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The analysis of pressure drop, spray angle, and sprinkling intensity distribution in the spray stream produced by the water-foam nozzle

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This paper summarises a series of large-scale fire suppression tests conducted to simulate a fire in the big surface and/or surface sprinkling. The subject of this paper is the research on water spraying with the use of the Turbo Jet 2011 water-foam nozzle manufactured by Supon Białystok. The results discuss the pressure losses caused by the flow through the discharge hose, spray angle, and the intensity of surface sprinkling. The greatest stream ranges and the highest maximum values of the sprinkling intensity were obtained at the capacity of 400 l/min, and a solid spray angle. The smallest values were obtained at 200 l/min, a pressure of 5 bar, and a solid spray angle. The actual pressures taking into account the losses in the hose section were calculated. As for the highest firefighting effectiveness of the stream, the authors recommended the following parameters: semi spray angle, 200 l/min, and 2.5 bar.

Keywords: fire safety, harvest fire prevention, atomization; spraying intensity, pressure drops.

INTRODUCTION

Fire protection is a field mainly based on the foundations of liquid spraying[1]. Fire is an element without which it is impossible to imagine life nowadays, but at the same time, it is a huge threat to people and property. During harvest periods with increased fire potential, fires cause millions of dollars in property damage, including loss of machinery, crops, and time. Injuries to farm workers and firefighters are also an unfortunate outcome in some instances. The oldest traces of firefighting activities date back to 2000 BC. At present, firefighting in its broadest sense is much more developed than even several years ago. All the time, better and more effective methods of fighting fire are being pursued. Water spraying is the key to dealing with fires, but just administering water is not enough. An important element is also knowledge and tactics, as well as knowledge of the equipment and the ability to use it. Water is the cheapest and most easily available extinguishing agent, and at the same time has very good thermal properties, thanks to which it has been used as the main means of fighting fires for many years. In the past, extinguishing fires relied on dense streams produced by nozzles of simple construction[2–4]. Current nozzles used by fire brigades have a wide range of possibilities, such as changing the spray angle or regulating the capacity of water supply to a large extent. It is important to be able to properly select all parameters in such a way as to extinguish the fire as quickly as possible and with the least material damage[5]. Various studies of water streams produced by nozzles and their effectiveness in extinguishing fires have been carried out for several years[5–7]. More and more often, the focus is turned towards their importance during real rescue and firefighting operations, because such research has an impact on the effective extinguishing of the flame[3, 5, 7]. The operational and design parameters of the water--foam nozzle are also important from the point of view of the other application, e.g. applied to dust control underground coal minethe[8, 9]. Only some of the tests were performed on a large-scale[5, 6, 10, 11].

Water streams can be divided into two basic types: solid and dispersed. Dispersed streams are divided into fog streams and droplet streams. Each of them has its own specific range of application[12]. The spray pressure and nozzle diameter, to have an influence on the spray angle, droplet diameter, droplet size uniformity, and sprayed area diameter[4]. A fog nozzle is a firefighting hose spray nozzle that breaks its stream into small droplets, its stream achieves a greater surface area in comparison to droplet streams[13]. Solid streams are streams with high mechanical energy. Their operation is primarily local, which makes them particularly useful when extinguishing fires from a greater distance, where the stream of water is to be directed at a specific point or when its purpose is to reduce the flames. One of the disadvantages of this type of streams is the significant loss of water caused by the fact that a large amount of it may not penetrate into the burning material. Another disadvantage is the reduction of the evaporation capacity of a large amount of water, which in turn reduces the extinguishing effect and causes stress on structural elements, e.g. a burning roof or damage to interior fittings. Therefore, solid water streams are mainly used to extinguish compact solids in the case of fully developed fires and in situations where it is necessary to put out the flames or supply water from a long distance[12, 14]. The droplet streams primarily have a surface effect. They can be used wherever solid stream should not be used. They cover a much larger area and do not have such high mechanical energy, which means that they have better cooling abilities and water evaporates faster, creating a layer of water vapor in the vicinity of the fire. At less capacity, they cause much less damage. They are used to extinguish fires of loose and fibrous materials, thanks to their dust deposition capacity[15]. Additionally, they have the ability to deposit fumes. The droplet stream can also be used to gradually cool down hot surfaces, which, under different extinguishing conditions, may be damaged or collapsed. Fog streams are spatial action streams having a similar application to that of droplet streams, but their effect is multiplied in cooling the surface. They can be used to extinguish fires of flammable liquids lighter than water that burn in a small area. They have the ability to deposit and displace fumes, which is why they are effective in fighting smoke. They also work well for extinguishing semi-solids such as tar, fats and waxes. Their disadvantage is primarily a small operating range and susceptibility to air movements. However, the latter also makes it possible to protect the person operating the nozzle against thermal radiation. If the nozzle meets certain conditions, it can also extinguish live electrical devices using this type of stream. With fog streams, water losses are negligible, so they can be used to extinguish interiors. The use of this type of stream under sufficiently high pressure will shorten the total extinguishing time[12, 14].

The nozzles used in fire protection are mainly used for spraying water. Depending on their application or the type of produced streams, the following types can be distinguished[16]:

– standard nozzles – small hand-operated nozzles generating solid and dispersed water jets, e.g. from a hydrant or a fire extinguishing line,

– sprinklers and sprayers – water sprayers in fixed sprinkler and sprayer extinguishing devices,

– water curtains – devices producing water curtains to reduce the power of thermal radiation of a fire or to capture harmful substances from the air,

– mist nozzles – allow spraying to a very high degree of atomization,

– mist heads – a group of several or a dozen or so nozzles for spraying water with a very high degree of atomization, they are much more efficient than single mist nozzles due to the amount of water sprayed.

Nozzles are designed to properly form and deliver dispersed or solid water jets. We can distinguish nozzles for autopumps and motor pumps as well as hydrants used as equipment for hydrant cabinets. Depending on the intensity of the given water streams, we can distinguish nozzles of sizes 25, 52 and 75. These numbers inform us about the internal diameter of the discharge hose which can be connected to a given nozzle by means of connectors, i.e. 25, 52, 75 mm, respectively[17, 18]. Hydrant water nozzle type PWh-52/D13-150 produced by SUPRON 3 of diameter 52 mm is used for opening, closing and continuous adjustment of the efficiency and type of water stream (dispersed and compact) in fire-fighting equipment[19]. The diameter of 52 mm is most popular in water-foam nozzels.

When the fire system is designed, installed and maintained properly, the risk that it won't work is very little[3, 20]. As it is known the systems (sprinkler systems) are required in certain types of buildings with certain criteria. This differs from country to another, even within EU countries[3, 21]. The fire suppression systems should be acceptance tested (according to the any norms eg. National Fire Protection Association NFPA)[2], but in practice, their results are often not published. It is worth remembering that the current literature review is very limited in terms of water-foam nozzles, because there are few works devoted to this issue and one can find only a few works performed on a large-scale. Accordingly, and taking into account the fact that the operational and design parameters of the water-foam nozzle are very important in extinguishing the fire, the authors of the study decided to conduct research to describe the influence of selected parameters on water spraying with water-foam nozzle.

This paper summarises a series of large-scale fire suppression tests conducted to simulate a fire in the big surface and/or surface sprinkling. The tests were conducted with a water-foam spray nozzle Turbo Jet 2011 manufactured by Supon Białystok[22]. The aim of the work is to analyze the influence of parameters such as pressure, flow rate, and spray angle on water atomization with the use of the tested water-foam nozzle. The nozzle is produced in two sizes, with the size 52 selected for the tests. This type of nozzle is commonly used in firefighting, and its correct setting is extremely important for the effectiveness of extinguishing fires. A foam spray nozzle can be used for precise dust control. To perform the experiment, a fire extinguishing line was built, consisting of a water tank with an autopump, a developed pressure hose and a tested nozzle. It should be noted that the obtained results are important from the point of view of the appropriate selection of settings, which largely determine the extinguishing effect and effectiveness of the rescue and extinguishing action.

MATERIALS AND METHODS

As a water tank, a medium-sized Fire truck Renault S170 of 1989 was used, equipped with an autopump with a maximum capacity of 1600 l/min and a tank of 3000 l (Fig. 1) (power: 170 HP (125 kW), fuel: Diesel, gearbox: manual/6 gears, axles: 2/4×4). The truck belongs to Volunteer Fire Department of Stawiszyn (Great Poland, Poland) and has a certificate of approval of the Scientific and Research Center for Fire Protection.

Figure 1. Renault S170 medium rescue and firefighting vehicle

The pressure fire hose W 52-20ŁA/PCV by Bezalin was used as a connection of the fire engine pump with a further measuring system. The numbers in the name indicate the diameter and length, i.e. 52 mm and 20 m respectively. The hose is resistant to weather conditions, low temperatures down to –30 °C and ozone. The round-woven braid is made of polyester yarn of high strength and abrasion resistance. The inner lining is smooth, resistant to mildew and rotproof. It is usually made of plastics or synthetic rubber. In the experiment, a hose with a PVC (polyvinyl chloride) interior was used. The hose was equipped with aluminum STORZ connectors, in accordance with the PN-91/M-51031 standard. It meets the requirements of the technical conditions of the

Regulation of the Ministry of the Interior and Administration of April 27, 2010 on the list of products used to ensure public safety or protection of health and life and property, as well as the rules for issuing admittance for use of these products.

The Turbo Jet 2011 water-foam nozzle (Fig. 2) is manufactured by Supon Białystok, a manufacturer of fire fighting equipment. The nozzle is produced in two sizes: 52 and 75. A 52 size nozzle was used in this test. The nozzle is manufactured in accordance with the PN-EN 15182-2:2020-01 standard – English version. Detail technical specification of Turbo Jet 2011 water-foam nozzle used for experimentation is given in Table 1.

The nozzle is equipped with a ball valve. The nozzle body is made of aluminum rods, the handle and lever are made of die-cast aluminum, and the red plastic rings are made of polyethylene. It is designed to produce solid and dispersed streams with smooth regulation of the solid angle of the dispersed stream (minimum 110°). In total, 4 series of measurements were performed at the following variables: pressure, flow rate and spray angle (Table 2). This adjustment is possible by means of a swivel attachment. It has the possibility of step capacity adjustment in the range of 100–500 l/min and the flushing function. The working pressure is 6 bar[23]. The term "water-foam" suggests that the nozzle is also adapted to generate foam. For this purpose, a foam cap, specially adapted to a given nozzle, serves as a stirrer for air and water-foam solution.

To carry out the experiment, a fire extinguishing line was built, consisting of: a water tank with an autopump, a developed pressure hose and a water-foam nozzle. These elements were connected with each other using claw couplings. The 20 m length pressure fire hose W 52-20ŁA/PCV was used as a connection of the fire engine pump with a nozzle. The hose was connected to the fire engine pump at a height of 1 m. The nozzle determined the center of the test stand. In front of it, 27 plastic measuring containers were placed in three columns (Figure 3). In the experiment, transparent containers made of polypropylene with a volume of 29 l and dimensions of 390×580×180 mm were used. During

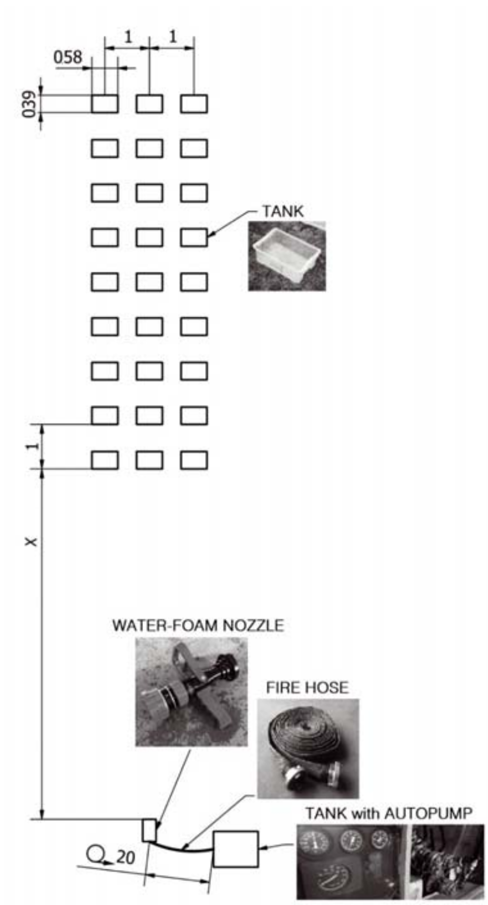

Figure 3. Diagram of the large-scale test stand (dimensions in meters) for: X = 11 m for a pressure of 5 bar and an capacity of 200 l/min and X = 14 m for a pressure of 2.5 bar and a capacity of 400 l/min

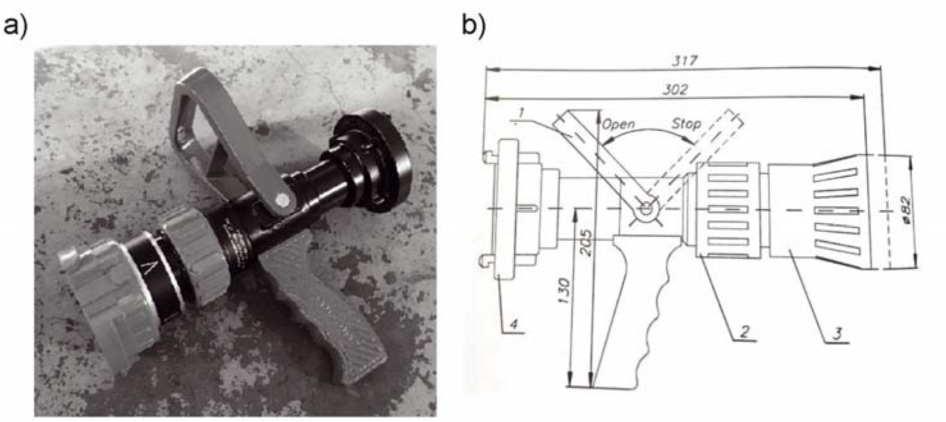

Figure 2. Turbo Jet 2011 water-foam nozzle: a) photo; b) scheme (1 – ball valve; 2 – capacity regulating knob; 3 – knob regulating the angle of the water stream; 4–52 mm cap)

Table 1. Technical specification of Turbo Jet 2011 water-foam nozzle

Size	Flow (l/min)	Length (mm)	Width (mm)	Height (mm)	Mass (kg)	Catalog No.
52/C	100–500	315	130	280	2.7	11225

Table 2. List of variables

Variable	Serie 1	Serie 2	Serie 3	Serie 4
Autopump pressure (bar)	5	5	2.5	2.5
Nozzle capacity (l/min)	200	200	400	400
Spray angle type	solid	semi-dispersed	solid	semi-dispersed

the first two measurements (Series 1 and Series 2), the proximal edges of the containers were 11–19 m from the nozzle. For the next two measurements, the distances were increased to the range of 14–22 m. There was exactly 1 m distance between the centers of the left and middle columns as well as the containers in the right and middle columns for all measurements.

RESULTS

The conducted experimental tests allowed to determine the volume of water collected in measuring containers depending on the operating pressure, volumetric flow rate of the liquid, spray angle and distance from the nozzle. The quantitative information is summarized in Table 3. The distance *X* means the distance between nozzle and a container.

Table 3. Experimantal data – volume of liquid in the tank (cm^3)

Series	Distance *X* (m)	Volume of liquid in the tank (cm^3)		
		Left column	Middle column	Right column
Series 1	11	360±25	1400±120	360±21
	12	350±22	1770±140	350±20
	13	390±20	1850±130	390±22
	14	300±21	1880±143	300±17
	15	200±15	2000±120	200±16
	16	80±5	1480±90	80±7
	17	100±7	1050±74	100±7
	18	80±5	640±50	80±6
	19	20±2	200±15	20±2
Series 2	11	120±10	800±28	120±9
	12	100±9	1120±56	100±9
	13	250±14	1300±78	250±15
	14	300±15	2380±58	300±17
	15	380±19	2450±80	380±20
	16	400±24	2030±76	400±20
	17	540±25	2520±90	540±20
	18	600±25	1000±72	600±20
	19	340±16	530±30	340±18
Series 3	14	480±27	1850±80	480±30
	15	610±30	2200±85	610±35
	16	680±34	1950±75	680±38
	17	610±30	2900±100	610±35
	18	630±30	3050±100	630±31
	19	790±36	3250±110	790±34
	20	1030±50	3700±115	1030±47
	21	1000±40	4650±160	1000±43
	22	1200±56	4450±165	1200±49
Series 4	14	1400±45	1890±76	1400±43
	15	1500±50	2370±95	1500±50
	16	1600±55	1920±90	1600±55
	17	1300±50	2930±105	1300±45
	18	1120±47	3400±100	1120±45
	19	1300±54	4000±127	1300±50
	20	1630±60	4000±130	1630±65
	21	2050±75	2700±90	2050±80
	22	1250±45	890±40	1250±52

In Figures 4 and 5 the dependence of the volume of water in the containers on the axial and radial distance from the nozzle are shown. With the setting of 5 bar on the fire engine pump control panel, the capacity of 200 l/min on the nozzle and a solid spray angle, the water volumes presented in the diagram in Figure 4 were obtained. As can be easily seen, the largest volume of water in 60 seconds was collected in the containers of the middle column. The maximum amount of collected water was contained in a container at the distance of 15 meters from the nozzle. At a distance of 19 meters

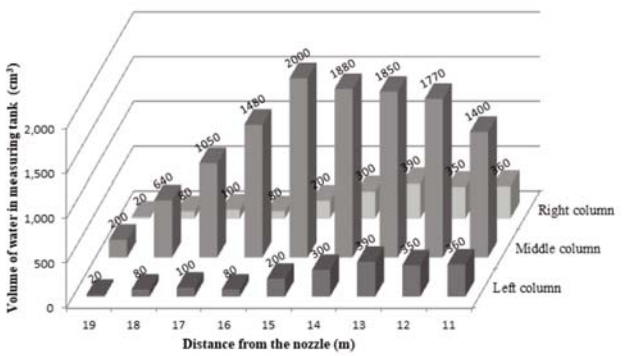

Figure 4. Measurement results for parameters: measurement time 60 s, pressure 5 bar, capacity 200 l/min, solid spray angle

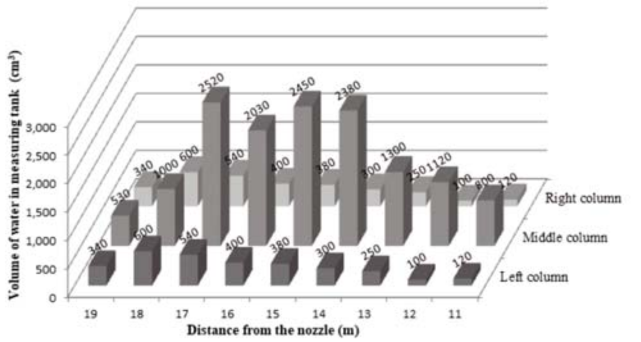

Figure 5. Measurement results for parameters: measurement time 60 s, pressure 5 bar, capacity 200 l/min, semi--dispersed spray angle

from the nozzle, the containers of each of the three columns contained the least amount of water. Figure 5 shows a graph for the same pressure and capacity settings as in Figure 4, the only variable distinguishing these two measurements was the spray angles. In this diagram (Fig. 5) we deal with the volume of water in the containers for the half-dispersed angle set on the nozzle. The maximum volume of water was obtained at a distance of 17 meters, but at 15 meters it is only slightly lower (2,520 cm^3 vs. 2,450 cm^3). Due to the change in the angle: solid to semi-dispersed, a greater dispersion of the stream and greater volumes of water were obtained in the containers of the left and right columns. Comparing the two graphs, a completely different water volume distribution in the right and left columns have been observed. At a solid angle, more water was found closer to the nozzle, while at a dispersed angle, larger volumes were measured at a larger distance (maximum at a distance of 18 meters). The water volume distribution in the right and left columns for the solid angle is opposite to that for the semi-dispersed angle.

Figure 6 shows a graph showing the measured water volumes at a setting of 2.5 bar, capacity on a nozzle 400 l/min and solid spray angle. The measurement time, as in the previous cases, was 60 s. The largest volumes of water in the containers of the middle column were observed at a distance of 21 and 22 meters from the nozzle (4,650 and 4,450 cm^3). These are much larger numbers than in the case of higher pressure and lower capacity (for 15 m – 2,000 cm^3). As for the right and left columns of containers, the maximum volume of water was recorded at a distance of 22 meters. Figure 7

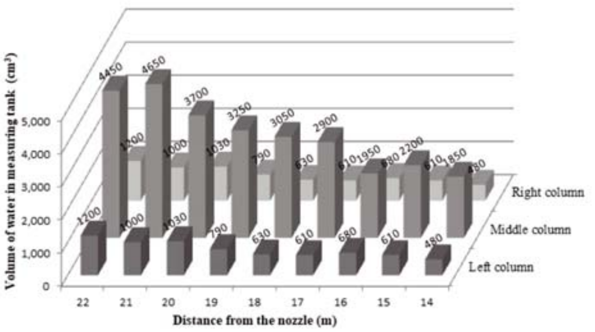

Figure 6. Measurement results for parameters: measurement time 60 s, pressure 2.5 bar, capacity 400 l/min, solid spray angle

shows the last measurement, which was performed with the same parameters as the previous one, but with the setting of the semi-dispersed spray angle. The smallest amount of water was measured in the last containers of the right and left columns at a distance of 22 meters, while the largest in the containers of the middle column at a distance of 19 and 20 meters from the nozzle. Comparing the graphs in Figures 6 and 7, it can be seen that in the second case the water volumes in the right and left columns were quite unequal, while in Figure 6 a gradual increase in these volumes can be seen. The jet dispersion resulted in a maximum volume in the middle column a little closer to the nozzle than in the case of a solid jet. Summarizing the research carried out in an open space, it would appear purposeful to carry out such tests also in an enclosed space in order to avoid the influence of possible weather conditions. However, in the case of a real rescue and firefighting operation, such tests would not be applicable, because it is impossible to exclude the influence of, for example, wind when providing sprayed water to the place of fire.

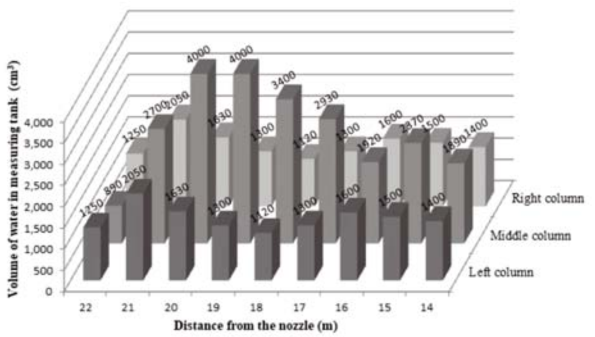

Figure 7. Measurement results for parameters: measurement time 60 s, pressure 2.5 bar, capacity 400 l/min, semi--dispersed spray angle

Most often, the intensity and pressure of the water supplied to the nozzle used are decisive for the extinguishing effect and the effectiveness of the rescue and firefighting operation. It depends, first of all, on the pressure losses in the hose line, as well as on the type and quality of the fire fighting equipment used[17]. It is usually assumed that the pressure loss in the hose line is directly proportional to the square of the water flow rate and inversely proportional to the fifth power diameter of the hose inner diameter. For practical purposes, the following equation[17, 23] is used:

$$\Delta p = \lambda \cdot \frac{l}{d} \cdot \frac{\rho}{2} \cdot w^2 \text{ (Pa)} \quad (1)$$

where: l – hose length (m), d – hose internal diameter (m), w – average water flow velocity (m/s), ϱ – water density (kg/m^3), λ – flow resistance coefficient (–). The average flow velocity was calculated as the ratio of the volumetric flow rate (Q_c) to the cross sectional area of the fire hose (F_h).

The equation for the flow resistance coefficient was selected, suitable for values in the range 3,000 < Re < 300,000[24]:

$$\lambda = \frac{0.3164}{Re^{0.25}} \quad (2)$$

The obtained values of the flow resistance coefficient for the tested efficiencies, i.e. 200 and 400 l/min are 0.0188 and 0.158 respectively. The estimated from Equations (1) and (2) pressure losses (Dp) for a working pressure of 5 bar and a capacity of 200 l/min are 8,890 Pa, and for a pressure of 2.5 bar and a capacity of 400 l/min – 29,900 Pa. Given the pressure losses resulting from the flow through the hose line, it is possible to calculate the actual pressure at the mouth of the nozzle. Pressure losses in the nozzle were neglected. Losses resulting from local resistances were also ignored, as the hose bends were minimal, and taking them into account would require a series of tests. The actual pressure is then:

$$p_a = p - \Delta p \text{ (Pa)} \quad (3)$$

The actual pressure (p_a) for a working pressure (p) of 5 bar and a flow rate of 200 l/min is therefore 4.9 bar, and for a pressure p = 2.5 bar and a flow rate of 400 l/min it is 2.2 bar, in both cases for both the solid and semi-dispersed angle setting.

The spraying intensity (I_r) is the minimum amount of water that can be determined by dividing the capacity of water flowing from the nozzle in l/min by the given surface area on which the water falls. It is expressed in (mm/min) and described with the equation[10, 11, 25]:

$$I_r = \frac{V_c}{F \cdot t} \text{ (mm/min)} \quad (4)$$

where: V_c – volume of liquid in the container (mm^3), F – surface of the container (mm^2), t – measurement time (min). The parameter of sprinkling intensity is one of the key parameters to determine the spraying process. This parameter has been assessed in weight and volumetric way using the measuring containers. The research confirmed reports in the literature that the spraying intensity strongly depends on the spray angle. The spraying intensity defined in this way allowed for the preparation of graphs of its dependence from the axial and radial distance from the nozzle, as shown in Figures 8–11. The solid jet is a much more effective stream than the dispersed jet for extinguishing fires from a greater distance, when it is necessary to deliver water to a spot or to extinguish the flames. The dispersed streams cover a much larger area than the solid streams. They are suitable for cooling hot surfaces, and thanks to the smaller diameter of the droplets, they can be used to extinguish fires of loose materials or fibrous materials and cause much less damage. By analyzing the

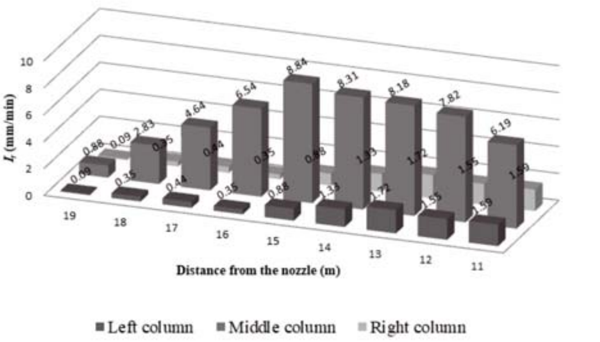

Figure 8. Sprinkling intensity for the parameters: pressure 5 bar, capacity 200 l/min, solid spray angle

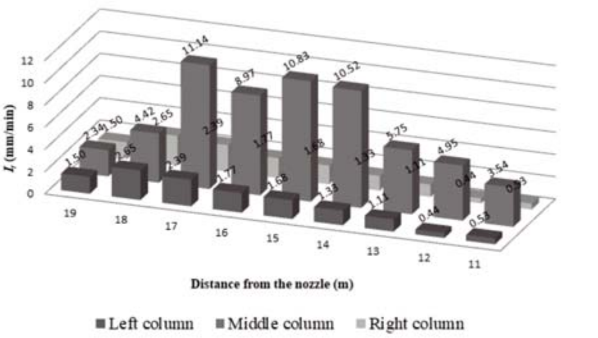

Figure 9. Sprinkling intensity for the parameters: pressure 5 bar, capacity 200 l/min, half-dispersed spray angle

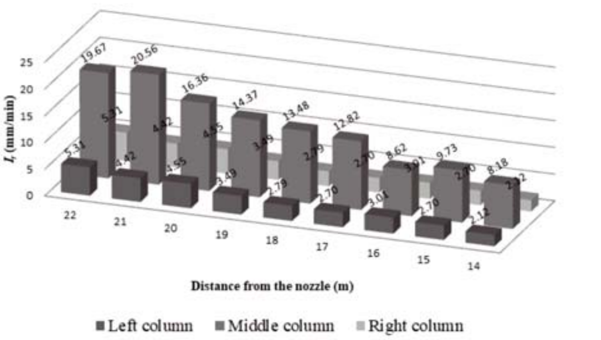

Figure 10. Sprinkling intensity for the parameters: pressure 2.5 bar, capacity 400 l/min, solid spray angle

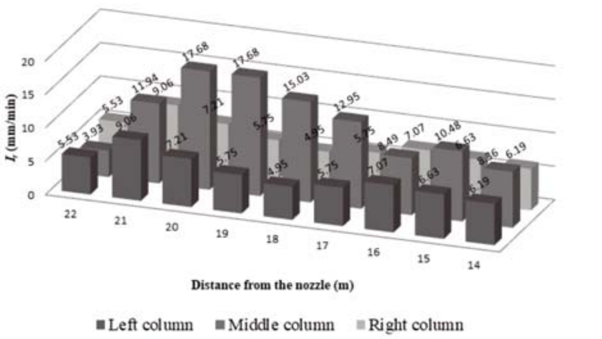

Figure 11. Sprinkling intensity for the parameters: pressure 2.5 bar, capacity 400 l/min, half-dispersed spray angle

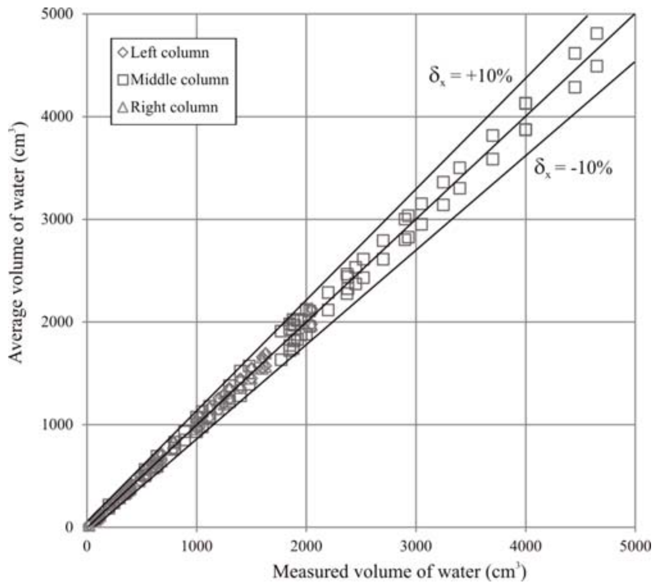

Figure 12. The relative error in percent

obtained images of the surface coverage effectiveness as well as the liquid flow rate and nozzle settings, it can be concluded that the sprayed surface is the most evenly covered for the following parameters: semi spray angle, and 400 l/min, and 2.5 bar (Fig. 11). Measurements were repeated 7 times for each condition (serie1 – serie4).

The relative error for the experiments is 10% and is presented in Figure 12. The largest observed deviations concern the smallest values of volume of collected water.

The tests show that there is a clear relationship between the intensity of sprinkling and the water application rate and other operational parameters. The analysis of the obtained data confirms the significant role of the liquid pressure and nozzle settings on the obtained spray jet, i.e. on the resistance related to the liquid flow and the intensity of sprinkling. This is an important aspect, as these settings determine the extinguishing effect and the effectiveness of the rescue and firefighting operation eg. on the plant field. Furthermore, the foam spraying from the foam nozzle eg. can effectively cover the dust sources[8, 9] which will have a remarkable effect on dust control at working face underground coal mines. In the future, the nozzle can be effectively used for the petrochemical industry and woods fire with several alterations in construction. With different variants of fire extinguishing media like CO_2, etc. other classes of fire like chemical, electrical, etc. can be extinguished. From a fire protection and control point of view, there is still a large scope for further development. The paper presents a comprehensive methodology of testing the intensity of sprinkling, which is important from a practical point of view. Large-scale tests require enormous costs, large amounts of liquid (500 l/min = 30,000 l/h) and therefore a smaller-scale test stand is planned. To transfer the results from large to small scale (usually the scale goes up, not down), you need to have them, and there is very little such data. In future research work, the conducted study will be verified with simulations and tests on an appropriate laboratory stand.

CONCLUSIONS

In the literature on the issue of water-foam nozzles, one can find only a few works performed in a large-scale.

The nozzles should be acceptance tested, but in practice, the results of experiments are often not published. This paper discusses the research carried out to describe the effect of pressure, flow rate and spray angle on water spraying with the use of the Turbo Jet 2011 water-foam nozzle manufactured by Supon Białystok. Four series of measurements were made by spraying water from the nozzle and collecting it in properly arranged containers. Two measurements were made at a pressure of 5 bar and a flow rate of 200 l/min. They differed in the spray angle, which was set to solid or semi-dispersed by means of the head on the nozzle. The next two measurements were made for a pressure of 2.5 bar, an capacity of 400 l/min and, respectively, for the solid and dispersed spray angle.

On the basis of the measured volumes of water in each of the containers, the values of the sprinkling intensity as well as the pressure losses caused by the water flow through the discharge hose were calculated. Graphs were also made showing the distribution of the measured volumes of water in the containers and the distribution of the intensity of sprinkling. The obtained results, graphs and their analysis allowed for the formulation of the following conclusions to be made:

– The highest maximum values of the sprinkling intensity were obtained at the capacity of 400 l/min, a pressure of 2.5 bar, a solid spray angle for containers located at a distance of 21 and 22 meters from the nozzle and along its axis. The smallest values were obtained at 200 l/min, a pressure of 5 bar, a solid spray angle for containers located at a distance of 19 meters from the nozzle in containers on the right and left sides.

– With the measurements taken for the half-dispersed spray angle, much larger water volumes were obtained in the right and left columns of the containers than for the solid spray angle measurements.

– At the setting of the flow rate of 400 l/min and the solid angle on the nozzle, the greatest stream ranges were achieved. Slightly shorter distances were achieved for the half-dispersed angle. Therefore, the pressure was reduced and the distance between the containers and the nozzle was increased compared to a flow rate of 200 l/min to keep the stream within the specified measuring distances.

– Increasing the pressure on the autopump increases the range of the jet throw.

– The actual pressures calculated taking into account the losses in the hose section were respectively 4.9 bar at the setting of 5 bar on the autopump and 2.2 bar at the setting of 2.5 bar.

– Increase in the spray angle results in the decrease in the throw range of the water stream.

– A solid water jet is preferred when extinguishing spotting fires from a greater distance, and a dispersed jet when cooling hot surfaces.

As for the highest firefighting effectiveness of the stream, the authors recommended the following parameters: semi spray angle, and 200 l/min, and 2.5 bar. The presented results showed that the nozzle studied fulfills the criteria of a universal nozzle and can be used in most rescue/firefighting operations. Good knowledge of the theoretical basis of water spraying and experimental data is necessary for the proper use of extinguishing water jets in the event of fires. Thanks to this, help provided by firefighters can be even more effective.

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