UDC 614. 841
DOI: 10.15587/1729-4061.2023.279616

# DETERMINING THE ELONGATION OF T-TYPE PRESSURE FIRE HOSES BASED ON FULL-SCALE EXPERIMENTS

**Serhiy Stas**
*Corresponding author*
PhD, Associate Professor*
E-mail: stas_serhiy@yahoo.com
**Artem Bychenko**
PhD, Associate Professor, Head of Department*
**Denis Kolesnikov**
PhD, Associate Professor
Department of Automatic Safety Systems and Electrical Installations**
**Oleksii Myhalenko**
PhD, Senior Lecturer*
**Mykhailo Pustovit**
Lecturer
Department of Civil Defense Equipment and Tools***
**Kostiantyn Myhalenko**
PhD, Associate Professor, Deputy Head of Faculty
Department of Automatic Safety Systems and Electrical Installations***
**Lesya Horenko**
PhD, Associate Professor
Department of Humanities***
*Department of Civil Defense Equipment and Tools**
**National University of Civil Defence of Ukraine
Chernyshevska str., 94, Kharkiv, Ukraine, 61023
***Cherkasy Institute of Fire Safety Named After Chornobyl Heroes of National University of Civil Defence of Ukraine
Onoprienka str., 8, Cherkasy, Ukraine, 18034

*The phenomenon of changing the geometric parameters of pressure fire hoses is manifested when they transport extinguishing liquids. Although the extension of pressure fire hoses does not have a significant impact on the fire extinguishing process, the energy costs associated with such changes should be taken into account. In fact, part of the power of the fire pump is spent not on transporting liquids and forming extinguishing jets but on the «optional» lengthening of pressure fire hoses. Latex pressure fire hoses with diameters of 51 mm and 77 mm and fire pressure hoses with double-sided polymer coating of 51 mm (all of type T) were randomly selected for the experiments. The temperature was 263 K and 298 K, the fluid flow rate was constant, the pressure values at the inlet of the Protek 366 fire barrel had fixed values. No significant changes in the diameters (expansion or narrowing) of pressure fire hoses were recorded during water transportation. An elongation of 79 cm with a hose length of 1960 cm (73 cm with a hose length of 1790 cm) was recorded when transporting water in the case of using hoses with a diameter of 77 mm, a pressure at their inlet of 0.8 MPa, a temperature of 263 K, and a water flow rate of 0 l/s. The force that provided such a stretch was 2.04 kN. When extinguishing liquid was supplied by pressure fire hoses with a diameter of 77 mm in the temperature range of 263–298 K, the elongation decreased slightly with decreasing temperature. A slight unevenness of stretching of pressure fire hoses along the length was found when stretching increased closer to their middle. The results indicate the dependence of the amount of stretching on the materials from which pressure fire hoses are made, as well as their diameter. The values of dynamic forces that cause stretching of pressure fire hoses established in the study can be used in practice when taking into account the forced energy losses for fluid transportation*

***Keywords:*** *fire hose, hose line, water transportation, geometric dimensions, fire hose extension*

*Received date 13.03.2023*
*Accepted date 16.05.2023*
*Published date 30.06.2023*

***How to Cite:*** *Stas, S., Bychenko, A., Kolesnikov, D., Myhalenko, O., Pustovit, M., Myhalenko, K., Horenko, L. (2023). Determining the elongation of T-type pressure fire hoses based on full-scale experiments. Eastern-European Journal of Enterprise Technologies, 3 (1 (123)), 13–20. doi: https://doi.org/10.15587/1729-4061.2023.279616*

## 1. Introduction

In order to transport water and working solutions of foaming agents, fire hoses of various lengths, diameters, and types can be used at a fire site. Fire trucks are equipped with pressure fire hoses (PFH) of type T. In accordance with the norms of the civil protection operational and rescue service, the frequency of testing pressure fire hoses should be at least once a year. Such requirements are due to the conditions, modes, and features of the use of these types of fire protection equipment.

PFHs are used as the main means for transporting extinguishing liquids to the site of most fires. The requirements for their reliability and operability are decisive since the result of fire extinguishing directly depends on their level. For manning fire trucks, PFHs of type T are used. They are usually made of synthetic materials and may have a rubber or polymer coating inside and outside. The main characteristics of PFH are geometric dimensions, operating pressure of the transported liquid, water resistance, and strength. The life cycle of PFH depends both on these characteristics and on the modes, frequency, and features of their operation.

PFHs during transportation of liquids have the ability to change their geometric dimensions, which is regulated by current Ukrainian state standards [1]. The ability to lengthen is primarily determined by the peculiarities of the PFH base material. Stretching of PFHs during their operation, along with mechanical damage during unwinding, dragging, etc., contribute to the destruction of their structure, which ultimately leads to the appearance of various manifestations of fluid leakage. Of course, the effect of lengthening the hose is difficult to use practically when laying hose lines when extinguishing fires, so its impact is seen as negative. For example, in confined spaces, the effect of lengthening the hoses can cause their critical refraction and kinks, there may be breaks in the water supply during fire extinguishing, which is unacceptable. It should be understood that part of the energy spent on transporting water from the water source to the combustion zone is spent on stretching and maintaining the length of PFH. The magnitude of the loss of this energy to ensure a change in geometric parameters can be determined experimentally by mechanical stretching. That is why studies aimed at investigating the phenomenon of elongation of fire pressure hoses are relevant and can be implemented by conducting full-scale experiments.

## 2. Literature review and problem statement

The peculiarities of PFH operation significantly affect their ability to fulfill their main purpose – to reliably ensure the transportation of water and water-foam working solutions. In [1], the results of studies on stretching part of the PFH under conditions of static loading-unloading cycles are presented. It was established that the change in the properties of the PFH material during successive cycles of loading-unloading deformation is reversible, but the relaxation time can be several hours. However, it is not clear whether the results of experimental studies will be similar at different values of fluid pressure. This similarity was established in [2]. At the same time, an important unresolved issue is the determination of the residual resource of PFHs, the possibility of their repair, and the reliability of further operation. Part of the problem of determining the residual resource of PFH is solved in work [3]. The authors identified the need and developed a scientifically based method that makes it possible to establish the level of PFH wear, the possibility and feasibility of its repair and further application. A prototype of PFH of type «T» with an internal diameter of 77 mm and a test length of 110 mm was fixed on the experimental installation DM-30M, which makes it possible to measure force and deformation. Five test cycles were carried out to load and unload it. In fact, the behavior of the sample for tension under the action of the load, as well as partial compression after the cessation of such an action was investigated [3]. The results of the study on determination of mechanical properties (elastic and dissipative) of pressure fire hose of type «T» with an internal diameter of 66 mm under static load conditions are given in [4]. At the same time, these studies on PFH deformation both in [3] and in [4] were conducted with its fragment 110 mm long, which is only about 0.5 % of the total length of the entire PFH. Thus, the question of compliance of the obtained results with the real values of stretching of the entire PFH remains unresolved.

As a result of repeated use, PFHs are damaged, microcracks and tears occur. In such cases, it becomes necessary to repair the hoses. Evaluation of the durability of hoses and the process of appearance of microcracks in them are considered in [5], where a numerical method for predicting the durability of the hose is proposed for the design of high-strength brake hoses. To do this, [5] describes a laminated structure consisting of layers of pure rubber and fabric. At the same time, in the case of PFH application, slightly different pressure ranges of the transported liquid, geometric dimensions, and materials from which they are made should be taken into account.

Improving the durability of PFH can be achieved primarily by providing constructive and technological bases for their design and manufacture. An important task is to determine the pressure at which the rupture of flexible pipelines, which include PFH, begins. It is necessary to take into account many different factors, such as the breaking force of the threads used for their manufacture, the radius of the hose, the geometric density of laying threads on the base of the hose, the diameters of the threads, the condition of the protective latex coating, etc. It is possible to partially take into account the various factors influencing the strength of the bearing cloth of the PFH coating by using the simplified mathematical model proposed in [6]. A slightly different approach to determining the strength of PFH is considered in work [7], which proposed a new calculation formula for the method for determining the strength of PFH with specified characteristics under the action of internal hydraulic pressure. Among other parameters, in [7], it is recommended to take into account the geometric features of winding different threads in the hoses. Further clarification of the methodology for calculating the strength of the PFH, as well as the method of designing PFH under the action of internal hydraulic pressure is proposed in [8]. At the same time, computational methods [8] for determining strength and proposals for techniques of design and production of PFH should be tested by conducting full-scale experiments. As a result of study [9], it was established that the pressure of rupture of PFH hose significantly depends on the geometric density of the winding of the threads, the force of thread breaking, and the radius of the PFH. The results of the study should be taken into account when designing new types of these technical products.

Practical implementation of proposals for determining the strength of PFHs and improving their design and production may be the best confirmation of the feasibility of taking into account the extension of PFH during fire extinguishing. Thus, the uninterrupted supply of extinguishing agents during fires on the railway due to the development of a prototype connecting device for lengthening high-pressure hoses is considered in [10]. The authors found that the lengthening of the hoses affects the effectiveness of their use in hard-to-reach places. Despite the fact that the proposals for the use of hoses provided in [10] can reduce the consumption of extinguishing agent, the difficulty of using equipment with high liquid pressure values remains. Moreover, sometimes the laying of the hose line is further complicated in places that are difficult to reach by a fire truck. In such cases, special backpacks for PFH can be used, a comparative analysis of their use was carried out in [11]. However, the use of such backpacks accelerates the wear of PFH as a result of bending and compression. Significantly different is the mode of application of PFH used permanently in buildings. Determination of the service life of such PFHs show that the deterioration of their operational characteristics increases significantly after 9 years of operation [12]. As a result of a long stay in a folded or twisted state, stretching such hoses can lead to their destruction. Partial overcoming of the corresponding difficulties is the need to determine and further take into account the amount of stretching of PFH at different values of pressures, fluid flow rates, and frequency of their use.

In work [13], the design is analyzed; the main technical requirements for flat-folding hoses for fire and rescue equipment, which are PFH, are indicated. Stretching and wear of flat assembly hoses depends on their longitudinal bending zone. That is why the improvement of the regulatory framework for technical requirements and test methods for PFH [14] provides for regular re-rolling of the PFH at least 2 times a year. Nevertheless, the materials used for the production of modern PFH differ significantly in their tensile and bending abilities, and detailed theoretical or experimental data on the effectiveness of re-rolling work have not been revealed. Therefore, there is a need to conduct full-scale experiments to study the phenomenon of elongation of fire PFHs of different types and different modes of operation.

A special case of using PFH is the use of robots when laying hose lines. The most common cause is the high risk of injury for firefighters. Features of the use of robots when laying hose lines are considered in [15]. It should be noted that the use of robots is focused primarily on meeting the safety requirements of workers and ensuring the laying of a hose line of increased complexity. It is clear that the issues of meeting the requirements for stretching the hoses are not decisive.

Thus, it is advisable to conduct a study on determining the amount of elongation of PFH during fluid transportation since some issues remain unresolved. Among them, for example, is the influence of ambient temperature, the uniformity of stretching of PFH along their length, as well as determining the amount of elongation of PFH at different values of pressure and fluid flow.

## 3. The aim and objectives of the study

The aim of this study is to determine the features of elongation of pressure fire hoses when transporting water under conditions of different temperatures, flow rates and fluid pressure. This will make it possible not only to determine the overall elongation of pressure fire hoses but also differences in the amount of tension in its different sections, to identify the influence of ambient temperature on the change in the geometric dimensions of pressure fire hoses.

To accomplish the aim, the following tasks have been set:

– to determine the thickening and elongation of hoses when they are filled with water at different values of the inlet pressure;

– to determine the lengthening of hoses when using fire barrels;

– to determine the amount of force that provides stretching of the hoses during transportation of water;

– to determine the influence of different temperature conditions on the stretching of hoses.

## 4. The study materials and methods

The object of research is the change in the geometric parameters of pressure fire hoses due to the transportation of extinguishing agents.

It can be assumed that part of the energy that should ensure the transportation of the extinguishing agent by the hose lines is lost to stretching and holding the hose line in a stretched state. To establish the fact of stretching and obtain the value of dynamic forces causing stretching of pressure fire hoses, empirical research methods were used, namely observation, measurement, and experiment.

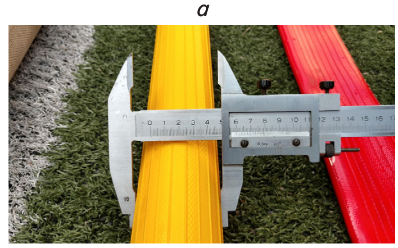
The study used 3 types of PFHs, which are the most used in Ukraine. Each of the studied types of PFHs was randomly selected in 6 pieces, that is, a total of 18 PFHs. All hoses have passed standard tests and were previously in use. The following results of the study are average values for each type of hose. Initially, a study was carried out on the change in the basic geometric parameters of the hoses (length and outer diameter) during their filling with water at different values of the inlet pressure. At the same time, in part of the experiments, plugs were installed at the end of the PFH, that is, fluid flow rate was zero. In other cases, fire barrels with fixed fluid flow values were used. At the next (second) stage of research, the magnitude of stretching of the PFH when using fire barrels was determined. In this case, the hoses ensured the transportation of water to the jet-forming device at an ambient temperature of 298 K. At the third stage, the amount of force required to ensure the deformation of PFH during water transportation was determined. In this experiment, only 3 PFHs were used, not 18, as in the previous stages. And finally, at the fourth stage, the influence of different temperature regimes when using PFHs was determined.

## 5. Results of investigating the elongation of pressure fire hoses of type T

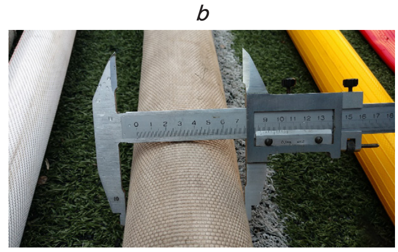
### 5. 1. Determination of changes in length and outer diameter of hoses when they are filled with water

The chosen method for determining the thickening (Fig. 1) did not allow us to detect significant changes in diameters. The initial length of the PFH was 1960 cm. The latex hose with a diameter of 77 mm underwent the greatest deformations in length, its elongation was 79 cm with zero fluid flow rate (Fig. 2) [16].

*a*



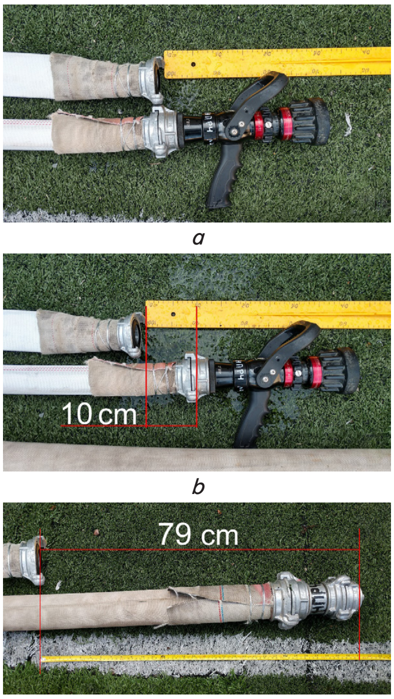
*b*



*c*

Fig. 1. Determination of the change in diameters of pressure fire hoses of type T: *a* — latex, 51 mm; *b* — double-sided polymeric, 51 mm; *c* — latex, 77 mm

After each of the experiments, consisting of a gradual increase in the inlet pressure from 0.2 to 0.8 MPa in increments of 0.2 MPa, the next PFH was used; the ambient temperature was 298 K.




*a*

*b*

*c*

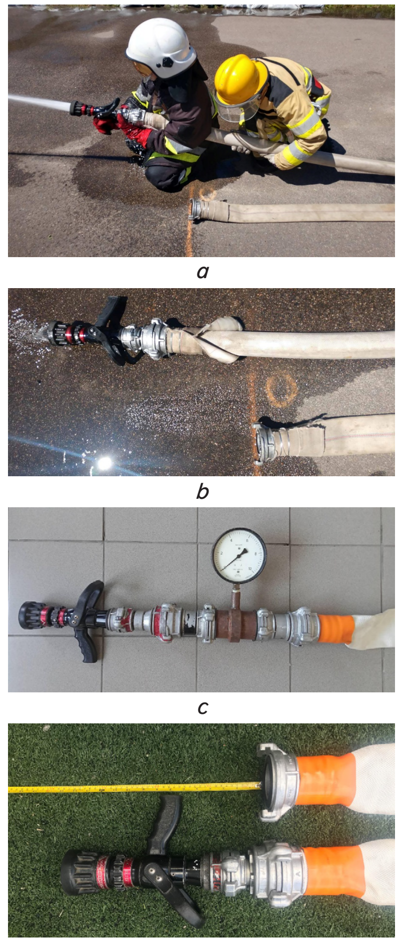
Fig. 2. Determination of the change in the lengths of pressure fire hoses of type T: *a* – registration of the reference point; *b* – latex hose, 51 mm; *c* – latex hose, 77 mm [16]

A slow compression of the hose was recorded after the inlet pressure decreased. Thus, after the inlet pressure decreased from 0.8 MPa to 0 MPa, the hose began to shrink. The mean compression time (return to 20 % tensile from the initial state) was 420 s, compression to 50 % tensile occurred after 143 s.

**5. 2. Determination of the amount of stretching of pressure fire hoses when using fire barrels**

At the next stage of research, the hoses transported water to a fire barrel at an ambient temperature of 298 K. The fire barrels Protek 366 (Fig. 3) [17] and RS-70 were used. At this stage of research, the initial length of the PFH was 1790 cm. A gradual increase in the inlet pressure from 0.2 to 1.0 MPa in increments of 0.2 MPa was ensured by the operation of the fire pump PN-60-R-R with a capacity of up to 60 l/s and a maximum pressure of 1.0 MPa. At different values of fluid flow using a fire barrel, as at the previous stage (at zero flow), no significant changes in the diameters of the PFH were recorded. The results of experiments for three types of PFH are shown in Fig. 4. The maximum elongation was recorded when generating a flow of extinguishing liquid using a latex hose with a diameter of 77 mm at a pressure at its inlet of 1.0 MPa and a flow rate of 1.9 l/s. The change in length was 620 mm (Fig. 4).

Thus, for a given PFH, the relative elongation was 0.032 (hose length, 1960 cm). It should be noted that the obtained value of relative elongation of 0.032 meets the requirements of current regulatory documents of Ukraine.



*a*

*b*

*c*

*d*

Fig. 3. Investigating the extension of pressure fire hoses when using fire barrels Protek 366 and RS-70: *a* – fragment of the experiment in; *b*–*d* – measurement elements

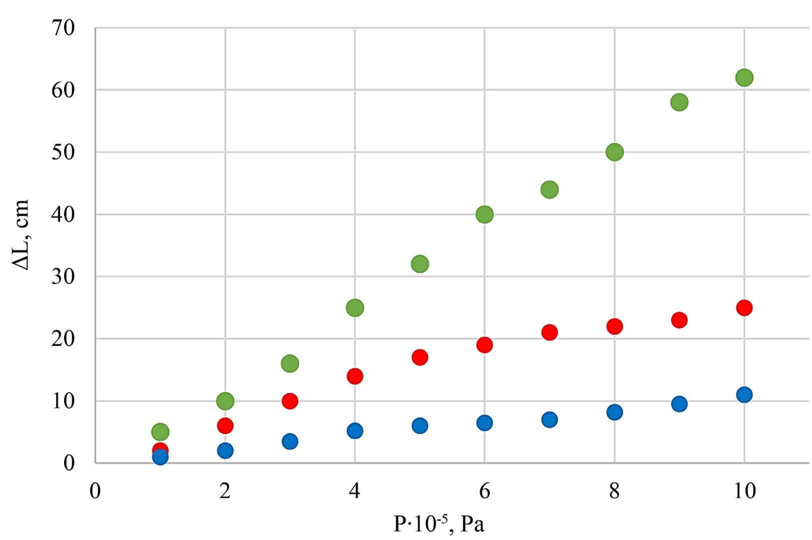



Fig. 4. Plot of changes in the lengths of the investigated pressure fire hoses when using the PROTEK 366 fire barrel: lower plot – double-sided polymeric, 51 mm; middle – latex, 51 mm; upper – latex, 77 mm

**5. 3. Determination of the force that provides tension of the pressure hose during water transportation**

Based on data from [1–3], it was decided to conduct a full-scale experiment using the entire PFH, rather than its fragment. To determine the force that provides stretching of the hoses during the transportation of water, a test installation was designed (Fig. 5). With the help of the installation, the amount of force required to ensure the deformation that in previous experiments caused the tension of the PFH during the transportation of water was determined.

The experimental data shown in Fig. 6 indicate an increase in the magnitude of elongation with an increase in the applied force and correspond to the results reported in [3].

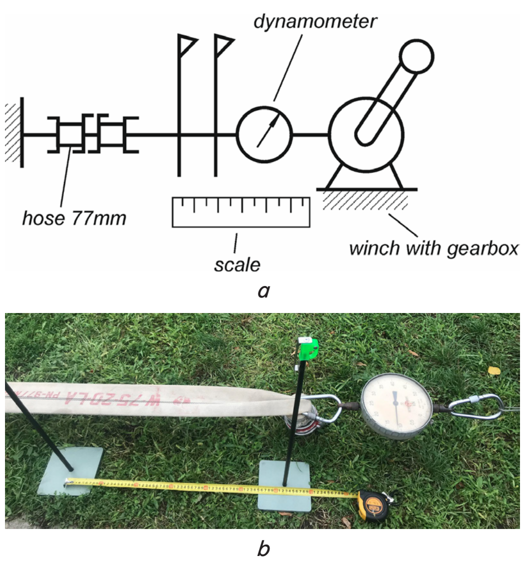



Fig. 5. Conducting a full-scale experiment using latex pressure fire hoses with a length of 1960 cm and diameter $D$=77 mm: *a* – schematic; *b* – fragment of the experiment

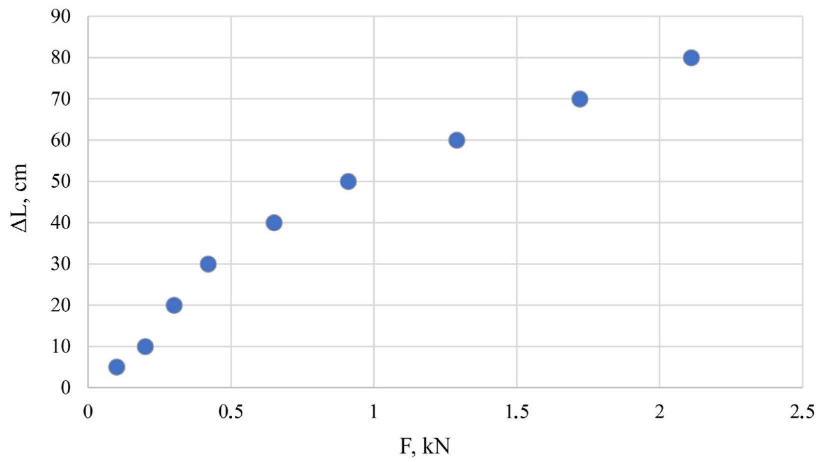



Fig. 6. Dependence of the elongation $\Delta l$ of latex pressure fire hoses with diameter $D$=77 mm on tensile force $F$

Thus, the elongation by 79 cm of the investigated latex PFH with a diameter of 77 mm corresponded to a pressure at its inlet of 0.8 MPa [8]. The force providing such stretching was 2.04 kN, and according to [3] – 2.28 kN.

The elongation by 62 cm of the investigated latex PFH with a diameter of 77 mm corresponded to the pressure at its inlet of 1.0 MPa and flow rate of 1.9 l/s [16]. The force providing such stretching was 1.41 kN, and according to [3] – 1.69 kN. Due to the peculiarities of the experiments and randomly selected fire hoses that were in operation, such discrepancies in our results can be considered acceptable.

**5. 4. Taking into account different temperature conditions when using pressure fire hoses**

The next stage of research was to conduct experiments to determine the tensile characteristics of PFHs at different ambient temperatures of 263 K (14 °F) and 298 K (77 °F). Measurement data are given in Tables 1, 2, respectively. Studies were conducted to determine the effect of temperature on PFH stretching. The temperature difference was 35 K. The pressure increase pitch was 0.2 MPa and the water flow rate was 0–115–230–360–475 l/min. The maximum elongation in both batches of experiments (at low and high temperatures) was recorded at the highest values of the inlet pressure and the lowest flow rate (Fig. 7, 8).

Table 1

Elongation $\Delta l$ of latex pressure fire hoses with diameter $D$=77 mm along length $L$=1790 cm (water consumption, 0 l/s; temperature, 263 K)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 25 | 50 | 100 | 150 | 250 | 500 | 750 | 895 | 1040 | 1290 | 1540 | 1640 | 1690 | 1740 | 1765 | 1790 | *L*, cm |
| 0 | 5 | 12 | 25 | 45 | 83 | 150 | 290 | 360 | 410 | 520 | 625 | 680 | 703 | 718 | 725 | 730 | *l*, mm, at 0.8 MPa |
| 0 | 3 | 6 | 13 | 25 | 45 | 130 | 200 | 240 | 280 | 348 | 443 | 465 | 476 | 484 | 487 | 490 | *l*, mm, at 0.6 MPa |
| 0 | 2 | 4 | 7 | 12 | 28 | 65 | 100 | 122 | 140 | 181 | 215 | 234 | 242 | 245 | 248 | 250 | *l*, mm, at 0.4 MPa |
| 0 | 1 | 2 | 4 | 6 | 11 | 24 | 42 | 54 | 66 | 85 | 92 | 99 | 103 | 106 | 108 | 110 | *l*, mm, at 0.2 MPa |

Table 2

Elongation $\Delta l$ of latex pressure fire hoses with diameter $D$=77 mm along length $L$=1790 cm (water consumption, 0 l/s; temperature, 298 K)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 25 | 50 | 100 | 150 | 250 | 500 | 750 | 895 | 1040 | 1290 | 1540 | 1640 | 1690 | 1740 | 1765 | 1790 | *L*, cm |
| 0 | 5 | 12 | 25 | 45 | 83 | 151 | 290 | 361 | 411 | 521 | 626 | 682 | 705 | 719 | 727 | 750 | *l*, mm, at 0.8 MPa |
| 0 | 4 | 6 | 13 | 25 | 45 | 131 | 201 | 241 | 281 | 349 | 445 | 467 | 477 | 486 | 489 | 510 | *l*, mm, at 0.6 MPa |
| 0 | 2 | 4 | 7 | 13 | 28 | 66 | 101 | 124 | 142 | 182 | 217 | 236 | 244 | 248 | 251 | 280 | *l*, mm, at 0.4 MPa |
| 0 | 1 | 2 | 4 | 6 | 12 | 24 | 43 | 55 | 67 | 86 | 93 | 100 | 103 | 107 | 110 | 120 | *l*, mm, at 0.2 MPa |

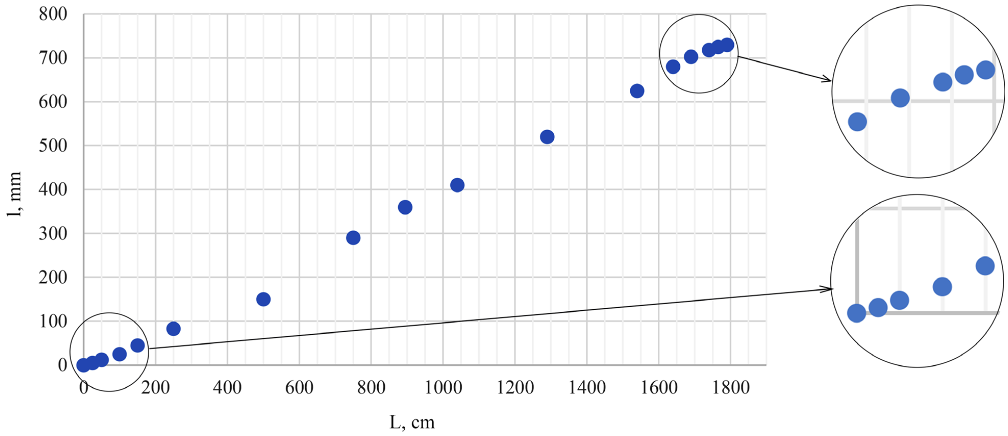



Fig. 7. Elongation $\Delta l$ of latex pressure fire hoses with diameter $D$=77 mm along length $L$=1790 cm in the case of using a plug at the end of the hose (water consumption, 0 l/s; pressure, 0.8 MPa)

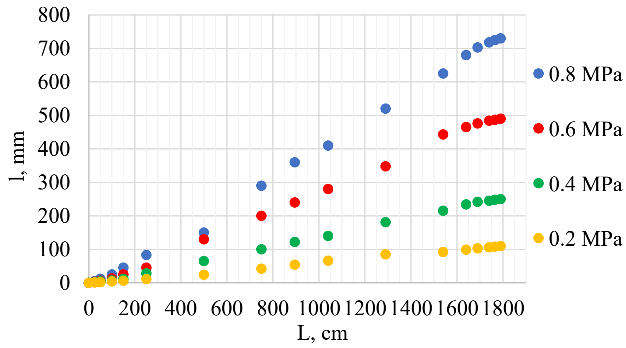



Fig. 8. Elongation $\Delta l$ of latex pressure fire hoses with diameter $D$=77 mm along length $L$=1790 cm at water flow rate 0 l/s, pressure 0.2–0.4–0.6–0.8 MPa, temperature 263 K

Each pressure increase and flow rate decrease was carried out only after the restoration of the original size at fire-rescue training department, which was at least 600 s at a temperature of 298 K. Instead, at a temperature of 263 K (Fig. 9), another dry PFH was used each time since the restoration of the hose to its original length was difficult due to its freezing.

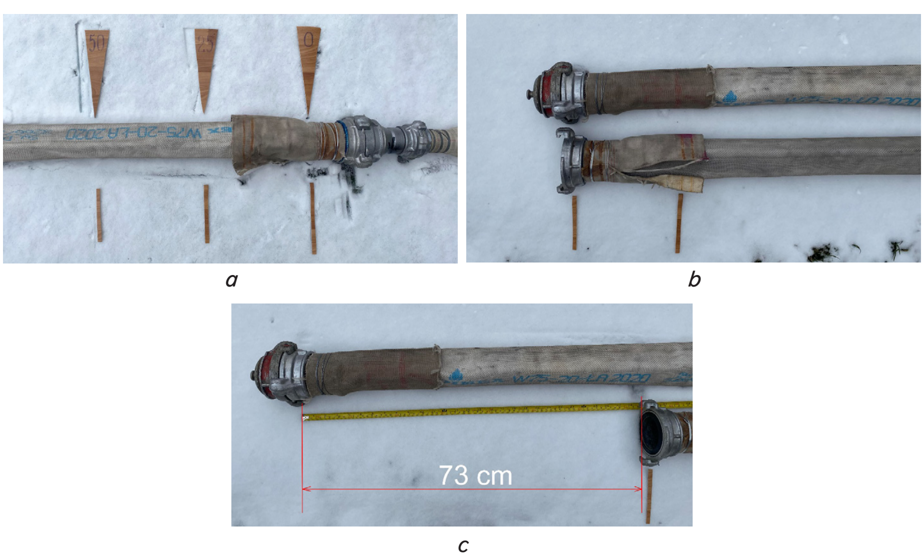



Fig. 9. Determining the tension of pressure fire hoses at an ambient temperature of 263 K: *a* – entrance section of the hose; *b* – fixed end of the hose before the experiment; *c* – lengthening of the hose under the action of water pressure

For the investigated types of PFHs, it was found that the elongation is almost independent of temperature (in the range of 263–298 K).

## 6. Discussion of results of determining the elongation of pressure fire hoses

As expected, as a result of the experiments, the dependence of the elongation of PFH on the value of the inlet pressure at which water is transported to the jet molding device was established. It was found that the elongation of different types of PFHs under the same initial conditions can vary significantly.

The phenomenon of stretching PFH can be explained by the physical and technical features of their structure, the influence of conditions and modes of their operation. Thus, the dependences of change in the lengths of the investigated PFHs when using the PROTEK 366 fire barrel were significantly different for PFHs with different material bases (Fig. 4). It is possible to allow the application of known laws of fluid motion through pipelines with solid walls with increasing pressures of transported liquids. However, this should take into account such manifestations of flexible pipelines-hoses as a sharp overlap of the fire barrel, the connection of new hoses through branching. It is important to take into account the lengthening of the hose line by adding new hoses, transitions of hose diameters, pulsation effects of fluid movement due to the operation of fire pumps [18], etc.

In general, a certain value of PFH elongation (up to 4.3 %) can be taken as a basis for further research related to the transportation of extinguishing liquids by flexible pipelines that change their original geometric dimensions, such as length. At the same time, as a result of the experiments, a significant level of dependence of the obtained results of PFH elongation on the state of their wear was established. For six latex PFHs of the same type with a diameter of 77 mm and a length of 1960 cm, the variation in the elongation value was about 12 % (73, 77, 79, 81, 82, 83 cm). For six latex PFHs with a diameter of 51 mm, the variation in the elongation value was about 9 %. Double-sided polymeric PFHs with a diameter of 51 mm were almost not extended.

Since fire hoses transported water, the properties of which differ significantly from some other extinguishing agents, it is advisable to conduct experiments using other liquids similar to those in [19–21]. In this way, it will be possible to develop new approaches to reducing dissipative losses during transportation of liquids to jet-forming devices. Determination of the value of PFH elongation allows creating the basis for ensuring an increase in fluid flow without changing the output pressure at the fire pump. Taking into account the magnitude of the elongation of PFH makes it possible to adjust the theoretical foundations of the method of rational laying of hose lines. A promising direction of research should be to find out whether the addition of foaming agent solutions to water in low concentrations will help reduce the tensile losses of PFH.

Experiments to determine the characteristics of PFH stretching were conducted at low (263 K, 14 °F, Table 1, Fig. 8) and normal (298 K, 77 °F, Table 2) ambient temperatures. They allow us to assert a low level of dependence of the elongation of the PFH on the temperature value. According to the data in Tables 1, 2, in real cases of PFH application during fire extinguishing, the stretching of the hoses for different temperatures almost did not change. Of course, with decreasing temperatures, the reverse compression of PFH after its use will slow down, which has been confirmed experimentally.

Regarding the limitations of this study, it should be noted that cases of using a hose line of two or more PFHs were not taken into account. In such cases, it will be necessary to take into account the pressure loss along the length of the hose line, which will affect the stretching of the PFH. In addition, all studies were conducted on a horizontal plane without taking into account the laying of the hose line with an offset in height.

The practical use of the results is complicated by an important drawback of the study, namely the difficulty of taking into account the amount of PFH wear.

## 7. Conclusions

1. The results of investigating the properties of pressure fire hoses of type «T» with internal diameter $D=77$ mm and a length of up to $L=1960$ cm at longitudinal deformations were confirmed by conducting a full-scale field experiment using not a fragment but the entire pressure fire hose. The maximum value of the tensile force was 2.04 kN, and the relative elongation did not exceed 0.032. However, unlike previous studies, the uneven stretching of the pressure fire hose was revealed when the stretching increased closer to its middle.

2. It has been established that an important factor influencing the ability to extend the pressure fire hoses is the state of their wear, primarily the number of cycles and operating conditions. Thus, for six latex pressure fire hoses of the same type with a diameter of $D=77$ mm and a length of $L=1960$ cm, the variation in the elongation value was about 12 % (73, 77, 79, 81, 82, 83 cm), for six latex pressure fire hoses with a diameter of $D=51$ mm, the variation of the elongation value was about 9 %.

3. The magnitude of the forces expended on stretching the pressure fire hose, but not involved in the process of transporting liquids, has been experimentally determined. In some cases, the tensile force of the pressure fire hose exceeded 2.04 kN.

4. For the investigated types of pressure fire hoses during water transportation, it was experimentally established that in the temperature range of 263–298 K there is no significant dependence of the elongation of the pressure fire hose on the ambient temperature value.

## Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

## Funding

The study was conducted without financial support.

## Acknowledgments

The study was carried out using the laboratory base of the Cherkasy Institute for Fire Safety named after the Heroes of Chernobyl (Ukraine); cadets and employees of this educational institution took part in some experiments.

## Data availability

All data are available in the main text of the manuscript.

References

1. Larin, A. N., Chernobay, G. A., Nazarenko, S. Y. (2014). Vyznachennia pozdovzhnoi zhorstkosti pozhezhnoho rukava. Problemy pozhezhnoi bezpeky, 35, 133–138. Available at: http://nbuv.gov.ua/UJRN/Ppb_2014_35_23
2. Nazarenko, S., Kovalenko, R., Asotskyi, V., Chernobay, G., Kalynovskyi, A., Tsebriuk, I. et al. (2020). Determining mechanical properties at the shear of the material of «T» type pressure fire hose based on torsion tests. Eastern-European Journal of Enterprise Technologies, 5 (7 (107)), 45–55. doi: https://doi.org/10.15587/1729-4061.2020.212269
3. Larin, O. M., Chernobai, H. O., Nazarenko, S. Yu., Zapolskyi, L. L. (2015). Vyznachennia dysypatyvnykh vlastyvostei napirnoho pozhezhnoho rukava typu «T» diametrom 77 mm. Naukovyi visnyk Ukrainskoho naukovo-doslidnoho instytutu pozhezhnoi bezpeky, 2 (32), 18–25.

4. Larin, O., Morozov, O., Nazarenko, S., Chernobay, G., Kalynovskyi, A., Kovalenko, R. et al. (2019). Determining mechanical properties of a pressure fire hose the type of «T». Eastern-European Journal of Enterprise Technologies, 6 (7 (102)), 63–70. doi: https://doi.org/10.15587/1729-4061.2019.184645
5. Cho, J. R., Yoon, Y. H., Seo, C. W., Kim, Y. G. (2015). Fatigue life assessment of fabric braided composite rubber hose in complicated large deformation cyclic motion. Finite Elements in Analysis and Design, 100, 65–76. doi: https://doi.org/10.1016/j.finel.2015.03.002
6. Motorin, L. V., Stepanov, O. S., Bratolyubova, E. V. (2011). The simplified mathematical model for strength calculation of pressure fire hoses under hydraulic influence. Tehnologiya tekstil'noy promyshlennosti, 1, 126–133.
7. Aripbayeva, A. E. et al. (2016). New Formula for Strength Calculation of Pressure Fire Hoses under Intrinsic Hydraulic Pressure. International Journal of Research in Engineering, IT and Social Sciences, 06 (12), 47–50. Available at: http://indusedu.org/pdfs/IJREISS/IJREISS_1022_58588.pdf
8. Aripbaeva, A. E., Myrkhalykov, Zh. U., Koifman, O. I., Bazarov, Yu. M., Stepnov, S. G. (2016). Perspective direction of calculation and design of reinforcing carcasses of tension fire hoses on basis of synthetic fibers. Izvestiya vysshikh uchebnykh zavedenii khimiya khimicheskaya tekhnologiya, 59 (7), 92–95. doi: https://doi.org/10.6060/tcct.20165907.5406
9. Aripbaeva, A. E., Mirkhalykov, Z. U., Kaldybaev, R. T., Koyfman, O. I., Bazarov, Y. M., Stepanova, S. M., Stepanov, S. G. (2020). Investigation of characteristics of woven reinforcing frames of pressure fire hoses and their influence on values of internal bursting pressures. Izvestiya vysshikh uchebnykh zavedenii khimiya khimicheskaya tekhnologiya, 63 (10), 96–104. doi: https://doi.org/10.6060/ivkkt.20206310.6234
10. Anikin, S. N., Danilov, M. M., Denisov, A. N., Korolev, P. S., Litvinov, A. A. (2022). Algorithm of actions of fire service to extend high-pressure hoses when extinguishing a fire on the railway. Fire and Emergencies: Prevention, Elimination, 3, 99–109. doi: https://doi.org/10.25257/fe.2022.3.99-109
11. Park, J., Kim, S.-J., Chun, K.-H. (2022). Verification of the Effectiveness of a Fire Hose Backpack in Areas Fire Trucks have Difficulty Accessing. Fire Science and Engineering, 36 (5), 134–141. https://doi.org/10.7731/kifse.db6da288
12. Kim, H., Song, Y. (2021). A Study on the Durability of Fire Hoses of Fire Hydrants. Journal of the Korean Society of Hazard Mitigation, 21 (6), 97–102. doi: https://doi.org/10.9798/kosham.2021.21.6.97
13. Prisyajnyuk, V., Semychayevsky, S., Yakimenko, M., Osadchuk, M., Svirskiy, V., Milutin, O. (2020). Analysis of structural compliance and basic technical requirements for layflat fire hoses for fire-rescue equipment. Series: Engineering Science and Architecture, 154, 324–327. doi: https://doi.org/10.33042/2522-1809-2020-1-154-324-327
14. Prisyajnyuk, V., Semychayevsky, S., Yakimenko, M., Osadchuk, M., Svirskiy, V., Milutin, O. (2020). About improvement of the regulatory base for technical requirements and test methods for delivery fire hoses. Series: Engineering Science and Architecture, 154, 312–317. doi: https://doi.org/10.33042/2522-1809-2020-1-154-312-317
15. Muramatsu, H., Iino, R., Yoneda, K. (2018). Development of Fire Hose Laying Robot. The Proceedings of JSME Annual Conference on Robotics and Mechatronics (Robomec), 2018, 1A1-I12. doi: https://doi.org/10.1299/jsmermd.2018.1a1-i12
16. Stas, S., Bychenko, A., Kolesnikov, D., Myhalenko, O., Pustovit, M. (2021). Experimental study of changes in the geometric parameters of fire hoses during the supply of extinguishing agents. Bulletin of the National Technical University «KhPI». Ser.: Hydraulic Machines and Hydraulic Units, 2, 39–42. Available at: http://gm.khpi.edu.ua/article/view/248744
17. Stas, S., Bychenko, A., Pustovit, M., Myhalenko, O., Kolesnikov, D. (2022). Experimental research of geometric parameters change of the of fire hoses when using the Protek 366 nozzle. Bulletin of the National Technical University «KhPI». Ser.: Hydraulic Machines and Hydraulic Units, 1, 78–82. Available at: http://gm.khpi.edu.ua/article/view/267053
18. Kostiuk, D., Kolesnikov, D., Stas, S., Yakhno, O. (2018). Research into cavitation processes in the trapped volume of the gear pump. Eastern-European Journal of Enterprise Technologies, 4 (7 (94)), 61–66. doi: https://doi.org/10.15587/1729-4061.2018.139583
19. Yakhno, O., Seminskaya, N., Kolesnikov, D., Stas, S. (2014). Destabilization of stream in a channel with the length-varying flow rate. Eastern-European Journal of Enterprise Technologies, 3 (7 (69)), 45–49. doi: https://doi.org/10.15587/1729-4061.2014.24658
20. Yakhno, O., Stas, S., Gnativ, R. (2015). Taking into account the fluid compressibility at its unsteady flow in pressure pipelines of fire extinguishing systems. Eastern-European Journal of Enterprise Technologies, 3 (7 (75)), 38–42. doi: https://doi.org/10.15587/1729-4061.2015.42447
21. Maglyovana, T., Nyzhnyk, T., Stas, S., Kolesnikov, D., Strikalenko, T. (2020). Improving the efficiency of water fire extinguishing systems operation by using guanidine polymers. Eastern-European Journal of Enterprise Technologies, 1 (10 (103)), 20–25. doi: https://doi.org/10.15587/1729-4061.2020.196881