Using Complex Liquid-Measuring Devices in Fire Hoses

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Abstract: *Up to now, it is still very common to use water for extinguishing fire. To be able to ensure the adequate water supply, it is essential to examine the parameters of the water supply system, especially in the case of firefighting devices, which are sometimes used under extreme conditions. To ensure the proper amount of firewater and to carry out the necessary modifications, it is vital to examine the firewater supply system from the pump including the pipes to the nozzle. We aim at making such a complex measuring instrument that provides accurate measurements in the pipes and at the nozzles used by firefighters and presenting its practical applications. First, we demonstrate the water supply system used during the process of firefighting, then we describe the measuring task, the applied instruments and devices. Our goal is to contribute to the increase of the efficiency of providing water supply required for firefighting.*

Keywords: *Firefighting pipe, water, nozzle, complex measuring instrument*

1. Introduction

During firefighting one of the most important tasks is carried out by firefighters handling nozzles at the end of the hose out of which the discharging water puts out the fire. These firefighters completing their task to be able to extinguish the fire fast and efficiently are constantly on the move, they change their positions both horizontally and vertically. Despite the fact that firefighters change their positions frequently, an adequate amount of firewater at a suitable pressure is expected to be provided. Ensuring these factors is a complex task, especially when the pump is required to operate multiple streams from the supply hoses. Therefore, examining the system providing water for firefighting and performing the necessary fluid mechanics measurements are essential. Several measurements can be carried out under laboratory conditions, however, the system providing water for firefighting is advised to be examined in 1:1 in field tests. We compiled a group of combined instruments measuring liquids necessary for the measurements and adapted it for practical application. We present our experience and measurement results in this study.

2. The elements of a firewater supply system

First, we find it important to introduce the elements of a firewater supply system before presenting the actual measuring task. The list of system elements can be extended with various parts, among which the elements used the most commonly, such as the pump, the hose, the manifold and the nozzle, are going to be presented below.

2.1. Firefighting pumps

The operation of a water supply system is mainly ensured by vortex pumps or in other names, centrifugal pumps. A vortex pump is primarily a machine travelling fluids and using up the mechanical energy driven into the pump and the angular momentum, it enhances the working capacity (its energy) of the travelled fluid with the extent necessary for forwarding the liquid to its place of use. Among the vortex pumps, firefighting pumps are a special class, which - due to their design - can even withstand being operated under not optimal conditions to a certain extent, however, it may lead to failures in the longer term. Most frequently, 2-5 multi staged pumps are used for firefighting purposes, whose performance is highly influenced by reaching the water supply or water source. The inappropriate installation of the pump onto the water source or a sudden extra water extraction may cause cavitation. The physical process of cavitation is related to the phenomenon of boiling water in which the forming vapour cavities in the liquid delivered suddenly implode. This process takes place at those locations in the pump where the pressure is under the vapour-pressure of the pumped medium. [1] Signs referring to cavitation are the various noises and the suddenly developing resonance followed by degradation in performance. Cavitation can occur in the course of operating pumps used by firefighters. In the initial phase well-detectable noises develop, then stronger and stronger shockwaves and vibrations are forming in the fluid and the travelling systems. Since the fluid has a minimum pressure at the leading edge of the impeller from the direction of the suction pipe, this is the location where cavitation may occur the earliest. The decrease of suction depth, applying suction pipes with a narrow diameter, resistance emerged in the suction pipe or an increase in the temperature of the fluid all contribute to the emergence of the phenomenon. [2]

2.2. Firehoses

In most cases lay-flat fire hoses of standard diameters (52-75 mm) fitted with standard Storz couplings and of unit length (20m) are used for firefighting. The hose with a diameter of 75 mm is called hose "B", while the one of 52 mm is called hose "C". A lay-flat fire hose is a soft wall hose which, when unpressurized internally, collapses to such an extent that the inner faces of the inside diameter make contact and the hose takes up a flat cross-sectional appearance making it easy to store and delivered reeled up. Essentially, lay-flat fire hoses are produced with an external jacket and a flexible impermeable lining. [3]

2.3. Manifolds

Manifolds are firefighting devices applied for distributing firewater flowing in the hose. In most cases, four-way valve manifolds are used which come with 1 Storz inlet of 75 mm in diameter, 1 Storz outlet of 75 mm and 2 Storz outlets of 52 mm. All outlets are fitted with manually operated mechanical fittings allowing the outlets to operate independently. [3]

2.4. Nozzles

One of the most important devices of extinguishing fire with water is the nozzle, which allows the water delivered in the firefighting system to be discharged onto the seat of fire. The nozzle itself is two confusers in line, [4], between which a combined closing device got installed. The multitude of nozzles not only allows the discharge of water, but they make it possible to vapourise the water into the required size and to form various stream types in order to ensure the optimal use of water. In the case of jet streams, nozzles are produced with various exit diameters according to the different uses. The most commonly used exit diameters of nozzles are d = 12 mm, 14 mm and 16 mm. [3]

3. Losses in firewater supply system

Carrying out firefighting tasks, in most cases, the conditions expected from the water supply system are not fulfilled in practice. The stream's change in height compared to the position of the pump and the changes of suction and total head when applying an external water source can show significant deviations with centrifugal pumps. It implies that the amount of the delivered firewater may decrease within a given time. Although creating optimal operating conditions in the course of firefighting is essential, field conditions and equipment available on the spot do not always make their creation possible, thus the actual pressure and amount of water fall short of expectations. Regardless of external factors, some elements of the water supply system show losses during operation. The pressure of the liquid exiting the fire pump discharge can be expressed as the sum of the following pressure losses: [5]

$$\Delta p = \Delta p_L + \Delta p_t + \Delta p_h + \Delta p_0 \qquad (1)$$

In the equation:

- Δp: pump pressure

- Δp_L:pressure at the nozzle tip
- Δp_t: friction loss in hoses
- Δp_h: pressure loss due to change in height
- Δp_0: pressure loss of devices (e.g. manifold, restrictor, pressure equalizer unit)

Studying the available literary sources dealing with pressure loss in hoses, we concluded that the data show differences, therefore the hoses' pressure loss per meter in the function of flow rate should be calculated in each case. It should be noted that although the hoses are to meet the standards, these values may vary slightly depending on the manufacturers and the age of the hoses.
The pressure loss-flow rate data of the nozzles are included in the relevant standards in a spreadsheet. Taking a nozzle tip of 12 mm with Q=206 l/min=0,00343 m^3/s flow rate as an example, it states exactly $\Delta p_L = 5 \cdot 10^5$ Pa pressure drop.[3] It must be added that the pressure differential is not a huge loss since the pressure and kinetic energy at intake diameter of the nozzle is converted into kinetic energy at the discharge diameter. When no relevant pressure-flow rate data is available for the required nozzle, it can be calculated using only the geometric data with a reasonable approximation. Writing the Bernoulli equation between the intake and discharge diameters of the nozzle, the pressure and kinetic energy turns into clearly kinetic energy [4]:

$$\frac{\Delta p_L}{\rho} + \frac{v_{L1}^2}{2} = \frac{v_{L2}^2}{2} \qquad (2)$$

In the case of the pressure loss coming from raising water, 1 bar per meter ie. 10^5 Pa can be calculated. The manufacturers generally do not or only in certain cases indicate the Resistance Coefficient of the fittings, so it needs to be calculated later [3]. According to the source cited, in the case of manifolds the pressure drop is taken into consideration with 10 PSI ie. 0.69 bar.
As shown above, during the operation of a firewater supply system several losses occur and their calculation is not simple even in the case of a static system, but when the firefighter handling the stream constantly changes his position or multiple streams are to be operated simultaneously, determining the momentary flow rates and the amount of the discharge water becomes extremely complicated. For the reasons given above, we decided to choose measuring, since applying measurement instruments which do not change the flow conditions of the water supply system, valid results can be gained.

4. Assembling the complex measuring device

Preparing our complex measuring device, we took similar equipment used in practice as a starting point allowing each measurement sub-task to be carried out individually, however the simultaneous measurement of the flow in the hose and the parameters of the water discharging from the nozzle was not possible. The elements of the complex measuring device being able to be applied individually in the firewater supply system and being able to measure the characteristics of the flowing fluid connected to each other and to the end of the fire hose raised as a requirement as well. As the streams used in firefighting activities are mainly operated with "C" hoses of 52 mm and the most commonly used nozzles are also fitted with Storz couplings may be connected to "C" hoses, each component of our complex measuring device was fitted with Storz couplings compatible with "C" fire hoses. First, we had to choose a flow meter which is capable of measuring the parameters of the fluid travelling through so as not to modify its flow characteristic and not to cause any turbulence. The device is expected to be able to carry out measurements under non-laboratory conditions and to determine the flow parameters of the water gained from fire water sources. Considering the abovementioned facts, we chose a flow meter type Arad Octave 50 for our purposes. The instrument itself, seen in the figure 1., was not suitable for being applied in firewater supply system by default.

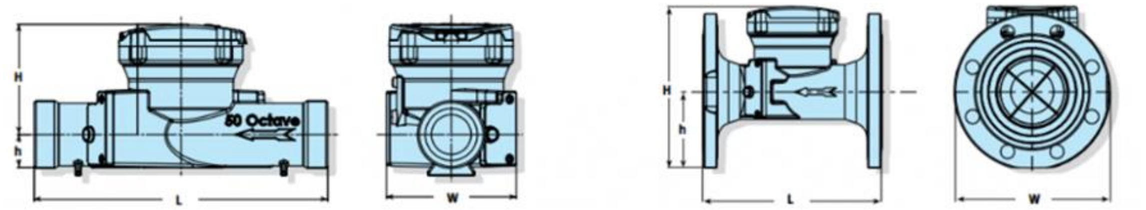

Fig. 1. Flow Meter type Arad Octave 50 (Source: Factory catalogue with authors' additions)

To obtain accurate measurement results, the device had to be fitted with a connector, a semi-rigid discharge hose and Storz couplings for the ideal application. The technical drawing made by dimensioning - based on which the supplementary hoses got manufactured - can be seen in the figure 2.

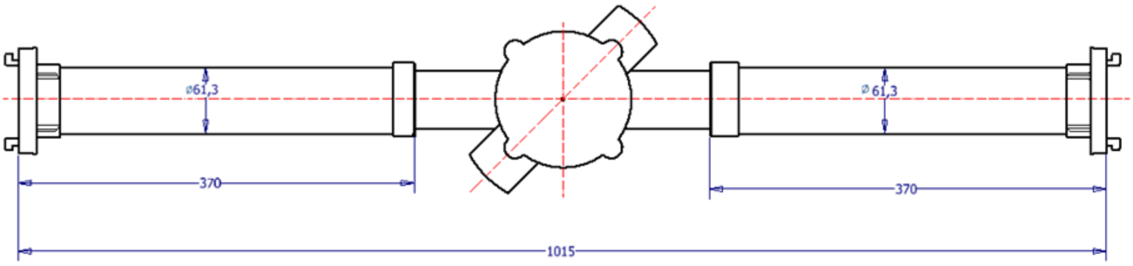

Fig. 2. Ultrasonic Flow Meter type Arad Octave 50 (Source: prepared by the Authors)

The next part of the measuring device is made up of a pressure gauge that can be connected to a "C" type fire hose, a nozzle with two confusers whose tip is replaceable making it possible to use it for measuring with a nozzle of 12, 14 and 16 mm in diameters. A Storz coupling for "C" type fire hose was mounted to the sleeve on the intake. In the figure 3. the pressure gauge and the measuring nozzle can be seen connected to each other.

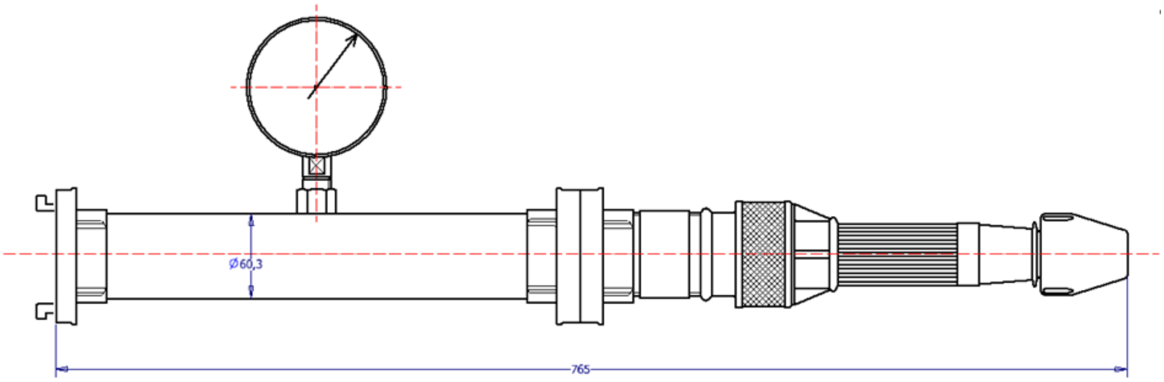

Fig. 3. The connected pressure gauge and measuring nozzle (Sources: prepared by the Authors)

The pressure gauge presented in the figure can be used individually built into the hose system as well. The measuring nozzle cannot be used for firefighting tasks, it was specifically designed for measuring purposes. When coupled, the unit fitted to the end of the hose is perfectly suitable for determining the water discharging from the nozzle of whichever size against pressure.

5. The measurement

We made in field measurements and operated two manifolds with a two-storey difference in height, whose water supply was provided by a heavy-duty Steyr Rosenbauer TLF 4000 fire engine. An RB NH 30 centrifugal pump was installed into the fire truck, whose drive is ensured by the engine through the driving mechanism mounted on the gear box. During our measurements, the outlet pressure of the pump was set for 5 bar, which is the most commonly used pressure in firefighter activities. In accordance with the regulations applied by fire departments, standard fire-fighting equipment and pressure hoses were used during the measurement. We operated the pump in suction mode, its water supply was ensured by 2 pieces of "A" type suction hoses of d=110mm and a suction strainer. 2 pcs of "B" type pressure hoses of d=75 mm internal diameter, 4 pcs of "C" type pressure hoses of d = 52 mm inner diameter and 2 pcs of 75/52 four-way valve manifolds were applied during the installation. The amount of water flowing through the examined hoses was measured by an ultrasonic flow meter type Arad Octave 50, meanwhile the amount of water discharging from the nozzle was measured by the pressure gauge we constructed combined with the measuring nozzle with a nozzle tip of 14 mm diameter. As for the rest of the streams, we applied standard reel nozzles with a nozzle tip of 14 mm in diameter. A separate measurement was performed with the stream at ground-level and the stream on the second storey. The figure 4. shows how the water supply system serving firefighting purposes was installed and operated.

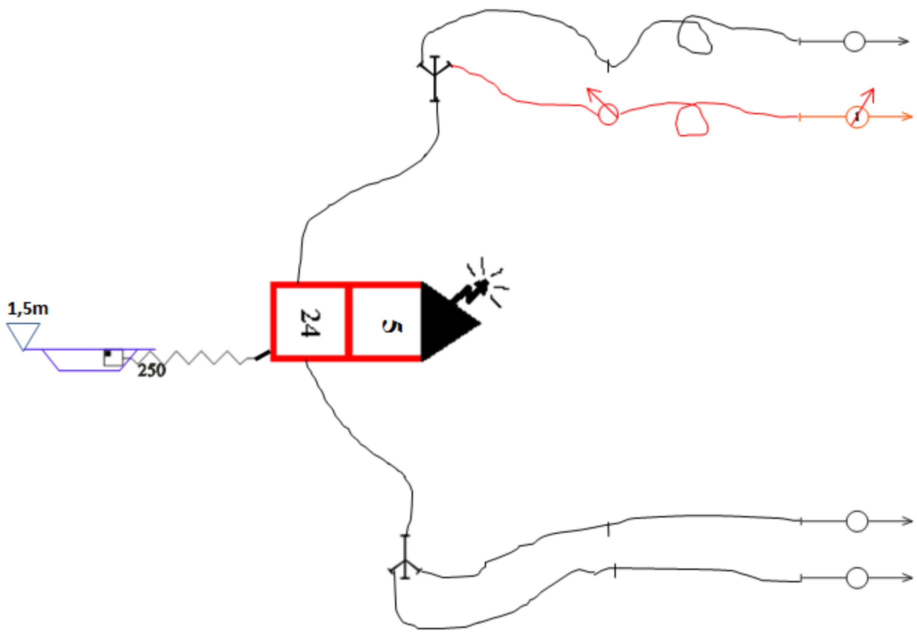

Fig. 4. The firefighting system design for our measurements (Source: Compiled by the Authors)

Performing the measurement, we first sucked water with the pump, then we activated the streams one by one. First, we installed the complex measuring device into the stream placed on the storey. We installed the ultrasonic flow meter type Arad Octave 50 behind the first 'C' type fire hose and the measuring nozzle connected to the pressure gauge at the end of the second "C" type fire hose. Our next step was to activate the other streams as well, then we continuously increased the performance of the pump reaching 5 bar outlet pressure on the measured stream. At that time, the outlet pressure of the pump was 6 bar. The data were recorded continuously and prepared for validation. We calculated the amount of water discharging from the nozzle with 14 mm of diameter at the different pressures. Up to 5 bar outlet pressure, the changes of water discharge in the stream placed on the storey are shown in the table 1.

Table 1: The changes of discharge water in the stream positioned on the storey (Source: Compiled by the Authors)

Pressure at the nozzle-Storey 2 [bar]	Discharge water at the nozzle [l/min]	Pressure at the pump [bar]	Flow rate [l/min]
1	163.528	1.8	164.67
1.5	200.280	3	207.67
2	231.263	3.9	243
2.5	258.560	4.5	273.5
3	283.238	5	303.5
3.5	305.932	5.5	322.17
4	327.055	5.9	339.83
4.5	346.895	6.5	356.33
5	365.659	7.2	377.83

Next, the changes of discharge water in the ground stream were measured. The complex measuring unit was installed into the system as previously. The measurement results are indicated in the table 2.

Table 2: The changes of discharge water in the ground positioned on the storey (Source: Compiled by the Authors)

Pressure at the nozzle- Groundfloor [bar]	Discharge water at the nozzle [l/min]	Pressure at the pump [bar]	Flow rate [l/min]
1	163.528	1	164.33
1.5	200.280	1.6	204.17
2	231.263	2.2	238.67
2.5	258.560	2.9	262.17
3	283.238	3.5	291
3.5	305.932	4.2	315.17
4	327.055	5	337.5
4.5	346.895	5.9	353.67
5	365.659	6.5	369.5

Finishing the measuring process, the performance of the pump was continuously decreased and finally stopped. After that we disassembled the system.

6. Conclusions

Our research project was to examine the operating parameters of a firewater supply system. In order to keep the measurement procedure simple and to gain accurate results, we constructed a complex measuring device. We conducted our measurements in an infield 1:1 experiment creating a realistic firefighting environment. Analysing our measurement results, we concluded that the amount of water obtainable at different heights show differences, so it must be taken into consideration during the firefighting process. We also concluded that during operation significantly high losses occur inside the fire hoses, which can be demonstrated without complicated calculations only by applying our complex measuring device. Our measuring nozzle assembled with a pressure gauge and fitted with a replaceable tip is suitable for performing accurate discharge water measurements, furthermore, with a simple calculation method the water flows belonging to the outlet pressure values can be determined and demonstrated in a table. The table format makes it easy to identify the discharge water values belonging to the relevant outlet pressure, which simplifies the measuring process. The size of the replaceable nozzle tips in our measuring nozzle equals to of the most commonly used ones, therefore, our measurement results can be used in practice during firefighting activities.

References

[1] Józsa, I. *Vortex Pumps in practice / Örvényszivattyúk a gyakorlatban*. Budapest, Invest-Marketing Bt., 2013: 108-196.
[2] Fecser, N., and R. Kuti. "Examining Fire Pump Metz Fp 24/8 on Cavitation." *Hidraulica*, no. 4 (December 2017): 98-104.
[3] Szabó Béla, L. *Water Supply Studies/ Vízellátási ismeretek*. Budapest, BM Könykiadó, 1983: 244.
[4] Lajos, T. *The basics of hydrodynamics /Az áramlástan alapjai*. Budapest, Műegyetemi Kiadó, 2004: 571.
[5] Spurgeon, P. "Every Pump Operator's Basic Equation." *Fire Engineering* 165, no. 10 (October 2012): 51-64.