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## CHECKING THE HYDRAULIC EFFICIENCY AND IMPROVING SAFETY OF THE INTERNAL WATER SUPPLY

*Water management systems in industrial facilities, industrial zones, hospitals and other internal water systems relatively frequently fail to meet the intended purpose for which they were built when an extraordinary event occurs. They may even pose a safety hazard. The causes of this condition may be of internal or external origin. Given that internal water supply systems of large premises always have a multipurpose character, i.e. to provide enough drinking water for drinking and sanitation purposes and also as a source of fire water for the fire safety of buildings, they must meet a wide range of hydraulic conditions and technical-operational capabilities. By what means and methods it is possible to achieve the desired state in economically-acceptable dimensions, while maintaining all the necessary hydraulic capabilities of the supply points of drinking and fire water, is briefly described in this article.*

**Keywords:** internal water supply network, water lines, water connection, hydraulics, risk, risk reduction, reliability

### 1. Introduction

Important locations and extensive premises of public and private infrastructure of cities and towns cannot do without the construction and subsequent operation of an internal water supply network. The continuity and reliability of supplying drinking and fire water is one of the basic conditions of their operational functions and building safety. Even a short-term interruption of water (about 8-10 hours), required to repair damaged equipment of the waterworks system, causes serious or even critical problems for water consumers. It threatens food production, disrupts the functioning of accommodation and catering facilities and can seriously disrupt inter alia the operability of hospitals.

Since the occurrence of accidents and extraordinary events in water supply systems of the public water supply or water installations cannot be completely prevented, it is necessary to know and analyze the causes and conditions that give rise to these situations and prepare for their solution.

In some cases, it is possible to eliminate operational security risks via technical and investment funds during the construction of the given type of infrastructure of the built-up area. Other risks emerge during the operation of the systems as a result of errors and deficiencies in their use, when underestimating the changing characteristics of hydraulic piping systems over time, mainly due to changes in the surface roughness of the inner pipe walls

and a subsequent change in flow capacity. Usually, in the case of a lack of the hydraulic efficiency control of the waterworks system's internal water supply system, problems are fully reflected in critical situations and, as a consequence, excessive damage is incurred [1].

To reduce or eliminate the operational and security risks of each internal water supply network, upon which the entire premises are dependent, it is necessary to understand and abide by at least the principles set out in this article.

### 2. Internal water supply as a comprehensive operating system

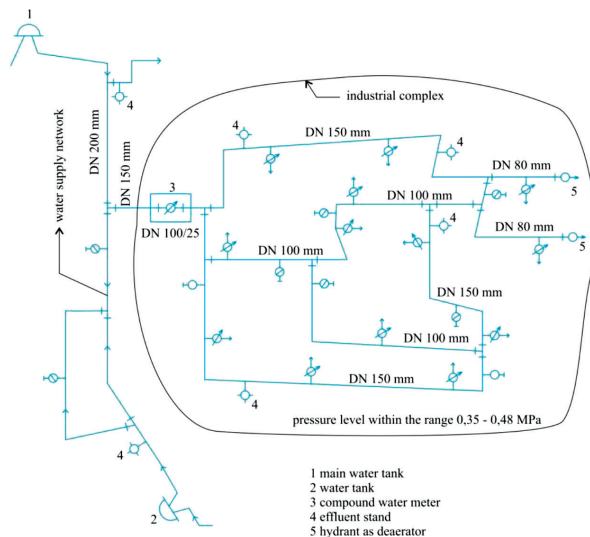
The reliability and flow volume capacity of water supply is always primarily dependent on the water source from which it draws water to be transported to individual structures or their complexes on the operated premises. In the Czech Republic and Slovakia, similarly to most other states, the source of water for internal water supply networks in public and private infrastructures, is almost always the water supply system for public needs, see Figure 1. It consists of a water line, which includes a system measuring water flow and a variously complex piping system of one or more pressure zones, depending on the technological needs of the premises.

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**Figure 1** Diagram of the internal water supply network of an industrial complex with fire water supply points

In some specific situations, the source of potable and fire water can be an independent supply of surface or underground water. In such situations, the surface water must always be purified according to the parameters for drinking water in water treatment, which is an integral part of the internal water supply system. Underground water must be treated to obtain drinking water only in cases where it does not meet the requirements for drinking water laid down by law [2].

To meet the expected effect of the water supply network in the supply of drinking water and in many cases, fire water, it is necessary to view the system as one comprehensive system. Underestimating some parts of this system often produces a ripple effect. For example, a lack of water velocity in individual water lines reduces water quality and may give rise to serious health problems of consumers. Conversely, changes in flow capacities often cause technical glitches of control fittings of the water supply network or a change in the roughness of the inner pipe due to encrustation. The former hydraulic cause threatens the health and lives of people; the latter has the effect of compromising the fire safety of the entire premises due to a lack of fire water for fire hydrants or discharge pillars.

### 3. Hydraulics and its importance for the reliability and safety of water supply

For these and other reasons, each operator of an internal water supply network must know not only the hydraulic conditions of the entire system, but also of its individual distribution segments. The technical and operational parameters of water lines change over time. Significant changes and a reduction in the hydraulic

**Table 1** Water flow in water lines

| dimension [mm] | water flow [l/s] |
|----------------|------------------|
| 40             | 1.257            |
| 50             | 1.964            |
| 80             | 5.027            |
| 100            | 7.854            |

efficiency of the water supply system occur primarily for the following reasons:

- the age of the pipeline systems,
- the quality of the flowing water,
- the operational load of the lines and water velocity.

The aforementioned root causes have various negative effects on the overall operating characteristics of the water supply network. If the age of the pipe is a fixed value, then the designer must respond to the known or suspected water quality while designing the structure of water lines (a branched, round or combined system) and calculate the dimensions of individual lines. When calculating the dimensions of the lines, the following procedure must be complied with.

#### 3.1 Dimensions proposal for water lines

A variety of calculation methods can be used for the dimension design of water lines of the internal water supply systems. One of the most progressive current methods is the mathematical modeling of the water supply network. It is particularly advantageous for the calculation of the new pipes with zero encrustation of the internal network, where it allows for achieving a high reliability of output calibrated values. Mathematical modeling gives designers and operators of water supply the answer to a number of fundamental questions. In particular, the speed of water flow in individual lines and the value of the hydrodynamic pressure at varying operating load (water flow in l/s).

For most internal water supplies providing only a supply of drinking, process and sanitary water, it is suitable to comply with the following principles when designing lines:

- ensuring water velocity in the pipe system (the optimum is 0.8 to 1.1 m.s<sup>-1</sup>)
- maintaining the freshness of drinking water in the entire system (max. delay - 24 hours).
- maintaining the secondary level of the health safety of drinking water throughout the entire water residence time in the internal water supply system, including its water supply connections (0.2 mg/l Cl<sub>2</sub>).

These parameters of water quantity and quality can be achieved in the design and implementation of pipe lines and water connections of the following dimensions are listed in Table 1.

**Table 2** Water line dimension depending on the supply points of fire water

| dimension | branch water supply network |  | circular water supply network |  |
|-----------|-----------------------------|--|-------------------------------|--|
|           | water flow [l/s]            |  | water flow [l/s]              |  |
|           | fire hydrant                |  | pump outflow stand            |  |
| 80        | 5.027                       |  | -                             |  |
| 100       | 7.854                       |  | -                             |  |
| 150       | 17.672                      |  | 35.344                        |  |
| 200       | 31.416                      |  | 62.832                        |  |

**Figure 2** An example of moderately encrusted piping

The dimension design of internal water supply and individual water connections to buildings is always dependent on calculating the maximum and minimum water consumption connected to various branches of the water lines or water connections.

If the water system is currently designed as a multipurpose fire water supply for the area in question, it is necessary to consider the design of DN (diameter nominal) piping, depending on the type of withdrawal place of fire water, as shown in Table 2.

The dimension design of internal water pipelines, serving the purpose of the fire protection of buildings, is operationally very problematic. When the pipe dimensions are 100 mm, 150 mm, 200 mm, it is no longer possible, besides in exceptional cases, to maintain the freshness of drinking water and its health safety in the pipe system.

From the above significantly reduced procedure for the design of the suitable pipe dimensions depending on the desired quantity of water flow, a close connection between determination of the optimal dimensions of the pipeline and the pressure losses in the operating system is evident. In the event of an underestimation of this bond and its interdependence, the situation shown in Figure 2 may occur in a relatively short period of time (the first third of the pipeline's lifetime)

Such a situation occurs on water installations with insufficient flow velocity, especially in the design of branched systems, in connection with mineralized water with higher content of Fe and

Mg. Aside from a reduced water velocity in the pipe below  $0.4 \text{ m.s}^{-1}$ , a more rapid formation of or increased encrustation also occurs as a consequence of drawing water from local groundwater resources and a lack of sufficient demineralization of groundwater during the purification to drinking water.

The subsequent risk of changes in hydraulic efficiency of water supply due to excessive encrustation of the inner pipe and their effect on the hydrodynamic properties of the pipe network is shown in Figure 3.

From Figure 3 it is clear that even at a slightly above-average water flow in water lines, the water supply network is not able to maintain the sufficient hydrodynamic pressure of water. That fact is a risk not only for operational purposes and various appliances that utilize water, but mainly for fire safety of the premises. Of the whole range of specific threats that have the potential to disable each internal water supply, the most important are the following events:

- contamination of drinking water with organic or inorganic substances,
- reduction in the level of drinking water supply in the distribution system,
- limitation or interruption of the water supply from its source.

If the abovementioned and other extraordinary events cause „merely“ economic damage for industrial and commercial consumers of drinking water, for hospital premises and long-term sickness facilities, they will almost always result in the complete or partial evacuation of patients. For healthcare facilities, it does not serve the intended purpose of a classic reserve water supply, but always only as a direct supply of water to individual pavilions.

#### 4. The safety risks of operating an internal water supply network

Given the importance and indispensability of the operational functions of water supply to the utility values of the premises, it is necessary to conduct checks, as a part of an emergency prevention and reduction of consequential damage. This issue is addressed on a general level in particular by CSN ISO 31000 Risk Management - Principles and Directives, which sets out the binding procedure for risk assessment technique.

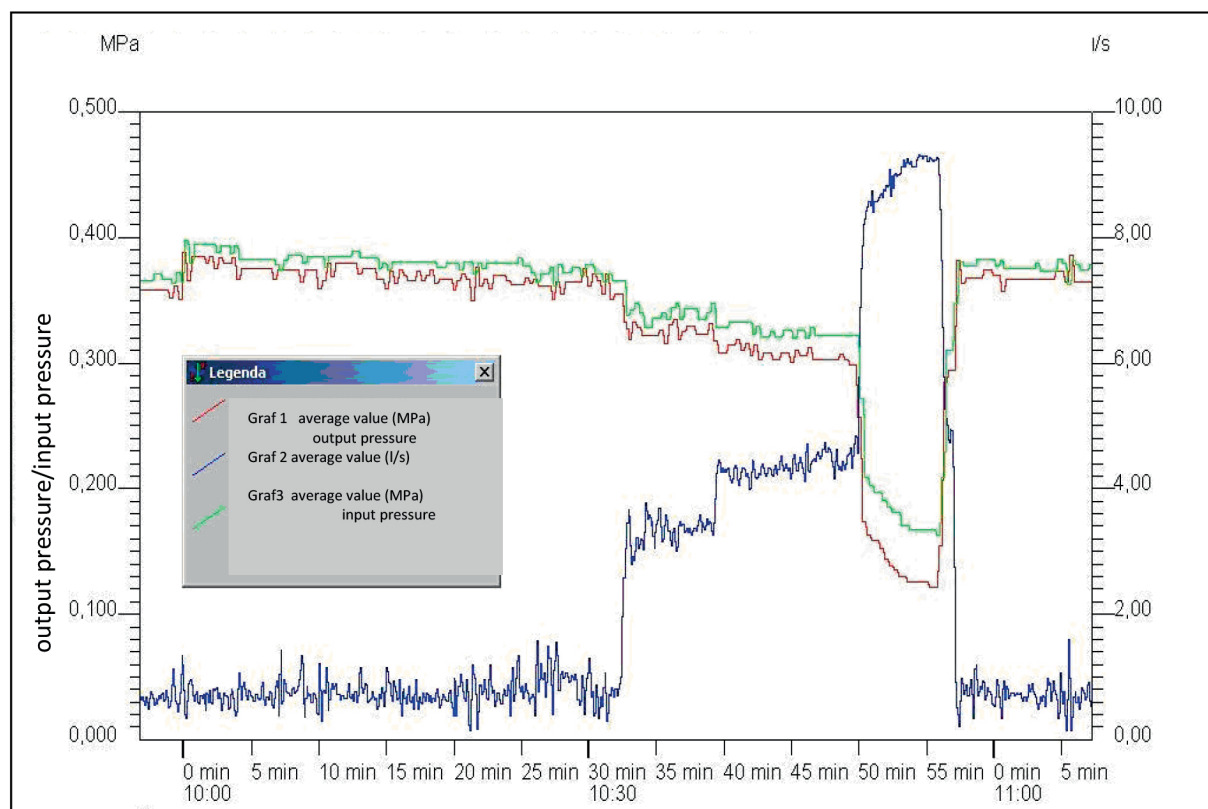


Figure 3 Representation of the hydraulic efficiency of the water supply network during capacitive loading

Checks should be focused primarily on exposing the weaknesses of the system and increasing its strengths.

#### Weaknesses

Internal water piping of industrial facilities, industrial zones and extensive technical-operational areas of various users, have a variety of weaknesses, with which one must be familiar and able to prepare operational plans to reduce them. The basic factors include the following:

- usually only one source of drinking and fire water,
- differing operating reliability of the water source, depending on its type,
- heavily undersized water connections in relation to the requirements of maximum supplies
- low hydraulic efficiency of water supply pipe systems,
- the risk of changes in the quality and safety of drinking water [3].

#### Strengths

Strengths are reflected primarily in optimally solved and constructed internal water piping, but they can be found to a lesser extent in essentially all waterpipes [4]:

- direct water supply to the place of consumption,
- fire safety of facilities on the premises,

- the possibility, upon agreement with the water supplier, to increase hydrodynamic water pressure in parts of the water supply network up to the parameters necessary for its technological use [5].

A relatively balanced state can be achieved if danger, stemming from the weaknesses, is recognized early and the potential of strengths is exploited, [6]. Attention should be focused on the following areas:

- monitoring of hydraulic and operating parameters of the internal water supply system,
- refinement of operational and handling rules,
- preparation of crisis preparedness plans of the subject in question.

The activity in question must not be segmented, however, it must be the output of a comprehensive risk analysis of the entire functional or utilized environment of the operator.

## 5. Discussion

Due to the irreplaceable significance of internal water supply systems for the functioning of production plants, shopping centers and hospitals, it is necessary not only to operate them optimally,

but also to seek ways of further rationalization. An extremely effective form could be national and international discussions of the professional public and the transmission of positive and negative experiences with the operation of these types of water cannons. Professional discussions could focus primarily on the following areas:

- how to avoid the danger of changes in the quality of drinking water and maintain its health security while preserving the hydraulic capacity of combined pipeline systems for drinking water and fire water for structures,
- economically acceptable and feasible ways to achieve a substantial increase in the reliability of water supply from internal water piping in the case of an extraordinary event or a crisis situation,
- finding new rational methods of using water in internal water supply networks during the technological utilization, before its conversion to waste water.

The topics proposed for discussion will become increasingly important in the light of occurring climate changes. Their meaning and scope transcends national boundaries and they are utilizable by everyone interested in increasing the economic efficiency and reliability of internal water supply systems.

## 6. Conclusion

The function of internal water supply of industrial and commercial complexes and industrial zones is irreplaceable. It does not only provide the drinking water to individual buildings on the premises, but it is also an important multipurpose source of fire water for the entire operating system. In order to be able to fulfill their specified purposes, they must be designed

and implemented in accordance with the hydraulic principles mentioned in this article. These principles include, in particular, the following characteristics:

- a consistent overview of water losses throughout the distribution system,
- accurate knowledge of the amount of water in individual sectors or pressure zones of the internal water supply,
- the ability to operate only the strategic parts of the water supply network in crisis situations via the control system, for the most important premises of the operational area, for selected and reduced supply points of fire water, to ensure their specified amount of supply during the crisis.

Failure to follow these principles not only significantly reduces the value of the entire construction work, it can also seriously disrupt the reliability requirements of the water supply for sanitary and technological purposes of the operator of the premises and, the last but not the least, the hydraulic reliability of the relevant multipurpose source of fire water.

The construction of the article and its structure defines the ways and means to minimize the risk that internal water supply will not meet the required and necessary technical and operational parameters upon commissioning.

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## References

- [1] STRELCOVA, S., REHAK, D., JOHNSON, E. A. D.: Influence of Critical Infrastructure on Enterprise Economic Security. Communications - Scientific Letters of the University of Zilina, 17(1), 105-110, 2015.
- [2] Act no. 254/2001, Collection of laws: On Waters and Amending Some Laws (the Water Act), as amended.
- [3] Act no. 252/2004, Collection of laws: Hygiene Requirements for Drinking and Hot Water and the Frequency and Extent of its Control.
- [4] KROCOVA, S., REZAC, M.: Infrastructure Operation Reliability in Built-Up Areas. Communications - Scientific Letters of the University of Zilina, 18(1), 75-78, 2016.
- [5] ADAMEC, V., MALEROVA, L., ADAMEC, M.: How to Assess Territory Vulnerability. The Science for Population Protection 1, Population Protection Institute of Lazne Bohdanec, 17, 35-40, 2016.
- [6] KROCOVA, S.: Industrial Landscape in the Period of Hydrological Drought. Inzynieria Mineralna, 18(1), 29-32, 2017.