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Reduction of Risk to Fire Fighters in Responding to Basement Fires

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DRDC CSS CR 2011-05

Project # CPRC 91022

February 2011

Canada

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Abstract

The use of aerosol suppression technology was evaluated in four separate scenarios involving a simulated fire in a basement of a single family dwelling unit. In each scenario observations were made on fire compartment temperatures, the impact of using an aerosol fire suppressant agent on the fire growth, and actions of the firefighting team. Thermocouples were used to measure fire compartment temperatures in three areas. Video recording as well as thermal imaging recordings were made during each evaluation.

The observations showed that even under concentrations below those recommended by the manufacturer there was a marked decrease in the temperature in the fire compartments that the fire fighters would be entering. The use of the aerosol agents did however significantly reduce visibility. As a result of these observations a recommended protocol was developed when such devices are used in conjunction with interior attack of basement fires.

Résumé

On a évalué l’utilisation d’un agent extincteur en aérosol dans quatre scénarios différents avec simulation d’un incendie au sous-sol d’une habitation unifamiliale. Dans chaque scénario, on a observé la température dans des compartiments résistant au feu, l’effet sur le développement de l’incendie résultant de l’utilisation d’un agent extincteur en aérosol, et les interventions de l’équipe de lutte contre l’incendie. On a utilisé des thermocouples pour mesurer la température dans trois compartiments résistant au feu. On a effectué des enregistrements vidéo et des enregistrements d’imagerie thermique durant chaque évaluation.

Les observations ont montré que, même quand les concentrations étaient inférieures à celles recommandées par le fabricant, il y avait une nette baisse de la température dans les compartiments où les pompiers pénétraient. Toutefois, l’utilisation des agents en aérosol a nettement réduit la visibilité. Sur la base de ces observations, on a élaboré un protocole recommandé concernant l’utilisation de tels agents pour combattre les incendies dans les sous-sols intérieurs.

Executive Summary

Suppression activities during residential basement fires pose a significant risk to fire fighters. In these perilous situations, responding fire fighters enter dwellings from the floor above the fire and then proceed down a stairwell while being exposed to the super-heated gases produced by the fire. Additionally, the uncontrolled fire can burn exposed floor trusses such that the floor can give way without warning. Recent tests conducted by Underwriters Laboratories have established that this can occur without any indicators in less than 10 minutes from ignition in new lightweight truss assemblies[3]. Aerosol suppression technology due to its rapid knockdown effect has the potential to substantially reduce the risk to the lives of fire fighters entering a structure with a working basement fire by knocking down the fire and limiting further floor degradation and reducing the potential for flashover. In addition to this, damage to the structure may be reduced, there would be less use of water and more evidence related to the cause and origin of the fire may also be preserved.

The use of aerosol suppression technology in basement fires has not yet been sufficiently documented under controlled conditions. It has however been effectively deployed in a number of live fires across North America. This project addressed residential basement fire scenarios and not the effectiveness in other fire cases.

The scope of this project included:

- Training the fire service personnel on the product and how to use it to suppress a fire in a residential property
- Brief personnel on the use of the device and the conduct of test/training evolutions
- Create three identical burns to compare the effective of deploying the device to an uncontrolled burn (NOTE: because of available time a fourth burn was conducted to evaluate the effectiveness of the technology in conjunction with positive pressure ventilation.)
- Collection of data such as temperatures in the fire compartment, temperature of escaping gases, water used, and observations by responding personnel.
- An analysis of the data collected, verified by an independent Professional Engineer with fire service experience and an Ontario Association of Fire Chiefs representative
- Development of deployment procedures that optimize the effectiveness of the technology and reduce any potential risks
- Promulgation of the results

This project followed as closely as possible the safety protocols identified in *NFPA 1403 Standard on Live Fire Training Evolutions for* safety on the fire ground. Three test scenarios were planned for the day of the evaluation. These compared an uncontrolled burn to the deployment of the device into the fire compartment and then compared the results when the device was thrown into a room remote from the fire compartment. A fire was designed that would as closely as

possible simulate the fuel load determined by the National Research Council of Canada that is found in a Canadian residence.
The aerosol product used in the fire scenarios was used in a basement with a greater volume than the rated capacity of the product for extinguishment of Class A fires. Regardless the aerosol suppressant had a marked impact on the temperature in the fire compartment. Prior to the deployment of the aerosol devices these temperatures were even higher than those exhibited in the benchmark fire.

The use of aerosol suppressions technology may in certain cases reduce the risk to fire fighters entering a basement fire even though the evaluation was into a volume greater than the rated capacity for a single device. The technology does have some limitations such as the significantly decreased visibility that can limit the effectiveness of first responders when entering the structure. Entry should not be considered without the use of a thermal imaging camera and other operational changes such as those found in the produced guideline.

The potential benefits of using the aerosol devices with positive pressure ventilation to increase visibility was not conclusive but should be explored in future evaluations.

Sommaire

L’extinction d’un incendie de sous-sol résidentiel pose un danger de taille pour les pompiers. Dans ce genre de situation périlleuse, ces derniers doivent pénétrer à l’intérieur de la demeure à l’étage situé au-dessus de l’endroit où l’incendie fait rage, puis descendre un escalier tout en s’exposant aux gaz surchauffés produits par le feu. De plus, un feu non maîtrisé peut brûler les poutres du plancher, ce qui peut faire céder ce dernier sans avertissement. Selon des essais récents menés par Underwriters Laboratories, cela peut se produire sans laisser aucun indice dans les dix minutes suivant l’embrasement dans les structures de poutres légères. Grâce à son puissant effet suppresseur, un agent extincteur en aérosol peut réduire considérablement le danger que courent les pompiers lorsqu’ils s’introduisent dans une structure où il y a un incendie au sous-sol. En effet, en éteignant le feu rapidement, on limite la dégradation du plancher et on réduit le risque de propagation de l’incendie. En outre, on diminue le risque d’altération de la structure, on utilise moins d’eau et on a plus de chances de trouver des indices permettant de déterminer la cause et l’origine de l’incendie.

À ce jour, très peu d’études en milieu conditionné concernant l’emploi d’un agent extincteur en aérosol pour éteindre un feu de sous-sol ont été réalisées. Pourtant, ce produit a été utilisé pour éteindre de brillante façon bon nombre d’incendies en Amérique du Nord. Le projet dont il est question dans le présent document porte exclusivement sur des scénarios d’incendie de sous-sol de résidence.

La portée du projet comporte les éléments suivants :

- Donner une formation aux pompiers portant sur la façon d’utiliser le produit pour éteindre un incendie de résidence;
- Informer le personnel quant à l’utilisation du produit et la tenue des essais et de la formation.
- Faire trois feux identiques afin de comparer l’efficacité du produit pour éteindre un feu non maîtrisé (NOTA : nous avons eu le temps de faire un quatrième feu pour évaluer l’efficacité du produit avec ventilation à pression positive).
- Recueillir des données comme la température dans le compartiment résistant au feu, la température des fuites de gaz, la quantité d’eau utilisée et les observations des intervenants.
- Effectuer une analyse des données recueillies vérifiée par un ingénieur ayant de l’expérience dans la lutte contre l’incendie et un représentant de l’Ontario Association of Fire Chiefs (Association des chefs pompiers de l’Ontario).
- Élaboration d’une procédure d’utilisation du produit visant à en maximiser l’efficacité et à réduire les risques.
- Publication des résultats

Nous avons respecté le mieux possible le protocole de sécurité sur les lieux d’incendie établi dans la norme relative aux conditions d’entraînement avec incendie réel de la NPFA (*NFPA 1403*

Standard on Live Fire Training Evolutions). L’évaluation consistait à comparer trois scénarios différents : un incendie non maîtrisé dans un compartiment résistant au feu en guise de point de référence, l’utilisation du produit à l’intérieur même du compartiment, puis l’utilisation du produit dans une pièce à l’extérieur du compartiment. Nous avons tenté, dans la mesure du possible, de reproduire la charge de combustible que l’on trouve habituellement dans une résidence canadienne selon le Conseil national de recherches du Canada.
L’extincteur en aérosol a été utilisé dans un sous-sol trop grand pour sa capacité nominale d’extinction de feux de classe A. Néanmoins, l’utilisation du produit a eu un effet marqué sur la température dans le compartiment. Avant l’application de l’agent en aérosol, la température dans les compartiments destinés à l’essai du produit était même plus élevée que celle du compartiment utilisé comme point de référence.

Bien que l’évaluation ait été conduite dans un compartiment aux dimensions dépassant la capacité nominale d’un seul dispositif, dans certains cas, le fait d’avoir recours à un agent extincteur en aérosol peut réduire le danger auquel s’exposent les pompiers lorsqu’ils pénètrent à l’intérieur d’un sous-sol enflammé. Par contre, son emploi comporte des inconvénients; par exemple, la visibilité des premiers intervenants est nettement réduite lorsqu’ils pénètrent dans la structure. Il faut donc se munir d’une caméra thermique et prendre diverses précautions comme celles recommandées dans les directives élaborées à cette fin.

L’essai de l’agent extincteur en aérosol avec ventilation à pression positive dans le but d’améliorer la visibilité n’a pas été concluant, mais c’est un aspect qui mérite d’être évalué plus en profondeur à l’avenir.

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Acknowledgements

This project was funded by the Canadian Police Research Centre.

The project team wishes to thank the Fire and Emergency Services Training Institute (FESTI) personnel for their assistance in completing the requirements of this project. In particular, the team wishes to thank Chief Training Officer Brian Ross for his professionalism and ability to find resources needed for the successful completion of this project. The FESTI centre is a world class training centre with highly qualified staff located in Canada. Their facilities and professional staff highlight the competencies of the Canadian Fire Service in general and reflect positively on Canada.

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1 Introduction

1.1 Background

The mandate of the Canadian Police Research Centre (CPRC) is to harness science and technology knowledge to strengthen the Tri-Services (police, fire and emergency medical services) across Canada through research, development of standards, product evaluation, technology transfer, science and technology advocacy, and by providing specialized expertise in this field.

Suppression activities during residential basement fires pose a significant risk to fire fighters. In these perilous situations, responding fire fighters enter dwellings from the floor above the fire and then proceed down a stairwell while being exposed to the super heated gases produced by the fire. Additionally, the uncontrolled fire can burn exposed floor trusses such that the floor can give way without warning. Recent tests conducted by Underwriters Laboratories have established that this can occur without any indicators in less than 10 minutes from ignition in new lightweight truss assemblies[3]. Aerosol suppression technology due to its rapid knockdown effect has the potential to substantially reduce the risk to the lives of fire fighters entering a structure with a working basement fire by knocking down the fire and limiting further floor degradation and reducing the potential for flashover. In addition to this, damage to the structure may be reduced, there would be less use of water and more evidence related to the cause and origin of the fire may also be preserved.

The use of aerosol suppression technology in basement fires has not yet been sufficiently documented under controlled conditions. It has however been effectively deployed in a number of live fires across North America. This project shall only address residential basement fire scenarios and not the effectiveness in other fire cases.

The scope of this project was to include:

- Training the fire service personnel on the product and how to use it to suppress a fire in a residential property
- Brief personnel on the use of the device and the conduct of test/training evolutions
- Create three identical burns to compare the effective of deploying the device to an uncontrolled burn (NOTE: because of available time a fourth burn was conducted to evaluate the effectiveness of the technology in conjunction with positive pressure ventilation.)
- Collection of data such as temperatures in the fire compartment, temperature of escaping gases, water used, and observations by responding personnel.
- An analysis of the data collected, verified by an independent Professional Engineer with fire service experience and an Ontario Association of Fire Chiefs representative
- Development of deployment procedures that optimize the effectiveness of the technology and reduce any potential risks
- Promulgation of the results

1.2 Defining the Hazard

The National Institute for Occupational Safety and Health (NIOSH) in the US has a number of detailed reports on fire fighter fatalities when responding to basement fires. These reports highlight the unique risks inherent in these fires as well as identifying recommended safety protocols. [4 5]

> Fire burning underneath floors can significantly degrade the floor system with little indication to fire fighters working above. They need to be aware of rapid heat build-up, little or no ventilation, limited accessibility, and whether it is a storage place for unknown hazards (e.g., combustibles, hazardous materials, and flammable liquids). Also of concern for fire departments is how to determine how long a fire has gone undetected. … Structural support members may be directly exposed to fire, causing them to weaken and increase the likelihood of an above-floor collapse. Interior crew(s) intending to operate on the floor above a basement fire should limit their operating time, especially if ventilation, suppression, and accessibility are not progressing. The floor's structural members will continue to weaken as fire and heat intensify. Specifying an exact length of time for how long suppression crew(s) should operate above a basement fire is questionable, and the IC should make that determination by performing a hazard analysis/risk assessment. … SOPs should be developed to address structural fire fighting operations specific to basement fires, because these types of fires present a complex set of circumstances and following established SOPs will minimize the risk of serious injury to fire fighters.[6]

The recommended practice when attacking basement fires is to ensure that there is proper ventilation to reduce the build-up of hot gases throughout the structure and improve visibility for the team attempting entry. Ventilation can increase the potential risks to fire fighters inside the structure as the added increase in oxygen to fuel the fire could cause sudden growth thus potentially trapping or killing the entry team. Other conventional means to reduce this risk may involve cooling of these fires prior to entry by the indirect method of spraying large quantities of water in through basement windows. This can result in significantly greater water damage and still may not necessarily reduce the risk to the entry personnel if the fire is in a sheltered area. Furthermore this could require additional fire ground personnel that may not be immediately available.

The personnel must attempt entry into the basement area as soon as possible to prevent the rapid growth and spread of the fire. The longer the delay the greater the potential damage to floor systems. Aerosol suppressant agents can be deployed if authorized by the Incident Commander while the attack team is preparing for entry. Anecdotal reports and manufacturers' data show that these devices can rapidly knock down Class A, and Class B fires. This may have the effect of stopping further fire spread, reducing temperatures, and therefore have the same or better effectiveness than ventilation. It may reduce property damage and reduce the risk of personal injury to the fire fighters. What has not been reported is the potential impact that employing the technology may have on fire fighter operations.

1.3 How the Technology Works

Aerosol devices work through a chemical reaction. A portable device generates a large quantity of salts and oxides of alkali and alkaline metals in an aerosol form. The aerosol is discharged from a canister as a hot white smoke that will then disperse throughout the fire compartment. The particles generated are approximately one micron in size and because of this small size they will remain airborne in the compartment for up to 50 minutes. The small size of the particles allow them to be draw on thermal currents into the seat of the fire where they would bond with free radicals interrupting the chain reaction that sustains the fire. The heat present in the room provides the needed energy to fuel this chemical reaction. This should be evidenced in a significant drop in the fire compartment temperature. As these small particles can remain airborne for up to 50 minutes there is a significant reduction in any potential for the fire's re-ignition. The fine aerosol product has been assessed by the manufacturers and is determined not to be hazardous to humans; however, it is an irritant and therefore should be avoided. The US Environmental Protection Agency (EPA) has identified aerosol suppressants as acceptable replacements for halon gases in normally unoccupied spaces under its Significant New Alternatives Policy (SNAP) program. The technology has been installed in land and marine based fixed installations for over a decade. It has also been proven to be safe for electrical components.

The fixed versions of aerosol devices are primarily considered for use in normally unoccupied spaces. This was due to the concern on it being an irritant as well as severely reducing visibility within a fire compartment. It was also unknown what impact it might have on a fire fighters gear including SCBA, bunker gear and how it might affect use of thermal imaging devices. It was therefore of interest to record the responding personnel's actions and observations when responding into an area where the aerosol has been deployed.

The device used for the evaluation was the ARA FIT Pro™ device marketed by ARA Safety. It should be noted that there are other products on the market using similar technology. The ARA

Fit Pro™ device has the largest rated capacity for the available devices. In this case it is rated for 60 m^3 for suppression of Class A fires. This is considerably less than the dimensions of the basement which had a volume of 302 m^3.

This technology does require that the device be relatively close if not in the room of fire origin. Its effectiveness also requires that there be sufficient containment of the aerosol for a sustained period of time. A basement fire is a relatively contained fire due to the limited number of openings found in a basement. It was also of interest to observe what the impact would be of the device being in a room remote from the fire and whether it would be as effective in suppressing or knocking down the fire.

2 Purpose

The objective of this project was to measure the effectiveness of an aerosol suppressant agent in a basement fire scenario and then to evaluate the impact that it may have on the operations performed by fire service personnel. A detailed search of past research projects on the matter of basement fires did not result in a significant number of research projects. Those that were found were related to fire growth modeling[1] and fire performance of structural components[2]. A review of fire service literature found many fire fatality related reports and the need to improve safety. There were no reports found on the use of aerosol technology in this high risk environment.

This research project was intended to produce data for further evaluation of the effectiveness of aerosol suppression technology in extinguishing basement fires. It was also to produce an optimal deployment procedure for the technology. Following the publication of the report the project was to share the results of all of the work with Canadian fire services through the annual meetings of their associations. ARA Safety, a Canadian company, is one manufacturer of an aerosol suppression device, the ARA Safety Pro™, of the size needed to extinguish a large scale residential fire. There are other devices that work on the same principle. The report however is intended to be generic.

3 Methodology

3.1 Concept for Testing

This project will follow as closely as possible the safety protocols identified in *NFPA 1403 Standard on Live Fire Training Evolutions for* safety on the fire ground. The training structure at FESTI is ideally suited for this evaluation because of its unique construction and the presence of thermocouples and other measuring devices. The construction of the tower allows for safety personnel to rapidly intervene if necessary during the evaluation. As well safe egress routes are available throughout the structure. The structure is also non-combustible therefore there is no risk of structural members collapsing during the fire attack. Modifications for safety are not necessary.

Modifications of the training building were completed by FESTI to simulate basement windows and to enclose the basement stairwell such as would be found in a typical Canadian residence. Three test scenarios were planned for the day of the evaluation. These were to compare an uncontrolled burn to the deployment of the device into the fire compartment and then to compare the results when the device was thrown into a room remote from the fire compartment. A fire was designed that would as closely as possible simulate the fuel load determined by the National Research Council of Canada that is found in a Canadian residence.

3.1.1 Standard Fire

The test shall attempt to use the same fire load as per the NRC Research Report: IRC-RR-207 *Development of a Fuel Package for Use in the Fire Performance of Houses Project* dated March 31, 2006. This results in a fire load density of 350 MJ/m2 for an 8.3 m2 floor area. The fuel loading was also adjusted to limit the burning to 20 minutes so as to facilitate the evaluation. There was little value seen in running the tests beyond this time.

The dimensions of the FESTI training building is approximately 46' 6'' length (14.17 m), 27ft (8.23 m) wide, with a Ceiling height 8 ft 5'' (2.59 m). The basement floor area is therefore 116.62 m^2 with a volume of 302 m^3. This fuel package was then adjusted based on the room dimensions such that it will be as close to 350MJ/m2. This would consist of a three seat sofa with standard polyurethane cushions, and a combination of pallets and/or straw bales.

Photo 1 below shows a typical configuration of a fuel package prior to its ignition. The fuel package was then ignited by a marine flare. It was allowed to grow unrestricted for five minutes in the evaluations where an aerosol device was used. The intervention by the FESTI personnel was timed to commence after 6 minutes from the start of the fire, and one minute after the deployment of the aerosol device.

It was believed that by the five minute mark the fire would have been expected to have reached its peak heat release rate. Also due to the limitations on the amount of fuel that we would reasonably expect to place in the training structure an advanced intervention time is being used.


Photo 1: Interior view showing typical fuel load.

3.1.2. Evaluation Scenarios

The original project submission only called for two simulations to be run in a surplus duplex in Sechelt, BC – with and without an aerosol device being deployed. This was no longer possible and FESTI was chosen as the follow-up site. Because of the FESTI training buildings permanence and flexibility it was proposed that three tests be run on site. A fourth test was added at the suggestion of the peer review observers on the day of the evaluation. The evaluations conducted on 28 September 2010 consisted of:

- Evaluation 1 – Free burn without the deployment of the aerosol device
- Evaluation 2 – With the deployment of the aerosol device into the fire compartment
- Evaluation 3 – With the deployment of the aerosol device into a compartment remote from the fire.
- Evaluation 4 - With the deployment of the aerosol device into a compartment remote from the fire. Windows opened and the use of positive pressure ventilation at the entry door.

3.2 Field Experiment Methods

3.2.1. Safety Protocols

Photo 2: Fire truck with suppression and safety lines attached.

The project attempted to follow as closely as possible the safety provisions for live fire burning found in *NFPA 1403 Standard on Live Fire Training Evolutions*. The safety requirements identified for the project were developed by the project team in conjunction with FESTI staff.

3.2.2. Instrumentation

Data from the evaluation was recorded in the form of videotaping, interviewing of responders, recording actions of the responders inside the structure and measuring temperature of escaping gases using data recording thermal imaging cameras, temperature in fire compartment area, and measuring total water flow.

Thermocouples were located as per Drawing 2 in each of the fire compartments and at the base of the stairwell inside the fire compartment. The thermocouples would provide temperature measurement to portable readers located outside the structure. Data from the thermocouples was recorded a 1 minute intervals – results of the data from each test can be found at Annex B.

Photo 3: Installed thermocouple System and improvised set-up.

Water usage by the personnel was measured in all four scenarios. Due to the limited contents involved this data was seen as offering no valuable information for analysis. In these evaluations between 0.11 to 0.43 cubic meters of water were used. The only combustibles were the fuel added. No water was used in indirect attack as a means of cooling.

The FESTI training centre was equipped with a number of fixed installed thermocouples in the basement area. The facility had recently undergone a major refurbishment including an overhaul of these thermocouples. These had previously been tested and confirmed in operation however on the day of the evaluation the recordings were not operational. The electrical contractor was on site; however, these could not be made operational. The result was to use three hand portable thermocouples that read the temperatures at ceiling height in compartments A, B and at the base of the stairs in compartment D.

Photo 4: Suppression team commencing entry

The entry team was composed of 3 personnel. Two on the attack hose and a third operating the recording TIC camera. An additional two personnel were standing by as a RIT team for safety purposes

A recording thermal imaging camera was provided and operated by Commercial Solutions for this project. In addition to guiding the interior attack team it recorded their experiences and temperature readings for the team performing the interior attack. These images are available at Annex C.

A videotaping crew was also on site for filming and recording exterior shots of the responding crew and their observations following the response. This is also available at Annex D.

3.2.3. FESTI Training Centre Description

Photo 4: Exterior view of training tower. Photo 5: Exterior view of entry doorway

FIRST FLOOR

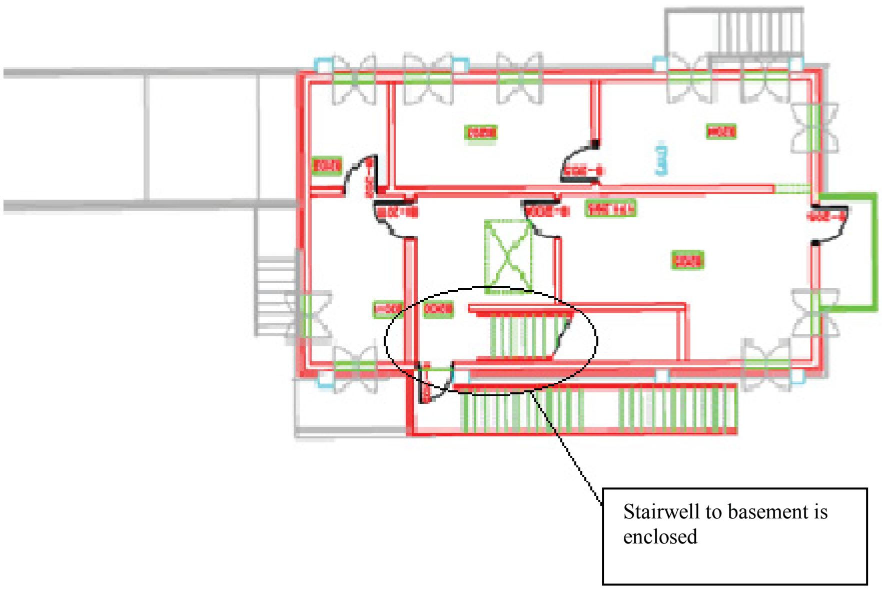

Diagram 1: Upper Floor FESTI Training Building

Site Modifications

1. Door way at the top of the stairs leading to basement is to be framed in with a 5/8 inch sheetrock mounted on 2/4 members. Sheet rock on both sides. A fire door has been installed at the base of the stairs.

2. Floor ventilation between basement and 1st floor has been covered over with steel sheets to limit escaping gases.

BASEMENT FLOOR

Room	Dimensions (All ceiling heights 8'6")	Volume (cubic feet)
A	36' x 8' 10"	2723.4
B	9' 4" x 7' 6"	592.9
C	14' 2" x 7' 6"	898.9
D	25' x 9' 6"	2018.8

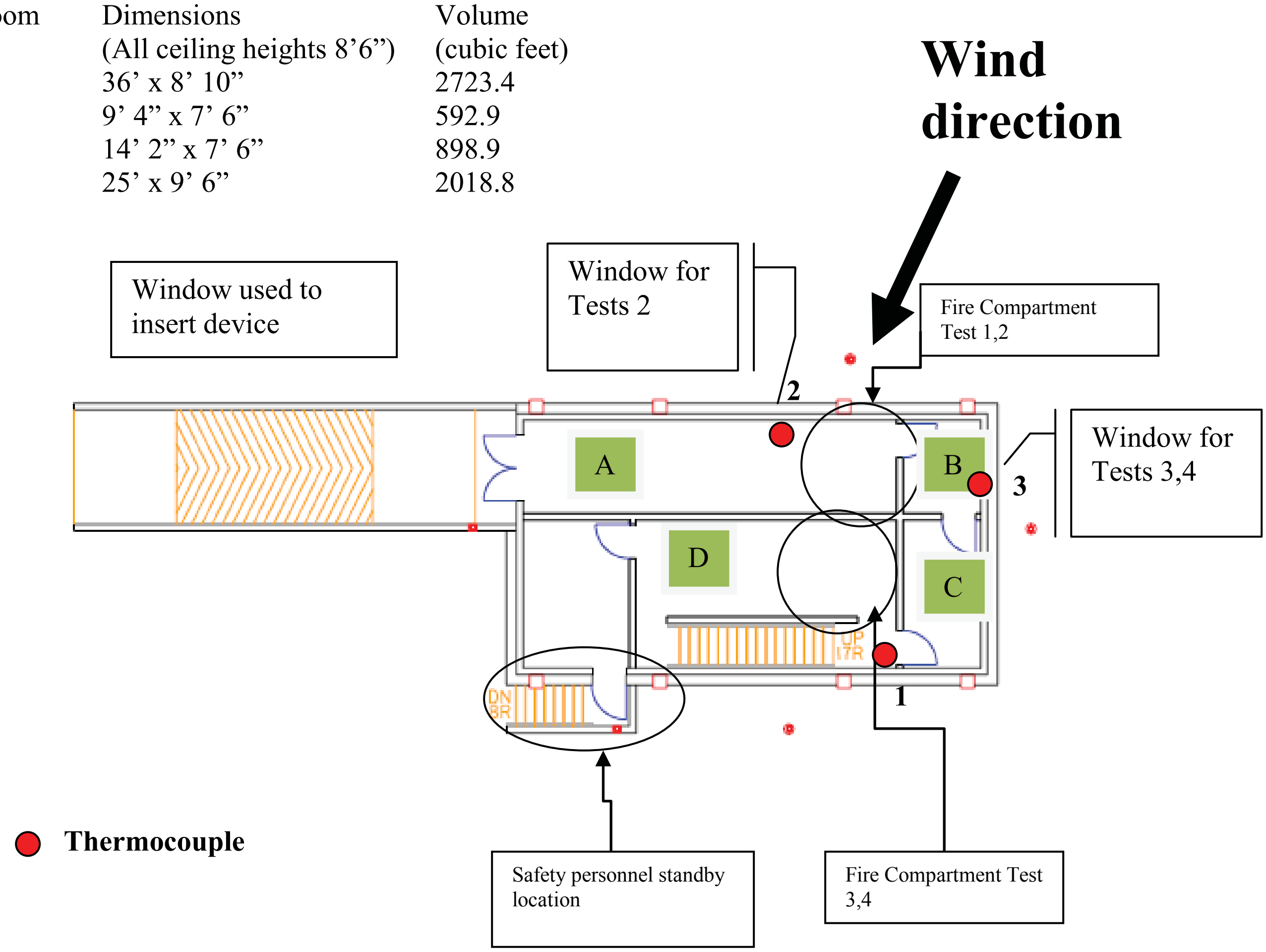

Diagram 2: Basement Floor FESTI Training Building

Site Modifications

1. Two windows have been installed as part of the FESTI tower modifications.
2. Interior basement doors are to remain open with the exception of the double doors simulating the garage door.

4 Results

4.1 Observations

4.1.1. Observations Evaluation # 1 - Free burn - Without the deployment of the aerosol device

The temperature data Annex B showed that the fire within two minutes in the fire compartment rose to 340 Celsius degrees. In the other compartments the fire temperature rose to approximately 200-270 Celsius and at the base of the stairs the temperature averaged around 120 Celsius degrees. The temperature in the fire compartment reached a peak of around 340 Celsius. After the entry and suppression activities were started at the 6:00 minute mark. These were eventually dropped down to 158 Celsius degrees. It appears the fire growth was limited due to lack of ventilation as there was unspent fuel removed from the structure, the temperature appeared to plateau, and it only reduced once suppression activities started. The crew performing entry was therefore exposed to temperatures as high as 300 Celsius while performing their tasks.

Post evolution interviews and video footage found on the DVD Annex D resulted in some baseline observations by the responding personnel. The visibility was observed to be reasonably good considering the nature of the fire and the type of contents burning. These would typically be characterized by dense black smoke. Although visibility was poor at no time did the interior attack team lose sight of personnel on the team. Temperatures were reported to be hot and that these intensified somewhat when they used water on the fire.

4.1.2. Observations Evaluation # 2 - With the deployment of the aerosol device into the fire compartment

The temperature data in Annex B showed that the fire had reached a peak temperature of 552 Celsius at the 5:00 minute mark – when the aerosol device was deployed. Within one minute from activation this then dropped to 175 Celsius. There was a similar drop in ceiling temperatures in the adjoining compartment with the fire dropping from 361 Celsius to 165 Celsius in the same period of time. The entry personnel were therefore entering into lower fire compartment temperatures and there was greatly reduced likelihood of flashover. At approximately 7:00 minutes into the evaluation the thermocouple in the room of fire origin shorted out resulting in a loss of readings from the device. At this time the last recorded temperature reading was 175 Celsius.


Photo 6: Preparing to launch device through compartment window

Post evolution interviews and video footage are found on DVD Annex D to the report. On the activation of the device and its insertion into the basement compartment observers heard the audible activation of the device -a characteristic cyclic whooshing sound until it had completely dispended the aerosol product. It was also noted that the characteristics of the smoke leaving the compartment changed markedly. Smoke in the upper floors was also noted to be visible. This is believed to be due to the opening of the basement stairwell which then permitted more smoke to be dispersed through the structure.

In the post evaluation interviews it was commented that the temperature was noticeably reduced. Visibility was reported to be "really poor" and "could not see your hand in front of your face". This resulted in potential concern for foot placement while descending the stairs as well as potential for disorientation. It was also noted that the temperature had dropped so rapidly in the compartment that even use of the infrared camera was limited. The attack team, although intimately familiar with the training tower, took approximately 5 minutes from entry to suppress the fire. This was due to the disorientation they experienced. It was believed that the response would take longer on an unfamiliar structure. The temperature reported by the attack team was that this was unlike a typical basement fire and the escaping gases were very cool. It was reported that finding the fire was difficult because of the lack of visible flames. There was no observed impact on the effectiveness of the SCBA or bunker gear caused by the aerosol product. No residue was visible whatsoever on the fire fighters.

4.1.3. Observations Evaluation #3 - With the deployment of the aerosol device into a compartment remote from the fire.

This evaluation was intended to challenge the capabilities of the aerosol device by putting it into a compartment remote from the fire and see if the aerosol produce would be drawn into the fire compartment and aid in the cooling of the compartment. This might be a case where an Incident Commander may be unsure of the exact location of the fire in the basement compartment.

In this case the temperature data showed that the fire compartment rapidly rose to a peak temperature of 540 Celsius and then stabilized at around 480 Celsius degrees and remained there until the device was launched into the adjoining compartment at the 5:00 minute mark. At that time the temperature began to draw down and within one minute had dropped to 300 Celsius and then went lower. Even at the lower than rated concentrations the aerosol device was reducing the temperatures in the fire compartment.

Post evolution interviews showed again that the visibility was a major concern as soon as they entered into the basement compartment. The escaping gases again were observed to be noticeably cooler and the location of the fire was difficult because of the lack of visible flames. It appears that the fire may have been extinguished in this case by the aerosol device. Locating the fire was commented to be “a guessing game” and that the crew had to listen for the crackling of the fire. A further concern raised by the attack team leader was that without the visibility and not personally having the TIC camera he had no indicators as to the size and location of the fire. They could be walking through it or around it unknowingly.

4.1.4. Observations Evaluation #4 - With the deployment of the aerosol device into a compartment remote from the fire. Windows opened and the use of positive pressure ventilation at the entry door.

This test was an optional add-on undertaken after discussions with peer review personnel on site. It was of interest to see what effect on visibility the use of positive pressure ventilation may have on the tactics employed and the ability to improve visibility of the responders. Unfortunately the wind conditions had picked up at the time of the evaluation that may have reduced the efforts of the forced ventilation as the wind was blowing in a direction opposing the forced ventilation. In this evaluation the shutters over the windows were also removed to increase ventilation. This was to better simulate what would be done in actual ventilation operations. The effect of the wind opposing the ventilation efforts was confirmed in the video where it was evidenced that following the initial deployment of the aerosol device a large quantity of the product escaped. It was subsequently observed that the aerosol powder was no longer escaping from the compartment and more oxygen was entering the compartment thus potentially feeding the fire.

Photo 7: Exterior view of east window showing effect of prevailing wind.

The temperature readings for the fire compartment peaked at 645 Celsius then appeared to steadily drop to 475 Celsius by the time the device was launched into the adjoining compartment. Although these temperatures were significantly hotter than the first evaluation (a peak of 340 Celsius) the fire should not have diminished but instead intensified with the increased ventilation. This may have been a result of materials used in the fire. With the introduction of the aerosol suppressing agent the fire did reduce in the compartment but this cannot be concluded that it was a result of the aerosol agent.

Once the basement door was opened and the ventilation efforts commenced we could again see the aerosol product escaping from the compartment. Visibility throughout the entry efforts was reported to be poor or nil. Even after suppression of the fire visibility was still reported to be poor. In the post evolution interviews it was observed that the fan did not appear to help.
The anecdotal observations regarding the temperature experienced by the entry team was that it appeared to be higher although "it wasn't unbearable". The fire was visible this time even without the TIC camera. Therefore it can be concluded that in this evaluation there was sufficient thinning of the aerosol materials to improve some visibility to at least see the fire. It was not conclusive that the aerosol suppressant due to its possible dispersal was as effective as in Evaluation #3.

4.1.5. Summary of Observations

The aerosol product that was used in the fire scenarios was used in a basement with a greater volume than the rated capacity of the product for extinguishment of Class A fires. Regardless, in Evaluations #2 and #3 the aerosol suppressant had a marked impact on the temperature in the fire compartment. Prior to the deployment of the aerosol devices these temperatures were even higher than those exhibited in the benchmark fire (Evaluation #1).

Visibility was an obvious concern. The responding personnel were intimately familiar with the training structure yet visibility was so greatly reduced they had difficulty negotiating the structure and stairs and finding the fire. They reported not being able to see their hands. This would be evidenced in the added time that it took the entry personnel to find and extinguish the fire. The TIC camera was essential for entry personnel. Familiarity with the use of the TIC camera even in this environment is also essential. The camera had to be held up to the face piece of the SCBA for improved visibility. One potential area of concern was what impact the aerosol product may have had on the bunker gear, SCBA and other components. No impact or comments were reported.

4.2. Assembly of Best Practice Guidance Document for Emergency Responders

Based on the observed data and anecdotal comments made by responding personnel, a review of past NIOSH reports, and a review of past deployment reports provided to ARA Safety a draft operating guideline was prepared. This was then forwarded for comment/review by FESTI responders as well as the peer review personnel that were present.

In addition to the peer review panel above, a copy of the draft Best Practice Guidance document was posted on the on-line collaboration forum for first responders at PTSC-Online (www.ptsc-online.ca). This site has been a Public Safety Canada (PSC) funded project run by the Canadian Association of Fire Chiefs (CAFC). The draft guidance document was posted for a three week period commencing 8 November 2010.

The final version of the Best Practice Guideline can be found at Annex D to this report. This guideline was not intended to be a comprehensive guideline for all basement or structural fires instead it was intended to be incorporated into the department's existing risk management plans.

4.3. Recommendations for Operational Guidelines

In compiling the operational guideline document several NIOSH Firefighter fatality reports for basement fires were also reviewed so as to incorporate some of their recommendations if applicable. In summary some of the highlighted recommendations to reduce the added risks to personnel when aerosol devices are deployed are:

- Only personnel who have undertaken the manufacturers required training should be authorized to deploy these devices.
- The Incident Commander (IC), after a thorough size-up of the fire, should make the determination if the device should be deployed.
- Entry into the structure should only be authorized by the IC after at least one minute from activation of the device.
- Entry personnel including Rapid Intervention Team (RIT) personnel should have a thermal imaging camera.
- Entry personnel should be equipped with radios and regularly report fire conditions back to the IC.

5 Transition and Exploitation

In conducting this evaluation fire service representation from the Ontario Association of Fire Chiefs was provided. This helped to ensure that their issues and concerns were addressed during the conduct of the evaluation and incorporated into the final report. Additionally, the proposed operational guideline that is attached as Annex E, was posted for comment on the Partnership Towards Safer Communities Online website (www.ptsc-online.ca) for review and comment by its members. PTSC Online is a project undertaken by the Canadian Association of Fire Chiefs (CAFC) under funding provided by Public Safety Canada to enable better communication and collaboration amongst emergency services personnel.

As a required deliverable of this project a communication plan for the results of the evaluation is required to be prepared and approved. All work and costs associated with the communication of the results of the evaluation are being identified as contributions in kind. This plan shall include preparing a number of articles for publication by journals that are circulated to the fire service. These include Fire Fighting in Canada, Canadian Fire Fighter, Canadian Fire Chief, and Fire House magazine. The author sits on the editorial board of one of these magazines. In addition, notices shall be sent off to Canadian provincial fire chief associations as well as CAFC regarding possible technical presentations.

6 Conclusion

The use of the aerosol devices in this case was well below the rated capacity of the product for extinguishment. Nonetheless the presence of the aerosol extinguishing agent had a marked effect on the temperatures in the fire compartment and at the base of the stairwell. However, it did negatively impact the visibility within the fire compartment. The data from the thermocouples also showed that the temperatures were reduced at the entry point for the suppression team.

The use of aerosol suppressions technology may in certain cases reduce the risk to fire fighters entering a basement fire even though the evaluation was into a volume greater than the rated capacity for a single device. The technology does have some limitations such as the significantly decreased visibility that can limit the effectiveness of first responders when entering the structure. Entry should not be considered without the use of a thermal imaging camera and other operational changes such as those found in the produced guideline.

The potential benefits of using the aerosol devices with positive pressure ventilation to increase visibility was not conclusive but should be explored in future evaluations.

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5 NIOSH Line of Duty Death Report August 31st, 2009

6 NIOSH Line of Duty Death Report March 19th, 2010

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Annex A Project Team

This project was completed by ARA Safety in fulfillment of a contract issued to it by the Canadian Police Research Centre (CPRC). Its purpose was to investigate the effectiveness of aerosol suppression technology in knocking down or suppressing basement fires versus the common current baseline procedure of entry from above a fire. The comparative study would provide the basis for the development of a deployment protocol. The results of this project would then be communicated to the fire service. The evaluations took place at the Toronto Airport Fire Training Centre - Fire and Emergency Service Training Institute (FESTI) on September 27, 2010. This evaluation and enclosed operating guideline constitutes Deliverable #7 for this project and is subject to approval by the Technical Authority.

Project Lead: Sean Tracey, P.Eng., MIFireE – ARA Safety Technical Advisor

Other Contacts:

FESTI Contact – Chief Training Officer Brian Ross

ARA Safety – Michael Gardiner

Canadian Police Research Centre – Al Parisien

Peer review was conducted by a representative of the Ontario Association of Fire Chiefs, Fire Chief Steve Kraft of Richmond Hill, ON and a professional engineer with fire service experience, Barry Colledge of Morrison Hershfield.

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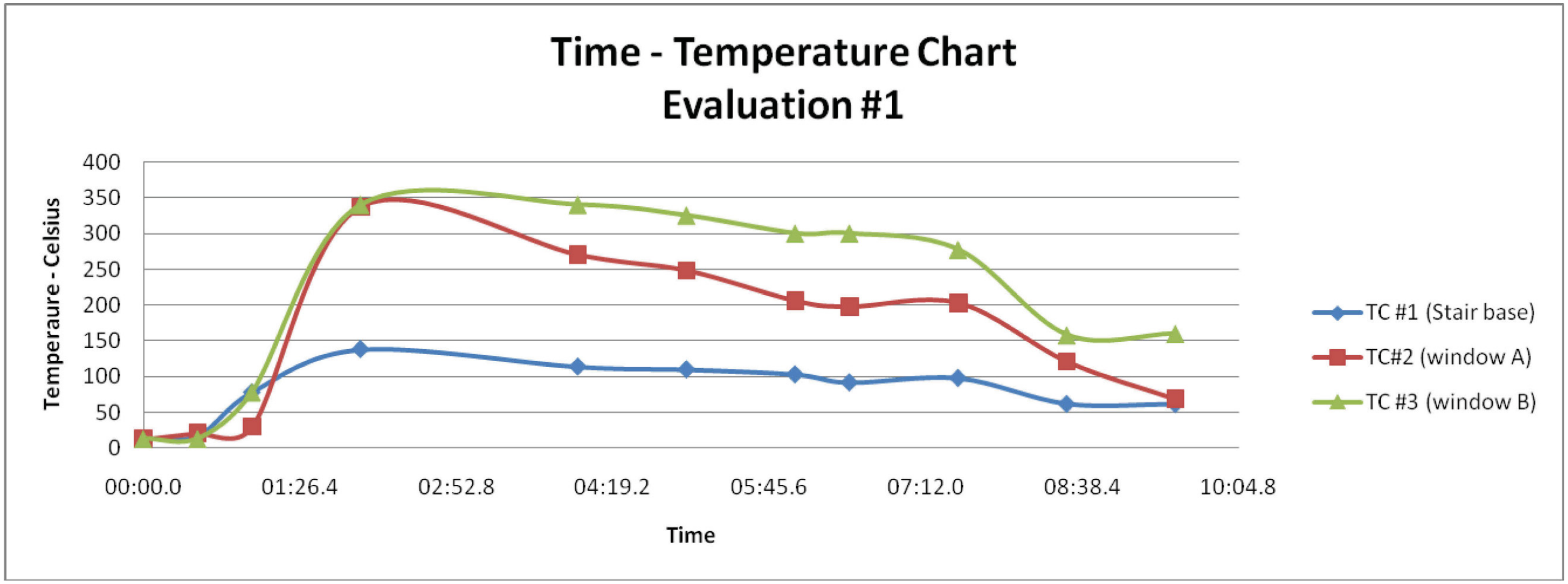
Annex B Thermocouple Data Observations

DATA RECORDING FROM DEVICES

TEST NO. 1 Time 0944 hrs

Met Conditons Wind direction: 040 deg @ 9.25 kmph knot.
Temperature: 14 deg C.
Precipitation type: N/A.

TIME	TC #1 (Stair base)	TC#2 (window A)	TC #3 (window B)	NOTES
00:00.0	13.4	12.8	13.3	
00:30.0	17	21.5	13.3	
01:00.0	78.6	30.1	78.6	
02:00.0	138.2	337	340	
04:00.0	114	270	340	
05:00.0	110.1	248	325	
06:00.0	103.2	206	300	Commence entry
06:30.0	92.1	198	300	
07:30.0	98.2	203	277	
08:30.0	62.2	121	158	
09:30.0	62	68.8	160	Fire extinguished



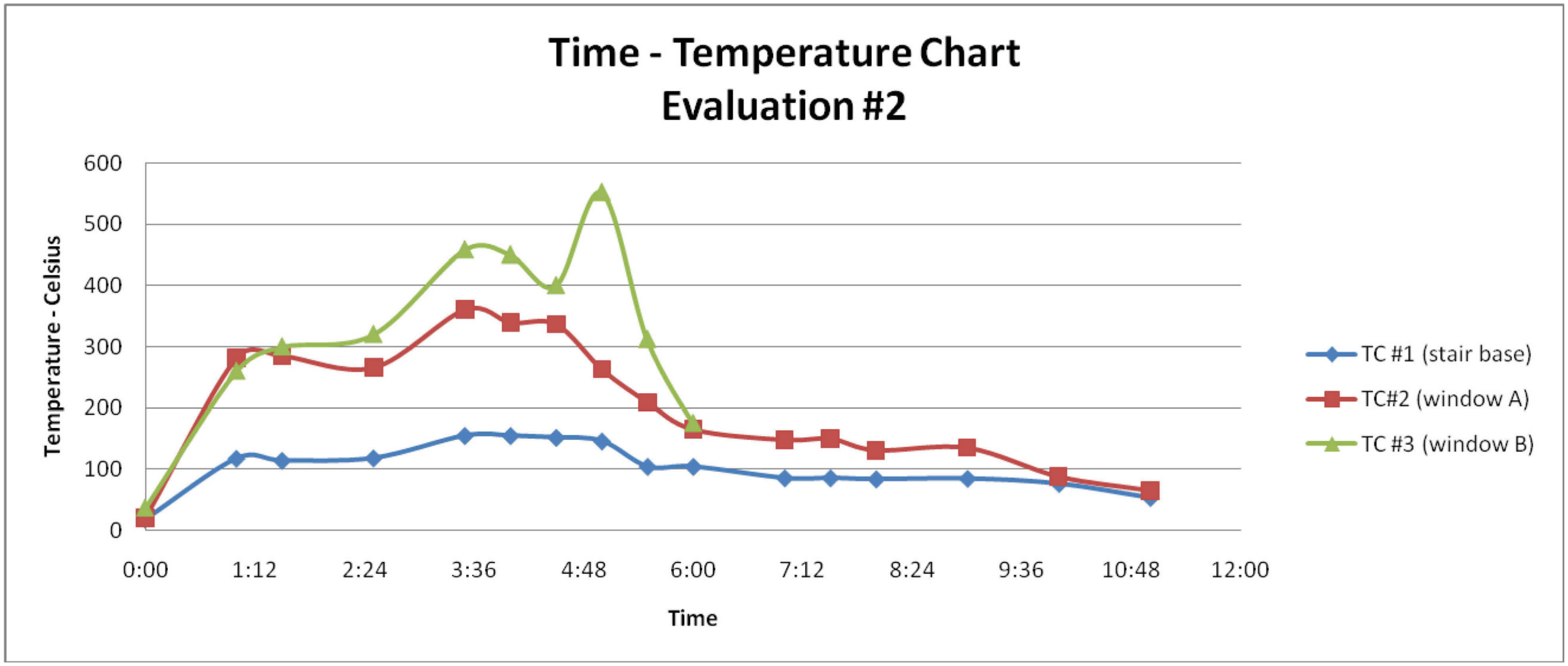
Time - Temperature Chart
Evaluation #1
Temperaure - Celsius
400
350
300
250
200
150
100
50
0
00:00.0
01:26.4
02:52.8
04:19.2
05:45.6
07:12.0
08:38.4
10:04.8
Time
TC #1 (Stair base)
TC#2 (window A)
TC #3 (window B)

DATA RECORDING FROM DEVICES

TEST NO. 2 Time 1050 hrs

Met Conditions Wind direction: 040 deg @ 9.25 kmph knot.
Temperature: 14 deg C.
Precipitation type: N/A.

TIME	TC #1 (stair base)	TC#2 (window A)	TC #3 (window B)	NOTES
0:00	17.3	20	36.5	
1:00	117.4	282	260	
1:30	114	285	300	
2:30	118	266	320	
3:30	155	361	458	
4:00	155	340	450	
4:30	152	337	400	
5:00	146	263	552	activation
5:30	104	209	312	
6:00	104	165	175	
7:00	85.2	148.1		thermocouple shorted out
7:30	85.2	150		
8:00	83.4	131		
9:00	84.3	135		
10:00	76	87.7		
11:00	52.8	65		

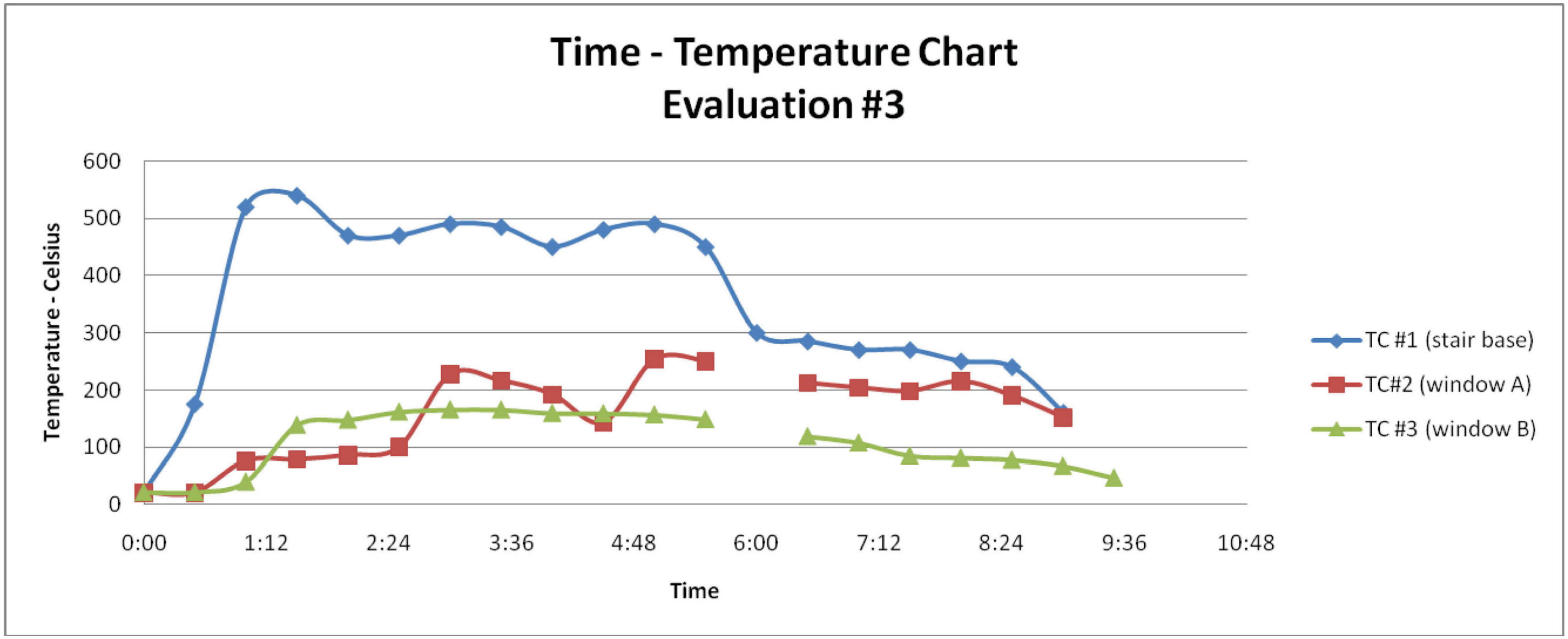

Time - Temperature Chart
Evaluation #2
600
500
400
300
200
100
0
Temperature - Celsius
0:00
1:12
2:24
3:36
4:48
6:00
7:12
8:24
9:36
10:48
12:00
Time
TC #1 (stair base)
TC#2 (window A)
TC #3 (window B)

DATA RECORDING FROM DEVICES

TEST NO. 3 Time 1320 hrs

Met Conditions Wind direction: 040 deg @ 9.25 kmph knot.
Temperature: 14 deg C.
Precipitation type: N/A.

TIME	TC #1 (stair base)	TC#2 (window A)	TC #3 (window B)	NOTES
0:00	19.4	20.8	21.1	
0:30	175	20.6	21.3	
1:00	520	76.3	39.5	
1:30	540	78.4	139	
2:00	470	86	148	
2:30	470	100	162	
3:00	490	227	166	
3:30	485	216	165.8	
4:00	450	192	159.7	
4:30	480	143	159.3	
5:00	490	254	157	Launch device
5:30	450	250	149	
6:00	300			Entry starts, Note 1
6:30	285	212	119	
7:00	270	204	107.7	
7:30	270	198	85.1	
8:00	250	215	81.4	
8:30	240	190	78	
9:00	160	152	67.2	
9:30			46.4	
NOTES:	1. Too busy at window to record data			

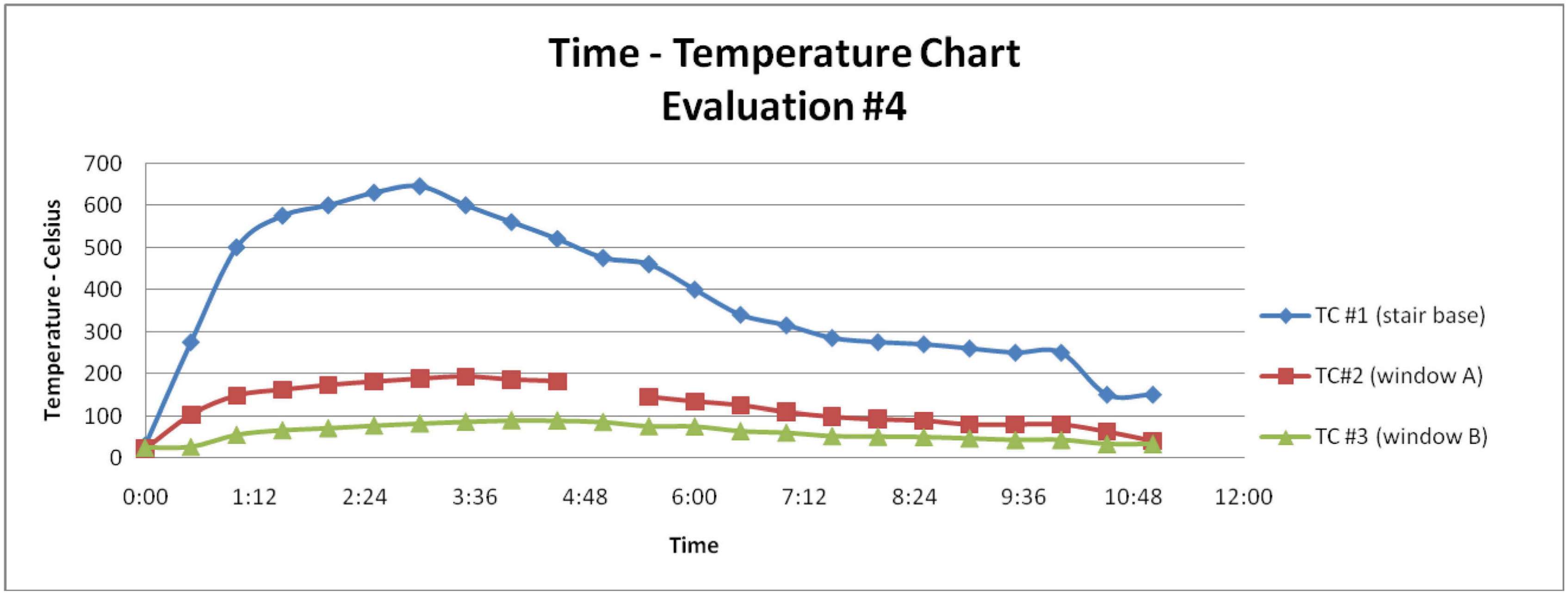

Time - Temperature Chart
Evaluation #3
Temperature - Celsius
600
500
400
300
200
100
0
0:00
1:12
2:24
3:36
4:48
6:00
7:12
8:24
9:36
10:48
Time
TC #1 (stair base)
TC#2 (window A)
TC #3 (window B)

DATA RECORDING FROM DEVICES

TEST NO. 4 Time 1500 hrs

MetConditions Wind direction: 040 deg @ 9.25 kmph knot.
Temperature: 14 deg C. Precip type: N/A

TIME	TC #1 (stair base)	TC#2 (window A)	TC #3 (window B)	NOTES
0:00	30	22.3	25.6	
0:30	275	103	27.7	
1:00	500	148	56.3	
1:30	575	162	67.3	
2:00	600	173	72	
2:30	630	181	78.2	
3:00	645	188	83.2	
3:30	600	193	87.3	
4:00	560	186	90.5	
4:30	520	182	90	
5:00	475		86.6	Launch device; Note 1
5:30	460	145	76.7	
6:00	400	134	76.3	Entry starts
6:30	340	125	65.1	
7:00	315	109	61.3	
7:30	285	98	53.1	
8:00	275	92	52	basement door opened
8:30	270	89	50.9	
9:00	260	80	47.7	
9:30	250	80	44.1	
10:00	250	80	44.4	knock down
10:30	150	63	34.6	
11:00	150	41	34.5	switch to negative pressure
notes:	1. Too busy at window to record data			


Time - Temperature Chart
Evaluation #4
Temperature - Celsius
700
600
500
400
300
200
100
0
0:00
1:12
2:24
3:36
4:48
6:00
7:12
8:24
9:36
10:48
12:00
Time
TC #1 (stair base)
TC#2 (window A)
TC #3 (window B)

Annex C Fire Department Best Practice Operating Guideline

Fire Department Best Practice Operating Guideline # 000.0

Operations Division
Issued 00-00-00
Revised 00-00-0000 Page 1 of __
Date for Next Review 00-00-0000

EMERGENCY PROCEDURES – RESPONDING TO BASEMENT FIRES USING AEROSOL SUPPRESSION TECHNOLOGY

I. Overview

This Operational Guideline identifies recommended practices for fire department personnel when deploying an aerosol suppression device at a confirmed basement fire in a single family dwelling.

The Incident Commander upon initial size-up can make the decision to employ one or more aerosol suppression devices in a relatively enclosed basement compartment prior to personnel entry for search and rescue or fire suppression activities. If the area is open or experiencing high winds the aerosol product may disperse thus reducing its effectiveness. The IC should therefore exercise judgment whether the device should be deployed.

All responders should be aware of and fully understand the unique risks they can potentially be exposed to when operating at a basement fire. Additionally, personnel need to be aware of the risks that are created when deploying such a device. Visibility shall be greatly diminished and therefore unique tactics and additional training is needed before a fire department attempts entry into a structure when such a device has been deployed. Entry into the structure should also be delayed by one minute or as per the manufacturer's guidelines to allow full deployment of the product. The guidelines contained within this document are to be used in concert with a department's existing operating guidelines for suppression activities. Actions taken by responders should also be in compliance with applicable manufacturer's Emergency Response Guide for that specific product. This guideline should also be adjusted based on the fire departments own experience with deploying such devices.

These guidelines are intended to supplement existing fire suppression operating guidelines and as such are not comprehensive. They only identify concerns unique to the deployment of aerosol devices when responding to basement fires.

II. Goals and Objectives

The preferred tactic when responding to a basement fire is to extinguish the fire rapidly. This protects the occupants and prevents or limits fire extension to other areas of the involved building. Due to their restricted access basement fires often pose a greater level of risk to responders due to restricted access, unknown building contents, and difficulty in applying direct hose streams.

Ventilation operations to reduce the temperature and presence of hot gases may delay the suppression or inadvertently allow for fire growth. The likelihood of a flame spread to buildings' structural components or other locations greatly increases once fire reaches an advanced stage, due to delayed fire fighter arrival and an inability to immediately extinguish the fire.

The deployment of one or more aerosol suppression device may knockdown or suppresses the fire thus reducing the increase in temperature, spread of hot gases, and further deterioration of structural components. Personnel entering the structure may therefore do so under reduced risk of personal injury; however, the aerosol suppressing agent will greatly reduce visibility.

III. Operational Practices

Due to the hazardous nature of firefighting and the unique impact of the device on the dynamics of the fire the following operating rules are to be observed:

A. Training:
   a. Prior to issuing the aerosol devices all potential operators of the devices should complete the manufacturer's required training and read all training materials on the product.
   b. Only personnel who have completed such training should be authorized to deploy the device.
   c. Fire departments should attempt to incorporate training on the deployment of an aerosol device and the use of thermal imaging cameras (TIC) with training for interior suppression activities.

B. Incident Command:
   a. The Incident Commander (IC) shall perform a 360 degree size-up of the structure to observe entry points, windows, location of the fire as well as a possible location to launch the device.
   b. The IC shall communicate their findings to all personnel on-scene before entering the building.
   c. The IC shall make the determination whether one or more aerosol suppression devices shall be deployed based on the volume of the dwelling and the rated capacity of the product.
   d. If deployed, then entry into the structure should not be attempted until after at last one minute from activation of the device(s) to permit the full deployment of the aerosol suppressing agent.
   e. The IC must receive periodic interior status reports including visibility, perceived temperature, crew location and status. The IC shall continually evaluate the effectiveness of the operation on a basis of risk to personnel versus potential gain.
   f. The IC shall be responsible for members operating in hazardous locations and shall ensure that all personnel are accounted for at all times.

B. Fire Control:

a. At the direction of the IC one or more aerosol suppressing devices shall be launched into the basement area as close to the room of fire origin as possible. The quantity of devices employed shall be based on manufacturer's specifications. If possible use a window located up wind to help limit ventilation of the product. Follow manufacturer's instructions for initiating the device. Wait a minimum of one minute prior to entry.
b. Increased ventilation of the structure prior to making entry should be avoided if an aerosol device has been deployed as this reduces the device's effectiveness. NOTE: This is counter to normal basement fire suppression guidelines and thus this should be communicated to all personnel on the fire ground and incorporated into fire department training.
c. All persons entering the structure shall wear full personal protective equipment (PPE). No one, regardless of rank, shall enter a hazardous atmosphere without self-contained breathing apparatus (SCBA).
d. Ensure a Rapid Intervention Team (RIT) is on the scene as part of the first alarm and is in position to provide immediate assistance prior to crews entering. Ensure the RIT has received a site assessment of the building and occupancy prior to entry.
e. Entry into the structure shall only be attempted once two personnel are available with a charged fire hose.
f. Entry teams including the RIT shall also be equipped with a thermal imaging camera (TIC). NOTE: the presence of the aerosol extinguishing agent will reduce visibility even when using a TIC. The TIC operator must ensure he/she brings the camera as close to his/her face piece as possible to improve vision of the TIC screen.
g. The TIC operator should be within the vicinity of the nozzle operator. This ensures the handline is in a position to provide protection for the TIC operator and crew members. By operating in the vicinity of the nozzleman, the TIC operator can guide the nozzleman in stream placement. The TIC operator shall point out hot spots, the seat of the fire, and any high heat conditions that pose a hazard to crews operating in the vicinity. NOTE: Due to the employment of a TIC the location of the fire may be difficult due to the effectiveness of the aerosol agent in knocking the fire compartment temperature down.
h. Entry teams are to report fire conditions to the IC on a regular basis. This includes team integrity, perceived temperature conditions, visibility and team location.
i. Do not enter a structure, room, or area when fire or operating fire fighters are suspected to be directly beneath the floor.
j. Never assume the structural integrity of any floor that has had a significant fire under it.
k. Immediately evacuate using alternate exit routes if possible when the structural integrity of the floor system is believed to have been weakened by fire.
l. All personnel operating in the structure shall have a portable radio.

C. Property Conservation

a. Ventilation of the structure should only be considered after the interior crew has located and suppressed the fire and investigated any possible fire extensions into void spaces. The residual aerosol can assist in fire suppression and containment while searching for hot spots.
b. Once the fire has been extinguished ventilation of the aerosol suppressing agent can commence.
c. SCBA shall be worn during all ventilation operations.
d. Ventilation shall continue for a minimum of 30 minutes under mechanical means, and for at least one hour by natural means, or as per manufacturer's instructions.

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DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (The name and address of the organization preparing the document. Organizations for whom the document was prepared, e.g. Centre sponsoring a contractor's report, or tasking agency, are entered in section 8.)

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Ottawa, Ontario K1A 0K2

2. SECURITY CLASSIFICATION (Overall security classification of the document including special warning terms if applicable.)

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3. TITLE (The complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title.)

Reduction of Risk to Fire Fighters in Responding to Basement Fires.

4. AUTHORS (last name, followed by initials – ranks, titles, etc. not to be used)

Tracey, Sean

5. DATE OF PUBLICATION (Month and year of publication of document.)

April 2011

6a. NO. OF PAGES (Total containing information, including Annexes, Appendices, etc.)

54

6b. NO. OF REFS (Total cited in document.)

6

7. DESCRIPTIVE NOTES (The category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

Contractor Report

8. SPONSORING ACTIVITY (The name of the department project office or laboratory sponsoring the research and development – include address.)

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Ottawa, Ontario K1A 0K2

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

CPRC 91022

9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (The official document number by which the document is identified by the originating activity. This number must be unique to this document.)

DRDCCSS CR 2011-05

10b. OTHER DOCUMENT NO(s). (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

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The use of aerosol suppression technology was evaluated in four separate scenarios involving a simulated fire in a basement of a single family dwelling unit. In each scenario observations were made on fire compartment temperatures, the impact of using an aerosol fire suppressant agent on the fire growth, and actions of the firefighting team. Thermocouples were used to measure fire compartment temperatures in three areas. Video recording as well as thermal imaging recordings were made during each evaluation.

The observations showed that even under concentrations below those recommended by the manufacturer there was a marked decrease in the temperature in the fire compartments that the fire fighters would be entering. The use of the aerosol agents did however significantly reduce visibility. As a result of these observations a recommended protocol was developed when such devices are used in conjunction with interior attack of basement fires.

Résumé

On a évalué l’utilisation d’un agent extincteur en aérosol dans quatre scénarios différents avec simulation d’un incendie au sous-sol d’une habitation unifamiliale. Dans chaque scénario, on a observé la température dans des compartiments résistant au feu, l’effet sur le développement de l’incendie résultant de l’utilisation d’un agent extincteur en aérosol, et les interventions de l’équipe de lutte contre l’incendie. On a utilisé des thermocouples pour mesurer la température dans trois compartiments résistant au feu. On a effectué des enregistrements vidéo et des enregistrements d’imagerie thermique durant chaque évaluation.

Les observations ont montré que, même quand les concentrations étaient inférieures à celles recommandées par le fabricant, il y avait une nette baisse de la température dans les compartiments où les pompiers pénétraient. Toutefois, l’utilisation des agents en aérosol a nettement réduit la visibilité. Sur la base de ces observations, on a élaboré un protocole recommandé concernant l’utilisation de tels agents pour combattre les incendies dans les sous-sols intérieurs.

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