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RELIABILITY AND EFFECTIVENESS OF SPRINKLER SYSTEMS IN POLAND

ABSTRACT

The article presents research on the reliability and effectiveness of sprinkler systems in selected countries around the world as well as results of similar studies conducted in Poland based on the data of the State Fire Service. First discussed are the specifics of analysed data and the problems regarding its acquisition and presentation in a simplified form without proper reflection and the assessment of its specificity, quality, detail, uncertainty and completeness. The next step presents the methodology of detailed data analysis based on full description of fire events and the segregation of fire events into separate subcategories. Such an analysis allowed the presumption that in the five-year period 2013–2017, in 94.4% of relevant fire events sprinkler systems in Poland have demonstrated the achievement of their intended goals. This result is similar to the results achieved in other countries known for high level of fire safety culture (USA, UK, Sweden). In the author's opinion, this proves the high immanent reliability of these systems, which results from their simple construction and proper maintenance, and not from the country in which they were installed.

Taking into account these results, it is recommended that Poland should update its regulations in a manner similar to that of developed countries, so that they take into account in a greater extent the protective value and characteristics of sprinkler systems and the benefits resulting from their application. It is also recommended to increase the detail of publicly collected data on fire protection systems in buildings because better knowledge about the characteristics of these systems in Poland may allow achieving an even higher level of their reliability and effectiveness.

KEYWORDS

sprinklers, fire protection systems, reliability, fire statistics

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NIEZAWODNOŚĆ I SKUTECZNOŚĆ SYSTEMÓW TRYSKACZOWYCH W POLSCE

ABSTRAKT

W artykule przedstawiono badania nad niezawodnością i skutecznością instalacji tryskaczowych w wybranych krajach świata oraz wyniki podobnych badań w Polsce na podstawie danych Państwowej Straży Pożarnej. W pierwszej kolejności omówiono specyfikę analizowanych danych oraz problemy związane z ich pozyskiwaniem i prezentacją w formie uproszczonej, bez wystarczającej oceny ich specyfiki, jakości, szczegółowości, niepewności i kompletności. W kolejnym kroku przedstawiono metodykę szczegółowej analizy danych opartej na pełnym opisie zdarzeń pożarowych oraz segregacji zdarzeń pożarowych na odrębne podkategorie. W wyniku tak przeprowadzonej analizy stwierdzono, że w pięcioletnim okresie 2013–2017 systemy tryskaczowe w Polsce wykazały osiągnięcie zamierzonych celów w 94,4% istotnych zdarzeń pożarowych. Wynik ten jest zbliżony do rezultatów osiąganych w innych krajach znanych z wysokiej kultury bezpieczeństwa pożarowego (USA, Wielka Brytania, Szwecja). Zdaniem autora świadczy to o wysokiej niezawodności tych systemów, która wynika z ich prostej konstrukcji i właściwej konserwacji, a nie z kraju, w którym zostały zainstalowane. Biorąc pod uwagę te wyniki, zaleca się, aby Polska zaktualizowała swoje przepisy w sposób zbliżony do krajów rozwiniętych, tak aby w większym stopniu uwzględniały one wartość ochronną i właściwości

instalacji tryskaczowych oraz korzyści wynikające z ich stosowania. Zaleca się również zwiększenie szczegółowości gromadzonych publicznie danych o systemach ochrony przeciwpożarowej w budynkach, gdyż lepsza znajomość charakterystyki tych systemów w Polsce może pozwolić na osiągnięcie jeszcze wyższego poziomu ich niezawodności i skuteczności.

SŁOWA KLUCZOWE

tryskacze, instalacje przeciwpożarowe, niezawodność, statystyki pożarowe

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INTERNATIONAL RESEARCH

The reliability and effectiveness of sprinklers have been tested around the world for many years. The most recent research includes studies conducted in several countries known for a high level of fire protection, such as the USA 2017 [1], UK 2017 [2] and Sweden 2017 [3]. These are quite extensive and detailed studies covering such issues as reliability, effectiveness, causes of failure, reasons for failure, number of sprinklers activated, fire area, fire characteristics, building type, number of fatalities and injuries among building occupants and firefighters or type of sprinkler system. Table 1 shows the main results of each mentioned study.

The results prove a high reliability of sprinkler systems in terms of activation, which is 92–99%, although some attention should be paid to varying approaches to calculations in different countries and a number of circumstances that impair the final result, which would be even higher after taking them into account (e.g. manual intervention, which often reduces the chance of sprinklers being activated). Swedish data show that the collected data are less detailed than those in the USA and UK. For this reason, Swedish researchers had to resort to painstaking analyses of verbal descriptions of all events and investigation using other sources (local media, personal communication with the affected organizations or the fire service involved in the firefighting activities). As a result, the final Swedish score (99%) represents an increase over the previous 2008 study, where sprinkler reliability was found to be 92%. An additional source of significant data and considerations on

the reliability of sprinkler systems, not mentioned here in detail, is the 2013 New Zealand study [5]. In addition to the data, the mentioned scientific article also includes a theoretical analysis of the issues of reliability and effectiveness of sprinkler systems.

Table 1. Summary of research from USA, UK and Sweden

USA	Number of events	49840
	Years covered	2010–14
	Percentage of events where sprinklers became activated and were effective	88%
	Percentage of events where sprinklers became activated but were not sufficiently effective	4%
	Percentage of incidents where sprinklers failed	8%
	Percentage of events among those where sprinklers became activated in which sprinklers helped control the fire	96%
	Percentage of events where one sprinkler became activated	79%
	Percentage of events where five or fewer sprinklers operated	97%
	Percentage among failure events where the cause was that the installation was turned off	40%
	Percentage among failure events where water did not reach the fire	51%
	Other failure and ineffectiveness factors: manual fire extinguishing intervention, insufficient water supply, lack of maintenance, damage to system components, inadequate installation for the specific type of fire	
UK	Number of events	2294
	Years covered	2011–16
	The number of times the sprinklers have operated	945
	Number of events where the effects of sprinklers on the fire are known	677

cd. Table 1

UK	Number of events where the cause of the failure has been determined	879
	Percentage of events where a fire was controlled by sprinklers	62%
	Percentage of events where a fire was extinguished by sprinklers	37%
	Failure factors: fire in an area not covered by sprinklers (370), fire too small (115), system off (18), manual intervention (13). Number of events in which operation was expected but did not happen (57).	
	Reliability in terms of activation	94%
	Effectiveness when activated	99%
Sweden	Number of events	2294
	Years covered	2005–14
	Number of incidents where sprinklers did not operate or did not operate as expected / satisfactorily	611
	Number of events in which, after detailed analysis, it was found that the likely cause was a failure of the sprinkler installation	3
	Reliability / efficiency	99%
	Reasons for failure: manual intervention, fire too small, smoke only, other type of installation, fire in a hidden space, fire in a tank, machine, engine, inside a structure, in a ventilation system, chimney, toilet, in an area not covered by sprinklers, outside the building	

Source: own study

PREVIOUS RESEARCH IN POLAND

In recent years several statistical reports were published and discussed from the period of 2010–2012, which concerned the reliability of fire protection

measures, including fire suppression systems. These reports were based on fire events attended by the State Fire Service. The SFS collects such data submitted by firefighters about each event in a special incident database (SWD – Command Support System). Alarming conclusions have been drawn from the presented summaries suggesting that in certain types of buildings fire suppression systems in Poland that operate in the event of a fire are at an operational order at the level as low as 50–60%, and on average in about 70%. It is a very low level, which differs significantly from the global data, and therefore the authors decided to investigate this problem in more detail. This is necessary as the data on reliability has a significant impact on the proper understanding of fire suppression systems by the involved professional communities, i.e. owners and managers of buildings, entrepreneurs and investors, insurers, fire experts, architects, designers, as well as officers of the State Fire Service and other experts involved in legislative processes regarding fire regulations. Incorrectly presented data affect adversely the credibility of the installation, which proves to be particularly unfavourable for the fire suppression industry directly affected by it, while the dissemination of unreliable knowledge concerns and affects the activities of all these environments. Inaccurate information on the reliability of fire suppression installations may also have far-reaching negative financial consequences for the country's economy, as the reliability of installations is taken into account in risk assessment and setting premiums by insurers. In the interest of the entire Polish community of fire protection specialists, this issue should be clarified as objectively as possible and consistently with reality.

DATA ANALYSED IN THIS RESEARCH

The analysis of effectiveness and reliability of sprinkler systems in Poland was possible thanks to the reports of the State Fire Service submitted in the years 2013–2017 to the Command Support System. This data set was investigated by the author in his master dissertation [7]. The administrator of the data contained in the system is the Main Headquarters of the State Fire Service, which collects reports on events from all over the country. The report form includes fields concerning the presence, operability and activation of the suppression system.

Table 2. Fire protection system data in the incident report filled by firefighters after returning to their fire station

Type of system	Present	Operational	Activated / Used
Detection	Y / N	Y / N	Y / N
Alarm monitoring and transmission	Y / N	Y / N	Y / N
Suppression	Y / N	Y / N	Y / N
Smoke control	Y / N	Y / N	Y / N
Internal hydrants	Y / N	Y / N	Y / N

Source: own study

In the years of 2013–2017 there were 936 fires recorded in buildings furnished with a fire suppression system. Unfortunately, there are some doubts since a general presence of the installation is insufficient to enable the determination of the type of such installation (sprinkler, gas, fixed, semi-fixed, etc.). There are even greater doubts concerning the operability of the installation. If the data were presented in a non-reflective manner, we would get results shown in Fig. 1, which imply that the suppression systems are operable order only in 55% of cases.

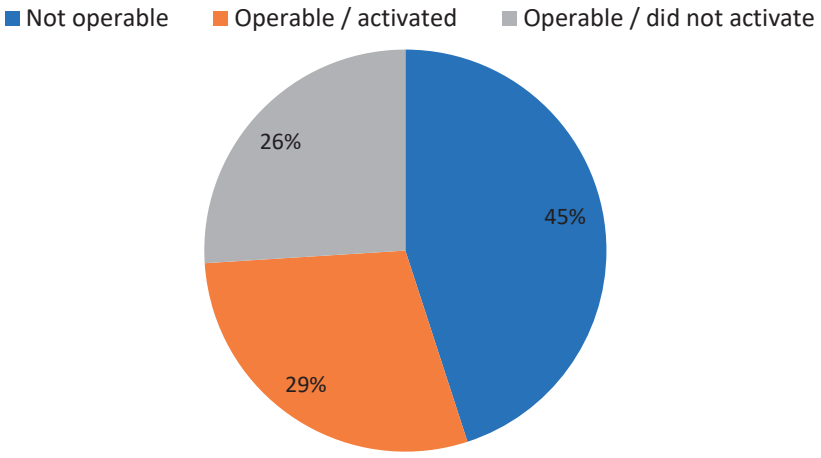

Fig. 1. Simplified summary of data on the operability and activation of fire extinguishing systems based on the data of the State Fire Service (without an in-depth analysis)
Source: own study

This is a very superficial conclusion, as it does not take into account important nuances pertaining to the way data is entered. This issue was discussed in detail by the author in another article [6]. The aforementioned article describes the results of a survey carried out among firefighters, which indicate that when completing a report on fire suppression systems, especially in terms of whether it is operational or not, commanders have a big problem with determining this aspect. This arises from several diverse reasons, mainly due to the lack of specialist knowledge and real physical and time capabilities during the incident, which does not allow a professional and correct judgment of the condition of the installations on site. This leads to a significant error in conclusions drawn from raw data without proper analysis.

After a detailed data processing as presented in following tables and graphs, the sprinkler system either did not activate or was ineffective in 5.6% of relevant 144 cases (7 and 1 cases respectively) and in 94.4% of relevant cases the installation operated and controlled or extinguished the fire (73 and 63 cases respectively). The activation reliability (successful activations) can be established at 95.1% of relevant cases.

An analysis of the above chart suggests that almost half of all cases are made up of only two groups of fires, i.e. fires that are too small and food left unattended (on cookers, in microwaves and in ovens). Fires put out by the quick reaction of employees are another significant group. This shows the importance of appropriate training and activities undertaken by the personnel who, most often using handheld firefighting equipment or internal hydrants, suppressed the fire or delayed its development until the arrival of the fire brigade. The "fire in another area/compartment" item includes cases where the sprinklers were not directly in the fire area, e.g. sauna room, chimney ducts or garage. In most cases, the spontaneous suppression ended with short-circuits in electrical switchboards, where the heated cables generated smoke that triggered the fire alarm system. A fire in a location not fitted with sprinklers includes such cases, as student dormitories where a sprinkler system is unlikely to occur. Unchecking this option by firefighters can be explained, among other things, by the firefighters confusing the extinguishing system with a hydrant system.

Table 3. Detailed statistics of events involving buildings with fire suppression systems

Event group – installation operation	The category of the event in the context of operation of an installation	Number of events	% in the event group	% of all events	
It worked, or it should work	The system extinguished the fire	63	43.8	6.73	15.4
	The system controlled the fire	73	50.7	7.80	
	The system did not work or was not effective	8	5.6	0,85	
It did not work because objectively it did not have to or a shortcoming of the event reporting system	Unattended food (often smoke only)	191	24.1	20.41	84.6
	Manual response of the personnel	142	17.9	15.17	
	Fire too small	196	24.7	20.94	
	Another type of an installation	102	12.9	10.90	
	Insufficient incident description	14	1.8	1.50	
	Self-extinguishing	44	5.6	4.70	
	Supervising work in facilities with installation	2	0.3	0.21	
	Fire in a location without sprinklers	78	9.8	8.33	
	Fire in another area	23	2.9	2.46	
Total		**936**	**100**	**100**	**100**

Source: own study

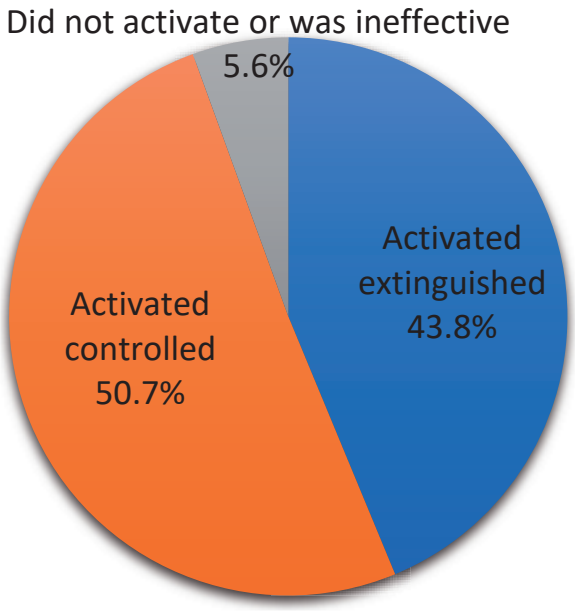

Fig 2. Percentage of events after discounting low significance data
Source: own study

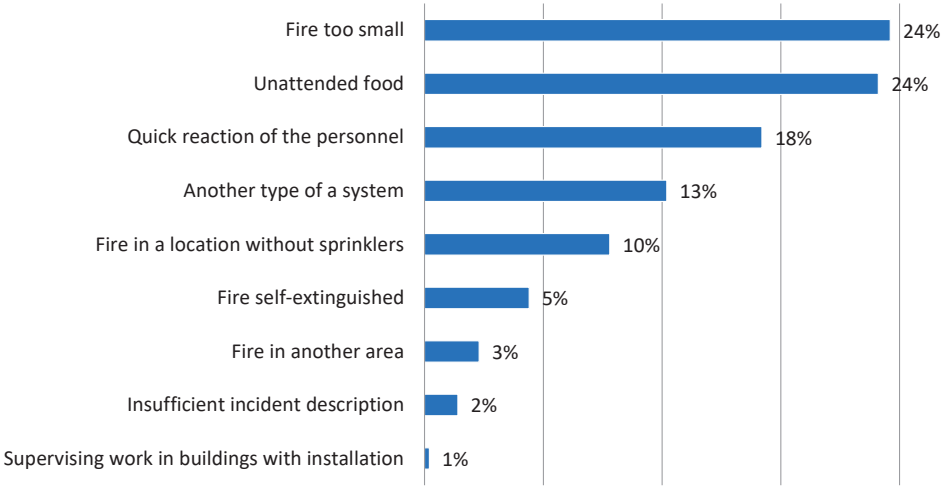

Fig. 3. Reasons for discounting an event for establishing reliability and effectiveness
Source: own study

Table 4. A detailed breakdown of the category where an event qualifies as a sprinkler failure

The category of the event in the context of the operation of the installation	Specified category of the event	Number of events
fire too small	electric	121
	machines and devices	37
	garbage	15
	plastic and cellulose fires	8
	human inattention (flares, candles, cigarette butts)	6
	fire hazardous work	5
	another	4
food unattended	a dish on the stove	130
	microwave	31
	stove	18
	fryer	10
	another	2
fire in another area / compartment / location without sprinklers	multi-family / single-family	27
	outside the building	13
	student house	11
	technological installation	10
	another	6
	sauna	5
	bathroom	3
	hotel	3
different installation	gas installation	48
	deluge system	19
	other installation, e.g. steam, technological	12
	internal hydrant	10
	dry riser	5
	spark extinguishing system	3
	semi-permanent water / foam installation	3
	powder installation	1

Source: own study

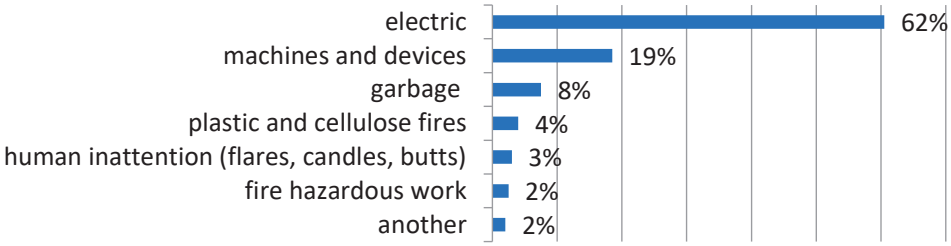

Fig. 4. Fires too small
Source: own study

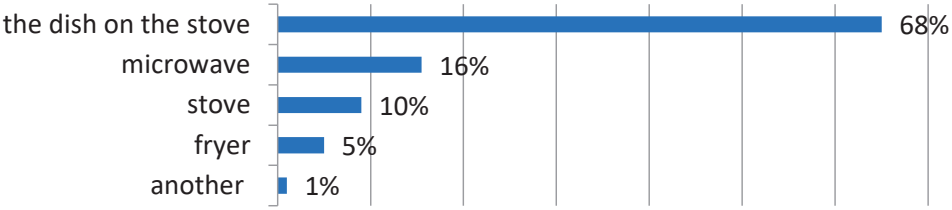

Fig. 5. Dishes without supervision
Source: own study

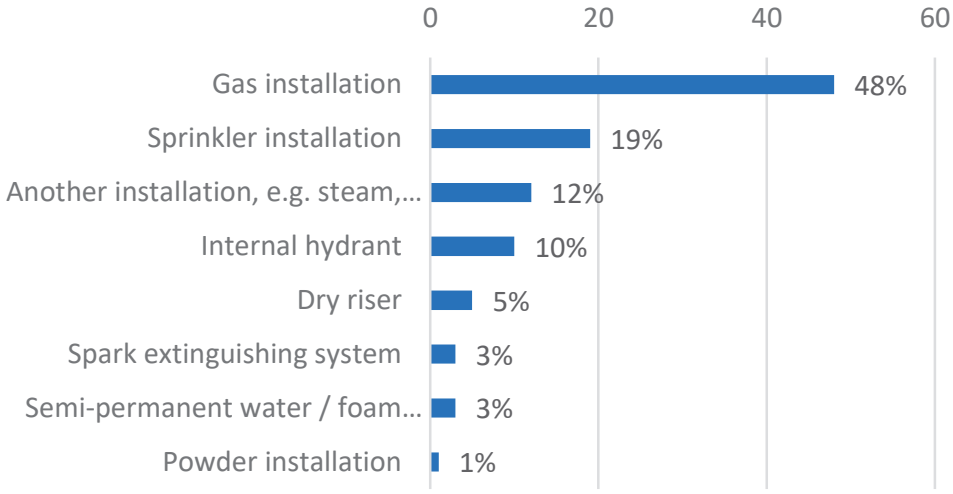

Fig. 6. Types of installations
Source: own study

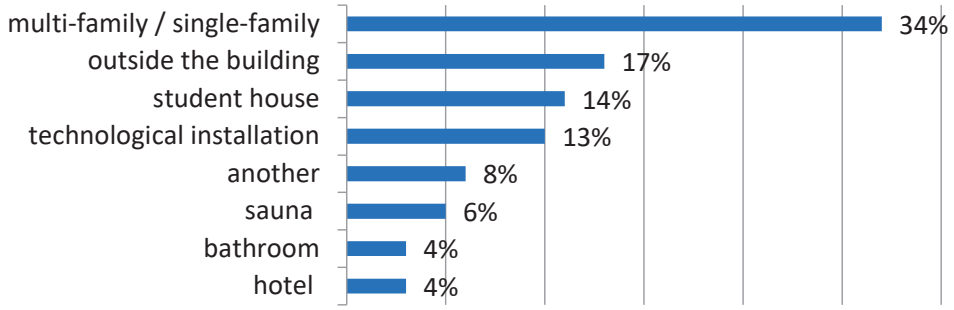

Fig. 7. Cases also classified as "other installations"
Source: own study

EFFECTIVENESS OF SPRINKLER SYSTEMS

The number of events where sprinkler system became activated (137) has been grouped into those in which the sprinkler system extinguished the fire, controlled it or was ineffective. The installation present in the facility extinguished the fire in 46% of these cases and controlled the fire in 53.3 % of cases. Only in one case (0.7% of cases) the installation proved to be so ineffective that it has in fact led to extensive losses. This leads to conclusion that the effectiveness of sprinkler systems in Poland is 99.3% once activated.

Table 5. Effects of sprinkler system operation (when activated)

Controlling the fire	Extinguishing the fire	Ineffective
73 events (53.3%)	63 events (46.0%)	1 event (0.7%)

This statistic shows that when the sprinklers became activated, they contributed significantly to controlling of the fire. This allows categorisation of automatic fire sprinkler systems as devices of very high operating reliability, i.e. as an almost completely reliable installation for the protection of various types of facilities. The result of the effectiveness of sprinkler installations puts Poland on par with the international rankings in this aspect.

The events in the table below are instances where the sprinkler system has failed or did not function as required. This comparison shows that sometimes when dividing events into different subcategories, one has to deal

with uncertainty and with an insufficient scope of available information. In almost all of these cases it was possible to try to find answers to the missing questions, but unfortunately full precision in this respect was beyond the time scope of this analysis.

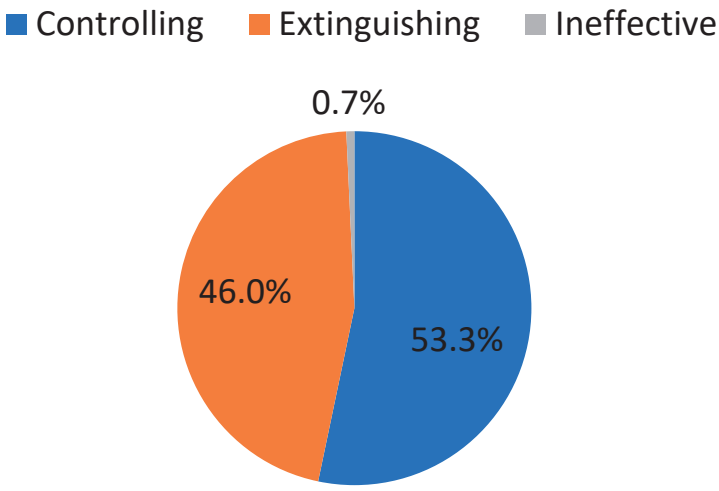

Figure 8. Effects of sprinkler system operation (when activated)
Source: own study

Table 6. Cases of no activation or ineffectiveness of the installation

No.	Case type	Building type and event characteristics	Clarification of the case qualification	Losses [PLNm]	Fire size [m^2]
1	No activation	Year 2014. Multi-family building (underground car park) car fire; the sprinkler above the vehicle did not work; damaged ceiling of the building; burned wires hung over the car	No water applied to the car directly under the sprinkler. Taking into account the information on destruction of the ceiling, it is assumed that conditions for activating the sprinkler could exist	0.13	20

cont. Table 6.

No.	Case type	Building type and event characteristics	Clarification of the case qualification	Losses [PLNm]	Fire size [m^2]
2	No activation	Year 2014. Production and warehouse building (ink mixing and printing house) explosion; fire within the entire space of the ink mixing room and printing house; no water in internal hydrants; difficulties in the water intake for extinguishing purposes	The course of the event is unknown. On the basis of the report, it is not possible to assess whether the installation should be operable or not, or whether the explosion cased damage to it. If the explosion has spread the fire over a large area, this is a scenario that is beyond the scope of the installation.	99.9	2200
3	No activation	Year 2014. Production and warehouse buildings (technological line) dust explosion; employees extinguished the fire with the use of internal hydrants, and then 4 fire extinguishing currents of the State Fire Service	The course of the event is unknown. The report provides no information whether the installation should work or not, and whether the explosion did not damage it. If the explosion has spread the fire over a large area, this is a scenario that is beyond the scope of the installation. Personnel firefighting operations may have reduced the chances of the sprinklers being triggered.	0.5	100

cont. Table 6.

No.	Case type	Building type and event characteristics	Clarification of the case qualification	Losses [PLNm]	Fire size [m^2]
4	Ineffectiveness	Year 2014. Production and warehouse buildings (technological line) pellet fire; large amount of fuel; the installation is ineffective - the fire has spread	Despite the operation of the installation, the fire has spread. The installation is considered not to be fully effective. The reason for the ineffectiveness is unknown, but it is possible that the building was operated in a manner other than as foreseen in the installation design	1.5	284
5	No activation	Year 2015. Production and warehouse buildings (technical room) Fire: 8 cabinets in the technical room; operations using an internal hydrant	The fire is severe enough to raise the temperature in the room with a capacity of 1512 [m^3] and cause its complete smoke-logging. Such conditions are usually sufficient to activate the sprinkler.	1	8

cont. Table 6.

No.	Case type	Building type and event characteristics	Clarification of the case qualification	Losses [PLNm]	Fire size [m^2]
6	No activation (system failure)	2015. Production and warehouse buildings (fire tank) freezing of the reduction valve; pressure drop and commissioning of the installation; fire of the mantle of the fire protection tank	The installation led to the causeless activation of the sprinklers in the facility, and then the heating spiral preventing the water from freezing caused the tank shell to ignite. The event is classified as an installation failure.	0.055	65
7	No activation	2016. Shopping mall (overground car park) car fire; employees extinguished with handheld equipment	The installation could start. It is not known what effect the staff reaction had. Regardless of the amount of powder used to extinguish the fire (2 units 25 kg and a 6 kg extinguisher), the fire was only extinguished by fire service units. It appears that the sprinklers should have become activated in those specific conditions.	0.015	2

cont. Table 6.

No.	Case type	Building type and event characteristics	Clarification of the case qualification	Losses [PLNm]	Fire size [m^2]
8	No activation	2017. Production and warehouse building (Production line) fire of insulation of polyethylene foam pipes; fire of the entire zone: roof collapsed	The fire caused collapse of the roof. The reasons for the failure of the installation are unknown. Presumably the fire spread was faster than expected or other circumstances occurred (e.g. installation shut down)	8	1166

Source: own study

SUMMARY

Data collected in Poland were found not to be as detailed in terms of the reliability and effectiveness of sprinklers systems as data collected in other countries, especially in the USA and United Kingdom. The way data are currently collected in Poland gives room for drawing wrong conclusions. The operability of the installation is the least reliable of the collected data due to many reasons, especially the knowledge and training of firefighters who draw up fire incident reports. The presence of the installation, although it seems simple, is also often doubtful, because the analysis shows that firefighters assigned with filling in the report sometimes confuse the fire suppression installation with the hydrant installation. Based on the data collected in this way the State Fire Service is unable to properly monitor the reliability and effectiveness of fire suppression systems and other fire protection systems, which is disadvantageous for needs of appropriate development of pertinent regulations and for shaping the knowledge of both officers involved in rescue and firefighting activities and those involved in fire prevention. Currently, the only analysis that allows achieving an improvement in the precision of

estimates concerning the reliability and efficiency of the installation is a direct analysis of the descriptions from each event where the presence of the fire extinguishing installation was marked. Only this type of approach allows grouping events into relevant categories. Thanks to this detailed analysis based on 936 descriptions, 144 events have been selected as relevant for needs of further analyses, which subsequently established that the automatic fire sprinkler systems was activated in 137 (95.1%) of the analysed cases and operated according to its intended goal and function, and namely controlling or suppressing the fire and thus preventing significant losses in 136 (99.3%) during those events. In one event (0.7% of all cases where sprinklers have become activated) they proved to be ineffective to control the fire.

High reliability and efficiency of sprinkler systems should be adequately taken into account in Poland under relevant fire regulations. At present, this seems to be insufficient, for example in the rules for increasing the area of single-story production and warehouse buildings, according to which a 100% increase in the compartment can be achieved either by using sprinklers or using a fire ventilation system. It is not a rational rule if one takes into account the fact that the fire ventilation system does not limit the fire size (heat release rate), which eventually may be too extensive to be suppressed when the fire brigade starts their extinguishing operations. In many developed countries the reward for sprinkler system is several times higher in terms of compartment area or even allows an unlimited compartment area.

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