Examination of Losses in Fire Extinguisher System Operated from Centrifugal Pump

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Abstract: *Nowadays, the most often used fire extinguisher material for fire extinguishing is still water, whom transportation can be conducted in different fire extinguishing systems to the spot of fire. The quantity of the water mass, which can be extracted of the fire extinguisher system depends on the applied unit, and is influenced by losses that occur during water transportation. It is very important to examine the losses occurring inside the water supply system, since they influence the quantity of extracted water, thus the fire extinguishing itself. To be aware with this topic in more detail, to increase the efficiency of fire extinguishing in practice, we examine in our paper the terms of occurring losses in the most commonly used centrifugal pump operated fire extinguisher systems, particularly regarding effective fluid movement. The aim of our research is to determine the optimal conditions for fire extinguisher systems, and further to help the work of firefighters.*

Keywords: *Fire fighting system, operation parameters, losses, effective fluid flow, optimization*

1. Introduction

The transportation of fire extinguisher water from the source is made possible most of the times by the fire extinguisher system assembled by firefighters. Its parts are the pump, hose, manifolds and nozzles. According to the requirements of usage, numerous equipment were developed. Among pumps that are capable of water transportation, fire extinguisher pumps constitute a separate group, these can withstand due to their structure, operation in non-optimal conditions [1]. However, it has to be in consideration, that there can be severe differences between the nominal liquid movement performance given by the manufacturer and the extracted water mass from the fire extinguisher system [2]. These can derive from the attributes of the area and the losses that occur in the water transporting system. It is inevitable to take the occurring losses into consideration while examining the effective liquid movement in fire extinguisher systems. The achieved results help in practice to ensure safety operation in long-term.

2. Creating a calculation model

In case of fire extinguisher pumps, performance parameters are measured in most cases along with 1.5 – 3 meters pumping depth, with a measuring unit placed directly onto the discharge port of the pump, they measure it between different speed boundaries. During fire extinguishing tasks, these conditions cannot be realized, changing the intake and pressure height mean performance variation in case of centrifugal pumps, the water mass can decrease in a given time period. To realize optimal operating conditions during fire extinguishing tasks is inevitable, however, on-spot conditions, equipment available do not always enable these, thus real pressure and water mass values cannot meet the desired ones. After studying data in available literature, we found only the part of solutions, but we have not found a unique and obvious answer to the problem. There is a strong need for complex calculations while every possible loss is taken into account. This cannot be conducted during an accident due to time factor. As a solution, we decided to compile a simplified calculation model, that represents the necessary elements for conducting fire extinguishing tasks, as system. The necessary data and formula for the calculations, we have collected, is also published in this paper. To ease the calculations, we assembled a simple fire extinguisher system and used it. The elements of the base model can be extended, if necessary. The elements of the system assembled are the following:

- Centrifugal pump,
- Standard inlet and discharge fire hoses,
- Manifold,
- Nozzle.

The examined and assembled fire extinguisher from the elements mentioned above, consists of a centrifugal pump and ray "C". As pump, a Rosenbauer Fox III. Portable pump is examined that is used in EU countries everyday, its supply comes from artificial water tank, in intake operation mode. As requirement that has to be met in case of the arranged fire extinguisher system, it is determined that the pump should support the water mass necessary to operate the DIN EN 15182-3 type nozzles and to ensure 5 bar water pressure to create a proper ray in 10 meter fire fighting. The next figure shows vertical image of the assembled fire extinguisher system.

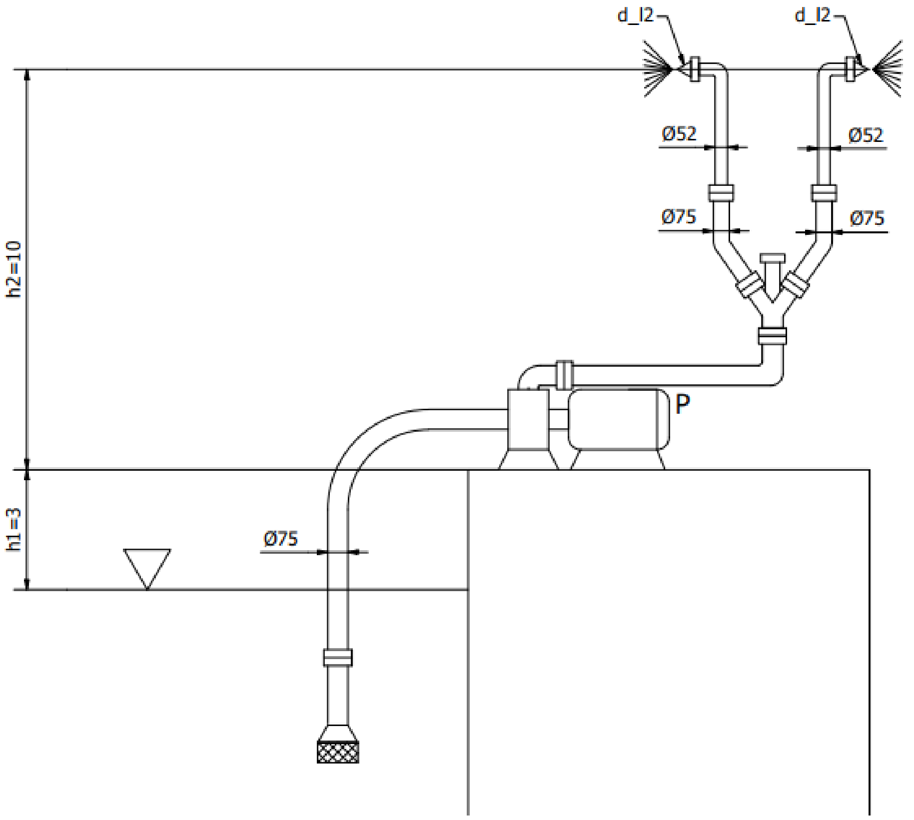

Fig. 1. The vertical structure of fire extinguisher system (Source: authors' compilation, marking of [3] used)

To meet our demands, all rays of the system have to ensure a water ray of Q=0.00343 m^3/s (206 l/p) volume flow, with a nozzle operated in h= 10 m height whose nozzle has an outlet with d_{L2}=12 mm diameter. The length of water supply hoses is L=40 m. To examine the fire extinguisher system, we have to determine the operation point to the operation speed of the pump.

Further task is to calculate the impulse force that impacts on the nozzle and on the fire fighter who holds it. According to Paul Spurgeon [4] the pressure of the liquid in the discharge port of the pump can be defined as the sum of pressure losses:

$$\Delta p = \Delta p_L + \Delta p_t + \Delta p_h + \Delta p_o \tag{1}$$

In the equation:

- Δp :pump pressure
- Δp_L : pressure at nozzle
- Δp_t : friction loss of fire hoses
- Δp_h : pressure loss coming from lifting
- Δp_o : pressure loss of units (for e.g. manifold, transfer piece, pressure stabilizer unit)

In the following, we represent the calculation method for certain pressure losses in case of one ray.

2.1 Pressure loss of fire hoses

After studying the available literature about the pressure losses of fire hoses, we could determine, that data show differences, thus we calculated the pressure loss in meters in correspondence to volume flow, accordint to data in [3]. After converting the data from anglo-saxon measurement units to the SI units, the two most frequent dimensions were 2” and 3”, so 52 and 75 mm as hose diamater. We edited the diagrams that contain the pressure loss for every meters, these are in Figure 2. Parabolas can be fitted on the measurement points with a good estimation.
The ratio in case of the 52 mm diameter “C” hose: $c_{52} = 3.4 \cdot 10^7 \ Pas^2/m^6$.
In case of 75 mm diameter “B” hose $c_{75} = 5.1 \cdot 10^6 \ Pas^2/m^6$.
We have to mention, that these values can differ in a small extent depending on the manufacturers and age of hose – although they have to meet the requirements of the standards.

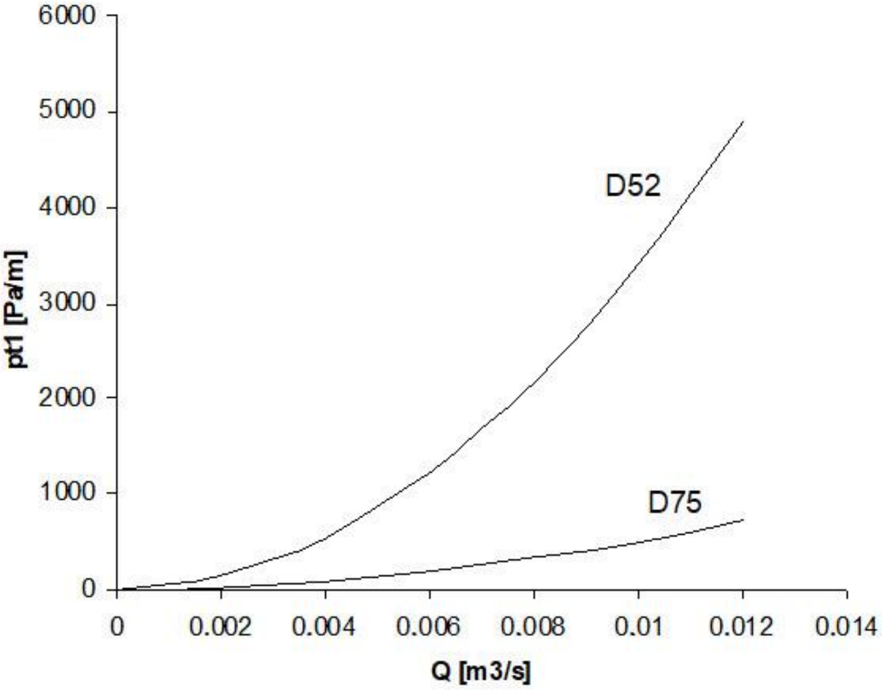

Fig. 2. Pressure loss to every meter of 52 and 75 mm diameter (Source: authors’ compilation)

2.2 Pressure difference of nozzle

A key element in the system, is the nozzle, which actually is, two confusors connected into two, in-between them a combined closing unit is assembled. The following figure shows a DIN EN 15182-3 type confusor used with nozzle.

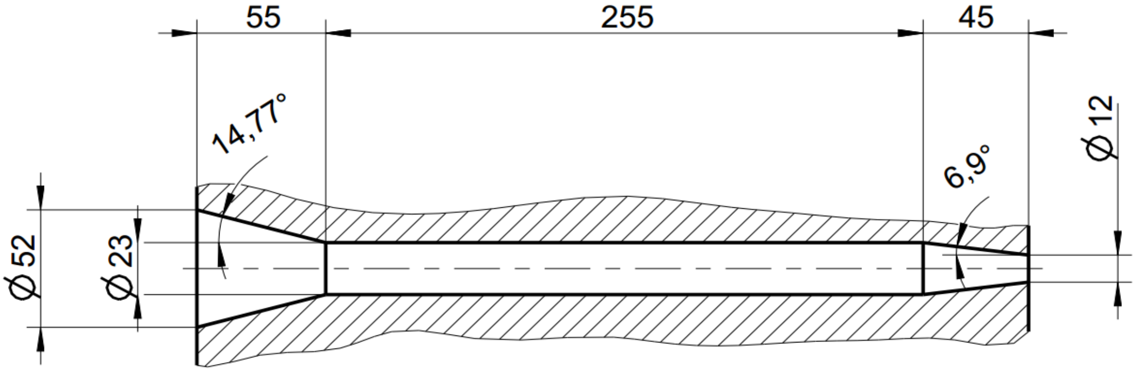

Fig. 3. Drawing of confusor and the cross-section of nozzle (Source: authors’ compilation and [5])

The pressure drop and volume flow data of nozzles are represented as a table format in MSZ 1059 standard. A 12 mm diameter nozzle has a pressure drop of $\Delta p_L = 5 \cdot 10^5$ Pa in case of m Q=206 l/min=0.00343 m^3/s volume flow. We have to mark, that pressure difference is not totally a loss, since kinetic and pressure energy in the inlet cross-section of the nozzle convert into velocity energy. If the pressure-volume flow data for the appropriate type of hose is not available, we can it calculate with a good estimation only with the known geometries.
As we write the Bernoulli-formula between the in- and outlet of the nozzle, pressure and kinetic energy convert into pure kinetic energy [5]:

$$\frac{\Delta p_L}{\rho} + \frac{v_{L1}^2}{2} = \frac{v_{L2}^2}{2} \tag{2}$$

Velocities are determined by the volume flow, the pressure difference existing between the in- and outlet cross-section of the nozzle, the following correlation can be determined:

$$\Delta p_L = \underbrace{\frac{\rho}{2}\left(\frac{1}{A_{L2}^2} - \frac{1}{A_{L1}^2}\right)}_{k_L} Q^2 = \frac{1000}{2} \cdot \frac{4^2}{\pi^2}\left(\frac{1}{0.012^4} - \frac{1}{0.052^4}\right) 0.00343^2 \approx 460\ kPa \tag{3}$$

The standard calculates with 96 percentage discharge loss, thus $\Delta p_L \approx 480$ kPa.
This value barely differs from the value presented in the table – probably rounded – 500 kPa.
Pressure drop that occurs in the nozzle – similarly to the pressure loss of the hose – is proportional to the volume flows quadriatic. The ratio for the given nozzle: $k_L = 4 \cdot 10^{10}\ \ \mathrm{Pas}^2/\mathrm{m}^6$

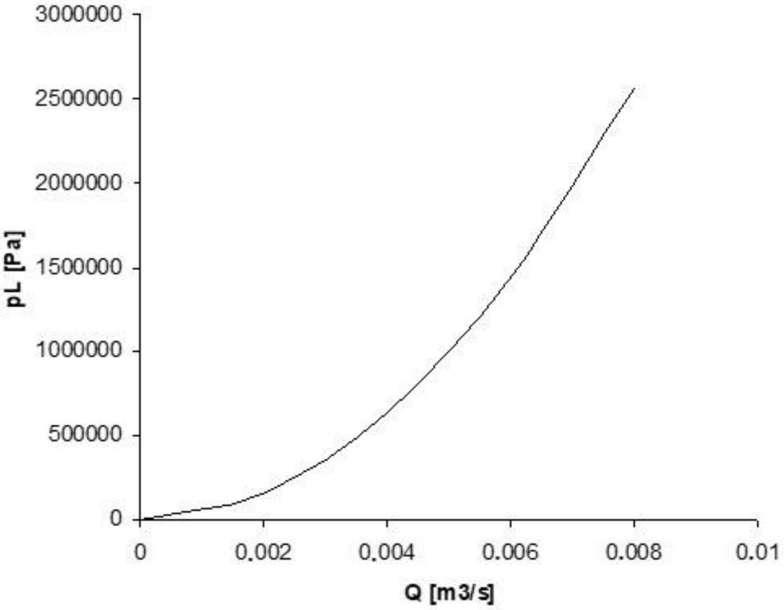

Fig. 4. The pressure drop of the 12 mm diamater nozzle in correspondance of volume flow (Source: authors' compilation)

In case of the nozzle, it is necessary to mention, that an impulse force acts on the nozzle and it cannot be neglected. This force is originated by the narrowing cross-section of the hose and so the impulse of the liquid changes.
Impulse force can be calculated from

$$F = \dot{m}(v_2 - v_1) = \rho \frac{A_1 - A_2}{A_1 A_2} Q^2 \tag{4}$$

correlation. Impulse force is represented in correspondence of volume flow, in case of the 12 mm diameter nozzle:

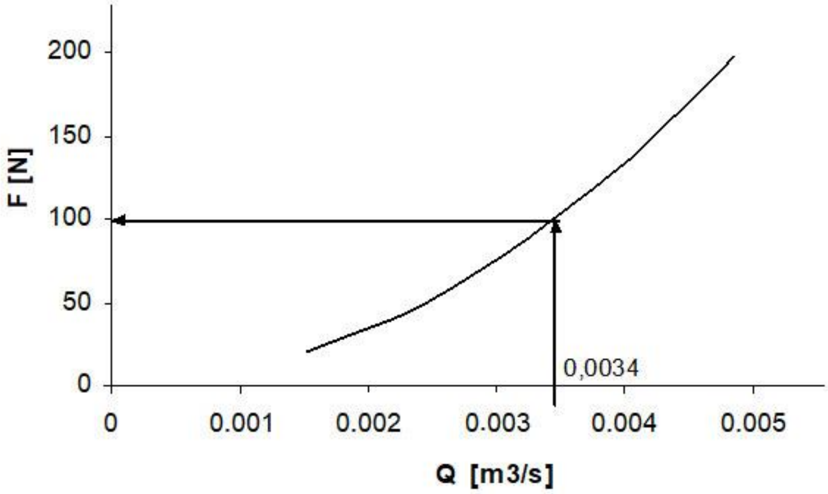

Fig. 5. Impulse force in correspondence of volume flow, in case of nozzle with 12 mm diameter (Source: authors' compilation)

2.3 Pressure loss due to lifting and the pressure loss of the manifold

In case of the pressure loss coming from lifting, we can calculate with 1 bar per meter, so 10^5 Pa loss [6]. Manufacturers usually do not, or just in certain cases, define the resistance coefficient of the unit, that has to be determined with calculation later [3]. According to the referred source, in case of the manifolds, pressure drop has to be considered with 10 PSI, so 0.69 bar losses [6].

3. Conclusions

In our research work we determined the losses occuring in fire extinguisher systems. After executing the calculations, represented earlier and evaluating the results, we determined that the fire extinguisher system, we created, can be operated in practice. The required water yield and pressure at the nozzles could be supplied by the pump. By analysing our results, we determined, that there are differences between the extracted water masses in case of rays operated on different levels. This has to be taken into account during fire fighting. We could conclude, that inside fire hoses during operation, signifiant losses occour. The examination of the pump is also inevitable, because without it, there is no obvious conclusion, whether our pump is capable of operation in given condition with the required water yield and pressure supply. During result analysis, with the proper conclusions, the operation of water supply systems can be supported. With the application of the represented calculations, the examination of assembled fire extinguisher systems can be easily carried out and experiences can be adapted to practice, so as, water supply problems can be prevented that are originated from inproper operation.

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