EUROPEAN FIRE SPRINKLER NETWORK

Position paper on the interaction between sprinklers and smoke ventilation in warehouses

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Introduction

Sprinklers and smoke and heat ventilation systems (SHEVS) are widely used fire safety measures, often required in building codes. Sprinklers control fires, extinguishing them in about a third of cases and otherwise keeping them small. SHEVS allow heat to be removed and smoke to be cleared, so that occupants can see to escape. Once the fire brigade arrives, SHEVS can clear smoke to help firefighters find the fire. At first glance the two systems appear to complement each other, and often they do. Yet in some cases the combination of sprinklers and smoke ventilation can produce worse outcomes than sprinklers alone. This is because the operation of the smoke ventilation system too early releases the heat needed at the ceiling to activate the sprinklers, delaying their activation and allowing the fire to grow. Open smoke vents can also draw hot gases towards them and towards sprinklers that are not over the fire, so that sprinklers activate to release water in the wrong place.

In many countries debates about the interaction between sprinklers and SHEVS were held long ago and it was agreed how to combine the two systems for the best result. The EFSN has learned that in some countries these agreements are now being reopened. This position paper has been written to set out how best to manage combinations of sprinklers and SHEVS. It focusses on warehouses, where sprinkler systems are most vulnerable to negative impacts from a SHEVS if it operates first.

Purpose of sprinklers

In all buildings sprinkler systems operate when a fire is relatively small, needing moderate amounts of water to keep the fire small so that when firefighters arrive they can quickly complete extinguishment. In total far less water is used than when firefighters tackle an unsprinklered fire, which would be much larger on their arrival. In many cases sprinklers extinguish the fire before firefighters arrive. Damage to the building and its contents is limited and activities can often resume the same day. Smoke and heat production are reduced, compared to the same fire without sprinklers, because the fire remains small. Where a SHEVS is fitted with sprinklers, the SHEVS designer can often assume there will be less heat and smoke to ventilate thanks to the sprinkler system, which in turn can reduce the cost of the smoke ventilation system.

In smaller rooms such as in apartments and hotels the cooling of smoke causes it to contract, reducing room overpressure and the tendency for smoke spread to other rooms. This is less relevant to warehouses, which have high ceilings and large volumes to accumulate smoke.

In warehouses the main purposes of sprinklers are to:

- Detect the fire, give an alarm and start to fight the fire
- Keep the fire small to aid firefighters in their extinguishment work
- Protect the lives of those who have not evacuated the building
- Prevent damage from fire to the building and its contents
- Prevent business interruption due to damage from fire
- Prevent damage to the environment from emissions of toxic gases or run-off of large quantities of contaminated extinguishing water

Sprinklers complement the work of firefighters. Warehouses are not usually designed to withstand burnout of their contents but have limited fire resistance and are vulnerable to collapse when they experience a fire. This means that it can be very dangerous for firefighters to enter these buildings unless the fire has been controlled by a sprinkler system. Without a sprinkler system, firefighters

often must restrict their efforts to ensuring the fire does not spread through radiation to nearby buildings. The building on fire then becomes a total loss.

Performance of sprinklers

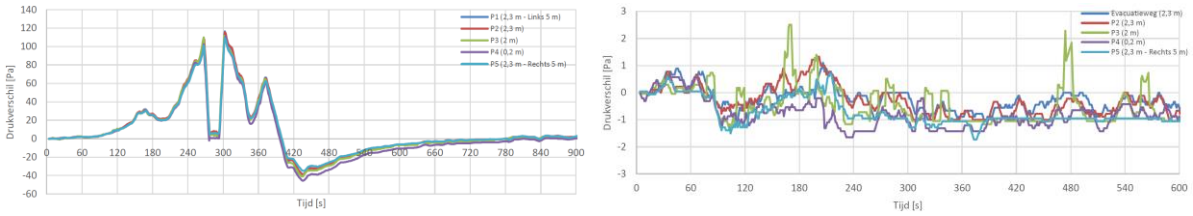
Individual sprinklers operate as they are heated by a fire and spray water onto the fire. Usually, the first sprinkler to operate cools the fire sufficiently so that other sprinklers do not operate. An analysis of over two thousand fires in buildings protected with sprinklers, conducted on behalf of the National Fire Chiefs Council in the UK [1], found that in 65% of fires only one sprinkler operates and in 84% of fires just one or two sprinklers operate. That said, research reports of warehouse fire tests often reveal that more than two sprinklers operate. The same UK study found that 37% of fires were extinguished by the sprinkler system and that 93% of fires were either extinguished or controlled.

Reliability studies conducted in other European countries found the following, even higher figures:

Denmark 97, 98% [2]
France 97-100% [3]
Germany 98% [4]
Poland 95% [5]
Sweden 99% [6]

Not only do sprinklers limit and reduce the fire heat release rate, they cool the hot gases so that they contract. This reduces room overpressure and the tendency for smoke to spread to other rooms. This benefit is particularly relevant in apartment buildings and care homes. Fire tests in The Netherlands [7] showed that a fire in an apartment forced smoke into neighbouring apartments, the corridor and other floors. This did not happen when a suppression system was fitted. Similarly, fire tests in Belgium [8] showed that smoke spread from a communal living room in a care home to adjacent bedrooms, despite their fire doors being shut. With sprinklers smoke did not spread to the bedrooms. The room overpressure exceeded 100 Pa without sprinklers but did not reach 3 Pa with sprinklers, as shown in Figure 1.

Figure 1: Communal room overpressure in Belgian fire tests without and with sprinklers



Without sprinklers

With sprinklers

[1] Efficiency and Effectiveness of Sprinkler Systems in the United Kingdom: An Analysis from Fire Service Data, Optimal Economics, Edinburgh, UK, 2017
[2] Reliability of Water Sprinkler Systems, DBI, Hvidovre, Denmark, 2003 & 2008
[3] Facteurs d'influence sur la capacité d'une installation sprinkleur à fonctionner correctement, CNPP, St Marcel, France, 2012
[4] Schadenspiegel, Munich Re, Munich, Germany, 2006
[5] Reliability and Effectiveness of Sprinkler Systems in Poland, The Main School of Fire Service, Warsaw, Poland, 2021
[6] Tillförlitlighet för automatiska vattensprinkler-anläggningar, Brandkonsulten AB, Stockholm, Sweden, 2017
[7] Rookverspreiding in woongebouwen, Institut Fysieke Veiligheid, Arnhem, The Netherlands, 2020
[8] Brandveiligheid in ouderenvoorzieningen, Exova WFR Gent & Universiteit Gent, Belgium, 2016

For warehouses, smoke spread from the room where the fire starts to other rooms due to room overpressure only applies to offices. Where the goods are stored, the large volumes and openings in walls mean overpressure is unlikely. Nevertheless, a sprinkler system will greatly reduce the volume of smoke produced by a fire in a warehouse and so help to protect the lives of those in the building.

Purpose of SHEVS

SHEVS remove heat and smoke from the part of a building where a fire starts or prevent it entering another part of the building (as in the case of stair pressurisation or the use of ventilated lobbies). It is the toxic gases in smoke that cause most fire deaths. Smoke removal assists building occupants to escape by preventing a deterioration of visibility and exposure to toxic gases. Smoke removal can also help firefighters to see the fire.

Many jurisdictions require SHEVS as a life safety measure to maintain smoke-free escape routes in residential and public buildings where evacuation can be slow because occupants are unfamiliar with the building, asleep or need assistance to escape, or are affected by a combination of these factors.

While some claim that SHEVS protect property from smoke damage, we are not aware of evidence that SHEVS slow fire development, nor of evidence that they reduce property damage. Property insurers rarely advocate SHEVS. However, if sprinklers have controlled a fire it may help to reduce contents damage if the smoke is then promptly ventilated.

Purpose of SHEVS in warehouses

In the past, SHEVS in warehouses were operated manually by firefighters to vent heat from brick or concrete warehouses so that they would not be structurally weakened. Firefighters could then attack the fire inside the building without risk of its collapse. Modern warehouse designs with exposed or lightly protected structural steel are more vulnerable to a rise in temperature and require an automatic sprinkler system to prevent structural collapse.

In a warehouse, occupants are awake and can be assumed to be familiar with the building since most jurisdictions require periodic fire drills where employees learn to move promptly on hearing the fire alarm and to gather at an agreed location outside the building. The large volume and high ceiling of a warehouse can accumulate smoke while visibility remains clear at floor level, allowing occupants plenty of time to evacuate before smoke fills the volume above them down to eye level to become dangerous. Hence an automatic SHEVS offers little benefit to life safety in a warehouse.

Instead SHEVS can be required as a tool to help firefighters see the fire. For example, the authorities in Catalonia in Spain issued requirements for the operation of SHEVS in industrial buildings which state, '*In industrial uses, especially in warehouses, the smoke and heat ventilation system design goals tend to be the ones to help with fire-fighting and property protection operations.*' [9] Not all jurisdictions require SHEVS in warehouses and modern fire brigades are equipped with thermal imaging equipment, which assists firefighters to see the fire while smoke is still present. Often firefighters vent smoke using positive pressure fans before and while they extinguish the fire and smoke vents can assist this process. As a SHEVS in a warehouse is a tool for firefighters to improve

[9] Instrucció Tècnica Complementària – Sistemes de control de temperature I evacuació de fums en magatzems industrials que disposen de sistemes de ruixadors automatics SP 129:2018, Generalitat de Catalunya

visibility there is no technical need for it to operate automatically. Instead, its operation should be placed in the control of firefighters so that they can use it when they arrive at the scene. For these reasons, some jurisdictions require that SHEVS in a warehouse be configured for manual activation by firefighters or designed to operate after the sprinklers. In a warehouse it is also common for SHEVS to be opened at night during the summer to cool the building. This can also delay the operation of the sprinkler system. One solution is to add a sprinkler beneath each vent.

Interaction between smoke ventilation and sprinklers in warehouses

Sprinklers are activated by heat rising from the fire below to accumulate and spread at ceiling level to reach the sprinkler. In sprinkler system design standards the maximum distance of a sprinkler from the ceiling is limited to ensure that its thermal element is exposed to heat as soon as possible. If a SHEVS operates there is a concern that the heat will escape and not activate the sprinklers, or at least that their activation will be delayed. Any delay in activation means that the sprinkler system has to tackle a larger fire and if the delay is too great the fire may be so large that it overwhelms the sprinkler system. Contributing to this potential scenario is the likelihood that an open smoke vent will draw hot gases towards it, activating sprinklers that are not over the fire and so depleting the available water pressure and flow to sprinklers that are over the fire. There would then be a risk that the fire would overwhelm the sprinkler system.

Ceiling-only sprinkler protection designs using ESFR or CMSA sprinklers are particularly dependent on heat reaching the sprinklers as fast as possible. Any delay in their activation due to an open smoke vent allows the fire to grow larger and could impact the control of the fire by the sprinklers.

As the purpose of SHEVS in a warehouse is to remove smoke to help firefighters see the fire, it need not operate before the sprinklers, nor need it operate automatically. While this paper has to this point discussed the impact of SHEVS on sprinkler systems, the activation of a sprinkler system also impacts the operation of a SHEVS. Sprinklers cool hot fire gases and smoke, causing them to contract and reducing their buoyancy. Videos of fire tests of sprinklers on rack storage[10] show the smoke and steam moving downwards once the sprinkler system has controlled the fire. With this loss of buoyancy natural smoke ventilation will be less effective so there is a case for using mechanical ventilation where a SHEVS is to be installed in a warehouse. A second benefit is that mechanical SHEVS require fewer vents. Here again, the system is for firefighters and the decision to use it should be for them to make on arrival at the scene.

In 1998 the National Institute of Standards and Technology in the US published a report [11] on a two-year research project funded by the National Fire Protection Research Foundation to document 'the fire protection performance relationships of sprinklers, vents and curtains.' NIST conducted some tests using a heptane burner, manually turning up the heat release to follow an αt^2 curve in line with the typically assumed design fire for a SHEVS in warehouse. The ceiling height was 7.6 m. Tests were also conducted with the Factory Mutual Research Corporation standard plastic test commodity, a cartoned group A unexpanded plastic consisting of corrugated paper cartons containing polyethylene cups stacked on wooden pallets. Vents were individually operated manually or using fusible links. The researchers found that when the fire was not ignited directly beneath a vent there was no delay in the activation times of the sprinklers nearest to the fire. However, when the fire was directly below a vent, if the researchers manually activated the vent before the sprinklers there was

[10] FM Global fire tests, YouTube

[11] Sprinkler, Smoke & Heat Vent, Draft Curtain Interaction – Large Scale Experiments and Model Development, National Institute of Standards and Technology, Gaithersburg, MA, USA, 1998

a significant delay in activation of the sprinklers. The researchers also found that draft curtains increased the number of sprinklers that operated and affected their discharge pattern, so that fire damage was greater. Regarding vent operation, the tests showed that sprinklers could delay or prevent the operation of vents operated by a fusible link.

In 2005 the University of Karlsruhe, on behalf of the Standing Committee of German State Interior Ministers and Senators conducted research on the interaction between sprinkler and smoke ventilation systems. [12] Experiments were conducted with SHEVS operating before, at the same time and after the sprinkler system. The heat source was a propane burner operating at a steady 100-1,150 kW, a low heat release rate for a warehouse fire and without any increase in heat release rate over time (in fire tests with combustible materials on pallets the heat release rate is typically greater than 5 MW when the first sprinkler operates). The ceiling was at 7.25 m, similar to the above NIST experiments but low for a warehouse. Under these conditions the SHEVS had little effect on sprinkler activation. While these tests were intended to address the warehouse situation, they were so far from representative that their conclusions cannot safely be applied to that scenario. Sprinkler activation times at the low heat release rates in these tests were much longer than would be expected for a rack storage fire and much longer than for the NIST experiments; the fire did not grow after ignition and the heat release from the burner remained constant after the sprinklers operated. None of this is representative of a warehouse fire in a sprinklered building. However, the tests indicate that for lower ceiling heights and slower fire growth rates there may not be a negative impact from the SHEVS on the sprinkler system. Thus, a sprinkler system in a corridor in a hotel should be effective if a smoke vent opens.

FM Global, a major property insurer, has conducted more recent research. With the help of over a dozen universities and research institutes it has developed the open source FireFOAM [13] computational fluid dynamics modelling software. Its predictions correlate well with the results of full-scale rack storage fire tests, greatly reducing the amount of fire testing required to verify new sprinkler design concepts. Using this tool FM Global showed that in a rack storage scenario without a vent, the first sprinkler would open after 61 seconds when the heat release rate was 7.5 MW, whereas when a vent directly above the sprinkler opened at 39 seconds (22 seconds before the sprinkler activated without a vent), activation of the first sprinkler was delayed by almost 60 seconds and the heat release rate was then be over 20 MW (see Table 1). The model also showed no reduction in heat release rate due to the vent. [14]

Table 1 Effect of vent presence and offset on sprinkler activation in fire tests by FM Global

Vent offset (ft)	Vent activation (s)	Sprinkler activation (s)	Fire size at sprinkler activation (MW)
No Vent	-	61	7.5
0	39	120	21
5	42	65	8.2
10	86	61	7.5

[12] Untersuchung der Wechselwirkungen zwischen gleichseitig betriebenen Sprinkler- und Rauch/Wärme-Abfuhr-Systemen, C. Axel Fohl, Forschungsstelle für Brandschutztechnik an der Universität Karlsruhe (TH), Germany, 2005

[13] https://www.fmglobal.com/research-and-resources/research-and-testing/theoretical-computational-and-experimental-research/open-source-fire-modeling

[14] The Impact of Automatic Smoke and Heat Vents on Sprinkler System Performance, Alex Krisman, K Meredith & Y Wang, FM Global, Proceedings of Interflam 2019

Position of insurers

Insurers and their representative organisations do not call for SHEVS to be fitted in warehouses. In fact, many advise against automatic SHEVS. Below is a brief overview of their guidance.

France

APSAD R1 [15] is the design and installation rule for sprinkler systems specified by many French insurers. French government regulations require SHEVS in most buildings, including warehouses. To accommodate this requirement while minimising the negative impact on the sprinkler system, APSAD R1 includes table '*T13.2.7.5 Release mode for smoke ventilation as a function of the type of sprinklers and risk protected*'. Over two pages this table details criteria for the opening of smoke vents. For CMSA and ESFR sprinklers, which are widely used in warehouses, it specifies an activation temperature of at least 140°C for individually thermally activated vents and in all cases bans thermal activation of vents in groups. It also strongly advises against activation of vents by electronic detection systems in all industrial and warehouse buildings.

Germany

German State regulations often require SHEVS in industrial buildings. VdS, which is owned by GDV, the German Insurance Association, has produced guidance to work with this requirement. [16] The VdS guidance has a table with its position on various combinations of sprinklers and SHEVS. With ESFR sprinklers it requires mechanical SHEVS to be manually operated. With ESFR sprinklers it permits natural SHEVS to be automatically activated but only by a thermal element with an activation temperature one step higher and a response time index one step slower than the sprinklers. ESFR sprinklers are widely used to protect high-rack warehouses, generally with sprinklers only at the ceiling. Testing has shown that these sprinkler designs are more sensitive to any delay in sprinkler operation. For other sprinklers VdS accepts automatic SHEVS as long as the sprinklers are fast response with their thermal elements no more than 15 cm from the ceiling.

Spain

CEPREVEN has guidance which refers to the Spanish standard for smoke control, UNE 23585 [17]. The standard includes guidance on how to avoid negative impacts from the interaction between SHEVS and sprinkler systems. For ESFR and CMSA sprinklers it requires that the SHEVS only be operated manually. It also states that if the purpose of the SHEVS is to aid firefighting it should operate with a delay of 10 minutes from activation of the sprinkler system flow switch. There is also guidance for the SHEVS designer on the assumed area of the fire depending on the presence of sprinklers. For ceiling sprinklers in warehouse buildings with storage higher than 5 m the area in square metres is 4/3h (w + 0.18h), where h is the height of storage and w the rack depth. For in-rack sprinklers it is 2/3h (w + 0.18h), while without sprinklers it is 81 m^2. This aligns with 1990s guidance from the Smoke Control Association in the UK. It appears to assume that SHEVS limit the fire area to 81 m^2. We are not aware of evidence that SHEVS alone can stop fire spread in warehouses.

[15] Référentiel APSAD R1 Extinction automatique à eau de type sprinkleur, CNPP, St Marcel, France, 2020
[16] VdS 2815: Zusammenwirken von Wasserlöschanlagen und Rauch- und Wärmeabzugsanlagen (RWA), VdS, Cologne, Germany, 2018
[17] UNE 23585:2017 Seguridad contra incendios. Sistemas de control de humo y calor. Requisitos y métodos de cálculo y diseño para proyectar un sistema de control de temperatura y de evacuación de humos (SCTEH) en case de incendio estacionario.

UK

RISCAuthority, which brings together technical experts from the UK's leading insurers, published a position statement on SHEVS in warehouses. [18] It highlights the concerns expressed above in the section about the interaction between SHEVS and all types of sprinklers in warehouses and states, '*Introducing automatic smoke venting systems may reduce the effectiveness of a sprinkler system.*' It recommends, '*Where both systems are installed, it is essential that the early operation of automatic sprinkler systems is assured by arranging that smoke vents are only opened after automatic sprinkler systems have activated sufficient heads to suppress the fire and discharged water for a period that ensures effective fire control. This approach is viewed as the most beneficial in terms of both life safety and property protection, where smoke venting and sprinkler systems are to be used in combination.*'

FM Global

FM Global is a leading property insurer. It owns a research facility where it conducts full-scale fire tests and other tests to determine which measures are appropriate for the protection of the businesses it insures. Much of this guidance is published in the form of property loss prevention data sheets on its web site. Data sheet 2-0 Installation Guidelines for Automatic Sprinklers states, '*Do not install heat vents or smoke vents in buildings protected by ceiling-level sprinklers. If the installation of heat vents or smoke vents is unavoidable, use the flowchart in Figure 2.5.1.3.1 to determine potential corrective options due to their presence.*' The flowchart calls for measures such as the thermal vents being operated by a 182°C thermal link, there being a 20 minute delay for the vents to operate, or additional sprinklers being required under the vents. The vents are to be individually operated.

The flowchart, Figure 2.5.1.3.1, gives three options for SHEVS that operate automatically. In addition, there is the possibility that the normal ventilation grills can remain open (which would be the worst case for the sprinkler system) and their surface is equal to or greater than 0.4 m^2. In such a case the following options are given in Figure 2.5.1.3.2(a):

'Option 1 – for non-storage occupancies – 'Provide automatic closing of the horizontal opening upon activation of the sprinkler system waterflow alarm, heat detection or smoke detection;

Option 2 - Install a flat, continuous false ceiling equipped with supplemental sprinklers under the horizontal opening as shown in Figure 2.5.1.3.2(b);

Option 3 - Install supplemental sprinklers directly underneath the horizontal opening as shown in Figure 2.5.1.3.2(c).'

Recommendations in codes and standards for SHEVS in warehouses fitted with sprinklers

Belgium

In Belgium the fire protection requirements for industrial buildings are set out in Appendix 6 [19]. Regarding SHEVS they say (translated from the original Dutch and French):

[18] Requesting a standard approach by the UK Fire and Rescue Authorities to operation of smoke vents where proposed in warehouse buildings benefiting from automatic sprinkler protection, RISCAuthority, Moreton-in-Marsh, UK, 2015

[19] Bijlage 6 – Industriegebouwen, Belgisch Staatsblad, 15.07.2009

5.3 Smoke and heat ventilation system

To limit the spread of fire and smoke in the affected compartment, the industrial building is equipped with a smoke and heat ventilation system.

This requirement does not apply:

3. To compartments equipped with an automatic gas or water mist extinguishing system or an ESFR sprinkler system.

5.3.2 Operation of the smoke and heat ventilation system

The smoke and heat ventilation system is operated by the automatic fire detection system, except when the compartment is fitted with an automatic extinguishing system of the sprinkler type or volume protection. It must also be manually operable.

If the compartment is fitted with a sprinkler system the smoke and heat ventilation system, in derogation from NBN S 21-208-1, is automatically operated by the alarm valve of the sprinkler system.

France

French regulations require SHEVS in warehouses. At the same time, they require the SHEVS not to compromise the sprinkler system, '*The automatic opening devices of the outlets, when they exist, are regulated in such a way that the opening of the smoke extraction devices cannot occur before the triggering of the automatic extinguishing system, if the installation is equipped with one.*' [20]

Netherlands

The Netherlands has NEN 1073, a complementary national standard to address areas not covered by EN 12845, the European sprinkler system design, installation and maintenance standard. NEN 1073 states that sprinklers and SHEVS may not be both installed in buildings that store dangerous packaged goods (such as aerosol cans). It also states that SHEVS in high hazard storage warehouses (sprinkler hazard categorisation HHS) must be manually operated and only by the fire brigade. Where the sprinkler hazard categorisation is HHP (high hazard process) an automatic SHEVS is allowed as long it is operated by fusible elements with RTI>80 set at 70°C above the activation temperature of the sprinklers.

Spain

The Catalan instruction referenced earlier in this paper requires natural smoke and heat vents to be fitted with a fusible link set at a temperature 20°C higher than the sprinkler activation temperature. It also requires automatically operated SHEVS to operate 10 minutes after a signal from the sprinkler system flow switch, if not already manually operated. For ESFR and CMSA sprinkler systems, the SHEVS is only allowed to be operated manually.

EN 12845

EN 12845, the European sprinkler system design, installation and maintenance standard, is referenced in building codes in many European countries, although for warehouses NFPA 13 (see below) or FM data sheets (see above) are often accepted as alternative design approaches to comply

[20] Arrêté du 11 avril 2017 relatif aux prescriptions générales applicables aux entrepôts couverts soumis à la rubrique 1510

with building regulations. Where these standards are applied to comply with regulations the measures in them become mandatory. They are also the basis of sprinkler contracts.

EN 12845 is under review. The first draft of the revised standard, prEN 12845-1 [21], introduced limited guidance to ensure that sprinkler systems are not adversely affected by SHEVS:

'Smoke vents shall be implemented such that they do not adversely impact upon the capability of the sprinkler system.

NOTE 1 Experience has shown this can be best achieved by either:

- *manual control of smoke vent operation (for activation only by the fire brigade);*
- *where the opening of smoke vents is automatic, activation at a temperature equal to or greater than the automatic sprinkler system;*
- *where the temperature of the smoke vents and automatic sprinkler systems is the same, having a sprinkler response class faster than the smoke vent's activation response.'*

This text could still be revised, since at the time of writing there are a number of CEN enquiry comments on it that have yet to be addressed. While this text is perhaps suitable for sprinklers in warehouses it may not be appropriate for sprinklers in other applications, such as apartment buildings, hotels and offices, where a SHEVS in corridors and staircases is needed to assist evacuation by clearing smoke from escape routes. In these applications the ceiling height is relatively low (compared to a warehouse) so heat from the fire has a shorter journey to the nearest sprinkler and that journey is less likely to be affected by air movement created by a SHEVS, even if it operates a little before the sprinkler system.

To complement prEN 12845-1, an additional draft standard has been published, prEN 12845-2 [22], dedicated to the design of ESFR and CMSA sprinkler systems. These sprinkler designs are installed in warehouses. It says the following about SHEVS:

5.2.4 Heat and smoke vents or other ceiling vents

In ESFR or CMSA installations only manual smoke or heat vents shall be used. Drop-out-type heat vents shall not be installed.

If national regulations require the installation of automatic smoke and heat vents, the operation and performance of the sprinkler system shall not be impaired by the venting system. To achieve this, the following solutions shall be applied:

- *where the installation is an ESFR or CMSA installation corresponding sprinklers, directly under the vent opening, evenly distributed on a maximum 1,2 m linear spacing with a maximum distance of 0,6 m to the edge of the vent shall be installed. When installing the sprinkler inside a skylight the requirements for minimum and maximum vertical distances (see 5.1.3.4.2) to the ceiling shall be applied between the deflector and the closed skylight. Ensure these sprinklers have, at a minimum, the same k-factor and orientation as the adjacent ceiling-level sprinklers and are fed by sprinkler piping no smaller than the ceiling level range pipes. Sprinklers located under the ceiling vent and installed as outlined above may not need to be added to the hydraulic design of the ceiling sprinkler system. See Figure 3 for a diagram of this arrangement; or*
- *vents equipped with a standard-response 141°C or higher nominal thermal activating device shall be installed;*
- *automatic smoke vents shall be individually activated.*

[21] prEN 12845-1 Fixed firefighting systems – Automatic sprinkler systems – Part 1: Design, installation and maintenance, CEN, Brussels, Belgium, 2021

[22] prEN 12845-2 Fixed firefighting systems – Automatic sprinkler systems – Part 2: Design and installation of ESFR and CMSA sprinkler systems, CEN, Brussels, Belgium, 2022

NFPA 13

Versions of the International Building Code (IBC) [23] are adopted as State law throughout many US States. Since 2009 there has been a clause within the IBC referring to SHEVS. In the 2021 Version of the IBC this clause is as follows:

[F]910.2Where required.
Smoke and heat vents or a mechanical smoke removal system shall be installed as required by Sections 910.2.1 and 910.2.2.

Exceptions:

1.Frozen food warehouses used solely for storage of Class I and II commodities where protected by an approved automatic sprinkler system.

2.Smoke and heat removal shall not be required in areas of buildings equipped with early suppression fast-response (ESFR) sprinklers.

3.Smoke and heat removal shall not be required in areas of buildings equipped with control mode special application sprinklers with a response time index of 50 (m · s)1/2or less that are listed to control a fire in stored commodities with 12 or fewer sprinklers.

The IBC also refers to the NFPA 13 standards as the reference for the design and installation of sprinkler systems. Annex C of NFPA 13 refers to research conducted to determine how smoke ventilation can increase the number of sprinklers that operate, so that the fire potentially overwhelms the system.

Regarding sprinklers and smoke vents NFPA 13 states:

*20.9.5.1**

Manually operated roof vents or automatic roof vents with operating elements that have a higher temperature classification than the automatic sprinklers shall be permitted.

20.9.5.2

Early suppression fast response (ESFR) sprinklers shall not be used in buildings with automatic heat or smoke vents unless the vents use a high-temperature rated, standard-response operating mechanism.

*20.9.5.3**

Draft curtains separating ESFR sprinklers at system breaks or from control mode sprinklers or between hazards shall be permitted. (see 14.2.5.)

C6 [20.9.5]

Tests were conducted as part of this program with eave line windows or louvers open to simulate smoke and heat venting. These tests opened 87.5 percent and 91 percent more sprinklers than did comparative tests without windows or louvers open. Venting tests that were conducted in other programs were without the benefit of sprinkler protection and, as such, are not considered in this report, which covers only buildings protected by sprinklers. The design curves are based upon the absence of roof vents or draft curtains within the building. During mop-up operations, ventilating systems, where installed, should be capable of manual exhaust operations.

[23] 2021 International Building Code, International Code Council, Washington, DC, USA, 2021

Conclusions

While the original purpose of SHEVS in warehouses was to release heat to reduce the risk of structural collapse, allowing firefighters to fight fires in concrete buildings, warehouses today are much more vulnerable to fire and likely to collapse in the absence of sprinklers. Sprinkler systems rely on heat from the fire to operate and if this heat is released by a SHEVS before the sprinklers have operated their activation could be delayed, allowing the fire to grow and present a greater challenge to the sprinkler system, potentially overwhelming it.

Warehouse occupants are awake and have plenty of time to escape before smoke from a fire could fill a warehouse from the ceiling down to head height, so SHEVS are not required to secure visibility in escape routes. There is therefore no life safety need for a SHEVS in a warehouse to operate before the sprinkler system. Instead SHEVS are required in warehouses by some jurisdictions as a tool for firefighters to help them see the fire, although not all jurisdictions require SHEVS in warehouses.

The activation of a sprinkler system in case of fire significantly reduces the overall smoke and heat release and supports firefighter access to the fire. It also reduces smoke buoyancy so if a SHEVS is required in a warehouse a mechanical SHEVS is likely to be more effective. As a SHEVS in a warehouse is a tool for firefighters to help them see the fire there is no need for it to operate automatically and manual operation by firefighters on their arrival should be the default. This is particularly important for warehouses protected by ESFR or CMSA ceiling-only sprinkler designs, which are highly dependent on heat reaching the sprinklers as fast as possible.

If local regulations or firefighter procedures nevertheless require a SHEVS in a warehouse to be automatic, it should operate after the sprinkler system. This can be achieved by operating the SHEVS using a signal from the sprinkler system flow switch, with a delay of some minutes to ensure that the sprinkler system has had time to control the fire. If smoke vents operate individually using fusible links they should operate at a higher temperature and have a higher RTI than the sprinklers.