SFPE EUROPE

Q1 2021 ISSUE 21

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A Word from the Editor

All,

Looking forward to this 2021 and the opportunities to share knowledge among us.

This is our seventh year of delivering high quality articles, and finally I start to feel that we are going into a nice routine of identifying and delivering articles to you.

The magazine is making a difference; with our current 20K+ subscribers we have become truly global. The possibilities of sharing information, identifying peers and learn from each other has reached a significant level. We do not see it clearly yet and we might not ever, but I am confident that we are creating “sub-activities” on a whole range of different levels, and this is very positive. It is not just a matter of being able to learn and read about fire safety a great part of it is to understand what is going on in other places and to identify people and contacts, and this is what will lead to these “sub-activities”. The magazine has turned into a very effective Mission tool for SFPE (*SFPE's mission is to define, develop, and advance the use of engineering best practices; expand the scientific and technical knowledge base; and educate the global fire safety community, in order to reduce fire risk*) and that is way more than we hoped for at the beginning.

I want to put some focus on our first article, which in my mind is a bit of a sunshine story. One of the objectives behind the development of the SFPE Core Competencies document “Recommended Minimum Technical Core Competencies for the Practice of Fire Protection Engineering.” was that educational institutions should be able to identify and learn about the knowledge and competencies a fire safety engineer should possess, and based on that develop courses and programs that are specifically tailored towards the practice of Fire Engineering, you use this together with the SFPE curriculum and we got a fruitful recipe. This is exactly what ETH Zurich did and you can read about it in our first article. I am confident that this will turn into a success story.

ETH is also cooperating with other universities (through the IMFSE, International Master in Fire Safety Engineering) in Europe. Cooperation will be the key to future educational programs for Fire Safety Engineering, one single entity cannot do it all by themselves, there will always be areas where there will be a lack of knowledge. This last year all of us have learned how to do things virtually and to be honest I think that it has shown to be something useful. Hopefully, this year of “virtual” experiences of will open up new ways of cooperation between new and existing universities. Its difficult to do something on your own but with the help and support of others it can be done.

If there are readers out there that feel that you have an important subject that you would like to share with the industry do not hesitate to contact us, we can make that happen.

As always, a great thanks to the people who have put in a lot of time and effort to make this issue a reality.

The next issue will come in July.

Yours sincerely,

Jimmy Jönsson, Managing Editor

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A Message from the SFPE Europe Council Chair

Dear SFPE Europe members,

It is a great honour to take over the role as SFPE Europe Council Chair from Kees. A special thanks to Kees for his great leadership over the last two years. It will be a tough act to follow!

As you know SFPE celebrated 50 Years of Engineering A Fire Safe World this year. Maya Angelou once said: "I have great respect for the past. If you don't know where you've come from, you don't know where you're going." I believe it is worth looking back to understand what it took to get us where we are now in Europe. In 1948 NFPA President John L. Wilds appointed a special committee "to consider the professional status of fire protection engineering ...". Professor Ahern was appointed chairman of this special committee. After considerable work on the part of the committee and NFPA staff, in July 1950, the NFPA Board voted to implement the concepts presented by Prof. Ahern. The provisional organization was completed in October 1950 with John J. Ahern elected president and the first SFPE Annual Meeting was held in May 1951 in Michigan. After another 20 years, the Society of Fire Protection Engineers was incorporated as an independent professional society on February 10, 1971.

The first European Chapter was established by the SFPE in Italy in March 1993. As the number of chapters grew the chapter leaders expressed the desire for a more formal structure and the European Chapters Coordination Group (ECCG) was established in 2013 with "the purpose of fostering inter-chapter exchange of information and sharing of activities among the SFPE chapters throughout Europe." To my amazement, even at that time there was no Swiss chapter, the statement was signed on 8th October 2013 in Basel. SFPE Europe continues to grow with currently 15 chapters and 4 student chapters. Due to the growth in numbers of chapters and members, the regular meetings amongst the chapter leaders and the establishment of SFPE Europe conferences (this year will be the 4th SFPE Europe conference) there was the desire to introduce a formal SFPE entity in Europe. Just as Prof. Ahern set the tone at the first Annual Meeting, this still holds with SFPE Europe: "This society, with your active participation and help well be a real asset to the fire protection field and will focus attention on the vital part which the fire protection engineer plays in our national life."

With this in mind the most important part for SFPE Europe starts now – through our active participation and exchange we get it working to achieve the goals we have set for ourselves! The first SFPE Europe board meeting will take place in March, which will be followed by the first General Assembly meeting sometime before the summer. I look forward to working together with you to further SFPE in Europe and hope that this venture will be as successful as that of our forefathers in the US!

Reflecting on last year it is also incredible how much has changed within the space of one year. Whereas previously I had hardly used videoconferencing, in the last three months I have probably spent 70% of my working hours in online meetings. So, with the first daffodils appearing I really hope this summer may bring us back the possibilities to meet and travel again! I really miss the in-person conferences and networking that goes with it.

David Grossmann SFPE Europe Council Chair 2021

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The new Master of Advanced Studies Program of Fire Safety Engineering at ETH Zurich

By: Michael Klippel and Andrea Frangi, ETH Zurich, Switzerland,
Matthias Wegmann and David Grossmann, Basler & Hofmann, Switzerland,

ETH Zurich started a new master of advanced studies (MAS) on Fire Safety Engineering in 2020. The MAS is a two years program and was developed on the basis of the SFPE curriculum in cooperation with the International Master of Science in Fire Safety Engineering (IMFSE). The participants of our program graduated a first study program already and attend this MAS as Continuing Education Program in parallel to their job. The program runs successfully at the moment with very positive feedback by participants and great support by lecturers and also authorities.

Current state of application of fire safety engineering in Europe

Fire safety in Europe is mostly planned according to prescriptive rules. For common standard buildings, prescriptive rules are usually well applicable. For unusual or existing buildings, prescriptive rules sometimes lead to unsuitable, unsafe or disproportionate solutions. In such cases, a performance or even risk-based design by a fire engineer is preferable.

The majority of designers working in fire safety in central Europe have an education in a related discipline (such as architecture, civil or mechanical engineering). For fire safety design, they have often passed further training in the application of prescriptive rules. Engineers or natural scientists from related fields sometimes design specific individual aspects using performance-based engineering methods.

At present, there are relatively few fire safety designers or authorities having jurisdiction (AHJ) in Europe with specialization in fire engineering and who are able to develop holistic risk- or performance-based fire safety concepts and to comprehensively assess their effectiveness. For this reason, fire safety concepts often tend to rely on the application of prescriptive rules rather than the development and choice of appropriate measures. Often, the focus of fire safety design is more on building permits than on the safety of people. Even unconventional buildings are designed according to prescriptive rules for which they are not intended. Fire safety designers often work like lawyers, interpreting regulations, and negotiating with the AHJ. Physical principles, risk considerations, the effectiveness of measures and their feedback effects are therefore of secondary importance.

In the field of fire safety there is a great demand for comprehensively trained fire engineers. The fire engineering profession must be better established and more widely recognized. SFPE develops a decisive basis for fire engineering. For example, SFPE has defined Recommended Minimal Technical

Competencies for the Practice of Fire Protection Engineering as well as the model curricula for university studies. The current state of knowledge is recorded in SFPE publications, above all the Handbook of Fire Protection Engineers. Currently, the fundamentals of performance-based design are defined and international design standards are drawn up.

All these great resources can only be effective if young people are educated as fire engineers. Ten years ago, the Universities of Ghent, Lund and Edinburgh took the initiative and launched the International Master in Fire Safety Engineering (IMFSE). This master's program meets the comprehensive and broad requirements of SFPE.

In Switzerland, we have recognized the need for action in fire engineering. Therefore, we founded the Swiss Chapter of the SFPE and are engaged in standardization and training. We realized that ETH Zurich conducts research in many different areas of fire protection – however, there was hardly any exchange between the individual research groups. Engineering companies from the private sector encouraged ETH to make use of its broad competences and become active in teaching fire safety. During the development of the Master of Advanced Studies in Fire Safety Engineering (MAS FSE), we conducted in 2019 a broad market survey on current needs in Switzerland, Germany and Austria. We were pleasantly surprised by the very large response and the broad agreement that such a MAS program is necessary and becomes more and more important in the future, see Figure 1. In German speaking countries there seems to be a large consensus that fire safety must be increasingly operated according to first principles and that ETH should train engineers for this purpose. This is certainly most advanced in Switzerland but Germany and Austria are starting this process as well. Further, the participants of the survey found the SFPE curriculum as very meaningful and purposeful to be applied. We found a great willingness on all sides to support the program.

Survey question: How do you see the demand of fire safety engineering methods (today/ in 5 years/ in 10 years)?

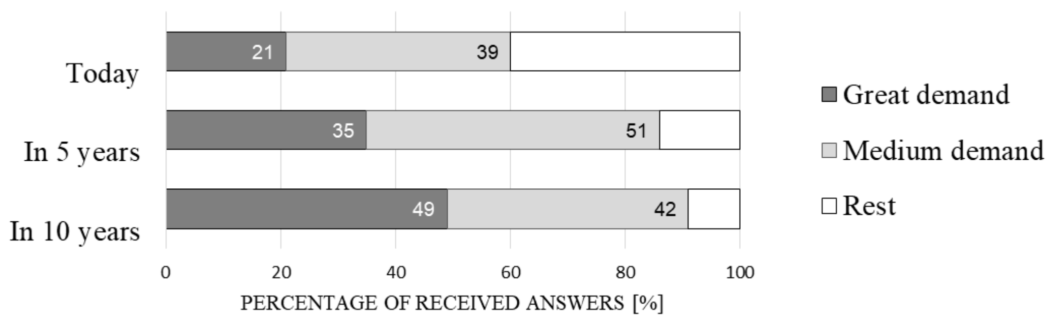

Figure 1. Survey result of the question "How do you see the demand of fire safety engineering methods?" showing that most of the about 600 survey participants indicated the increasing demand of fire safety engineering approaches in the near future.

The MAS ETH Fire Safety Engineering

On basis of the SFPE curriculum and in cooperation with IMFSE, it was possible to launch a comprehensive engineering course at ETH Zurich within a short time. The first MAS FSE students have been studying at ETH Zurich since autumn 2020 and will graduate in 2022. In order to achieve the high ethical goals of SFPE, it is to be hoped that other countries and universities will follow these examples and that the profession of fire protection engineering will soon be widely established all over Europe.

The contents of the MAS ETH Fire Safety Engineering cover all topics of fire safety engineering. The MAS is currently taught mainly (80%) in German language and is divided into five modules (see Figure 2). The core topics of these modules are the physical and chemical fundamentals for the fire action, the fundamentals for performance and risk-based verification in fire protection and organizational (e.g. evacuation), structural (e.g. structural performance-based fire design) and technical fire protection. Lecturers from ETH Zurich, from partner universities and engineers from practice teach the basis of fire safety engineering and the direct application of theory and methods.

We found that especially the module 2 (Fire Safety Design) added an important and unique aspect to our MAS. This module deals with performance-based design and risk management topics. Within this module, key knowledge regarding the development of fire protection engineering solutions from first principles to achieve performance goals, objectives, and criteria from specific quantified fire scenarios are taught. This includes the concepts of goals, objectives and criteria, design fires, fire safety analysis, concepts for evaluating design options, concepts of uncertainty quantification, sensitivity analysis and documentation. Further to this, an overview of acceptance criteria for risk-based analysis and knowledge in the areas of probability and statistics is content of this module. This module also brings researchers from different disciplines within ETH Zurich together and proves again how inter-disciplinary fire safety is.

All modules integrate practical project work in groups and self-study time. Each module is completed directly with a performance assessment on the last day of the module. The program is completed with a master's thesis, which can be carried out in cooperation with the participants' own employer or a (foreign) university. Detailed information is given on the programs website www.mas-brandschutz.ethz.ch.

We have been learning from the first run of the MAS and improved the lectures, organization and content already. The start of this MAS during the pandemic was challenging but with close communication with both the lecturers and participants we successfully applied new learning forms and learning management systems. Positive feedback showed us that there are many opportunities and advantages in online teaching forms for everyone involved. Our experience so far shows us that we are on the right track and we look forward to exciting next steps within this new master of advanced studies of Fire Safety Engineering at ETH Zurich.
For interested readers and possible new participants: The second run of the program starts in autumn 2022. The application window is open from January to April 2022.

Module 1	Module 2	Module 3	Module 4	Module 5
Fire science	Fire safety design	Human behavior and evacuation	Structural fire design	Fire protection systems

Figure 2. The master of advanced studies Fire Safety Engineering at ETH Zurich is taught in five modules over a timeframe of two years.

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Data transfer at the speed of light, but is it reliable in a fire?

By: Joakim Åström and Sofia Lindahl, Students at Lund University, Sweden.

Data transfer have almost exclusively been done through electrical cables, but the use of fibre optic cables is increasing. Is a fibre optic cable transferring data with the same quality as an electrical cable? As it turns out the fibre optic cable might be the better choice.

Sometimes the communication between devices is taken for granted. Take an ordinary light switch for example. When you flip the switch, the light comes on, this is due to electricity being transported along a cable to the light bulb. Much the same happens when we control more advanced equipment that carry out actions, such as closing a valve, instead of bringing light to your kitchen. Sometimes there are situations at which this action is absolutely critical to the safety of humans, for example in a nuclear power plant.

In these types of facilities, the actions need to be carried out from a distance and that is where the cables come in. In case of an emergency the cables need to work. This can be shown through a real example, the Browns Ferry Nuclear Power Plant accident in March 1975 [1]. A fire damaged 1600 cables, where 600 of these were cables that monitored or controlled safety features of the plant. The damages to the cables caused several faults to occur; some safety features could no longer be operated from a distance, some safety features were put into motion by themselves, and some instruments on the control panel showed misleading indications [1].

The misleading and erroneous signals in the Browns Ferry accident was probably due to the use of electrical cables for control equipment. In other words, there was a possibility for the signal to go the wrong way if the cables came in contact with each other. Signals that are interpreted by computers have mainly been sent using electricity, but it is also possible to use light to send the same signals through fibre optic cables. The fibre optic cables offer higher speed as well as an inherent electrical isolation. With fibre optic cables, the problem with signals going the wrong way becomes impossible as they themselves are electrically insulated. Instead, the problem with a fibre optic cable subjected to fire is how the light being transmitted is disturbed, and thus the actual data can be affected. This problem was identified by the European Spallation Source (ESS) and a master thesis was conducted on how fire conditions affect the attenuation through a fibre optic cable [2]. However, this attenuation could not be translated to a loss of data. To further investigate fibre optic cables' behaviour during fire a recent master thesis, that includes of an experimental study, has been conducted. This master thesis [3] investigated how data transfer is affected and an effort to create a probabilistic distribution was made. However, some of the technical aspects as well as the experimental setup will first be described.

Fibre optics and data transfer

In a fibre optic cable, a wave of light is guided through a core made of clear glass. Surrounding the core is something called cladding which is glass that is less refractive [4]. When the light hits the cladding, it bounces back into the core and continues forward [4]. As the wave of light propagate through the cable the amplitude and intensity decrease along the way, and this is called attenuation [5]. The amplitude decreases over a distance and can be explained by Figure 1. The original data signal is a pattern of on and off (up and down), as the light propagates the difference between on and off decrease and finally the signal can no longer be interpreted.

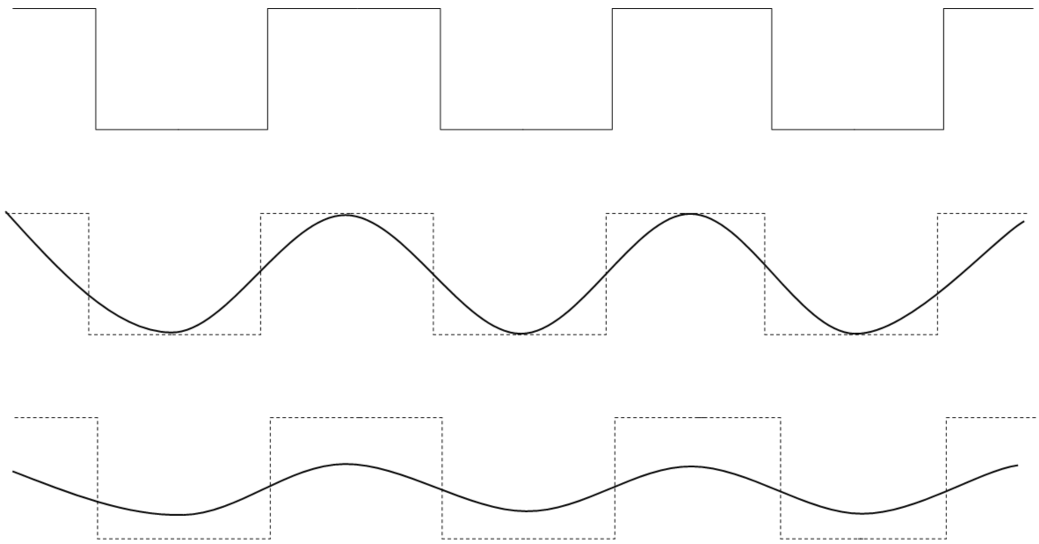

Figure 1. Decrease in amplitude of the light. Top, outgoing signal. Bottom, signal being stretched out due to attenuation, with the original shape for illustrative purposes.

The other part of attenuation is the loss of intensity, or loss of photons in the wave of light. This is a result of mainly three different properties: absorption, scattering and leakage (radiation) [4, 6]. In short, absorption is when light is absorbed into the molecules of the fibre. Scattering is a combination of light hitting the molecules as well as impurities in the fibre, and leakage is light that escape out from the core and cladding. As a cable is bent or mismanaged, cracks can form which leads to an increase in leakage. One study has been made on tensile strength of fibres from fibre optic cables, the result of this was that the strength decreased with increasing temperature [7]. If the tensile strength decreases, the fibre will start to crack even more, and more light can be lost due to leakage.

The signal needs to be interpreted by a computer as ones and zeros, in other words as a digital signal [4, 5]. Disturbance in the signal due to loss of light or other disturbance can have effects on the end result, for example if the data loss is too large some computer systems can shut down or in other ways malfunction [8]. Regardless if data is sent through light or electricity there needs to be a unified set of rules, called protocols, for the sending and receiving computer to interpret the signal [9]. These protocols create data packages, clusters of ones and zeros, that can be measured.

Sample holder and test setup

In the recent master thesis project [3] a sample holder for the cable was constructed based on previously conducted experiments and details from two standards on cable testing. In the IEC 60331-25:1999 standard, the cable is suspended in the air by resting on metallic rings [10], and in the SS-EN 50200:2006 standard, the cable is mounted in a U-shape on a non-combustible board [11]. Both these details were incorporated in the thesis work by having the cable suspended in the air in a U-shape with a non-combustible board under the cable. A pendulum was also installed to strike the sample holder every 10 minutes and the details for the pendulum was incorporated from the SS-EN 50200:2006 standard [11]. The cables were installed in the sample holder with the smallest bend diameter recommended by the manufacturer. The sample holder can be seen in Figure 2, where the yellow marking indicates where the pendulum struck the sample holder.

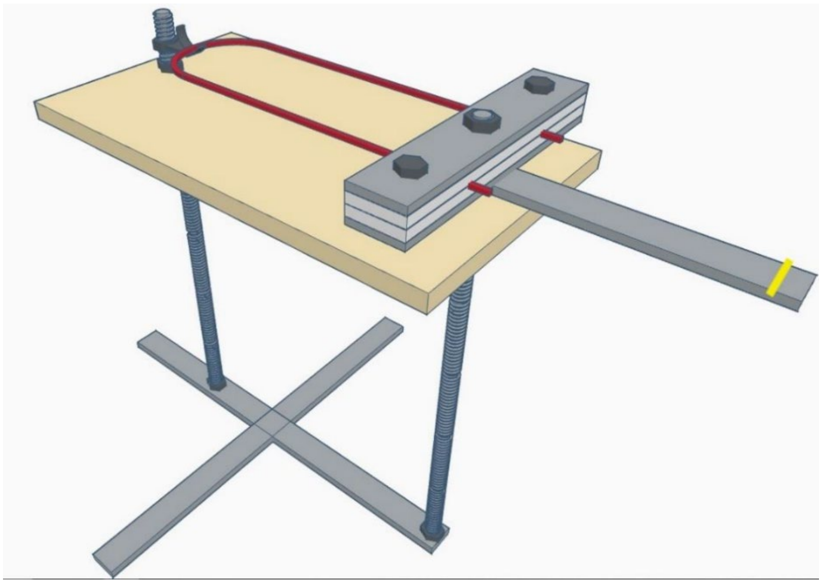

Figure 2. Sample holder setup.

During the tests, a cable was gradually exposed to an increasing heat flux from a cone calorimeter [12]. In the tests, the heat flux started at 15 kW/m^2 and was increased to 25 kW/m^2 after 10 minutes, 35 kW/m^2 after another 10 minutes, and finally 50 kW/m^2 after another 10 minutes. After 30 minutes the heat flux was at the maximum value for the experiment and remained at 50 kW/m^2 until the cable could no longer transfer data or until 90 minutes of the test had passed. The cables that were used for these tests were single-mode cables with one fibre. These cables were chosen because the goal was to examine the functionality of the cable, with as little protection as possible. A picture of a test cable mounted in the sample holder can be seen in Figure 3. In addition, SM cables are becoming more common than MM cables. Since the goal was to measure data loss, a local area network (LAN) was created between two computers. The data was then transferred from one computer to another, where bandwidth and data loss for the transferred data was measured continuously.

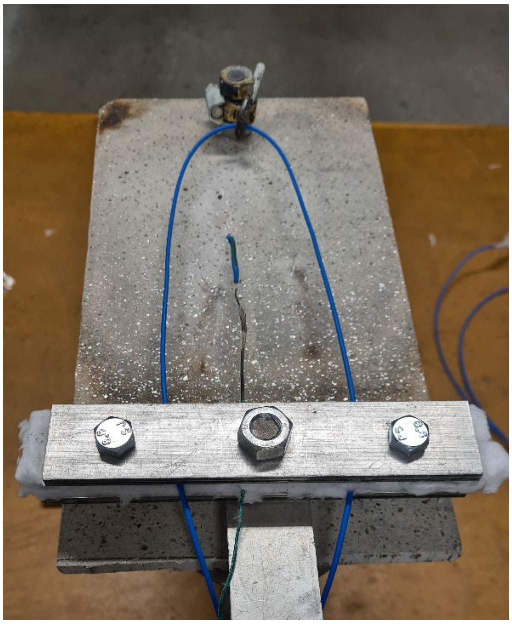

Figure 3. Cable mounted in the sample holder.

Results and conclusions

The tests resulted in zero data loss until the cable broke or the test was terminated after 90 minutes. The conditions for breaking of the cable were shown to be a relationship between temperature and mechanical strain from smaller bend diameter created by the fibre moving due to thermal influence. For those tests that led to a break in the cone calorimeter, temperatures of 400 – 600 ºC were measured. Besides measured data, such as data loss and temperature, the cables were also visually examined and interesting events were timed to help draw conclusions. With the temperature measurements at the time of break, a data analysis was made where a probabilistic distribution for temperature at the time of break was fitted.

A couple of conclusions could be drawn from the tests and they are presented below:

- The signal in a single-mode fibre shows resilience to fire exposure.

- Based on this study, a probabilistic distribution of the critical temperature resulted in a 5th percentile of 336 ºC, i.e., 95% of the cables have a critical temperature above 336 ºC.
- Even if installed according to the manufacturer’s recommendations, bends that lead to break can be formed on the cable due to thermal stresses.
- Fibre optic cables have inherent properties such as electrical isolation which makes them useful for critical safety systems in, for example, high reliability facilities.

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Q1 2021 ISSUE 21 AN OFFICIAL PUBLICATION OF SFPE

Evaluation of the Legal Framework for Building Fire Safety Regulations in Spain

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Brian J. Meacham, Meacham Associates, USA

Overview

With respect to safety from technological hazards, the idea that the risk affecting society is significantly influenced by regulation and its effective implementation and enforcement was recognized some decades ago [1]. More recently, similar concerns have been expressed for building fire safety, where it has been noted that the issues defining the appropriateness of the performance may not be function of the code, the design methods, or of the material used, but of the overall performance of the regulatory system and the market working together to deliver the intended goal [2]. The treatment of the risk associated with innovative methods and materials, within the regulatory system, is also signaled as a possible contributing factor affecting the fire safety of buildings.

After the tragic fire at the Grenfell Tower in London, the European Commission observed that "EU Member States remain responsible for setting the level of fire safety in buildings on their territory and to enforce their building regulation" [3]. This points to the importance of building fire safety legislation and regulation assessment in all member states, including Spain.

Regarding the review of the building regulatory system in England following the fire at the Grenfell Tower, Dame Judith Hackitt [4] concluded in part that the complete body of regulations explored and the way of enacting them, is not appropriate and allows shortcuts. Furthermore, assessment of the interaction of components in the building regulatory system, intended to deliver fire safe buildings in England, demonstrates the importance of aligning legal structures, policy objectives, technical safety provisions, and supporting infrastructure [5].

Overall, a comprehensive assessment of the building fire safety regulatory system (regime) requires an in-depth analysis of the legal provisions covering the building sector and of the roles and responsibilities of professionals, building and fire officials, and other actors in the market. An assessment of the data that are available on the fire performance of buildings is needed as part of the process.

Assessing the Situation in Spain

Prior to the Grenfell Tower tragedy and European focus on fire safety legislation, it was recognized that challenges exist in the building fire safety regulatory regime in Spain, and a comprehensive assessment was undertaken [6]. In framing the assessment, attributes of different regulatory regimes were studied, including prescriptive-based, performance-based and systems-based [7,8]. Each regulatory regime involves a way of developing, implementing, and enforcing regulations that is essential to develop and maintain an efficient legal framework. Focusing on performance-based systems, it is suggested that the ideal building regulatory regime should be founded on a sound definition of five fundamental aspects: (a) regulatory goal, (b) building agents, (c) roles, (d) professional prerequisites, and (e) accountability [6].

To evaluate the efficacy of these fundamental aspects for the Spanish building regulatory system, the following more specifically defined requirements were deemed important: (a) a complete statement of the regulatory goal or goals concerning the building is an essential aspect, which, in turn, must be clarified by specific acceptance criteria; (b) clear identification of the agents involved in the process of developing, implementing, or enforcing the regulation (stakeholders); (c) clear definition of the role that each stakeholder plays in the process and their associated accountability; (d) professional prerequisites for any agent to enable them to dutifully perform their role, and (e) all aspects must be complete with crystal-clear statements of the accountability and responsibility of every agent [6].

When applied to the Spanish building regulatory system, the points noted below were identified. While this approach was developed based on an assessment of the Spanish building regulatory system, it is suggested that the approach and outcomes of this assessment not only highlight concerns that should be addressed in Spain but can be useful for those assessing building fire safety regulations in other countries as well.

Outcomes and Recommended Aspects to be Addressed.

- With respect to the regulatory goal of fire safety, the building regulations lack sufficient information to facilitate performance-based solutions to assure the target fire risk levels are achieved. To advance in this direction it is necessary to carry out some adjustments within the current regime with regard to adding performance criteria and better defining a performance-based design approach for fire. More analysis of actual fire risk performance, given the first loss statistics, would also be beneficial.
- With respect to administrative procedures, implementation, and enforcement related to performance-based options, more detail is needed. That is, better definition of roles and responsibility, as well as technical guidelines within the Building Management Law [9] and the Technical Building Code [10], could ease the understanding and adoption of such approach.
- Regarding design for and verification of fire safety, it is important to specify the educational and professional requirements needed to develop and approve performance-based approaches. This aspect is particularly important, since a certain degree of knowledge is required, not only for designers but also for other actors, such as code enforcers (e.g., [11,12]).
- Concerning the need to assure the adherence to the regulatory goals, the definition of the design process and the intervention of different stakeholders are essential within the system.
- With respect to the extent of stakeholders, there are other actors involved in the construction process, which could be considered building agents but are not specifically (e.g., code enforcers, reviewers from professional associations), who should have roles and responsibilities defined with respect to fire safety. Each has a particular role to play, requiring specific knowledge required to carry it out, and thus holds a social accountability for this as part of the fire safety system. These are considered crucial aspects that must be clarified.

- Expansion of engagement with stakeholders is needed. Without an appropriate representation of the diversity of stakeholder interests, key issues can be missed, inadequate regulations can be enacted, or other unfortunate outcomes may occur.
- As long as national guidelines and educational programs are not in place, some international tools and methods could be useful to highlight the implementation of fire regulations, such as the International Fire Safety Standards: Common Principles [13] or the *SFPE Guide to Human Behavior in Fire* [14], which could be included in the official registry of the Ministry of Development. These guides not only refer to the use of engineering tools or the implementation of the performance-based approach, but also other aspects related to the prescriptive option. Some interesting works addressing the relationship between building activity, space, and occupant characteristics have been done, which could be useful to achieve a desirable flexibility when choosing a prescriptive option; in this sense, the provision of the scientific background of the prescription could also be helpful.
- With respect to the role that the code enforcers should play in the performance-based approach design process and the required educational background, international guidelines refer to the role of a peer reviewer (e.g., [15, 16]). The Local Ordinance of Procedures for Urban Planning Licences in Madrid [17] is an example of the progress towards the implementation of the performance-based design in Spain. This local ordinance expresses that performance-based projects are to be monitored by local official enforcers from the earlier stages of the project until the proposal final validation. In the absence of other legal provisions on technical and procedural indications, it indicates the general stages for the evaluation and approval of the project and points out the possible implication of a third reviewer when the official enforcers consider it appropriate.

Conclusions

The analysis concluded that relevant drawbacks exist within the current building regulatory regime in Spain with respect to fire safety provisions. Some of these are derived from the lack of consistency between the different approaches to legislation governing various aspects of the regulatory system, which results in an impact on procedures and responsibilities. Others concern the lack of a clear regulatory goal/mandate for fire safety, incomplete identification of responsibilities and accountability in the system, and inadequate reference to technical guidance. Furthermore, some accountability aspects in case of accidental fires remain unclear. It is important to notice that these problems may not affect solely the fire safety objective, but all the building basic requirements.

Additional details are available in the article:
Osácar, A.; Echeverria Trueba, J.B.; Meacham, B. Evaluation of the Legal Framework for Building Fire Safety Regulations in Spain. *Buildings* 2021, *11*, 51. https://doi.org/10.3390/buildings11020051

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SFPE EUROPE

Q1 2021 ISSUE 21 AN OFFICIAL PUBLICATION OF SFPE

Evacuation Data from Retirement Facilities in New Zealand

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Aging populations are generating new challenges for buildings and infrastructure designers around the world. Elderly populations are more likely to have mobility impairments and require a longer time to respond and evacuate during a fire than able-bodied adults. As such, it is fundamental requirement to account for the differences in evacuation performance of aging populations when designing retirement facilities. To date, only a few studies have been carried out to measure the evacuation performance of elderly evacuees during the pre-travel and travel phases [1,2]. This work provides an overview of new data obtained by analyzing unannounced and announced day time evacuation drills carried out in several retirement facilities in Auckland, New Zealand, in 2018-2019[3]. The data was collected through the observation of the behaviors of 118 elderly evacuees and 16 staff members. A summary of the pre-travel time distributions, speed distribution, and fundamental diagrams for elderly evacuees are reported in the following sections.

Fire Drills

Data were collected from 16 drills carried out in independent living apartments and common areas belonging to different retirement facilities. All of the drills were unannounced, with the exception of one. None of the drills prompted a full evacuation of the entire building. Rather, the goal of the drills was to evacuate single fire compartments by evacuating horizontally from one fire compartment to its adjacent fire compartments. The unannounced drills were started by activating one of the smoke detectors in the fire compartment. This started a local fire alarm, which required one staff member to identify the origin of the fire and to activate the alarm in the entire compartment. In the announced drill, the fire compartment alarm was activated by the evacuation consultant running the drill after informing the participants a walkthrough drill would take place.

Pre-Travel Phase

Pre-travel times were collected in all of the unannounced drills focusing on independent living apartments and common areas of the retirement facilities. The pre-travel time of an evacuee is defined as the time between the activation of the alarm in fire compartments and the time when the evacuee started to move towards a place of safety. Figure 1 shows the pre-travel times observed in independent living apartments and common areas. These data were used to estimate pre-travel time distributions, which are published in [3].

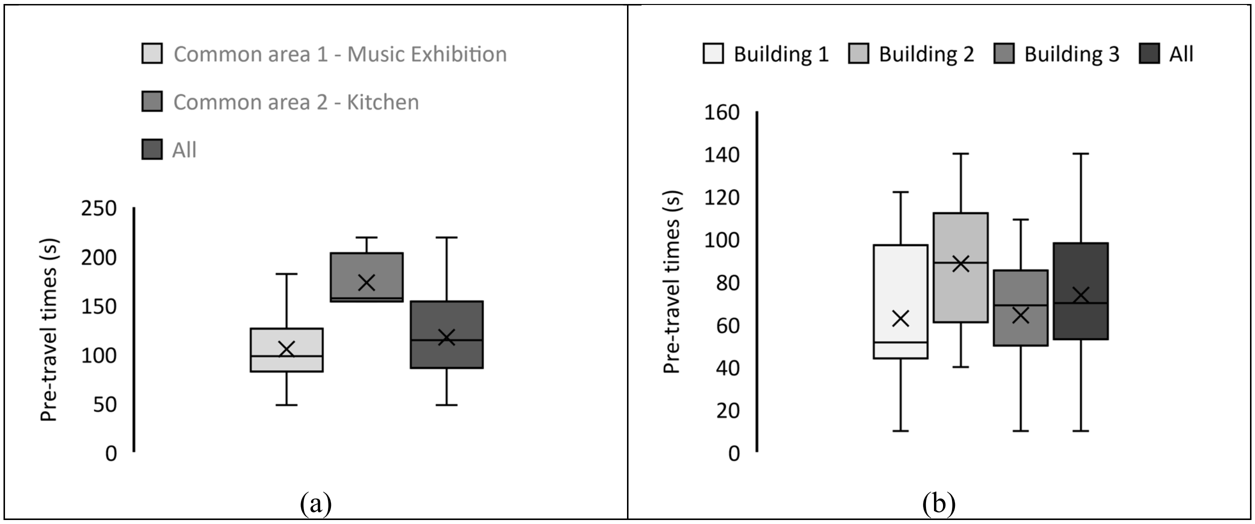


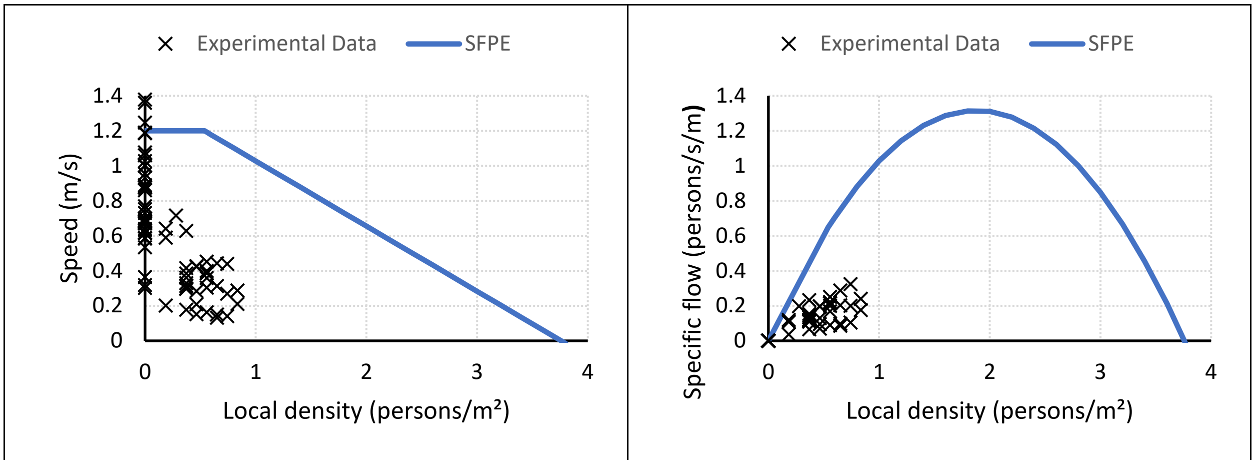
Figure 1 – Pre-travel times of (a) the common areas and (b) the independent living apartments

Travel Phase

Unimpeded horizontal walking speeds were collected in different drills wherever the density of the evacuees was smaller than 0.54 persons/m². These speeds were divided into two classes depending on whether the evacuees were using walking aids. Figure 2 illustrates the speed data for these two groups. The boxplots clearly illustrate that evacuees in retirement facilities move at different speeds depending on their need for walking aids. Evacuees who used walking aids moved at an average speed of 0.51±0.19 m/s, while evacuees who did not use walking aids moved at an average speed of 0.91±0.29 m/s. This difference was proven to be statistically significant.

Figure 2 –Unimpeded horizontal walking speeds

The announced drill also allowed the investigation of the relationship between density and horizontal speed. The local density and speed were measured in a section of a corridor using the assumptions described in Section 3.2 of [3]. This data is shown in Figure 3 and is compared with the SFPE fundamental diagrams published in [4]. The figure shows that the walking speeds ranged from 0.13 to 1.55 m/s, the local density ranged from 0.00 to 0.83 persons/m², and the specific flow ranged from 0.00 to 0.33 persons/s/m of effective width. The figure also shows that most experimental data points fell below the SFPE relationships. This indicates that the use of SFPE fundamental diagrams in the modelling of retirement home evacuations may lead to overly optimistic results, and it can severely underestimate the required evacuation time.



(a) (b)

Figure 3 - Fundamental diagrams: (a) speed versus local density and (b) specific flow versus local density

Conclusion

This work summarizes the main findings obtained from 16 evacuation drills carried out in three retirement facilities in New Zealand. The drills involved 61 staff members and 118 residents. Results indicate that pre-travel time ranged from 48s to 219s in communal areas and from 10s to 140s in areas with independent living apartments. While the pre-travel times from the independent living apartments are in line with the one study existing in the literature, the times from common areas are lower than those reported in the literature. This work presents new unimpeded horizontal walking speeds for residents of retirement facilities. These speeds range from 0.3m/s to 0.73m/s when using walking aids and from 0.37m/s to 1.55m/s when not using walking aids. Finally, comparison of the proposed data and the SFPE fundamental diagrams highlights that most of the experimental data points in the current study fall below the SFPE design curve.

Note: This paper is a short version of a manuscript that has been published in the Fire Technology journal. Further information about the evacuation drills and collected data can be found in the full article associated with this work [3].

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Q1 2021 ISSUE 21

AN OFFICIAL PUBLICATION OF SFPE

INVESTIGATION OF THE EFFECTS OF PHOTOVOLTAIC (PV) SYSTEM COMPONENT AGING ON FIRE PROPERTIES FOR RESIDENTIAL ROOFTOP APPLICATIONS

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INTRODUCTION

According to the International Energy Agency, worldwide energy demand is expected to rise significantly at a rate of 2.1% per year to the year 2040, in line with ever-increasing population growth and rapid industrial development [1]. This increasing demand necessitates higher electricity generation due to swift economic expansion and recent growth in developed and developing countries [2,3]. Presently, electricity is generated using conventional thermal power generation such as coal-fired, oil-fired or gas-fired power plants that convert the respective energy sources into electrical energy. Nevertheless, the burning of these energy sources also emits greenhouses gases which contributes to global environmental pollution and climate change issues [4]. Moreover, ever since the energy crisis in the early 1970s there has been an interest in exploring and venturing into renewable energy to meet this growing energy demand. Just like conventional power plants, renewable energy also derives its energy from natural sources. Therefore, renewable energy is preferred over fossil fuels because the sources are inexhaustible and do not run out over time, thus making it a more reliable source [1,5]. By 2050, renewable energy will be one of the major contributors to global energy consumption as projected by International Energy Outlook [6]. The abundance of solar energy is one of the best options to be used as a renewable energy source [7]. One of the leading-edge technologies that utilises the solar power is photovoltaic (PV) technology.

PV technology is a system used to harness the thermal radiation from the sun and convert it into electricity. PV systems are a relatively young technology and classified as an active solar technology which uses mechanical and electrical equipment in converting those sun’s energy. In 1954, researchers at the Bell Laboratories had successfully invented the first industrial PV application [8]. The team demonstrated their solar panel by using it to power up a small toy Ferris wheel and a radio transmitter [8]. These first silicon solar cells (also known as photovoltaic cells) reached about 6% efficiency in solar-electrical energy conversion, which had been acknowledged as a massive improvement in comparison to any previous solar cells [8]. Since then, PV technology has continued to evolve with regard to conversion efficiency and system reliability. Nowadays, this state-of-the-art technology provides a sustainable solution for the planet to reduce the worldwide greenhouse effect due to the burning of fossil fuels from conventional thermal power plants [9].

PV systems can be categorised into two types – off-grid and grid-connected. Generally, a PV system consists of PV panels and other mechanical and electrical components, for instance, PV cables, DC/AC inverters, connectors and isolators. However, the main difference between standalone off-grid PV systems and grid-connected PV systems is that off-grid PV systems have additional components, namely battery banks and charge controllers. In an off-grid system, the solar panels will convert the sun's energy and store the energy for use at night or on cloudy days when the sunlight intensity is low. In contrast to the grid-connected system, the main grid will supply electricity to the household during any cloudy days and at night. Current PV power systems come in a variety of sizes based on the utilisation which can range from powering up any portable system, up to households or even for a large-scale utility application. Nowadays, the rooftop grid-connected PV systems have become the popular choice for residential building as the setup does not require additional land area and traditional electricity bills can be offset. Figure 1 shows the typical layout of a grid-connected PV system for rooftop application.

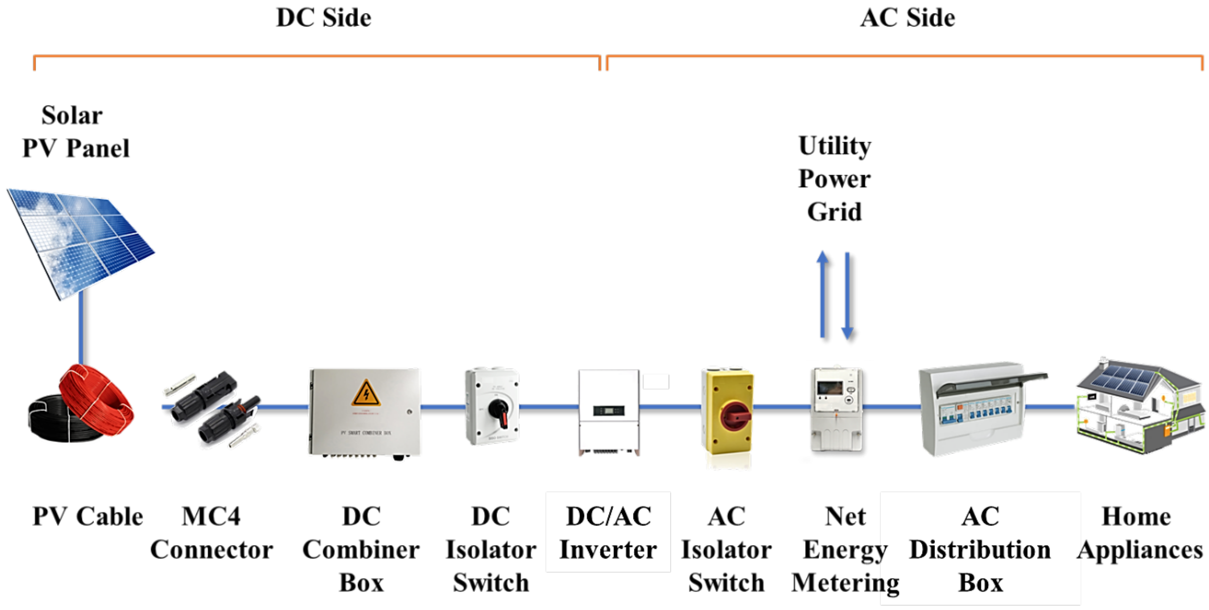

Figure 1. General layout of grid connected PV system according to MS 1837 which has been outlined by Department of Standard Malaysia together with SIRIM Malaysia [10]

FIRE HAZARD

In recent years, growth in installation of PV systems has occurred, which can be seen with the increasing amount of generation capacity. Although the initial installation of a PV system involves significant costs, in the long run, the operating and maintenance costs for a PV system are relatively low. While advances in PV technology have offered many benefits for energy generation, this young technology also raises concerns about fire safety and is often seen as a potential fire hazard [11]. Ideally, PV systems are a relatively safe and reliable technology [12]. The results of the '1,000 and 100,000 roofs program' conducted in Germany concluded that PV system failures are scarce and mostly related to the PV equipment itself [13]. However, PV systems are often installed with very little consideration given to fire safety. As PV systems are part of the electrical family, they are also subjected to the typical types of electrical fire ignition [14].

The common primary ignition scenarios reported within internal PV systems are:

(i) DC arc fault and overheating due to error or poor mechanical installations [14-18]
(ii) DC arc fault and overheating due to low quality of PV components [15,19]

(iii) DC arc fault and overheating due to aging or degradation of PV components which leads to spontaneous ignition [14,15,18]
(iv) Localised overheating due to hot spot effects [14,15,18,20,21]
(v) Defective or damage system components or product failure leading to localised overheating [15,16]

These common primary ignition scenarios show that the causes of fire in PV systems can be classified into DC arc fault and localised overheating of PV components. In comparison to AC arcing, DC arc faults are more hazardous as the voltage continues to remain once the arcing is established. Statistics recorded in the USA, Germany and Italy show that a large number of DC arc fault events in PV systems have led to fire and significant damage [14,22]. When a solar panel catches fire, it does not just result in the reduction of power generation but also emissions of toxic gas (e.g. HF and HCl), property damage, injuries and even death [15,17]. In 2009, a fire occurred on the membrane rooftop of a retail store in California, USA damaging 1826 PV modules [11]. In the same year, another 15 events of solar PV module related fire were incidents recorded in the Netherlands [15]. In 2012, fire associated with solar panels occurred in a warehouse in Goch, Germany burning approximately 4000 m^2 of roof area [23]. Another large fire incident occurred in 2013 at a food warehouse in New Jersey, USA where the roof was covered by 7000 PV modules [23]. Unfortunately, the building and contents were completely destroyed in the fire [23]. According to an investigation conducted by the BRE National Solar Center in 2018, 13 of the 80 reported PV fire incidents resulted in casualties (10 injuries/psychological trauma and 3 fatalities) [17]. The Netherlands began an investigation in 2018 into a fire incident involving PV panels on the roof with the aim of clarifying whether solar panels were responsible following the recent rise in rooftop fire incidents [24]. In 2019, the Japanese government warned against the fire risk from rooftop installed PV systems due to the upsurge of fire incidents logged from 2008 to 2017 [25]. Therefore, it is recommended that the design stage of a PV system should also be extended beyond the efficiency and reliability by considering fire safety aspects as well [14].

WAY FORWARD

Other than installation errors, the usage of low quality and aging PV components also substantially contributed to the occurrence of DC arc faults as well as overheating incidents. Solar panels are usually installed with the intention of the system having a service life of 20 to 30 years. However, the PV panels and other PV components are constantly exposed to extreme weather, especially in certain countries where the climate is hot and humid, such as in Asia. According to Manzini et al., in 2015 there were no standards specifically focused on the fire behaviour of PV modules [26]. Hence, it is crucial to investigate the fire hazard of both new and aged PV modules, as well as the other PV components, by thermally characterising the component's materials to evaluate the potential fire danger so as to help improve the fire safety associated with PV systems. Figure 2 shows several examples of damage to PV components due to fire.

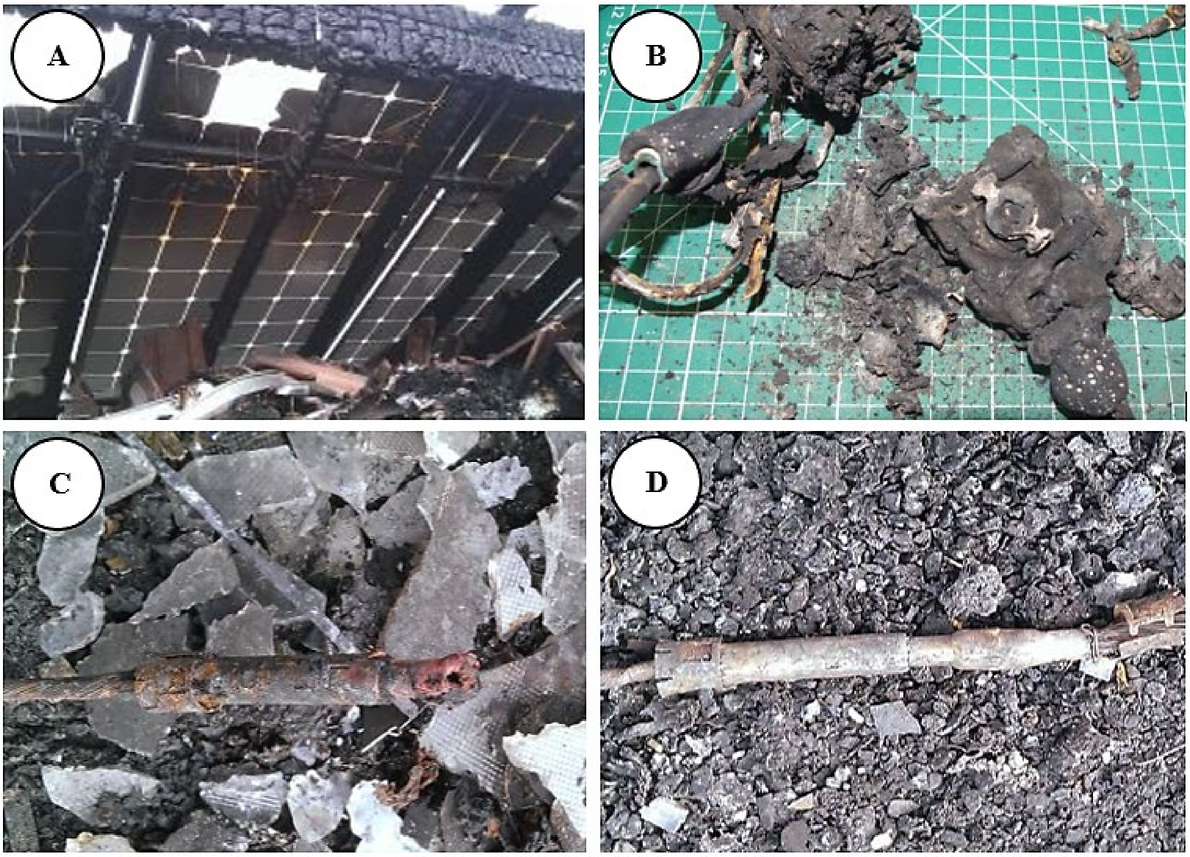

Figure 2. (A) Burnt-out roof with parts of the PV system intact [17] (B) Remains of a DC isolator being disassembled and inspected in the laboratory [17] (C) Remains of a DC connector ablated by arcing and burnt insulations [17] (D) Damaged connector with contacts still intact and engaged [17]

Currently, a research team from the Safety Engineering Interest Group at the Universiti Putra Malaysia is at the initial stages of a project that is investigating fire safety of PV systems with a particular emphasis on aged systems and components. By investigating the thermal properties of the material, additional safety elements can be considered in the design phase to reduce the frequency and severity of fire incidents caused by PV electrical systems installed on residential rooftops. Accurate predictions of fire may enable the design of appropriate fire safety systems. Besides that, the results can be utilised for more sophisticated computational assessments to simulate real-scale fire scenarios. Lessons learnt from past fire incidents involving PV systems, will provide valuable information and data to develop fire safety strategies for PV systems that are based on real-world fire incidents.

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