STUDY ON FLOW CHARACTERISTICS OF IN-LINE FOAM CONCENTRATE INDUCERS USED IN FIRE PROTECTION AREA

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Research article

Abstract: Research on flow characteristics of selected in-line foam concentrate inducers used currently in fire protection and its comparison with standard requirements are discussed in the paper. On the basis of the studies carried out either theoretical or real characteristics of tested devices are presented. A comparative analysis of the tested ejectors and the final conclusions are included at the end of the paper.

Keywords: In-line foam concentrate inducer, flow characteristics, experimental testing, equipment to make foam.

Nomenclature

β - pressure coefficient [-]

β_t - the theoretical pressure coefficient [-]

C - the concentration value set on the knob regulatory [% v/v]

C' - the actual inlet concentration [% v/v]

C_p - actual concentration determined using the calculation, [% v/v]

ΔC_p - the difference between the actual concentration ΔC, and set on the knob C regulatory [% v/v]

d_1 - nozzle diameter [m]

d_2 - mixing chamber diameter [m]

f_{r1} - surface area of working nozzle [m^2]

f_{r2} - surface area of the inlet cylindrical part of the mixing chamber [m^2]

f_{r3} - surface area of the outlet cylindrical part of the mixing chamber [m^2]

f_{r4} - outlet surface area of diffuser [m^2]

L - length of in-line foam concentrate inducer [m]

H - height of in-line foam concentrate inducer [m]

S_1 - width of in-line foam concentrate inducer [m]

S_2 - distance between inlet cross-section, where foam agent is sucked and vertical section of inducer [m]

dm - diameter of mixing chamber [m]

p - pressure in mixing chamber [MPa]

Δh - pressure loss in mixing chamber [MPa]

m, m_1, m_2, m_3 - construction factor [-]

n - rotation speed of the pump [-]

s - relative pressure loss [%]

p_r - factor of the inlet working pressure choke [MPa]

p_t - the pressure of the refrigerant at the outlet working with choke [MPa]

p_z - pressure inlet factor [MPa]

Q_r - output of working fluid [dm^3/s]

Q_z - output of inlet fluid, [dm^3/s]

u - output coefficient [-]

V_r - competent worker factor volume [m^3/kg]

V_z - an appropriate volume of the induction agent [m^3/kg]

V_t - volume of the liquid mixture suitable for spotlights [m^3/kg]

φ_1 - speed factor taking into account the loss of hydraulic power during expansion work stream [-]

φ_2 - speed factor taking into account the loss of hydraulic mixing chamber [-]

φ_3 - speed factor taking into account the losses in hydraulic diffuser [-]

φ_4 - speed factor taking into account the loss of hydraulic power during the expansion process [-].

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M - point corresponding to maximum pressure in mixing chamber

M1 - pressure gauge measuring the pressure p_r

M2 - pressure gauge measuring the pressure p_t

M3 - vacuum gauge measuring the under pressure p_z

ZO - shut-off valve liquid aspirated

ZR - control valve.

Introduction

Selection of suitable extinguishing agent is dependent on fire conditions as well as properties of burning material (Mizerski, 2002). Firefighting foam thanks to its cooling properties and insulation body is applied to extinguishment of fires of the Group A and B. Therefore, it has become one of the most effective and immediately after the water the most widely used means of extinguishing. This is confirmed by statistics carried out by the Headquarters of the State Fire Service (Materials, 2014).

In the manufacture of the foam on the spot relief activities-for specialized equipment is needed, which is the most important element for pull and mixing foam concentrate with water is a spotlight or a device designed to suck in and picking up liquids or for mixing liquids with solid (Derecki et al., 1981; Derecki, 1999; Placek, 2011).

In liquid ejectors Venturi effect is utilized, occurring in Venturi tube supplied by any working fluid. The State Fire Department in this area is based on proven technology liquid ejectors, however when you share more often to obtain the appropriate foam parameters is impossible. Usually the reason is incorrect concentration, which in turn can be caused by improper construction or operation of liquid ejectors used in fire protection, for example line foam concentrate.

Currently, in addition to the linear foam concentrate used in The State Fire Department (PSP) for the manufacture of aqueous getting installed dispensers are also used water systems-foam fire-fighting vehicles. This improves the speed and also translates to the effectiveness and enhancing the quality of relief activities-for. The market also appeared an innovative foam generation system under high pressure - Compressed Air Foam System (CAFS), which, however, has not yet supplanted the existing proven technology (http://www.arktos.home.pl/firemax/materialy/pliki/systemy_gaszenia_sg_cafs.pdf). In contrast to the traditional manufacture of foam, in the CAFS where air pressure range 1160-1813 bar into, and then to be delivered together with a mix of water and foam concentrate to the nozzle discharge hose.

Simple design and ease-of-implementation of them provided their spotlights a wide range of applications in technology. The basic types of liquid ejectors used in fire protection are linear sucker (pumping out water from flooded rooms) and linear foam concentrate (Gałaj et al., 2004). Despite new technology, linear foam concentrate through its reliable design, still constitute the basic equipment of vehicles for the Headquarters of the State Fire Service.

Materials and methods

Structure and working principle of in-line foam concentrate inducers

Principle of operation

In-line foam concentrate inducer are devices used in the State Fire Service for many years to suck foam. Through the use of kinetic energy that a liquid (water) they produce aqueous solution in relief activities fire-fighting foam for is used to manufacture extinguishing. Is built of several interconnected elements forming a unified whole. The schematic view of the liquid ejector is shown in Fig. 1.

The essence of the construction of the liquid ejectors is based on the phenomenon of Venturi and its main elements are: power nozzle (A), suction Chamber (B), mixing chamber (C) and diffuser (D) (Goliński et al., 1979).

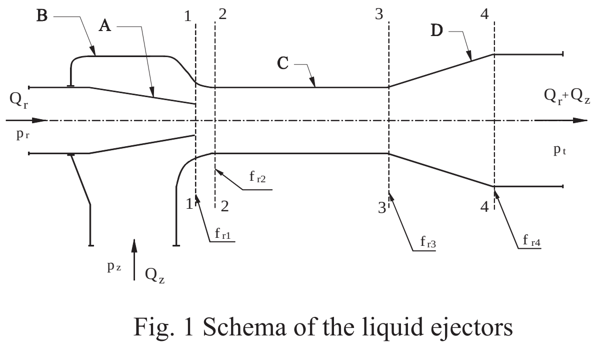

Fig. 1 Schema of the liquid ejectors (Gałaj et al., 2004)

Embossed water snakes and brought to in-line foam concentrate inducer reaches the pressure p_r about expenditure Q_r and splits into two currents. The first (axial) responsible for the creation of negative pressure is to supply nozzle to the surface f_{r1}. In confusor, followed by an increase in the speed of the liquid reaching after the departure of the nozzle speed proportional to the square root of the pressure p_r even up to 30 m/s. Once you reach

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that speed follows the slackness and pressure drop in stream below atmospheric pressure. Thanks to differential pressure p_r and p_t foam agent is sucked at Q_z from the external tank. In the mixing chamber stream liquid suck (foam), and the working fluid (water) creates a mixture, with the result that follows the alignment of speed at minimum pressure losses. Losses are the smaller the smaller the difference between diameters d_1 (f_{r1}) and d_2 (f_{r1}). The ability to suck a big impact is set to tip in one axis of symmetry to the mixing chamber. Failure to comply with this requirement may result in a decline in the ability to suck in and in extreme cases the total disappearance of it. The mixture of a certain kinetic energy and total capacity $Q_r + Q_z$ the diffuser, which is converted into potential energy pressure p_t a lower working pressure p_r. (Derecki et al., 1981).

The remainder of the water, which does not affect the suction chamber after filtering screens to led by flow-through chamber until the base of the outlet. The task of this stream is to fill the space around the diffuser and the suction chamber, causing pressure on the spring in flux concentration. The regulator provides a pumping of water with varying intensity by closing and opening the flow. When the pressure in the system rises, regulator restricts the flow of water from the lower to the upper part of the chamber of shipping at the same time directing it to the suction chamber of the choke. The regulator controls the amount of downloaded getting foam from the tank (Gil, 2013).

Basic parameters characterizing the work of in-line foam concentrate inducer

In-line foam concentrate inducer parameters (Tab. 1) have been adapted to the parameters of nozzles and foam generators used in fire protection meeting the requirements of standards PN-93/M-51068 (Fire-fighting equipment. Foam nozzles) and PN-93/M-51078 (Fire-fighting equipment. Foam generators.) (Heyman, 1997).

Having regard to the physical properties of the working and suction liquid, energy loss, the surface sections of nozzles and the mixing chamber, the equation for the characteristics of liquid ejectors is of the form. (Gałaj et al., 2004)

Tab. 1. Parameters of in-line foam concentrate inducer Z-2, Z-4 and Z-8 at the pressure of an aqueous solution of 0.55 MPa at the exit nozzle foam (PN-M-51069 1996)

Parameter	Unit	The inducer		
		Z-2	Z-4	Z-8
A flow rate of the solution of water foaming agent	[dm³/min]	200 ± 10	400 ± 20	800 ± 40
Maximum loss of the pressure	[% v/v]	34		
A concentration of the solution of water foaming agent		1-7		
A maximum deviation of sucked foaming agent		± 15	± 8	

$$\beta = 2\frac{\varphi_1}{\varphi_3}\frac{f_{r1}}{f_{r3}}\left[\begin{array}{l} K_1 + \left(K_2 - \frac{1}{2}\cdot\frac{\varphi_3}{\varphi_1}\right)\cdot\frac{f_{r1}}{f_{z2}}\cdot\frac{V_z}{V_r}\cdot u^2 - \\ -\left(1 - \frac{1}{2}\cdot\frac{\varphi_3}{\varphi_1}\right)\cdot\frac{f_{r1}}{f_{r3}}\cdot(1+u)^2\cdot\frac{V_t}{V_r}\end{array}\right] \quad (1)$$

where:

$$u = \frac{Q_z}{Q_r} \quad (2)$$

$$\beta = \frac{p_t - p_z}{p_r - p_z} \quad (3)$$

$$f_{r1} = \frac{\pi \cdot d_1^2}{4} \quad (4)$$

$$f_{r3} = \frac{\pi \cdot d_2^2}{4} \quad (5)$$

$$f_{z2} = f_{r3} - f_{r1} \quad (6)$$

$$K_1 = \varphi_1 \cdot \varphi_2 \cdot \varphi_3 \quad (7)$$

$$K_2 = \varphi_2 \cdot \varphi_3 \cdot \varphi_4 \quad (8)$$

The relationship (1) takes the form of a dimensionless. Assuming ideal conditions for ejector operation we assume that speed factors are equal, that is, $\varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = 1$ and $K_1 = K_2 = 1$. If we consider that the working liquid and suction is the same liquid, then $V_r = V_z = V_t$

By such theoretical assumptions spotlights equation can be written in the following form:

$$\beta_t = 2\frac{f_{r1}}{f_{r3}}\cdot\left[1 + \frac{1}{2}\cdot\frac{f_{r1}}{f_{z2}}\cdot u^2 - \frac{1}{2}\cdot\frac{f_{r1}}{f_{r3}}\cdot(1+u)^2\right] \quad (9)$$

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It follows that the characterization is the parabola and is dependent on, among other things: the distinguishing feature of design **m** as well as the coefficient of expenditure **u**.

Attribute design **m** represents the ratio of the cylindrical section of the mixing chamber into the nozzle inlet section of the workstation.

$$m = \frac{f_{r1}}{f_{r3}} \quad (10)$$

From the analysis of the expression (9) shows that with the increase in the coefficient **m** is growing pressure coefficient $\boldsymbol{\beta_t}$ and the expenditure ratio **u** decline in addition, spotlight sucks much of the liquid when the pressure ratio is equal to zero (Gałaj et al., 2004).

The actual characteristics of liquid spotlight for various structural factors shown in Fig. 2.

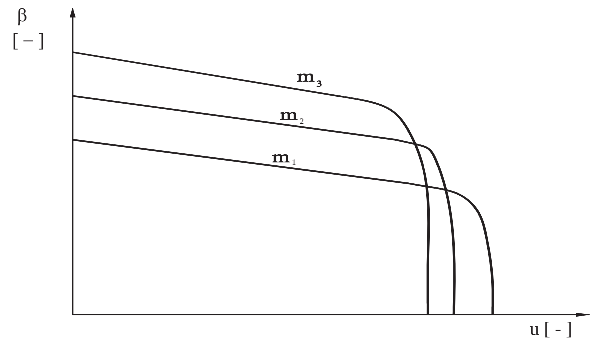

Fig. 2 The actual characteristics of the liquid ejectors for various construction factors ($m_1 > {}_2m >_3$) described by formula (10) (Gałaj et al., 2004)

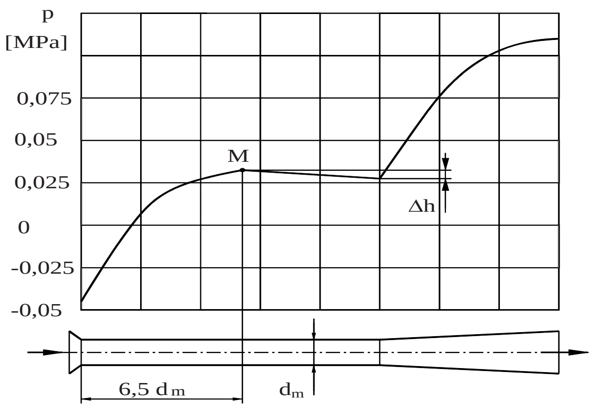

Fig. 3 Process the pressure variation in the mixing chamber and diffuser of liquid ejector (Gałaj et al., 2004)

A graph showing characteristic of spotlight pressure distribution along the mixing chamber of a cylindrical and conical diffuser spotlight is presented in Fig. 3. Initially you may experience increased pressure to a point M (maximum), in which the mixing process ends. In the next phase of the pressure curve falls as a result of losses caused by friction (Gałaj et al., 2004).

The requirements for in-line foam concentrate inducer

Poland Standard PN-M-51069 1996 fire-fighting equipment, in-line foam concentrate inducer, which replaced the standard PN-75/M-51069 with 1975 regulates all the requirements aimed at increasing reliability work mopping-up the line.

Depending on the nominal value of the flow of aqueous solution of foaming agent respectively 200 dm^3/min, 400 dm^3/min and 800 dm^3/min there are three sizes of linear mopping-up Z-2, Z-4 and Z-8.

All the elements of the choke must be made of appropriate materials resistant to corrosion by the aqueous foaming and extinguishing. The maximum dimensions and weight of the linear chokes in accordance with the Polish Standards is shown in Tab. 2.

Tab. 2 Main dimensions and mass of in-line foam concentrate inducers (PN-M-51069 1996)

Type	**Maximum dimensions**				**Maximum mass**
	L	**H**	**S_1**	**S_2**	**[kg]**
	[mm]				
Z-2	420	200	200	100	8.0
Z-4					
Z-8	600	220	200	100	11.5

Constant concentration of the solution should be automatically maintained by the regulator outlet pressure increase in the concentration of the choke to at least 0,15 MPa.

With such growth it provides suction constant percentage foaming agent. Increased pressure can be caused by accidental collapse pressure hose or in the case of transfers of nozzle on a ladder. Choke should not show any leakage at a pressure of water tightness while attempting to 1,8 MPa for 2 min. when trying the strength of water with a pressure of 2.4 MPa for 2 min should not have warp and cracks (PN-M-51069 1996). The maximum parameters of pressure losses, which are caused by the work of the choke may not exceed 34%, while the quantity deviation suck foaming agent respectively for Z-2 shall be ± 15%, and for the Z-4 and Z-8, ± 8%.

Overview of in-line foam concentrate inducers used by Firefighting and Rescue Units on the example of Silesian province

Overview of in-line foam concentrate inducer used in the Firefighting and Rescue Units for Silesia render decision support System ST 3.0 (SWD-ST 3.0) in the Provincial State Fire Department in Katowice (current day 09.01.2014). Missing data was supplemented on the basis of the information received from the individual Commands of urban in Silesia (Materials, 2014). From these data, it appears that there are 135 pieces of linear mopping of different types. They were produced between 1968 and the year 2013 and they come from five different manufacturers, such as: Ł.S.P.M PROGAZ, AWG ZUMISCHER, SUPON BIAŁYSTOK, ENPOL BIAŁYSTOK and POHORJE MIRNA. Distribution of in-line foam concentrate inducer according to the manufacturer is shown in Fig. 4.

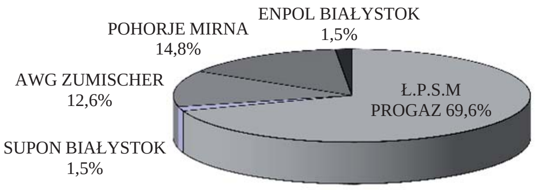

Fig. 4 Distribution of in-line foam concentrate inducers according to the manufacturer (Materials, 2014)

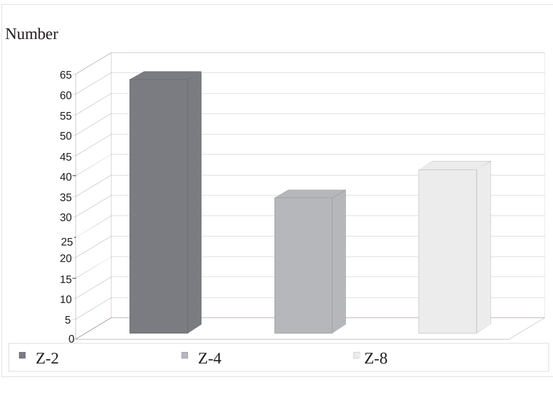

Fig. 5 Distribution of in-line foam concentrate inducer by type (Materials, 2014)

The most common in-line foam concentrate inducer turned out to be the product of Ł. S. P. M PROGAZ. It is 69.6% of all in the in-line foam concentrate inducer used in Firefighting and Rescue Unit in the province of Silesia This is equipment introduced in 1980s and 1990s, which now is not longer produced. In-line foam concentrate inducers manufactured by POHORJE and ZUMISCHER are respectively represented only by 14,8% and 12.6%. They will gradually replace the existing equipment. Based on the obtained statement, in accordance with the Polish standard, an allocation of three types: Z-2, Z-4 and Z-8 are presented graphically in Fig. 5.

In-line foam concentrate inducer Z-2 with a score of 45,93% (62 units) accounts for nearly half of the equipment which have Firefighting and Rescue Unit in the province of Silesia. Other types are less common, and their share is as follows: Z4-24,44% and Z8-29,63%.

On the basis of analysis of the number and types of the chokes supplied in the Silesian province was considered necessary to test in-line foam concentrate inducer type Z-2 from company Ł.S.P.M. PROGAZ. In order to compare the results obtained with the new, currently produced in-line foam concentrate inducer, to comparative tests in-line foam concentrate inducer type Z-2 manufactured by AWG ZUMISCHER has been selected.

Results

Purpose and scope of the study

In-line foam concentrate inducer Z-2 produced in Poland by Ł.S.P.M "PROGAZ" from 1984 (Fig. 6), included in Firefighting and Rescue Unit in Silesian Siemianowice and the equivalent produced by German company “AWG" (Fig. 7), which is located in the Department of Fire Fighting and Rescue Equipment at The Main School of Fire Service in Warsaw were used for testing (Fig. 6). The basic data of the tested chokes Z2 are included in Tab. 3.

Fig. 6 General view of Z-2 produced by "PROGAZ"

Fig. 7 General view of Z-2 produced by AWG

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Tab. 3 The basic data of the chokes Z2

Manufacturer	Type	Year of output	Water capacity	The scope of the concentration
AWG ZUMISCHER	Z-2	2011	200 dm^3/min	1-7%
Ł.S.P.M PROGAZ	Z-2	1984	200 dm^3/min	1-5%

Description of the research stand

The research stand used for the experimental tests of linear chokes is located in the Laboratory of Hydromechanics at The Main School of Fire Service in Warsaw. Its overall view is shown in Fig. 8.

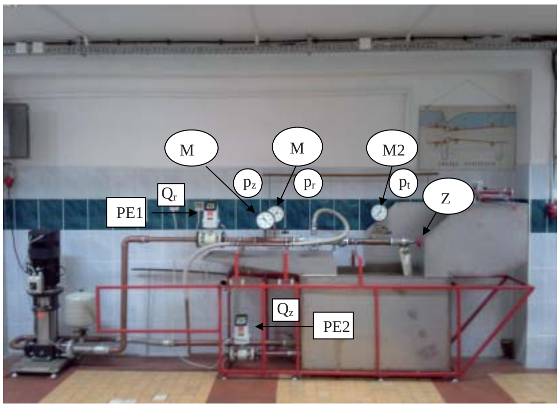

Fig. 8 General view of research stand

The scheme of the measuring system is shown in Fig. 9. The test object, which is the in-line foam concentrate inducer, is built in the discharge line. Its suction chamber is connected with suction chamber of the tank by means of wires, rigid and flexible. Choke nozzle is powered by a pump with a built-in automatic adjustment system for, among other things, stabilize the supply pressure. On the electromagnetic flow-meter installed, the mains lead does not flow distortions that PE1 can be used to measure the working expenditure Q_r and M1 gauge designed to measure operating pressure p_r. For choke gauge installed M2 intended for measuring the pressure p_t and the valve to adjust the ZR expenditure. In the electromagnetic flow meter installed In suction line PE2 electromagnetic flowmeter is installed to measure fluid flow Q_z and M3 gauge for measuring the suction pressure p_z. Economic reasons during the layout uses a closed water cycle. Working factors, getting sucked in and the mixture have the same density equal to the density of water. In accordance with the Polish Standard PN-M-51069 in measurements, it is also recommended to replace the foam with water.

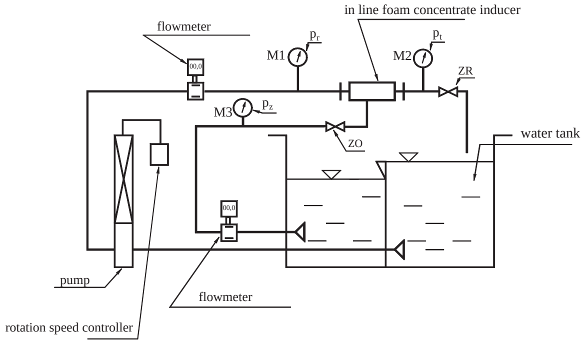

Fig. 9 Schematic diagram of the measurement system (Gałaj et al., 2004)

Vertical multi-step pump CW 16/60 by GRUNDFOSS was used for water supplying during laboratory tests. Two electromagnetic flowmeters MAG 2500 by Danfoss were used for the measurement of outputs Q_r and Q_z without giving effect to distortion of flow. Pressures p_r and pt were measured using a traditional elastic gauges manufactured by KFM (Kujawska Factory Pressure Gauges) with a range of 0-1 MPa, while the under pressure p_z are measured by the same type of the gauge with a range -0,1 MPa -1 MPa (Placek, 2011).

Measurement procedure

After having installed the in-line foam concentrate inducer to position measurement, tightness of the connections have been checked for accuracy and correctness of installation of measuring instruments (Kaliciecki, 1977). The pump motor is running and set to desired set point speed regulating the control valve ZR located behind the choke. Control of working liquid output was made using a combination of changes in pump speed (preliminary adjustment) and by throttling poppet valve ZR. This allowed obtaining the required pressure and flowing parameters of the measurement system (Gałaj et al., 2004).

After stabilization of the indications on measurement devices the following parameters were read and filed in the measuring table:

a) supply pressure p_r [MPa] - M1 gauge,
b) discharge pressure p_t [MPa]- M2 gauge,
c) pressure in the suction line p_z [MPa] - M3 gauge,
d) output of the working flow Q_r [dm^3/s] - flowmeter PE1,
e) output in suction line Q_z [dm^3/s] - flowmeter PE2.

In each series of measurements the registration carried out until Q_z = 0 [dm^3/s]. These steps were

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made for fixed supply pressure pr, corresponding to the maximum rotational speed of the pump motor (faster rotation the higher the pressure) and for three different concentrations established by using of dispensing valve 1%, 3% and 5%.

In order to calculate coefficients f_{r1} and f_{r3} power nozzle and mixing chamber diameters were measured for every tested device. They are as follows:

Z-2 "PROGAZ":

d_1 = 0,009 m

d_2 = 0,0105 m

Z-2 "AWG":

d_1 = 0,009 m

d_2 = 0,0110 m

Results of the experiments

Theoretical β_t = f(u) and the actual characteristics β = f(u) of in-line foam concentrate inducers Z-2 "PROGAZ" and Z-2 "AWG" are presented in Fig. 10 and 11. They are received on the basis of the values listed in Tab. 5-10, where all measured and calculated parameters are included for three different concentrations of 1%, 3% and 5%. Values C' and s in Tab. 5-10 were calculated from the following formulas:

$$C'=\frac{Q_z}{Q_r+Q_z}\cdot 100\ [\%] \quad (11)$$

$$s=\frac{p_r - p_t}{p_r}\cdot 100\ [\%] \quad (12)$$

Tab. 5 Results for Z-2 PROGAZ and set of concentration C = 5%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm³/s]	Q_z [dm³/s]	u	β	β_t	C' [% v/v]	s [%]
1.	0.07	0	0.01	2.801	0.3801	0.1357	-0.1667	0.8106	11.95	100
2.	0.09	0.04	0.009	2.798	0.3062	0.1094	0.3827	0.8293	9.86	56
3.	0.14	0.08	0.009	2.796	0.2319	0.0829	0.5420	0.8503	7.66	43
4.	0.19	0.12	0.009	2.783	0.1929	0.0693	0.6133	0.8619	6.48	37
5.	0.24	0.16	0.008	2.774	0.1782	0.0642	0.6552	0.8664	6.04	33
6.	0.28	0.2	0.008	2.745	0.1626	0.0592	0.7059	0.8709	5.59	29
7.	0.33	0.24	0.008	2.783	0.1586	0.0570	0.7205	0.8729	5.39	27
8.	0.43	0.32	0.008	2.773	0.1481	0.0534	0.7393	0.8762	5.07	26
9.	0.56	0.42	0.008	2.703	0.1238	0.0458	0.7464	0.8833	4.38	25
10.	0.56	0.44	0.008	2.659	0.0825	0.0310	0.7826	0.8975	3.01	21
11.	0.57	0.46	0.008	2.652	0	0.0000	0.8043	0.9296	0.00	19

Tab. 6 Results for Z-2 PROGAZ and concentration C = 3%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm³/s]	Q_z [dm³/s]	u	β	β_t	C' [% v/v]	s [%]
1.	0.07	0	0.01	2.792	0.3667	0.1313	-0.1667	0.8136	11.61	100
2.	0.09	0.04	0.009	2.787	0.2801	0.1005	0.3827	0.8362	9.13	56
3.	0.14	0.08	0.008	2.784	0.1883	0.0676	0.5455	0.8634	6.34	43
4.	0.24	0.16	0.008	2.733	0.1096	0.0401	0.6552	0.8887	3.86	33
5.	0.26	0.18	0.008	2.729	0.1043	0.0382	0.6825	0.8905	3.68	31
6.	0.28	0.2	0.008	2.729	0.09346	0.0342	0.7059	0.8944	3.31	29
7.	0.4	0.3	0.008	2.732	0.07879	0.0288	0.7449	0.8997	2.80	25
8.	0.45	0.34	0.008	2.728	0.07845	0.0288	0.7511	0.8998	2.80	24
9.	0.48	0.36	0.008	2.726	0.08115	0.0298	0.7458	0.8988	2.89	25
10.	0.56	0.42	0.008	2.662	0.07962	0.0299	0.7464	0.8986	2.90	25
11.	0.56	0.44	0.008	2.644	0	0.0000	0.7826	0.9296	0.00	21

Tab. 7 Results for Z-2 PROGAZ and concentration C = 1%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm³/s]	Q_z [dm³/s]	u	β	$β_t$	C' [% v/v]	s [%]
1.	0.06	0	0.01	2.724	0.3504	0.1286	-0.200	0.8154	11.4	100
2.	0.09	0.04	0.009	2.719	0.2525	0.0929	0.3827	0.8422	8.50	56
3.	0.14	0.08	0.009	2.716	0.1567	0.0577	0.5420	0.8723	5.45	43
4.	0.18	0.12	0.008	2.688	0.09481	0.0353	0.6512	0.8934	3.41	33
5.	0.24	0.17	0.008	2.691	0.05514	0.0205	0.6983	0.9081	2.01	29
6.	0.28	0.2	0.008	2.671	0	0.0000	0.7059	0.9296	0.00	29

Tab. 8 Results for Z-2 AWG and concentration C = 5%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm³/s]	Q_z [dm³/s]	u	β	$β_t$	C' [% v/v]	s [%]
1.	0.1	0	0.01	2.922	0.1977	0.0677	-0.111	0.8342	6.34	100
2.	0.12	0.04	0.01	2.922	0.1964	0.0672	0.2727	0.8346	6.30	67
3.	0.16	0.08	0.01	2.901	0.1962	0.0676	0.4667	0.8343	6.33	50
4.	0.34	0.2	0.01	2.897	0.1938	0.0669	0.5758	0.8348	6.27	41
5.	0.38	0.24	0.01	2.9	0.1932	0.0666	0.6216	0.8350	6.25	37
6.	0.44	0.28	0.01	2.901	0.1944	0.0670	0.6279	0.8347	6.28	36
7.	0.54	0.36	0.01	2.865	0.1916	0.0669	0.6604	0.8348	6.27	33
8.	0.58	0.4	0.01	2.748	0.1752	0.0638	0.6842	0.8373	5.99	31
9.	0.6	0.44	0.01	2.654	0.1412	0.0532	0.7288	0.8456	5.05	27
10.	0.6	0.48	0.01	2.607	0.06424	0.0246	0.7966	0.8692	2.40	20
11.	0.6	0.5	0.01	2.546	0	0.0000	0.8305	0.8907	0.00	17

Tab. 9 Results for Z-2 AWG and concentration C = 3%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm³/s]	Q_z [dm³/s]	u	β	$β_t$	C' [% v/v]	s [%]
1.	0.08	0	0.009	2.897	0.1236	0.0427	-0.127	0.8541	4.09	100
2.	0.14	0.08	0.009	2.851	0.1239	0.0435	0.5420	0.8535	4.16	43
3.	0.2	0.12	0.009	2.845	0.1238	0.0435	0.5812	0.8534	4.17	40
4.	0.26	0.16	0.009	2.849	0.1242	0.0436	0.6016	0.8534	4.18	38
5.	0.32	0.2	0.009	2.833	0.1246	0.0440	0.6141	0.8531	4.21	38
6.	0.36	0.24	0.009	2.841	0.1253	0.0441	0.6581	0.8530	4.22	33
7.	0.56	0.4	0.009	2.812	0.1255	0.0446	0.7096	0.8525	4.27	29
8.	0.6	0.46	0.009	2.645	0.06241	0.0236	0.7631	0.8701	2.31	23
9.	0.6	0.48	0.009	2.606	0	0.0000	0.7970	0.8907	0.00	20

Tab. 10 Results for Z-2 AWG and concentration C = 1%

No.	p_r [MPa]	p_t [MPa]	p_z [MPa]	Q_r [dm^3/s]	Q_z [dm^3/s]	u	β	$β_t$	C' [% v/v]	s [%]
1.	0.08	0	0.009	2.898	0.06803	0.0235	-0.127	0.8702	2.29	100
2.	0.16	0.08	0.009	2.881	0.07135	0.0248	0.4702	0.8691	2.42	50
3.	0.18	0.1	0.009	2.848	0.07108	0.0250	0.5322	0.8689	2.44	44
4.	0.24	0.14	0.009	2.867	0.0714	0.0249	0.5671	0.8690	2.43	42
5.	0.26	0.16	0.009	2.862	0.07153	0.0250	0.6016	0.8689	2.44	38
6.	0.4	0.26	0.009	2.868	0.07142	0.0249	0.6419	0.8690	2.43	35
7.	0.48	0.32	0.009	2.871	0.07153	0.0249	0.6603	0.8690	2.43	33
8.	0.56	0.38	0.009	2.808	0.07139	0.0254	0.6733	0.8685	2.48	32
9.	0.56	0.4	0.009	2.771	0.07159	0.0258	0.7096	0.8682	2.52	29
10.	0.57	0.42	0.009	2.748	0.07107	0.0259	0.7326	0.8681	2.52	26
11.	0.57	0.44	0.009	2.649	0	0.0000	0.7683	0.8907	0.00	23

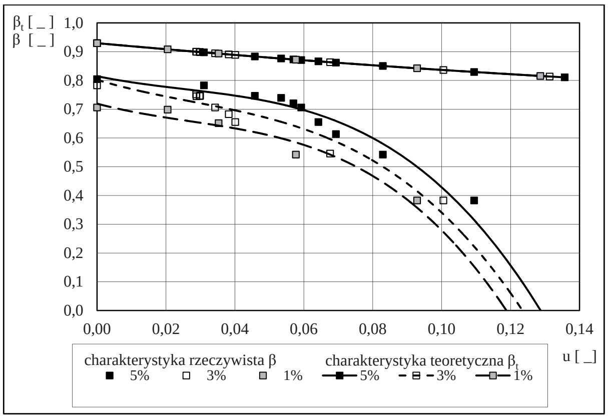

Fig. 10 The theoretical $β_t$ = f(u) and experimental β = f(u) characteristics for the in-line foam concentrate inducer Z-2 "PROGAZ" at three concentrations tested

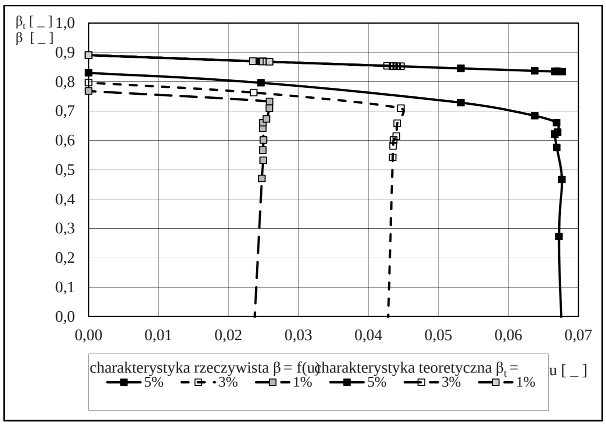

Fig. 11 The theoretical $β_t$ = f(u) and experimental β = f(u) characteristics for the in-line foam concentrate inducer Z-2 "AWG" at three concentrations tested

Conclusion

On the basis of the presented statistics and flow characteristics of linear choke Z2 received during experiments the following general conclusions were formulated:

- Firefighting and Rescue Units in Silesia province is equipped in 45.93% with in-line foam concentrate inducer of type Z-2 and in 69.6% with linear chokes produced by Ł.S.P.M. PROGAZ. Such equipment is on each individual fire-rescue.
- Firefighting and Rescue Units in Silesia province is equipped only in 12.6% with in-line foam concentrate inducer ZUMISCHER produced by AWG, which has a high stability during suction foam.
- Pressure losses are consistent with the Polish standard PN-M-51069 (s < 34%) for working pressure respectively Ł.S.P.M PROGAZ $p_r \geq 0.12$ MPa, and for AWG ZUMISCHER $p_r \geq 0.18$ MPa.
- The theoretical characteristics of the data obtained after substituting equation (9) and the dissolution of the mathematical test, depending on the two-line chokes (in-line foam concentrate inducer) Z-2 "PROGAZ-2" and "AWG", overlap each other. They differ only in the values of the coefficient of spending "u" in the charts $β_t$ = f(u).
- With increasing pressure p_t and p_r a noticeable drop in value of the output of working and suction flow Q_r and Q_z can be observed.
- With the increase of pressure p_t and p_r output ratio "u" decreases until a value equal to zero, while the pressure ratio "β" growing for both tested chokes.
- On the basis of the results obtained during experiments a large discrepancy of the actual concentration of liquid sucked compared to the values determined by the manufacturer on the

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knob adjustment has been found in the case of in-line foam concentrate inducer Ł.S.P.M PROGAZ.

- On the basis of the results obtained during experiments a minimum discrepancy of the actual concentration of the sucked agent to the value indicated by the manufacturer on the knob adjustment not exceeding 1% have been found in the case of in-line foam concentrate inducer AWG ZUMISCHER.

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