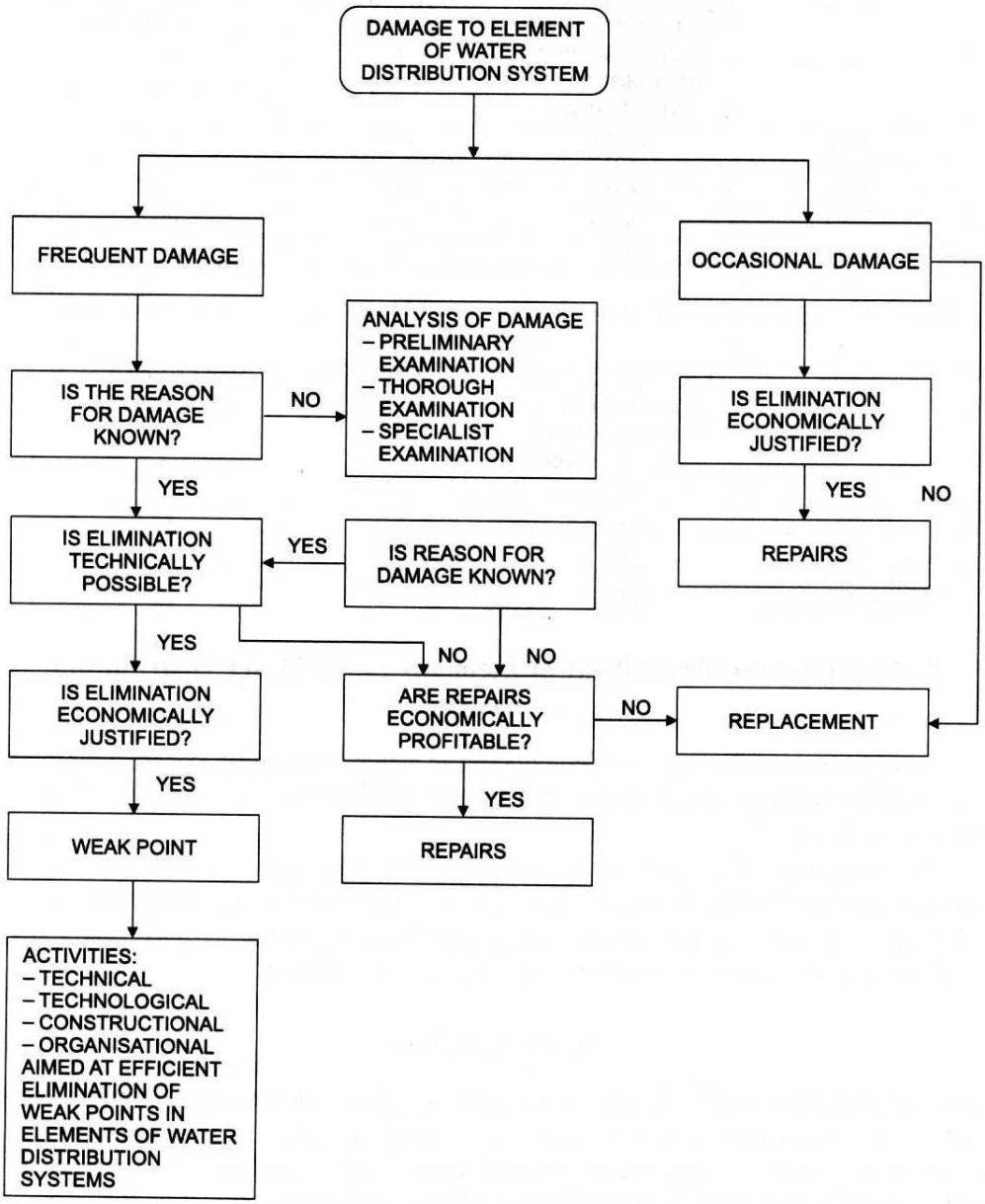

Fig. 3. Method of the weak points verification of elements of a water distribution systems

from which it clearly results that the value of a single frequency of damages gets reduced and is within the recommended limits (0.25 damages/year/km).

The detailed analysis of the exploitation data conducted proved the utility of the method; it contains scientific elements and practical advantages during its application in the process of the utilization of water distribution systems.

The introduction of contemporary scientific and research methods into utilization aspects in water distribution enterprises becomes an element necessary and guaranteeing an increase in the reliability of their functioning.

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